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THE ASSISTANT-SECRETARY OF THE GEOLOGICAL SOCIETY.

Quod si cui mortalium cordi et curæ sit non tantum inventis hærerere, atque iis uti, sed ad ulteriora penetrare; atque non disputando adversarium, sed opere naturam vincere; denique non belle et probabiliter opinari, sed certo et ostensive scire; tales, tanquam veri scientiarum filii, nobis (si videbitur) se adjungant. —*Novum Organum, Præfatio.*

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CORRIGENDA.

- Page 27, line 3 from bottom, for "fig. 17" read "fig. 12."
Page 28, line 8 from bottom, for "Div. G" read "Div. A."
Page 93, line 1, insert "Mr. Woodward's" after "and."
Page 99, line 28, for "(g)" read "(h)."
Page 101, line 17, insert "c" after "clay."
Page 102, line 7, after "of" insert "the deposit containing."
Page 103, line 5, after "f" insert "fig. 2."
Page 103, line 13, for "be" read "represent."
Page 105, line 13, after "m" insert "fig. 7."
Page 106, fig. 7, insert "f" to the bed below "e" and "m" to the bed below "l."
Page 106, line 3 from bottom, insert "these" before "very."
Page 106, line 2 from bottom, delete "also."
Page 108, line 1, for "to" read "and."
Page 108, note §, insert "as myself" after "conclusion"
Page 109, line 40, after "Shingle" insert "(f to i)."
Page 110, for "c" above the letter f on the right of fig. 8, read "e."
Page 111, line 9, after "8" insert "dotted outline underneath, to the left."
Page 187, last line, insert "venture" before "to."
Page 422, line 23, for "Cephalaspides" read "Cyphaspides."
Page 458, add to the List 1* :—

1864. Seeley, H. G. Fossils of the Hunstanton Red Rock. Ann. & Mag. Nat. Hist. (3) vol. xiv. pp. 276-278.
1866. Seeley, H. G. Fossils of the Carstone Formation. *Ibid.* vol. xvii. p. 181.
1869. Wiltshire, T. Red Chalk of Hunstanton. Quart. Journ. Geol. Soc. vol. xxv. p. 187.
1883. Whitaker, W. Presidential Address. Proceed. Norwich Geol. Soc. vol. i. p. 234.

In the Map, Pl. XVI., the areas represented as "Volcanic basic rocks"—three at Westcot, three at Gatton, and one to the north of Castle Pulverbatch—are *Baryta Veins*.

On the same Map the thick black lines indicate *Faults*.

THE UNIVERSITY OF CHICAGO

PHILOSOPHY DEPARTMENT

PHILOSOPHY 101

LECTURE NOTES

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THE
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THE GEOLOGICAL SOCIETY OF LONDON.

VOL. XLVI.

1. *On some PALÆOZOIC OSTRACODA from NORTH AMERICA, WALES, and IRELAND.* By Prof. T. RUPERT JONES, F.R.S., F.G.S.
(Read November 6, 1889.)

[PLATES* I.-IV.]

Introduction.—1. Some good specimens of North-American Ostracoda from the Lower-Helderberg and Cincinnati Groups, in the British Museum and my own collection, have given occasion for a critical revision and careful illustration of several forms shown in Pl. III. figs. 1-20, 24, 25, and Pl. IV. figs. 16-24. For comparison with some of these, three Russian specimens (Pl. III. figs. 21-23) are introduced.

2. In the 'Palæontology of New York,' vol. iii. 1859, several of the Palæozoic Ostracoda of New-York State were described, but pls. 79 A and 79 B, intended to contain figures of some of them, could not be then produced. With Dr. James Hall's permission, copies of some of the original drawings have been courteously supplied by Mr. J. M. Clarke, of Albany, and are here reproduced (Pl. I. figs. 1-6, and woodcut, fig. 1), thus enlarging our knowledge of the Lower-Helderberg fauna by the illustration of seven out of the ten forms originally intended for the unpublished plates †.

3. Prof. R. P. Whitfield, of New York, having kindly sent a large series of Palæozoic Ostracoda, collected in the Lake-Champlain district and elsewhere in North America, for examination, they are illustrated in Pl. I. figs. 7-15, and Pl. II. figs. 1-13. Figs. 7-10 and 15 of Pl. I. are from the Lower Silurian of Lake Champlain; Pl. I. fig. 12 and Pl. II. figs. 1 and 6 are from the Upper Silurian

* These Plates have been drawn with the aid of a Grant from the Royal Society.

† Only "*Leperditia parvula*," *op. cit.* p. 376, pl. 79 A, figs. 9 a, b, remains now unrepresented.

of Nova Scotia; Pl. I. figs. 11, 13, 14, and Pl. II. figs. 2-5 and 7-13, are from the Hamilton Group of Lake Erie.

4. The specimens shown by Pl. IV. figs. 1-3, belonging to the "Utica Slate" series, were given to me by Mr. John Young, F.G.S., of Glasgow, who had them from Ontario, Canada.

5. An interesting series of five Lower-Silurian (Ordovician) species, from near Welshpool, Montgomeryshire (Pl. IV. figs. 4-13), comprising a characteristic Cincinnati species, were sent to me by Mr. J. Bickerton Morgan, F.G.S., of Welshpool.

6. Lastly, Pl. IV. figs. 14, 15, represent a rare Palæozoic Cytheroid Ostracod from Kildare, Ireland, collected by Mr. Joseph Wright, F.G.S.

7. The specimens are described as nearly as possible in the order of their natural relationship; and thus, besides adding to the known forms, they illustrate the modifications exhibited by the genera and species of these minute bivalved Crustaceans, both in limited districts and in different regions, as indicated in the following LIST (p. 3) of 44 species (with notable varieties) belonging to 11 genera.

Range of some Palæozoic Genera of Entomostraca.

	Lower Silurian.	Upper Silurian.	Devonian.	Carboniferous.	Permian.	Recent.
*Primitia	*	*	* H	*		
Aparchites	*	*				
*Isochilina	*	*	H			
*Leperditia	*	*	* H	*		
*Primitiopsis	*	H			
Entomidella	*					
*Entomis	*	* H	*		
Bolbozoe	*				
*Æchmina.....	...	*				
Placentula	*				
*Bollia	*	*				
*Klœdenia	*				
*Beyrichia.....	*	*	* H	*		
Kirkbya.....	...	*	...	*	*	
*Strepula	*	*	H			
Moorea	*	...	*		
Thlipsura.....	...	*				
Octonaria.....	...	*				
Bursulella	*				
Macrocypris	?	*	...	*	?	*
Pontocypris.....	?	*	*
Bairdia	?	*	*	*
Bythocypris.....	?	*	...	*	?	*
Cythere	?	*	...	*	*	*
*Xestoleberis.....	*	*	...	*	...	*
Cytherella	*	...	*	*	*
Cytherellina	*	...			

NOTE.—H means that the genus is represented in the "Hamilton Group" of the United States.

Of the 11 genera marked *, 44 species are described in the present paper.

*List of some new or not well-known Palæozoic Ostracoda from
North America and elsewhere.*

- I. PRIMITIA. Genus ranging from the Cambrian to the Carboniferous.
1. *P. mundula*, Jones, var. *cambrica*, nov. Pl. IV. fig. 7. Lower Silurian. Wales.
 2. *P. humilis*, J. & H., var. *humilior*, nov. Pl. IV. fig. 5. Lower Silurian. Wales.
 3. *P. seminulum*, Jones. Pl. II. fig. 2. Hamilton group. New-York State.—Upper Silurian. Europe.
 4. *P. Morgani*, sp. nov. Pl. IV. fig. 6. Lower Silurian. Wales.
 5. *P. Ulrichi*, sp. nov. Pl. IV. figs. 1, 2, 3. Lower Silurian. Canada.
 6. *P. unicornis* (Ulrich). Pl. IV. figs. 8–13. Lower Silurian. Wales, Cincinnati.
 7. *P. minuta* (Eichwald). Pl. III. figs. 18, 19, 21–23. Lower Silurian. Cincinnati.—Upper Silurian. Russia.
 8. *P. Whitfieldi*, sp. nov. Pl. III. fig. 24. Lower Silurian. Cincinnati.
- II. PRIMITIOPSIS. Known also in the Upper Silurian of Scandinavia.
1. *P. punctulifera* (Hall). Pl. II. figs. 7, 12, 13. Hamilton Group. New-York State.
- III. ENTOMIS. Known in the Upper Silurian, Devonian, and Carboniferous.
1. *E. rhomboidea*, sp. nov. Pl. II. figs. 9, 10. Hamilton Group. New-York State.
- IV. STREPULA. In the Lower and Upper Silurian of Britain and Scandinavia.
1. *L. sigmoidalis*, sp. nov. Pl. II. fig. 4. Hamilton Group. New-York State.
- V. ÆCHMINA. In the Upper Silurian of Britain and Scandinavia.
1. *Æ. spinosa* (Hall). Pl. III. figs. 4–8. Upper Silurian. New-York State.
 2. *Æ. Byrnesi* (Miller). Pl. III. figs. 9–11. Lower Silurian. Cincinnati.
- VI. BOLLIA. A Lower- and Upper-Silurian Genus.
1. *B. symmetrica* (Hall). Upper Silurian. New-York State.
 2. *B. lata* (Vanuxem & Hall). Pl. III. figs. 1–3. Upper Silurian. New-York State.
- VII. KLÆDENIA. An Upper-Silurian Genus.
1. *Kl. notata* (Hall). Pl. IV. figs. 22, 23. Upper Silurian. New-York State.
 - 1*. *Kl. notata*, var. *ventricosa* (Hall). Pl. I. fig. 1; Pl. IV. fig. 24. Upper Silurian. New-York State.

VIII. BEYRICHIA. Ranging from the Lower Silurian to the Carboniferous.

1. *B. trisulcata*, Hall. Pl. I. fig. 2. Upper Silurian. New-York State.
2. *B. Hallii*, sp. nov. Pl. IV. fig. 21. Upper Silurian. New-York State.
3. *B. granulata*, Hall. Pl. I. fig. 3. Upper Silurian. New-York State.
4. *B. oculina*, Hall. Pl. I. fig. 4. Upper Silurian. New-York State.
5. *B. Buchiana*?, Jones. Pl. III. fig. 25. Lower Silurian. Cincinnati.
6. *B. parasitica* (Hall). Woodcut, fig. 1, p. 17. Upper Silurian. New-York State.
7. *B. Clarkei*, sp. nov. Woodcut, fig. 2, p. 17. Upper Silurian. New-York State.
8. *B. æquilatera*, Hall. Pl. II. fig. 6. Upper Silurian. Nova Scotia.
9. *B. tuberculata*, Boll, var. *pustulosa*, Hall. Pl. II. fig. 1. Upper Silurian. Nova Scotia.
10. *B. hamiltonensis*, sp. nov. Pl. II. fig. 3. Hamilton Group. New-York State.
11. *B. ciliata*, Emmons. Pl. III. figs. 12-16, and Pl. IV. figs. 16-18. Lower Silurian. Cincinnati.
12. *B. oculifera*, Hall. Pl. IV. figs. 19, 20. Lower Silurian. Cincinnati.

IX. ISOCHILINA. From the Lower Silurian to the Devonian.

1. *I. lineata*, sp. nov. Pl. II. figs. 5 & 8. Hamilton Group. New-York State.
2. *I. (?) fabacea*, sp. nov. Pl. II. fig. 11. Hamilton Group. New-York State.
3. *I. Seelyi* (Whitfield). Pl. I. fig. 7. Lower Silurian. Lake Champlain.
4. *I. gregaria* (Whitfield). Pl. I. figs. 9, 10. Lower Silurian. Lake Champlain.
5. *I. cristata* (Whitfield). Pl. I. fig. 8. Lower Silurian. Lake Champlain.
6. *Isochilina*?, sp. Pl. I. fig. 15. Lower Silurian. Lake Champlain.

X. LEPERDITIA. From the Lower Silurian to the Carboniferous.

1. *L. (?) seneca*, Hall. Pl. I. figs. 13, 14. Hamilton Group. New-York State.
2. *L. (?) sinuata*, Hall. Pl. I. fig. 12. Upper Silurian. Nova Scotia.
3. *L. hudsonica*, Hall. Pl. I. figs. 5 & 11. Hamilton Group. New-York State.
- 3*. *L. hudsonica*? Pl. III. fig. 20. Lower Silurian. Cincinnati.

4. *L. Claypolei*, sp. nov. Pl. III. fig. 17. Lower Silurian. Cincinnati,
 5 & 6. *L. alta* (Conrad) et *L. Jonesi*, Hall. (*L. alta*, var., Pl. I. fig. 6.) Upper Silurian. New-York State.
 7. *Leperditia nana*?, Jones. Pl. IV. fig. 4. Lower Silurian. Wales.

XI. XESTOLEBERIS. Lower and Upper Silurian, Carboniferous, and Recent.

1. *X. Wrightii*, sp. nov. Pl. IV. figs. 14, 15. Lower Silurian. Ireland.

I. Genus PRIMITIA, Jones and Holl, 1865.

Primitia, J. & H. 'Ann. & Mag. Nat. Hist.' ser. 3, vol. xvi. p. 415.

1. PRIMITIA MUNDULA, Jones, var. CAMBRICA, nov. (Pl. IV. fig. 7.)

Size: length .86 mm., height .5 mm.

This is a true *Primitia*, related to *P. mundula*, Jones, especially fig. 31, pl. vi. 'A. M. N. H.' ser. 2, vol. xvi. 1855, although the valve is not quite so regular in outline, and the sides of the sulcus are not so stiffly tubercled. We may call it var. CAMBRICA.

From the Bala beds, near Welshpool, Montgomeryshire*.

Primitia mundula, with its varieties, is a very wide-spread species.

2. PRIMITIA HUMILIS, Jones & Holl; var. HUMILIOR, nov. (Pl. IV. fig. 5.)

Size: length .86 mm., height .5 mm.

Fig. 5 is a simple suboblong *Primitia*, of the same type as *P. humilis*, J. & H., 'Ann. & Mag. Nat. Hist.' ser. 5, vol. xvii. 1886, p. 409, pl. xiv. figs. 6 & 9, but is longer, higher behind, and has a much fainter sulcus.

From the Bala beds near Welshpool.

3. PRIMITIA SEMINULUM, Jones. (Pl. II. fig. 2.)

Primitia seminulum, Jones, 'Ann. & Mag. Nat. Hist.' ser. 5, vol. xvii. 1886, p. 413, pl. xiv. fig. 14.

Size: fig. 2, length 1.2 mm., height .8 mm.

Fig. 2 is a characteristic specimen, but the valve is broken away below and behind the centre. The meshes of the ornament are specialized at the sulcus.

In a limestone consisting of Crinoidal joints, Brachiopods, &c., belonging to the Hamilton Group, from Eighteen-mile Creek, Lake Erie Shore, N. Y.

P. seminulum is known in the Upper Silurian of Wales, Shropshire, and Scandinavia.

4. PRIMITIA MORGANI, sp. nov. (Pl. IV. figs. 6 a, b.)

Size: length .5 mm., height .3 mm.

A small, semicircular, bituberculate, punctate *Primitia* (the in-

* Figs. 4-13 of Pl. IV. were sent to me by Mr. J. Bickerton Morgan, F.G.S., of Welshpool, by whom they were collected from dark shales of Bala age at Gwernybrain, near Welshpool, Montgomeryshire, North Wales.

terval between the two little knobs representing the generic sulcus). The tubercles are relatively larger than in *P. æqualis*, J. & H., 'A. M. N. H.' ser. 5, vol. xvii. 1886, p. 412, pl. xiv. fig. 11, and the valve differs very much from *P. bicornis*, Jones, *op. cit.* 1855, p. 173, pl. vi. fig. 23.

From the Bala beds near Welshpool, North Wales. Collected by Mr. J. Bickerton Morgan, F.G.S., to whom we are indebted for this and other Lower-Silurian (Ordovician) species.

5. *PRIMITIA* *ULRICHI*, sp. nov. (Pl. IV. figs. 1 *a*, *b*, *c*; et var. figs. 2 & 3.)

	Length.	Height.
	mm.	mm.
Size { Fig. 1	·8	·46
2	·73	·4
3	·8	·46

Suboblong, straight above, elliptically curved below; hinder end semicircular; front part compressed and narrower, with a nearly straight slope, which makes a blunt antero-ventral angle with the lower edge. A small but well-marked tubercle rises on the posterior quarter; there is a slight subcentral swelling, with a very faint oblique hollow between it and another but faint tubercle in the antero-ventral region. The valve has a slight convexity, and the hinder tubercle gives a blunt profile to that end of the valve (fig. 1 *c*). The surface is ornamented with a minute reticulation, which has elongate meshes, and passes into striæ along the ventral region.

Primitia diversa, J. & H. 'Ann. & Mag. Nat. Hist.' ser. 5, vol. xvii. (1886), p. 412, pl. xiv. fig. 10, may be said to be a relative of the species under notice, but the differences of shape and surface are sufficiently distinctive.

Fig. 2 is a variety of *P. Ulrichi*. It has the central swelling and two little tubercles; but the anterior tubercle is higher up than in figs. 1 *a*, *b*, and the outline of the valve is more Leperditoid, and its convexity is more uniform. Except as to the outline of the valve, this shows a striking analogy to the subrhomboidal and Upper-Silurian *Primitia armata* (Richter), described and figured in the 'Geol. Mag.' 1881, p. 341, pl. ix. fig. 11.

In fig. 3 the central swelling only is visible. Without this feature it would probably pass for some of the forms that have been grouped as "*Leperditia (Isochilina) cylindrica*," Hall; but with it the valve approximates to the Devonian *Primitia Dagon* (J. M. Clarke), 'Bullet. U.S. Geol. Survey,' no. 16, 1885, p. 29, pl. 2. figs. 5, 6, 7. The species is here named after Mr. E. O. Ulrich, of Newport, Ky., who, having worked assiduously on the Palæozoic Entomostraca, has favoured me with much information.

The specimens, figs. 1-3, given to me by Mr. John Young, F.G.S., of Glasgow, are in a slab of Lower-Silurian bituminous shale ("Utica Slate"), full of the remains of *Asaphus canadensis*, Chapm., *Triarthrus Beckii*, Green, *Lingula curta*, Conrad, and *Orthoceras*, sp., brought from Collingwood Oil-springs, Lake Huron, Ontario, by Mr. D. C. Glen, F.G.S., of Glasgow.

6. PRIMITIA UNICORNIS (Ulrich). (Pl. IV. figs. 8-13.)

Leperditia unicornis, Ulrich, 'Journ. Cincinn. Soc. Nat. Hist.' vol. ii. 1879, p. 10, pl. vii. fig. 4.

		Length. mm.	Height. mm.
Size {	Fig. 8	1.23	.8
	9	1.3	.76
	10	1.3	.8
	11	1.4	.66
	12	1.6	.76
	13	1.6	.76

Figs. 8-13 would come under *Aparchites*, were all Primitian characters absent; but fig. 9 has not quite lost all trace of the Primitian sulcus, and fig. 13 has a shallow residual pit near the middle. Figs. 8-13 are varieties evidently of one species—namely, Ulrich's "*Leperditia unicornis*." The varying extent of submedial or mid-dorsal depression, the modification of outline and of the posterior tubercle (almost obsolete in fig. 11, which takes on two subcentral tubercles) make the individuals disagree to some extent among themselves; and the very numerous specimens in the shale show many modifications of these features.

Bala Beds, near Welshpool, Montgomeryshire. From Mr. J. B. Morgan's collection.

Mr. Ulrich's specimens were from the Lower Silurian of Cincinnati, Ohio.

7. PRIMITIA MINUTA (Eichwald). (Pl. III. figs. 18 & 19, Cincinnati; figs. 21, 22, 23, Russia.)

		Length. mm.	Height. mm.
Size {	Fig. 18	1.0	.46
	19 . . . . .	.8	.43
	21	1.53	.73
	22	1.26	.73
	23 . . . . .	.6	.3

Cypridina minuta, Eichwald. 'Bulletin Imp. Soc. Nat. Moscou,' vol. xxvii. part 1, 1854, p. 99, pl. ii. figs. 6 a, b; 'Beiträge zur Geologie und Palæontologie Russlands,' 8vo, Moscau (and Moskwa), 1854, p. 123, pl. ii. figs. 6 a, b.

Leperditia minuta, Eichwald, 'Lethæa Rossica,' vol. i. livr. 7, 1860, p. 1335, pl. lii. figs. 2 a, b.

*Cytheropsis concinna**, Jones, 'Ann. & Mag. Nat. Hist.' April 1858, p. 249, pl. x. figs. 3, 4; *Primitia concinna*, *op. cit.* December 1865, p. 424.

* At one time (*op. cit.* June 1888, p. 398) I thought that this might be looked upon as *Bythocypris* figured upside-down; but I have strong doubts on that point, and prefer to keep it among the almost furrowless, but not quite even, *Primitiæ*, there being "a faint dorsal hollow in the original, which may stand for the sulcus" (*ibid.* 1865, p. 424). Such a feature characterizes some *Primitiæ* in which the sulcus is becoming obsolete.

Leperditia (Isochilina) cylindrica (?)*, Hall, 'Twenty-fourth Report State Cab. N. Y.' 1871-72, p. 231, pl. viii. fig. 12; and 'Geol. Surv. of Ohio, Palæontology,' vol. ii. part 2, 1875, p. 101, pl. iv. fig. 5.

The figures given by d'Eichwald in 1854 (and 1860) differ much one from another †; but the author makes them synonymous. The specimens shown in Pl. III. figs. 21, 22, 23, were sent to me by M. d'Eichwald some years ago, labelled "*Leperditia minuta*, from Talkof" ‡, where his figured specimens were also obtained; and I take fig. 21 to represent the type, putting aside the author's bad drawings referred to above. Figs. 22 and 23 may be varieties or closely allied forms, or, indeed, valves not quite free from the matrix.

Among the fossil Ostracoda from Cincinnati there are many specimens similar to fig. 21, and with even a more strongly pronounced subcentral depression, reaching to the dorsal border. For instance, in No. 59722, British Museum, which is a seam of solid dark-grey limestone (15 mm. thick), shaly on two faces, rusty at the edge, and composed of small organisms, chiefly *P. minuta*, with *Leperditia? minutissima*, and some other, but obscure, Ostracods, as well as Encrinites, Polyzoans, Brachiopods, and Gasteropods, from Covington, Kentucky. Also No. 59723 and No. 59725, Brit. Mus.; in the latter the valves of *P. minuta* are of a red colour.

Figs. 18 and 19 are from the piece of Cincinnati Limestone containing *Æch. Byrnesi* and *L. hudsonica* (?), given me some years ago by Dr. E. W. Claypole, F.G.S.

If, then, we regard the sulcus as a variable feature, both the *concinna* and *cylindrica* above mentioned fall under *P. minuta*, as defined above. If the sulcus be definitely absent throughout a series, we have *Aparehites* (Ann. & Mag. Nat. Hist., May 1889, p. 384). It is quite probable, however, that there are in the Cincinnati Limestones more than one or two kinds of little Ostracods having nearly the shape and aspect of the *P. minuta* here noticed, but furnished with other special characteristics. Among the many associated little valves, exhibiting only their interiors, some evidently differ from the above in their outlines; others, showing exteriors, have an undulating surface, emphasized in many by one or both of their terminal fourths being elevated, and even produced into short spines or tubercles. These, corresponding with the Welsh

* Hall's *Cytherina cylindrica*, 'Palæont. N. Y.' vol. ii. 1852, p. 14, pl. iv. figs. 8 a, 8 b, from the Medina Sandstone, of Medina, Orleans Co., is really a *Leperditia*. See 'Ann. & Mag. Nat. Hist.' November 1884, p. 344.

† Figs. 6 a, b, are subreniform, with the convex edge upwards; and figs. 2 a, b, show a parallelogram with rounded ends. Drawings made from partly imbedded specimens might give such results. *Primitia tenera*, J. G. O. Linnarsson, 'Kongl. Svenska Vet.-Akad. Handl.' vol. viii. no. 2, 1869, pl. ii. fig. 70, also has a long oblong shape with rounded ends, and was regarded by Linnarsson as being near *P. concinna*.

‡ *L. minuta*, Eichw., from Talkof, was referred to as a *Primitia* by Magister Fr. Schmidt, 'Mém. Acad. Imp. Sciences St.-Petersbourg,' sér. 7, vol. xxi. no. 2, 1873, p. 4.

specimens figured in Pl. IV. figs. 8-13, appear to be *Primitia unicornis* (Ulrich), 'Journ. Cincinn. Soc. N. H.' vol. ii. 1879, p. 10, pl. vii. fig. 4.

"*Leperditia cylindrica*, Hall," is mentioned by H. M. Ami as occurring, with *Beyrichia oculifera*, in the Siphonotreta-limestone ('Ottawa Naturalist,' December 1887, p. 3 of separate copy); also by C. D. Walcott ('Albany Instit. Trans.' 1879, pp. 23 & 37 of separate copy), with *B. oculifera* and *B. cincinnatensis*, in the "Utica Slate" of Oneida Co., N. Y.

Small casts of a similar species occur in the hard black shale ("Utica Slate") of Ottawa, with Trilobites, Encrinital joints, &c.

8. PRIMITIA WHITFIELDI, sp. nov. (Pl. III. figs. 24 a, 24 b.)

Size: length .8 mm., height .33 mm.

Elongate-oblong, convex, with a wide shallow dorsal depression; ends rounded unequally, the posterior having a cardinal angle, whilst the anterior end is neatly rounded. The surface is ornamented with a very delicate reticulation of long, oblique, minute meshes (fig. 24 b).

This specimen is in the British Museum, marked 59723, from Cincinnati, Ohio. It is in a thin piece of grey limestone, split off a mass along the bedding; made up of small organisms, shaly on one face, and rusty at the edge. On it are "*Leperditia cylindrica*, Hall," very abundant, with *Leperditia? minutissima*, *Primitia Whitfieldi*, and *Beyrichia Buchiana?* (fig. 25). The last two are very rare; the *Beyrichia* is in the cast of a small ripple-mark on the bed-plane.

II. GENUS PRIMITIOPSIS, JONES, 1887.

Primitiopsis, Jones, 'Silur. Ostrac. Gothland,' 1887, p. 5; and 'Ann. & Mag. Nat. Hist.' ser. 6, vol. ii. 1888, p. 406.

1. PRIMITIOPSIS PUNCTULIFERA (Hall). (Pl. II. figs. 7 a, b; 12 a, b; 13 a, b.)

Leperditia punctulifera, Hall, 'Thirteenth Annual Report of the Regents of the University of New York,' 1860, p. 92.

		Length.	Height.	Thickness*.
		mm.	mm.	mm.
Size {	Fig. 7.....	1.08	.6	.48
	12.....	1.35	.84	.8
	13.....	1.48	.84	.8

Figs. 7 a, b, fairly correspond with Dr. James Hall's description referred to above, but there are more than one little tubercle on the valve, and the ventral margin is not so distinctly thickened. (Fig. 7 a has had its postero-dorsal edge partly broken away.)

Taking fig. 7 as a young form, and figs. 12 and 13 as adults, we find in the latter a subovate carapace, full in the middle, contracted at the ends, not quite equally; and more strongly compressed in

* "Thickness" refers throughout to the thickness of the carapace (closed valves).

front than behind, the anterior third sloping gently, and the posterior more suddenly to the margin (figs. 12 *b* and 13 *b*); a reticulate surface-ornament supplies the "minute puncta or pits" of the original description, but dies out at each end (in the Scandinavian *Primitiopsis* only in front), and there are three small, smooth tubercles, one central and two on the posterior region; the meshes are more distinct just round the middle tubercle. Fig. 7 is more oblong and flatter, but the features may have been produced by pressure, as the outline of the united valves (fig. 7 *b*) is not symmetrical, and the postero-dorsal edge has been damaged; the reticulation, not so strongly pronounced, reaches to the end-margins, though weak just there; the central tubercle is represented by a spot of stronger meshes a little in advance of the centre, and the two posterior tubercles are present.

The original specimens were from the Hamilton Group (often abundant on the shaly laminæ), from the shores of Lake Erie to Canandaigua Lake, N.Y. The specimens here figured are: fig. 7 from the Hamilton Group, at Seneca Lake, N.Y.; fig. 12, in a dark argillaceous schistose rock, with calcareous organisms, from Darien, N.Y.; fig. 13, also from the Hamilton Group, at Eighteen-mile Creek, Lake Erie.

III. Genus ENTOMIS, Jones.

Entomis, Jones, 'Ann. & Mag. Nat. Hist.' ser. 4, vol. xi. 1873, p. 413.

1. ENTOMIS RHOMBOIDEA, sp. nov. (Pl. II. figs. 9, 10 *a*, *b*.)

		Length.	Breadth.	Thickness.
		mm.	mm.	mm.
Size {	Fig. 9.....	·88	·38	
	10.....	1·0	·46	·48

Both of these specimens have probably suffered from pressure; but fig. 10, having the sulcus in its normal vertical position, has apparently best preserved the original shape. Rhomboidal, straight above and below, with the ends obliquely rounded, unequally in fig. 10 *a*. Surface flattish and sloping rapidly down at the free margins, especially posteriorly (fig. 10 *b*); impressed with a definite dorsal sulcus; ornamented with numerous strong, longitudinal, but inosculating raised striæ, or thin wrinkles, with a tendency to become concentric, as more fully expressed in *E. concentrica* (De Koninck) and *E. biconcentrica*, Jones.

In fig. 9 the valve is more truly rhomboidal, with the sulcus oblique (probably by pressure), and parallel to the truncated sloping ends, which are equal, and have their angles rounded, with one pair of the alternate angles less rounded than the other.

Oblong and subrhomboidal forms of *Entomis* are indicated by figs. 19, 20, 21, pl. iv. 'Monogr. Carbonif. Cypridinadæ, Pal. Soc.' 1874; and by fig. 7 (oblique by pressure), pl. xi. 'A. M. N. H.' September 1879.

Both specimens are from the Hamilton Group: fig. 9 from Seneca Lake, N.Y.; fig. 10 from Eighteen-mile Creek, Lake Erie Shore, N.Y.

IV. Genus STREPULA, Jones and Holl.

Strepula, J. & H. 'Ann. & Mag. Nat. Hist.' ser. 5, vol. xvii. 1886, p. 403.

1. STREPULA SIGMOIDALIS, sp. nov. (Pl. II. fig. 4.)

Size: length .8 mm., height .44 mm.

A left valve, small, acute-subovate, straight on the back; posterior edge broadly and obliquely curved to join the ventral margin, which slopes upwards to the sharp antero-dorsal extremity. On the posterior third, and parallel with the hinder margin, is a raised sharp ridge, bifurcating forwards as two feebler ridges, one of which curves back in the antero-dorsal region to form a sigmoid flexure about the middle of the valve and within the larger ridge. There is no published *Strepula* having these characteristics.

From the Hamilton Group, at Eighteen-mile Creek, Lake Erie Shore, N.Y.

V. Genus ÆCHMINA, Jones and Holl.

Æchmina, J. & H. 'Ann. & Mag. Nat. Hist.' ser. 4, vol. iii. 1869, p. 217.

1. ÆCHMINA SPINOSA (Hall). (Pl. III. figs. 4-8.)

Beyrichia spinosa, Hall, 'Natural History of New York, Geol. Survey; Palæont. New York,' vol. ii. 1852, p. 317, pl. A lxvi. figs. 17-21.

	Length.	Height.	Length of Spine.	
	mm.	mm.	mm.	
Size {	Fig. 4.....	.8	.46	
	5.....	.86	.46	.26
	6.....	.86	.53	.66
	7.....	1.2	.8	.73
	8.....	1.26	.86	.73

Valves somewhat Beyrichian in appearance, but the central lobe is replaced by a strong, oblique spine, thick and hollow at the base, either elongate or short, pointing upwards, outwards, and forwards, and sometimes slightly bent. Each valve is thickened on its free borders with a raised, rounded, but irregular margin. The area at the base of the spine is hollow and smooth. Sometimes the raised margin is punctate (fig. 8). Fig. 4 is much like Dr. Hall's fig. 21; and fig. 5 is like his fig. 20.

In a thin limestone-seam made up largely of *Æchmina spinosa*, with *Bollia lata* (rare), Encrinital joints, Tentaculites, fragments of Trilobites, &c. From Lockport, State of New York. Given to me by Prof. R. P. Whitfield in 1884.

Also in a dark-grey limestone, composed of Encrinital remains, Tentaculites, small Brachiopods, fragments of Trilobites, and numerous small Ostracods, *Æchmina spinosa* (very numerous),

Bollia symmetrica (rare). From the Niagara Group, Lockport, New-York State. Given to me by Dr. James Hall, F.M.G.S.

2. *ÆCHMINA BYRNESEI* (Miller). (Pl. III. figs. 9-11.)

Leperditia Byrnesi, A. S. Miller, 'Cincinnati Quart. Journ. of Science,' vol. i. 1874, p. 123, fig. 10.

Size	Fig. 9	Figs. 10 & 11..	Length.	Height.	Thickness.
			mm.	mm.	mm.
			1.06	.7	
			1.06	.7	.3 (.43 with the spine).

This species has oblong valves, unequally rounded at the ends, and each valve bears a short oblique spine, with a short angular sulcus or notch behind it, and this is succeeded by a swelling or knob at the postero-dorsal angle. The rest of the valve is smooth and moderately convex, sloping gently to the free border, which has a very slight, unequal, marginal rim.

The individuals are numerous, constituting a considerable portion of a thin layer of small organisms (*Leperditia hudsonica* (?), rare, Encrinites, Brachiopods, Polyzoa, Annelid jaws, &c.), on a compact, blue-grey limestone from the Cincinnati Group (Lower Silurian), Cincinnati, Ohio. Given to me by Prof. E. W. Claypole some years ago.

VI. Genus BOLLIA, Jones and Holl.

Bollia, J. & H. 'Ann. & Mag. Nat. Hist.' ser. 5, vol. xvii. 1886, p. 360.

1. *BOLLIA SYMMETRICA* (Hall). (Not figured here.)

Beyrichia symmetrica, Hall, 'Palæont. New York,' vol. ii. 1852, p. 317, pl. lxxvii. fig. 16 (containing four figures not separately numbered); Dana, 'Manual of Geology,' 3rd edit. 1874, p. 227, fig. 452.

Size: length about 1 mm.

This is closely allied to *Bollia lata*, but the curved or horse-shoe ridge is thinner, with a somewhat sharp ventral bend, and encloses a much larger and wider subtriangular depression or sulcus than in *B. lata*. The two other ridges, at the ends of the valves, curve down to the ventral border. In the lower left-hand figure they are thicker than the horse-shoe ridge; and one appears to overhang the margin, the other being distinct from the edge. In another (lower right-hand) of the enlarged views, one barely touches the margin, while the other is divided off from its end of the valve by a distinct curved furrow.

From the Niagara Shale of Lockport, N.Y.

2. *BOLLIA LATA* (Vanuxem and Hall). (Pl. III. figs. 1, 2, 3.)

Agnostisis[us] latus, Vanuxem, 'Nat. Hist. New York; Geology,' pt. iii. 1842, pp. 80; 83 (the species is mentioned here).

Beyrichia lata, Hall*, 'Palæont. New York,' vol. ii. 1852, p. 301, pl. lxxvi. figs. 10, 10 a, b and 10 d (not figs. 10 c, 10 e).

* The species is here referred to "Conrad in Vanuxem."

Beyrichia regularis, Emmons, 'American Geology,' vol. i. pt. ii. 1855, p. 219, fig. 74 b; 'Manual of Geology,' 2nd ed. 1860, p. 100.

Beyrichia lata, Jones, 'Ann. & Mag. Nat. Hist.' ser. 2, vol. xvi. 1855, p. 168, pl. vi. fig. 13*.

		Length.	Height.
		mm.	mm.
Size {	Fig. 1 . . . . .	.8	.46
	2 . . . . .	.73	.46
	3	1.0	.66

Valves having a *Beyrichian* aspect, but bearing centrally a bent ridge, somewhat like a horse-shoe, with the curvature downwards, in the ventral region, and variable in thickness. The ends of the valves have raised margins, sometimes much thickened (fig. 2) and even doubled (fig. 3). Thus usually the valve bears a short, but broad and strong sulcus in the middle of the dorsal region ("Sub-central depression," Hall, *l. c.*), and two longer, curved furrows across the valve near each end. The surface sometimes shows a delicate reticulation.

The *B. ungula* of Pennsylvania, in Dr. Claypole's collection, is a close ally of *B. lata*.

This species has evidently been confused with another form at p. 301 and in pl. A lxvi. figs. 10 a-e; c and e being a true *Beyrichia*, near to *B. Klædeni*. Prof. Hall's specimens were from the Clinton Group of Oneida County, N.Y. Prof. Emmons mentions the Blue Limestone of Ohio, and the Trenton Limestone, as the source of his *Beyrichia*.

Our figured specimens are in a thin limestone seam, largely made up of small Ostracoda (*Bollia lata*, *Æchmina spinosa*, *Prinitia cylindrica*), with Brachiopods, Encrinites, Tentaculites, and fragments of Trilobites. From Lockport, State of New York. Given to me by Prof. Whitfield in 1884.

VII. GENUS KLÆDENIA, Jones and Holl.

Klædenia, J. & H. 'Ann. & Mag. Nat. Hist.,' ser. 5, vol. xvii. 1886, p. 347.

1. *KLÆDENIA NOTATA* (Hall). (Pl. IV. figs. 22, 23.)

Beyrichia notata, Hall, 'Palæont. New York,' vol. iii. p. 379 (pl. lxxix. B, figs. 3 a-c; not published).

		Length.	Height.
		mm.	mm.
Size {	Fig. 22	1.6	.86
	23	1.8	1.1

This is a *Klædenia* closely allied to *Kl. Wilckensiana*, Jones †, but the subcentral lobe and its lateral sulci are feebly developed,

* The ventral curve of the horse-shoe ridge is not sufficiently distinct from the subsidiary ridge in this figure.

† Ann. & Mag. Nat. Hist. ser. 2, vol. xvi. 1855, p. 90, pl. v. figs. 17-19; and ser. 5, vol. xvii. 1886, pp. 347, 362; and ser. 6, vol. i. 1888, p. 398, *note*.

not reaching the dorsal line, and very variable in expression, as indicated in the figures. In some instances the valves are more oblong than in *Kl. Wilckensiana*, but in others they are much less so, the posterior moiety being contracted below, with a strong postero-ventral slope, giving rise to Prof. Hall's variety *ventricosa*. Here also the middle lobe is variable in development. Prof. Hall notes that the surface is delicately granulose (p. 379) in this species.

It is represented by *Kl. pennsylvanica* in Dr. E. W. Claypole's collection.

Kl. notata and its variety are abundant in the Tentaculite-limestone (Lower Helderberg), Herkimer Co., N.Y. (Hall, *l. c.*).

They abound also in a limestone of the Waterlime Group from near Utica, N. Y. State (British Museum). *Beyrichia Hallii* accompanies them.

1*. *KLÆDENIA NOTATA* (Hall), var. *VENTRICOSA*, Hall. (Pl. I. figs. 1 *a*, 1 *b* [after the original drawings]; Pl. IV. fig. 24.)

Beyrichia notata, var. *ventricosa*, Hall, 'Palæont. N. Y.' vol. iii. p. 380 (pl. lxxix. B, figs. 4 *a-c*; not published).

Size		Length.	Height.
		mm.	mm.
Size	Pl. I. fig. 1 <i>a</i>	2·5	1·2
	1 <i>b</i>	2·7	1·2
	Pl. IV. 24.....	1·8	1·03

This variety is noticed above, under *Kl. notata*.

Tentaculite-limestone from Coeymans, Albany Co., N.Y., collected and given by Mr. J. M. Clarke, of Albany, N.Y., consists of thin slabs of compact grey limestone showing on the bed-planes Polyzoa, small Brachiopods, numerous Tentaculites, and small obscure Ostracods, such as *Primitia minuta* (?), a larger oblong form, and many small *Klædenia notata*. Among them are some much larger individuals of this last species, attaining a length of more than 3 and of even 4 mm.

Mr. Clarke has also favoured me with some Palæozoic Ostracoda, mostly of new species, (1) from the decomposed chert of the Corniferous Limestone of Ontario Co., N.Y., and (2) from the Hamilton Group in Clarke Co., Indiana.

[From no. 1. *Primitia* near *P. fabulina*, J. & H.; *Eurychilina reticulata*, Ulrich (? a frilled *Primitia* near "*Beyrichia reticulata*," Bornemann); *Beyrichia*, *Strepula*, and *Moorea*.—December 16, 1889.]

VIII. GENUS BEYRICHIA, M'COY, 1846.

1. *BEYRICHIA TRISULCATA*, Hall. (Pl. I. fig. 2, after the original drawing.)

Beyrichia trisulcata, Hall, 'Palæont. N. Y.' vol. iii. 1859, p. 381 (pl. lxxix. B, figs. 5 *a, b*; not published).

Size: length 1·3 mm., height ·75 mm.

Fig. 2 looks like a small *Klædenia* with three short and nearly equal sulci dividing the dorsal region into four almost equal lobes. *Kl. plicata* has even four furrows, but the subcentral prominent lobe is always distinct in this genus, and I would rather regard the form under notice as a *Beyrichia*, because if the three sulci were more distinct, more unequal, and reached to the ventral region, the valve would approximate to that of *Beyrichia digitata*, Krause, Zeitschr. d. D. g. Ges. 1889, p. 20, pl. ii. fig. 12.

The lobe at one end is the smallest of the series. The surface is stated to be finely granulose.

From the Lower-Helderberg group, State of New York.

2. BEYRICHIA HALLII, sp. nov. (Pl. IV. fig. 21.)

Size: length 1·3 mm., height '76 mm.

A trisulcate *Beyrichia* form, but not *B. trisulcata*, Hall. The three furrows are broad and shallow, reaching a little more than two thirds across the valve. The two sulci near the ends are curved nearly parallel to their respective margins, but at some distance from them; the middle sulcus has an elongate oval outline. The lobes or ridges are moderately convex, and vary, but not very much, in size. Two lobes in the middle form a curved, nearly semicircular ridge, not free in the ventral region, as is the horse-shoe ridge in *Bollia*, but coalescing with the two end lobes along that region; and the surface of the valve slopes smoothly and gently down to the margin, all along the free border.

The valve is suboblong; straight on the back, with a cardinal angle at the posterior end, and rounded off anteriorly. Ends unequally rounded; ventral margin slightly incurved.

British Museum. Rare, in a piece of limestone of the Waterlime Group, from near Utica, N.-Y. State. This limestone is compact and dark-grey, weathering brownish-grey. Largely composed of small organisms, especially *Klædenia notata*, with small Brachiopods, &c.

3. BEYRICHIA GRANULATA, Hall. (Pl. I. fig. 3, after the original drawing.)

Beyrichia granulata, Hall, 'Palæont. N. Y.' vol. iii. 1859, p. 377 (pl. lxxix. B, figs. 1 a-d; not published).

Size: length 3·5 mm., height 2·0 mm.

Fig. 3 represents a *Beyrichia* much like *B. Klædeni*, var. *tuberculata**, Salter, but its dorsal line is straight, and its free border is thickened with a broad marginal rim. Of the three the posterior lobe is the largest, and it unites with the front lobe below the well-marked, oval, middle lobe.

From the Pentamerus-limestone of the Lower-Helderberg Group, Schoharie Co., N.Y.

* Geol. Mag. 1881, p. 345, pl. x. fig. 13; Ann. & Mag. Nat. Hist., ser. 5, vol. xvii. 1886, p. 354, pl. xii. fig. 8.

4. BEYRICHIA OCLINA, Hall. (Pl. I. fig. 4, after the original drawing.)

Beyrichia oculina, Hall, 'Palæont. New York,' vol. iii. 1859, p. 378 (pl. lxxix. B, figs. 2 a-e; not published).

Size: length 2·3 mm., height 1·8 mm.

This little *Beyrichia* to a considerable extent resembles *B. Saltzeriana* *, Jones, having a neat symmetrical form, with a central and two other lobes; but the latter coalesce ventrally, and, according to Dr. Hall's description, the posterior (largest) lobe is sometimes crossed by a slight depression, and projects upwards above the hinge-line.

From the Pentamerus-limestone, Schoharie Co., N.-Y. State.

5. BEYRICHIA BUCHIANA (?), Jones. (Pl. III. fig. 25.)

Size: length ·43 mm., height ·3 mm.

This is a very small, not well-preserved, three-lobed *Beyrichia*. The front lobe or ridge is free; the middle lobe, curving ventrally, probably joined the hinder ridge, which is divided into two unequal parts, its upper (smaller) portion being round, and the lower part pyriform.

Reuter's *Beyrichia tuberculato-Kochiana* † has a somewhat similar valve, but its middle lobe is short, and the hinder ridge is much too large and tuberculate. Some varieties, however, of *B. Buchiana*, Jones, figured and described by Kiesow as var. *nutans* ‡, on account of the strangulation of the top of the posterior ridge, supply a near equivalent to the little form under notice. Hall's *B. cequilatera*, from Arisaig, Nova Scotia (as figured, Canad. Nat. Geol. vol. v. 1860, p. 158, fig. 20), is like this, but the free ridge is larger, and the central lobe is very much smaller.

Another form near to this is Ulrich's *Beyrichia persulcata* (Journ. Cincinn. Soc. N. H. vol. vii. no. 1, 1879, p. 12, pl. vii. fig. 6); but the latter has a ridge or lobe between the divided ridge and the margin.

In the specimen, Brit. Mus. 59723; a thin limestone, largely made up of "*L. cylindrica*, Hall," obscure and imbedded, chiefly on one plane; *L. minutissima*, Hall, and *Primitia Whitfieldi*, nov., are also present. On one plane is the cast of a little ripple-mark, and this small *Beyrichia* lies in it.—Cincinnati, Ohio.

6. BEYRICHIA PARASITICA (Hall). (Woodcut, fig. 1.)

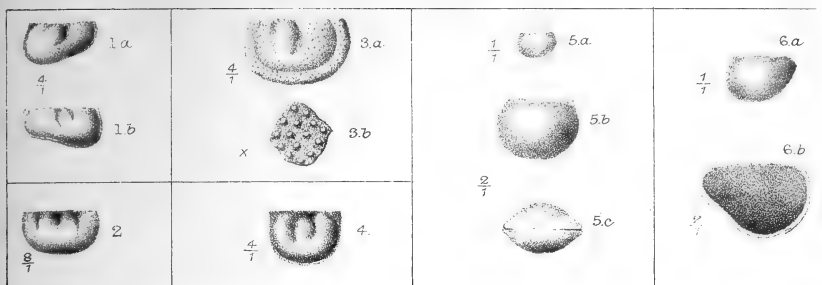
Size: length 1·15 mm., height ·625 mm.

Mr. J. M. Clarke, of Albany, has kindly sent me a sketch of what was probably intended for "*Leperditia parasitica*," Hall, Palæont. New York, vol. iii. 1859, p. 376 (pl. lxxix. A, figs. 8 a, b; not published).

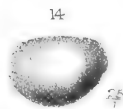
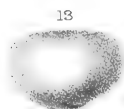
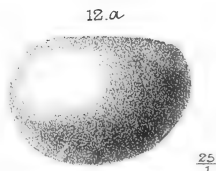
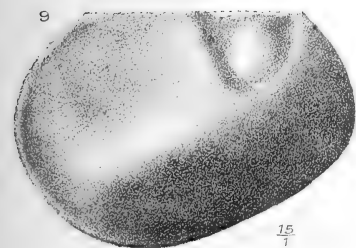
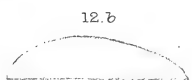
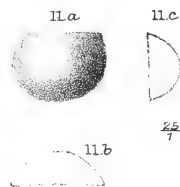
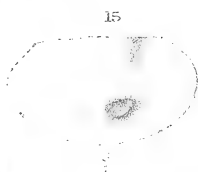
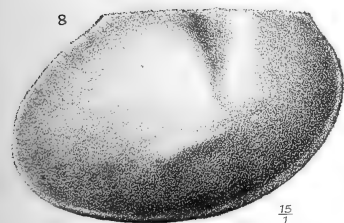
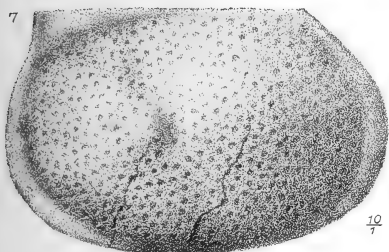
* Ann. & Mag. Nat. Hist., August 1855, p. 89, pl. v. figs. 15, 16; Krause, Zeitschr. d. D. g. Ges. 1877, p. 35, pl. i. fig. 17 a; Reuter, *op. cit.* 1885, p. 645, pl. xxvi. fig. 19 A a.

† Zeitschr. d. D. g. Ges. 1885, p. 643, pl. xxvi. fig. 14; in this and in some of his varieties of *B. Buchiana* it is the anterior lobe that is shown to be divided into two parts.

‡ *Op. cit.* 1888, p. 7, pl. i. figs. 11 and 14.



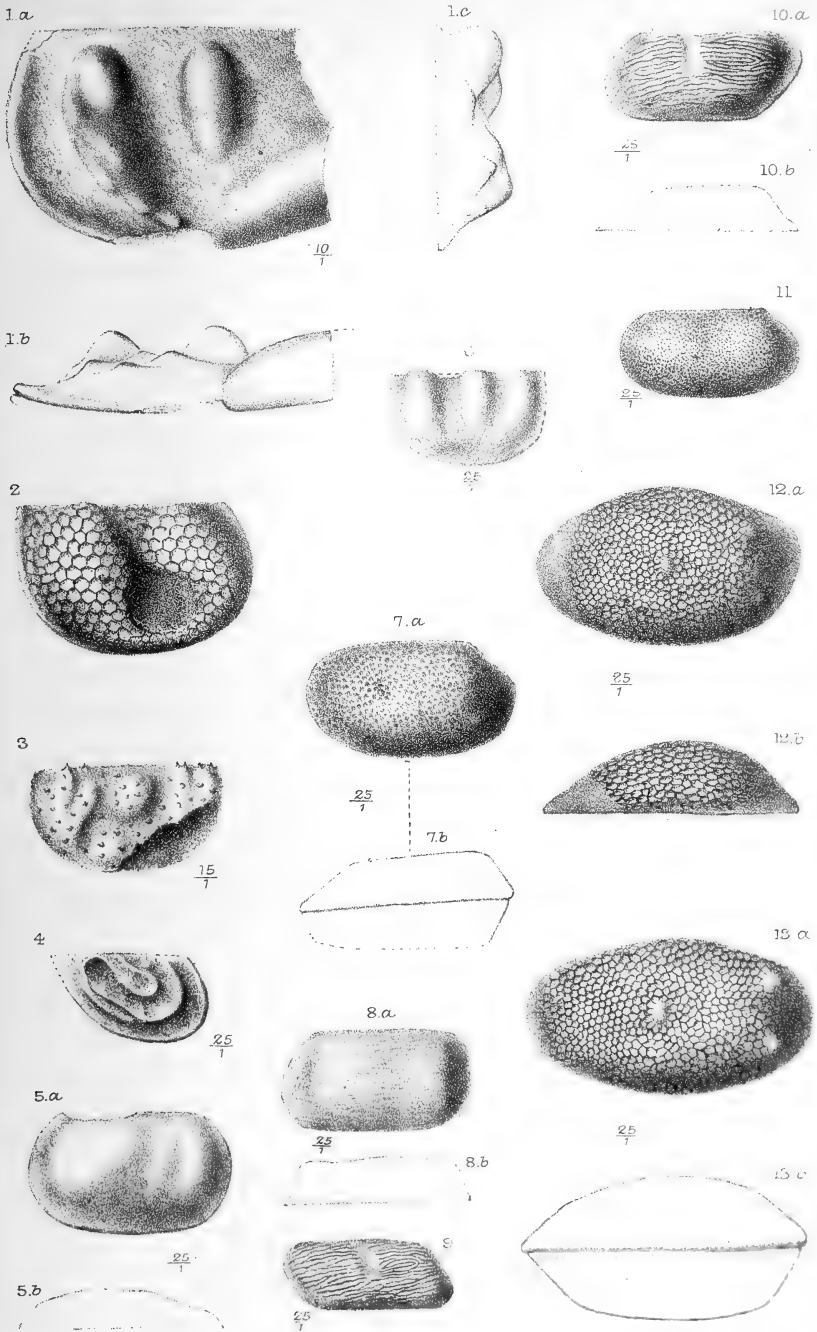
J.M.C.



E.C. Knight del. et lith.

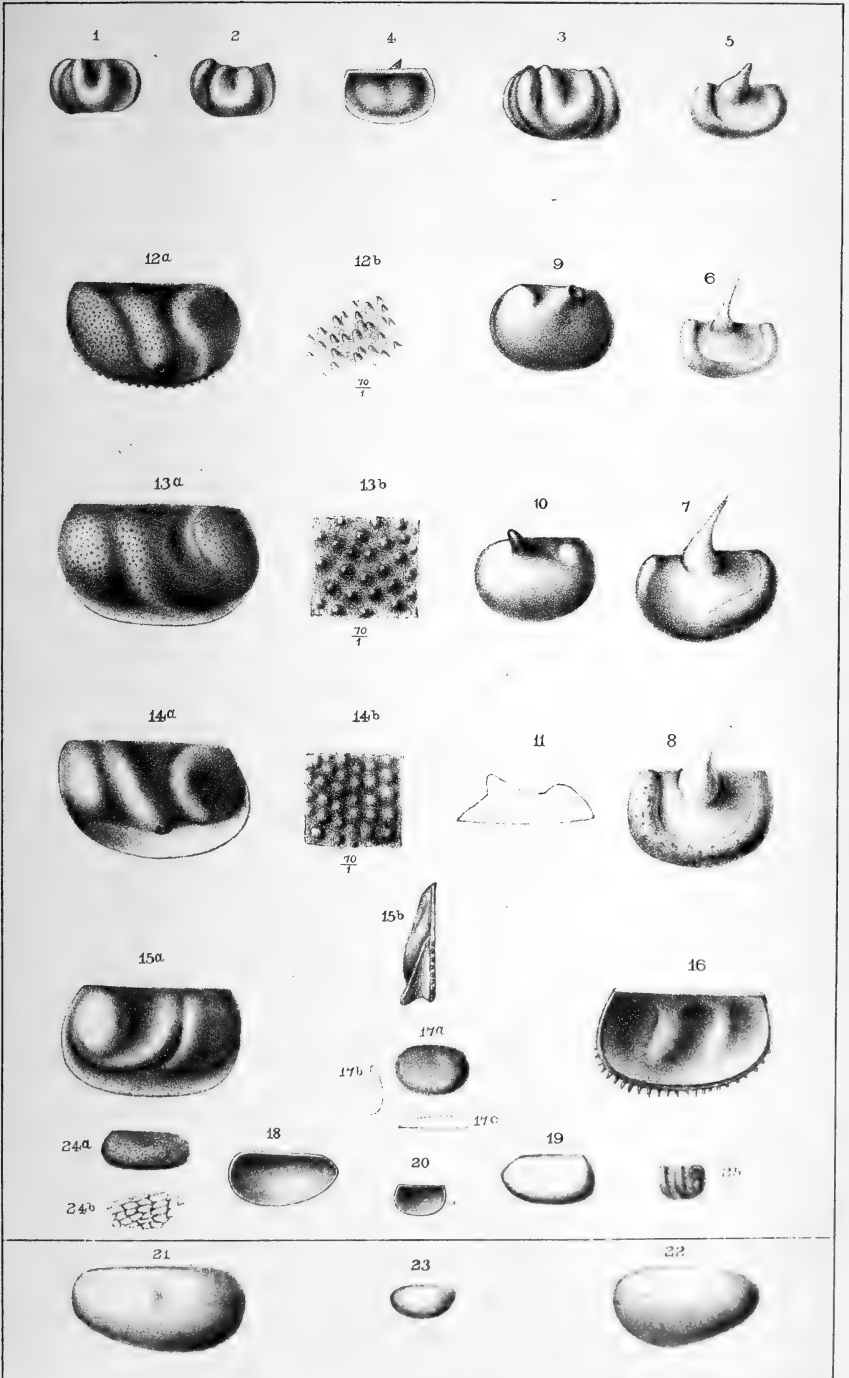
West, Newman & Co. imp.



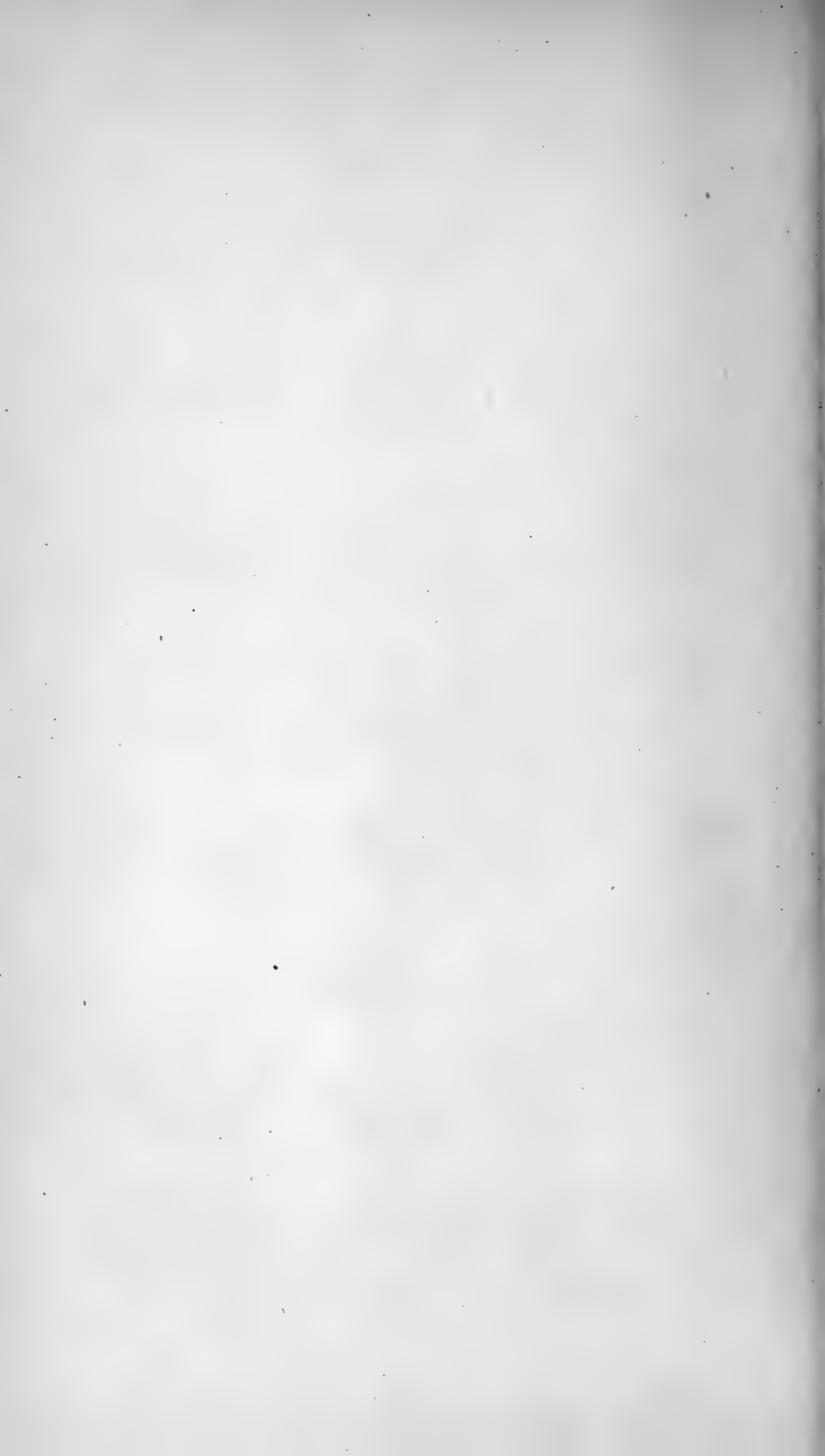


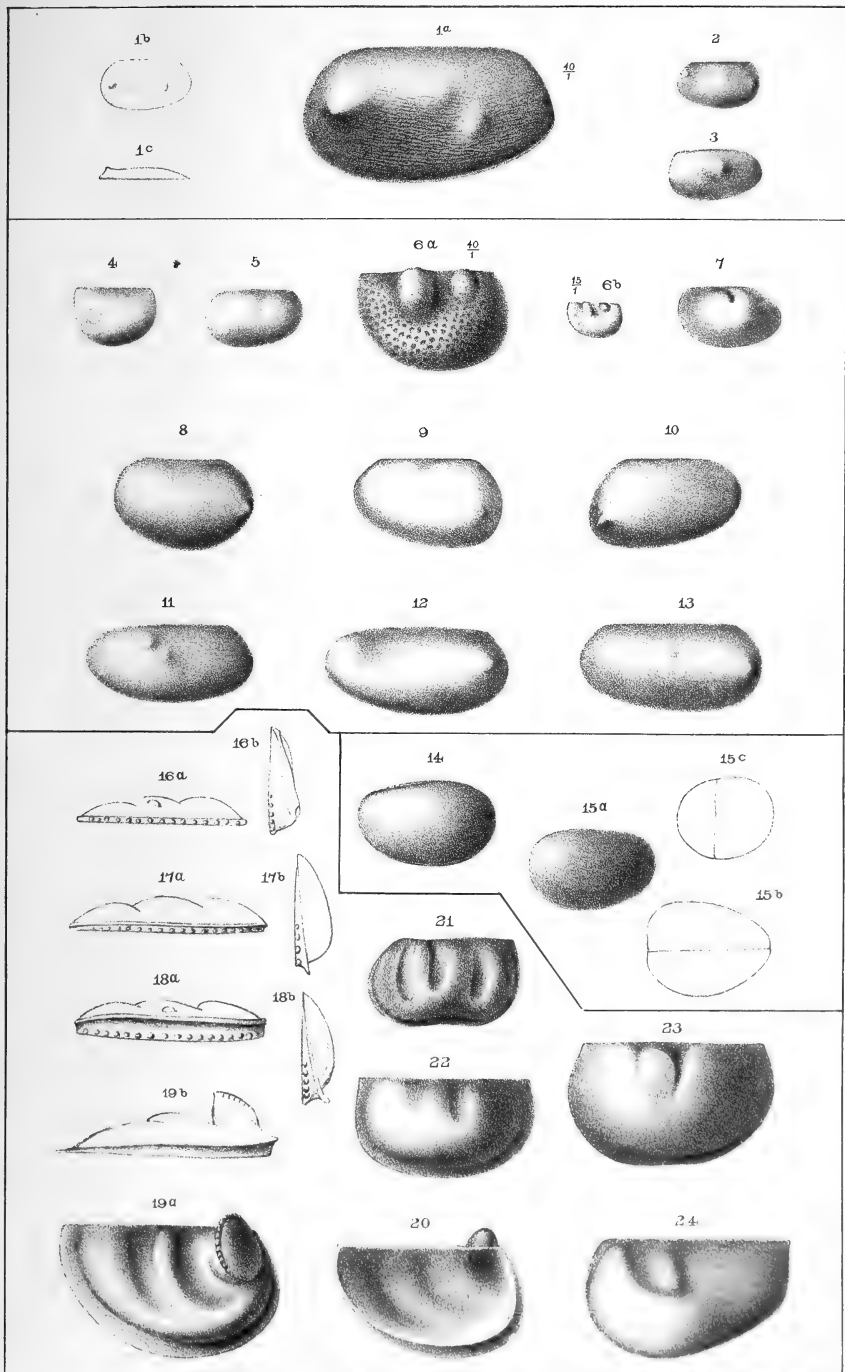
E.C. Knight del. et lith.

West, Newman & Co imp



GeoWest & Sons del lith of imp





GeoWest & Sons del lith et imp

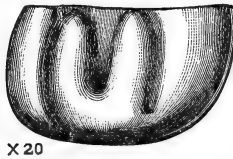
The specimen is from the Tentaculite-limestone of Herkimer Co., N.Y. It is about 1.15 mm. in length, and belongs to the *B. Kløedeni-clausa* group, passing almost into *Kløedenia*, by the full ventral coalescence of the fore and aft lobes and the feeble development of the anterior sulcus.

Fig. 1.—*Beyrichia parasitica* (Hall).
(Magnified 20 diameters.)



This drawing (fig. 1) is remarkably similar to the specimen from New Brunswick, described and figured in the *Ann. & Mag. Nat. Hist.* ser. 6, vol. iii. 1889, p. 381, pl. xvii. fig. 7 a, as being probably the same as *Beyrichia arcuata* (Bean).

Fig. 2.—*Beyrichia Clarkei*, sp. nov.
(Magnified 20 diameters.)



7. BEYRICHIA CLARKEI, sp. nov. (Woodcut, fig. 2.)

Size: length 1.45 mm., height .9 mm.

Mr. Clarke has also courteously supplied me with a drawing of a small Ostracod (fig. 2) which is associated with *Beyrichia oculina* and *B. notata-ventricosa* in the Lower-Helderberg Group of Herkimer Co., N.Y.

Subquadrate and deeply sulcate, this appears to be intermediate to *Bollia lata* (Pl. III. fig. 3) and *Beyrichia Hallii* (Pl. IV. fig. 21), see above, pages 12 and 15. The middle or horse-shoe ridge not being free below, and the two lateral sulci not quite reaching the ventral margin, place it nearer to the quadrijugate *B. Hallii* than to *Bollia*. In this we can see a passage-form between the two genera.

I propose to distinguish this interesting form as *Beyrichia Clarkei*, naming it after my obliging friend, Mr. J. M. Clarke, Prof. Hall's accomplished palæontological assistant in the State Museum at Albany, N.Y.

8. BEYRICHIA ÆQUILATERA, Hall. (Pl. II. fig. 6.)

Beyrichia equilatera, Hall, 'Canadian Nat. & Geol.' vol. v. 1860, p. 158, fig. 20.

Beyrichia equilatera, Dawson, 'Acadian Geology,' 3rd edit. 1878, p. 609, fig. 217.

Size : length .8 mm., height .52 mm.

The specimen shown by fig. 6 is a poor cast of a *Beyrichia*, related to *Beyrichia Klædeni*. It is from Arisaig, Nova Scotia, in the same kind of sandstone as that containing *B. pustulosa* (see below). It is labelled *B. equilatera*, but is not much like the figure published in the 'Canadian Naturalist and Geologist,' 1860, which seems to have one strong curved ridge, a small central lobe, and two little lobes (not mentioned in the description) representing a third ridge. Our figured specimen has the third lobe slightly modified by a faint oblique sulcus, but is not actually divided. The anterior ridge at the other end rises high up dorsally, and curves well down to join the middle lobe.

9. BEYRICHIA TUBERCULATA, Boll, var. PUSTULOSA, Hall. (Pl. II. figs. 1 a, b, c.)

Beyrichia pustulosa, Hall, 'Canad. Nat. & Geol.' vol. v. 1860, p. 157, fig. 19; Dawson, 'Acad. Geol.' 2nd edit. 1868, & 3rd edit. 1878, pp. 608, 609, fig. 216.

Beyrichia tuberculata, Jones, 'Quart. Journ. Geol. Soc.' vol. xxvi. 1870, p. 492; 'Geol. Mag.' 1881, p. 344, pl. x. figs. 8, 9, & 10.

Size : length 5 (?) mm., height 2.8 mm., thickness of carapace 2 mm.

Our fig. 1 is one of the forms of this Nova-Scotian *Beyrichia*, and being an internal cast is comparable with fig. 8, pl. x. Geol. Mag. 1881; but it has lost its anterior fourth by fracture, and the hypertrophy of the antero-ventral lobe makes a difference. Although the hinder lobe in fig. 8 (Geol. Mag.) is partly broken away, the two specimens may have agreed in this region. As for the valve itself, fig. 9 (Geol. Mag.) is quite equivalent to the cast shown in fig. 8 and to our specimen, except that the latter has the hypertrophied lobe, which, however, is not at all an essential or specific feature*.

Our fig. 1, if restored with its valve complete, may be regarded as equivalent to Boll's *B. tuberculata*, having the large lobe, fig. 1 a (Archiv Ver. Fr. Nat. Meklenburg, 16 Jahrg., 1862, p. 119). This form, and the same without the big lobe, are described and figured by G. Reuter (Zeitschr. d. D. g. Ges. vol. xxxvii. 1885, p. 634, pl. xxv. figs. 2 A & 2 B) as *B. tuberculata-gibbosa*. Fig. 10 (Geol. Mag.) is not quite perfect along the antero-dorsal margin; but may be regarded as a large growth of *B. tuberculata*, with the lower portion (preserved) of the anterior lobe proportionally and normally large.

* Ann. & Mag. N. H., April 1886, pp. 339-342.

These slightly differing forms may require a varietal name; Dr. Hall's "PUSTULOSA" precedes that given by Herr Reuter, and can be retained.

Our specimen, labelled "*Beyrichia pustulosa*: Arisaig, Nova Scotia," is a sandstone cast of the inside of a right valve, coated with hæmatite. It lies on a small piece of fine-grained micaceous sandstone, almost wholly stained red, but whitish here and there.

10. BEYRICHIA HAMILTONENSIS, sp. nov. (Pl. II. fig. 3.)

Size: length 1.66 mm., height .93 mm.

Suboblong, straight on the back, elliptically rounded below; multilobed, the middle lobe isolated and oblique; anterior lobe forked by a vertical sulcus; posterior lobe similarly furcate, but not so deeply, and passing downwards and forwards (broken) to a swollen portion just at the middle of the ventral region. All the surface is pimpled, some of the granulation becoming sharp and prickly at the dorsal region. This is distantly allied to *B. dubia*, Reuter, Zeitschr. D. g. Ges. vol. xxxvii. p. 648, pl. xxvi. fig. 22, and remotely to *B. tuberculata*, Boll, which may be taken as the central form of a large group of these Ostracoda.

B. hamiltonensis is so-called from its belonging to the Hamilton Division of the Devonian Series in the United States. It came from Eighteen-mile Creek, Lake Erie Shore, N.Y.

11. BEYRICHIA * CILIATA, Emmons. (Pl. III. figs. 12 a, b, 13 a, b, 14 a, b, 15 a, b, 16; Pl. IV. figs. 16 a, b, 17 a, b, 18 a, b.)

Beyrichia ciliata, E. Emmons, 'American Geology,' vol. i. pt. 2, 1855, p. 219, fig. 74 c (right valve); 'Manual of Geology,' 2nd edit. 1860, p. 100, fig. 90.

B. tumifrons, Hall, 'Twenty-fourth Report State N.Y. Mus. N. H.' 1871-72, p. 231, pl. viii. fig. 11 (right valve); Report Geol. Survey Ohio, vol. ii. pt. 2, 1875, p. 102, pl. iv. fig. 8 (right valve).

		Length.	Height.	Thick- ness.
		mm.	mm.	mm.
Size {	Pl. III. fig. 12; Pl. IV. fig. 16..	1.53	.86	.6
	fig. 13; fig. 17..	1.7	1.06 (with flange)	.66
	fig. 14; fig. 18..	1.6	1.0 do.	.6
	fig. 15	1.56	.93 do.	.53
	fig. 16	1.6	.86 (no flange)	

Valves suboblong, ends rounded unequally, but almost parallel; in some cases upright or nearly so (Pl. III. figs. 13 a and 15 a); sometimes oblique from above downwards and backwards (Pl. III. fig. 14 a); dorsal edge straight, with a long hinge-line; ventral

* Mr. E. O. Ulrich proposes to find a more convenient generic group for this and some allied forms.

border gently curved and ciliated (Pl. III. figs. 12 *a*, 16, and Pl. IV. fig. 16 *a*, *b*), and in many instances provided with a broad, thin, smooth, outstanding lip above the ciliated border, and hiding it (Pl. III. figs. 13 *a*, 14 *a*, 15 *a*, *b*, and Pl. IV. figs. 17 *a*, *b*, 18 *a*, *b*). This flange-like lip varies in breadth with different individuals, and in its distance from the ciliated edge (see Pl. III. fig. 15 *b*, and Pl. IV. figs. 17, 18). The surface of the valves is crossed by two strong, and more or less curved or even sigmoidal furrows, varying in width and intensity, as seen in Pl. III. figs. 12 *a*, 13 *a*, 14 *a*, and 15 *a*. There are consequently three unequal, obliquely transverse lobes. The curve of the hindermost furrow encloses the highest and roundest of the lobes. The middle lobe sometimes curves round ventrally to join the hindermost (as in figs. 13 *a* and 15 *a*); but sometimes it ends ventrally in an isolated hollow process or spine (broken in figs. 12 *a* and 14 *a*). Another difference among the specimens is to be seen in the flange and prickles of the ventral margin. These may both be present (as in Pl. III. figs. 13 *a*, 14 *a*, 15 *a*, *b*, and Pl. IV. figs. 17 and 18). In Pl. III. figs. 12 *a* and 16, and Pl. IV. fig. 16, the fringe only appears. This feature gave origin to Dr. Emmons's name for the species. The swollen lobe not being in front, but behind, vitiates the name given afterwards by Dr. Hall.

The surface of the valves is always granulose, the granules having different degrees of coarseness, according to age apparently (see figs. 12, 13, 14; in figs. 14 *a* and 15 *a* this feature was inadvertently neglected owing to the granules becoming lower, broader, and coalescent).

The figure given by Prof. Hall resembles Pl. III. fig. 15 *a*, except that the outstanding flange is not defined. Prof. Emmons's figure (except that it is a right instead of a left valve) is comparable with Pl. III. fig. 12 *a*, but without the ventral process. The interior of a left valve (Pl. III. fig. 16) shows the reverse aspect.

This well-marked species occurs in two pieces of stone (marked 59725) in the British Museum:—1. A thin, light brown (weathered) limestone, consisting of small organisms, such as Encrinital joints, Brachiopods, and Polyzoans, with *B. ciliata* and *Primitia minuta* (red in colour), standing out more freely on one face than the other. 2. A dark grey, thin, similar limestone, with light grey shaly faces. Both from Cincinnati, Ohio.

Also in specimen I. 512, Brit. Museum; a grey limestone seam, weathering brownish grey, made up of small organisms (Encrinital joints, Brachiopods, Polyzoans, &c., with Ostracoda, chiefly *B. ciliata*). From the Hudson-River Group, Cincinnati, Ohio.

Figs. 15 and 16, Pl. III., are in a bluish-grey limestone (weathering brownish) consisting of small organisms, such as Polyzoa, Encrinital joints, fragments of Trilobites, &c., with *B. ciliata*. Cincinnati Group, Lower Silurian, Cincinnati, Ohio. Given to me some years ago by Dr. E. W. Claypole, F.G.S.

The edge views in Pl. IV., figs. 16–18, correspond to the valves in Pl. III. figs. 12–14 respectively.

12. BEYRICHIA OCULIFERA, Hall. (Pl. IV. figs. 19 *a*, *b*, 20.)

Beyrichia oculifera, Hall, 'Twenty-fourth Report N. Y. State Mus. N. H.' 1871-72, p. 232, pl. viii. figs. 9, 10; Report 'Geol. Surv. Ohio,' vol. ii. pt. 2, 1875, p. 103, pl. iv. figs. 9, 10.

Size	Fig.	Length.	Height.	Thickness.
{	19	1.9	1.1	.66 (without the boss).
	20	1.7	1.0	

This interesting species is related to *B. ciliata*, Emmons (*B. tumifrons*, Hall), having the two curved parallel furrows and three curved lobes; but the latter, more uniform and thinner than in *B. ciliata*, are not separated one from another ventrally, and the hindermost is developed in the dorsal region into a remarkable process, like a small thick-stemmed mushroom, smooth (?) on the top*, and delicately beaded round its edge. This is directed backwards, and projects so high, that it is not usually preserved, as it is in fig. 19 *a*, *b*, but worn away, as in fig. 20. This projecting ornament is on the hindermost (highest and thickest) third of the valve, and has no relation to an eye †.

The valve has a neat, smooth, ventral flange.

British Museum (no. 59719). Light bluish grey, thin, argillaceous limestone, containing on the bed-planes Ostracoda (*B. oculifera* chiefly), Polyzoa, Brachiopoda, and fragments of Trilobites, all abundant, and some Encrinital joints. Cincinnati, Ohio.

IX. ISOCHILINA, Jones, 1858 & 1870.

1. ISOCHILINA LINEATA, sp. nov. (Pl. II. figs. 5 *a*, *b*, and 8 *a*, *b*.)

Size	Fig.	Length.	Height.	Thickness.
{	5	1.04	.64	.4
	8	1.0	.52	.48

Fig. 8 indicates a young individual; oblong, straight above and below; ends unequally rounded; surface undulate, steep at the free edges, and particularly abrupt at the ends; ornamented with very delicate longitudinal striæ.

The adult form in fig. 5 is oblong, with nearly equal rounded ends; surface gently and almost equally convex, but undulate; broader and sloping more gently at one end (anterior), and margined with a weak rim or lip on the free edges; smooth, but faintly lineate near the posterior end.

This differs from *I. lineata* in its young state (fig. 8) in being larger, convex without abrupt ends, more distinctly lipped, and only feebly striate.

* In our specimens the facet-like marks figured by Prof. Hall are not visible, and the edge is not fringed but beaded.

† This fact has already been alluded to in the Ann. & Mag. N. H., April 1886, p. 341.

Both specimens are from the Hamilton Group, at Monteith's Point, Canandaigua, State of New York.

2. *ISOCHILINA* (?) *FABACEA*, sp. nov. (Pl. II. fig. 11.)

Size: length .92 mm., height .44 mm.

Narrow-oblong, bean-shaped, straight above, gently curved below, semicircular in front, obliquely rounded behind, faintly impressed in the middle of the dorsal region; sloping gently dorsally, and more abruptly on the free margins. Surface apparently punctate, but in reality delicately reticulate all over.

From the Hamilton Group, at Eighteen-mile Creek, Lake Erie Shore, N.Y.

3. *ISOCHILINA* *SEELYI* (Whitfield). (Pl. I. fig. 7.)

Primitia Seelyi, Whitfield, 'Bulletin American Mus. Nat. Hist. vol. ii. no. 2, 1889, p. 60, pl. xiii. figs. 6, 7.

Size: length 5.0 mm., height 3.2 mm.

The specimen here figured differs somewhat from Prof. Whitfield's illustration in being less Leperditoid, that is, more oblong, being as high in front as behind, in having a more developed posterior cardinal angle, in not showing a smooth space in the antero-dorsal region, and in having a slight swelling (with a faint depression) on the median line behind the centre. Its ventral margin is that of an *Isochilina*. I cannot refer it to *Primitia*. One of its nearest allies is *Isochilina labrosa*, Jones, Ann. & Mag. N. H., May 1889, pp. 383, 384, figs. 3 and 4, and pl. xvii. fig. 11; and another, but not so near, is *Isochilina Jonesi*, Wetherby, 'Journ. Cincinnati. Soc. Nat. Hist.' vol. iv. 1881, p. 4 (separate), pl. ii. figs. 7, 7a.

From a dark blue limestone, Shoreham, Vermont, and waterworn fragments of a granular limestone, Providence Island, Lake Champlain; probably Birds-eye Limestone. Our figured specimen is in grey limestone largely composed of *Isochilinae* (Providence Island).

4. *ISOCHILINA* *GREGARIA* (Whitfield). (Pl. I. figs. 9, 10.)

Primitia gregaria, Whitfield, 'Bulletin N. H. Mus. N. Y.' vol. ii. no. 2, 1889, p. 58, pl. xiii. figs. 3-5.

		Length.	Height.
		mm.	mm.
Size {	Fig. 9	2.9	2.06
	10	2.6	1.8

This species is variable in outline and features, as noticed by Prof. Whitfield. Fig. 10 agrees in outline with Prof. Whitfield's fig. 5, but the aspect of the nuchal notch and its tubercles approaches that of his fig. 3. Our fig. 9 differs from all in outline and notch; but, as to the latter feature, it approaches fig. 5, one tubercle lying in a broad notch. The furrowed sides of the notch in our fig. 10 remind us of a complex furrow on the front slope of a Carboniferous *Cyclus*, sp., having lumpy margins, and of the ocular spot and its

broad furrowed notch in the Devonian *Kyamodes Whidbornei*, Ann. & Mag. N. H. ser. 6, vol. ii. 1888, p. 296, pl. xi.

The valves have a bright surface; they are in the same black rock as that containing *Isochilina cristata*. These two have their representatives in the Lower-Silurian rocks of Canada, which supplied *Isochilina gracilis* and *I. Ottawa*, Ann. & Mag. N. H. ser. 3, vol. i. 1858, p. 248.

Isochilina gregaria is closely allied to *Isochilina grandis*, Jones, Ann. & Mag. N. H. ser. 2, vol. xvii. 1856, pl. vii. fig. 14, and *op. cit.* ser. 5, vol. ix. 1882, p. 171.

In hard black calcareous shale, Cave Island, Ball's Bay, Lake Champlain, Vermont. Probably from the Calciferous-Sandstone Formation.

5. ISOCHILINA CRISTATA (Whitfield). (Pl. I. fig. 8.)

Primitia? cristata, Whitfield, 'Bulletin Amer. Mus. N. H.' vol. ii. no. 2, 1889, p. 59, pl. xiii. figs. 1 & 2.

Size: length 2.8 mm., height 1.8 mm.

The specimen here figured differs somewhat in outline from either fig. 1 or fig. 2 of Prof. Whitfield's memoir; it has a more simple nuchal depression without any tubercles, and shows a non-punctate surface. The nuchal mark varies in intensity in different specimens. The short, oblique ridge below the centre is always present.

This also is an *Isochilina*, there being no ventral overlap; otherwise it might well be a *Leperditia*. From Cave Island, as above.

For the three foregoing species of *Isochilina*, characteristic specimens were chosen and drawn before the Memoir by Prof. R. P. Whitfield came to hand.

6. ISOCHILINA ?, sp. (Pl. I. fig. 15.)

Size: length 4.1 (?) mm., height 2.3 (?) mm.

In fig. 15 we have indications of a Leperditoid valve with a nuchal depression as in fig. 8, and a broken, hollow, subcentral process, analogous to the oblique ridge in fig. 8, but apparently stronger and more limited in area. It may, however, have been more like the sharp process in Kolmodin's *Leperditia tuberculata*, Öfvers. k. Vet.-Akad. Förh. (1879), 1880, p. 135, pl. xix. figs. 1 a, 1 b; and Walcott's *Leperditia (Isochilina) armata*, 'Thirty-fifth Report N.Y. State Mus. N. H.' 1883, p. 213, pl. xvii. fig. 10.

From Cave Island, as above.

X. GENUS LEPERDITIA, Rouault, 1851.

1. LEPERDITIA (?) SENECA, Hall. (Pl. I. figs. 13, 14.)

Leperditia seneca, Hall, 'Fifteenth Annual Report, University of the State of New York,' 1862, p. 112.

	Length.	Height.
	mm.	mm.
Size { Fig. 13.....	·62	·44
14.....	·56	·36

Small, subtriangular, with the back straight, the ventral margin strongly curved, giving great relative height to the valve.

In a fine-grained sandstone, calcareous and finely micaceous; from the Hamilton Group, Ontario Co., New-York State.

2. *LEPERDITIA* (?) *SINUATA*, Hall. (Pl. I. figs. 12 *a*, *b*, *c*.)

Leperditia sinuata, Hall, 'Canad. Nat. & Geol.' vol. v. 1860, p. 158; and Dawson, 'Acadian Geology,' 3rd edit., 1878, pp. 609, 610.

Size: length .99 mm., height .60 mm., thickness .48 mm.

This is a small, black, shining *Leperditia* (?), subovate in outline, being straight on the back and without distinct cardinal angles; semicircular behind; boldly curved below, but rising with a less bold curvature to the limited curve in front. Our specimen does not show the minute tubercle, but the sinuous mark or little fold on the postero-ventral border is present, and reminds us of a somewhat similar feature in *Beyrichia hians*, Boll, 1856.

In a grey limestone with Brachiopods &c. from Arisaig, Nova Scotia.

3. *LEPERDITIA HUDSONICA*, Hall. (Pl. I. figs. 5 *a*, *b*, *c* (after the original drawings), and figs. 11 *a*, *b*, *c*; and Pl. III. fig. 20 ?.)

Leperditia hudsonica, Hall, 'Palæont. New York,' vol. iii. 1859, p. 375 (pl. lxxix. A, figs. 7 *a*, *b*, *c*; not published).

		Length.	Height.	Thickness.
		mm.	mm.	mm.
Size {	Pl. I. fig. 5	..... 5.0	3.50	3.0
	I. fig. 11	..... .48	.36	.32
	III. fig. 20	..... (?) .46	.26	

Carapace small, symmetrical and very convex (subglobular), being almost as thick as it is high, straight on the back, with the anterior cardinal angle more developed than the other; free margin (ventral edge and two ends) well rounded, rather more than semicircular; anterior extremity less truly rounded than the other. Further exact description is given by Prof. Hall (*l. c.*), especially that the right overlaps the left valve. His specimen came from the base of the Lower-Helderberg Group, at Becraft's Mountain, near the Hudson.

A very similar, if not identical, form has been sent to me by Prof. Whitfield for examination. This, of very much smaller size, is shown by figs. 11 *a*, *b*, *c*, taken from two little subglobose valves, somewhat pustulose towards the curved edge. Excepting the granulation there is apparently nothing to separate them from *L. hudsonica*. They occur on a piece of limestone ("500 *d*"), consisting of Crinoidal joints, Brachiopods, Polyzoans, &c., and belonging to the Hamilton Group (Devonian); at Eighteen-mile Creek, Lake Erie Shore, New-York State.

Fig. 20, in Pl. III., is a minute Leperditian valve of the same shape as *L. hudsonica*, but not quite so high in proportion. Its cardinal angles are too strong for *Leperditia (Isochilina) minutissima*, Hall; and it is less Leperditoid in shape, having more equal ends, thus approaching *Leperditia anna*, Jones (1858), in outline. It is from one of the Cincinnati limestones, associated with *Primitia minuta* (Pl. III. figs. 18, 19) and *Æchmina Byrnesi* (Pl. III. figs. 9-11). Given to me long ago by Dr. E. W. Claypole, F.G.S.

L. subquadrata of Pennsylvania (Claypole Collection) is a true *Leperditia*, and nearly allied to *L. hudsonica*.

4. LEPERDITIA CLAYPOLEI, sp. nov. (Pl. III. figs. 17 a, b, c.)

Size: length .66 mm., height .45 mm., thickness .2 mm.

Minute, suboval, cardinal angles not being developed at the ends of the nearly straight back; ends nearly semicircular, ventral border elliptically curved; compressed, especially at one end (anterior) and along the dorsal region. This is less Leperditoid in shape and much less convex than Hall's *Leperditia (Isochilina) minutissima*, 'Twenty-fourth Report N.-Y. State Museum Nat. Hist.' 1871-72, p. 231, pl. viii. fig. 13 [right valve]; 'Geol. Surv. Ohio,' vol. ii. pt. 2, 1875, p. 102, pl. iv. fig. 4 [right valve]. The ventral border having a slight flange (not shown in the figure), allowing an overlap, we can regard this little valve as belonging to a true *Leperditia*.

It occurs in one of the Cincinnati limestones with *Beyrichia ciliata*, collected years ago by Prof. E. W. Claypole, D.Sc., F.G.S., whose energetic geological work in the United States has supplied me with numerous specimens of Palæozoic Ostracoda, and after whom it is here named.

5 & 6. LEPERDITIA ALTA (Conrad), and L. JONESI, Hall. (*L. alta*, var., Pl. I. figs. 6 a, b; after the original drawings.)

Cytherina alta, Conrad*, 'Third Annual Report on the Palæontol. Departm. of the Survey, N.Y., 1840, p. 204.

Cytherina alta, Vanuxem, 'Natural History of New York, Geology, Part III. Survey of the Third Geological District,' 1842, p. 112, fig. 23, no. 6 (bad drawing); copied in Emmons's 'Manual of Geology,' 2nd edit. 1860, p. 113, fig. 162, no. 6; and in L. Lincklaen's "Guide to the Geology of New York," in the 'Fourteenth Annual Report of the Regents of the University, State N. Y.' 1861, p. 58, fig. 19, no. 6 (pl. ix. fig. 6).

Cytherina alta (?), Hall, 'Palæont. New York,' vol. ii. 1852, p. 338, pl. lxxviii. figs. 2 a, b, c, d [figs. a & b, *alta*; c (?) & d, *Jonesi*].

Leperditia alta (?), Jones, 'Ann. & Mag. N. H.' ser. 2, vol. xvii. 1856, p. 88, pl. vii. figs. 6 & 7 [fig. 6, *Jonesi*; fig. 7, *alta*].

Leperditia alta, Jones, 'Ann. & Mag. N. H.' ser. 3, vol. i. 1858, p. 250, pl. x. figs. 8 & 9.

Leperditia alta, Hall, 'Palæont. N. Y.' vol. iii. pt. i. 1859, p. 373

* See Dr. James Hall's Preface to the 'Palæont. New York,' vol. i. 1846, pp. x, xi.

(pl. lxxix. A, figs. 6 *a-e*, not published); and *Leperditia Jonesi*, p. 372 (figs. 7 *a-e*, not published).

Leperditia alta [var.], Dana, 'Text-book of Geology,' 1870, p. 98, fig. 175 (reversed); 'Manual of Geology,' 3rd edit. 1874, p. 239, fig. 473.

Leperditia alta, Meek, 'Geol. Survey Ohio,' 1873, p. 187, pl. xvii. figs. 2 *a* [*Jonesi*], 2 *b* [*alta*].

Leperditia alta, Jones, 'Ann. & Mag. N. H.' ser. 5, vol. viii. 1881, pp. 345, 346.

Leperditia alta, Whitfield, 'Geology of Wisconsin,' vol. i. 1883, p. 198, fig. e [*alta*, var.]; vol. iv. 1882, p. 323, pl. xxv. figs. 8 & 9 [*alta*].

Leperditia alta, Jones, 'Ann. & Mag. N. H.' ser. 5, vol. xiv. 1884, pp. 342-344.

Size:—

	Length. mm.	Height. mm.	Thickness. mm.	
Pl. I. fig. 6	9	6		(<i>L. alta</i> , var.).
Pal. N.Y. vol. ii. pl. lxxviii.:				
fig. 2 <i>c</i>	18	11½		} (<i>L. Jonesi</i> ?).
fig. 2 <i>b</i>	12	7		
fig. 2 <i>a</i>	5	2½		
These are described as "individuals of different size"; and therefore are figured probably of the natural size.				
A. & M. N. H. 1856, pl. vii.:				
fig. 6	8½	6	5	} Arctic Regions.
fig. 7	5	3	2	
A. & M. N. H. 1858, pl. x.:				
fig. 9	8	4½		} (<i>L. alta</i>) Pennsylvania.
fig. 8	6	3½		
Geol. Surv. Ohio, 1873, pl. xvii.:				
fig. 2 <i>a</i>	10½	7½		} Ohio.
fig. 2 <i>b</i>	11½	6½		

Some confusion exists in the definition and nomenclature of these species. The drawing in Vanuxem's work is very bad, but Prof. Hall retained the specific name (with some doubt) for the four specimens which he described and figured in the 'Palæontol. New York,' vol. ii. 1852, p. 338, pl. lxxviii. figs. 2 *a*, *b*, *c*, *d*.

1. In 1859, 'Pal. N. Y.' vol. iii. p. 372, one of the forms usually associated with *L. alta* was separated by Prof. Hall as *Leperditia Jonesi*, being of larger size and greater proportional height, more convex centrally, and becoming papillose (part of a valve, fig. 2 *d*) on the surface when weathered. If we take fig. 2 *c* for this species, it is obliquely subovate, well rounded behind, and curving obliquely upwards and forwards in front; the valve is therefore higher behind than in front. It is straight on the back, with its hinge-line much shorter than the full length of the valve (proportion:

11 to $18\frac{1}{2}$, with 12 for the height); cardinal angles distinct, but blunt; the front end slopes downwards suddenly to meet the antero-ventral curve. With this species, Jones's fig. 6 of pl. vii. 1856, and Meek's fig. 2 a, pl. xvii. 1873, more or less conform, but the former is much rounder, and the latter is more subovate.

2. The two smallest of the three whole valves above mentioned remain for *L. alta*. Fig. 3 b is suboblong, with a straight dorsal and slightly arched ventral border; the posterior extremity is semi-circular, and the anterior has rather less height and curvature; the antero-dorsal angle and slope are less pronounced than in fig. 2 c; the hinge-line is also proportionally longer (8 to 12, the height being 7). Fig. 2 a is evidently badly drawn. Jones's fig. 7, pl. vii. 1856, is equivalent; and his figs. 8, 9, pl. x. 1858, Meek's fig. 2 a, pl. xvii. 1873, and Whitfield's fig. 8, pl. xxv. (Wisconsin), 1883, are also probable equivalents, though their outlines taper somewhat anteriorly.

3. The published illustrations resembling the drawing sent from Albany and here reproduced (Pl. I. fig. 6) are Prof. Whitfield's fig. e (Lower Helderberg), p. 198, 'Geol. Wisconsin,' vol. i., and a small woodcut in Dana's 'Manual' and 'Text-book of Geology.' The great depth and elliptic curvature of the postero-ventral, and the narrowness of the antero-ventral region, give a subtriangular outline to the valve. It is probably a variety.

4. Prof. Hall found *L. alta* abundant in the Tentaculite-limestone (Waterlime Group) of Albany, Schoharie, Greene, Herkimer, Oneida, and Cayuga Counties in the State of New York ('Pal. N. Y.' iii. p. 374); and *L. Jonesi* in the Coralline Limestone (Niagara Limestone) of Schoharie and Herkimer Counties (*op. cit.* p. 372); both limestones belong to the Lower-Helderberg group. Meek's specimens were from Greenfield, Ohio; Whitfield's from Waubakee, Wisconsin; Jones's from Schoharie and from Pennsylvania (all of these being from the Lower-Helderberg Group), and some from the Upper Silurian of Wellington Channel in the Arctic Regions.

In the British Museum a specimen (I. 511) of black limestone, with Brachiopods, from the Lower-Helderberg Group, of the Helderberg Mountain, New-York State, contains several individuals of two forms of *L. alta*, Hall; but the edges of the valves cannot be satisfactorily examined, being, as usual, more or less imbedded in the matrix.

7. *LEPERDITIA NANA*?, Jones. (Pl. IV. fig. 4.)

Size: length .73 mm., height .53 mm.

Pl. IV. fig. 4 would be very much like *Leperditia (Isochilina) minutissima*, Hall, were its ventral border more elliptically curved and not so semicircular; nor are the dorsal angles of Hall's species so acute as in our fig. 4, which is probably equivalent to the Lower-Silurian *Leperditia (?) nana*, Jones, of Canada, Ann. & Mag. Nat. Hist. ser. 3, vol. i. 1858, p. 245, pl. ix. fig. 17.

From the Bala Beds near Welshpool, Montgomeryshire, North Wales, collected by Mr. J. B. Morgan, F.G.S.

XI. XESTOLEBERIS, Sars, 1865.

1. XESTOLEBERIS WRIGHTII, sp. nov. (Pl. IV. figs. 14 & 15 a, b, c.)

Size	Fig.	Length.	Height.	Thickness.
		mm.	mm.	mm.
{	14.....	1·2	·76	
	15.....	1·2	·73	·8

A Cytheroid Ostracod probably allied to the recent *Xestoleberis*, see Ann. & Mag. Nat. Hist. ser. 5, vol. xviii. 1886, p. 264, pl. ix. fig. 8.

Carapace tumid, oviform, but more convex on one edge than the other, and one valve much larger than the other; both smooth.

Named after Joseph Wright, Esq., F.G.S., of Belfast, who has added much to our knowledge of fossil and recent Entomostraca. It was obtained by him from the Lower-Silurian beds of the Chair of Kildare, Leinster, Ireland, some years since. For some Cytheroid and other Ostracoda sent from this locality by Mr. Baily and Mr. Wright, see Ann. & Mag. N. H. ser. 4, vol. ii. 1868, pp. 54-62, pl. vii.

[ADDENDUM, December 18, 1889.—Since this paper was read the following interesting specimens from North America, and collected by himself, have been shown to me by Dr. G. J. Hinde, F.G.S.:—

1. Several individuals of *Primitiopsis punctulifera* (Hall), various in their development and in the intensity of the reticulate surface-ornament, from the Hamilton Group, at Thedford, Ontario. Also, from the same formation at Eighteen-mile Creek, a small *Strepula*, sp. nov. (?), and a small *Bollia*, near to, if not identical with, *B. bicollina*, J. & H.

2. Schoharie, N. Y., Lower-Helderberg group:—*Leperditia alta* (Conrad) and *L. Jonesi* (?), Hall; together with *Klædenia notata* (Hall).

3. Arisaig, Nova Scotia, Lower-Helderberg group (C to D groups of Honeyman):—*Beyrichia pustulosa*, Hall (casts), scarcely distinguishable from *B. tuberculata*, Boll; and *B. æquilatera*, Hall (casts), scarcely separable from *B. Klædeni*.

4. Niagara Formation, Dundas, Ontario; small, simple *Primitia*; flattened; one has a minute tubercle at its sulcus.

5. Cincinnati Formation (Div. G of Billings), English Head, Anticosti:—Numerous Ostracoda on thin limestone, some like *Bairdia*, probably sp. nov.

6. Clinton or Niagara Formation, Division 2 of Anticosti Group, W. of Jupiter River, Anticosti:—a fringed *Primitia*, sp. nov.?

7. Cincinnati Formation, Group 1 of Billings, S. of Junction Cliff, Anticosti:—several minute Ostracoda attached to small fossils; some probably spp. nov.]

EXPLANATION OF PLATES I.-IV.

PLATE I.

North-American Ostracoda.

- Fig. 1. *Klædenia notata* (Hall), var. *ventricosa*, Hall. *a*, left; *b*, right valve. (Magnified 4 diam.)
2. *Beyrichia trisulcata*, Hall. Left valve. (Magn. 8 diam.)
3. *Beyrichia granulata*, Hall. *a*, left valve (magn. 4 diam.); *b*, part of surface (highly magnified).
4. *Beyrichia oculina*, Hall. Left valve. (Magn. 4 diam.)
5. *Leperditia hudsonica*, Hall. *a*, carapace (nat. size); *b*, right valve, side view, and *c*, edge view (magn. 2 diam.).
6. *Leperditia alta* (Conrad), var. *a*, right valve (nat. size); *b*, inside view (magn. 2 diam.).
- [Figs. 1-6 are copied from the original drawings intended for publication in 1859.]
7. *Isochilina Seelyi* (Whitfield). Left valve. (Magn. 10 diam.)
8. *Isochilina cristata* (Whitfield). Right valve. (Magn. 15 diam.)
- 9 & 10. *Isochilina gregaria* (Whitfield). Right valves. (Magn. 15 diam.)
11. *Leperditia hudsonica*, Hall. *a*, right valve; *b*, edge view; *c*, end view. (Magn. 25 diam.)
12. *Leperditia sinuata*, Hall. *a*, right valve; *b*, edge view; *c*, end view. (Magn. 25 diam.)
- 13 & 14. *Leperditia seneca*, Hall. Right valves. (Magn. 25 diam.)
15. *Isochilina*?, sp. Right valve. (Magn. 6 diam.)

PLATE II.

North-American Ostracoda.

[Figs. 1 *a*, *b*, *c*, are magnified 10 diameters; all the other figures 25 diameters.]

- Fig. 1. *Beyrichia tuberculata*, Boll, var. *pustulosa*, Hall. Cast. *a*, right valve, broken in front; *b*, edge view; *c*, end view.
2. *Primitia seminulum*, Jones. Left valve, broken in the middle.
3. *Beyrichia hamiltonensis*, sp. nov. Left valve.
4. *Strepula sigmoidalis*, Jones. Left valve.
5. *Isochilina lineata*, sp. nov. Adult. *a*, right valve; *b*, edge view.
6. *Beyrichia æquilatera*, Hall. Cast. Right valve.
7. *Primitiopsis punctulifera* (Hall). Young. *a*, left valve; *b*, edge view.
8. *Isochilina lineata*, sp. nov. Young. *a*, left valve; *b*, edge view.
9. *Entomis rhomboidea*, sp. nov. Left? valve, altered in shape.
10. *Entomis rhomboidea*, sp. nov. *a*, left? valve, less altered; *b*, edge view.
11. *Isochilina fabacea*, sp. nov. Left valve.
12. *Primitiopsis punctulifera* (Hall). *a*, left valve; *b*, edge view.
13. *Primitiopsis punctulifera* (Hall). *a*, left valve; *b*, edge view of carapace.

PLATE III.

Silurian Ostracoda.

[All the figures are magnified 15 diameters, except figs. 12 *b*, 13 *b*, 14 *b*, and 24 *b*, which are $\times 70$ diameters.]

- Figs. 1, 2, 3. *Bollia lata* (Vanuxem & Hall). Separate valves.
- 4-8. *Æchmina spinosa* (Hall). 4, inside of left valve; 5-8, right valves.
- 9-11. *Æchmina Byrnesi* (Miller). 9, right valve; 10, left valve; 11 edge view of fig. 10.

- Figs. 12-16. *Beyrichia ciliata*, Emmons. 12 *a*, left valve; *b*, ornament, $\times 70$ diam.: 13 *a*, left valve; *b*, ornament, $\times 70$ diam.: 14 *a*, left valve; *b*, ornament, $\times 70$ diam.: 15 *a*, right valve; *b*, end view: 16, inside of left valve.
17. *Leperditia Claypolei*, sp. nov. *a*, left valve; *b*, end view; *c*, edge view.
- 18, 19. *Primitia minuta* (Eichwald). Left valves; 18, inside; 19, outside of a poor specimen.
20. *Leperditia hudsonica* (?), Hall. Inside of valve.
- 21-23. *Primitia minuta* (Eichwald). 21, left valve (true shape); 22, right valve; 23, right valve. (These are from Talkof, Russia.)
24. *Primitia Whitfieldi*, sp. nov. *a*, right valve; *b*, ornament, $\times 70$ diam.
25. *Beyrichia Buchiana* (?), Jones. Left valve, not well preserved.

PLATE IV.

Silurian Ostracoda.

[All the figures are magnified 15 diameters, except figs. 1 *a* and 6 *a*, which are $\times 40$ diameters.]

- Figs. 1-3. *Primitia Ulrichi*, sp. nov. 1 *a*, right valve, $\times 40$ diam.; *b*, outline of the same; *c*, edge view: 2, left valve of a variety; 3, right valve of another var. (All these are from the "Utica Slate" of Canada.)
4. *Leperditia nana* (?), Jones. Right valve.
5. *Primitia humilis*, J. & H., var. *humilior*, nov. Right valve.
6. *Primitia Morgani*, sp. nov. *a*, left valve, $\times 40$ diam.; *b*, the same, $\times 15$ diam.
7. *Primitia mundula*, Jones, var. *cambrica*, nov. Right valve.
- 8-13. *Primitia unicornis* (Ulrich), and varieties. Fig. 10 is a right valve; the other figures are left valves.
(Figs. 4-13 are from the Bala Beds near Welshpool, Montgomeryshire.)
- 14, 15. *Xestoleberis Wrightii*, sp. nov. 14, carapace, with the left valve outwards: 15 *a*, carapace, right valve seen; *b*, edge view; *c*, end view. (From the Chair of Kildare, Ireland.)
- 16-18. *Beyrichia ciliata*, Emmons. 16 *a* and *b*, edge and end views of fig. 12, Pl. III; 17 *a* and *b*, of fig. 13; and 18 *a* and *b*, of fig. 14.
- 19, 20. *Beyrichia oculifera*, Hall. 19 *a*, left valve; *b*, edge view of the same: 20, inside of a right valve (the boss injured).
21. *Beyrichia Hallii*, sp. nov. Right valve.
- 22, 23. *Klædenia notata* (Hall). 22, right valve; 23, left valve.
24. *Klædenia notata*, var. *ventricosa*, Hall. Left valve.

(Figs. 16-24 are from the United States.)

DISCUSSION.

The PRESIDENT asked whether the Author had seen the originals of the specimens from which the American drawings had been made. He cited several instances showing the errors which had arisen from describing forms from drawings only.

Dr. WOODWARD commented upon the care the Author had taken in describing these Ostracods, and the long time he had held his work over whenever he felt any hesitation concerning his conclusions. He felt sure that the Author had not described his new forms without the greatest care having been taken to exclude the possibility of error.

Mr. J. S. CRAWFORD said that he had collected many American specimens, which he would be happy to lend to the Author, or to place in the Society's Museum.

Dr. HINDE said that although the Entomostraca of the Hamilton group closely resembled those from the Silurian, the fauna of this group generally was unmistakably Middle Devonian.

The AUTHOR, in reply, assented to Dr. Woodward's remarks concerning the upward passage of Lower-Silurian forms to recent times, and said that he would examine Mr. Crawford's specimens with pleasure.

2. *The CATASTROPHE of KANTZORIK, ARMENIA.*

By MONS. F. M. CORPI. (Read November 20, 1889.)

(Communicated by W. H. HUDLESTON, Esq., F.R.S., Sec. G.S.)

KANTZORIK, a small village of 215 inhabitants in the *Caza de Tortoum*, a dependency of the vilayet of Erzeroum, was situated in a narrow valley at an altitude of about 1600 metres. It was at a distance of 60 kilometres from Erzeroum, and of 10 kilometres from Nikhah, the seat of the "Kaimakamlik."

The inhabitants of Kantzorik having noticed certain subterraneous noises, and that the springs of a great mountain situated at the western opening of their valley had dried up, were alarmed at these phenomena and gave notice to the local authorities, who directed them at once to evacuate their village; but before they had time to execute this project, towards noon on the 2nd of August, 1889, a frightful noise was heard, a part of the Eastern Mountain burst open, the village was buried under a great muddy mass, and 136 villagers perished in it. Such is the account given by the survivors of this terrible catastrophe, who affirm that they saw a red torrent, which would lead one to think that this fluid mud was in a state of ignition.

His Excellency Samit Pacha, Governor General of the vilayet of Erzeroum, moved by the great misfortune which had happened at Kantzorik, hastened to send assistance to the sufferers; and to prevent fresh disasters to the other villages which seemed to be menaced with the same fate, he took prompt and intelligent measures, placing their inhabitants in safe places, and did me the honour of entrusting to me the task of going to investigate this phenomenon on the spot from a geological point of view.

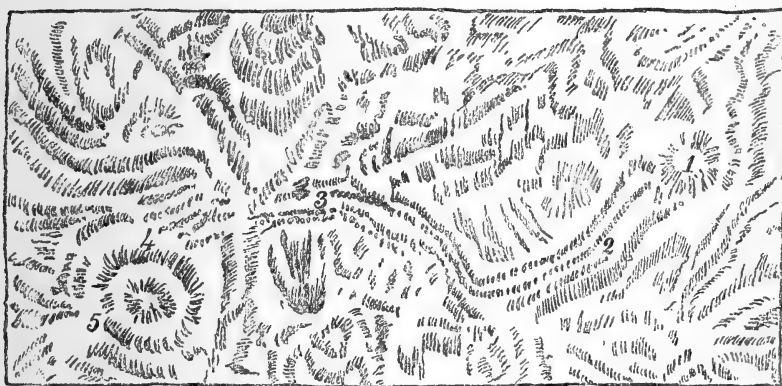
On the 9th August I proceeded to the locality of the disaster and visited this region, which is so excessively hilly as to present an Alpine configuration.

In fact, the whole of this part of the *Caza de Tortoum* had been formed in the Secondary period of Triassic, Jurassic, and Cretaceous strata, which, in consequence of a Plutonic movement, were broken up and torn by granitic, trachytic, and especially basaltic rocks, now forming great mountains, cones, and lofty peaks without any system, and still presenting numerous traces of the former constitution which they overtop, or to which they serve as a base according to the nature of the dislocation.

In going from Nikhah towards Kantzorik, I was surprised by the great number of balls of mud which occurred among the rolled pebbles of the ravine forming the continuation of the great valley of Kantzorik. These balls, varying in diameter between 10 and 40 centimetres, and formed of sand and calcareous fragments of very close grain cemented by an ashy material, did not appear until after the disaster of Kantzorik.

After walking for half an hour I arrived at the western opening of the valley and the terminal point of the flow. There I could see at once the complete *bouleversement* which had been produced a week before. From this point to the foot of the great Eastern Mountain (which is situated at the other extremity of the valley in

Sketch-plan of the district of Tortoum, where the catastrophe occurred in August 1889.*



1. Eastern Mountain. 2. Kantzorik. 3. Nikhah.
4. Tortoum Kalé. 5. Sagher.

the direction from east to west), for a distance of about 7 or 8 kilometres, and for a width varying between 100 and 300 metres, according to the configuration of the ground, stretched, like a vast motionless river, a mass of solidified marly mud, the greater part of which was of a bluish-grey colour, and the remainder of various other tints.

This material, which, taking account of its superficies and of the inclination of the flanks of the mountains and hills forming the valley, may be estimated approximately at more than 50,000,000 cubic metres, has the appearance of an undulating sheet, some asperities of which attain a height of as much as 10 metres, and sufficiently demonstrate that, after having been thrown out in the fluid state, by contact with the cold air and the rapid volatilization of the gases which it contained, it became solidified, and retained upon its outer surface the character produced by its undulatory movement, and the contraction which it underwent more or less rapidly, which enabled it, even at its margins, to remain, like a talus, above the level which it must have taken, had it spread further, in extending. Of course the solidification of this fluid mass could only take place from above downwards; and while the upper part acquired consistence, the lower part still allowed of the passage of more liquid materials, carrying with them the balls of which I have already

* This is a photographic reproduction of a sketch sent by the Author.

spoken—that is to say, unless they were thrown out first of all, which is also very possible.

I ascended the whole of the valley to the spot where the village of Kantzorik was situated, which is indicated by a much more strongly marked elevation of the muddy mass, in consequence, apparently, of the obstacle which it presented to the surging stream, although débris of houses and enclosures were carried on in great quantities even to the extremity of the gigantic flow, where they are still lying.

Continuing my progress, I arrived at the foot of the hill abutting on the northern slope of the great mountain, but there in consequence of the numerous deep crevasses, sinkings in and landslips (*éboulements du terrain*), I could not reach the summit without much difficulty and fatigue. Finally, after all the trouble of ascending this basaltic cone, I was repaid by the near view of a mountain in full course of demolition.

The great Eastern Mountain, crevassed in all directions, presented, for an extent of over 400 metres in width, an enormous vacuity produced by the sinking in of a great part of its western flank, and showed a gigantic trench between this part and its base. This trench, this rupture of the mountain, the bottom of which could not be seen in consequence of a fold of the strata, certainly served as the orifice for the issue of the enormous quantity of mud which spread over the valley, exhaling, they said, a strong odour, and bringing death and desolation where an instant before there was life and tranquillity, and transforming a smiling and fertile region into a lugubrious cemetery.

The violent projection of this nearly liquid and incandescent (?) mass tore from the mountain large blocks, which, by their displacement, dislocating and affecting the equilibrium of the superior parts, occasioned their fall also. And in fact an enormous portion of the mountain has been carried away by the bluish-grey muddy material, upon which it may be recognized by its yellow colour, arranged in bands of different dimensions over a very great extent of the flow.

A noise comparable to that produced by the passage of a railway train over a long iron bridge continued to be heard at short intervals, and great slips (*éboulements*) take place, throwing up a fine powder, which rises into the air like a band of smoke. However, it is impossible to make out whether these noises are produced by the sinking in of the mountain, or whether they are the result of the work of an internal commotion which conjointly provokes these falls.

I have also ascertained the presence of distinct fissures and of depressions of the ground upon the granitic mountain at the foot of which is situated the village of Nikhab, 10 kilometres from Kantzorik; and I have been told that crevasses of the same nature were also produced at another point 2 or 3 kilometres further on.

By this cataclysm we certainly recognize the action of an interior fire, but we can only ascertain the result produced. Will this volcanic action stop at the point it has now attained? Will this region

be transformed and modified by the continuation of the actual disturbance? or, again, should a volcano be established, will it allow of the expansion of the gases which appear to exert so strong a pressure upon the crust of the earth in this region? No one can foresee.

DISCUSSION.

The PRESIDENT, in commenting on the remarkable nature of the phenomenon, regarded the offer of the paper on the part of the Author as a compliment to the Society. It was not a volcanic eruption, but more of the nature of a mud-flow produced by a big landslip—possibly connected with the stoppage of the springs. Still it was on a very large scale, though clearly the effect of water and not of fire.

Dr. EVANS agreed with the President. It was difficult to reconcile the alleged incandescence with the other phenomena. Infiltration of water probably had something to do with the outburst. It was not even a mud-volcano. The falling in of the mountain, he thought, might have been due to soft beds covered by harder material having oozed out. It would be interesting to know if there had been an increased rainfall prior to the occurrence. There was nothing of a truly volcanic nature mentioned in the paper. He should like to have further information about the incandescence.

Mr. DALLAS (who translated the paper) said that the "redness" was reported by the people to the Author.

Rev. EDWIN HILL thought that the mud-balls could in no way be explained by igneous agency. The photographs gave no indication of the presence of steam. As a landslip the amount was very great, and possibly the phenomenon might be something similar to the overflow of peat-bogs.

Mr. HUDLESTON recalled the statement of the Author regarding the geological constitution of the district, where masses of Secondary rocks are folded within igneous ones, probably of Tertiary age. It was likely, therefore, that some of the softer Secondary marls, pressed in more than one direction by harder rocks and soaked by water, might at last have given way. The immediate cause of the catastrophe could scarcely be indicated without a knowledge of the district. Such events occurred from time to time elsewhere. The Russian topographers, if his memory served him right, had described the bursting of a mountain-side, with fatal results, in one of the valleys near Lake Issyk Kul. The smoke-like powder, resulting from the continued falls of rock, had often given rise to the notion of volcanic action. There could be no better instance of this than the case of Mount St. Elias, the highest mountain in North America. In geography-books this mountain has almost invariably been described as a volcano, and a portion has actually been designated as the crater. This illusion had been occasioned by the dust of rock-falls resembling smoke. We might well pardon the Author for speculating on the probability of a return to volcanic activity in a region which bears so many traces of it as this part of Armenia.

3. *Contributions to our Knowledge of the DINOSAURS of the WEALDEN and the SAUROPTERYGIANS of the PURBECK and OXFORD CLAY.*
By R. LYDEKKER, Esq., B.A., F.G.S., &c. (Read November 6, 1889.)

[PLATE V.]

THE present communication is divided into four sections—the first giving an account of Iguanodont remains obtained from the Wadhurst Clay near Hastings subsequently to the writer's previous paper on this group; the second devoted to the description of a metatarsus of a Megalosaurian from the same deposits; the third recording some vertebræ of a Sauropterygian from the Purbeck of the Isle of Portland; while the fourth gives a description of an associated series of remains of a Pliosaur from the Oxford Clay near Peterborough.

I. *The Iguanodonts of the Wadhurst Clay.*

Two years ago I brought under the notice of the Society* certain remains of large Iguanodonts collected by Mr. C. Dawson, F.G.S., from the Wadhurst Clay (Lower Wealden) in the neighbourhood of Hastings, and now preserved in the British Museum. Among these a left ilium and some associated vertebræ presented such differences from the corresponding bones of *Iguanodon Mantelli* and *I. bernis-sartensis*, that I felt justified in regarding them as the types of a distinct species, for which the name *I. Dawsoni* was proposed. I was careful at that time to mention that these specimens only were taken as the types, and it is fortunate that this was done, since it now appears that the sacrum and ischium which, in the absence of any evidence to the contrary, were referred to the same species, belong to a distinct form.

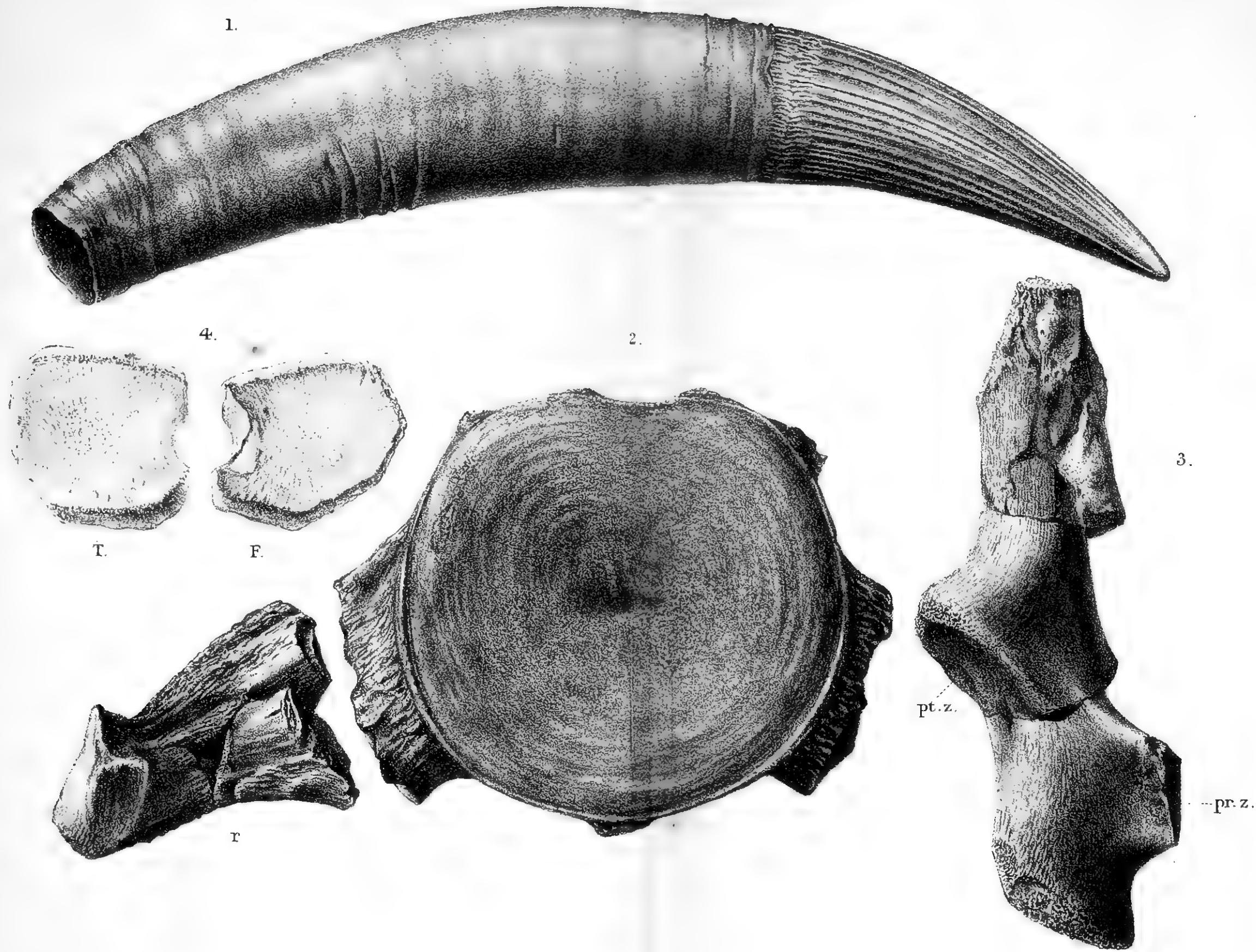
Since the publication of that paper Mr. Dawson has assiduously continued his collecting in the quarries of the Wadhurst Clay, the result of which has been the acquisition of a very large series of new specimens—many of them being associated—although, unfortunately, he has not yet succeeded in obtaining a skull. These specimens, all of which are preserved in the British Museum, indicate the existence in the Lower Wealden of two Iguanodonts which appear to be distinct from *I. Dawsoni*, and of which I have given a preliminary notice in the 'Geological Magazine'†, under the names of *I. Fittoni* and *I. hollingtoniensis*. Before, however, proceeding to give a fuller account of some of the specimens on which these species are founded, it will save trouble to formulate a brief summary of the chief characters of *I. Dawsoni*, as derived from the type specimens, supplemented by others taken from an imperfect skeleton recently acquired by the British Museum.

* Quart. Journ. Geol. Soc. vol. xlv. pp. 46-52 (1888).

† Decade 3, vol. vi. pp. 354, 355 (1889).



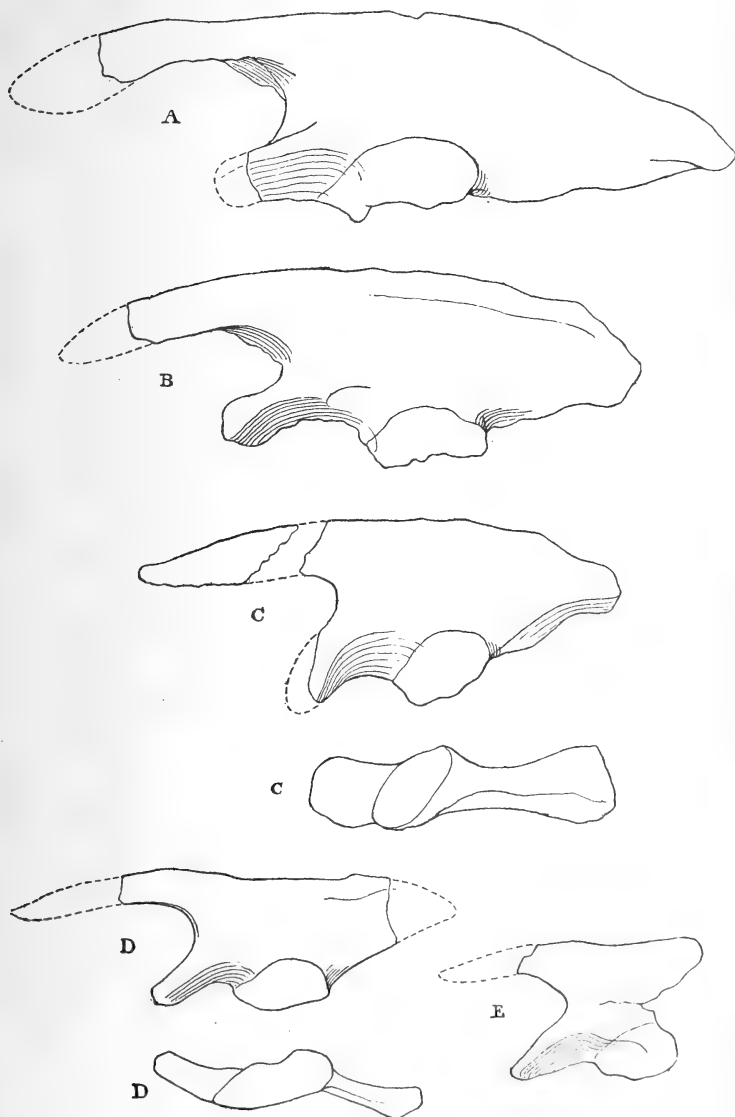




PLIOSAURUS FEROX.

Mintern Bros del. et lith

Fig. 1.—*Left Iliac of Wealden Species of Iguanodon.*
(About $\frac{1}{10}$ nat. size.)



A. *I. bernissartensis*. B. *I. Dawsoni*. C. *I. Fittoni*. D. *I. Mantelli*. E. *I. holingtoniensis* (?). E is reversed from the right ilium. In C and D the ventral, as well as the outer, surface is shown.

Iguanodon Dawsoni was a species intermediate in size between *I. bernissartensis* and *I. Mantelli*, the middle dorsal vertebræ* having but slightly compressed centra, with the rib-facet rising to the level of the neural platform. The ilium, of which a greatly reduced representation is given in fig. 1 B, is characterized by its great vertical depth, and the absence of that reflection of the superior border which is so marked in *I. bernissartensis* (fig. 1 A) and *I. Mantelli* (fig. 1 D); and also by the contour of its postacetabular portion, which forms a long and deep plate with a rounded termination, in which there is only a very slight inflection of the inferior moiety. Equally characteristic is its preacetabular process, which is long and comparatively shallow, with a broad horizontal roof-like inward extension at its point of origin from the preacetabular notch, and an outward inclination of its lower border as it approaches the extremity. The pubic process is mainly directed forwards. An imperfect skeleton in the British Museum (No. R. 1627) from the Wadhurst Clay of Brede, near Hastings, may be referred to this species, since the portion of the right ilium which now remains agrees exactly with the type specimen. The femur of this skeleton has a length of about 37 inches, and the head placed approximately at right angles to the shaft; but the form of the inner trochanter cannot be determined owing to the imperfection of this part of the bone.

Having now indicated the chief characters of *Iguanodon Dawsoni*, we may proceed to notice the chief specimens of the other forms from the same deposits.

Iguanodon Fittoni †.—The type specimen of this species is the ilium represented in fig. 1 C (B.M. No. R. 1635), which was obtained from Shornden Quarry near Hastings, from a three-foot bed of ferruginous sand, which is separated by a stone band of two feet in thickness from the underlying clay bed, four feet thick, which yielded the type specimens of *I. Dawsoni*. At a distance of some 25 yards to the westward in the same stratum an imperfect caudal vertebra and the proximal extremity of a left ischium were obtained; while 25 yards still more to the west was found the undermentioned sacrum, also in the same bed. It might be considered that an interval of 50 yards between two specimens would show that they were not referable to the same individual. In this case, however, no other bones have been found in the same part of the quarry, and the position of the ischium serves to connect the ilium with the sacrum. Moreover all these bones belong to the same region of the body, while the ischium and ilium are both of the left side. That different bones of a single individual in these deposits do become widely separated horizontally is proved by the metatarsals of *Megalosaurus* described in the second section of this paper, one of which was obtained in 1884, while the other was found in 1889 at a distance of about 180 yards from the spot where the first occurred. It seems, therefore, to be most probable that the four above-men-

* Quart. Journ. Geol. Soc. vol. xlv. p. 48, fig. 1.

† Geol. Mag. decade 3, vol. vi. p. 354.

tioned specimens belong to one and the same individual. The type ilium is fortunately the left one, and is therefore strictly comparable with the type of *I. Dawsoni*. This specimen, although it has been fractured, is nearly entire, but unfortunately the preacetabular process is broken, and a fragment is missing near its origin, so that its exact length cannot be determined. The extremity of the pubic process is also missing. Compared with the ilium of *I. Dawsoni* (fig. 1 B), this specimen appears to indicate a somewhat smaller form, and is of a relatively deeper type, with a highly convex superior border, a more concave external surface, and a less defined acetabulum and ischial tuberosity. The preacetabular process is deeper and apparently shorter, and has no roof-like inner extension at its origin from the preacetabular notch, nor any tendency to an outward inclination of its inferior border. Posteriorly the difference from *I. Dawsoni* is still more decidedly marked. Thus the lateral surface of the postacetabular portion terminates in a comparatively sharp point; while inferiorly this portion gives off a shelf-like projection standing out almost at right angles to the vertical plate. As minor features of this ilium, it may be observed that the preacetabular notch is very shallow from above downwards, the prepubic process is deflected downwards, the interval between the pre- and postacetabular notches is comparatively short, and in the preacetabular notch the surface of the bone is rounded off. The vertical height of this specimen from the inferior border of the middle of the acetabulum is 11·3 inches, and the approximate total length (allowing one inch for the missing fragment of the preacetabular process) 32 inches.

The associated ischium has the hammer-shaped head characteristic of the one I have figured in association with the ilium of *I. Dawsoni* in my previous paper.

The sacrum, which is imperfect, is characterized by the lateral compression of the component vertebræ, and thereby agrees with the somewhat smaller sacrum from the Weald Clay referred, and I believe rightly, by Sir R. Owen to *I. Mantelli*. The vertebral centra are completely anchylosed together.

That the present form, as typified by the ilium, is perfectly distinct from *I. bernissartensis* and *I. Mantelli* of the Upper Wealden is quite evident; the great development of the inwardly directed horizontal shelf of the postacetabular portion of the ilium being of itself a sufficient distinction. The vertebræ from the Upper Wealden on which *Sphenospondylus gracilis* is founded appear to be much too small to have belonged to this form; while since its distinctness from *I. Dawsoni* has been already sufficiently indicated, there appears no doubt as to the right of *Iguanodon Fittoni* to rank as a distinct species.

In referring this species to the genus *Iguanodon* rather than to the allied *Camptosaurus* (*Camptonotus*) I have been mainly guided by the characters of the sacral vertebræ, which are those of one of the typical group of *Iguanodon*, and also by the large size of the present species—*Camptosaurus* being typically of comparatively

small dimensions. So far, however, as I can judge from the figure given by Prof. Marsh*, the ilium of the present form appears to present a considerable resemblance to that of the type species of *Camptosaurus*. This is especially shown in the great vertical depth, in the form of the postacetabular portion, in the deflection of the pubic process, and the shallowness of the preacetabular notch. The preacetabular process is also of great depth in both, although it is much shorter in the American form. I am not, however, disposed to attach much importance to the latter difference, more especially since there is a comparatively long preacetabular process in the ilium of the so-called *Iguanodon Prestwichi*, which I am unable to separate from *Camptosaurus*. In the compressed sacral vertebræ *I. Fittoni* differs, however, very widely from *Camptosaurus*; and I am accordingly disposed to consider this species as one which while retaining an ilium approximating to that of the less specialized *Camptosaurus* type, has acquired the sacrum of a typical *Iguanodon*.

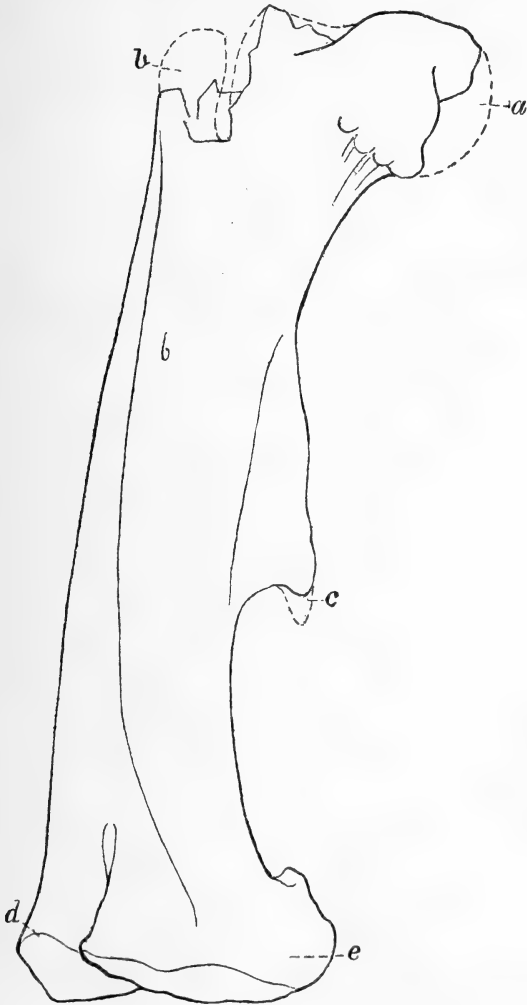
Iguanodon hollingtoniensis †.—Of this form there is unfortunately no complete example of the ilium among the specimens collected by Mr. Dawson, so that its diagnosis cannot at present be given so concisely as is desirable. The specimens which I take as the type of this species are a large number of associated bones from the Wadhurst Clay of the Hollington quarry near Hastings, one moiety of which (B.M. No. R. 1148) was obtained in 1887, while the others (B.M. No. R. 1629) were collected in 1889. The former moiety comprises the right femur (fig. 2), part of the tibia of the same side, a metatarsal, and two imperfect dorsal vertebræ; and these specimens were provisionally entered on p. 217 of part i. of the writer's 'Catalogue of Fossil Reptilia and Amphibia in the British Museum' under the heading of *I. bernissartensis*, it being suggested that they might belong to an immature individual of that species, although it was also pointed out that they might perhaps be referable to *I. Dawsoni*. The second moiety includes the two scapulæ, the left radius and ulna, a phalangeal spine of the pollex, the left femur, parts of the left tibia and fibula, a metatarsal, &c. It is further believed that an associated series of sacral and caudal vertebræ (B.M. No. R. 1632) from the same quarry are referable to the same individual.

The right femur of the type skeleton is represented in woodcut fig. 2, and, with the exception of the lesser trochanter and part of the adjacent region, is practically entire, although it has been much crushed and broken. It has a length of some 32 inches (or approximately the same as the corresponding bone of *Iguanodon Mantelli*), and is characterized by the marked convexity of the anterior profile of the shaft, by the "pendent" form of the large inner trochanter, which is situated in the lower half of the shaft, and by the obliquity of the setting-on of the head to the shaft. Now both the form and the position of the inner trochanter distinguish this bone from the femur of *I. Mantelli*, in which this trochanter is of

* Amer. Journ. ser. 3, vol. xviii. pl. iii. (1879).

† Geol. Mag. decade 3, vol. vi. p. 355 (1889).

Fig. 2.—*The Right Femur of Iguanodon hollingtoniensis*, $\frac{1}{7}$ nat. size;
from the *Wadhurst Clay near Hastings*.



a, head; *b*, lesser trochanter; *c*, inner ditto; *d*, ectocondyle; *e*, entocondyle.

the "crested" type*. The position of this inner trochanter is, indeed, very similar to that obtaining in the larger femur of *I. bernissartensis* †; but in the latter the trochanter is decidedly of the "crested" type. There is accordingly evidence as to the specific distinctness of the form under consideration from the two species mentioned above. With regard to *I. Dawsoni*, the femur already alluded to (p. 38) as referable to that species is somewhat larger than the present one, and, so far as its imperfect condition admits of comparison, appears to present structural differences, its shaft being much less curved. The two dorsal vertebræ associated with the femur of the present form are much smaller than those of *I. Dawsoni*. Other collateral evidence will be adduced as to the distinctness of the form under consideration from the latter species; but in the meantime it may be observed that in its curved shaft and pendent trochanter the femur before us approximates to that of *Camptosaurus* ‡, although these features are not so strongly marked as in the latter.

Turning now to the sacral and caudal vertebræ from the Hollington quarry (No. R. 1632), which are believed to have been associated with the type specimens, it may be observed that the sacrals are characterized by the absence of ankylosis between their centra, and also by the flattened hæmal surfaces of the latter; in both of which respects they resemble *Camptosaurus*. Now these sacrals are of the same type as those (No. R. 811) which I have previously referred to *I. Dawsoni*; the latter (which likewise came from the Hollington quarry) being associated with dorsal vertebræ (No. R. 604) of the same form as those of the type skeleton. There is accordingly every probability that these sacral vertebræ are referable to the present form. There is, however, associated with the sacrals (No. R. 811) an imperfect left ilium (No. R. 811 b), which although much broken and flattened affords important evidence. This specimen is represented in fig. 1 E. Its preacetabular portion differs from that of *I. Dawsoni* by the absence of an inner roof-like extension, and the whole bone is of a much less massive build. Compared with the ilium of *I. Fittoni* (fig. 1 C), the present one differs by the shallower preacetabular process, the longer interval between the pre- and postacetabular notches, the greater depth of the preacetabular notch, and apparently also by the more forward direction of the pubic process. Precisely similar characters are found in the imperfect right ilium, belonging to another imperfect skeleton collected by Mr. Dawson (No. R. 1636), which I am accordingly disposed to refer to the present form.

We are now in a position to sum up the evidence of the specific distinctness of the Hollington *Iguanodon* from the other species. The evidence of the femur justifies its separation from *I. Mantelli* and *I. bernissartensis*. The same evidence, so far as it goes, is in

* See Dollo, Bull. Sci. France et Belg. 1888, pp. 215-224.

† Dollo, *op. cit.* p. 216, fig. 1. When suggesting in the work cited that the present specimen might belong to a young individual of *I. bernissartensis*, my attention had not been directed to the difference in the contour of the inner trochanter.

‡ Compare Dollo, *op. cit.* p. 216, fig. 2.

favour of its distinctness from *I. Dawsoni*. This is supplemented by the evidence of the sacral vertebræ and ilium. Thus it has been shown that the dorsals associated with the sacrals are similar to those associated with the types of *I. hollingtoniensis*, and that the sacrals and ilium are not referable to *I. Dawsoni*; and there is accordingly, apart from the apparent association of some of these sacrals with the above-mentioned types, every reason for regarding this form of sacrum and ilium as referable to *I. hollingtoniensis*. If I am right in this respect there will be equally good evidence as to the distinctness of the *Iguanodon* to which I have applied the name last mentioned from *I. Fittoni*.

The skeleton, No. R. 1636, is remarkable for the great relative length and slenderness of its scapula, and the same feature is apparently shown in an imperfect skeleton from the Hollington quarry (B.M. No. 33), which I believe to be also referable to *I. hollingtoniensis*.

In the characters of the sacrum and femur *I. hollingtoniensis* approximates to *Camptosaurus*, although, as I have already observed, the "pendent" character of the inner trochanter is less strongly marked than in the type of the latter. My reason for referring this species to *Iguanodon* rather than to *Camptosaurus* is the modification of the one phalangeal of the pollex into the conical spine characteristic of the former; but the species must be regarded as connecting the typical forms of *Iguanodon* with the less specialized genus *Camptosaurus*.

[Since the above was written, Mr. S. H. Beckles, of Hastings, has been good enough to send to the British Museum part of the skeleton of a small *Iguanodon* from the Wadhurst Clay of that neighbourhood, which affords important evidence as to the characters of *I. Fittoni*. These associated specimens include the right ilium, a pubis, the left femur, and several more or less imperfect vertebræ. The ilium accords in contour with the type of *I. Fittoni*, but in its smaller dimensions agrees with the corresponding bone of *I. Mantelli*; this smaller size may be indicative either of immaturity or of sexual difference from the type.

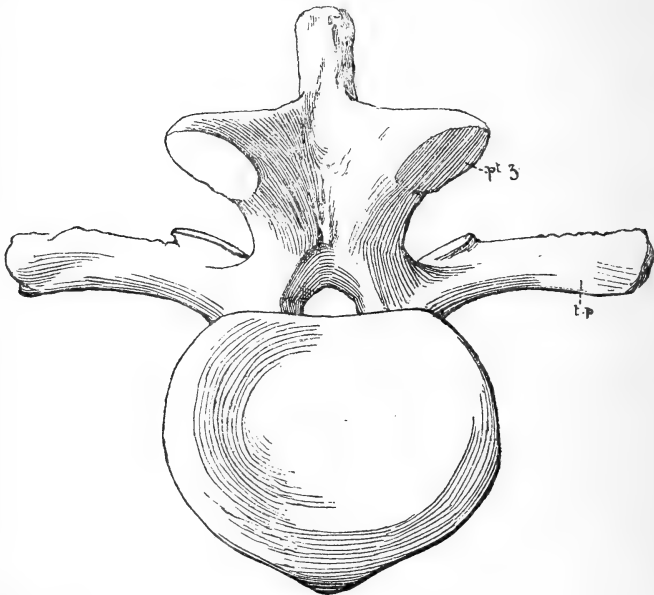
This ilium shows the peculiar outward curvature of the preacetabular process, which is obscured through fracture in the type; it has the same inflection of the inferior surface of the postacetabular as in the latter; and also the rounded surface of the bone in the preacetabular notch. The difference in the contour of this ilium from that of the figured ilium of *I. Mantelli* (B.M. No. R. 113) is well seen if the two are put side by side and viewed from the ventral aspect, when a difference similar to that seen between fig. 1 C and D is observable. In *I. Mantelli* the surface of the bone forming the preacetabular notch has a sharp edge, while the inner inflection of the postacetabular process is much less marked, and does not commence till much nearer the posterior extremity. The whole bone is also less deep and less curved from above downwards in *I. Mantelli*.

The femur of Mr. Beckles's specimen is very important, since it shows that the inner trochanter was of the "crested" type of

I. Mantelli, and quite different from the "pendent" type of that of *I. hollingtoniensis* (fig. 2); so that we have now decisive evidence of the distinctness of the latter from *I. Fittoni*. The inner trochanter of the femur of the latter is placed lower down than in *I. Mantelli*.

It may be added that some of the caudal vertebræ of Mr. Beckles's specimen present the peculiarity of being ankylosed together, while some of them have also become procœlous. All these peculiarities must, however, be regarded as quite abnormal, and it is not improbable that they are due to an injury received during the lifetime of their owner.]

Fig. 3.—*Posterior aspect of a late Cervical Vertebra of an Iguanodon; from the Wealden, near Hastings.* ($\frac{1}{4}$ nat. size.)



pt.z., postzygapophysis; *tp*, transverse process.

Cervical Vertebra.—Quite recently Mr. C. Dawson has procured me the loan of a cervical vertebra of a large *Iguanodon*, which on account of its remarkable state of preservation is deserving of a brief notice. This specimen was found by Mr. P. Rufford, of Hastings, imbedded in a nodule on the beach near that town; and it has been extracted from its matrix with scarcely any damage. I am unable to say from what horizon in the Wealden this fine specimen was derived, but since it is smaller than the cervicals from the Upper

Wealden referred to *I. bernissartensis*, and much larger than those of *I. Mantelli*, it appears very probable that it may be referable to the Lower Wealden *I. Dawsoni*, which is intermediate in size between these two species. The specimen is represented on a reduced scale in fig. 3 from the posterior aspect. It will be seen from the figure that, with the exception of the parts of the edge of the posterior terminal cup of the centrum, the specimen is practically entire. The distinct neural spine, long transverse processes, and the position of the capitular rib-facet high up on the centrum indicate that the specimen is from that part of the vertebral column where the cervicals are just acquiring the characters of dorsals; but since the centrum is opisthocœlous, and apparently carries the whole of the capitular facet, I think the specimen should be reckoned as a cervical. The extreme height of this specimen is 13 inches; the height from the base of the neural canal to the summit of the neural spine 7 inches, and the transverse diameter of the posterior cup of the centrum 6·5 inches.

II. *Metatarsus of Megalosaurus from the Wadhurst Clay.*

In 1887 Dr. Ernst von Koken*, of Vienna, described and figured a Megalosaurian tooth from the Lower Wealden of Germany, which in 1884 Prof. Dames had made the type of the species *Megalosaurus Dunkeri*. In the following year, when cataloguing the Dinosaurian remains in the British Museum †, finding that the Megalosaurian teeth from the English Wealden presented no characters by which they could be specifically distinguished from the type of *M. Dunkeri*, I referred the whole of them, irrespective of size, to that species; under which heading I also included a number of vertebræ and limb-bones.

Among the limb-bones was the imperfect metatarsus (No. 2559) figured in Owen's 'Wealden and Purbeck Reptilia' (Mon. Pal. Soc. pt. iv. pl. xi.) as *Hylaosaurus*, which, as I have indicated in a former communication to this Society ‡, appears to be Megalosaurian. In addition to this specimen there were also entered a dorsal vertebra (No. R. 604 *a*), an imperfect tibia (R. 604 *c*), and the fourth left metatarsal (R. 604 *d*), all of which were obtained (as I am now informed) by Mr. Dawson in 1884 from the Hollington quarry, near Hastings, in immediate association, and which may be safely regarded as referable to a single individual. I considered that this metatarsal agreed with the metatarsal of No. 2559, described by Owen as the fourth; the whole of that metatarsus being figured by him as belonging to the left side.

Thus matters stood still till the spring of 1889, when Mr. Dawson brought another metatarsal of *Megalosaurus* (B.M. No. R. 1525) which had recently been obtained from the same quarry, but at

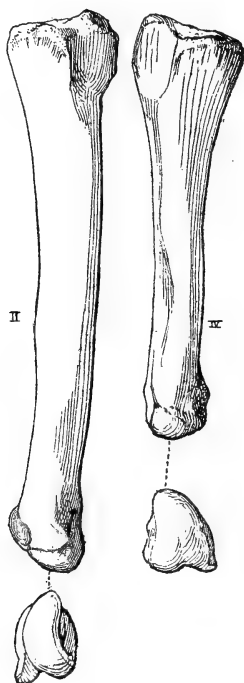
* Pal. Abhandl. vol. iii. p. 316, pl. ii. fig. 2.

† Cat. Foss. Rept. Amphib. Brit. Mus. pt. i. pp. 163-168. The authority for the species is there erroneously given as Koken.

‡ Quart. Journ. Geol. Soc. vol. xlv. p. 53.

a distance of some 180 yards to the eastward of the spot where the other specimens had been discovered in 1884. On putting this new specimen in its proper relative position to the metatarsal (No. R. 604 *d*), there can be no question but that the two belong to the left foot of the same individual, the new specimen being the second metatarsal. In woodcut fig. 4 these two metatarsals are represented in their approximate relative positions.

Fig. 4.—*The second and fourth Left Metatarsals of Megalosaurus Dunkeri; from the Wadhurst Clay, near Hastings. (About $\frac{1}{4}$ nat. size.)*



Placed in apposition with the metatarsus No. 2559, it is at once apparent that the Hollington specimens are specifically distinct from the former; and they further show that the former belongs to the right side, and not to the left as in Owen's figure. This is proved by the circumstance that in this group it is always the second metatarsal that is longer than the fourth, and it is evident that in No. 2559 the imperfect metatarsal marked II. in Owen's figure would when complete have been longer than the one marked IV. Further comparison between the Hollington metatarsus and No. 2559

shows that the former bones are characterized not only by their larger size, but also by their relative length and the great excess in the length of the second over the fourth. Moreover, both these bones have their antero-internal borders rounded, while the distal surface of the fourth is comparatively narrow. In No. 2559, on the other hand, the bones are absolutely smaller and apparently relatively shorter, the second being but slightly longer than the fourth; while both these bones have sharp antero-internal borders and the distal surface of the fourth metatarsal is broad and squared.

Seeing, therefore, that there is clear evidence of the existence of two species of Megalosaurians in the English Wealden it remains to determine which should be referred to *M. Dunkeri*; for I have no hesitation in believing that the British and Continental forms were specifically identical. Now the type tooth of *M. Dunkeri* is of comparatively large size, and was obtained from the lower division of the Hastings beds, which must be equivalent either to the Wadhurst Clay or the underlying Ashdowns; while No. 2559 came from the higher division of the overlying Tunbridge sands at Cuckfield. The Hollington metatarsus agreeing, therefore, in relative size with the type tooth and coming from approximately the same geological horizon, there is every probability that it belongs to the same species, to which I accordingly propose to refer it. It is of course unsatisfactory to have a species founded upon such an uncharacteristic portion of the skeleton as a single tooth; but being so, we are bound to accept and make the best we can of it. So far as it goes, the circumstance that the Iguanodons of the Wadhurst Clay appear to be all specifically different from those of the Tunbridge beds and Weald Clay is in favour of the view that the Hollington metatarsus really belongs to the species to which I propose to refer it.

Finally, seeing that the Cuckfield metatarsus is decidedly specifically distinct from the latter, I have made it the type of a distinct species, under the name of *Megalosaurus Oweni* *.

III. CIMOLIOSAURUS PORTLANDICUS from the Purbeck.

In part II. of the British Museum 'Catalogue of Fossil Reptilia and Amphibia' † I have referred the vertebræ from the Portlandian described under the names of *Plesiosaurus winspitensis* and *P. carinatus* (= *P. Phillipsi*) to *Cimoliosaurus (Pliosaurus) portlandicus* of Owen, on the ground that all the known vertebræ from these beds are of one type, and are therefore almost certainly referable to the species typically represented by the bones of the pelvic limb.

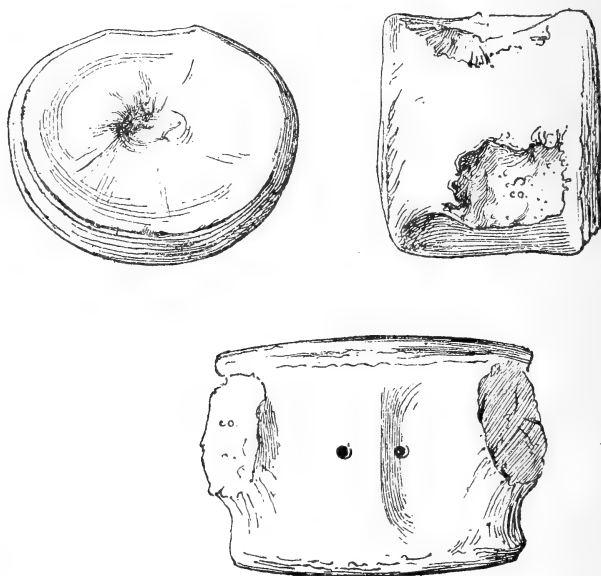
Hitherto this species has been known solely from the Portlandian, but I am now able to bring evidence that it ranged upwards into the Middle Purbeck. This evidence is afforded by the imperfect centra of two posterior cervical vertebræ which I procured during the past summer from the quarries at Portland. They were obtained from the 'Cinder-bed' of the Middle Purbecks, which, as is well

* Geol. Mag. decad. 3, vol. vi: p. 325 (1889).

† Pp. 227, 228 (1889).

known, is one of the few marine beds found in that series. The best-preserved of the two specimens is represented in fig. 5; and it will be seen therefrom that both the ribs and the neural arch were not ankylosed to the centrum, from which we may probably infer that the specimens belong to an individual which had not attained full maturity. Apart from the fractures which they have sustained in

Fig. 5.—Anterior, right lateral, and ventral aspects of the Centrum of a Dorsal Vertebra of *Cimoliosaurus portlandicus*; from the Purbeck of the Isle of Portland. ($\frac{2}{3}$.)



co, costal facet.

the process of extraction from their bed, these specimens are beautifully preserved, and are thereby in marked contrast to the posterior cervicals from the Portlandian in the collection of the British Museum, all of which have suffered by rolling. The extreme prominence of the carina on the hæmal surface at once shows that these specimens agree with the cervical figured by Phillips* as *Plesiosaurus carinatus*. They are, indeed, of somewhat larger dimensions, as is shown by the following table:—

	Phillips's specimen.	Present specimen.
Length.....	1.63 in.	1.9 in.
Height.....	1.60 in.	1.9 in.
Width.....	1.95 in.	2.4 in.

* Geology of Oxford, p. 375.

This, however, I cannot regard as anything more than a difference in age or of individual development, seeing that both specimens are apparently immature.

The two posterior cervicals in the British Museum (Nos. 41238, 45904) are still smaller than Phillips's specimens, and have the depression on either side of the hæmal carina much less strongly marked, this being partly due to their water-worn condition and partly also to their immaturity.

In describing those specimens in the Museum Catalogue, I considered that they would agree in relative size with the femur on which *Cimoliosaurus portlandicus* was founded. A subsequent opportunity of comparing the size of that limb with the entire skeleton of *Cimoliosaurus Richardsoni* has, however, convinced me that the present specimens are more nearly of the size which accords proportionately with the hind limb; from which I also infer that *C. portlandicus* was of the approximate size of the last-named species.

Hitherto, so far as I am aware, the only evidence of the occurrence of a Sauropterygian in the Purbecks is afforded by an imperfect humerus or femur mentioned on p. 227 of the above-mentioned 'Catalogue.' It was then suggested that the specimen in question might be referable to the Wealden *C. limnophilus*, but it may equally well belong to the present form.

The freshwater vertebrates of the Purbecks, judging from the Chelonia, appear to be closely allied to those of the Wealden, at least one species (*Hyleochelys latiscutata*) being common to the two series. It is therefore of considerable interest to find that where marine conditions obtained there was an equally close alliance, if we may judge from a single instance, with the vertebrate fauna of the Portlandian.

IV. A Pliosaurian Skeleton from the Oxford Clay of Peterborough.

In a paper read before the Society on the 21st of November, 1888, I described under the name of *Peloneustes* * the remains of a comparatively small Pliosaurian from the Oxford Clay, which I regarded as a more generalized form than *Pliosaurus*, although it was doubtful if it could be regarded as the direct ancestor of that genus. My reasons for separating *Peloneustes* from *Pliosaurus* were the great length of the mandibular symphysis, the attachment of the neural arches and cervical ribs by suture to the vertebræ, and the relatively longer epipodial bones, of which the ulna and fibula were subreniform. I may add that in this description I considered that the pectoral limb was larger than the pelvic; but from specimens in the collection of Mr. Leeds it appears that the reverse condition obtains †, as in *Pliosaurus*.

* Quart. Journ. Geol. Soc. vol. xlv. pp. 48-56 (1889).

† The limb figured on p. 54 of the memoir cited will accordingly be the pelvic instead of the pectoral, as, indeed, I considered to be the case when the figure was drawn. The tibia (*t*) is drawn too small in proportion to the fibula (*f*).

Quite recently Mr. A. N. Leeds of Eyebury, near Peterborough, has added to his unrivalled collection of Saurian remains from the Oxford Clay of that neighbourhood a considerable proportion of the skeleton of a large Pliosaur, which is important as being not only the first example (exclusive of *Peloneustes*) of the association of teeth, vertebræ, and limbs, but also as being a generalized form connecting the typical Kimeridgian species of *Pliosaurus* with the smaller forms described as *Peloneustes*. Mr. Leeds has been good enough to permit me to select such portions of the skeleton as appeared best to illustrate the affinities of this form, the description of which I now give. The specimens collected by Mr. Leeds include the greater part of the mandible, showing the entire symphysis, a number of detached teeth in very beautiful preservation, several cervical vertebræ, in some instances with the neural arches and ribs, the greater portion of the pectoral limb of one side, and portions of that of the other, and several bones of the pelvic limbs.

These specimens indicate an individual agreeing approximately in size with an imperfect skeleton of *Pliosaurus brachydirus* in the British Museum, No. 46796 *, the cervical vertebræ of both examples being of nearly the same size, and the mandibular symphysis having a transverse diameter of about six inches. The humerus measures nearly 24 inches in length, or slightly more than in the type skeleton of *P. brachydirus* from Market-Rasen.

The mandibular symphysis agrees with that of the typical Kimeridgian species of *Pliosaurus* in that it extends back as far as the seventh tooth. Except for its much larger size the mandible presents no characters by which it can be distinguished from a probably immature mandible from the Oxford Clay in the Eyebury collection which I have referred † to *Pliosaurus ferox*.

Of the detached teeth one of the largest is represented in Pl. V. fig. 1, this and other similar ones being the finest specimens of Pliosaur teeth that I have ever seen. Whether this tooth belonged to the upper or lower jaw, there are no means of definitely determining, but it is evidently either from the premaxillary or the symphyseal region. The pulp-cavity is open and extends the whole length of the root and some distance into the crown. The crown of this tooth is almost undistinguishable from that of the smaller type of teeth belonging to *Peloneustes philarchus*. It also closely resembles the Pliosaurian teeth commonly occurring in the Oxford Clay of Peterborough, which are undistinguishable from the Continental examples described under the name of *Liopleurodon ferox*, a name which I have altered to *Pliosaurus ferox* ‡. It is true that in the present examples the intercarinal space of the teeth of typical Pliosaurus is scarcely definable, and the ridges are rather more continuous and closer together than in typical examples of *P. ferox*; yet, after careful comparison with a number of specimens, I find such a transition from the typical form to the present type that it

* Cat. Foss. Rept. and Amphib. Brit. Mus. pt. ii. p. 124 (1889).

† 'Catalogue,' *op. cit.* p. 145.

‡ 'Catalogue,' p. 145.

appears impossible by the teeth alone to distinguish this Pliosaur from *P. ferox*.

Of the cervical vertebræ a centrum, with the cervical ribs, from the hinder region of the neck, is represented of three fourths the natural size in Pl. V. fig. 2. This vertebra presents all the characters of a typical Pliosaur. Its terminal faces are subcylindrical, and have no mamilla round the central depression; the costal facets are very prominent; and the external surface is highly rugose. The dimensions are: length 1·75, height 3·6, and width 4·0 inches. The length is therefore very nearly half the vertical diameter. A rather later cervical, in which the terminal faces have become transversely ellipsoidal, has a height of 3·7 and a width of 4·3 inches, the true length not being determinable owing to crushing. The neural arch represented in Pl. V. fig. 3 shows the presence of large and well-developed zygapophyses. Unfortunately the nature of the cervical zygapophyses in the Kimeridgian Pliosaurus does not appear to be known. In the dorsal region, however, the zygapophyses were of very small size and almost aborted in the Pliosaurus of the Kimeridge Clay; and an immature vertebra in the Eyebury collection shows that the same condition obtained in at least one of the Pliosaurus of the Oxford Clay. There are no signs of any sutural connexion of the arches and ribs with the centra of the cervical vertebræ in the specimens under consideration.

If my memory does not fail me, these cervicals closely resemble an associated series in the Cambridge Museum from the Oxford Clay of Great Gransden, near St. Neots, Huntingdonshire, to the owner of which Prof. Seeley has applied the name of *Pliosaurus pachydirus*, although without any description to justify the adoption of that name*, these specimens being noticeable for the prominence of the costal articulations. The form to which that name was applied I have provisionally included in the work cited in *P. ferox*. On p. 146 of that work an imperfect late cervical vertebra (No. 47429) from the Oxford Clay near Peterborough is provisionally referred to the same species. On comparison with the present specimens such a marked resemblance is presented by that vertebra, that there seems to be every reason for considering both as specifically the same. It is true, indeed, that in the British-Museum vertebra the costal facets are less prominent than in Mr. Leeds's specimens; but I think this difference may be partly due to individual variation, and partly to the edges of these facets in the former specimen having been chipped.

That the vertebræ under consideration indicate a totally different form from the one to which the name of *Pliosaurus Evansi* has been applied, is quite evident†. Thus the typical cervical vertebræ of the latter (which through the courtesy of Prof. Hughes I have been enabled to compare with the specimens under consideration) differ not only in their much smaller size, but in their proportionately greater length, which much exceeds half the vertical diameter of

* See 'Catalogue' *op. cit.* p. 145.

† See 'Catalogue,' p. 128.

their terminal faces, and in their smooth external surface. Compared, indeed, with the cervical vertebræ of *Peloneustes philarchus* there is such a close resemblance, that I think there is little doubt that *Pliosaurus Evansi* should be transferred to *Peloneustes*; and from the agreement in relative size between the cervical vertebræ and the mandible and paddle from the Oxford Clay in the Eyebury collection figured by Phillips as *Pliosaurus*, which I have shown* to be referable to *Peloneustes*, it appears probable that those specimens are likewise referable to *P. Evansi*.

The only other bones to which it will be necessary to refer are the epipodials (radius and ulna, and tibia and fibula). A reduced figure of the tibia and fibula is given in Pl. V. fig. 4, from which it will be apparent that these bones differ from their homologues in the Kimeridgian species of *Pliosaurus* in that they are vertically instead of transversely elongated, in which respect they agree precisely with the corresponding bones of *Peloneustes*.

Summing up the result of the foregoing observations, it appears that we have to do with a large Pliosaur which in dental characters cannot be satisfactorily distinguished from *Pliosaurus ferox*, and may accordingly be referred to that species, a reference which will confirm the conclusion that the vertebræ named *P. pachydirus* are likewise referable to the same species. This Pliosaur, while agreeing with the typical Kimeridgian forms in the character of the mandibular symphysis and vertebræ, is allied by the teeth and epipodial bones to the smaller forms known as *Peloneustes*, and therefore serves to connect the latter with *Pliosaurus*, although not necessarily leading to its abolition.

Further, the available evidence points to the transference of *Pliosaurus Evansi* to *Peloneustes*, and also indicates that the more elongated centra of the cervical vertebræ may be added to the distinctive characters of that genus.

The evidence now clearly shows that *Peloneustes*, which may have been descended from the Longirostrine group of *Plesiosaurus*, is the direct ancestral type of *Pliosaurus*, which has gradually become more specialized in the characters of the teeth, in the imperfect articulation between the centra and appendages of the vertebræ, in the shortening and widening of the epipodial bones, in the shorter mandibular symphysis, and, finally, in the increase in absolute corporeal bulk.

EXPLANATION OF PLATE V.

Remains of *Pliosaurus ferox* from the Oxford Clay, near Peterborough.

- Fig. 1. A tooth, natural size.
 2. Anterior aspect of a late cervical vertebra, with the rib (*r*) of the right side, $\frac{2}{3}$ nat. size.
 3. Imperfect neural arch of a cervical vertebra, $\frac{2}{3}$ nat. size. *pt.z.*, postzygapophysis; *pr.z.*, broken base of prezygapophysis.
 4. A tibia (*T.*) and fibula (*F.*), $\frac{1}{2}$ nat. size.

* See 'Catalogue,' p. 154.

DISCUSSION.

The PRESIDENT regretted the absence of those best acquainted with the subject, and alluded to the difficulties in the way of criticism.

Mr. LEEDS, referring to the fossil from the Oxford Clay, observed that the jaw is identical with *Pliosaurus* and the paddle with *Peloneustes*. He was in possession of a large jaw of *Pliosaurus*, measuring 4 ft. 7 in., with which he identified the lower jaw of this species. The body-bones were much broken up. There was great difference in the size of the paddles, but he did not know whether the fore or hind paddles were the larger.

Mr. E. T. NEWTON was satisfied, with regard to the specimens of *Iguanodon* referred to, that the species were distinct.

Dr. WOODWARD spoke of thanks being due to Mr. Leeds for the care with which he had worked the clay-pits of the country round Peterborough. In this country remains of Saurians were too often fragmentary, whilst in Belgium they were often entire. Mr. Leeds had secured complete remains of Oxford and Kimeridge Clay marine reptiles, and had taken care to match the individual bones with the individual specimens.

He also spoke of the good work of Mr. Dawson amongst the Wealden Dinosaurs, and of Mr. Rufford as regards the vertebra of *Iguanodon*.

Prof. HUGHES inquired as to the evidence for the association of the bones referred to the same individuals.

Mr. LEEDS explained that some of his specimens consisted of the entire skeleton, whilst others were imperfect. These particular bones were much broken, but were all found on one level; had it been otherwise he would not have connected them. He proceeded to describe the position of the bones, which were certainly those of one animal, there being none other.

Dr. MURIE, alluding more especially to *Iguanodon*, spoke of the difficulty of judging from diagrams in the absence of the specimens. Looking at the femurs, one might say that the difference was one of age rather than of species.

Mr. SMITH WOODWARD thought that *Peloneustes* should be redefined or done away with. With regard to the skeletons obtained by Mr. Leeds, there could be no doubt as to the natural association of the bones; they rested upon well-defined old floors in the clay, marked by accumulations of broken shells.

The AUTHOR, in reply, stated that he had given his reasons for regarding the Iguanodont remains as associated; there was no question whatever as to those of the Pliosaurian belonging to a single individual. He could not admit Dr. Murie's view that the differences in the Iguanodont remains were due to age. In reply to Mr. Smith Woodward, the Author remarked that *Peloneustes* was distinguished from *Pliosaurus* by its cervical vertebrae as well as by the longer mandibular symphysis. He acknowledged his obligations to Mr. Leeds and Mr. Dawson.

4. *On a NEW GENUS of SILICEOUS SPONGES from the LOWER CALCAREOUS GRIT of YORKSHIRE.* By GEORGE JENNINGS HINDE, Ph.D., F.G.S. (Read November 20, 1889.)

[PLATE VI.]

NEARLY forty years since*, Dr. H. C. Sorby, F.R.S., communicated to this Society a paper on the microscopical structure of the Calcareous Grit of the Yorkshire coast, in which reference was made more particularly to the nature of certain microscopic reniform bodies with which the rock in places was largely filled. In mineral constitution some of these bodies were of calcite, others of chalcedonic silica, whilst in others both these minerals were present, and the question as to their original constitution was decided by Dr. Sorby in favour of the calcite, since it was thought extremely improbable that, if originally of silica, this material would have been dissolved and replaced by calcite, whereas the substitution of silica in place of calcite was a well-known phenomenon. The definite form and outline of these bodies left no doubt that they were of organic origin, and Dr. Sorby recognized their resemblance to the small siliceous globules which form an outer crust to many existing sponges, but rejected this view on the ground of their supposed calcareous nature, and he finally concluded that they were small shells, possibly Foraminiferal, in whose interior calcareous or siliceous materials had been infiltrated, in the same manner as in the chambers of the Ammonites occurring in the same rock.

Subsequently, in 1876, Prof. J. F. Blake †, F.G.S., discovered similar minute bodies in rocks of nearly the same age in Dorsetshire and Wiltshire, and noticed that some of them were hollows enclosed by thin crusts or shells, which dissolved in acid, and further that their surfaces were ornamented by regular rows of small pits, which were supposed to indicate minute perforations in the shell. On these grounds they were described as peculiar forms of Foraminifera, and named *Renulina Sorbyana*. In an incidental reference in a later ‡ paper, Prof. Blake hints at the possibility that they may have been originally siliceous.

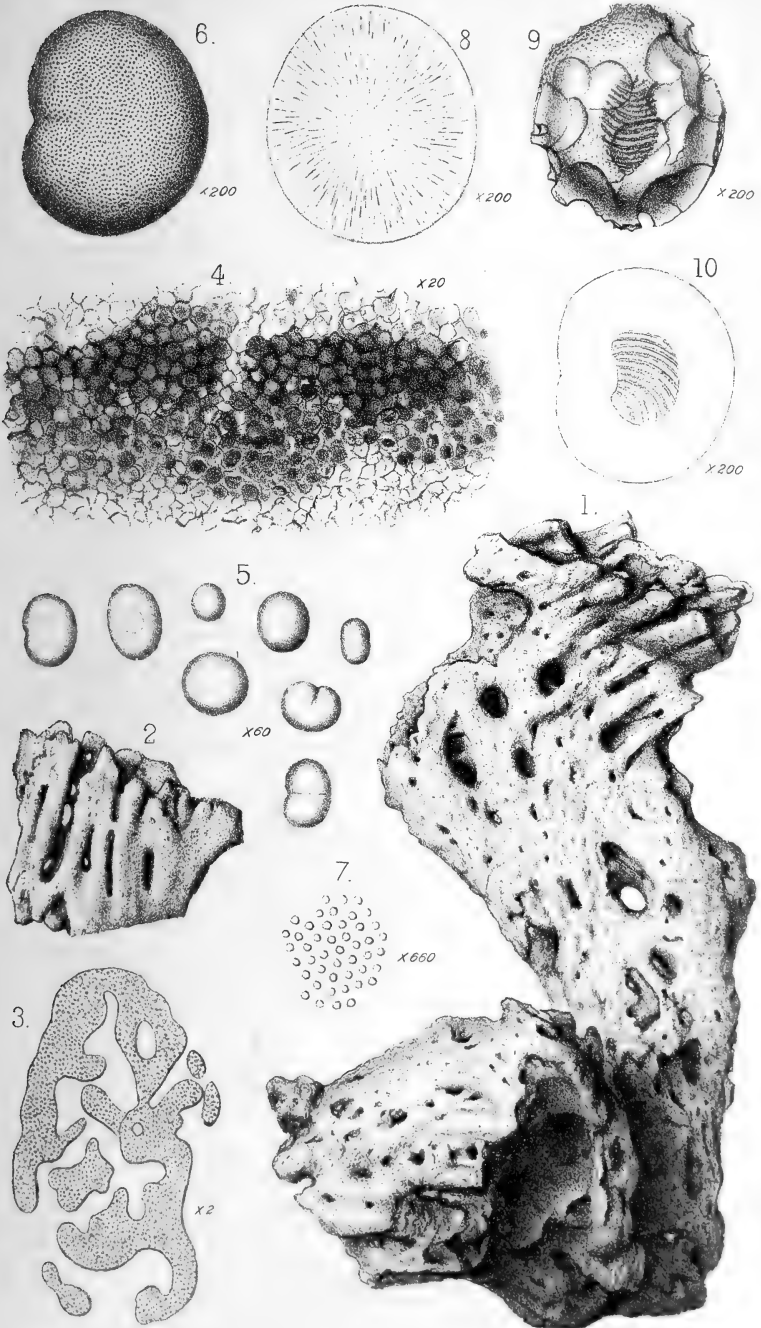
Mr. W. H. Hudleston §, F.R.S., likewise refers to these same reniform bodies in treating of the generally siliceous character of the Coral Rag at North Grimston, in Yorkshire, and adopts the view that they were siliceous spicules, similar to those forming the outer layer of the recent sponge, *Geodia arabica*. In this case the author

* Quart. Journ. Geol. Soc. vol. vii. (1851), pp. 1-6. See also 'Proceedings of the Geological and Polytechnic Society of Yorkshire,' June 5, 1851, vol. iii. pp. 197-206, pl. iv.

† Monthly Microscopical Journal, vol. xv. pp. 262-264.

‡ Proc. Geologists' Assoc. vol. v. (1877), p. 266.

§ *Ib.* vol. v. p. 443.



A.T.Hollick del.

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RHAXELLA PERFORATA.

remarks that the acerates and the anchor-spicules appertaining to the same sponges must have been equally abundant, affording a copious supply of organic silica, which has been one source of the chalcidonic matter so largely pervading portions of the Rag.

Dr. Sorby again mentions the small reniform shells in his presidential address to the Society in 1879*, and states that in the *Perna*-bed in Dorsetshire and in certain beds in Yorkshire they constitute as large a part of the bulk of the rock as the Foraminifera do in all but a very few exceptional specimens of Chalk.

In 1880 †, Prof. Sollas compares these bodies with the globate spicules of *Geodian* sponges in the Upper Chalk, and on the supposition that they belonged to similar sponges, changed Blake's name to *Geodites Sorbyana*.

The view that these detached reniform spicules, or globates as they have been termed, belonged to the dermal crust of siliceous sponges like those of the living genus *Geodia*, has been very generally accepted as correct, though an objection of considerable weight could be urged against it, namely, that they occurred almost exclusively in these rocks, without admixture with other forms of spicules, whereas in the existing *Geodian* sponges the globates of the crust form but a small proportion of the entire mass of the body-spicules, and as these latter are larger and more robust than the globates, it is natural to suppose that they would be present in the same rocks with them; and, in fact, this is the case in the contents of the Upper Chalk flints of this country and in the Kreidemergel of Westphalia, where the fusiform acerates and characteristic trifid or fork-spicules of *Geodia* are mingled with the globates. The absence of the detached larger acerate and fork-spicules in the Calcareous Grit would tend to show that the globate spicules did not form the crust of sponges like the recent *Geodia*, and this is now proved by the occurrence of several more or less perfect specimens of sponges in the same rocks with the detached spicules, which seem to be entirely composed of this one form of globate spicule, and thus explain its exclusive occurrence in the rock. Sponges with skeletons thus formed are very distinct from any others yet discovered as fossil, though there is a living genus to which they may possibly be related. Independently of their remarkable structural features, these sponges are very exceptional instances of the preservation as fossil of the connected skeleton, although its constituent spicules are not organically united together, and the fact of their existence in such great numbers that their microscopic detached spicules contribute no small part of the mass of certain beds of rock, adds further interest to their description.

I may premise that the sponges in question belong in part to the Natural History Museum at Scarborough, and in part to that at York, and I am indebted to the kindness of Mr. C. Fox Strangways, F.G.S., and to the Trustees of the York Museum, through Mr. H.

* Proc. Geol. Soc. 1879, p. 51.—Appendix, pl. vi. fig. 1.

† Ann. & Mag. Nat. Hist. ser. 5, vol. vi. p. 392.

M. Platnauer, F.G.S., for the opportunity of studying them*. Some of the specimens, from their porous aspect, had been recognized and labelled as sponges; but, so far as I am aware, no reference to them has ever been published, and the resemblance of their spicules to the detached bodies in the Calcareous Grit does not seem to have been noticed.

The specimens are now for the most part weathered out on the surface of a hard matrix of the Calcareous Grit, consisting principally of sand-grains and detached spicules like those of the sponge, cemented together by calcite or silica. In one specimen the matrix is decayed, so that the sponge has been quite freed from it. The sponges appear to have been upright, palmate or fan-shaped, and in the early stage of growth funnel-shaped in some instances (Pl. VI. fig. 1). No specimen is perfect; the largest individual measures 140 millim. in height by 80 millim. in width, and the walls are about 14 millim. in thickness. The walls consist of plates or indistinct trabeculae, which anastomose to form a labyrinthine structure (Pl. VI. fig. 3). The plates are perforated irregularly by ovate apertures or slits of varying dimensions (fig. 2), ranging from 1 to 9 millim. in width; they vary in thickness from .5 millim. to 4 millim., and the interspaces between the plates of the wall correspondingly vary from 1 to about 4 millim. The outer surface of the wall in some cases is smooth, in others rough to the touch; occasionally small oysters are attached to it.

These laminate walls appear to be entirely composed of the small reniform or so-called globate spicules already mentioned, which are closely aggregated into a solid mass, and now firmly cemented together by silica resulting from the fossilization. In a transverse section through the sponge-wall the spicules are seen in close contact, their individual outlines for the most part being clearly shown; but in the central portions of some of the laminae, secondary crystallization has fused them into a mass of fibrous chalcedony (fig. 4). The nature of these spicules can be more favourably ascertained from the detached forms, obtained by dissolving some of the matrix in acid, than from those in the connected skeleton, which appear to be more altered. Their mineral characters have already been carefully described by Dr. Sorby, and no further reference needs here to be made to the circumstance that some are at present of crystalline calcite, since it is now well established that these are but replacements after silica. Some of the siliceous spicules retain outlines as smooth and perfect as in recent forms (figs. 5, 6, 8, & 10), whilst others are corroded in varying degrees, small concave hollows having been scooped out from their surfaces, so that they now present a very jagged appearance (fig. 9). The central portion in some of the spicules also shows differently tinted, banded layers of chalcedony, whilst the outer zone is transparent (fig. 10). Mounted in Canada balsam they are so

* Since my paper was sent into the Society, Mr. W. H. Hudleston has shown me two specimens of this sponge in his own collection, one from Scarborough and the other from the Coral Rag of Settrington.

transparent that little more than their outlines can be distinguished; whereas in glycerine they stand out prominently, and their surface features are clearly seen. The spicules vary from ellipsoidal to subspherical in form, with a small notch or hilum which gives them their characteristic kidney-shaped appearance. In sections of the sponge-wall they range from $\cdot 11$ to $\cdot 15$ millim. in diameter, but some of the detached forms are not more than $\cdot 08$ millim. in thickness. On the surface of the best-preserved spicules there is an ornamentation of minute subcircular spots with shaded borders, apparently regularly quincuncially arranged; the spots are very minute, averaging only $\cdot 002$ millim. in width (figs. 6 & 7). They were first noticed by Prof. Blake, and supposed by him to indicate perforations in a surface-shell. I have also noticed in a few of the spicules traces of very fine lines or fibres radiating from their centres to the surface (fig. 8). These and the surface-markings indubitably prove the structural similarity of the fossil spicules to the siliceous globates of the crust of the recent *Geodia* and other sponges; for it has long been known that each of these recent globate spicules is built up of a great number of minute siliceous radial fibres which extend from the centre of the spicule and terminate on its outer surface in nodose or spined ends, and the traces of radiate fibres and the surface-spots in the fossil spicules are really due to the original structure of minute fibres like those of the globates of the recent *Geodia*. The subcircular spots representing the terminal ends of the fibres in the fossil globates are, however, much finer than those of recent forms, but they correspond more nearly in this respect with the globates of the recent genus *Placospongia*, mentioned below.

Hitherto no sponge has been described, either fossil or recent, with a skeleton entirely composed of globate spicules, as seems to be the case with this fossil form, and its systematic relations are consequently somewhat uncertain. As a rule, globate spicules, like those of this fossil, form a firm dermal crust to sponges whose main skeletal spicules are of quite a different character; thus in *Geodia*, as already mentioned, the mass of the skeleton of the sponge usually consists of relatively large fusiform acerate and long-shafted forks and anchor spicules; and in the Jurassic *Lecanella pateriformis*, Zittel, whilst the surface is stated by * v. Zittel to be covered with innumerable globate spicules of precisely the same character and size as in our fossil, the main skeletal spicules are irregularly branching Lithistid forms. There is, however, a very remarkable recent genus, *Placospongia*, Gray, in which the globate spicules form a solid interior axis to the sponge, of much the same character as the anastomosing plates of the interior of the present fossil. In the type species of this genus, *P. melobesioides*, Gray †, which I have had an opportunity of examining in the Natural History Museum, South Kensington, there is in addition to the solid axis of globate spicules a dense dermal crust of the same kind of spicules, and in

* "Studien über fossile Spongien," Abb. der k. Bayer. Akad. der Wiss. Cl. ii. Bd. xiii. Ab. i. p. 135.

† Proc. Zool. Soc. Jan. 1867, p. 127.

the interspace between the axis and the crust a layer with numerous pin-like spicules, frequently in sheaf-like bundles with their pointed ends directed to the exterior, and scattered globates as well. But for the presence of this layer of skeletal pin-like spicules, of forms characteristic of an important group of Monactinellid sponges, there would have been considerable analogy between the present fossil and *Placospongia*. The possibility that pin-like spicules may have been originally present in the interspaces between the anastomosing wall-plates of this fossil sponge is not altogether excluded; for judging by their disposition in *Placospongia*, they would be much less likely to be preserved *in situ* than the dense axis of globates, and some show of probability is given to this supposition by the occurrence of a few detached pin-like spicules mingled with the globates in the rock matrix. In the sponges themselves, however, there is no evidence of an intermediate layer of pin-like or other spicules; their walls, as already stated, appear to be entirely composed of the minute globates. As, moreover, we find that the globates are associated in different sponges with various types of skeletal spicules, Tetractinellid, Lithistid, and Monactinellid, there is no antecedent improbability that they may exclusively form the skeleton in this fossil.

In addition to possessing a solid interior skeleton of globate spicules, there is another point of resemblance between *Placospongia* and this fossil, in the fact that the minute siliceous component radial fibres of the globates in the two forms are very similar, whilst they are distinctly smaller than the radial fibres of the globates in *Geodia*.

The presence of a distinct zone of pin-shaped spicules in *Placospongia* and their apparent absence in this fossil indicates, however, a very marked systematic distinction between these forms; and they may respectively prove to be types of two distinct families*.

It may be inferred that the detached globate spicules probably belong to more than a single genus and species, and it is therefore necessary to propose a special designation for the particular sponge above described. The generic name *Renulina*, given by Prof. Blake to the globates, has moreover been preoccupied †. I propose therefore to name this fossil genus *Rhaxella* ‡, and the family Rhaxellidæ, with the following diagnosis:—

* There is considerable difference of opinion as to the proper systematic position of *Placospongia*. By Dr. Gray and others it has been placed near *Geodia* on account of the similarity of the globate spicules, whilst Mr. H. J. Carter, F.R.S., relying on the characteristic pin-like spicules, places the genus in the Suberitida, that is, with Monactinellid sponges (Ann. & Mag. Nat. Hist. ser. 5, vol. vi. (1880), p. 477). Dr. Vosmaer states (Bronn's Klassen u. Ordn. des Thierreichs, Spongien, p. 405) that it should probably come at the end of the Geodidæ.

† See Lamarck, Hist. Nat. Anim. s. Vert. vii. p. 605 (1822); Blainville, Dict. Sci. Nat. tome xxxii. (1824).

‡ *ῥάξ*, a berry, dimin.

Genus RHAXELLA, Hinde.

Sponges with walls of anastomosing plates or trabeculæ, composed entirely of aggregated masses of globate spicules.

RHAXELLA PERFORATA, sp. n. (Pl. VI.)

Sponges palmate, flabellate, or perhaps funnel-shaped; the largest specimen, which is not complete, is 140 millim. in height and 80 millim. in width. Outer surface smooth or faintly ribbed, perforated irregularly by oval or slit-like apertures from 1 to 9 millim. in diameter. The plates of the wall are from .5 to 4 millim. in thickness, usually from 1 to 2 millim. They interosculate so as to form labyrinthine interspaces of varying width. The globate spicules vary from ellipsoidal to nearly spherical in form, with a well-marked depression or hilum. They are mostly from .11 to .15 millim. in diameter; very small forms are only .08 millim. The fibres of the globates are very minute; their distal ends are sub-circular, and average .002 millim. in diameter.

Distribution. Corallian: Lower Calcareous Grit (Zone of *Ammonites perarmatus*): Scarborough, Yorkshire. Coral Rag: Settrington, Yorkshire (*Huddleston*). Detached spicules, some of which probably belong to this species, also occur in the Coral Rag of North Grimston, Yorkshire (*Huddleston*), and on nearly the same horizon at Sturminster Newton, Dorsetshire, and at Hilmarton, near Colne, Wiltshire (*Blake*).

SUMMARY AND CONCLUSIONS.

In the Lower Calcareous Grit of Scarborough definite sponges of somewhat irregular outlines, varying from funnel-shaped to sub-palmate in form, occur partially weathered out, as a rule on the surface of the rock. The sponges are siliceous, their walls consist of irregularly perforated plates or anastomosing trabeculæ, which are entirely built up of aggregated masses of minute globate spicules similar to those of the recent genera *Placospongia* and *Geodia*, without any apparent intermixture of other spicular forms. The globates show traces of component radial fibres and surface-markings precisely similar to those of analogous spicules in recent sponges.

Sponges of this type of skeletal structure, with labyrinthic walls wholly of globate spicules, have not hitherto been known either fossil or recent; as a rule, spicules of this form are associated with acerate, trifid or pin-shaped spicules, and in one fossil genus with lithistid spicules. The recent *Placospongia*, which has a solid central axis of globate spicules, presents the nearest analogy to the fossil *Rhaxella*.

These sponges are very good instances of the preservation of the entire or nearly entire skeleton of the organism in spite of the fact that the component spicules are not originally united together or held in position otherwise than by the soft animal structures, which necessarily perish after the death of the animal. Such instances are extremely rare; for as a rule sponges of this character fall to pieces

and their individual spicules are scattered over the sea-bottom. A similar fate undoubtedly befell the great majority of these sponges in the ocean of the Lower Calcareous Grit; for, whilst the entire skeletons are very seldom met with, the detached component spicules form a very notable proportion of the rock-matrix in which they are imbedded, and the specimens may be considered as the scantiest relics of an enormous multitude, which by specially favourable circumstances have escaped disintegration.

These sponges also furnish additional proof of the connexion between these organisms and beds of chert and silica (other than quartz). Thus in the Cliff at Scarborough, as Mr. Hudleston has shown, there is in the Lower Calcareous Grit, from which these sponges have been obtained, a bed of 3 feet 4 inches (about 1 mètre) of intensely hard chert, and beneath this, 30 feet (9 mètres) of a calcareous grit, largely cemented by silica. There can be little doubt that most of the silica in this considerable thickness of rock (not reckoning the sand grains) is due to the siliceous sponges; for throughout these beds, not only at Scarborough itself but in the adjoining areas, Mr. Hudleston has pointed out that where these minute globates are not themselves now present in the siliceous strata, they are represented by minute empty moulds, which bear witness that the spicules themselves have been dissolved and the resulting silica has been redeposited to form the siliceous cement in the rock. Mr. Hudleston has given so excellent a description of the Calcareous Grit which has been thus formed that I venture to quote the passage*:
 —“It is almost entirely devoid of calcic carbonate, and consists chiefly of a poriferous mass of siliceous matter, which includes a quantity of extremely fine quartzose sand. The cherty portions exhibit the pores also, but then they seem further apart and less connected. Sometimes the pores are empty—pin-hole structure; sometimes they contain a white powder, which is either silica or a silicate—speckled structure. In a greater or less degree, the above characters may be recognized in very much of these yellow sponge-cake calc.-grits, giving rise to the idea of the decomposition of granular bodies of almost microscopic minuteness, which, during the formation of the rock, had formed no inconsiderable portions of its mass, but which, subsequent to consolidation, have in most cases been removed by solution.” Proc. Geologists' Association, vol. iv. (1875), p. 32, sep. cop.

EXPLANATION OF PLATE VI.

Rhaxella perforata, Hinde, gen. et sp. nov.

- Fig. 1. An imperfect subpalmate specimen, showing the irregular mode of growth and the perforate character of the wall. Natural size. The specimen is now quite free from the matrix. It comes from Scarborough, and now belongs to the Museum at York.
2. A fragment of another specimen in which the wall exhibits a flattened trabecular structure with slit-like apertures. Natural size.
 3. A transverse section of the above, showing the labyrinthic disposition of the laminae of the wall. Enlarged two diameters.

* Proceedings of the Geol. Assoc. vol. iv. (1875), p. 44, sep. cop.

- Fig. 4. A transverse section of a fragment of the wall-plates, enlarged twenty diameters, showing its structure of globate spicules. In this specimen the sponge is imbedded in a matrix of transparent granular calcite.
5. Several of the globate spicules, obtained by dissolving in acid the rock-matrix in which one of the sponges is partially imbedded, showing variations of form and size. Enlarged sixty diameters.
 6. A globate spicule, enlarged two hundred diameters, showing the minute points on its surface produced by the distal ends of its component siliceous fibres. The specimen is mounted in glycerine.
 7. A portion of the surface of a globate spicule, showing the markings enlarged to six hundred and sixty diameters.
 8. A globate spicule, enlarged two hundred diameters, showing traces of its component radial fibres. The specimen is mounted in Canada balsam.
 9. A globate spicule, enlarged two hundred diameters, showing the effects of corrosion on its surface, whilst the interior has been replaced by banded chalcedony. Mounted in glycerine.
 10. A similar spicule, showing central replacement, whilst the surface remains unaltered. Mounted in Canada balsam.

DISCUSSION.

The PRESIDENT said that palæontologists were greatly indebted to Dr. Hinde for his researches on sponge-structure. They would especially welcome these details on an entirely new form. He noticed the apparent anomaly of "globates" being called "spicules."

Mr. HUDLESTON had been greatly interested in the results of this particular piece of work, since it helped to clear up some disputed points in connexion with the Corallian rocks of Yorkshire. These microscopic globates, though swarming in parts of the Lower Calcareous Grit, were far from uncommon in portions of the Coral Rag. He had been struck with the amount of chalcedonic silica in certain portions of the Rag, and had endeavoured to ascertain its source. The rock-sections prepared for this purpose were full of small granular bodies, which Prof. Sollas pronounced to be globates of a siliceous sponge such as *Geodia*. The difficulty, of course, was to account for the absence of the elongate spicules, and Mr. Hudleston admitted that his own remarks on this point at a time when no one had any suspicion of a sponge whose spicules were all globates, might be open to correction. But since elongate spicules are traversed by a canal, where the action of solvents first shows itself, he still thought it possible that they might disappear as soon, if not sooner, than the more microscopic globates. The Author thought otherwise. Anyhow, the problem, which had puzzled Mr. Sorby and led to so much discussion, was now conclusively solved by the recognition of the true nature of the Scarborough fossil,—one of the many results of Dr. Hinde's intimate acquaintance with sponge-structure.

The AUTHOR, in reply, said that he agreed with the remarks of the President as to the anomaly of the term "globate" spicules, but the word "spicule" might be advantageously employed in a general sense for the small bodies which compose the skeletons of sponges. He did not think that Mr. Hudleston was much to blame for referring the detached globates to *Geodia*, as he himself had been quite astonished at the discovery of such a sponge as the one now described.

5. *On the Occurrence of the STRIPED HYÆNA in the TERTIARY of the VAL D'ARNO.* By R. LYDEKKER, Esq., B.A., F.G.S., &c. (Read November 20, 1889.)

IN cataloguing the remains of fossil Carnivora preserved in the British Museum *, I entered, under the head of *Hyæna striata*, a portion of the left maxilla of a hyæna obtained by the late Mr. Pentland from the Tertiary deposits of the Val d'Arno, in Tuscany. At that time I had no evidence of the existence of this species in the Pliocene, and the specimen was accordingly provisionally regarded as of Pleistocene age, since beds of that epoch are known to occur in the Val d'Arno. At a later date I again referred to this specimen in a paper read before the Society on May 12th, 1886 †, and concluded that it might be from beds of Upper Pliocene age. In the same communication I also described and figured a right upper carnassial of a hyæna from the Red Crag, which was likewise referred to the existing Striped Hyæna (*H. striata*). Following, however, the lead of Professor A. Gaudry, I was at that time disposed to regard *H. arvernensis*, of the Upper Pliocene of the Auvergne, as nothing more than a large variety of *H. striata*. It was also considered that the premolars from the Red Crag, described as *H. antiqua*, were in all probability referable to the same existing species.

In a recent memoir on the fossil Hyænas of the Val d'Arno, Dr. K. A. Weithofer ‡, who appears to have had the opportunity of examining actual specimens, concludes that *H. arvernensis* is entitled to rank as a valid species. Thus it is much larger than *H. striata*, while the inner tubercle of the upper carnassial is directed more anteriorly, so that the width of this tooth across the tubercle is much less in proportion to its length than in the Striped Hyæna, and the hind talon and inner cusp of the lower carnassial are relatively smaller than in the latter.

In noticing the carnassial from the Red Crag, figured by myself in the paper already quoted, and referred to *H. striata*, Dr. Weithofer § accepts my determination, although, of course, implying that its identification with *H. arvernensis* is erroneous. When, however, Dr. Weithofer || comes to speak of the specimen from the Val d'Arno, which I have referred to *H. striata*, he states that all the specimens from the Pliocene beds of that locality which have come under his notice are more nearly allied to the Crocutine group,

* Cat. Foss. Mamm. Brit. Mus. pt. i. p. 88 (1885).

† Quart. Journ. Geol. Soc. vol. xlii. p. 364 (1886).

‡ Denkschr. k. Ak. Wien, vol. lv. p. 341 (1889).

§ *Op. cit.* p. 344. The words are:—"Lydekker bildet aus dem Red Crag einen oberen Reisszahn einer Hyæne ab den man allerdings—für sich allein—als mit *H. striata* identisch erklären muss."

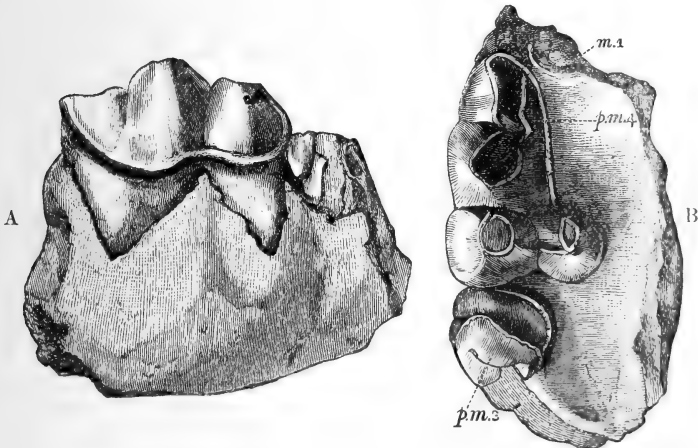
|| *Op. cit.* p. 340.

while in the Pleistocene he finds only *H. crocuta (spelæa* *); and by this he implies that my identification of the British-Museum specimen with *H. striata* is incorrect. Since, however, the occurrence of this species in Southern Europe is of some interest, I have deemed it advisable to lay the evidence before the Society.

The specimen, of which two views are given in the accompanying woodcut, comprises a fragment of the left maxilla, containing the entire carnassial, the imperfect hinder half of the third premolar, and traces of the inner extremity of the true molar. I give, in the first place, the dimensions of the carnassial of this specimen (B.M. No. M. 469) as compared with the corresponding measurements of two recent examples of *H. striata*, and also of the above-mentioned carnassial from the Red Crag. The dimensions of the recent specimens given in the first column are taken from Dr. Weithofer's memoir (p. 341), and those in the second column from a specimen in my own collection.

Dimensions of Upper Carnassials of H. striata.

	Recent.	Red Crag.	Val d'Arno.
Total length	0·031–0·031	0·0325	0·0315
Width across inner tubercle ..	0·019	0·018	0·0195
Width of inner tubercle	0·009–0·008	0·0075	0·009
Length of 1st lobe.....	0·009	0·010	0·010
Length of 2nd lobe	0·011	0·015	0·011
Length of 3rd lobe	0·011	0·011	0·0105



Lateral (A) and oral (B) views of part of the left maxilla of *Hyæna striata*; from the Val d'Arno. Nat. size. pm. 3, third premolar; pm. 4, fourth premolar (carnassial); m. 1, true molar.

* Dr. Weithofer's words are as follows:—"Nach dem Material jedoch, das mir zu Gebote steht, gehören beide Hyänen, die im Arnothal in pliocänen Lagern gefunden worden, dem *Crocute*-typus an; dasselbe gilt auch von der im Pleistocän der Umgebung von Arezzo gefundenen Hyäne (= *Hyæna spelæa*, Goldf.)."

The slight differences in these measurements are well within the limits of individual variation. With regard to the actual contour of the fossil and recent teeth, I can find absolutely no difference in them, whether I compare the Val d'Arno or the Red Crag example with the recent jaw. Thus in all these teeth the inner tubercle is very large, and does not extend so far forward as the anterior border of the first lobe, while the upper border of the crown of the external surface of the third lobe is characterized by its sharp downward deflection, thus rendering the enamel on the hinder part of this surface of very small extent. The outer surface of this third lobe is also characterized by the distinct median vertical groove. The true molar in the Val d'Arno specimen is represented only by a minute fragment, which does not indicate its original contour. The third premolar is likewise exceedingly imperfect, but the portion remaining accords with the corresponding tooth of *H. striata*.

In the absence therefore of any difference between the Val d'Arno specimen and the corresponding portion of the jaw of the Striped Hyæna there appears every reason for referring the fossil to that species.

Comparing the British-Museum specimen with the upper jaws of the hyænas from the Val d'Arno figured by Dr. Weithofer, it will be at once apparent that it has nothing to do with *H. robusta*, of which the upper carnassial is represented in pl. ii. fig. 3 and pl. iv. fig. 1 of the memoir cited, that species being, indeed, as Dr. Weithofer points out, closely allied to the crocutine *H. felina* of the Siwaliks. Compared with the upper carnassial of the specimen represented in pl. ii. figs. 1, 2 of Dr. Weithofer's memoir under the name of *H. topariensis*, there is, indeed, a somewhat nearer resemblance, although there are well-marked specific differences. Thus the length of the upper carnassial of *H. topariensis* is 0.034, while its inner tubercle is relatively smaller, and extends as far forward as the anterior border of the first lobe. Again, in the third lobe of the carnassial of *H. topariensis* the upper border of the outer surface of the crown is not deflected, so that there is a large surface of enamel in this part of the tooth, while there is not the distinct vertical groove found in *H. striata*. Most of these differences are, indeed, noticed by Dr. Weithofer when he contrasts the carnassial of *H. topariensis* with the specimen from the Red Crag above mentioned; and he observes that the two are altogether different.

In describing the specimens figured as *H. topariensis*, Dr. Weithofer regards them as closely allied to, if not identical with, *H. Perrieri* of the French Pliocene; and it appears to me that there can be little doubt that the French and Italian specimens belong to a single species, for which the latter name should be retained. If this be so, we have evidence that *H. Perrieri* is markedly distinct from *H. crocuta*, with which it has been compared, and is, apparently, more nearly allied to *H. brunnea*, as Dr. Weithofer suggests in the description of his specimens. *H. Perrieri* (*topariensis*) is, indeed, distinguished from *H. brunnea* by the presence of an anterior talon to the last lower premolar, and by the absence of the

inner cusp to the lower carnassial, although one specimen of the living species in the Museum of the College of Surgeons also shows the same deficiency. In *H. brunnea*, however, judging from a single specimen, the inner tubercle of pm. 4 does not extend forward to the anterior border of the first lobe of this tooth, in which respect this species resembles *H. striata**.

So far as I can gather, *H. arvernensis* seems also to be closely allied to *H. brunnea*, having an inner cusp to the lower carnassial, although there is no evidence as to the position of the tubercle in the upper carnassial. I am, indeed, not very clear how *H. arvernensis* can be even specifically distinguished from *H. brunnea*, and I would observe that both these forms seem decidedly nearer to *H. striata* than to *H. crocuta*, while *H. Perrieri* seems to connect them with the latter.

Finally, I submit that sufficient evidence has now been adduced to prove beyond reasonable doubt the occurrence of the Striped Hyæna in the ossiferous deposits of the Val d'Arno, and also that none of the specimens hitherto figured from these beds are referable to that species.

DISCUSSION.

The PRESIDENT called attention to the remarkable geographical distribution of recent and fossil Hyænas. He remarked that *H. crocuta* had been found by Mr. Lydekker in some of the Indian caves, though *H. striata* was the only form living in that country: and that at the present day *H. striata* was not found anywhere along with *H. crocuta*, although both, or their ancestors, appear to have inhabited Europe in late Tertiary times.

* Too much importance must not be attached to the position of this tubercle. Thus in *H. crocuta* it usually extends to the anterior border of the first lobe, but in one recent skull preserved in the Geological Department of the British Museum it is behind this border, and a considerable variation may be observed in the series of fossil specimens in that collection.

6. NOTE on the GLACIATION of PARTS of the VALLEYS of the JHELAM and SIND RIVERS in the HIMALAYA MOUNTAINS of KASHMIR.
By Capt. A. W. STIFFE, F.G.S. (Read December 4, 1889.)

(Abridged.)

THE extent of the former glaciation of the Himalayas has been discussed by various authors, and very different views have been expressed as to its magnitude. Mr. Lyddeker has noticed the unstratified deposits of boulders in the Jhelam gorge, and the probability of their being ice-borne *; Messrs. Theobald and Wynne have described glacial deposits in the plains of the Punjab, not remote from the foot of the mountains †; quoting Dr. Verechere's remarks on erratic blocks about 100 miles S.W. of the Jhelam valley ‡, Mr. Wynne § describes similar blocks near the Indus river southward of Attock, and enormous moraines and angular blocks in the Eastern parts of the Salt Range, also others 20 miles southward of Jhelam City; Col. Godwin-Austen || also refers to extensive glaciation of the Jhelam valley.

The Author records his own experience while on a visit to the valleys of the Jhelam and Sind rivers, stating, in the first place, his belief in the gigantic scale of the ancient glaciation, and then giving first a general description of the principal features of the Sind valley and the existing glaciers near Sonamarg, which are at present apparently still shrinking. The existence of snow-fields far below the foot of the glaciers is an unusual feature.

Very perfect and typical older terminal moraines exist at Sonamarg, some 4 miles below the present glaciers, at an elevation of about 10,000 feet, and these, at a not remote period, blocked up the valley of the Sind river, and formed a small lake now replaced by a small Alpine plain; the sections cut by the rivers through these moraines are remarkable.

The glaciated appearance of the gorge through the mountains just below Sonamarg is very striking, and the indications reach to great heights above the present valley-level, and the whole of the Sind valley is characterized by a succession of moraines, through which the river has cut gorges, sometimes very deep. The most marked positions noted were as follows:—One on each side of Gagangair, one with several concentric curved mounds about 5 miles above Kongan, and another, just above Gootlibagh, only seen on the south side of the valley.

But to go much further than this, the hillsides of the valley generally were observed to be comparatively rounded in outline up to

* Memoirs of the Geological Survey of India, vol. xxii.

† Records of the Geological Survey of India, November 1880.

‡ Journ. Asiat. Soc. Bengal, vol. xxxvi. p. 113.

§ Mem. Geol. Surv. India, vol. xiv.

|| British Association Report, 1880.

a definite height of 2000 feet or more, above which horizon they were very rugged, suggesting forcibly the idea that the valley must at one time have been filled with ice even to that greater depth; and there is no difficulty in believing this to have been the case.

The lakes still existing in the Kashmir valley are referred to as remains of a former extensive lake which has been filled up by recent alluvium, and the Author describes the outlet of the drainage of the valley at Bâramulla; he then proceeds to notice the present state of the supposed glacial deposits in the Jhelam valley, and states that he formed the opinion that the dam or barrier near Bâramulla was partly morainic, and he has since seen that Prof. Leith Adams considered that some of the gravels at this point were of glacial origin.

The whole valley or gorge of the Jhelam from this point as far as Mozufferabad, where it makes a sharp turn back on itself, shows extensive glacial or morainic deposits. Below this bend, the Author is not able to speak from observation.

The deposits have here been much modified by the river cutting through them and depressing the valley, and by the superposition of fluvial deposits, chiefly from lateral valleys, and of the appearance described as "fans" by other writers.

Good sections of both kinds of deposits are seen in many places where the river has cut through them, and also along the line of the new road now being carried up the valley.

The two classes of deposits thus seen together are widely different in appearance: the morainic matter with large and small blocks or stones scattered at random through the clay, sometimes far apart, and of mixed materials, partly subangular, and some of the blocks very large; and the "fans" with closely packed well-rounded pebbles of comparatively uniform dimensions and with some appearance of stratification.

In conclusion, the Author mentions the great deposits of travelled granite blocks near Rampoor, which, on account of their size and difference of composition from any neighbouring rocks seen *in situ*, he thinks can only have been distributed by ice; and, finally, he refers to the excavation of the valley by fluvial action, partly through these glacial beds, since glacial times.

DISCUSSION.

The PRESIDENT had not himself visited Kashmir, but would call attention to two points: first, did glaciers come down to a lower level in the Himalayas in Glacial times than they do now? this he thought had been proved; secondly, what was the origin of the large stones in the Jhelam valley and of those found in the region west of Rawul Pindi? Commenting upon the supposition that the latter had been transported by floating ice, he called attention to the great floods of the Indus. Some of these were owing to the damming up of tributaries, possibly by ice. In the Glacial period the Jhelam

might have been so dammed. He discussed the former extension of the ice in other Himalayan regions.

Mr. LYDEKKER said that there was no question that glacial deposits occurred in the Sind valley at Sonamarg and somewhat lower down the valley. In the Jhelam valley the evidence was not so satisfactory. The granite boulders never crossed small intervening ridges between one valley and another, but followed locally the stream-courses. He thought that when the lower parts of valleys had been filled with detrital material it was difficult to refer this to the action of glaciers, which should rather have cleared out the valley-bottoms. The granite boulders disappeared lower down the river. He referred to the detrital deposits in Thibet, which certainly were not glacial.

Gen. MACMAHON was familiar with adjoining parts of the Himalayas. He thought there was no doubt that at no very distant period there was an extension of the ice in the Inner Himalayas. He had found the usual scratched and polished rocks at considerable distances from the valley-heads. Even in the Outer Himalayas he had found a remarkable moraine at Mamul, 14 miles from Dalhousie, at an elevation of 4740 feet above the sea, perched upon the crest of a spur running down from a mountain 9108 feet high, containing granites and schists resting upon Carboniferous Limestone. Referring to the question of boulders, he did not think that in the Outer Himalayas these always furnished evidence of glaciers. Some, he believed, had slipped down upon snow.

Prof. HUGHES noted that the evidences of glaciation above the Kashmir plain were unquestioned, whilst further down the origin of the boulders was disputed. He asked whether the evidence of glaciation of this part rested upon the boulders alone, suggesting methods by which these boulders might have been transported by water.

The PRESIDENT observed that boulders 20 or 30 feet across were found many miles away from the Himalayas on the Punjab plains.

The AUTHOR, in reply, said that the blocks below Baramulla were subangular, and that no rocks of similar character appeared *in situ*. The boulders were furthermore imbedded in clay, and though he had seen no ice-scratches on the blocks, he could not conceive clay and boulders being deposited together by water. He maintained that the detrital fans and the deposits which he referred to glacial action were quite distinct. There were indications that the ice had gone even higher than he had argued for in his paper.

7. *The IGNEOUS CONSTITUENTS of the TRIASSIC BRECCIAS and CONGLOMERATES of SOUTH DEVON.* By R. N. WORTH, Esq., F.G.S.
(Read December 4, 1889.)

IN the paper on "The Elvans and Volcanic Rocks of Dartmoor" which I had the honour of laying before this Society on the 3rd of April last, I mentioned that the examination of a number of fragments of igneous rocks included in the Triassic breccias and conglomerates of South Devon had shown that many so-called "porphyritic traps" among them were really "elvans" or felsites, whilst others presented a near approach to true volcanic types*.

My present purpose is to follow up that remark by giving the results of a detailed investigation of the igneous constituents of these beds. The subject is by no means a new one; for the origin of these fragments has now and again engaged the attention of geologists, some of great eminence, for nearly seventy years. But the opinions expressed have been diverse, and the problem can neither be regarded as settled nor as having approached a definite solution. So far as I am aware, indeed, no recent attempt has been made at a general investigation; and there has certainly been no such application of modern methods of petrological research.

Under these circumstances it is hoped that the present paper may prove of service as a record of observed facts affording material for judgment; and that it will not be thought the attention of the Society has been needlessly called to a topic in itself perhaps unimportant, but which, nevertheless, has weighty bearings on the physical history of the West of England. There is no occasion, for example, to enlarge on the proposition that very different conclusions would have to be drawn with regard to the conditions prevailing during the formation of these breccias and conglomerates, from the presence in them of foreign rocks on the one hand or of native rocks on the other.

I preface the results of my own inquiries with an outline sketch of the

HISTORY OF THE QUESTION.

The first detailed attempt at a lithological examination of these rocks was made by the Rev. J. J. Conybeare, F.R.S., and set forth in a letter in the 'Annals of Philosophy,' dated February 1821†. Mr. Conybeare identified "Granite and Porphyritic Rocks" as forming a "very considerable portion of the imbedded fragments;" and described them under five classes and twelve varieties, in terms which show that he had before him just such rocks as are commonly present now, specially indicating schorlaceous pegmatites and "elvans," and suggesting "that the whole contents of this breccia

* Quart. Journ. Geol. Soc. vol. xlv. p. 399.

† 2nd ser. vol. i. pp. 254-259.

had been furnished by the inferior rocks of its immediate neighbourhood." While, however, Mr. Conybeare names granite, none of the descriptions given by him apply to genuine granitic rocks.

Sir H. de la Beche, in his well-known 'Report on the Geology of Cornwall, Devon, and West Somerset,' indicates the common local origin of these clastic beds, but notes the conglomerates of the strip of Trias trending west from Crediton to Jacobstow as comprising "besides rounded fragments of the adjoining carbonaceous sandstones and slates, pebbles of porphyritic rocks, and some which seem rolled fragments of Dartmoor granite"; and the conglomerates "from the neighbourhood of Exeter to the sea" as made up "of angular fragments and rolled portions of the various sandstones, slates, and limestones on which they rest," with certain igneous rocks not so identified—most numerous towards the Teign; and finally he thus sums up the evidence:—

"When the detritus composing the conglomerate occurs in sufficiently large pieces there is little difficulty in perceiving that with the exception of some fragments of igneous rocks in South Devon, it is derived from the adjacent and disturbed older beds, or from igneous rocks associated with the lower part of the series; and we infer that the finer portions are more comminuted parts of the same rocks."

Half a century since, therefore, the only question treated as open, touching the constituents of these conglomeratic beds, was the origin of certain of their igneous components, and that has remained the single point of doubt or controversy, though it may seem strange that the invariable local character of the sedimentary constituents had not almost forced the conclusion that their igneous associates were local too.

Sir Henry de la Beche failed to detect any granite similar to that of Dartmoor in the conglomerates south of Exeter to the sea, "while fragments of other igneous rocks, chiefly porphyries, a large proportion of which are not known to occur in place, are extremely abundant." His general suggestion with regard to these porphyries was that they might "readily have formed portions of igneous masses covered up by the Red Sandstone series, and it is by no means improbable that such masses are thus concealed"*.

While Sir Henry had thus accepted the occurrence of rocks resembling "some varieties of Dartmoor Granite" in the conglomerates near North Tawton and Sampford Courtenay, Mr. Godwin-Austen, F.R.S., positively denied in the most absolute terms the presence of any granite among the materials of the red conglomerates of Devon. "No granite pebbles have been found among the various materials of which the new conglomerates are composed"†. It is no doubt partly due to the uncertainty of one authority and the overcertainty of the other, that this question has remained so long in suspense. But the chief hindrance may have been the

* The citations from Sir Henry de la Beche are taken from the chapter in his Report on the "Red Sandstone Series," *passim*, pp. 193-220.

† Geol. Trans. 2 ser. vol. vi. p. 478.

search for Dartmoor *granite* in particular, instead of Dartmoor *rocks* in general.

The presence of indubitable fragments of Dartmoor granite in the conglomerates of North Tawton and Haldon has, however, long been recognized. They were found there by Mr. Vicary, F.G.S., and somewhat later by Mr. Pengelly, F.R.S., in company with him, at least thirty years since.

And so Mr. G. W. Ormerod, F.G.S., in a paper read before this Society, on "The Murchisonite beds of the Valley of the Exe," in 1875*, identified the Murchisonite as clearly of Dartmoor origin, and mentioned the occurrence of granite pebbles at Teignmouth.

But it is to Mr. Vicary that we owe the most definite pronouncement on this head. In a paper read before the Devonshire Association for the Advancement of Science, Literature, and Art in 1867 †, he avers unhesitatingly that "the masses containing Murchisonite are but altered portions of the granite of Dartmoor," the variation in colour and texture between the Murchisonite pebbles and the *in situ* granite being quite paralleled by the changes which have taken place in fragments of Carboniferous Grit and Devonian Limestone in the same association. Moreover, he remarks that "they occur in the Trias in close proximity with pebbles of schorl and altered rock, a collocation strikingly similar to that met with in Dartmoor streams." His final conclusion is (and I have his authority for saying that it is only strengthened by subsequent investigations), "If the granite was exposed at the surface at the era of the red rocks, Dartmoor must have furnished a large proportion of the conglomerated materials. I feel confident that a thorough examination of these materials will prove that granite is a far more important constituent than geologists generally suppose."

More recently it has been suggested that we should look elsewhere especially for the origin of the characteristic red felspar porphyries; and Mr. W. A. E. Ussher, F.G.S., has suggested that their source may be in the Channel area ‡.

Mr. Ussher also points out that while the breccias or conglomerates frequently contain igneous fragments distinctly referable to the destruction of such igneous patches as those of Washfield, Killerton, Silverton, and Spencecombe, "the porphyritic and Murchisonite fragments are confined to the South-Devon breccia."

Instead of suggesting that these comparatively unworn fragments are in any sense "foreign," such facts seem to me to assign them a distinctly local character, and to indicate a probable origin in the direction towards which the area of the beds containing them narrows. We have another valuable hint in the fact that these fragments attain their largest size in the vicinity of Teignmouth, and that thence both to the north and south they rapidly graduate downward to very moderate dimensions, and, in fact, into sand. It

* Quart. Journ. Geol. Soc. vol. xxxi. pp. 346-354.

† Trans. Dev. Assoc. vol. ii. pp. 200-202.

‡ Vide Quart. Journ. Geol. Soc. vol. xxxiv. pp. 461-462, vol. xxxv. pp. 245-247.

is not meant to imply that there is any absolute natural assortment; but that the range decreases, from materials varying between boulders and sand, to materials in which the larger pieces would fairly be called gravel.

This recital marks out the purport and scope of the present inquiry.

INVESTIGATION.

In the preparation of this paper special examination has been made of the breccio-conglomerates near Crediton, Exeter, Heavitree, Exminster, Dawlish, and Teignmouth, with specimens of the contained rocks collected at other points—to the number, in all, of several hundreds, indeed thousands.

Generally speaking, the largest fragments occur, as already noted, at and near Teignmouth; and many very interesting examples may be seen there built into walls near the sea. Especially prominent also are the boulders in the Dawlish valley. Blocks occur ranging to four and five feet in diameter. Around Teignmouth and Dawlish, too, the breccias and conglomerates are most varied in their composition, and contain the largest proportion of granitoid rocks.

The constituents of the Exminster conglomerates come next in size, and frequently range up to four or five inches in diameter, occasionally more. The granitoid character is also well preserved.

At Heavitree the same leading associations are fairly prominent, but the fragments show a smaller average, and the proportion of immediately recognizable granitoid examples is smaller also.

In the immediate Crediton district granitoid constituents, though present, are not prominent, although at points igneous fragments abound. They are plentiful, however, to the west, in the strip of Trias ranging along the north of Dartmoor, especially near North Tawton and Sampford Courtenay.

The igneous fragments in the Torbay conglomerates diminish in size and importance southward from the Teign. They are less conspicuously granitoid, and are frequently better rounded than their sedimentary associates.

In the Triassic outlier at Slapton, if we may draw any conclusion from the modern beach, granitoid pebbles must have been fairly common, since there are plenty of well-characterized examples on Slapton Sands which could not have been brought thither by any modern river, but may well be Triassic waste.

The following is a complete list of the various kinds of igneous and altered rocks noted. Most of them are represented by numerous examples and occur at different points, and very few can be regarded as rare.

I. GRANITES.

1. Coarse-grained granite with porphyritic feldspars, partly kaolinized. Differs from ordinary coarse-grained Dartmoor granite only in its reddish colour, though here, as in the dark-red porphyries, the kaolinized feldspars are white. I am indebted for this example to Mr. Vicary.

2. Fine-grained schorlaceous granite from Exminster. This is the only example which gave rise to doubt. Macroscopically it seemed a fine-grained granite with a little mica and a fair proportion of schorl. When sliced it suggested a possible clastic origin, and as I felt unable to satisfy myself I obtained Professor Bonney's ever-ready help; and he pronounces it a fine-grained granite, probably from a vein or small boss. Also precisely identical with Dartmoor varieties.
3. In a quarry at Exminster there occur small patches of granitic material, quartz, kaolin, and mica, which are clearly the relics of decomposed granite fragments; and very similar looseness of texture may be observed in granitoid remnants elsewhere.
4. A comparison of sand from the Trias at Heavitree with modern sand from the bed of the Teign at Chagford (both given me by Mr. Vicary) shows the following results:—*Heavitree*: felspar fragments, including Murchisonite; quartz-grains, many of the smaller fairly rounded; granitoid rock, with schorl; grit, slate, Lydian stone; felspathic trap (andesite?); colour ruddy. *Chagford*: Bulk of the material essentially identical with that of Heavitree, but less rounded and not iron-stained; quartz; felspar; felsite; schorlaceous granite; a little slate and grit; mica: it chiefly differs from that from Heavitree in the plain presence of mica and the absence of felspathic trap; while slates and grits are naturally more plentiful at Heavitree than at Chagford.

II. FELSITE GROUP.

These rocks afford the widest range of variation, and are far more plentiful than the true granites. I include under this head all the granitoid fragments, seeing that most of the varieties pass easily into each other, but divide them into schorlaceous and non-schorlaceous.

A. *Non-Schorlaceous.*

1. Pegmatite, apparently vein. Quartz, with some well-crystallized felspar. Teignmouth.
2. Quartz-felspar vein, with decayed mica and kaolinized felspar. Exminster.
3. Reddish quartz-felspar rock, like a Dartmoor vein-stone. Teignmouth.
4. Glassy quartz-felsite, reddish grey. Undistinguishable from some Dartmoor elvans. Teignmouth.
5. Grey spherulitic felsite, with porphyritic quartz, slightly vesicular; some cavities lined with crusts, some filled with kaolin. Under the microscope the spherulitic structure is well marked. Teignmouth.
6. Grey quartzose rock of trachytic aspect, of somewhat porous texture; base appears like an open granular felsite; contains

- remains of decayed porphyritic feldspars, quartz-blebs, and little nests of black mica, the latter a feature of frequent occurrence in many lavas. Teignmouth.
7. Dark red rock, presenting much the same general characters. Teignmouth.
 8. Reddish-grey granular open-textured rock, with blebs of quartz, mica-nests, and feldspar-cavities lined and partly filled with kaolin; some red iron-oxide in irregular cavities. Teignmouth.
 9. Grey granular rock of trachytic aspect, with some porosity; cavities with remains of kaolinized feldspars; decayed mica; a little differentiated quartz. Teignmouth.
 10. Pinkish-brown felsite, rough texture, slightly vesicular; porphyritic feldspars; fluxion-structure indicated. Teignmouth.
 11. Somewhat similar rock with quartz-blebs; cavities with kaolinized matter; some white mica; porous rather than vesicular. Teignmouth.
 12. Yellowish-brown quartz-porphry, loose-textured subvesicular base, with quartz-blebs and developing feldspars in part kaolinized; matrix very porous in parts, yet heavy. Under the microscope this rock shows hardly a trace of felsitic reaction, though it does not suggest a texture between felsitic and andesitic so closely as some of its associates. There is a little mica. Dawlish.
 13. Greenish rhyolite or liparite with compact base, and large cavities, elongated in direction of flow; occurs in wall at Teignmouth; and is no doubt from conglomerate.
 14. Finely vesicular rhyolitic rock with compact semivitreous green-grey base; porphyritic quartz and feldspar, the latter partly kaolinized; nests of mica; shows distinct fluxion-structure.
 15. Earthy-textured red and grey felsite with porphyritic feldspars, nests of mica, and vesicles partially filled with kaolin. Teignmouth.
 16. Red felsite with porphyritic quartz and feldspar, quartz predominating. Torbay.
 17. Vesicular felsite ("horny" base) with porphyritic quartz, mica, and feldspar; full of irregular cavities. Torbay.
 18. Red porphyritic felsite with quartz, kaolinized feldspar, a little mica; somewhat open-textured. Torbay.
 19. Reddish coarse-grained porous variety, with mica more prominent; shows flow-structure.
 20. Compact red felsite with porphyritic quartz, feldspar, and mica. Heavitree.
 21. Pinkish-grey felsite, subvitreous base, with porphyritic quartz and feldspar, the latter partly kaolinized; has a decidedly rhyolitic look. Heavitree.
 22. Granular red felsite, porphyritic quartz and feldspar; some decayed mica. Heavitree.
 23. Pinkish crystalline-granular felsite with porphyritic quartz and feldspar; small flakes of mica. Crediton.

24. Porphyritic red and white quartz- and felspar-rock ; apparently a vein-stone from "felspathic trap." Crediton.
25. Grey-green felsite, finely granular texture, with porphyritic quartz, kaolinized felspars, and some decayed mica. Crediton.
26. Fine-grained crystalline-granular felsitic rock. Exminster.
27. Reddish-grey quartzose felsite. Exminster.
28. Dull-brown porphyritic rock, felsitic base with kaolinized porphyritic felspars, Murchisonite, quartz, and mica. Some has a brecciated look. Is closely allied to next.
29. Deep-red porphyritic rock, varying to red-brown and purplish-brown ; compact felsitic base with porphyritic quartz and felspar, some of the latter kaolinized, some Murchisonite ; occasionally but not invariably some mica. This is the so-called red "porphyritic trap," more or less characteristic of the conglomerates within our area, from Torbay to the Crediton valley, and the origin of which has been a special topic of discussion. Save in colour, however, these fragments are hardly distinguishable from some Dartmoor elvans.

I have been fortunate enough to trace them home as veins to the so-called "felspathic traps," in fragments of which I have found them occur, both at Exminster and Teignmouth. They appear in some instances to have produced contact-alteration. They are really what they seem to be (porphyritic elvans), which have traversed granites and "traps" alike, and are of purely local origin. They have undergone as much alteration, probably, as any class of rock in the breccias, ranging in texture from an earthy to a vitreous base, but can be followed without difficulty from one phase to another. One example really differs from the rock it intrudes on more in structure than anything else, both showing felsitic characters, but the vein being coarser and distinctively porphyritic.

B. *Schorlaceous.*

1. Granular schorlaceous pegmatite. Exminster, Teignmouth.
2. Reddish compact felsite with blebs of quartz, a little mica, and schorl pseudomorphous after felspar, and in spots. Exminster.
3. Variety of same rock, with somewhat granular texture, porphyritic quartz, decayed felspars, and veined with schorl. Exminster.
4. Finer variety of same. Exminster.
5. Felsite like number one, with mica-aggregates. Exminster.
6. Granular greyish-drab felsite, with acicular schorl. Exminster.
7. Fine-grained reddish felsite, with porphyritic quartz and felspar, base sprinkled with black specks. Exminster.
8. Red felspar- and schorl-rock. Exminster.
9. Quartzo-felspathic rock with blebs of quartz, large porphyritic felspars, and schorl. Teignmouth.
10. Base black schorl and quartz, with porphyritic quartz and felspars (kaolinized) ; a little mica. Teignmouth.

11. Porphyritic vein-stone, with Murchisonite, decayed feldspars and schorl. Exminster. (Possibly associated with andesite.)
12. Fine-grained grey felsitic rock, with quartz-blebs, porphyritic feldspars, kaolinized feldspar-granules, fine mica, and acicular schorl. Exminster.
13. Grey granular felsite, with quartz, mica, and schorl. Exminster.
14. Quartz-feldspar-schorl rock. Heavitree.
15. Schorlaceous felsite. Red compact base with small porphyritic feldspars, quartz-blebs, mica, and patches of blue radiating schorl—a beautiful microscopic object. Teignmouth.
16. Reddish felsite with dots and nests of schorl, bluish-grey and radiating. The microscope reveals the existence of radial structure in the ground-mass, apart from the schorl. Teignmouth.
17. Schorlaceous felstone, with more prominent porphyritic feldspars, nests of schorl-needles, and some porphyritic quartz. Teignmouth.
18. Schorlaceous felsite ranging from fairly compact to granular; long feldspar-crystals, quartz-blebs, decayed mica-clusters, light spotty schorl. Teignmouth.
19. Rock with an andesitic rather than a felsitic look, but containing occasional needles of schorl. Teignmouth.

III. ANDESITIC GROUP.

I class under this head the various examples of "felspathic traps" which, like those *in situ*, range between andesites and basalts, but are chiefly of the former class. They are found in the breccias and conglomerates more or less plentifully throughout the district under review, and in many cases present no distinctive characters from some of the varieties *in situ*. Nor is the range of variation greater in the one than in the other. The chief point to notice is the frequent kaolinization of the feldspars in these fragments, which, in the case of the rocks with felted texture, gives them a curious speckled mosaic aspect.

1. Fine-grained greyish-red or reddish-grey mica-andesite. Torbay.
2. Ditto, but quartzose and slightly open-textured, suggestive of a rock intermediate with a felsite. Torbay.
3. Red-grey speckled, felted andesite, with porphyritic vein containing Murchisonite. Teignmouth.
4. Fine-textured andesitic rock, with acicular or felted base; red, speckled with grey and spotted with black (? iron-oxide) and containing kaolinized lath-feldspars. Traversed by a porphyritic felsitic vein, having a red compact subvitreous base, with porphyritic quartz and feldspars, and some mica. Exminster.
5. Fine-grained speckled variety, closely resembling sandstone. Exminster.

6. Red speckled base, with kaolinized porphyritic feldspars. Exminster.
7. Slightly amygdaloidal variety, granular base with quartz-blebs and porphyritic feldspars. Suggests felsitic alliances, and present aspect may be in part due to alteration. Exminster.
8. Speckled variety, with blackish patches.
9. Felted andesitic porphyry, red-speckled, lined with white. Heavitree.
10. Examples resembling rock of Rougemont and of other spots in the vicinity of Exeter. Heavitree.
11. Loose-textured, dark-brown patches occur in the breccia at Exminster, which appear to be the remains of fragments of decayed scoriaceous rock, like that of Thorverton or Washfield.
12. Rough-textured dark basaltic rock, closely resembling trap of Yeoton. Teignmouth.
13. Loose-textured micaceous rock, closely resembling trap of Killerton. Teignmouth.
14. Rock like vein in trap at Posbury. Teignmouth.

IV. MISCELLANEOUS.

1. Quartz vein-stone. Exminster.
2. Glossy quartz-vein-stone. Yeoton. (Both these are of Dartmoor character.)
3. Schorl rock. Teignmouth, Exminster, Heavitree—in fact almost universally distributed.
4. Schorl-vein-stones, some laminated. Exminster.
5. Felted schorl-rock, with porphyritic feldspar. Exminster.
6. Schorl-feldspar-rock with scoriaceous aspect. Teignmouth.
7. Reddish-brown altered brecciated rock, with schorl-crystals.
8. Veined schorl- and quartz-rock.
9. Highly altered, consolidated, bluish-grey schist, traversed by numerous minute veins, some of which suggest cassiterite, now very hard and compact. Teignmouth, Crediton.
10. Altered slate, baked and partly veined by felsitic matter. Crediton.

Of these four classes of igneous and associated altered rocks, containing in all 76 species or varieties, two (I. and IV.) can unhesitatingly be assigned a Dartmoor origin in gross, and the same remark applies to the schorlaceous division of II. The remaining class, III., can with equal certainty be identified with or allied to the *in situ* "felspathic traps" of the neighbourhood.

We have thus to consider further only the non-schorlaceous section of No. II., and here we find the same characteristics; the bulk of the examples differ in no essential particular from Dartmoor elvans, and in the majority of the cases are practically identical with them.

Of the residue, with but three exceptions, it may at once be said that they belong to the same category, the only noteworthy distinc-

tion between them and admitted Dartmoor felsites being that they are of a looser and more open texture, displaying at times a porous character which approaches an irregular vesicularity. They are apparently the more surface portions of felsitic dykes, or, it may even be, fragments of felsitic lavas; and, at any rate, they may reasonably be supposed to represent less deeply-seated rocks than the ordinary elvans. The very wide range of characters which elvans assume, even in the same flow, was pointed out in my paper of April last, and need not be enlarged upon here; and I will only add that approaches to this trachytic or open texture are by no means absent *in situ*.

The only examples, then, in the whole series that show any material divergence from existing Devonian rocks of the general felsitic type are (5) the spherulitic felsite; (13) the greenish rhyolite or liparite; and (17) the vesicular felsite with horny base—three rocks extremely likely to be found in this connexion, and affording no reason why they should be regarded as an exception to an otherwise universal rule.

I do not think the fragments generally can be regarded as having been altered to the extent frequently imagined. Structural change has been very slight; and the chief points to note are the very general modification of colour in sympathy with the ferruginous surroundings (though this is by no means universal), and the somewhat exceptional extent to which kaolinization has proceeded, especially in the andesitic contingents.

CONDITIONS OF FORMATION.

To complete our inquiry we must consider the conditions under which these breccias and conglomerates were formed. That the materials were carried to the places where we now find them by water is clear. It is evident also that this water must have operated over a wide area and with varying force. The current which carried the great blocks of Teignmouth and Dawlish was more powerful than that which distributed the sand and gravel of Heavitree; but the bulk of the material must have quickly come to rest, or we should have no breccias. At the same time there was enough trituration and travel to reduce the softer sedimentary rocks very considerably. These conditions would be fulfilled by high land with short rapid rivers abutting on a shore-line, along which the material which they brought down would speedily be distributed; and in the present instance I suggest that we have a relic of this high land in what is now Dartmoor. The work done by the existing Dartmoor rivers, in its degree, strikingly resembles that of these ancient Triassic streams; but the latter, while unquestionably of greater volume, had, in all probability, powerful assistants in a glacial climate on the one hand, and the disturbing effects of volcanic activity on the other. Of the existence of volcanic action there is ample evidence.

Sir Henry de la Beche writes cautiously, but plainly indicates his

belief in the causal association of igneous action. "Near Tiverton the igneous rocks would seem to have been ejected after a certain thickness of conglomerate had been accumulated. . . . Near Exeter igneous action seems to have accompanied the earliest deposit"*. He also directs attention to the fact that "the igneous rocks associated with the lower part of the red sandstone series near Exeter . . . occur in the prolonged direction of the granitic bosses and elvans extending from the Scilly Isles to Dartmoor, themselves apparently ranging in a line through which trappean matter had been previously erupted"†.

Next, discussing the occurrence of fossiliferous Devonian fragments in the Trias of Tiverton, the late Rev. W. Downes, F.G.S., was led to postulate the existence of "an active volcano upon the coast of the early Triassic sea"‡; and in 1885 Mr. A. Somervail suggested a volcanic origin for the basal breccias of the South-Devon Trias §.

The highly interesting group of rocks which have been classed as the felspathic traps of Devonshire are commonly, though not universally, associated with the South-Devon Trias. They make their "appearance at or near the junction of the Carboniferous and Triassic formations, from Washfield, near Tiverton, on the north, to Haldon on the south. They extend westward along the strip of Trias which runs from Bradninch to Jacobstow, and occur frequently along both north and south lines of junction of the two formations as far as Greenslade near North Tawton"||.

To this it must be added that a member of the series occurs associated with a Triassic outlier at Cawsand on the shore of Plymouth Sound, and that a dyke of mica trap at Roseash, unconnected with Trias, appears to be of similar character ¶.

These traps are in part antecedent to, and in part contemporaneous with, the breccias and conglomerates which we are considering. They are pre-Triassic, because their fragments are found in these beds. They are continuous into the Triassic era, because at certain points they overlie and alter the Trias.

They are commonly red or reddish-brown in colour, but by no means universally so, and appear in this respect to have been somewhat influenced by the Triassic rocks *in situ*, as well as in the breccias and conglomerates, where, indeed, they display this colour-character more constantly. The trap of Cawsand very well illustrates this Triassic influence. In contact with the remnants of the Triassic outlier it is red, but the veins sent off into the Devonian rocks for a considerable distance become drab and grey. The Roseash rock is yellowish brown; so is much of the Killerton, where the rock occurs in mass.

One of the most important points connected with the chronology

* Report, p. 215.

† Report, p. 216.

‡ Trans. Dev. Assoc. xiii. p. 297.

§ *Ibid.* xvii. p. 285.

|| "On the Feldspathic Traps of Devonshire," W. Vicary, F.G.S., Trans. Dev. Assoc. i. pt. iv. p. 43.

¶ Trans. Dev. Assoc. xvi. p. 498.

and stratigraphical relations of these traps remains to be considered. They are traversed at so many points by felsitic dykes that this association has a constant and not a merely casual character. Mr. Vicary noticed these dykes and their strong resemblance to elvan courses, though, as "a matter of convenience," calling them sandstone*. Mr. Etheridge, F.R.S., suggested that a "dike-like line" in an example submitted to him by Mr. Vicary from Posbury, "appeared to be an elvan."

Sir H. de la Beche remarked, "the quartziferous porphyry near Dunchideock closely resembles some elvans in all except colour" †, an exception which my experience shows does not hold good. Mr. Townshend M. Hall, F.G.S., in 1879 ‡ announced the discovery of a granitoid vein traversing the Triassic outlier at Portledge, which "appeared to be a true porphyritic granite." I have myself found within the past few months fragments of syenitic veinstone closely associated with the Cawsand trap.

When we add to this the occurrence of veins of porphyritic felsite traversing fragments of felspathic trap in the breccias and conglomerates, the chain of evidence seems complete that these felspathic traps are comprised within the period of igneous activity represented by the Dartmoor elvans, and that therefore Sir H. de la Beche was right in suggesting a connexion between the two, though this connexion was probably much more intimate than he suspected.

It is perfectly clear that there are no rocks to be seen now *in situ* which can have yielded the examples of felspathic trap found in the conglomerates in the neighbourhood of Dawlish and Teignmouth and thence to the southward; for these fragments must have come with their granitoid and schorlaceous associates from the direction of Dartmoor; and not only are there no exposures of such rocks between the conglomerates of this district and the Moor, but no places where they could be hidden from view unless it were by the deposits of the Bovey basin, which for other reasons may be dismissed. Lava-flows, it is true, might be wholly removed and leave no trace in place behind; but necks and dykes cannot be got rid of by denudation in any such way, and would still be apparent.

The fact that these fragments came from the direction of Dartmoor, coupled with the absence of any locality between Teignmouth and Dawlish and their vicinities and Dartmoor whence they can have come, thus points directly to Dartmoor itself as their source. If that great granitic plateau is the base of a volcano, and if the granites now exposed passed upwards into felsites, rhyolites, and volcanic rocks, all is perfectly clear; but I cannot see that any other hypothesis will meet the case.

The great bulk of the igneous fragments of these breccias and conglomerates is more or less of a volcanic type, and the Plutonic examples, though present, are comparatively few. The former represent an enormous amount of degradation and denudation, which

* *Op. cit.* p. 47. This character is often simulated by elvans.

† Report, p. 217.

‡ Trans. Dev. Assoc. xi. pp. 430, 431.

the existing remnants of the felspathic traps by no means indicate a capacity to supply : and beyond the Dartmoor area we seek in vain for a source of sufficient magnitude. And it will be borne in mind that on the most moderate estimate an enormous amount of superincumbent matter must have been removed from Dartmoor before its 300 square miles of granite could have been exposed as we see them to-day, and that it is as absolutely certain as any geological hypothesis can be, that a large proportion of this must have gone to build up the beds of the adjacent Trias.

CONCLUSIONS.

My conclusions may be summarized as follows :—

1. That the igneous materials of the Triassic breccias and conglomerates of South Devon are, as well as the sedimentary, of local origin.

2. That they consist of granites, felsites, and volcanic types, ranging from andesites to basalts.

3. That the granites are wholly, the felsites mainly, identifiable with the granites and elvans of Dartmoor and its borders.

4. That the great bulk of the volcanic rocks are undistinguishable in character from "felspathic traps" associated *in situ* with the South-Devon Trias, but that andesitic features predominate.

5. That schorlaceous and contact-altered rocks occur in the breccias and conglomerates, which may be referred with absolute confidence to the outer (or upper) zone of Dartmoor.

6. That the few examples of igneous rocks in the breccias and conglomerates which, allowing for alteration, cannot be absolutely assigned to rocks yet existing *in situ* in Devon, are rocks of precisely similar character, such as it is natural to expect in the same association, and simply phases of the same magma.

7. That the condition under which the "felspathic traps" of Devon occur *in situ*, their characteristic association with elvans, and the part which they bear in the constitution of the Triassic breccias and conglomerates, are calculated to lead to the inference that they are volcanic phenomena connected with the igneous activities of the Dartmoor region, and probably represent its final period, as the epidiorites and proterobases of the north and west of Dartmoor may its earlier stages.

8. That the elevation of Dartmoor and the associated igneous phenomena, which have been commonly regarded as post-Carboniferous and pre-Triassic, may in all probability be assigned to narrower limits, and be regarded as not earlier than Permian times, and possibly as occupying the Permio-Triassic interval, continuing into the earlier stages of the Trias. Certainly if the eruptions of the "felspathic traps" of Devon and their associated elvans are related to the great Dartmoor movement (and, as we have seen, these traps are in part of Triassic date), we cannot well give the origin of that movement a higher than Permian antiquity.

DISCUSSION.

The PRESIDENT said that the question whence the materials were derived was one of great interest, and must be worked out by careful determination of the specimens.

Prof. BONNEY observed that the subject was one difficult to discuss, requiring great caution. But few specimens were shown, which added to the difficulty; we required to see those from the breccia and the *in-situ* rocks together. He was inclined to think the Author right in his main contentions, and knew that he was an enthusiastic worker. There was certainly Dartmoor granite in the breccia: those rocks also with large crystals in a more compact matrix might represent more rapidly consolidated portions of the same material. He was glad a Devonshire geologist had taken up the subject. The breccias indicated unmistakably the proximity of high land at the time of their deposition.

Dr. GEIKIE had been over part of the ground, and was unable to see the connexion between the composition of the breccias and the supposed occurrence of a volcano on the site of Dartmoor. The materials had not come from very far. During Triassic times there was undoubted volcanic activity from many points of eruption, so that there was no necessity for bringing the basic volcanic rocks from Dartmoor; indeed, the presence of Dartmoor granite in the breccias was unfavourable to the notion of volcanic rocks having been derived from that source.

Dr. HICKS had no doubt that some of the fragments had been derived from rocks such as are known to occur in Dartmoor; but that need not necessarily indicate more than that there was a pre-existing ridge of such rocks in that area.

Mr. HUDLESTON had arrived at much the same conclusion as Dr. Geikie, especially as to the source of most of the volcanic fragments. If Dartmoor had been a volcanic pile at the time of the deposition of the breccias, its bulk ought to have contributed more material in proportion to the local sedimentary rocks than is the case. There was no *à priori* improbability in the Dartmoor granite having terminated upwards, at one time, in volcanic rocks; but the period was probably not later than the close of the Carboniferous when the great earth-movements took place. Most of this material would have been removed before the accumulation of the Triassic breccias. Hence he was prepared to accept the theory of a great Devonshire volcano, but rather doubted the evidence of its existence in the South-Devon breccias.

Prof. HUGHES inquired about the possibility of some of the fragments having been thrown up by volcanic outbursts, from rocks not then exposed at the surface. He had missed any reference to the presence of harder volcanic material, such as is more or less seen to be intercalated in the Devonian.

Prof. Judd said that the subject could only be attacked by a local worker. He regretted the absence of the Author and that there

was not a larger series of rocks exhibited. The Author's argument appeared to be that the breccias contained granites, dyke-rocks, and surface-lavas; that the two former of these came from the Dartmoor area; and that it was not unreasonable to suppose that the third class came from the same source.

8. *On the RELATION of the WESTLETON BEDS, or PEBBLY SANDS of SUFFOLK, to those of NORFOLK, and on their EXTENSION INLAND : with some OBSERVATIONS on the PERIOD of the FINAL ELEVATION and DENUDATION of the WEALD and of the THAMES VALLEY, &c.*
By JOSEPH PRESTWICH, D.C.L., F.R.S., F.G.S., &c.—PART I.*
(Read June 5, 1889.)

PART I.

§ 1. *Introduction.*

IN a paper on the Crag Beds of Norfolk and Suffolk † which I had the honour of laying before the Society early in 1870, I proposed to term the great bed of flint-pebbles overlying the Chillesford Beds and underlying the Boulder-clay in Suffolk, the “Westleton Sands and Shingle,” remarking that “the importance to be attached to those beds does not arise so much from their exhibition here [Suffolk], as from the circumstance that they will serve to determine the position and age of some beds of sand and gravel, generally without fossils, which have a wide range in the south-east of England, and the exact [geological] position of which it is important to know in consequence of their bearing on many interesting problems connected with the denudation of the country.” I further mentioned that these marine sands and shingle had a much greater extension than had their associated beds on the Norfolk coast, that they ranged through Suffolk, Essex, and far up the Thames Basin, and that the main character by which they were to be recognized was the great preponderance of well-worn rounded *pebbles of flint* and of *white quartz*, with smaller variable proportions of angular or *subangular chalk-flints*, and of *Lower-Greensand chert and ragstone*, mixed with a few pebbles of quartzite, sandstones, slates, and lydian stone, the whole indicating the action of currents or streams, not from the north as with the Glacial Drifts, but from the south and south-east.

For some years afterwards various circumstances hindered me from resuming my notes, many of which were made in 1845–1855 during the construction of the Great Eastern Railway and its branches, where the sections are no longer visible. At the meeting of the British Association in 1881, however, I gave a short account of the extension inland of these beds, and mentioned their occurrence on some of the hills in Essex, Hertfordshire, Buckinghamshire, Berk-

* Part I. only of this paper, dealing with the coast sections, is here printed. Parts II. and III. will deal with the relation of the beds here described to the Glacial Beds in the Thames Valley, and with some other questions.

† Quart. Journ. Geol. Soc. vol. xxvii. p. 461.

shire, Kent, and Surrey. But that paper was only published in abstract, and without tables or sections.

In the meantime the significance of these beds had not escaped the attention of Mr. Whitaker, who adopted the name of the "Pebbly Series;" but as there are very similar pebbly beds of Tertiary age in the Blackheath, Addington, and Bagshot districts, I think the local name of Westleton, where their typical characters can be best seen, preferable. In 1880* Mr. Whitaker came independently very much to the same conclusion as myself with respect to certain Pebble-beds on some of the hills around London, as likewise did Mr. S. V. Wood, who gave in his paper of 1880† a plate of sections and a map showing a number of outliers in the London and Hampshire Basins, but with the drift-cappings marked in many instances doubtfully, and mostly without local descriptions or proofs. I shall have occasion to refer to both these papers at greater length presently.

As regards classification, Mr. S. V. Wood, in his several papers (1866-1872), places the Pebbly Sands of the Bure Valley at the base of the Glacial Series (or of his "Lower Glacial"); whereas Mr. H. B. Woodward, in his Survey Memoir, classes them with the Upper Crag. It is true that in Norfolk they succeed immediately, and in many cases conformably to the Norwich Crag and Chillesford Beds; but, as pointed out by Mr. Wood, there is also often a line of erosion between the two, and although the marine fauna contains similar species, it is poorer and more purely northern than that of the Crag Series. Further the Pebble-beds extend far beyond the area of the Crag, and afford evidence, as I shall endeavour to prove presently, of great physiographical changes having intervened between these two groups. There is evidence also of an equally important, if not a still stronger, break between the "Pebbly Series" and the Glacial Beds. I would therefore assign to the Westleton Beds a position apart, whether in relation to the Crag or to the Glacial Series. They mark a great change not only in the physical geography, but also in the life of the times, for it was then that the existing Mammalian fauna began to supersede the extinct species, and the Molluscan fauna to resolve itself almost entirely into species now common in this country, with a few others, which although still living are, like some of the land animals, relegated to colder climates. This applies also to the flora.

For these reasons and also because this period is one of those coincident, as I hope to show in the second part of this paper, with the time of the final elevation of the Weald and of the genesis of the Thames (the main excavation of the valleys and the great denudation of the Weald being referable to subsequent Glacial and Post-Glacial times), much importance attaches to this geological horizon. I also look upon these beds as the base of the Quaternary Series.

Since 1870 a number of important papers, including several

* Mem. Geol. Survey, "Guide to the Geology of London and the Neighbourhood," pp. 55-57.

† Quart. Journ. Geol. Soc. vol. xxxvi. p. 457.

Memoirs by the officers of the Geological Survey, on different parts of the Eastern Counties, have appeared, and various opinions have been expressed respecting the age, and the correlation, as well as the classification of these beds. It may be desirable therefore, before proceeding to the second part of this paper, to give my reasons for differing from some of these conclusions. The Memoirs of the Survey, to which I shall have frequent occasion to refer, now supply a mass of valuable details, which greatly facilitate the task and do away with the necessity of much local description. I shall confine myself therefore to my own notes and a few typical sections, and to questions of synchronism and classification.

§ 2. *Historical Review.*

In my notice of the Westleton Beds, I referred, but very briefly, to the Bure-Valley Crag of Messrs. S. V. Wood and Harmer, as I touched only incidentally on the beds of north Norfolk*. At the same time, I felt justified in expressing my own views with respect to their general bearing, not only because they differed in many material points from those of Mr. Wood, but likewise on the ground that my paper was the result of independent observations made during the preceding quarter of a century, and our conclusions differed on many material points. It would appear that we were both working independently at the same subject, and the difference of views may have arisen in a great measure, as suggested by Mr. Whitaker, from the fact that whilst Mr. Wood was working from north to south and chiefly inland, I had been working from south to north and chiefly on the coast-line.

That I was not singular in hesitating to accept Mr. Wood's views will be evident from the remarks of Mr. H. B. Woodward, Mr. Clement Reid, and others, who have since surveyed the district.

In 1866 Mr. Wood stated briefly, in the supplement to a paper by his father on the Crag Mollusca †, that in the Bure Valley there was a fossiliferous Crag consisting of sands and shingle with shells (*Tellina obliqua*, *Cyprina islandica*, *Cardium edule*, &c.) in patches, and that this Crag was newer than the Norwich Crag. As these beds in the Bure Valley rest, however, directly on the Chalk, and as the diagrams were only generalized ones, we were, in the absence of detailed local sections, left without the necessary strati-

* I regret that Messrs. Wood and Harmer should have thought that my statement was a misrepresentation of their views. I mentioned, I believe correctly, that they had placed the Bure-Valley Beds on a higher level than the Norwich Crag, though I may have misunderstood, with reference to the Weybourn Crag, the meaning they attached to the term "Lower Glacial," with which they associated these beds. In the absence of more detailed sections and definitions, it was difficult to follow the exact meaning of Mr. Wood's earlier papers. Whether there was anything new in my views, I must leave the reader to judge. There are certainly material differences in our interpretation of the phenomena.

† Quart. Journ. Geol. Soc. vol. xxii. p. 547.

graphical evidence in proof of their exact relationship to the associated strata.

In the following year Mr. F. W. Harmer gave a section of the Yare Valley *, confirming the views of Mr. Wood; and in 1868 these gentlemen read at the Meeting of the British Association in Norwich a joint paper, illustrated with a large map and local sections, but of which an abstract only was published in that year †. In this it was stated that the Pebbly Beds or Crag of Belaugh in the Bure Valley, and the Crag of Weybourn and Cromer, were newer than the Chillesford Beds, and that "the 'sands with pebbles' occupy in the south of Norfolk and the north of Suffolk, the same place relatively to the 'contorted Drift' as is occupied on the Cromer coast by the Weybourn Sand (or so-called 'Crag' of the Cromer coast), the Cromer Till, and the indenting sand (or bed C). These pebble-beds may thus represent in time either the whole or any one of the formations A, B, and C; or they may form merely the closing bed of the true Crag Series, in which case the Weybourn sand, the Cromer Till, and bed C are entirely unrepresented in the south of Norfolk and north of Suffolk." On the next page A is stated to represent the Weybourn Sand with shell patches resting on the Chalk, and "passing up by interbedding into B, the Cromer Till or Lower Boulder-clay," and C the sands which indented into "a deeply-eroded surface of the Till."

In 1869 a paper was communicated to the Norwich Geological Society by Mr. Harmer ‡, which gives a clearer exposition of Mr. Wood's views, and is accompanied by a list of the Belaugh shells, including these of Weybourn (*postea*, p. 93)§. In this Mr. Harmer says that "the only doubt felt by Mr. Wood and himself in connexion with the beds of the Crag Series in Norfolk is, whether or not the pebbly sands of Belaugh and Weybourn are identical with the Pebbly Sands and Pebble-beds which overlie the Chillesford Clay in the neighbourhood of Norwich, of Ladden, of Halesworth, and of Beccles, or whether they do not form a still later deposit," . . . "so that for the present they do not express any opinion on the identity of the Pebble-beds in these two areas."

In other papers published in 1869 || those gentlemen again give the succession of beds about Norwich, and state that the Pebbly Sands and Pebble-beds (a name which they were the first to adopt), which succeed to the Chillesford Clay, "expand northwards into the Weybourn Sand and Boulder Till of the Cromer-Cliff section: this bed is unconformable to the Crag and Chillesford beds, is palæonto-

* Quart. Journ. Geol. Soc. vol. xxiii. p. 89.

† Geol. Mag. Oct. 1868, vol. v. p. 452. The map and sections were not published until 1872, when they appeared in the 'Supplement to the Crag Mollusca.'

‡ Geol. Mag. vol. vi. p. 231.

§ Mr. H. B. Woodward's list of these fossils given at p. 93 is corrected by Mr. Wood up to 1881.

|| Quart. Journ. Geol. Soc. vol. xxv. p. 446.

logically distinct from them, and is characterized by the first appearance in England of *Tellina balthica*."

In 1870* Mr. Wood reiterates his opinion that the Pebbly Sands of Belaugh, from which he had then obtained 35 species of Mollusca, are "continuous with the pebbly sand underlying and *interbedded with the Till* along the Cromer coast and yielding similar shells," and he groups these together with the Contorted Drift, as "*Lower Glacial*" (the italics are mine).

In January 1870 my paper on the Norwich Crag and Westleton Beds was read †, although it was not published until 1871, owing to difficulties connected with the lists of fossils. The main object of that paper was to correlate the Westleton with the Mundesley Fluvio-marine Beds, and to show that they passed unconformably *under* the Till of Cromer, with which they have no connexion, and overlay the Norwich Crag.

It was not until 1872 ‡ that Mr. Wood published the detailed sections upon which his conclusions were founded, and gave a full list of the fossils of the "Lower Glacial" beds, including the Bure-Valley and Weybourn Crags. This showed that although we had both arrived independently at the conclusion that the Pebble-beds of both counties were newer than the Chillesford Beds, there were many points, such as in the correlation of the Weybourn Beds, the passage upwards of the Pebbly Sands into the Glacial Beds, the construction to be put on many of the Suffolk Beds, and other points, which I shall have occasion to notice as we proceed, that constituted radical differences.

We have in 1880 § the last expression of Mr. Wood's views with reference to the Pliocene, Glacial, and Postglacial deposits. In this paper he deals with the many theoretical considerations connected with the changes of level and conditions, and the range of the several deposits. He also alters some of his previous determinations in the Suffolk area, and explains his views of the "origin and mode of accumulation of the Pebbly Sand and Cromer Till as one formation." But to obtain a correct knowledge of Mr. Wood's range of work, the reader should consult the several papers here referred to. It is difficult to epitomize them owing to the frequent introduction of theoretical considerations among the questions of fact, and the repeated subordination of the latter to the former.

In 1881 || Mr. H. B. Woodward came to the conclusion that in Norfolk the beds between the Glacial Drift and the Chalk formed an indivisible group—"the Upper Crag or Norwich Crag Series"—composed of a variable group of sands, Pebble-beds, and laminated

* Geol. Mag. vol. vii. p. 17.

† Quart. Journ. Geol. Soc. vol. xxvii. p. 452.

‡ 'Introduction to the Supplement to the Monograph of the Crag Mollusca,' Palæontographical Society, 1872-1874, pp. xv-xviii.

§ Quart. Journ. Geol. Soc. vol. xxxvi. pp. 457-527.

|| 'The Geology of the Country around Norwich,' Mem. Geol. Survey Expl. of Sheet 66 N E., S.E. pp. 31-41.

clays, with occasional seams or patches of shells. In this he includes the Pebbly Sands, the Bure-Valley (or Westleton) Beds, the Chillesford Clay, and the lower Fluvio-marine Crag. The Weybourn Crag he considers, with Mr. Wood, to belong to the upper or Pebbly-sands division. He remarks on the importance of the Molluscan fauna and on the fact that the shells are, with few exceptions, of the same species throughout, but varying, though on the same horizon, "in the abundance of particular forms" and "in the number of different species." He dwells on the fact that in the Bure-Valley Crag of Belaugh there are "only two species not positively known to occur in the Crag near Norwich, namely *Tellina balthica* and *Paludina vivipara*," and states that *it is nowhere seen in section in its fossiliferous form above the other "zones" of the Crag** (p. 36). He also considers that the Haddiscoe gravels, "with which the pebblebeds of Halesworth, Henham, and Westleton are correlated, are distinct from the Pliocene Bure-Valley Beds, which I (H. B. W.) group with the Upper Crag" (p. 85).

In Mr. Clement Reid's memoir "On the Country around Cromer," 1882 †, he expressed an opinion that my divisions of the Crag on that coast will not hold good, in that I have placed the Chillesford Clay at different horizons; but as he does not say to which of my sections this observation applies, I am unable to answer the objection. This stratigraphical objection will, however, be met further on in this paper.

In a later paper ‡ Mr. Woodward expresses his belief that the Westleton and Mundesley Beds on the Cromer coast "are not the same as the Bure-Valley beds inland," and he gives an amusing account of "the confused and deplorable condition that the nomenclature of the Pliocene and Post-Pliocene deposits is in." He fears "that the introduction of the words 'Chillesford Clay' had been at the root of nearly all the evil in the shape of confused or complicated classification," but he confesses "that coming from a county where some of the rocks are measured by thousands of feet, he may have contemplated with too little respect divisions that dwindle into inches," no less than five subdivisions having been introduced into 30 feet of strata, and "of these nearly all had two or three names. But most distressing of all has been the indiscriminate identification by some observers of the Chillesford Clay with any micaceous and laminated clay-seam"§.

It may be thought that Mr. Woodward somewhat magnifies the

* The italics are mine.—J. P.

† Mem. Geol. Survey, Explan. of Sheet 68 E.

‡ "Notes on the Bure-Valley and the Westleton Beds," Geol. Mag. dec. ii. vol. ix. p. 452 (1882); and 'Geology of England and Wales,' 2nd edit. pp. 469-508.

§ Laminated clays are common in the Westleton and Mundesley, as well as in the Norfolk Glacial Series. To be sure of the Chillesford Clay, it is necessary to determine it either by superposition or by its fossils, when present, or by following its range on a given horizon. Mr. Gunn named the upper divisions of the Mundesley group "Preglacial Laminated Series."

risk incurred by the adoption of such meagre divisions; but in the absence of more important masses of strata, we have unavoidably to depend on these smaller beds, although it must be with the qualifications he names.

Mr. Woodward states that his conclusions differ from mine in some important particulars, chiefly in the correlation of the beds in several localities. He bases much on the fact that in the general sections I have coloured the Dunwich Cliffs as Glacial Sands*. That, however, in no way affects the special question. Whether the Dunwich Cliffs, which are much obscured, belong to one division or the other is unimportant. Mr. Woodward satisfied himself that they belong to the Westleton Beds, but Mr. Whitaker has since shown reason to believe that the lower part at all events belongs to the unfossiliferous sands of the Crag. At one spot they are capped by a small patch of Westleton pebbles with an overlies of Boulder-clay; while the lower part of the cliff, consisting of sands without fossils, may very probably, as Mr. Whitaker supposes, belong to the Crag †.

Mr. Woodward objects to Messrs. Wood and Harmer grouping the Bure-Valley Beds as Lower Glacial, and sees no satisfactory palæontological reason for separating them from the Norwich Crag, with which he unites them under the name of the "Norwich-Crag Series." He states that "the grounds on which Messrs. Wood and Harmer separated the Bure-Valley Crag from the Norwich Crag have proved to be unsound. The Bure-Valley Crag is palæontologically identical with the Weybourn Crag, as they originally pointed out. Both beds contain the *Tellina balthica*. But as my colleague Mr. C. Reid has shown, the Weybourn zone is to be traced at the base of the Forest-Bed Series, at Sherringham and other places; whereas another bed, at a higher horizon, since called the '*Leda-myalis* bed' by Mr. Reid, was also correlated by Messrs. Wood and Harmer with the Bure-Valley Beds. Thus we have a fossiliferous zone at the top and another at the base of the 'Forest-Bed Series,' both of which have been called the Bure-Valley Beds; and this is the reason why some observers have stated that the Norwich Crag overlies the Forest Bed of Cromer, while others have maintained that the Crag underlies it. The true fossiliferous Bure-Valley Zone, however, as just stated, occurs at the base of the Forest-Bed Series, and is represented by the Weybourn Crag. The *Tellina balthica* thus occurs beneath beds which Messrs. Wood and Harmer have grouped as 'Pre-glacial,' and their argument that this shell is confined to Glacial and more recent deposits loses all weight." "For the same

* I find that I overlooked one of my early note-books, in which I had noted Boulder-clay and Westleton Shingle at one point on the top of the cliff, as described by Mr. Whitaker in his 'Geology of the Suffolk Coast,' pp. 52-59.

† In 1871 Messrs. E. T. Dowson and W. M. Crowfoot, of Beccles, found a fossiliferous bed quite at the base of this cliff, from which they procured 44 species of shells with a few Mammalian remains. They refer this bed to the Fluvio-marine Crag.

reason, also, the Mundesley and Westleton Beds, identified by Prof. Prestwich on the Cromer coast, are not the same as the Bure-Valley Beds inland."

Mr. Woodward further states that under the term "Lower Glacial Drift" he would include not only the Cromer Till and Contorted Drift, but also the "Middle Glacial," as he regards them as intimately connected; "hence the Westleton Beds would be Lower Glacial, the Mundesley Beds would come in the debatable ground called Preglacial, the Bure-Valley Beds are Pliocene."

In a subsequent paper* Mr. Woodward, in speaking of the Crag and Pebbly Gravel, says "In their notes on the pebbly gravel and its relation to beds above and below, Messrs Wood and Harmer have expressed their opinion that on the coast the Weybourn Sand (=Bure-Valley Beds) passes up by interbedding into the Cromer Till, while the pebbly gravels around Norwich that immediately underlie the Lower Glacial brickearth, were considered by them to be, to some extent, the equivalents of the Cromer Till."

He then observes, "Neither my colleague Mr. Reid nor myself have seen any evidence to corroborate this opinion; on the contrary, the line between the undoubted pebbly gravels (which are grouped by us as Pre-glacial) and the overlying Glacial Drift is generally sharply defined,"—a conclusion in which I quite agree.

I quote these remarks of Mr. Woodward (the bearer of a name so long and honourably connected with the investigation of the Crag and Glacial series of Norfolk) to show how complicated the question has become, and how diverse the opinions on the subject still are. The classificatory objections to Messrs. Wood's and Harmer's Bure-Valley Crag do not, however, affect the question of superposition, on which their main contention on this point is founded.

In 1887, Messrs. W. Whitaker and W. H. Dalton, in their memoir 'On the Geology of the Country around Halesworth and Harleston' †, state that in the area they describe, the beds of the Pebbly Series vary, and "to the west and north-west they change into fine sands and loams, each exposure showing different peculiarities." They express a preference for the use of the lithological name instead of the geographical ones of Mr. Wood and myself, and leave the question of the relation of the Pebbly Series to the Glacial Drift and Chillesford Clay or to the Pliocene below an open question.

The reasons for not pledging himself to the question of classification are given by Mr. Whitaker in a later memoir ‡. In this he makes some pertinent remarks on the "Pebble Series" and its literature. In explanation of the various names and classifications that have been proposed for these beds by different writers, he suggests that "It seems possible that anyone working southward from the northern part of Norfolk might get into a somewhat dif-

* Mem. Geol. Survey Expl. Qt. Sheet, 68 N.W. and S.W. pp. 11-14 (1884).

† Mem. Geol. Survey Expl. Qt. Sheet 50 N.E. pp. 11-17.

‡ "The Geology of Southwold and of the Suffolk Coast, from Dunwich to Covehithe," Mem. Geol. Survey, Explanation of Sheet 49 N., 1887, p. 22.

ferent mental groove from anyone working northward from the southern part of Suffolk. Both may be locally right; but it does not follow that either must be right generally; at all events the variety of opinion that has been evolved is rather bewildering." This must be my apology for the present digression.

In his memoir of 1884 Mr. Whitaker records the occurrence in the highest part of the Westleton shingle at Henham of a band of ironstone with casts and impressions of shells; but the species are not named. He likewise announces the discovery of fossils—in the Southwold area—of this age, in one case in a pit on the Lowestoft Road, two thirds of a mile N.N.W. of Southwold Church, and in another in the railway-cutting near the station (p. 29), and gives lists (p. 85) of the species, on the authority of Mr. W. M. Crowfoot and of Mr. S. V. Wood. I am not, however, quite satisfied that these shells, or at least all of them, belong to the Westleton beds. As this is a point of considerable interest, I give the species in the Table at p. 93 for the purpose of comparison with those of other localities.

In the first-named locality casts and impressions of shells were found in an iron-concreted portion of the shingle, whilst at the bottom of the pit actual shells were found. In the second locality the shells occurred in a lenticular mass, 6 inches thick and about 5 feet deep, in a cutting 7 feet in depth, and in another small patch about 12 yards northward. It appears to me, however, possible that some of these shells may belong to the Upper Crag (the Chillesford Sands); for the Chillesford Clay has been much denuded*, so that the Pebble Beds often come into juxtaposition with the Upper or Fluvio-marine Crag. A little north of Southwold, the cliff section, in fact, shows the pebbly (Westleton) beds in contact with yellow sands of this age, owing to the removal of the Chillesford Clay. It may be therefore that the lower part of the sections belongs to the Crag, or that the shells are derived from it.

The following are the species mentioned by Mr. Whitaker as occurring in the above-named places. To these I have added a column for the species enumerated by Mr. H. B. Woodward from the typical Bure-Crag localities of Belaugh and Wroxham, although even there, I think, there is some uncertainty whether the latter beds are free from intermixture with the Fluvio-marine Crag. It must, however, be borne in mind that the range and location of species in the Crag are extremely variable.

* Mr. Whitaker mentions that the Chillesford Clay is wanting in places near Southwold, probably having been cut off by the Pebble Beds (*op. cit.* p. 62). It was wanting also in the Southwold well, where the underlying Crag was fossiliferous.

Mr. Whitaker's Mollusca of Southwold beds and of the Bure-Valley beds of Norfolk, compiled from the lists of Mr. W. Whitaker* and Mr. H. B. Woodward †.

The third column shows the species that occur also in the Upper or Fluvio-marine Crag of the adjacent localities of Easton Bavant (near Southwold) and of Norwich (near the Bure Valley).

	Southwold. P. Pit ; S. Station.	Bure Valley. B. Belough ; W. Wroxham.	Fluvio-marine Crag of Norwich (N.). Easton Bavant (E.).
<i>Anomia ehippium</i> .....	.....	W.	N.
<i>Anomia striata</i> .....	.....		N.
<i>Astarte borealis</i> .....	.....	B., W.	E., N.
<i>Astarte compressa</i> .....	.....	B., W.	E., N.
<i>Cardium edule</i>	P., S.	B., W.	E., N.
<i>Cardium grœnlandicum</i>	S.	.....	E., N.
<i>Cardium islandicum</i>.....	.....	B. frags.	
<i>Corbula striata</i> ...	S.	B.	E., N.
<i>Cyprina islandica</i>	P., S.	B., W.	E., N.
<i>Donax vittatus</i>	S.	B.	* ?
<i>Leda oblongoides</i> .....	.....	B., W.	N.
<i>Lucina borealis</i>	S.	B., W.	E., N.
<i>Mactra ovalis</i> .....	.....	B.	E., N.
<i>Mactra solida</i> .....	.....	W.	N.
<i>Mactra subtruncata</i> .....	.....	W.	E., N.
<i>Mya arenaria</i>	S.	B., W.	E., N.
<i>Mytilus edulis</i> .....	.....	B., W.	E., N.
<i>Nucula Cobboldiæ</i> .....	.....	B., W.	E., N.
<i>Pecten tigrinus</i> , var. <i>lævis</i> .....	.....	W.	
<i>Pholas crispata</i>.....	.....	B.	N.
<i>Saxicava arctica</i> , var. <i>rugosa</i> .....	.....	B.	N.
<i>Serobicularia plana</i> .....	.....	B.	* N.
<i>Tellina balthica</i> .....	.....	B., W.	
<i>Tellina lata</i>	P., S.	B., W.	E., N.
<i>Tellina obliqua</i>	P., S.	B., W.	E., N.
<i>Tellina prætenuis</i>	S.	B., W.	E., N.
<i>Thracia papyracea</i> .....	.....	B.	N.
<i>Buccinum undatum</i> .....	.....	B.	E., N.
<i>Cerithium tricinatum</i>	P., S.	.....	* N.
<i>Littorina littorea</i>	P., S.	B., W.	E., N.
<i>Littorina rudis</i>	S.	B.	w, N.
<i>Melampus pyramidalis</i>	P., S.	.....	E., N.
<i>Natica catena</i>	P. ?	B., W. ?	E., N.
<i>Natica helicoides</i> .....	.....	B.	E., N.
<i>Paludina media</i>	S.	.....	E., N.
<i>Paludina</i> ? <i>glacialis</i> .....	.....	B.	
<i>Purpura lapillus</i>	P., S.	B.	E., N.
<i>Scalaria grœnlandica</i> .....	.....	B., W.	E., N.
<i>Trophon antiquus</i> .....	.....	B., W.	E., N.
<i>Trophon antiquus</i> , var. <i>contrarius</i>.....	.....	B., W.	N.
<i>Turritella terebra</i>	S.	.....	E., N.

The specimens in the third column marked with an asterisk are also found in the Crag near Southwold ; *w* in the Southwold well.

* Mem. Geol. Surv. 1887, pp. 82-84.

† *Ibid.* 1881, pp. 42-53.

It thus appears that of the 18 species from the Southwold sections 13 are recorded in the Bure Valley; whilst of the other species, three (*Melampus pyramidalis*, *Cerithium tricoloratum*, and *Paludina media*), which are characteristic of the Fluvio-marine Crag, have not been met with in the Bure-Valley Crag. The other two are also Norwich species, but have a wider range. On the other hand, of the 36 species quoted from the Bure Valley, 16 are wanting at Southwold, amongst which is the only characteristic shell of that Crag, *Tellina balthica*, while other such common Westleton and Bure-Valley shells as *Scaloria grænlandica*, *Natica helicoides*, *Astarte compressa*, *Leda oblongoides*, and *Mytilus edulis* are also wanting.

§ 3. Choice of Terms.

The main objection, however, to the adoption of the "Bure-Valley Crag or Pebble-beds" as terms for these geological zones, is that neither their palæontological value nor their stratigraphical relations are in that district free from uncertainty. Where the Chillesford Clay intervenes, there is no doubt of their distinctness; but where this bed is wanting, as is commonly the case in Norfolk, it is almost impossible to distinguish between the beds above and the beds beneath that zone; and as, in consequence of the Pebbly Beds resting upon an eroded surface of the Chillesford Beds, the juxtaposition of the two shell-beds is of frequent occurrence*, their duality then is lost. At Norwich this distinction still exists; but further northward, in the Bure Valley, the Chillesford Clay is either wanting or else exists in a very fragmentary form; so that, in such cases, owing to their having many characters in common, the distinction between the Bure-Valley and Norwich-Crag beds might pass unnoticed.

It may, in fact, be a question whether the thin seam of clay which in Mr. Wood's typical sections of Belaugh and Wroxham is intercalated near their base (see Mr. Woodward's memoir, pp. 60 and 62) does not represent the Chillesford Clay, and whether in the same way the thin occasional bed of clay a foot or two above the Chalk in the coast-section is not also of the same age, and whether the lower shell-bed in these several localities should not be referred to the Norwich Crag instead of grouping it with the overlying beds under the term of the "Weybourn Crag," or as the "Lower Glacial" of Mr. Wood. (See Supplement to the Crag Mollusca, pp. 203-219.) To test the point, I would keep the fossils from these beds separate until their exact relationship is ascertained with greater certainty. Mr. Woodward's short lists, at pp. 62 and 63 of his Norwich memoir, show slight but not unnoticeable differences between the upper and lower part of the section. *Tellina balthica*, which is stated by Messrs. Wood and Harmer to be almost the only shell in the Pebbly Sands that does not occur in the Norwich Crag, is not found in the lower bed at Wroxham, although it is at Belaugh; but I think (for reasons to be given hereafter) with Mr. Woodward, that the occur-

* Quart. Journ. Geol. Soc. vol. xxvii. p. 456 (1871).

rence of this one shell is a very insufficient palæontological distinction.

Where the Chillesford Clay is absent, evidence of its former presence often exists at the base of the Pebble-beds in the form of pebbles of clay, derived probably, in some cases, from that clay. The instance recorded by Mr. Woodward in the typical Wroxham district, of a gravelly bed with clay pebbles at the base of beds of buff sands and pebbly gravel (the Bure-Valley Beds*) in a cutting near the station may be of this character. It is easy, therefore, to imagine that, owing to this removal of the Chillesford Clay, the Bure-Valley Crag may often be in contact with beds of the age of the Norwich Crag, and that in the case of beds so much alike it would be difficult to detect the line of separation, while the fossils of the lower beds would be apt to get mixed with those of the upper one.

Therefore, while I admit the value of the distinction drawn by Messrs. Wood and Harmer between the Norwich Crag and the Bure-Valley Pebble-beds, I do not think that either the palæontological or stratigraphical proofs respecting the position of these Pebbly Sands are so well defined and certain in the Bure-Valley district as they are in the Westleton and Southwold districts, or so fitted to be taken as the type of a wide-spread geological zone. For these reasons, although the term of Bure-Valley Crag or Beds may be conveniently applicable to a local fossiliferous condition of the Pebbly Sands, I do not think it to be, for a general term, so suitable as the term of "*The Westleton and Mundesley Beds.*"

This is the term that in 1881 † I proposed to adopt in place of my original term of "Westleton Sands and Shingle," in 1870, for the reason that when a particular series of strata presents, in adjacent and conterminous areas, markedly different palæontological and structural characters, it may be convenient, as in the case of the "Woolwich and Reading Beds," to give them a double geographical name, indicative of the localities where the two types are respectively best developed, and their relation to the overlying and underlying strata best exposed. It will, however, be convenient, when speaking of the inland continuation of these beds, to use merely the term of "Westleton Beds or Shingle," as then we shall have to deal with that type of them alone.

§ 4. *The Structure and Palæontological Characters of the Westleton and Mundesley Beds, in Norfolk and Suffolk.*

Before proceeding with the inland range of these beds, I will describe more fully my view of the relation they hold—on the one

* Similar cases, having reference to this and other underlying clay-beds of the Forest-bed series, are common in the coast sections, and are recorded by Mr. C. Reid (*op. cit.* p. 15 &c.) and by myself (*Quart. Journ. Geol. Soc.* vol. xxvii. p. 465).

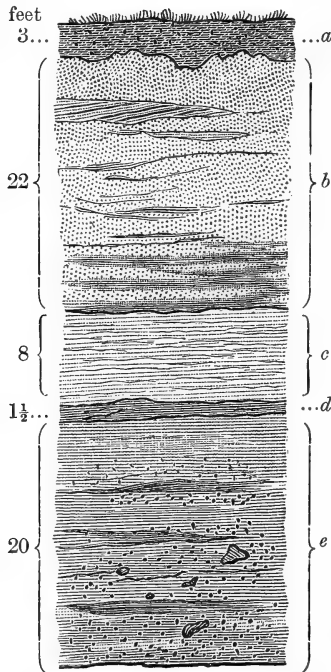
† This paper is an amplification of the one then read before the British Association, and which appeared only in Abstract.

hand to the Fluvio-marine Crag, and on the other to the Glacial beds in Suffolk and Norfolk.

The composition of the shingle will engage our particular attention, as it is an instance in which the evidence afforded by it is of more stratigraphical value than that of the fossils, as the latter are confined to the sea-board of the Eastern Counties, while the former has to be our guide over the wide inland area.

I will now drop the term "Pebbly Beds," which, although convenient as a temporary term, marking, as it does, a very distinctive character, has the inconvenience of defining a feature common to many other strata, as, for example, the Pebble-beds of the Bagshot Sands, or those of the Woolwich and Blackheath Beds. It is like

Fig. 1.—General Section of the Westleton Beds on Westleton Common.



a. Surface soil—gravelly.

b. Fine shingle, with lenticular beds of white sand.

c. White sands—quartzose—horizontal bedding.

d. Light greenish clay.

e. White sand passing down into ochreous pebbly sands, with a few large unworn blocks of flint and some ironstone bands and concretions.

No fossils were met with in these pits*.

* In another pit on the common, I found, in digging a few feet lower, a sandy clay with very friable specimens of *Tellina* and *Natica*.

the old designations of "Plastic Clay" and "Mottled Clays," which would specialize characters common in formations of Tertiary as well as of Secondary age.

The localities where the Shingle Beds are most extensively developed, and where the joint lithological and palæontological characters are best combined, will be found in the Ordnance Map, Sheet 49 W. and 50 E. From this centre I will first take their range northward.

Between Westleton and Dunwich there is a large tract of common, formed by low hills of pebbly shingle, which extends with little interruption to Blythburg and Southwold, and thence to Easton Bavant and Covehithe, forming a belt some 2-4 miles wide and 10 miles long. The higher ground is everywhere capped by Boulder-clay, from beneath which the Shingle Beds crop out, whilst on the coast the Chillesford Clay rises from beneath the latter (except where it has been denuded before the deposition of the Shingle), thus defining accurately the stratigraphical position of the Shingle Beds.

The Shingle consists of flint pebbles as well rounded and forming beds as massive as the Tertiary Beds of Blackheath or Addington, with subordinate sands and thin clays. From two of the closely adjacent large pits on the common, the accompanying general section (fig. 1) is constructed from notes taken some years since.

Unlike the overlying Glacial Beds with their northern drift, we have evidence in this Shingle of a decided transport from the southward in the presence of subangular worn fragments of Chert and Ragstone of the Lower Greensand, probably of Kent, a fact to which I formerly drew attention*. With these are associated a considerable proportion of small white quartz-pebbles and a few large flattish ovoid pebbles † of light-coloured Quartzite and Sandstone, with small pebbles of Lydian stone and jasper &c. There is a total absence of the larger darker red and grey rounded quartzite-pebbles (cobble) of the New Red Sandstone, so common in the Glacial Series. The average composition ‡ of this Westleton Shingle at Westleton may be roughly taken as under:—

	Per cent.
1. Black flint-pebbles	60
2. White quartz-pebbles, with a few rose-coloured	20
3. Subangular flints, not stained	10
4. Subangular fragments of grey pin-hole ragstone and dark yellow chert.....	4
5. Large flattish pebbles of light-coloured quartzite, light and dark sandstones, and small pebbles of veinstone, Lydian stone, and jasper, with a few subangular fragments of black chert (Carboniferous?), of a dark slaty rock, and of quartz	6
	100

* *Op. cit.* pp. 461 and 477 (1871); and British Association Reports for 1881, p. 620.

† They are very similar in shape and colour to the recent quartzite-pebbles on the Chesil Bank.

‡ The determinations in all cases can only be given approximately. For reasons given in Part II. of this paper these proportions may not be quite correct locally; but as the same error, if any, runs through all the localities, the general result is not seriously affected.

The proportions, as might be supposed, vary in every pit, and even in different parts of the same pit; but the constant presence of the first four constituent parts, and the absence of certain others, is a remarkable feature, and enables us to recognize these beds when other evidence is wanting, and to distinguish them from beds of Lower Tertiary, Bagshot, or Glacial age with which they might otherwise be confounded.

Near Halesworth, 6 miles N.N.W. from Westleton, where sub-angular flints are more abundant, the shingle consists of:—

1. Flint-pebbles.....	50
2. White quartz-pebbles	10
3. Subangular flints	34
4. Chert &c.	6
	<hr/>
	100

At Henham, on the other hand, the proportion of flint-pebbles to the other constituents is larger. In a pit in the Park, where there were about 20 feet of shingle, the upper 6 feet consisted of horizontal layers, while the lower beds exhibited an oblique lamination as good as that figured by Mr. S. V. Wood in the Red Crag at Bawdsey Cliff as typical of current-bedding*.

At Blythburgh and Reydon, the Westleton Beds are seen in the same relation to the Glacial Beds, and it was in a pit near the latter place (Quart. Journ. Geol. Soc. vol. xxvii. p. 462), that I found in a seam of pebbly sand concreted by iron-peroxide numerous casts and impressions of *Mytilus edulis*, double, and in all stages of growth. The beds generally have, however, been extensively decalcified, so that shells are extremely scarce.

At Easton Bavant cliff, the superposition of the Westleton Shingle on the Chillesford Clay and Sands, both of which latter are here fossiliferous, is very distinct, while the former exhibits very clearly the special characters which serve to distinguish it from Glacial beds.

It is composed as under:—

	Per cent.
1. Flint-pebbles	52
2. White quartz-pebbles.....	18
3. Subangular flints	20
4. Worn fragments of chert, quartzite pebbles, one large pebble of indurated clay with indistinct vegetable impressions	10
	<hr/>
	100

Here also I found, as at Reydon, a thin seam of ironstone intercalated in the upper part of the Pebble-bed with casts and impressions of *Cardium* (*C. edule*?), *Mytilus* (*M. edulis*?), *Littorina*, and *Natica*.

Since I visited this district it has been described by Mr. Whitaker, and allowing for changes in the coast-sections caused by the encroachment of the sea, our observations are in close agreement. He

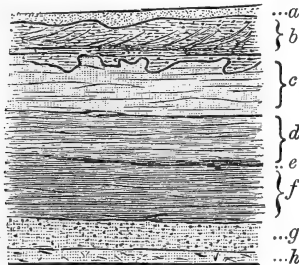
* Ann. & Mag. Nat. Hist. for March 1864, p. 3.

also describes the various interpretations* to which these beds have given rise.

As there is little positive evidence of ice-action during this period, it is interesting to note the discovery, recorded by Mr. Whitaker (p. 77), of a wedge-shaped block, $13 \times 13 \times 19\frac{1}{2}$ inches, of a micaceous quartzite in the pebbly gravel at Easton. I noticed in 1869 in a farm-yard near Reydon, a rather large boulder of granite, which may also have come from these beds.

At Easton Bavant the Chillesford Clay is well marked with its characteristic shells; but at the extreme north end of the cliff, near Covehithe, there are indications of a change. Some trenches opened at the base of the cliff a few years ago exposed the section annexed (fig. 2).

Fig. 2.—Section in Covehithe Cliff, north of Easton Bavant.



	feet.
a. Dark sandy soil	2
b. White pebbly sands (Westleton) indenting into c	3
c. Irregular white and yellow sands.....	4
d. Laminated brown clay	4
e. Irregular carbonaceous band.....	$\frac{1}{4}$
f. Laminated grey clay (Chillesford?).....	6
g. Fine gravel and sand	2
h. Shell-bed (fluvio-marine)	2+

Here the Chillesford Clay is unfossiliferous, and is overlain by a thin seam of carbonaceous matter succeeded by two beds of laminated clays and sands, also without fossils, on which rest the sands and shingle of the Westleton Beds. The beds c to e may represent a commencement of the Forest Series, and would thus show its relation to the Fluvio-marine Crag (g).

Another point of interest in this section is the presence of small pockets or indents of sand filling hollows on the top of the laminated bed c, on which rest the horizontal seams of sand and shingle b. The sand in the holes is the same as that of bed b. Mr. Whitaker (p. 75 of his Southwold Memoir) has described similar small contortions in these cliffs †, and Mr. C. Reid speaks of the

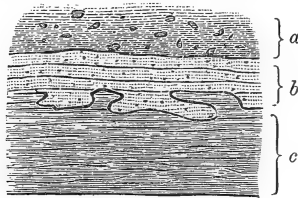
* "Geology of the Suffolk Coast," Mem. Geol. Surv. 1887, pp. 57-59, 68-72.

† It was possibly these contortions which led Mr. Wood to refer the sands and loam in the upper part of the Covehithe cliff to the "Contorted Glacial Drift."

same structure in the Forest Series at Trimlingham and other places. He remarks that the carbonaceous clay and overlying sand are apparently contorted together, and that the contortions are cut off by the overlying evenly bedded freshwater clays, and he suggests that this contorted structure may be due either to the treading of some of the large Mammalia in shallow waters, or else to the lateral thrust caused by alternate freezing and thawing of the beds in winter (p. 33).

In one of my note-books, I have the following sketch (fig. 3) of a similar contortion, but it was there, as at Covehithe and Easton Bavant, immediately under the Westleton Beds *b*.

Fig. 3.—Section at the base of the Cliff near Trimlingham.



	feet.
<i>a.</i> Boulder-clay (base of)	—
<i>b.</i> White sand in horizontal layers, with indents in <i>c.</i>	3
<i>c.</i> Laminated black clay and white sand	8

May not these small contortions be due to floes of river- or shore-ice impinging on beds of soft clay? just as at St. Acheul (Amiens), where there is reason to attribute the contortions (which are, however, on a larger scale) to the action of the river-ice* at the high-level period.

Another section exhibiting similar intermediate characters as at North Bavant, but still without anything definite, was formerly to be seen in a pit one mile W.S.W. of South Cove Church. It was as follows:—

	feet.
<i>a.</i> Westleton Shingle	4 to 5
<i>b.</i> Light-coloured sand.....	4
<i>c.</i> Light-coloured laminated clay	3
<i>d.</i> Dark grey clay.....	3

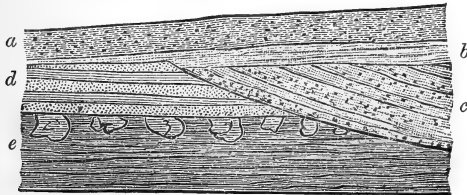
The clay was underlain by loam and then (it was said) by Crag (?). At the Frostenden brick-pit the same dark clay, also without fossils or pebbles, was worked under the Boulder-clay.

The coast-section resumes again, after a break of $1\frac{1}{2}$ mile, at the south end of Kessingland cliff (fig. 4), but it is often obscured, and owing to encroachment of the sea varies considerably from time to time. On the occasion of one of my early visits traces of the Westleton Shingle were to be seen resting on grey clay and sand, showing similar contortions to those before noticed at Covehithe and

* Phil. Trans. for 1860, p. 299, and 1864, p. 269.

Easton. The Shingle *d* is, however, soon replaced by the Middle Glacial sands and gravel *c*, which then rest directly on the Forest-Bed series, and maintain that position as far as Pakefield.

Fig. 4.—Section at the south end of Kessingland Cliff.



	feet.
<i>a.</i> Gravelly soil	3
<i>b.</i> Yellow sand	1
<i>c.</i> Irregularly bedded sand and gravel.....	5
<i>d.</i> Yellow pebbly sands (Westleton) indenting into <i>e</i>	4
<i>e.</i> Laminated grey and brown clay and sand	6

The laminated bed *e* is without fossils, and resembles bed *d* of section, fig. 2. Further north the cliff becomes higher, and the Upper Chalky Boulder-clay sets in; while at the base of the cliff there appears a compact greenish clay, with small fragments of flint, traversed to the depth of from 3 to 5 feet by rootlets, generally cut off on the top by the Glacial Sands. Between the beds *b* (fig. 5) and the Pebbly Clay, and forming at one place a shallow depression about 150 yards across, lies the dark carbonaceous clay with plant-remains, at the base of which is a thin seam of gravel and sand with *Unio*, *Cyclas*, &c., which I referred in 1871 to the Forest Series of Norfolk. The Pebbly Clay passes in places southward into a light-coloured sand, and again into clay, while at other places the flint-fragments disappear. Nearer Pakefield Mammalian remains occur in some abundance; but I failed to recognize the exact position of these remains, and was under the impression that the pebbly clay (*e*) represented the Chillesford Clay. Fig. 5 (p. 102) is a part of the section I then gave of this cliff*.

In 1872, Mr. S. V. Wood remarked that all that could be safely averred of those beds (the Forest Beds) at Kessingland is, "that they are anterior to the Middle Glacial and probably posterior to the Crag," an opinion endorsed in his subsequent papers of 1877 and 1880, although in the latter he seems to imply that the Mammalian remains are of the age of the Norwich Crag †.

In 1876, Mr. J. Gunn ‡ concluded, on the contrary, that both the so-called Elephant Bed and the Forest Bed in this cliff were not only beneath the Chillesford Clay, but also beneath the Norwich

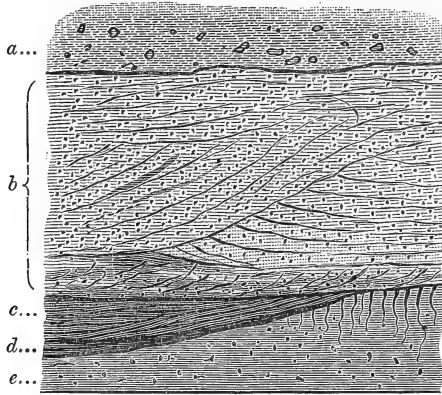
* Quart. Journ. Geol. Soc. vol. xxvii. p. 463.

† 'Supplement to the Crag,' p. xv; and Quart. Journ. Geol. Soc. vol. xxxiii. p. 74, and vol. xxxvi. p. 462.

‡ Quart. Journ. Geol. Soc. vol. xxxii. p. 123.

Crag Beds. In the following year Mr. Harmer questioned that view, and contended that the rootlet-bed does not represent the Chillesford Clay, but that it forms part of a freshwater deposit occupying a basin excavated in the Chillesford Clay, and is thus newer than the latter*. In 1880, Mr. J. H. Blake confirmed the opinion that these beds represent the Forest Bed of Happisburgh, and determined the exact position of the Mammalian remains as

Fig. 5.—Section at the base of the Cliff north of Pakefield.



	feet.
a. Chalky Boulder-clay (base of)	—
b. White sands with patches of gravel and fragments of shells (one <i>Tellina balthica</i> entire), irregularly bedded and ochreous at base	15 to 18
c. Laminated black carbonaceous clay, with branches of wood and a few small angular fragments of flint	4
d. Band of freshwater shells (<i>Unio</i> , <i>Cyclas</i> , &c.)	$\frac{1}{2}$
e. Compact greenish clay with fragments of flint, traversed by rootlets <i>in situ</i>	5+

“sometimes forming a distinct and separate bed, one stage more recent than the Chillesford Clay, and sometimes apparently passing down into the Chillesford Clay and forming as it were the uppermost portion of the same,” and, “with possibly a few trifling exceptions, all the Mammalian remains are to be found buried beneath the more or less denuded surface of the Rootlet Bed and the Chillesford Clay” †.

The only doubt to be felt is whether in this pebbly clay (*e*) we have the Chillesford Clay modified by its approach to land and the Forest estuary, or whether it belongs altogether to the Forest Series. It appears from the sections of the north end of Easton Bavant cliff and at Covehithe (fig. 2) that the laminated beds *c* and *d* overlie a carbonaceous seam *e*, and these may represent the Forest Beds, while the dark clay (*f*) appears to pass southwards without

* Quart. Journ. Geol. Soc. vol. xxxiii. p. 134.

† Proc. Norwich Geol. Soc. vol. i. pp. 137–160.

break and on the same horizon into the fossiliferous Chillesford Clay. At Pakefield we have an expansion of the seam *e* with rootlets traversing the clay, and occupying the position of *f* in the Easton Bavant section. Is it therefore that in the interval between Covehithe and Pakefield that this 'Pebbly Clay' sets in between *d* and *f*, or is it a continuation, modified by altered conditions, of the bed *f*?

At Alderby, 6 miles inland, the dark clay, which there overlies the Fluvio-marine Crag, also contains angular flints, and the late Mr. Rose had in his collection remains of the Elephant, Deer, and two species of Cetaceans from this same bed. Though it is not there overlain by the Westleton Beds, it was found to be so in a deep well sunk at Beccles on the other side of the valley, and is therefore generally held to be the Chillesford Clay-bed. There are again traces of the Forest Bed at the cliff at Corton with an underlying clay, of the same character as at Kessingland and with rootlets.

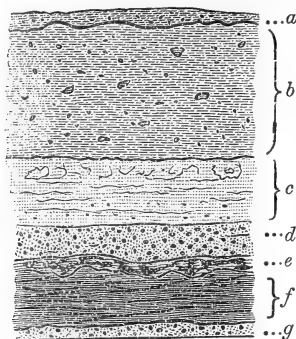
If this Suffolk bed is to be considered the equivalent of the Chillesford Clay, then the so-called Forest Bed of Happisburgh, Bacton, and Mundesley, which occupies the same position and contains the same remains, must also be referred to that age; but the peculiar character of its Mammalian remains—its numerous large Deer, its special Elephants, and other Mammalia, all so different from those of the Crag—the absence of Mastodon, which occurs both at Norwich and at Easton Bavant, together with the evident local and exceptional character of the Forest Series, renders it difficult to accept that solution of the problem.

Whatever may be the solution, it does not directly affect the particular question upon which we are engaged, as the Westleton Shingle is newer than the Forest Bed, and passes indiscriminately over it and over the Chillesford Beds. At the same time at the junction of the two former on the Norfolk coast there is to a certain extent a passage between them, land-conditions there alternating with marine during the accumulation of the Westleton Shingle. I shall therefore only refer incidentally to the Forest Bed, which is the less necessary as it has often been well and fully described, and will confine myself to following the range of the Westleton Beds.

The Shingle, which is displaced by the Glacial Sands at Kessingland, resumes its place in the neighbourhood of Pakefield and Lowestoft, where it exists in considerable force, consisting of the usual pebbles of flint and white quartz, with subangular fragments of flint, ragstone, and chert, and an unusually large proportion of other rocks, such as fragments of a mica-schist, of a dark green quartzose rock, and of yellow, green, and brown sandstones. In this part of the cliffs clay pebbles are common at the base of the Westleton Beds, arising probably from the partial destruction either of the Chillesford Clay or of one of the Forest Beds. Glacial sands again occupy much of the Corton and Gorleston cliffs. As the broad estuary of the Yare then intervenes, the Westleton Shingle is not met with again until we reach the Happisburgh Cliffs; and even there little is seen of it, although the Forest Bed with its multitude

of old stumps is often well exposed on the shore at low water. At Bacton, where the Westleton Beds are distinct, the section is as under (fig. 6).

Fig. 6.—Section at Bacton Cliff.



	feet.
a. Sandy and gravelly soil	2
b. Brown Boulder-clay, with a few fragments of shells...	10
c. Light yellow and white sands, contorted on top.....	5
d. Pebbly shingle with a few shells (Westleton)	3
e. A tangle of wood (local)	2
f. Laminated grey clay and sand	4
g. Fine gravel	1+

Mr. Gunn informs me that the Forest Bed has been met with about 8 feet lower. The shingle *d* contains * :—

Littorina littorea.	Astarte borealis.
— rudis.	Mytilus edulis.
Purpura lapillus.	Cardium edule.
Scalaria grœnlandica.	Trophon antiquus.

Another feature that I had occasion to observe here during one of my visits was a singular accumulation of twigs and branches of trees (*Pinus*, *Abies*, *Taxus*, &c.), forming in one place a loose matted mass from 2 to 3 feet thick, composed entirely of drifted wood débris, very little altered except in colour (fig. 6, *e*). Between Bacton and Mundesley the shingle continues with little interruption, and consists roughly of :—

	Per cent.
Flint-pebbles	50
White and rose-coloured quartz-pebbles.....	20
Subangular flints, not stained †	16
Subangular fragments of chert and ragstone.....	8
Lydian stone, jasper, quartzite, and sandstone pebbles...	6
	100

* This shell-bed was discovered by the Rev. C. Green in 1842.

† I may have under-estimated here and in some of the other places the proportion of subangular flints.

Besides the specimens named above, I also here found specimens of a black chert (Carboniferous?), of a light-coloured encrinital quartz (Carboniferous?), of chlorite schist, of a white fossiliferous chert, and of a dark-coloured slaty grit.

It is, however, at Mundesley, $2\frac{1}{2}$ miles north of Bacton, that we find these beds with their typical estuarine and freshwater conditions best exhibited. They there form a group of strata differing from those further south only inasmuch as they were deposited under local and different conditions, arising from the early emergence of this area, and the consequent introduction of a land fauna and flora.

In 1870 I made the mistake of supposing that the thin seam of gravel at the base of the Westleton Beds (*m*), and overlying the Forest Bed, represented the Elephant Bed of the Norfolk geologists. It is true that a few bones have occasionally been washed out of the Forest Bed, and are found in the gravel and sand overlying it; but the bone-bed proper is the underlying argillaceous sand in which the forest stumps are rooted, and to which the term of "Forest Bed" also applies, for it is in this bed that the remarkable group of mammalian remains with plant-débris are entombed. It has been questioned whether the stumps found on its surface are really *in situ* on the spot where the trees grew, or whether they were drifted there from a distance. Such may have been the case with some, but it is difficult to conceive that it could have been so with all. Their wide-spreading roots*, their position on one and the same level, the presence around them of their cones and branches, and the fact that the same bed at other places, where seen in section, is traversed by rootlets evidently *in situ*, show that the occurrence of such a forest-growth on the surface was both possible and probable. Some trees may doubtless have been overturned and drifted; and some strained by storms may have had their roots torn and broken. The argument that the small fibres which end the roots have generally been wanting at from one to three feet from the stem, has been disposed of by an observer so experienced on this point as Mr. T. M. Reade †, who states that in the case even of the more recently submerged forests of the Lancashire coast, the fine fibres of the roots are not preserved, having generally rotted away. The erect stumps of the Forest Bed, which I have myself from time to time seen, though not examined critically, seemed to me generally as good cases of growth *in situ* as the trees seen in peat-bogs.

I therefore see no reason to question the previous opinion of a forest-growth *in situ*, especially as the existence of a land-surface is confirmed by the presence in many places on the Forest Bed of a clay with land-, freshwater-, and marsh-shells and plants. This land-surface I take as the base on which the Westleton Beds were

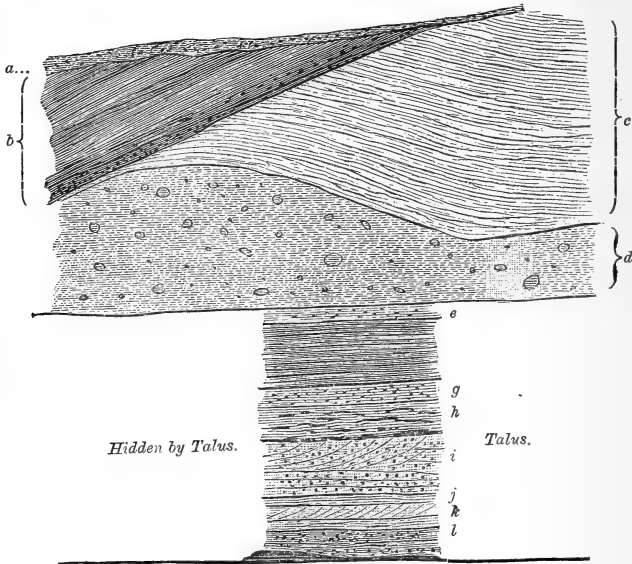
* In one case mentioned by Mr. C. Reid, the circle formed by the spread of the roots was 20 feet across.

† Geol. Mag. dec. ii. vol. x. p. 221 (1883).

spread. It marks a period of slow submergence, succeeded by the return at intervals of a very depauperized marine fauna.

The Forest Bed itself is a distinct and local deposit, beneath the Westleton Shingle; but whether it forms an intermediate deposit between the Shingle and the Chillesford Beds, or whether it is synchronous with, and representative of, the Chillesford Clay, I take to be a still unsettled problem.

Fig. 7.—Section of Cliff about $\frac{1}{4}$ mile north of Mundesley.



 Position of Forest Bed south of Mundesley.

	feet.
a. Subangular gravel	1-2
b. Post-glacial fluviatile bed	—
c. Yellow laminated loam (glacial), blue at base	20
d. Boulder-clay	12
e. Yellow sand	
f. Grey clay, laminated	} 23
g. Fine pebbly gravel and sand, with <i>Succinea</i> , <i>Cyelas</i> , &c.	
h. Laminated clay and sand, with drift wood	
i. Light-coloured shelly sands and shingle	
j. Sand	
k. Fine shingle, with <i>Mytilus</i> &c.	
l. Sand	
m. Gravelly bed, with mammalian remains, resting on dark sandy clay (Forest Bed)	

On either side of this section of the Mundesley series (e to m) very variable beds are hidden by talus. The position of the Forest Bed is also shown beneath the beach on the left hand.

It is on this part of the coast that the Forest Bed attains its greatest development. Mr. Gunn had a bore-hole driven into it at Happisburgh to a depth of 12 feet without reaching its base; while Mr. C. Reid, from observations made by dredging beyond low water-mark, concludes that its thickness is not less than 60 feet*. What may form the base of the Forest Series is at present a matter of conjecture. From the presence of drifted peat and plant-remains at its outcrop near Cromer, Mr. Reid infers the presence of another freshwater bed, beneath the main bed, and below that he places the Weybourn Crag.

The flora of the Forest Series has been admirably worked out by Mr. C. Reid and Mr. Carruthers †, and the fauna by the late Dr. Hugh Falconer ‡, Professor Boyd Dawkins §, and Mr. E. T. Newton ||. I need not further allude to them here, except to mention their extreme interest and importance.

The relation of the Westleton Beds to the Glacial Series above and to the Forest Beds beneath is extremely well shown on the coast at Mundesley, although it is only occasionally that the tree-stumps can be seen. Mr. Dix informed me that on the south side of Mundesley the greenish sandy clay of the Forest Bed crops out beneath the beach. Bones and teeth have often been dug out of it, and shortly before my last visit he had seen at low water the large erect stump of a tree, with, he said, all its roots branching from it. On another occasion, at very low water, a number of tree-stumps were seen with a mass of clotted leaves and branches. The best general section is that presented by the cliff on the north of the village (fig. 7).

Little of the Forest Bed is seen in this section, but in the gravel-bed (*m*) are occasionally found a few bones washed out of it. To this succeeds in places a grey clay, which to the south of Mundesley contains numerous freshwater shells, above which is a gravelly clay with *Mytilus* and *Succinea*. The sand and shingle *i* contain marine shells and fragments of wood. In bed *h* drifted wood occurs, while in the sand and fine shingle (*g*) freshwater shells are common. In the overlying laminated clay (*f*) are some wood and plant-remains. This section differs a little from those of Mr. Reid, owing to the variability of the beds, there having been an interval probably of some 20 years between our observations. The following is a list of the marine shells obtained from bed *k*:—

Cardium edule, <i>L.</i>	Littorina littorea, <i>L.</i>
Mytilus edulis, <i>L.</i>	— rudis, <i>Mat.</i>
Pholas crispata, <i>L.</i>	Purpura lapillus, <i>L.</i>
Balanus, <i>sp.</i>	Scalaria groenlandica, <i>Chemn.</i>

* It would be very desirable to have a deep boring made at Happisburgh or Mundesley.

† 'Geology of the country around Cromer,' p. 62 (1882). See also a paper by Mr. Reid in the 'Annals of Botany,' vol. ii. p. 178 (1888).

‡ 'Palaeontological Memoirs,' vol. ii. chapter ii. and pp. 476-480.

§ Quart. Journ. Geol. Soc. vol. xxxvi. p. 395, and other papers.

|| Geol. Mag. dec. ii. vols. vii. & viii., and Survey Memoir.

The freshwater shells in beds *i* to *k* consist of:—

Anodonta cygnea, <i>L.</i>	|	Bythinia tentaculata, <i>L.</i>
Pisidium amnicum, <i>Müll.</i>	|	Paludina gibba, <i>Sandb. ?</i>
Sphærium corneum, <i>L.</i>	|	Valvata piscinalis, <i>Müll.</i>
— rivicola, <i>Lea.</i>	|	

Bed *g* contains fewer species; the chief are:—

Planorbis complanatus, <i>L.</i>	|	Succinea putris, <i>L.</i>
Sphærium corneum, <i>L.</i>	|	— oblonga, <i>Drap.</i>

Beds *e* and *f* represent Mr. Reid's Arctic freshwater beds, in which he has found, in places, *Salix polaris*, *Betula nana*, and *Hippuris vulgaris*, with remains of *Spermophilus*; while bed *i* is on the horizon of his *Leda-myalis* bed*. The lower beds would, I presume, be included by Mr. Reid in his Upper Freshwater and Forest-Bed division. The relation to the lower and the Weybourn beds cannot be seen in this part of the coast-section.

The divisions of the strata under the Cromer Till (Lower Boulder-clay) on the Norfolk coast, according to Mr. C. Reid, are:—

Older Pleistocene (Glacial)	}	Cromer Till.	}		
		Arctic Freshwater Beds.			
	}	<i>Leda-myalis</i> Bed.	}	Upper Freshwater Bed.	
Newer Pliocene		"Forest-Bed" Series.		}	"Forest Bed" (Estuarine).
					Weybourn Crag.	Lower Freshwater Bed.
Chillesford Clay?					

The minor subdivisions are subject to considerable variations, and are of very restricted range, depending upon local conditions. It seems to me that all the beds *e* to *m* (fig. 7) are members of one series, and I have therefore grouped all down to the Forest Bed under the one term of "Mundesley Beds"; and as I take these beds to be on the same horizon and synchronous with the marine Westleton Beds of Suffolk, the term "Westleton and Mundesley Beds" † will serve to indicate the two types.

Mr. Reid considers that these terms ‡ can scarcely be adopted, because the shingle "at Westleton is now believed to belong to the Glacial Beds, and, at Mundesley, beds deposited under quite different conditions, and showing marked changes of climate, are included." It is quite true that the beds show somewhat different conditions, but that arises solely from the emergence of this area, and the introduction of a land- and marsh-fauna and flora oscillating with a marine fauna as the sea from time to time encroached §.

With respect to the climate, I do not see that the fossils indicate anything more than the continuance of that lowering of temperature which set in with the Crag beds. As the cold increased, many

* *Op. cit.* pp. 37, 48, 83.

† Report British Association, 1881.

‡ *Op. cit.* p. 9.

§ Dr. Sandberger came independently to the same conclusion from an examination of the fossils.

old forms gradually disappeared, the more northern and arctic forms alone surviving, until in the terminal "Arctic Freshwater Beds" both flora and fauna are such as show a climate fitly in accordance with the now near approach of the great ice-sheet.

The sea was probably too shallow to admit of the floating of large bergs with their massive boulders, yet we are not without evidence of ice-transport and ice-action on a small scale.

Large unworn and unbroken flints and smaller subangular ones are not uncommon. Small blocks of foreign rocks are, as before mentioned, occasionally met with, and Mr. H. B. Woodward records the occurrence in Norfolk of a block of basalt, about 18 inches square, in the Pebbly Sands near Aylsham*, all pointing to transport by ice.

The Forest Bed, with its trees and mammalian remains, may thence be traced northward as far as Cromer, but it finally disappears about one mile N.W. of that place, where the Upper Freshwater Bed and the basement beds of the underlying Forest-Bed series come into contact. Mr. C. Reid states that it is only at this point and at Trimlingham that his Lower Freshwater Bed at the base of the Forest Series is exposed. I cannot, however, agree with him in his interpretation of the Trimlingham section. I take the upper beds, nos. 2 to 4 of his section (p. 33), to be the base of the Mundesley series, nos. 5, 6, and 7 the Forest Bed, and no. 8 the Norwich Crag.

Another point at issue is whether the Weybourn Crag of Mr. Reid, considered by him to form part of his Forest Series, should be thus grouped, or whether it represents the Norwich Crag.

At the south end of the Forest-basin no marine bed underlies the Forest Series † until at a short distance beyond Kessingland the Chillesford Sands (Norwich Crag) set in. In the centre of the Basin at Happisburgh and Mundesley, nothing is known of the lower beds under the Forest Bed of Mr. Reid. As we proceed northward, owing to the thinning out of this latter bed, the base of the Mundesley Series with its pebble-bed (*m*) and derived bones comes, as before mentioned, into contact with the lower part of the Forest-Bed series.

But the sections are mostly obscure, and it is not until we reach the West-Runtun Gap (fig. 8) that the upper part of the series is seen clearly as at Mundesley, and the special character of the Westleton Shingle is again well marked. It here consists approximately of:—

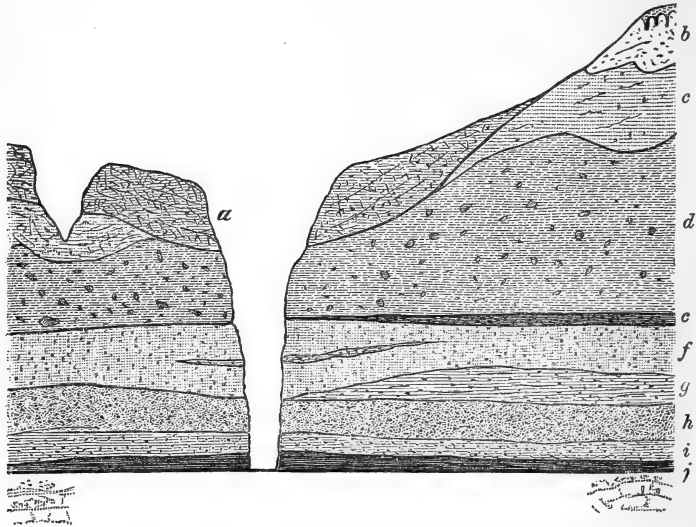
	Per cent.
Flint-pebbles	47
White quartz-pebbles	20
Subangular flints	15
Chert and ragstone	10
Lydian stone and quartzite, and light-coloured sandstone-pebbles	8
	100

* Mr. Reid's Memoir, p. 53.

† Except a doubtful specimen of *Buccinum undatum* at Pakefield.

Besides these constant constituents, I found in this shingle, which is sometimes concreted by iron-peroxide, some large subangular fragments of a fine-grained granite and mica-slate; and Mr. Reid mentions the occurrence of "a boulder of greyish granite measuring $2 \times 1\frac{3}{4}$ feet among the clay pebbles and bones," at the base of the Series, a short distance eastward of Runton Gap (p. 28).

Fig. 8.—Section at West-Runton (or Woman-Hythe) Gap.



	feet.
a. Subangular gravel	8
b. Chalk-rubble	5
c. Sand and gravel, with patches of broken shells	6
d. Boulder-clay	15
e. Sand and ironstone	2
f. Light-coloured sands	6
g. Loamy sands, very variable, with a few shells in position	3
h. Shingle, with shells mostly in fragments.....	4
i. Fine sand, variable	2
j. Peaty bed, with freshwater shells	2

The position of the Crag bed described by Mr. Reid is shown in faint outline below the base line on the left: g is not carried far enough.

The section at the Gap (fig. 8) does not show the beds down to the Chalk, but this is shown by the sections in faint lines which are given beneath.

This brings us to the moot point concerning the age and relation of the so-called Weybourn Crag to the other Crags. According to Mr. S. V. Wood it is synchronous with the Bure-Valley Crag or the Pebbly Beds, and therefore newer than the Forest-Bed Series; whereas Mr. Reid places it at the base of, and consequently as older than, that Series, although still newer than the Norwich Crag. Mr. H. B.

Woodward also places it in the same division as the Bure-Valley Crag.

Although the Forest-Bed Series thins off to the north, the fresh-water bed at the base of the Mundesley Series is prolonged, and forms a definite zone whereby the relative position of the associated strata can be fixed. These beds are in general thin, and the fossils few and badly preserved, but at one spot, a short distance east of Runton Gap, Mr. Reid found beneath them a bed of Crag abounding in well-preserved shells (fig. 8). The section he gives as under:—

		feet.
"Forest-bed."	Laminated clay full of lignite, small twigs and occasional fir-cones, and fragments of <i>Mytilus</i>	?
		?
Weybourn Crag.	Mass of rolled clay-pebbles on uneven surface.	?
	Grey shelly Crag, in the lower part alternating with thin loams.....	about 4
	Bed of unworn flints mixed with clay, and containing <i>Mya arenaria</i> and <i>Tellina obliqua</i> in the position of life.....	about 4½
Soft chalk with Paramoudras and rings of flint.		

His list of the Mollusca is the most reliable one we have for the Weybourn Crag, for at this spot it is free from any possible intermixture with the Pebbly Beds * :—

Lamellibranchiata.

Astarte borealis, Chemn.
 ———, oval var.
 ——— compressa, Mont.
 ——— incrassata, Brocchi.
 ——— crebricostata, Forbes.
 ——— sulcata, Da Costa.
Cardium echinatum, Linn.
 ——— edule, Linn.
 ——— grœnlandicum, Chemn.
Corbula contracta?, Say.
 ——— striata, W. & B.
Cyprina islandica, Linn.
Donax vittatus, Da Costa.
Leda oblongoides, S. Wood.
Lucina borealis, Linn.
Mactra ovalis, J. Sby.
 ——— stultorum, Linn.
Mya arenaria, Linn.
 ——— truncata, Linn.
Mytilus edulis, Linn.
Nucula Cobboldiæ, Sby.
Pecten opercularis?, Linn.
Pholas crispata, Linn.
Saxicava arctica, Linn.
 ———, gigantic var.
Scrobicularia plana, Da Costa.
Tellina balthica, Linn.
 ——— lata, Gmelin (*T. calcaria*).
 ——— obliqua, Sby.
 ——— prætenuis, Leathes.

Gasteropoda.

Buccinum undatum, Linn.
Bulla alba, Brown.
Cancellaria viridula, Fabr.
Chiton, sp.
Hydrobia (*Paludestrina*) *subumbilicata*, Mont.
Littorina littorea, Linn.
 ——— rudis, Maton.
Melampus (*Conovulus*) *pyramidalis*, J. Sby.
Natica catena, Da Costa.
 ——— clausa, Brod. & Sby.
 ——— helicoides, Johnst.
Pleurotoma (*Clavatula*) *linearis*, Mont.
 ——— turricula, Mont.
Purpura lapillus, Linn.
Scalaria grœnlandica, Chemn.
 ——— Trevelyana, Leach.
 ——— Turtonis, Turt.
Tectura virginea, Müll.
Trochus tumidus?, Mont.
 ———, sp.
Trophon antiquus, Linn.
 ———, reversed var.
Turritella terebra, Mont. (=communis, Risso).
Velutina lævigata, Linn.

Brachiopoda.

Rhynchonella psittacea, Chemn.

* Mem. Geol. Survey, p. 18.

As the upper part of this section belongs to the base of the Mundesley Series or else to the Forest-Bed Series, this Crag (in the absence of the Chillesford Clay, which may have been denuded, or may be represented by the mass of clay pebbles) occupies the position of the Fluvio-marine Crag of Norwich, while there is nothing to show relation to the Forest-Bed Series. The presence of the pebbles and the eroded surface show, on the contrary, a decided break between this Crag and the overlying beds. For these reasons, and also because all the 51 species in this list, are, with two exceptions, Crag species, I would assign this bed to the Norwich Crag. One exception is *Tellina balthica*, which has been found on this north-eastern coast only in the Crag Beds of the Bure Valley; the other *Astarte crebricostata*, which is only recorded from the Upper Glacial Beds. Besides these, there are found here two shells—*Cardium echinatum* and *Astarte incrassata*—which are Red-Crag species. On the other hand, of the 36 species recorded by Mr. H. B. Woodward from the Bure-Valley Beds, only 23 appear in the above list.

Mr. Reid, on the assumption that this Crag is the equivalent of the Bure-Valley Crag*, considers that Messrs. Wood and Harmer are wrong in placing the latter above the Forest Bed; but if I am right in referring this patch of Crag to the Norwich Crag, then the shingle *h* (fig. 8) above the lower part of the "Forest Bed" would correctly represent, as supposed by Messrs. Wood and Harmer, the Bure-Valley Beds.

It is evident that the palæontological differences are very small. The only marine Bure-Valley shell not found in the Crag at Norwich is *Tellina balthica*. But this shell is extremely uncertain in its habitat, and a slight difference in the quality of the water or of the bottom might account for its presence in the one district and its absence in the other. Dr. Gwyn Jeffreys informed me that at the present day it is abundant in Swansea Bay, although it is not to be found nine miles distant in Oxwich Bay. It prefers brackish waters, and "though in the main a northern shell, it is likewise common in many parts of the south of Europe." It is clear likewise that this Runton Crag presents far closer analogies with the more distant Crag at Norwich than with the Bure-Valley Crag in the intermediate area.

Between Runton and Weybourn, where the Forest Series entirely thins out, or few traces of it remain, the overlying Pebbly Beds come into juxtaposition with the Fluvio-marine Crag beneath that Series. The slight palæontological and lithological differences are then not sufficient to furnish any apparent distinction, except possibly in places where the Westleton shingle retains its more pronounced characters. The true faunal value of these zones can only be correctly determined by selecting localities, such as the one above, where they cannot possibly be in contact.

* Mr. Reid, however, suggests the possibility that the Weybourn Crag, as a whole, is the equivalent of the Chillesford and Aldeby Beds.

§ 5. *Conclusion.*

The plan I have therefore adopted has been to confine myself to those localities where, owing to the Chillesford Clay or Forest Beds intervening, there is no possibility of the Westleton Shingle having come in contact with the Norwich Crag. For this purpose I have limited the list of the marine Molluscan fauna of the Westleton and Mundesley beds (see p.115) to the species found at Reydon, Easton Bavant, Bacton, Mundesley, and West Runton (the last two being in the *Leda-myialis* Bed of Reid). This gives a list of only 19 species, all living, excepting possibly two, about which the most competent authorities differ. *Tellina obliqua* was considered by Sowerby and Searles Wood to be an extinct species, whereas by Forbes and Hanley and Gwyn Jeffreys it was considered to be a variety of *T. lata*, a living northern species; according to Jeffreys *Nucula Cobboldiæ* is now represented in the seas of Japan by a variety of the same species; whilst Searles Wood considered that they are distinct and that the Crag species is an extinct form. With two exceptions all the others are existing British species, although on the whole they are of northern types—10 ranging to Scandinavia and 9 to the Arctic seas: *Astarte borealis* is Scandinavian and Arctic only. The elimination of the more southern types seems to constitute the distinctive feature of this fauna.

The land- and freshwater Mollusca, of which there are 53 species, are from the freshwater beds (*g* to *m*, fig. 7) of the Mundesley series—the Upper Freshwater and *Leda-myialis* Beds of Mr. Reid. They are, with three questionable exceptions, all living species. All the others except four are species still living in Britain, but having a very ubiquitous range from north to south. Of the four latter, *Valvata fluviatilis* is now living in Belgium and Germany; *Hydrobia Steinii* in the north of Europe; *H. marginata* in the South of France; while *Corbicula fluminalis* ranges from Thibet to the Nile. The three extinct species include a slug (*Limax modioliformis*); *Paludina gibba*, formerly referred to *P. contecta*, a British and Finnish species*; and *Hydrobia runtoniana*: they are found fossil also in North Germany.

The freshwater bed (*j*) at West Runton is rich in Fish-remains. There are 10 species, all still living in the rivers of this country.

The Reptiles (2) and Amphibia (4), found in the same bed are also living British species.

Of the 21 species of Mammalia, 6 are extinct; and it is to be remarked that out of the total number there are 14 which are not met with in the Forest Bed and make their first appearance in this stage, and it is the same with all the Reptiles and Amphibians.

The 24 Plants are of special interest from the rarity of plant-remains in such deposits. They are all living species,—19 still living in this country, 5 being now relegated to more northern latitudes, and, as in the case of the Mammalia, a large proportion (14) are confined to the Mundesley freshwater beds, though this may

* *P. glacialis* and *P. media* are doubtful, and thought by Mr. Reid to be derived.

possibly be due to the circumstance that they consist in large part of small seeds which may have escaped notice or been destroyed from having been lodged in a matrix not so favourable for their preservation as the other bed.

In conclusion, if I am right in my interpretation of these intricate sections, the Crag of the Weybourn Cliffs has no standing *per se*, but results from the junction of the Bure-Valley and Norwich Beds; while with respect to the Bure-Valley Crag, as at present held, I cannot but think it open to the same doubt, although I believe in the existence of an upper division with marine shells, newer than the Norwich Crag, but having a much more limited fauna.

The construction I would therefore put upon the Pre-Glacial strata underlying the Boulder-clay Series on the coast of Norfolk is as under:—

- | | | |
|---|-----------|--|
| <p>THE WESTLETON AND
MUNDESLEY BEDS. (<i>The
Mundesley type.</i>)</p> | <p>{</p> | <p>1. Laminated clays, sands, and shingle with plant-remains and freshwater shells (<i>The Arctic Freshwater Bed of Reid.</i>)</p> |
| | <p>2.</p> | <p>Sand and quartzose shingle with marine shells (<i>The Leda-myalis Bed of King and Reid.</i>)</p> |
| | <p>3.</p> | <p>Carbonaceous clays and sands, with flint-gravel and pebbles of clay, driftwood, land- and lacustrine shells and seeds. (<i>The Upper Freshwater Bed of Reid.</i>)</p> |
| <p>THE FOREST-BED GROUP *</p> | <p>{</p> | <p>4. A greenish clay, sandy and laminated in places, containing abundant Mammalian remains and driftwood, with stumps of trees standing on its surface. (<i>The Forest- and Elephant-bed of authors. The Estuarine division of Reid.</i>)</p> |
| | <p>5.</p> | <p>Ferruginous clay, peat with land and freshwater remains, and gravel. (<i>The Lower Freshwater Bed of Reid.</i>)</p> |

The marine fauna of the "Mundesley and Westleton Beds" is very limited and often fails us. On the other hand there is a structural feature singularly persistent, that is, the presence throughout, from Southwold to Bacton, Mundesley, Runton, and Weybourn, of a shingle everywhere of the same character. The intercalated clay and peaty beds, with their land and freshwater remains, are subordinate, and confined to the east coast of Norfolk.

Although allied to the Norwich Crag by their marine fauna, and conformable with it in places, the Westleton and Mundesley beds constitute on the whole a distinct and separate group formed under changed physiographical conditions,—conditions that led to their extension far beyond the Crag area †; while, as I shall

* The fauna and flora of these beds are of peculiar interest, and have for years past been the object of active research on the part of many geologists. Large collections of the remarkable Mammalian remains have been made by Miss Anna Gurney, Mr. J. Gunn, and Mr. R. Fitch, and are now in large part preserved in the Norwich Museum. The later careful researches of Mr. C. Reid have made great additions to the smaller life and vegetable forms. (For details and lists, see Mr. C. Reid's Cromer Memoir before cited, and Mr. John Gunn's 'Sketch of the Geology of Norfolk.')

† We have evidence, however, of a similar southern drift in the presence of chert from the Lower Greensand, and quartz, quartzites, and other such specimens either from the Ardennes or the Rhenish Provinces, at the base of the Red Crag, and somewhat similar indications at the base of the Coralline Crag.

hope to show in the second part of this paper, they are separated from the deposits of the Glacial Period by further and equally important physiographical changes. In one case we have currents and drifts from the south and east; in the other, northern drifts solely. The importance of these features will be seen when we come to questions connected with the relative age of the drifts in the London Basin, especially as I take this Westleton Shingle as the base of the Quaternary Series, and as marking the time when the existing forms of life, both animal and vegetable, began to predominate in this country.

Lists of the Organic Remains of the Westleton and Mundesley Beds of Norfolk, compiled in greater part from the lists of Mr. Clement Reid's Memoir on Cromer, but grouped in accordance with the stratigraphical order proposed in the foregoing pages.

PLANTÆ.

Cryptogams.

Chara, sp.	
Hypnum turgescens, <i>Jens.</i>	Moss. (Northern regions.)
Equisetum, sp.	
Osmunda regalis, <i>Linn.</i>	Fern-royal.

Gymnosperms.

Pinus sylvestris, <i>Linn.</i>	Scotch Fir.
— abies, <i>Linn.</i>	Spruce Fir.
Taxus baccata, <i>Linn.</i>	Yew.

Monocotyledons.

Carex & Cyperus, sp. (several)	Sedges.
Juncus, sp.	Rush.
Potamogeton flabellatus, <i>Bab.</i>	} Pond-weeds.
— heterophyllus, <i>Schreb.</i>	
— trichoides, <i>Cham.</i>	
Zannichellia palustris, <i>Linn.</i>	Horned Pond-weed.

Dicotyledons.

Alnus glutinosa, <i>Linn.</i>	Alder.
Betula nana, <i>Linn.</i>	Dwarf Birch.
Ceratophyllum demersum, <i>Linn.</i>	Hornwort.
Corylus avellana, <i>Linn.</i>	Hazel.
Hippuris vulgaris, <i>Linn.</i>	Mare's-tail.
Menyanthes trifoliata, <i>Linn.</i>	Bog-bean.
Myriophyllum, sp.	Water Milfoil.
Prunus communis, <i>Huds.</i>	Sloe.
Ranunculus aquatilis, <i>Linn.</i>	Water Crowfoot.
—, sp.	Buttercup ?
Rumex maritimus, <i>Linn.</i>	Golden Dock.
Salix polaris, <i>Wahlb.</i>	Polar Willow.
Thalictrum flexuosum ?, <i>Bernh.</i>	Meadow Rue.
Trapa natans, <i>Linn.</i>	Water Chesnut. (Central Europe.)
Trifolium ?	Clover ?

INSECTA.

Donacia sericea, <i>Linn.</i>	| Timarcha ?, sp.
Notiophilus aquaticus, <i>Linn.</i>	

ENTOMOSTRACA.

- Cypris Browiana? (Extinct.)
 Candona candida, Müll.

MOLLUSCA.

Marine.

- Gasteropoda.*
 Buccinum undatum, Linn.
 Littorina littorea, Linn.
 — rudis, Maton.
 Natica catena, Da Costa.
 Purpura lapillus, Linn.
 Scalaria grœnlandica, Chemn.
 Trophon antiquus, Linn.
 — —, var. *contrarius*.

- Lamellibranchiata.*
 Astarte borealis, Chemn.
 Cardium edule, Linn.
 Cyprina islandica, Linn.
 Leda myalis, Couth.
 Mya truncata, Linn.
 — arenaria, Linn.?
 Nucula Cobboldiæ, Sby.?
 Ostrea edulis, Linn.
 Pholas crispata, Linn.
 Saxicava arctica, Linn.
 Tellina balthica, Linn.
 — obliqua, Sby.?

Land and Freshwater.

Lamellibranchiata.

- Anodonta cygnea, Linn.
 — —, var. *anatina*.
 Corbicula fluminalis, Müll.
 Pisidium amnicum*, Müll.
 — (casertanum), Poli.
 — pusillum, Gmel.
 — nitidum, Jenyns.
 — roseum, Scholtz.

- Pisidium Henslowianum, Shep.
 — pulchellum, Jenyns.
 Sphærium corneum, Linn.
 — rivicola, Leach.
 — ovalis, Fér.
 Unio pictorum, Linn.

Gasteropoda.

- Ancylus lacustris, Linn.
 Bythinia tentaculata, Linn.
 — Leachii, Sheps.
 Carychium minimum, Müll.
 Clausilia, sp.?
 Helix arbustorum, Linn.
 — nemoralis, Linn.
 — hispida, Linn.
 — concinna, Jeffr.
 — fulva, Müll.
 — pulchella, Müll.
 — pygmæa, Drap.
 Hydrobia marginata, Mich.
 — Steinii, v. Martens.
 — runtoniana, Sandb.
 Limax Sowerbyi, Fér.
 — modioliformis, Sandb.
 Limnæa limosa (peregra), Linn.
 — stagnalis, Linn.
 — palustris, Müll.
 — truncatula, Müll.

- Paludina gibba, Sandb.†
 Physa fontinalis, Linn.
 Planorbis corneus, Linn.
 — albus, Müll.
 — crista, Linn.
 — carinatus, Müll.
 — complanatus, Linn.
 — vortex, Linn.
 — spirorbis, Linn.
 — contortus, Linn.
 — nitidus, Müll.
 Pupa marginata, Drap.
 Succinea putris, Linn.
 — oblonga, Drap.
 Valvata fluviatilis, Colb.
 — piscinalis, Müll.
 — —, var. *antiqua*.
 — cristata, Müll.
 Vertigo antivertigo, Drap.
 Vitrina pellucida, Müll.
 Zua lubrica, Müll.

* *Pisidium astartoides*, being generally considered a variety of *P. amnicum*, is omitted, though Mr. C. Reid shows some reason for its being a distinct species.

† This is Dr. Sandberger's species, determined from specimens sent by Mr. Reid.

VERTEBRATA.

Pisces.

<i>Acerina vulgaris</i> ?	Ruff.
<i>Acipenser</i> , sp. ?	Sturgeon.
<i>Abramis brama</i> , <i>Linn.</i>	Bream.
<i>Barbus vulgaris</i> , <i>Flem.</i>	Barbel.
<i>Leuciscus erythrophthalmus</i> , <i>Linn.</i>	Rudd.
— <i>rutilus</i> , <i>Linn.</i>	Roach.
— <i>cephalus</i> ?, <i>Linn.</i>	Chub.
<i>Perca fluviatilis</i> , <i>Linn.</i>	Perch.
<i>Tinea vulgaris</i> , <i>Cuv.</i>	Tench.
<i>Esox lucius</i> , <i>Linn.</i>	Pike.

Amphibia.

<i>Bufo</i> , sp.	Toad.
<i>Rana esculenta</i> ..	Edible Frog.
— <i>temporaria</i> ?	Common Frog.
<i>Triton cristatus</i>	Common Water-Newt.

Reptilia.

<i>Pelias berus</i>	Viper.
<i>Tropidonotus natrix</i>	Common Snake.

Aves.

<i>Anas</i> ?, sp.	Duck.
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Mammalia.

<i>Arvicola amphibius</i> , <i>Linn.</i> ?	Water-Vole.
— <i>arvalis</i> , <i>Pallas</i>	Vole. (Central Europe. Extinct in Britain.)
— <i>glareolus</i> , <i>Schreb.</i>	Bank-Vole.
— <i>intermedius</i> , <i>Newton</i>	Extinct.
— <i>gregalis</i> , <i>Pallas</i>	Vole. (Central Europe. Extinct in Britain.)
<i>Canis vulpes</i> , <i>Linn.</i> ?	Fox.
<i>Castor europæus</i> , <i>Ow.</i>	Beaver.
<i>Cervus Sedgwickii</i> , <i>Falconer</i>	(Extinct.)
— <i>verticornis</i> , <i>Dawkins</i>	(Extinct.)
<i>Equus caballus-fossilis</i> , <i>Rütim.</i>	Horse.
<i>Martes sylvatica</i> , <i>Linn.</i>	Marten.
<i>Mus sylvaticus</i> , <i>Linn.</i>	Long-tailed Field-mouse.
<i>Myogale moschata</i> , <i>Linn.</i>	Shrew, var. (Russia.)
<i>Rhinoceros etruscus</i> , <i>Falconer</i>	Rhinoceros. (Extinct.)
<i>Sciurus vulgaris</i> , <i>Linn.</i> ?	Squirrel.
<i>Sorex vulgaris</i> , <i>Linn.</i>	Common Shrew.
— <i>pygmæus</i> , <i>Pallas</i> ?	Lesser Shrew.
<i>Spermophilus</i> , sp.	Marmot.
<i>Talpa europæa</i> , <i>Linn.</i>	Mole.
<i>Trogontherium Cuvieri</i>	Gigantic Beaver. (Extinct.)
<i>Ursus spelæus</i> , <i>Blum.</i>	Cave-Bear. (Extinct.)

DISCUSSION.

The CHAIRMAN remarked on the importance of the problem of the correlation of the East Anglian Drifts with those of the Thames basin, and of the especial qualifications of the Author of the paper for dealing with this great question.

Mr. CLEMENT REID noticed that the Author went further than he had previously done in accepting recent results. With regard to the correlation of the beds on the northern coast of Norfolk with those of Westleton, he thought it most dangerous to take the unfossiliferous beds of the latter place as a type. On the Norfolk coast the Weybourn Crag was classed by himself with the Forest Bed as a matter of convenience. Its fauna was sufficiently marked to show that it was slightly newer than the Norwich Crag. It always contained *Tellina balthica*, whilst that shell had never been found in the Norwich Crag. The fauna was also slightly more Arctic than that of the Norwich and Chillesford Crags. The beds which the Author bracketed as the Forest Bed, did not include the Upper freshwater bed. He gave reasons for his having himself included it with the Forest-Bed series. As to classing the Arctic freshwater bed with the Upper freshwater bed, he noted that the floras showed a difference of climate of 20°, and he considered the grouping together of the two inadvisable. He thought it unsafe to use the term Westleton Beds until some definite fauna was found at Westleton. If any definite name for the whole series was used, Mr. S. V. Wood's old term "Bure-Valley Beds" should be adopted.

Mr. H. B. WOODWARD believed that, for purposes of correlation, the terms Norwich-Crag Series, Forest-Bed, and Glacial Series should be used, while minor subdivisions, such as Bure-Valley Beds, Chillesford Beds, and Westleton Beds, might, with advantage, be dropped. He had himself come to the conclusion that the Westleton Beds were in the Glacial series. He agreed with the Author that the Weybourn Crag was Norwich Crag, for he placed it on the same horizon as the Bure-Valley Beds. Unfortunately beds which belong to a horizon higher than the Forest Bed had also been included with the Bure-Valley Beds by Mr. S. V. Wood. The name Mundesley Beds was a useful local term for these higher beds; but if the term Westleton Beds was associated with them, it might turn out in the end that there were no "Westleton Beds" at Westleton.

Mr. J. A. BROWN had obtained a stone apparently worked by human agency from the Weybourn Crag of Runton Gap. He had also found a black flake at Weststrand in peat.

Mr. TOPLEY remarked on the indebtedness of the Society to Prof. Prestwich for his many years' labour on this ground. The Survey had now agreed not to mark by any definite name these beds under dispute. Whatever classification might eventually be adopted, the lines on the Geological Map marked actual lithological differences. He would deprecate the re-introduction of the term Bure-Valley Beds.

The AUTHOR, in reply, stated that whilst Mr. Wood was working from north to south, he himself had worked from south to north. He had come to the conclusion that the beds, as he understood them, were distinct, both as regards their association and classification, from those which Mr. Wood had described as the Bure-Valley Beds. *Tellina balthica* is very irregularly distributed at the present day, and has a wide southern range. When the Chillesford Clay is absent, confusion arises from intermixture of Norwich-Crag and Westleton forms, whence the modified fauna known as the Weybourn Crag. Some of the fossils of the uppermost beds of his Forest-Bed series may also have been washed into the Mundesley or Westleton Beds. It is difficult to show that the Forest series is different from the Chillesford Beds; though his impression was that it is different and newer. The subordinate Arctic Freshwater Bed is of small dimensions and shows the setting in of cold, which we should expect as introductory to glacial conditions.

9. *On the RELATION of the WESTLETON BEDS, or PEBBLY SANDS of SUFFOLK, to those of NORFOLK, and on their EXTENSION INLAND; with some OBSERVATIONS on the PERIOD of the FINAL ELEVATION and DENUDATION of the WEALD and of the THAMES VALLEY, &c.* By JOSEPH PRESTWICH, M.A., D.C.L., F.R.S., F.G.S., &c. (Read December 18, 1889.)

PART II.

[PLATE VII. ; see also the Map in Part III.]

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2. Range inland of the Westleton Beds north of the Thames: Suffolk (p. 124); Essex (p. 128); Middlesex (p. 136); Hertfordshire (p. 137); South Buckinghamshire (p. 139); South Oxfordshire (p. 140); Berkshire (p. 141)	124
3. Westleton Beds on the South of the Thames: Kent; Surrey and Hampshire	143
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7. Conclusion—Elevation of the Westleton sea-floor; Formation of the Gorge of the Thames at Goring; Measures of Glacial and Post-Glacial Denudation. Age of the Chalk and Oolitic Escarpments... ..	148

1. *Objects of the Paper &c.*

In the first part of this paper * the relation of the Westleton Beds in the Eastern Counties to the Crag Series on the one hand, and to the Glacial Series on the other, was discussed. My object in this part is to trace the extension of the former beyond the area of the Crag, and to show that a Westleton Shingle-bed passes progressively over the Red Crag, the Tertiary strata, and the Chalk, and ranges westward through the length of the London Basin, while it rises to considerable heights above the Glacial Drifts and exists independently of them; and although it occupies only isolated and detached outliers, if the relation of these outliers to the Pre-Glacial Beds of Suffolk and Norfolk—the position of which has been proved—can be determined, we shall then have a definite base by which to correlate them and establish the order of succession and relative age of the many Drift Beds of the London Basin.

I purpose therefore to proceed step by step and to take each stage separately, confining myself now to the oldest and highest stage, where the distinctive characters of composition are best defined.

* Quart. Journ. Geol. Soc. for February 1890, p. 84.

E

Bures.
60.

Westleton.

Southwold.



- a - Post glacial Drift (site of)
- b Boulder Clay and Gravel.
- c Westleton Beds.
- d Southern Drift.
- e Brentwood Shingle.

N
Hatfield
200.

N
Writtle Park.
310.

- 1 - Crag and Chillesford Beds.
- 2 - Tertiary Strata.
- 3 - Chalk.
- 4 - Upper Greensand & Gault.
- 5 - Lower Greensand.
- 6 - Wealden.



— Scale. —

Vertical — $\frac{1}{10}$ inch = 100 feet.

Horizontal — 1" inch = $5\frac{1}{2}$ miles.

MARKS

- A - Boulder Clay.
- A' - Boulder Clay Gravel.
- B - Westleton Beds.
- C - Crag Beds.
- D - Bagshot Sands.
- E - London Clay.



Vertical Scale
1 inch = 60 feet



DIAGRAM - SECTIONS OF THE PRE-GLACIAL HILL-DRIFTS OF THE THAMES BASIN.

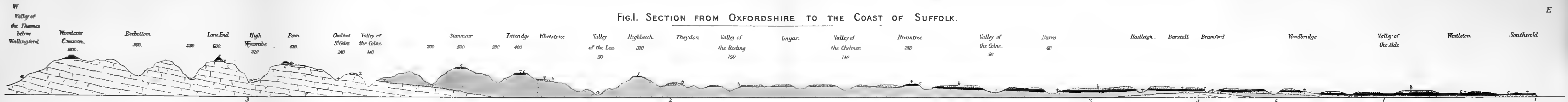


FIG. 2. SECTION FROM SURREY TO BUCKINGHAMSHIRE.

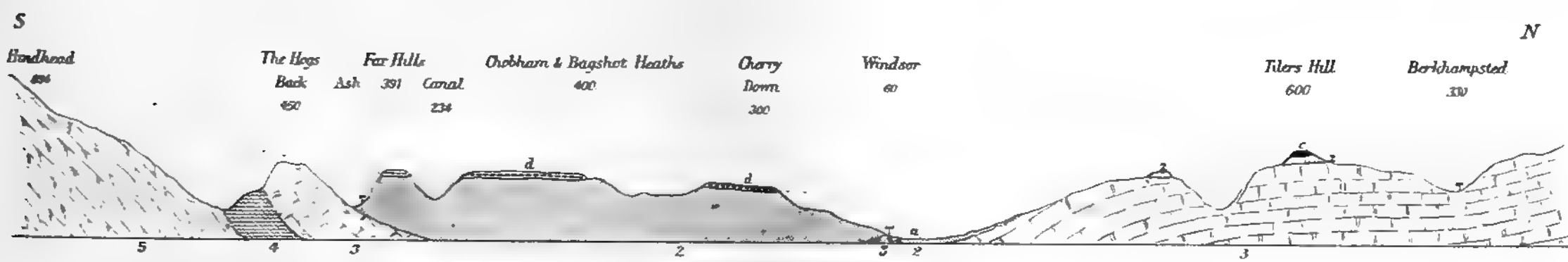
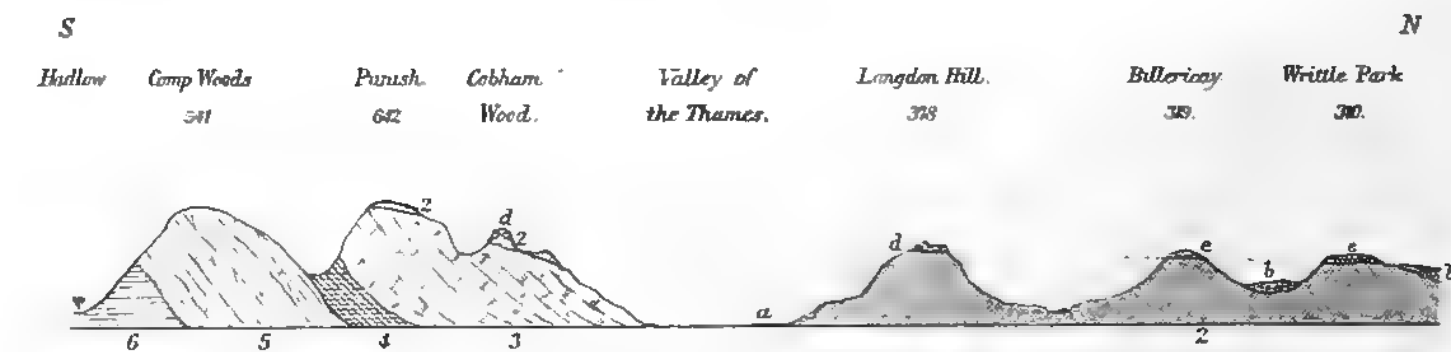


FIG. 3. SECTION FROM SURREY TO HERTFORDSHIRE.



FIG. 4. SECTION FROM KENT TO ESSEX.



- a - Post glacial Drift (site of)
 - b - Boulder Clay and Gravel.
 - c - Westleton Beds.
 - d - Southern Drift.
 - e - Brentwood Shingle.
 - 1 - Gray and Chillesford Beds.
 - 2 - Tertiary Strata.
 - 3 - Chalk
 - 4 - Upper Greensand & Gault.
 - 5 - Lower Greensand.
 - 6 - Wealden
- Scale —
Vertical — 1/2 inch = 100 feet
Horizontal — 1 inch = 5 1/2 miles.

FIG. 5. RAILWAY CUTTING, BRENTWOOD.

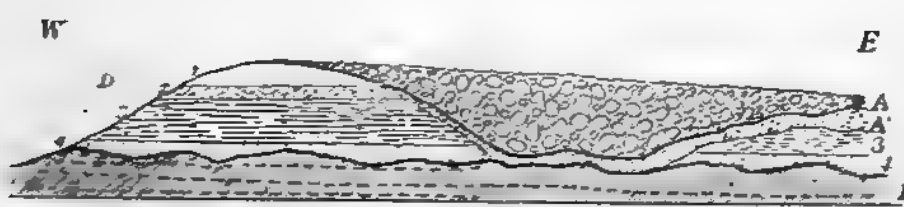


FIG. 6. RAILWAY CUTTING, BLACK NOTLEY NEAR BRAINTREE.

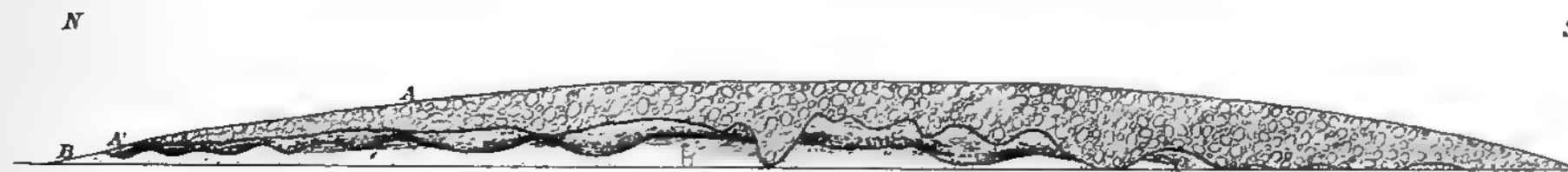
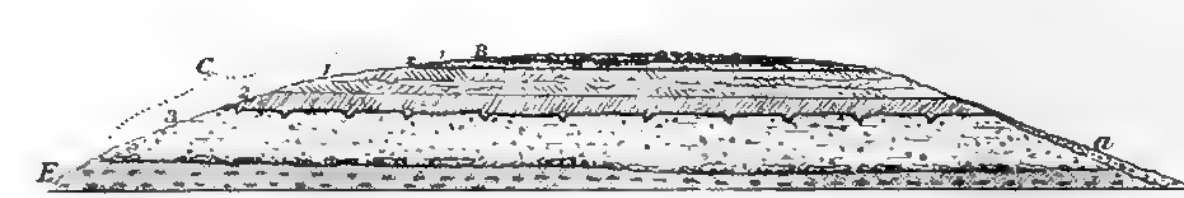


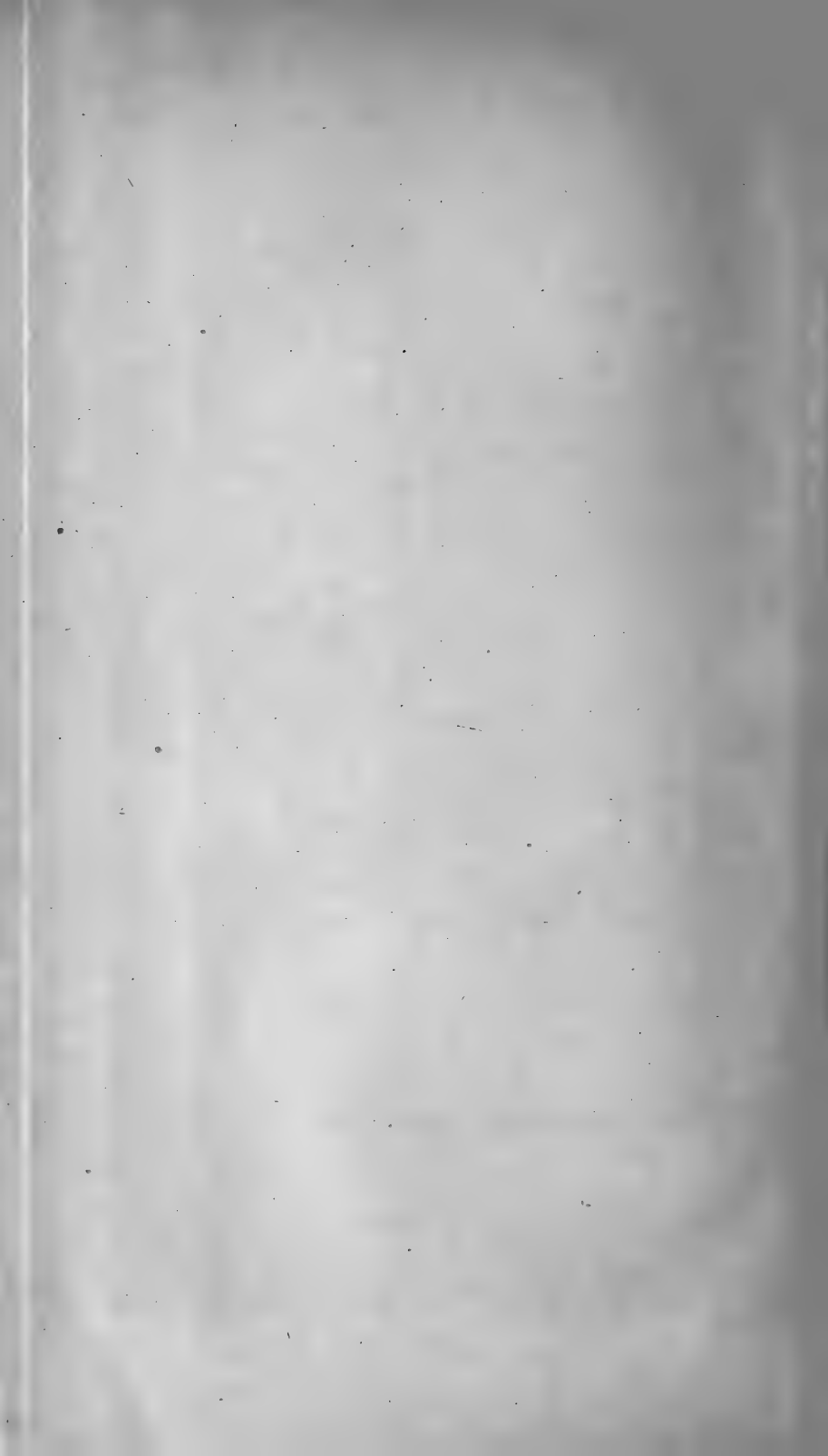
FIG. 7. RAILWAY CUTTING BETWEEN CHAPPLE AND MARKS TEY.



FIG. 8. RAILWAY CUTTING, KYSON NEAR WOODBRIDGE.



- A - Boulder Clay
 - A' - Boulder Clay Gravel.
 - B - Westleton Beds.
 - C - Gray Beds.
 - D - Bagshot Sands.
 - E - London Clay.
- Vertical Scale
1 inch = 60 feet



These are lost in later stages, owing to frequent reconstruction, but we can then follow by levels.

In 1847* I showed that in the neighbourhood of London there were hill-gravels as distinct from valley-gravels, but I was not then in possession of any clue whereby to fix their separate age. Subsequent observations, especially aided by the cuttings on the Great Eastern Railway then in course of construction, enabled me to follow the Pre-Glacial Beds of Suffolk in their inland range, and to recognize their higher position in relation to the Drifts of the Thames Valley.

In my paper of 1871 on the Westleton Beds † I briefly alluded to their extension into the Thames Valley area, but reserved the details for subsequent description. Other occupations and the need for verification of some of my early observations led to a long delay in publication, though in 1881 ‡ I gave a short preliminary notice of some of the hill-drifts in the London Basin—such as those at High-beech, Barnet, Southgate, Hertford, Hatfield, South Mimms, St. Albans, Tiler's Hill, Horsington, and Bowsey Hill §—which are capped by Drift Beds of Westleton age. I now purpose giving these in detail, and I only regret that owing to the lapse of time many of the sections I have to describe are no longer visible. The delay, however, gives me the advantage of the observations recorded by other geologists, and especially by Mr. Whitaker and other officers of the Geological Survey, and also enables me to avail myself of the heights and contours given in the last published sheets of the 1-inch Ordnance Survey, so indispensable in an inquiry of this description, and for which I had previously to depend on the observations I had made with an aneroid barometer ||.

In 1864, Mr. Whitaker, in his account of the Post-Pliocene Series ¶ of parts of Middlesex, Hertfordshire, Buckinghamshire, Berkshire, and Surrey, alludes to the occurrence of a "gravel wholly or for the greater part made up of flint pebbles" on the tops of various hills in Hertfordshire and Buckinghamshire.

In 1877 he stated that there were two gravels in East Essex**,

* 'The Ground Beneath us,' p. 30.

† Quart. Journ. Geol. Soc. vol. xxvii. p. 477.

‡ Reports Brit. Assoc. p. 420. I was not then acquainted with Mr. Whitaker's latest Memoir.

§ Other hills were named, but these relate to the Southern Drift, which I now take separately.

|| I regret also that I find it impossible to revisit, as I had intended, the many localities described, in order to check and revise my early observations, the greater number of which were made before my views were matured. Consequently, there may be inaccuracies which have escaped me, or analogies which I may have overlooked. I could also have wished to have given greater certainty to the percentage values of the Westleton and Southern Drifts—a plan which only occurred to me after much of the work had been done. I fear I may have overestimated the relative proportions of some of the essential constituent materials, but not to such an extent as to vitiate the general argument, while the facts, I trust, are recorded with sufficient accuracy to justify the conclusions at which I have arrived.

¶ Mem. Geol. Survey, Expl. Sheet 7, p. 69 (1864).

** "On the Geology of the Eastern End of Essex (Walton-on-Naze and Harwich)," Expl. of Sheet 48 S.E. p. 16.

one of which he considered to be of Glacial age, and the other Post-Glacial; and in the following year he noticed a small deposit of pebble-gravel capping the hills near Hertford*, which he thought might "be of Pre-Glacial age, but all that is known of it with absolute certainty is that it is older than the Boulder Clay (which occurs over it in other parts), and Mr. S. V. Wood, Jun., has classed it with his 'Middle Glacial.'"

In 1875, and again in 1880, Mr. Whitaker noticed in more detail † this "Pre-Glacial (?) Pebble-Gravel," and assigns to it more definite limits. He says, "On the tops of the London-Clay hills there is often a mass of sandy gravel of an exceptional sort, that is to say, it is almost wholly wanting in the more or less angular pieces of flint that form the greater part of the other gravels to be described, and, like the far older gravel-beds of the Blackheath and Bagshot Series, its component stones have been rounded into the form of pebbles. Showing at first sight a very great likeness to these old Tertiary pebble-beds, after a more careful examination this gravel is seen to be easily distinguished from them; for whilst the former are made up of flint-pebbles, that is not the case with the latter, which contains also a large proportion of pebbles of quartz and quartzite, and here and there a sub-angular flint." "The flint-pebbles have probably been derived from the destruction of the old Tertiary pebble-beds; but the pebbles of quartz, quartzite, and other older rocks that occasionally occur must have been derived from beds that are not found anywhere in our district.

"Of the age of this gravel we cannot yet speak with certainty. It is newer than the Lower Bagshot Beds, for it is known to overlies them; and it is older than the Boulder Clay, which is found above it, but between these extremes we are left to reason by analogy and by the evidence given by the manner of its occurrence."

"From its occurrence on the tops of the hills, whilst the Middle Glacial gravel often lies at their base, or on their flanks, it would seem that the pebble-gravel is the older of the two and was deposited long before those hills were cut into their present form, a process which must have been somewhat advanced before the other gravel was laid down. It is possible, therefore, that the pebble-gravel may represent some part of the 'Lower Glacial Drift' (of Mr. Wood), any known occurrence of which is, however, as far distant as the Crag."

"The chief localities are Stanmore Heath from Shenley south-eastward, west and north of Barnet, and at Totteridge, in Middlesex; at Highbeech, Jacks Hill, and Gayne's Park, east of Epping, in Essex, and at Shooter's Hill, in Kent."

In the larger valuable memoir ‡, published since these pages were written, Mr. Whitaker describes these Beds, which he places with

* "The Geology of the N.W. part of Essex and the N.E. part of Herts," Mem. Geol. Survey, Expl. of Sheet 47, 1878, p. 32.

† "Guide to the Geology of London and the Neighbourhood," Mem. Geol. Survey (1st edit. pp. 49-51, and 3rd edit. pp. 54-57).

‡ 'Geology of London,' vol. i. p. pp. 290-298 (1889).

“Doubtful Deposits,” in greater detail and with some slight changes, and retains the open term of “Pebbly Gravel.”

In 1867* Mr. Searles V. Wood, Junr., called attention to the relations between the Post-Glacial, Middle, and Upper Glacial deposits of the Valley of the Thames, in connexion with the position of the latter two on the hills and in the valleys of this area. Prof. Boyd Dawkins showed, however, that his contention—based on theoretical grounds, that certain valleys “could have had no existence at the period of the Glacial Clay”—was not in accordance with the Survey observations.

In 1868 † Prof. T. M^cK. Hughes described an outlier of peculiar gravel he had noticed near Hertford, under the term of “Gravel of the Upper Plain” in contradistinction to the “Gravel of the Lower Plain.” The latter he referred to the Glacial Series. Of the other he says, “From their great extent, persistent character, and uniform level, I think these gravels of the Higher Plain must be a marine deposit; but without a careful examination of the old coast-line, and of their behaviour as they approach the Crag country, I should not like to give any opinion as to their age.” He further states that they were of great antiquity and older than the Boulder-clay.

Mr. Wood, commenting on this communication, contended that this Gravel of the Upper Plain was of an age intermediate between his “Middle Glacial” and the Boulder-clay; while the outliers of other pebbly gravels at Brentwood, Highbech, South Weald, Langdon Hill, and others ‡, were “not improbably of Eocene age.”

Another paper of Mr. Wood’s on the Wealden Denudation §, only bears incidentally on this question, as showing the existence and extent of Drift Beds in the Thames Valley older than the lower-level Valley-gravels.

The most important contributions to this subject by Mr. Wood are, however, those in which he sums up his numerous and extensive observations, and gives his final views on this and collateral questions ||, accompanied by a map of the area occupied by the Chalky Boulder-clay, and a Plate of Sections showing the range and distribution of the Pre-Glacial, Glacial, and Post-Glacial Beds, with the position and probable relation of the hill-gravels throughout the south of England. The second part is devoted more especially to the consideration of the Post-Glacial Beds, particularly of those in the Thames and Hampshire Basins, and to the elaboration of his views respecting his Periods of Depression, Rise, and Glaciation. These papers, however, are not easy to summarize, but can be consulted with advantage.

The reader will also find in a paper by Mr. F. C. J. Spurrell,

* Quart. Journ. Geol. Soc. vol. xxiii. p. 394 (1867).

† *Ibid.* vol. xxiv. p. 283 (1868).

‡ *Ibid.* vol. xxiv. p. 464 (1868).

§ *Ibid.* vol. xxvii. p. 3 (1871).

|| “On the Newer Pliocene Period in England, Part I,” Quart. Journ. Geol. Soc. vol. xxxvi. pp. 457–528 (1880); Part II., *ibid.* vol. xxxviii. pp. 667–745 (1882).

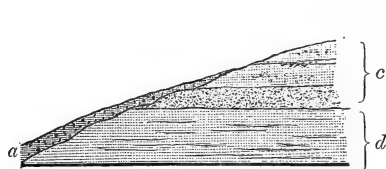
F.G.S. *, a notice of many of the hill-gravels of the London district, including the outliers on Shooter's Hill, Warley, Epping, Langdon Hill, and others, which he refers, with Mr. S. Wood, to the wreck of local Bagshot Beds.

The admirable "Drift Edition" maps of the Geological Survey, show the intricate ramifications of the Glacial and Post-Glacial Drifts in Suffolk, North Essex, and part of Herts (Maps 48, 47 †, and part of No. 7); but the Pebbly Gravel (Westleton) in Essex ‡, owing, I presume, to its being almost invariably hidden under Glacial beds, is not represented. Although, however, in that county the Westleton Beds are generally covered by Boulder-clay, the cuttings on the Great Eastern Railway which I had the opportunity of seeing showed that throughout that district they pass under the Glacial Series, and so help to connect the Hertfordshire, Buckinghamshire, and other outliers with the Westleton Shingle of Suffolk. These sections I will now proceed to describe.

2. Range inland of the Westleton Beds.

Suffolk.—In the westward range of the Westleton Beds, sands predominate in some places, shingle in others—often finely stratified and false-bedded. Besides their distinctive composition, they may generally be distinguished at sight by their pure white or ochreous colour, in contrast with the red of the Crag or the light drabs of the Glacial gravels. They pass, south of Westleton, from off the Chillesford Clay on to the unproductive sands of the Crag, as shown in the following section (fig. 1):—

Fig. 1.—*Pit on Rundell's Farm, Leiston Common (1860).*



a. Trail.

b. Boulder-clay not seen in pit, but showing a short distance higher up on the hill.

c. White sand, with seams of flint and white quartz-pebbles (Westleton).

d. Laminated ferruginous and yellow sands, ochreous and ferruginous sands.

Speaking of this district, Mr. Whitaker notices "a deposit of less certain classification which has been mapped only over the small tract north of the Minsmere Level. This is a gravel, with occasional sand, composed for the most part of pebbles (chiefly of flint, but some of quartz); and whilst it seems to underlie the lowest beds of the Glacial Drift, rests generally irregularly on the

* 'A Sketch of the History of the Rivers and Denudation of West Kent,' 1886.

† Excepting the extreme N.W. corner and Hertford Heath.

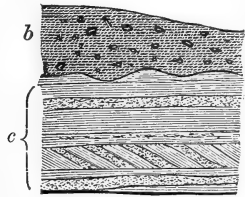
‡ Geology of the N.W. part of Essex and the N.E. part of Herts, with parts of Cambridgeshire and Suffolk, 1878.

Crag sand”*. Two pits near East Bridge where it is to be seen are also noticed †. Mr. S. Wood, on the other hand, was of opinion that most of these gravels, as well as those of which we shall have to speak in East Essex, belong to his Middle Glacial.

Eastward of this place the shingly sands pass apparently over the Crag of Sizewell Gap; while to the westward they form part of the sandy commons and heaths of the Snape and Tunstall districts, but definite sections are wanting.

To the west of Wickham Market, a bed of white gravel and sand is worked in several small pits; and in one near Easton indistinct traces of shells are observable in some thin intercalated seams of ironstone. The furthest point inland here at which I have seen the Westleton Beds is under the Boulder-clay at Brandeston (fig. 2). There may, however, be a little doubt about this determination.

Fig. 2.—Section at Brandeston Brick-pit (1847 ‡).



b. Dark bluish-grey Boulder-clay.

c. Light-coloured coarse quartzose sand with seams of gravel consisting largely of flint-pebbles and some of white quartz, with a few fragments of shells.

At Ufford Bridge, between Wickham Market and Woodbridge, the Westleton Shingle rests on the Red Crag, with the Boulder-clay above it. At Kyson or Kingston, near Woodbridge, the railway-cutting exposed a fine section of the Red Crag and overlying sands, capped by a bed of Westleton Shingle. The following are the local particulars; a general section is given in Plate VII. fig. 8 §.

	feet.
1. White gravel of flint- and quartz-pebbles (Westleton)	2
2. White and light yellow sand	2
3. Bright yellow sand without fossils.....	} 28
4. Gritty sand, false-bedded and with local and irregular seams of shells, and an underlie of a few inches of gravel resting on	
5. A thick bed of Red Crag, abounding in shells at the west end of the cutting, but with very few at the east end	
6. A thin seam of Coprolites with flint- and a few other pebbles resting on a floor of London-Clay Septaria	
7. London Clay.	

* Mem. Geol. Survey, Quarter-Sheets 49 S. and 50 S.E. p. 27 (1886).

† See Quart. Journ. Geol. Soc. vol. xxxiii. pp. 101–111 (1877).

‡ I give dates, because in all probability many of the sections no longer exist.

§ See also Quart. Journ. Geol. Soc. vol. xxvii. p. 334.

The Shingle (No. 1) is approximately composed of:—

	per cent.
1. Flint-pebbles	30
2. White quartz-pebbles	30
3. Subangular flints	20
4. Subangular fragments of chert and ragstone	12
5. Pebbles of light-coloured quartzite, sandstone, greyish arkose, and dark metamorphosed slate	8
	100

Its thickness is uncertain, as the Boulder-clay does not show until the higher part of the hill is reached.

West of Woodbridge the Westleton Beds have undergone considerable denudation, and are generally removed and replaced by Glacial gravels and Boulder-clay. They, however, sweep round to the north of this area, and were to be seen in some small exposures in pits north-east of Ipswich.

At Finnford Bridge the section gave:—

	feet.
b. { Bluish Boulder-clay with chalk pebbles, &c.	6
{ Seam of laminated brown clay	$\frac{1}{2}$
c. White sands and gravel, the lower part false-bedded.	12

In the lane leading from Withesham Street to Tuddenham I took the following section:—

	feet.
b. Light brown Boulder-clay.....	5
c. White sands and gravel (Westleton) ...	2 to 4
e. Red Crag.....	8

In the fine section described by Mr. Whitaker* near Bramford, 3 miles north-west of Ipswich, he expresses an opinion that Bed No. 2 may be of Crag age. I would take it to represent the Westleton Beds. The following is Mr. Whitaker's description of this pit. Beds 3 to 6 are given only in abstract †.

	feet.
1. Glacial drift. Gravel and sand, resting irregularly on 2... up to 8	
2. Fine light-coloured sand with thin clayey layers; at the bottom a thin layer of gravel with phosphatic nodules (may belong to the Crag)	up to 15
3 & 4. London Clay with a Pebble-bed at base	10
5. Reading Beds with a few flints and pebbles.....	18 or more
6. Thanet Sands	5
7. Chalk.	

Three miles south-west from the last pit is the village of Burstall, and on the slope of the hill on the banks of the small stream I found (1856) the following section:—

	feet.
b. Boulder-clay, chalky	3 to 10
c. { White gravel or shingle (Westleton)...	8 to 10
{ White sands	2

* Mem. Geol. Survey, 'Geology of Ipswich,' &c., 1885, p. 14.

† This pit had not been opened out to its full extent when I last visited it several years ago.

Lower down the hill the yellow sands of the Crag crop out.

The gravel has the well-marked characters of the Westleton Shingle, its approximate composition being as under:—

	per cent.
1. Small flint-pebbles	30
2. White quartz-pebbles	25
3. Subangular flints	23
4. Subangular fragments of chert and ragstone	12
5. Pebbles of light-coloured sandstone and quartzite, and Lydian stone	10
	100

Mr. F. J. Bennett has noticed a very similar section at Elmsett, 3 miles to the north-west of Burstall, where the Boulder-clay overlies a "rather coarse sandy gravel, with pebbles of quartz and of quartzite, about 2 to 10 feet," overlying a "fine buff rather clayey sand" *.

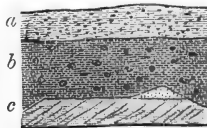
The railway-sections in this intermediate district afforded little information respecting the Westleton Beds. The Norwich line, between Ipswich and the valley of the Ottery stream, passes almost exclusively through thick Boulder-gravels and clay very much disturbed and deeply eroding the underlying beds; whilst the Yarmouth line, between the Orwell and the Deben, passes through Glacial loams, with but little gravel or Boulder-clay, overlying the Red Crag and unfossiliferous sands.

My notes, I regret to say, are not sufficiently detailed to give a definite account of the deep cutting on the northern side of the tunnel at Ipswich on the London line. This section, unlike that on the southern side of the tunnel, which was through a mass of Post-Glacial Drift, exposed:—

	feet.
Light-coloured sands with seams of gravel in horizontal layers.....	40
Red Crag with much false-bedding †	20
Dark brown London Clay.	

But though I failed to note the exact composition of the gravel, my belief is that this bed belongs to the Glacial Series. The next cutting (fig. 3), where the line passes under the London Road, shows how extensive the denudation accompanying the advance of the Boulder-clay has been.

Fig. 3.—Section on the Railway near Ipswich.



a. Ochreous gravel. b. Boulder-clay. b'. Light-coloured gravel.
c. Red Crag.

* 'Geology of Ipswich,' &c., p. 77.

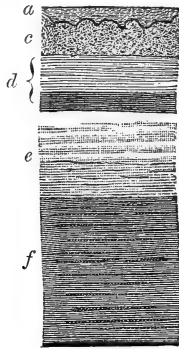
† Here, as at the Kyson Cutting, a layer of *Septaria* divides the Red Crag from the London Clay.

Essex.—On the south of the Crag area, the well-known cliffs at Walton-on-the-Naze exhibit a small patch of the Westleton Beds, composed of:—

	per cent.
1. Flint-pebbles.....	36
2. White quartz-pebbles	20
3. Subangular flints	20
4. Subangular chert	14
5. Quartzites, Lydian stone, &c.	10
	100

This gravel caps the cliffs near their western extremity, overlying a bed seemingly of the Chillesford Clay *. At the eastern end of the cliff, the unproductive sands are replaced by very fossiliferous beds of the Red Crag.

Fig. 4.—Section of Cliff east of Walton-on-the-Naze.



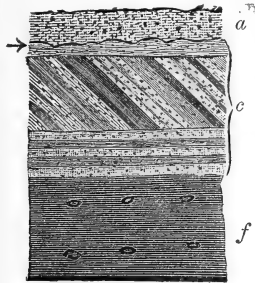
	feet. ¹
a. Surface-soil and gravel	1 to 2
c. Westleton Shingle	5
d. { Light-coloured laminated sands and clays	4
{ Dark carbonaceous clay with much wood and lignite	2
e. White and yellow sands. These are replaced at the other end (east) of the cliff by fossiliferous Red Crag.....	10
f. London Clay.	

From Walton to Clacton the low cliffs consist of London Clay capped by gravel. There are no Crag Beds. This gravel forms apparently one thick bed (12 to 20 ft.), but in reality it consists of two parts. The upper bed is much disturbed and not stratified, and is derived in considerable part from the *débris* of the lower bed; whereas the lower one is regularly stratified, and often shows well-marked false-bedding. It may be a question whether, although both the Red Crag and the Boulder-clay are absent in these cliffs, the lower gravel should not be referred to the Westleton Shingle. That there is a material difference of age between the two beds of gravel

* Mr. Clement Reid considers it to be something newer.

is evident from the circumstance that at the Clacton end of the cliffs these gravels * divide and admit between them the Post-Glacial mammaliferous deposit described by the late Mr. J. Brown and by the Rev. O. Fisher †.

Fig. 5.—Section of the Cliff one mile south-east of Clacton.



	feet.
a. Coarse ochreous Gravel.....	4 to 6
? c. Alternating beds of fine and worn gravel, finely bedded or with oblique lamination. Colours ochreous, white, and dark ferruginous	8 to 12
f. London Clay.	

At Clacton the two gravels are divided at → by the Post-Glacial clays mentioned above.

The Lower Gravel, which is imbedded in a matrix of loamy brown quartzose sand, quartz-grit, with innumerable fine fragments of flint, is composed as under :—

	per cent.
1. Flint-pebbles	24
2. White quartz-pebbles	16
3. Subangular fragments of flint, mostly white, but a few stained brown	32 ?
4. Subangular fragments of white and yellow cherty ragstone	10
5. Subangular fragments of brown and red chert	8
5. Pebbles of light-coloured (?) quartzite, dark sandstone, and Lydian stone	10 ?
	100

I have, however, some doubts about this correlation. The bed may be of Post-Glacial age.

It is also a question whether some of the thick gravels of Central east-Essex may not be of Westleton age ‡. Some well-sections seem to indicate that such is the case in respect to the base of the great spread of gravel west of Colchester. This bank is from 30 to 50 feet thick, and the upper part consists of gravel of Glacial age. It may be seen from the railway-sections how closely associated

* The surface of the lower gravel should be examined for palæolithic flints.

† Mag. Nat. Hist. ser. 2, vol. iv. p. 197 (1840); Geol. Mag. vol. v. p. 214 (1868). See also the Survey Memoir by Mr. W. H. Dalton.

‡ The Rev. O. Fisher informs me that the pebble-gravel is well developed at Elmstead, near Colchester, and at Alresford, near St. Osyth.

the Glacial and Westleton Series are in some parts of Essex, and how difficult, without the intervention of the Boulder-clay, it sometimes is to distinguish between them.

There is no group of sections in Essex more interesting than those adjacent to Sudbury. The Chalk, the Lower Tertiary Beds, together with Pre-Glacial, Glacial, and Post-Glacial Drifts, are there exhibited in the same or in neighbouring pits. Since I visited them they have been fully described by Mr. Whitaker, to whose sections I would refer the reader *. The Pre-Glacial beds are exposed at some of the pits on Balingdon Hill, where the Boulder-clay reposes upon so irregular a surface that in some places it rests on Pre-Glacial Sands, in others on some of the Tertiary strata, and in others on the Chalk.

On my first visit to these pits in 1845, I was inclined to believe that the thick bed of sand and gravel under the Boulder-clay belonged to the Crag; but later, I was led to conclude, on the score of position and composition, that it should be grouped with the Westleton Beds. I found no fossils; but Mr. Whitaker has since then found traces of shells (broken) with unbroken specimens of *Purpura lapillus* (var. *crispata*); and in another pit he discovered a bed of sandy ironstone, with casts of shells, of which 11 species (*op. cit.* p. 31) were determined, though with doubt, by Mr. Etheridge. With them were a few coprolites. On these grounds Mr. Whitaker classes this bed with the Red Crag, with a query.

The Red Crag has not, however, been met with within a considerable distance, and the fossils found are of a negative character. The *Purpura lapillus* occurs in the Westleton Beds of Norfolk and Suffolk—as also species of *Natica*, *Cardium*, *Mytilus*. Or the fossils and the coprolites may have been derived from the Red Crag; for the beds under the Westleton shingle are, as will be shown further on, often greatly eroded. Or we may have here a remnant of Red Crag at the base of sands and gravel belonging to the Westleton Series.

I express this opinion, however, with all reserve, though I think it is confirmed, not only by the section at Burstall, but also by one nine miles to the west of Sudbury, at a place called Burnt House, near Stoke (fig. 6). In the pit there a very similar, but much thicker bed of gravelly sands is seen resting on the Chalk, while the Boulder-clay is worked in another pit just above.

I found no fossils at this place; but they have been since recorded by the officers of the Survey, who give the following description of the pit †:—

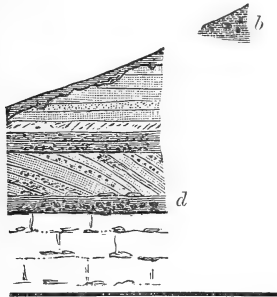
	feet.
“Glacial Drift. White, grey, and yellow false-bedded sand, partly coarse, partly fine, irregularly bedded. A mass of shells (<i>Purpura lapillus</i>) said to have been found at the bottom at one spot (? Crag)	30
? Drift or Red Crag. Bed of flints &c. (a piece of phosphatized bone)	1 to 2
Chalk, bedded, with flints.....	30”

* Mem. Geol. Survey. Geology of the N.W. part of Essex &c. pp. 14, 16, 31, 57 (1878); and *op. cit.* p. 132 (1885).

† Mem. Geol. Survey. Geology of the N.W. part of Essex &c. p. 49 (1878).

I omitted to notice whether chert and ragstone were present, nevertheless the composition and character of the sands and shingle are, I think, of the Westleton type. Both flint- and quartz-pebbles occur, it is true, in the Red Crag*, but never in such numbers, or proportion, as to form a compact bed of shingle like that of Westleton.

Fig. 6.—Section at Burnt House, near Stoke (1848).



feet.

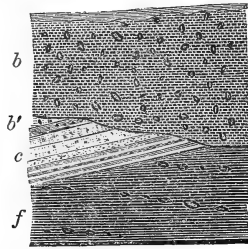
- b.* Bluish Boulder-clay exposed in another pit a short distance higher on the hill.
- c.* Bright yellow and white micaceous sands, fine at top, coarse below, succeeded by fine gravel or shingle. The sands show oblique lamination, and contain concretions or balls of soft limonite, some 1 foot in diameter 25
- d.* Layer of large flints, angular and rounded.

The railway between Sudbury and Mark's Tey exposed some interesting sections. The first deep cutting, 2 miles south of Sudbury, showed 5 or 6 feet of ochreous flint-gravel and sand, overlying from 5 to 10 feet of greyish-blue clay (Glacial), of which the lower part was finely laminated. Beneath this were 4 or 5 feet (base not reached) of white and yellow sands with seams of small shingle (Westleton?). The Lamarsh and other smaller cuttings were through Post-Glacial brick-earth and gravel. Between Bures and Chapple, the cutting passed through 12 feet of a blue Boulder-clay, separated from 10 feet of a brown Boulder-clay by 2 feet of ochreous gravel. Below the Boulder-clay was a bed, 4 feet thick, of ochreous gravel, under which were 7 or 8 feet of white sand and gravel (Westleton).

But the most important cutting was that between Chapple and Mark's Tey. It extends for nearly a mile, and reaches a depth of from 20 to 25 feet. At the two ends, the section exposed from 8 to 10 feet of Boulder-clay overlying Westleton Shingle, but in the centre resting on London Clay. The whole section is given at length in Pl. VII. fig. 7. A small enlarged portion is given below (fig. 7).

* Reference will be made to these in the third part of this paper.

Fig. 7.—North end of the Railway Section between Chapple and Mark's Tey (1849).



b. Bluish-grey Boulder-clay.....	feet
b'. Coarse ferruginous gravel	12
c. Stratified sands and shingle, yellow and bright ferruginous ochreous (Westleton)	2
f. London Clay.	6

No fossils were found in any of the sections, except in some Post-Glacial Beds at Sudbury and Lamarsh.

Similar sands and shingle have apparently a considerable development in North Essex; but they are generally hidden by Boulder-clay, or masked by Glacial gravel, which, when fine and stratified, they resemble in general appearance, and sometimes assimilate to it in composition, owing to an admixture of the two beds. On a hill 1½ mile north of Coggleshall there was a section showing 4 feet of Glacial gravel overlying 6 feet of bright yellow and ochreous sand with flint- and white quartz-pebbles (Westleton).

The Witham and Braintree branch line likewise exhibited some very illustrative sections of the Glacial and Westleton Beds (figs. 8, 9).

Fig. 8.—Section on the Railway, one mile north of Witham.



- a. Brick-earth. } Post-Glacial.
- a'. Flint-gravel. }
- b. Chalky Boulder-clay.
- c. White sand with shingle at base (Westleton).
- f. London Clay.

The shingle consisted of—

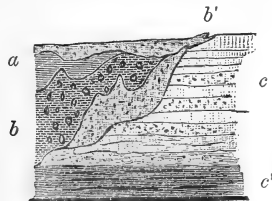
	per cent.
1. Flint-pebbles.....	32
2. White quartz-pebbles	24
3. Subangular fragments of flint	35
4. Subangular fragments of chert and ragstone	9
	100

Similar beds were passed through at various cuttings between this point and Bulford; but it was between Black Notley and Braintree that the section of greatest interest was exposed. The cutting, which is 25 feet deep, showed the Chalky Boulder-clay resting upon a deeply indented surface of coarse Glacial gravel, much contorted. This latter had likewise ploughed heavily into the underlying light-coloured Westleton sands and shingle, which were regularly stratified in horizontal layers, and intersected by a number of small faults of $\frac{1}{4}$ to 3 feet throw, which did not pass upwards into the Glacial Beds (Pl. VII. fig. 6).

The shingle consisted mainly of small flint- and white quartz-pebbles with a few subangular flints. No fossils were found. The overlying Glacial gravel consisted of large worn flints and some Chalk-*débris*, with pebbles of sandstone, of red quartzite (N.R.S.), and some small pebbles of flint and white quartz, the latter probably derived from the underlying beds. (See explanation of Pl. VII. p. 152).

The Westleton Beds were again exposed at the ballast-pit near Braintree Station. They are there much more ferruginous than usual, and are deeply indented by the overlying Glacial clay and gravel. In one part of the pit the section was as under (fig. 9):—

Fig. 9.—*Railway ballast-pit, Braintree (south end) (1848).*



		feet.
	a. Brown clay with subangular flints...	} Very variable and local.
	b. Very chalky Boulder-clay	
	b'. Ochreous Gravel (Glacial)	
Westleton Beds.	c. Finely stratified white sands and gravel, yellow in the lower part	13
	c'. Coarse dark ochreous gravel, with ferruginous concretions	4

The shingle consisted of the following materials, placed in the order of their relative abundance:—

1. Flint-pebbles.
2. Pebbles of white quartz.
3. Subangular flint-fragments.
4. Subangular fragments of chert and ragstone.
5. Large flattish light-coloured quartzite-pebbles.
6. Subangular pieces of Tertiary sandstone and puddingstone.
7. Small Lydian stones and pieces of white quartz.

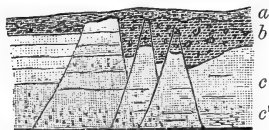
Beneath c', a hole sunk at the bottom of the pit showed 8 feet of interstratified white and yellow sands, with a shingle composed

largely of white quartz-pebbles. This gives a thickness at this spot of 25 feet of Westleton Beds; but these sands and gravels extend nearly to the top of the hill on which Braintree stands, and as the well at the waterworks lower down shows that the base of the sands is there 140 feet above O.D., while the summit of the hill is above 234 feet, the Westleton Beds, round which the Glacial Beds wrap, would seem to be here not less than from 70 to 80 feet thick (see Pl. VII. fig. 1).

It would appear from this and other instances to be named that these Westleton Beds had a large development in Central and Northern Essex, but that they have been extensively denuded by the overlying Glacial drifts. The independence of the Westleton Beds in respect to those of the Glacial Series here also becomes more apparent, owing to the rise of the land and its waste before the deposition of the Glacial Beds, in consequence of which the latter, in the districts further to the west, where the rise was greatest, gradually come to occupy a lower level than the former. The separation of these two Drift-series, first clearly apparent in this part of Essex, becomes more pronounced as we proceed westward in the London Basin. The presence of Chalk and Jurassic *débris*, with Quartzite pebbles derived from the New Red Sandstone, readily serves to distinguish the Glacial from the Pre-Glacial drifts.

The Westleton Beds extend to the north-west, though but rarely exposed, by Wethersfield to Dunmow and Thaxted. In a pit just south of the latter place is a section of some interest (fig. 10), as the pebbly sands, which I take to be of Westleton age, and the overlying Boulder-clay are both faulted. This, however, is from recollection. I omitted at the time to note the constituent parts of the gravel. The Survey officers consider it to belong to the Crag.

Fig. 10.—Section near Thaxted (1850).



- a. Pebbly soil.
- b. Whitish Boulder-clay.
- c. Coarse white sands with a few patches of gravel.
- c'. Ferruginous sand.

The Westleton Beds again showed in a pit at Braxted, 2 miles S.W. of Thaxted, the section of which was as under:—

1. Gravelly sand and clay.
2. White chalky Boulder-clay.
3. Ochreous gravel, consisting essentially of flint- and quartz-pebbles, with very few subangular flints.
4. Ochreous sand.

To return to the main line of railway. The sections from Witham to Manningtree are all through Glacial or Post-Glacial Beds, and are not of importance; while on the branch line to Maldon they are chiefly through London Clay and Post-Glacial gravels.

Maldon stands on a hill about 120 feet high, capped by gravel probably of Westleton age. My notes refer to it as a flint-shingle with quartz-pebbles and fragments of chert.

Danbury Hill, 6 miles S.S.W. of Witham, and 317 feet high, is capped by gravel of an anomalous character. It consists chiefly of subangular flints with a large proportion of flint-pebbles, and a few pebbles of quartzite, quartz, chert, and some old rock having more the character of a Glacial Drift. It may have been a Bagshot outlier invaded by the Glacial gravel. Lower down (about 150 feet) on the southern slope of the hill is another gravel in which chert- and quartz-pebbles are more prominent.

At the cutting on the main line which begins one mile west of Witham, and which reaches in places a depth of 25 feet, a very white chalky Boulder-clay passing down into bluish grey, overlies 5 feet of white sand with a seam of flint- and quartz-pebbles (Westleton) at base. At the western end of the cutting the same gravel, but with ochreous and white seams alternating, lies in hummocks beneath the Boulder-clay. The Hatfield cutting is through 20 feet of gravel at the eastern end, and through chalky Boulder-clay capped by 8 feet of brick-earth at the west end.

The long cutting from Springfield to Chelmsford (30 feet deep in the centre) is of interest from its showing the great erosion of the London Clay and the very irregular distribution of the gravel and Boulder-clay; but my notes relating to the gravel which underlies the Boulder-clay are insufficient for me to say whether it is of Glacial or of Westleton age.

A range of hills, capped by pebble-beds, commences a short distance westward of Chelmsford. But these, though really older than the Westleton Beds, I have relegated to Part III. of this paper. They include Writtlepark, Brentwood, Rayleigh, and other hills.

The Westleton Beds, which thus far have not reached a level of above 160 to 200 feet, now rise more rapidly as they trend westward, capping the hill-tops, and leaving the Boulder-clay and the Glacial gravels at lower levels in the intermediate lower ground. There is thus a considerable break before the next outliers are reached, though there are, I think, traces of the Westleton Beds to be met with near Ongar.

The next well-defined outliers are therefore on the western side of the valley of the Roding, on the range of the Epping hills, which at Highbeece and Jack's Hill attain a height of from 340 to 370 feet. On the top is a well-marked bed of the Westleton Shingle. The following is its approximate composition in a pit near the "Wake Arms," Jack's Hill:—

	per cent.
1. Flint-pebbles.....	50
2. White quartz-pebbles	15
3. Subangular fragments of flint.....	20
4. Subangular fragments of chert and ragstone	10
5. Pebbles of Lydian stone &c.	5
	100

A bed of white and yellow sand (Bagshot) underlies the gravel.

At Coopersale Common (or Gaynes Park), two miles N.E. of Epping, is another range of hills, from 340 to 360 feet high, on which there is also a capping of Westleton Shingle composed of

	per cent.
1. Flint-pebbles.....	56
2. White quartz-pebbles	20
3. Subangular fragments of flint	9
4. Subangular fragments of white Ragstone.....	12
5. Pebbles of Lydian stone &c.	3
	100

imbedded in a matrix of light yellow, loamy, quartzose sand.

To the south of these, and extending from Buckhurst Hill to Woodford Hill, is a considerable spread of pebbly gravel, 10 feet thick in places, of a character intermediate between the Brentwood and the Westleton Beds, but more analogous to the former. It consists almost entirely of flint-pebbles (Bagshot), with a very few white quartz- and other rock-pebbles imbedded in a variable matrix of sand and clay. The lower part is roughly stratified—the upper passes into an unstratified mass of brown and ferruginous clay with few flint-pebbles.

Middlesex.—The Drift Beds of the eastern and lower part of the county consist chiefly of Glacial and Post-Glacial gravels; while the higher hills on the north are capped by the Westleton Shingle. Thus the ridges from Barnet and Barnet Gate (410–460 feet), and from Totteridge to Highwood (400–410 feet), and again at Mill Hill, are capped by a poor gravel of this age, from 2 to 5 feet thick, and composed of

	per cent.
1. Flint-pebbles	50
2. White quartz-pebbles	15
3. Subangular flints, stained white and brown	20
4. Subangular ragstone and chert	12
5. Lydian stone &c.	3
	100

in a matrix of quartzose sand and greenish clay.

The Boulder-clay, at a level of about 100 feet lower, extends from Whetstone to Finchley and Muswell Hill. The gravel which underlies it in a pit near Finchley Church is of Glacial origin, and is full of northern *débris*. That at the old section opposite to the “Bald-faced Stag” has been referred to the Pebbly Gravels;

I should have placed it also with the same Glacial Beds; but my notes are insufficient.

The Westleton Beds are difficult to follow in this direction. They do not seem to rise so high as further north. Some beds at Hendon (280 feet) may possibly be referred to them, as also a small outlier which caps the hill (278 feet) at Horsington, two miles south of Harrow. This isolated patch, which is a mere remnant scattered on the surface, consists of

	per cent.
1. Flint-pebbles.....	42
2. White quartz-pebbles	10
3. Subangular flints stained brown	30
4. Subangular chert and ragstone	18
	100

With respect to Highgate and Hampstead Hills, which rise to the height 412 feet, I hesitate how to class them. I have found some fragments of worn cherty ragstone and a few rare quartz-pebbles on Hampstead Hill, with abundant flint-pebbles of local (Bagshot) origin; but the characters are not sufficiently marked to satisfy me. They may be Westleton or they may be outliers of the Southern Drift.

In the north of the county, a well-marked Westleton outlier may be seen in the wood (400 ft.?) $1\frac{1}{2}$ mile north of South Mimms, consisting of:—

	per cent.
1. Flint-pebbles.....	38
2. White quartz-pebbles	28
3. Subangular flints, not stained.....	24
4. Subangular chert &c.	6
5. Pebbles of white quartzite, Lydian stone, &c.	4
	100

The adjacent ridge, extending from Potter's Bar to Bell Bar (380 to 400 ft.), is also capped by a thin bed of Westleton Shingle, but there were no sections open at the time of my visits.

The Pebble-Beds of Stanmore, Elstree, and some adjacent hills belong to the Brentwood group.

Hertfordshire.—The London-Clay hills of the north of Middlesex, capped by Westleton Shingle, are continued into Hertfordshire, where they form, between Hatfield and Hertford Heath, a conspicuous range from 320 to 380 ft. high, and overlooking, at a level of from 180 to 240 ft. lower, the broad valley of the Lea and Mimram, over which are spread Glacial gravels and sands, covered in places by the Boulder-clay. The material difference of level and the marked character of the beds here bring out very clearly the discordant relation of these Glacial and Pre-Glacial Beds, as shown in the following section (fig. 11):—

Fig. 11.—Section from Hatfield Brick-pit to the G. N. Railway near Digswell Junction.



- a. Post-Glacial beds.
- b. Boulder-clay.
- b'. Light-coloured sands and ochreous gravel.
- c. Westleton Shingle.
- T. Lower Tertiary strata.
- C. Chalk.

Speaking of the characters of these gravels, Prof. T. M^cK. Hughes * says: "The gravel of the Upper Plain consists chiefly of pebbles; of these, about fifty per cent. are of quartz, about ten per cent. of quartzite, about five per cent. various (such as jasper and a conglomerate of quartz pebbles in quartzite), and the rest flint." These gravels have also been noticed by Mr. Whitaker and Mr. S. V. Wood in the papers before referred to.

This Hertfordshire shingle is remarkable for the large proportion of pebbles of white quartz and of Lower-Greensand débris †. A specimen from Brickenden Hill yielded broadly:—

	per cent.
1. Flint-pebbles.....	3½
2. White quartz-pebbles	28
3. Subangular flints—2 stained brown, and 3 not stained	17
4. Subangular fragments of red and brown chert and of white ragstone	18
5. Pebbles of Lydian stone &c.	3
	100

Further to the south-west similar beds are met with at Shenley Hill and again a little northward at Bernard's Heath near St. Albans, where they form a bed from 8 to 10 ft. thick, capping Lower Tertiary Sands and Clays, at an altitude of 406 feet. They there consist of:—1. Flint-pebbles; 2. White quartz-pebbles; 3. Subangular flints, not stained; 4. Subangular cherty ragstone; 5. Pebbles of Lydian stone, yellow quartzite, &c.; imbedded in a loamy red and yellow mottled sandy clay, disturbed at top.

Notwithstanding the extreme denudation which the high Chalk-plain, extending from Hertfordshire into Bedfordshire, Buckinghamshire, and Oxfordshire, has undergone, a few small outliers of Lower Tertiary strata still remain, rising above the general level of the Chalk-plateau with its scanty Glacial Drifts and its "Red Clay with flints"

These little isolated hills are frequently capped by a gravel- or shingle-bed, which I believe to be of Westleton age. They are

* *Op. cit.* p. 285.

† The chert and ragstone débris does not seem to have been hitherto recognized, or is mentioned under some other name.

very few in number, and gradually become rarer as we proceed northwards, although in a few instances they extend to the edge of the Chalk Downs.

At Collier's End (348 feet) and Sacombe Green (362 feet), five miles north of Ware, are two small Lower Tertiary outliers with a thin capping of quartzose shingle (Westleton). Others lie on some of those near Welwyn,—on Ayot (406 feet) and Burnham Green (407 feet) hills.

North of St. Albans, and between the valleys of the Lea and the Gade, traces of Lower Tertiary strata may be found as far north as Berkhamstead Common, but they are rarely in sufficient force to be worked, or high enough to bring in the Westleton Beds. At Bennett's End, near Hemel Hempstead, the Tertiary strata are capped at a height of 456 feet by a bed of sandy clay with a thin uneven patch of Westleton gravel, consisting in large proportion of flint- and quartz-pebbles with a few subangular flints (not stained), fragments of Lydian stone, and a few flat ovate light-coloured quartzite-pebbles. The bed varies from 1 to 6 feet in thickness, and rests on from 30 to 40 feet of London Clay and Lower Tertiary strata.

There is another Tertiary outlier at Little Heath and Potten, extending to Berkhamstead Common, or rather it is a mass of Tertiary strata preserved in a depression in the Chalk, of great extent. There is some appearance of Westleton Shingle, but too indistinct for description.

The hills to the west of the Gade present similar features. The Tertiary Beds are, however, so mixed up with Glacial débris that they are to be recognized only in a few instances. At Langley Common (440 feet) there are traces of Westleton Shingle, and closely adjacent to the borders of Hertfordshire is the more conspicuous outlier of Tiler's Hill.

South Buckinghamshire.—In this county, as in Hertfordshire, the picturesque high ground of the Chilterns is covered by a sprinkling of Glacial Drifts (but no Boulder-clay), and "Red Clay with Flints," with occasional Tertiary remnants.

Tiler's hill*, 2 miles east of Chesham, rises to a comparatively considerable height above the surrounding Chalk-plateau, and consists of Lower Tertiary strata with an outlier of London Clay†. On the summit, about 600 feet above the sea-level, is a small capping of gravel, composed of:—

	per cent.
1. Tertiary flint-pebbles, small and large, many of them weathered white	55
2. White quartz-pebbles	23
3. Very subangular fragments of flint, stained yellow; others are large, white and little worn.....	12
4. Chert &c.	5
5. Flat ovate pebbles of light-coloured quartzite and veinstone, with subangular fragments of Tertiary sandstone and pudding-stone	5
	100

* On the new one-inch map this name is altered to Crowcroft.

† Described by the author in Quart. Journ. Geol. Soc. vol x. p. 90 (1854).

The gravel rests on an uneven bed of London Clay. Lower Greensand débris is comparatively scarce, and the débris of Tertiary rock more abundant, while pebbles of the older rocks are rare.

There are several Tertiary outliers on the high Chalk-plateau between the Misbourne and the Wye. One of these, to the west of the village of Penn, near Beaconsfield, rises to the height of about 600 feet, and is capped by a well-marked bed of Westleton gravel like that on Tiler's Hill, while another gravel (Glacial?), derived in part from the Westleton Shingle, lies on the Chalk-plain at Penn (547 feet) and Penn Common. At Lane End (600 feet), four miles west of High Wycombe, there is also an outlier of Lower Tertiary sands and clays, capped by a similar gravel of flint- and white quartz-pebbles, subangular flints weathered white, with a few old-rock-pebbles (see Pl. VII. fig. 1).

South Oxfordshire.—From the borders of Buckinghamshire to the Thames between Pangbourne and Wallingford there are but few Tertiary outliers. The most conspicuous of these is that at Nettlebed hill*. The Westleton Shingle (?) there attains its highest level of about 650 feet. It is but a small patch, and presents a less definite composition than the others, as might be expected from its distance from the main body.

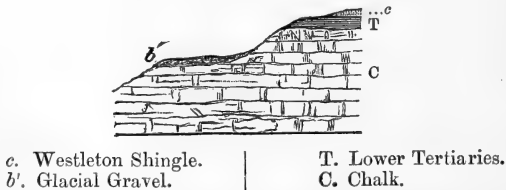
The shingle, which reposes upon a very uneven surface of the Lower Tertiaries, consists approximately of:—

	per cent.
1. Tertiary flint-pebbles	54
2. Small pebbles of white quartz.....	14
3. Subangular flints, not stained.....	20
4. Chert &c?	4
5. Pebbles of hornstone (?), veinstone, and Sarsen stone.....	8
	100

imbedded in a matrix of light quartzose sand.

Five miles S.W. of Nettlebed, and close to the edge of the Chalk escarpment overlooking the plains of Oxfordshire, a thin outlier of Lower Tertiaries (the mottled clays of the Reading Beds) overlies the Chalk at Greenmoor hill (560 to 600 feet) and Woodcote Common, about 3 miles east of Goring. It is capped by a well-

Fig. 12.—Section on the hill above the Thames, near Goring.



defined bed of Westleton Shingle, which is in marked contrast with the Glacial gravel, with its New-Red-Sandstone quartzites, which sets

* Described in Quart. Journ. Geol. Soc. vol. x. p. 89 (1854).

in near Coomb End at a short distance from it westward, and at a level of about 100 feet lower (fig. 12). This is the most distant outlier in this direction, and from its position on the edge of the Chalk Downs overlooking the Great Oolitic plains, possesses more than usual interest (see Pl. VII. fig. 1).

The shingle forms an ochreous sandy gravel, consisting largely of subangular flints much worn, flint-pebbles, and with none of the New-Red-Sandstone quartzites so common in *b'*. I noted at the time that it is much like the gravel on Bowsey hill (*infra*). Approximately it was composed of:—

	per cent.
1. Tertiary flint-pebbles, of which some were broken	44
2. White quartz-pebbles	10
3. Subangular and angular pieces of flint	30
4. Subangular pieces of Sarsen stone, of a hard dark sandstone, and of ironstone (Tertiary)	9
5. Flat ovate pebbles of light-coloured quartzite, with small pebbles of Lydian stone (?), and of a quartz-grit	7
	100

I failed to note either Chert or Ragstone.

A few miles to the south another Tertiary outlier extending from Chazey Heath to Rose Hill (300 to 350 feet) is capped, but not very distinctly, by a light-coloured gravel very similar to the above, while the intermediate and lower areas are overspread by the Glacial gravel, but Boulder-clay is absent.

Further to the south, as we approach the Thames, the valley-gravels set in and continue to the Berkshire side.

Berkshire and Wiltshire.—Between Reading and Maidenhead* the broad valley of the Thames, with its Post-Glacial gravels, becomes greatly contracted between Henley and Marlow by the high ground of Cookham Dean (350? feet) and Bowsey Hill, which is 467 feet high, or 350 feet above the Thames at Henley. The former of these hills is bare to the summit, whereas the latter is capped by a light ochreous sandy and pebbly gravel, from 5 to 8 feet thick, of a characteristic Westleton type. The following are its component parts, but I failed to note their relative proportion:—

1. Tertiary flint-pebbles, some of them entirely decomposed.
2. Numerous small white quartz-pebbles.
3. Subangular fragments of flint, weathered white.
4. Very few subangular fragments of white ragstone and one of fossiliferous chert.
5. Pebbles of light-coloured quartzite, yellow sandstone, and rose-coloured quartz-grit, with some small pebbles of veinstone, Lydian or hornstone, greenstone?, and red and grey quartz.

The quartzites are not the red and grey quartzites of the northern Drift.

* It would seem probable that the Thames at an early stage may have flowed in a direct line from Twyford to Maidenhead, by way of the valley of White Waltham, which offers a low and straight course, instead of the circuitous course it took in Post-Glacial times through the Henley and Cookham Hills.

The Berkshire Downs, which form the prolongation of the Chiltern Hills of Buckinghamshire and Oxfordshire, rise above Streatly and Goring to the height of from 400 to 600 feet. In the line of the Thames Valley there is a broad high terrace of Glacial Drift, whilst at a little distance further from the river the Westleton Shingle appears on a relatively higher level. The Glacial gravel forms a terrace at Southridge, and between Basildon and Ashampstead, at a level of about 400 to 420 feet, whilst the Tertiary outlier at Upper Basildon is capped by Westleton Shingle. The Tertiary outlier (350 to 380 feet) north of Bradford is also capped by a gravel which may be of the same age.

The Chalk Downs of Berkshire are much rarer than those of Oxfordshire and Buckinghamshire both of Tertiary outliers and of Drift. The former are extremely scarce until we approach the borders of the Tertiary basin near Newbury. Nevertheless it is probable that the Westleton Shingle extended over this area, for I found on the bare Chalk-hills above East Compton a pocket of Tertiary Sands and Drift, with flint- and quartz-pebbles, &c.,—a remnant probably preserved, like the Crag at Lenham, by the chance circumstance of its being in a pipe or hollow in the Chalk.

To the north and north-west of Newbury there are several gravel-capped hills, possibly of this date, such as Donnington Common and the hill east of Basford. One of the most prominent is that at the end of the spur of Tertiaries which extends north-westward from Newbury to Wickham. This hill, which is 560 feet high and rises 100 feet above the surrounding Chalk-plain, consists of Lower Tertiary strata (including the base of the London Clay)*, and is capped by a bed of gravel, from 3 to 5 feet thick, composed of flint-pebbles, with subangular flints imbedded in a quartzose sand and grit very much worn. From its position and general character I think it may be of Westleton age, but I have no note of its exact composition.

The bare Chalk-plains of East Berkshire and Wiltshire offer scant opportunities for determining the presence of the Westleton Shingle. Except in a few rare instances denudation has swept these plains clean of all but the superficial soil and trail. The higher Chalk-hills near Baydon, 8 miles E.S.E. of Swindon, are, however, capped by a gravel consisting of subangular flints and Tertiary flint-pebbles, with some quartz-pebbles; and a similar ridge to the east of Ogburn St. George, on the north-east of Marlborough, is also capped by a little flint-gravel with quartz-pebbles.

Quartz-pebbles also occur in places in flint-drift on the hills about $2\frac{1}{2}$ miles south of Marlborough †. Patches of a pebbly drift again occur on the higher points of the Chalk Downs at Bishopstone near Shrivensham and at Liddington and Basdrop to the south of Swindon, but they are very indistinct.

* Described in *Quart. Journ. Geol. Soc.* vol. x. p. 86 (1854).

† The Drift-beds of this district have been described by Mr. T. Codrington, in the *Magazine of the Wiltshire Archaeological and Natural History Society*, 1865.

The last trace of such drift I have met with on these Chalk Downs was on Monument Hill above Calne, where there are a few scattered pebbles of white quartz, quartzite, chert, and ironstone, with subangular flints and flint-pebbles, but its exact relation is uncertain.

3. *Westleton Beds on the South of the Thames.*

The Boulder-clay, it is well known, has not been found south of the Thames, though some Pre-Glacial beds have a considerable extension in that direction, and evidence of glacial action is not wanting. Owing, however, to their isolation and want of continuity the classification of these beds is attended with more uncertainty.

Kent.—In the north-eastern corner of Sheppey the cliffs at Draper's Point, there about 170 feet high, are capped by a Drift distinct from that which is spread over a great part of the higher ground of that island. It consists of from 15 to 20 feet of yellow sands with seams of clay and patches of gravel, the bottom bed of gravel being from 1 to 2 feet thick, and composed essentially of flint-pebbles of various sizes, of large subangular flints much worn and stained brown, numerous small flint-fragments, and some very small pebbles of quartz, and at one spot I found a much worn fragment of brown chert. It is not improbable that these beds are of Westleton age. They are overlain by a flint-gravel in small pockets.

I know of no other bed of this character in Kent, except one between Shottenden Hill and Sellings (400 feet), where there is a sprinkling of Drift consisting of Tertiary pebbles and pebbles of quartz. But both these cases are obscure.

I do not refer the shingle on the top of Shooter's Hill or the gravel on Swanscombe Hill to this horizon.

Surrey and Hants.—Further westward traces of the Westleton Beds become very indistinct. There are remnants of a quartz-drift at Englefield Green (264 feet) and on some adjacent hills; but it is another Pre-Glacial high-level gravel-drift (see Part III.) that prevails almost exclusively in this district.

4. *Possible Extension of the Westleton Shingle beyond the Thames Basin into Somerset.*

Passing from the Chalk Downs to the Oolitic Hills further westward, there is at one spot, Kingsdown near Bathford, about 550 feet high and 5 miles from Bath, a Drift of the Westleton character. It forms only a small patch on the otherwise bare surface of the Oolites, and consists of a light-brown sandy loam, with slightly subangular flints, some flint-pebbles, many white quartz-pebbles, and an occasional pebble of sandstone and of a greenish quartz*. It is covered by a brown earth with local Oolitic débris.

* The Rev. H. Winwood, F.G.S., has since found a subangular fragment of Sarsen stone and a pebble of black chert or hornstone.

The whole is only a few (5 to 8 feet) thick, and is preserved in a trough or hollow in the Oolite*.

Still further westward, on the Carboniferous-Limestone Hills near Clevedon, Mr. Trimmer † has recorded the existence of a patch of local débris with, I believe, quartz-pebbles, at a height of 300 feet above sea-level. This may be a continuation of the Kingsdown Bed, but intermediate connecting-links have yet to be discovered, and I was not successful in finding the place myself.

On the Chalk-hills to the south of the area we have described there are a few outliers which may be referable to this geological horizon, such, for instance, as the pebbly sands with worn fragments of hard Tertiary sandstones on Windmill Hill, near Alton, and a pebbly drift on the higher hills west of Andover; but these are too indistinct to pronounce definitely upon.

A better marked case is the one on the Chalk Downs of Copford, 8 miles east of Warminster, where a large Tertiary remnant has been preserved from denudation by having been let down into a cavity in the Chalk. This patch of Lower Tertiary (white sands and mottled clay) is overlain by an irregular spread of Drift consisting of:—

1. Tertiary flint-pebbles—the larger proportion much decomposed, white and very light.
2. White quartz-pebbles and a few rose-coloured ones.
3. Worn fragments of a light-coloured sandstone (Upper Greensand?).
4. Pebbles of a dark chert and Lydian stone.

These were imbedded in a light sandy matrix, and covered by a sandy clay-drift full of angular flints; this pit at the time of my visit was much obscured.

5. *The Relation of the Westleton Shingle to the Glacial Drifts of the Thames Valley.*

We have thus been able to follow the Westleton Beds from the coast of the Eastern Counties with some certainty as far as the Berkshire Downs, and with some probability as far as the Bristol Channel. On the Eastern coast this deposit lies at the sea-level, but as it ranges inland it gradually rises to heights of 500 or 600 feet. In the first instance the Westleton Beds underlie all the Glacial deposits; in the second they rise considerably above them, and their first seeming subordination to the Glacial series altogether disappears (see fig. 1, Pl. VII.).

The association, which is so close in Norfolk that it had led to the two series being considered members of the same group, becomes less so in Essex. At Braintree, where the Westleton Beds are largely developed, they stand up through the Boulder-clay and gravel which wrap round their base and partly surmount them.

* Mr. C. H. Weston, who first noticed this high-level drift, states also that Chalk-flints mixed with Oolitic débris occur on the surface of Farleigh Down at a height of about 600 feet (Quart. Journ. Geol. Soc. vol. vi. p. 449).

† Quart. Journ. Geol. Soc. vol. ix. p. 282 (1853).

They have there been disturbed and faulted (Pl. VII. fig. 6), before the intrusion of the Glacial Beds, which have deeply eroded them. As they rise to higher and more exposed levels, the Westleton Beds become greatly diminished in importance and are commonly reduced to a mere shingle-bed. On the hills near Epping, where they attain a height of 350 or 400 feet, they form a thin bed of sand and shingle, capping the London Clay, and quite apart from the Boulder-clay, which lies from 80 to 100 feet lower down on the slope of these hills at Theydon Bois and North Weald.

In Hertfordshire the distinction between the two deposits is very marked, as on the hills between Hoddesdon and Hatfield the Westleton Shingle forms a plateau-gravel high above the plain of the Lea, over which is spread the Boulder-clay with its associated sands and gravel. At Bell Bar and Mimms Wood the hills are also capped by this Shingle, while in the valley between them the Boulder-clay in the railway-cutting is at a level of from 100 to 150 feet lower. The Boulder-clay again enters the valley of the Colne at Bricket Wood and Aldenham, whilst Westleton Shingle lies on the neighbouring heights of Shenley and Bennett's End.

Here the Boulder-clay ends, and the Westleton Shingle alone is prolonged westward at intervals on the higher summits of the Buckinghamshire, Berkshire, and Oxfordshire Downs, the Chalk-plain on which these hills rise being in some places denuded, and at others thinly covered by Glacial Drift-beds. The Shingle-bed may, in this way, be traced to the northern edge of the Chalk Downs and to the extreme western end of the London Basin, which shows how extensive the submergence of these districts must have been at a time immediately antecedent to the Glacial period.

The height (500 to 600 feet) to which the Shingle-bed attains is sufficient to carry it over the summit of the Chalk and Oolitic hills of the Warminster and Bath districts. There may thus have been a Pre-Glacial sea bounded on the south by the Wealden anticlinal, and spreading northward over great part of Hertfordshire, Buckinghamshire, and Oxfordshire (and possibly beyond), while it stretched in the other direction from the North Sea to the Severn Basin or the Bristol Channel (see Part III. and Map).

6. *Origin of the Shingle.*

The distinctive features of the Westleton Shingle are of so marked a character and so different from those of the overlying Glacial series, that it is at once evident that their origin must be different. The characters of the latter are so well known that it is unnecessary to repeat them here; suffice it to say that they are essentially Drifts from the north and north-east, whereas that of the Westleton Beds is from the south and south-east, for the reason that the sources whence the several different component pebbles are derived is to be traced in those directions.

Thus:—1. The flint-pebbles are doubtlessly derived from the shingle-beds of Diestian, Bagshot, or Lower Tertiary (Woolwich)

age, whether in Belgium, the North of France, or Kent. 2. The Pebbles of white and rose-coloured quartz come apparently from the older rocks of the Ardennes or indirectly from some of the Bolderberg or Diestian beds of Belgium. 3. The subangular fragments of flint, some retaining their natural colour, others more worn and stained brown, are derived, the former directly from the Chalk, the latter from an older Drift, possibly of Pliocene age; or both may have been derived, in part, from the Southern Drift*. 4. The worn and subangular fragments of chert and ragstone are derived from the Lower Greensand of Kent and Surrey; or also, in part, possibly from the "Meule de Bracquagnies," or indirectly from the Southern Drift. 5. The Large Pebbles of a white or light-coloured quartzite and of a flat ovate shape, unlike the red or dark-coloured round ovoid quartzites from the Triassic conglomerates, may be derived indirectly from the shingle-beds of the Woolwich-and-Reading Series, where I have occasionally found them; or they may come from quartzites of the Palæozoic rock of the Ardennes, or possibly from both. 6. The small pebbles of Lydian stone, Jasper, veinstone, and worn fragments of old rocks may be derived, some directly from the Ardennes, and some indirectly from the pebbly beds of the Lower Greensand.

It is obvious, from the fossils found in it in Norfolk and Suffolk, that the Westleton Shingle is a marine Drift, the absence of shells in its inland range being no doubt in great measure owing to decalcification. Even in Suffolk, where the beds are more protected, it is rarely that anything more than casts are found.

But while marine conditions extended as far as the north of Belgium, on the south the Ardennes formed an elevated area of dry land, drained by the old Meuse and its tributaries as well as by the Schelde. The lower range of hills bordering these valleys above Spa and Liége are often capped by a terrace of gravel derived from the quartzose and schistose rocks, hard sandstones, and conglomerates of the Ardennes. Pebbles of quartzite, sandstone, and white quartz are consequently the common constituents of these gravels; while occasionally they contain fragments or pebbles of porphyry, slate, and, very rarely, of granite. Generally the pebbles vary in size from that of a marble to that of an egg, though they are sometimes the size of a man's head. Large blocks, but little rolled, are also occasionally met with.

Such was the old alluvium of the eastern tributaries of the Meuse, while on the terraces of the main stream at Dinant and Namur, pebbles of Triassic sandstones, of Cretaceous, Jurassic, Carboniferous, and Devonian rocks are met with, but a large proportion of them disappear lower down the course of the river, and only the harder rock-pebbles remain in its lower reaches. On the hill above Liége I noted in the flint-gravel palæozoic-rock pebbles very analogous to those found in the Westleton Shingle, namely:—

* To be described in Part III.

(Angular and subangular fragments of flint ;
 White quartz-pebbles (numerous) ;
 Flat ovate pebbles of light-coloured quartzites ;
 Pebbles of light-coloured sandstones, veinstone, and subangular fragments
 of a hard micaceous Sandstone, &c.,—

imbedded in a white and ochreous sandy matrix.

In descending the river the terraces become wider, and in the neighbourhood of Maestricht they spread out into plateau-sheets of great breadth, as in an estuary.

Another set of Drift-débris, including flint-pebbles from the Lower Tertiaries together with débris from the Carboniferous and Cretaceous strata, would be carried down by the Schelde, which flows through rocks of that age ; while the Rhine may have furnished débris from the rocks of the Rhenish Provinces, including possibly the basalt of the Rhine borders.

This mass of shingle, transported into the open sea to the north and aided by ice-action, drifted over to the coast of Norfolk and Suffolk, and thence, as the land subsided, was carried westward, in a direction towards the Severn Valley or the Bristol Channel. What, then, turned it aside from the northern sea, where it would seem it might have extended more northward as the Crag did * at the period immediately antecedent ? Could it have been that the great Scandinavian ice-sheet was then ploughing its way across the sea towards the coast of Norfolk, and so blocked up the sea in that direction and diverted the waters of the North Sea through this westward channel ?

On the south, the spread of the Westleton Beds was limited by the anticlinal of the Ardennes and the Weald, which then constituted a low mountain-range, for there are no marine beds of that character south of the line I have described. At the same time palæontological evidence of contemporaneous land conditions is very scanty.

In recent papers by the Rev. O. Fisher † and Mr. J. C. Mansel-Pleydell, F.G.S. ‡, we have accounts of the discovery of the remains of *Elephas meridionalis* on the Chalk-plateau at Dewlish, near Piddletown, in Dorsetshire, in a bed of sand and gravel 90 feet above the level of the adjacent stream. The facts of the case led Mr. Fisher to suppose that the deposit might be Pre-Glacial, while Mr. Mansel-Pleydell considered it to be of Pliocene age.

It is possible also that the high-level fossiliferous Drift on the summit of Portland §, which contains débris derived from the Tertiary and Cretaceous strata of the hills to the north of Weymouth, may be of the same age, and older than I was first led to believe on the evidence of the sparse remains of *Elephas antiquus*, *E. primigenius*?, and *Equus fossilis*. This view of the greater antiquity of that deposit would be more in conformity with the enormous amount of erosion, probably of Glacial date, that led to the formation of

* Mr. T. F. Jamieson, F.G.S., has shown that Crag-beds exist on the east coast of Scotland (Quart. Journ. Geol. Soc. vol. xvi. p. 371).

† Quart. Journ. Geol. Soc. vol. xlv. p. 818 (1888).

‡ Trans. Dorset, vol. x. p. 12 (1889).

§ Quart. Journ. Geol. Soc. vol. xxxi. p. 31 (1875).

the broad valley between Portland and Upway, above six miles wide and from 400 to 500 feet deep, since the deposition of that high-level Drift.

Dr. Mourlon has also recently recorded* the occurrence, at Ixelles near Brussels, of a bed of sand and gravel with Mammalian remains, which he thinks may be of the age of the Forest-bed; but the evidence is yet uncertain, owing to the fragmentary condition of the specimens. Amongst the species on which Dr. Mourlon relies, but which are determined with doubt, are *Elephas antiquus*, *Equus plicidens*, *Cervus canadensis*, and *Bison priscus*.

CONCLUSION.

It is clear from its uniformity and its marine origin that the Westleton Shingle must originally have formed a comparatively level sea-floor (or broad coast-line) throughout the area over which its outliers extend, and that all the inequalities of the surface below that level have been formed since it was deposited. If this conclusion be correct, then it follows that all the Tertiary strata, which spread originally over all the Chalk Downs of Hertfordshire, Buckinghamshire, Oxfordshire, Berkshire, Wiltshire, and some adjacent districts, have been removed subsequently to this early Pleistocene or so-called Pre-Glacial period; also that the gorge of the Thames at Pangbourne and Goring has been formed since then; and that most of the Pre-Glacial valleys in the district, to which no date, except that they were Pre-Glacial, had been assigned, are of the same geological age. It follows further that before this date the Thames had no existence; to this point we shall revert on another occasion.

During the Westleton period, we have to imagine a sea, with a coast-line extending from Belgium to the West of England, bounded on the south by the anticlinal range of the Wealden, and open to a yet uncertain distance to the north. This area then underwent an elevation from east to west, and from south to north, whereby it was raised at the extreme points from 500 to 600 feet or more above the sea-level, whereas it remained nearly at its original level and comparatively undisturbed at its other or eastern extremity; so that while on the east the chronological orders of succession of the strata continued unbroken, to the west they became discordant, in consequence of the physiographical changes which intervened between these successive stages.

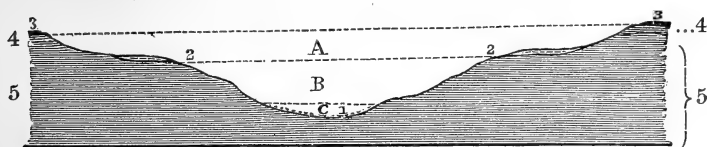
These changes and the action of meteorological agencies on the up-raised land, determined the plotting-out of its hills and valleys during the early Glacial epoch. Of the first stage we have now, in some cases, an exact measure. Thus, to take a few examples, it is obvious that at the gorge of the Thames at Goring the Westleton Shingle and Tertiary Strata were continuous from side to side of the valley until the last elevation of the land. As they emerged, and a land-surface was formed, these beds, together with the underlying Chalk, were first denuded in the line of the present Thames valley

* Bull. Acad. Roy. Belgique, 3^e sér. vol. xvii. p. 131 (1889).

to a depth of about 160 feet, and a width of from 2 to 4 miles, when the newly made channel received its covering of Northern Drift (2, fig. 13).

The successive increments of depth *, acquired during the different periods, are exhibited in the following section (see also fig. 12).

Fig. 13.—*Diagram-section across the Gorge of the Thames through the Escarpment of the Chalk at Goring.*



- | | |
|------------------------|---------------------------|
| 1. Post-Glacial Drift. | 4. Lower Tertiary strata. |
| 2. Glacial Drift. | 5. Chalk. |
| 3. Westleton Shingle. | |

	feet.
A. Denudation during the early Glacial Period	about 160
B. Denudation during the later Glacial Period	,, 220
C. Denudation during the Post-Glacial Period	,, 70

Taking the height above the sea-level of the Westleton Beds here at 600 feet, and that of the river at Goring at 150 feet, the above figures give, but very approximately, the depth to which the denudation of the valley at this place was carried during the successive Glacial and Post-Glacial epochs.

The relative depths of B and C may be subject to considerable correction. In the absence of sufficient evidence at Goring, I have been guided by the height of the high-level river-gravels at Oxford and Reading, where they are better developed.

These measures, of course, vary at different places. Lower down the Thames Valley, the channel A above Henley-on-Thames (Bowsey hill giving the Westleton level) is above 200 feet deep, while B is reduced in proportion.

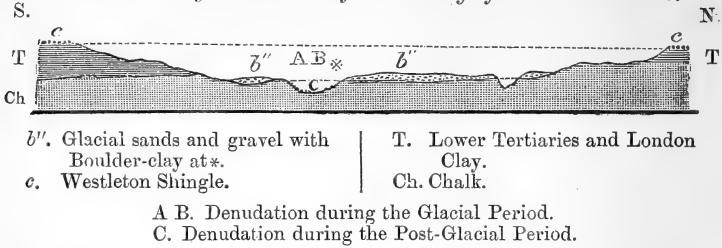
In the valley of the Lea, at Ware (fig. 14), taking the level of the Westleton Shingle at Hertford Heath on the south at 316 feet, and at Sacombe Green on the north at 362 feet, and that of the Lea at 110 feet, A and B together seem to amount, in round numbers, to about 200 feet, whilst C does not seem to exceed 50 feet.

In the valley of the Roding the level of the Boulder-clay is about 100 feet below that of the Westleton Shingle, at Jack's Hill, near Epping, whilst the extent of C is probably less than 30 feet.

Other instances might be mentioned, but these will suffice to show some of the stages in the denudation of this area and the initial step in the formation of its river-valleys. It will appear, from these facts, that the main denudation of the district has been effected after Pliocene times, and that the first stage (A) in the formation of the present gorge at Goring dates back to the time of

* These hold whatever may be the age of the shingle.

Fig. 14.—Diagram-section of the Valley of the Lea at Ware.



the emergence of the Westleton floor and is due to early Glacial action. To what extent the subsequent denudation (B) is due to continued glacial action it is difficult to say; but as the gravel-bed No. 2 (fig. 13) belongs to one of the earlier stages of the Glacial period, and Post-Glacial river-action (C) is limited to narrow bounds, there is reason to infer that the valley to about the base of B is due to erosion during the Glacial period.

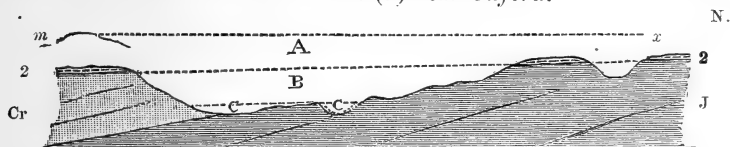
The position of the Westleton Shingle enables us also to suggest a solution of another question, namely, that relating to the age of the great escarpments of the Chalk and Oolites which run through the centre of England. The fact that the Westleton Shingle caps various Tertiary hills on the Chalk-plateau, which Tertiary strata extend to the edge of the Chalk-escarpment, renders it probable that this Shingle had, before the denudation of the Tertiary strata, a range to a certain extent coextensive with that of the Tertiary strata, and extending further northward than at present. This is manifested by the presence of the Shingle on an outlier so near the escarpment as Nettlebed Hill, and still more by the outlier on the very edge of the escarpment at Woodcote. Consequently, if, as this would show, the Westleton Beds had a range over and beyond the escarpment, the origin of that escarpment must be of a date subsequent to that of the Westleton Beds (Pl. VII. fig. 1).

Another argument is, I think, conclusive. The terraces of Glacial gravel (No. 2, fig. 13) which flank and originally spread across the gorge of the Thames at Goring at the height of 440 feet are evidently connected with the outliers capping the Coralline Oolite at Foxcombe and Wytham Hills near Oxford, at a height of about 500 feet, and which, again, cap the Forest Marble and Great Oolite on the higher hills of Wychwood Forest, near Witney. At the time that this spread of gravel took place, the intervening valleys must have been bridged over by a flooring of Cretaceous and Jurassic strata, which have been since removed and denuded to the depth of from 300 to 350 feet, as shown in the following diagram (fig. 15).

If, therefore, the channel through which the Glacial Drift passed from the north into the Thames Valley was formed, as we suppose, subsequently to the spread of the Westleton Shingle, but before the deeper late Glacial erosion, then it is evident that as the valley at the foot of and giving rise to the escarpment could

have had no existence at that time, the base of the escarpment must have been limited by the level of the line of 440 to 500 feet. By analogy the further relative heightening of the escarpment was concurrent with the deepening of the valley itself, which would correspond with B in fig. 15. In any case the escarpment could not

Fig. 15.—*Diagram-section from the Gorge of the Thames at Goring to the Oolitic hills (J) near Oxford.*



2. Glacial gravel with Triassic, Cretaceous, and other rock-débris. *m.* Position of Tertiary strata and of Westleton Shingle (outside the section). *Cr.* Cretaceous strata. *J.* Jurassic strata. (See also fig. 13, p. 149.)

at that early Glacial period (A) have had a face more than from 100 to 150 feet high, while at the Westleton period it is more than probable that it formed, with the distant Oolitic hills, a continuous plain (*x*).

Of the escarpment of the Oolites one can speak with less certainty, though if we admit the Kingsdown Drift outlier to be of Westleton age, it favours the conclusion that the escarpment of the Oolites dates no further back than the commencement of the Quaternary or Pleistocene period. The fact likewise that the two escarpments run in parallel lines seems in favour of a common denuding cause in the same direction. The time, geologically measured, is, however, so limited, and the extent of denudation so vast, that it is not easy to realize that these limits can suffice. Nevertheless, I do not see how the conclusions we have arrived at on this subject can well be avoided.

Another point to which I would draw attention is the small amount of erosion by river-action (C) in the area under review, compared with that effected by glacial or other agencies. To the latter are due the broad plains and passes and the isolated hills, whereas the effects of the former are limited to the valleys of comparatively moderate depth and width, which have been subsequently cut through the glaciated and deeply abraded land.

EXPLANATION OF PLATE VII. (see also Map, Pl. VIII.).

Diagram-sections of the Hill-Drifts of Pre-Glacial date in the Valley of the Thames within the Chalk-basin. Owing to the length of these sections and the limits of space the vertical scale is unavoidably exaggerated. In Fig. 1 it is not so important, as the gradients of the Westleton Shingle and Boulder-clay bear a tolerably uniform relation one to another; but in the other figures it misrepresents the incidence of level between the several Hill-Drifts, for which allowance must be made. The relative height of the hills and depth of the valleys are, however, on a true scale, and this is the essential point connected with the question. These are taken from the new 1-inch Ordnance Maps.

- Fig. 1. Section from Oxfordshire to the coast of Suffolk. The length of this section is about 140 miles. The dotted lines prolong the levels of the Westleton Bed and Boulder-clay, and serve to indicate the extent of denudation which has taken place since each of these epochs respectively.
2. Section, about 50 miles long, passing from Hindhead through the Bagshot district and across the Valley of the Thames, near Windsor, to the borders of Hertfordshire.
 3. Section from the edge of the Weald across the Norwood Hills, the Thames at London, and the Tertiary hills north of London, to the Valley of the Lea near Hatfield: distance about 40 miles.
 4. Section from the Valley of the Medway, near Tunbridge, by Cobham, near Rochester, across South Essex to the Brentwood group of hills: distance about 36 miles.

Railway-Cuttings.

Fig. 5. Section of the Great Eastern Railway, through Brentwood Common. This cutting was of greater depth; only the upper 40 feet are represented in the figure. The surface is 360 feet above O.D.

- A. Boulder-clay of a dark grey colour, containing fragments and small blocks of chalk, sandstone, Jurassic rocks, angular flints, and flint-pebbles, with a few specimens of *Gryphæa incurva* and a species of large Oyster. Eastward, it passes into a sandy bluish-green clay with flint-pebbles, and then into a brownish clay, roughly laminated and without pebbles. It has a maximum thickness of 30 feet.
- A'. Sand and gravel, consisting chiefly of flint-pebbles. The sand contains thin subordinate layers of grey and brown clay.

D. Lower Bagshot Sands.	{	1. Fine white sand passing into bed No. 2	10	feet.
		2. Ochreous and ferruginous, sandy, with some iron-sandstone	4	
		3. The upper part of this bed consists of a tough brown laminated clay, with grains of green sand and a few patches of white micaceous sand, passing down into a massive argillaceous dark green sand, with some lighter seams. This bed contains numerous small <i>Lingule</i> , with casts of various bivalves in iron-pyrites, teeth, and vertebræ of Shark and <i>Carcharodon</i> , and fragments of wood pierced by <i>Teredo</i> ...	16 to 20	
		4. Fine light-yellowish sand, interstratified with thin irregular seams of laminated dark-grey clay. Traces of carbonaceous matter. No fossils. This bed varies in thickness, resting on an uneven surface of the London Clay	4 to 12	

E. London Clay: dark grey with grains of green sand and concretions of iron-pyrites. Only traces of fossils.

Fig. 6. Section of the Black Notley Cutting on the branch line from Witham to Braintree. This fine and typical section was about half a mile in length, and about 25 feet deep in the centre.

- A. Boulder-clay containing numerous large angular flints and chalk-pebbles; it passes from dark brown to a whitish colour.
 - A'. Boulder-clay gravel, very coarse and much contorted. It consists chiefly of subangular flints, pebbles of flint and white quartz, of dark quartzite and sandstones. The upper part is of a dull brownish-white colour, whilst the lower part is dashed with ochreous, ferruginous, and black seams and streaks, passing in places into a dark ferruginous conglomerate
- 5 to 10 feet.

- B. Fine sand and shingle, horizontally stratified, and in places obliquely laminated. It consists essentially of sand, with subordinate seams of shingle, composed of small flint- and white quartz-pebbles with some subangular flints. The upper half of this bed is ochreous, and coarser than the lower half, which is of a light yellow colour with faint ochreous seams. It is traversed by a few small faults of from 3 inches to 3 feet throw 15 feet.

Fig. 7. Section between Chapple and Mark's Tey on the branch line to Sudbury.

- A. Dark grey Boulder-clay, divided into an upper chalky and light-coloured bed, and a lower one of a dark bluish-brown colour. 14 feet.
 B. Sand and gravel; the upper part coarse and ferruginous, the lower part white with ochreous seams and regularly stratified 10 feet.
 E. London Clay with seams of *Septaria*. This cutting is from 20 to 25 feet deep. At the time of my visit the central part was but just commenced, and is filled in from inference afforded by the trial-holes only.

Fig. 8. Section on the Railway at Kyson, one mile South of Woodbridge.

The Boulder-clay does not show in the Section, but crops out a little higher up the slope of the hill, above B.

a. Trail of loam and gravel.

		feet.
B. West- leton.	1. White sand, full of small flint- and white quartz-pebbles, subangular flints, chert, &c. (see p. 125)	2
	2. White and light yellow sand	1
C. Crag.	1. Bright yellow sand, with occasional oblique lamination, without fossils	10
	2. Coarse sand, much oblique lamination, shells in local patches	5
	3. Red Crag; very fossiliferous at the west end of the cutting, but fossils scarce at the east end. At the base is a thin bed of <i>Coprolites</i> , on a denuded floor of London-clay <i>Septaria</i>	12
E. London Clay.		

DISCUSSION.

The PRESIDENT said that a paper of this kind was the result of enormous observation and very careful reasoning. There was one point which had occurred to him: if the Westleton series were marine, either the whole area had been depressed uniformly, or there had been a greater depression to the westward. On the first hypothesis, thicker marine strata would probably have been found to the eastward and westward, and in the latter case it was remarkable that no marine beds of this age were found on the Western coast. He had no doubt that the Author had carefully considered the possibility of the subaerial origin of these beds before rejecting it.

Mr. TOPLEY called attention to the section at Hertford Heath, and asked whether the composition of the beds was not peculiar. The evidence as to the southern origin of the pebbles he considered very important. If the older beds and the Westleton Beds are composed of Southern Drift, they are sharply marked off from the Glacial beds. A section exhibited from Hindhead to Windsor was of interest as bearing on the relation of these beds to the Chalk escarpment and the Weald. The escarpments might possibly be

older, and the Westleton Beds have lapped over them. Even if older than the escarpments, the beds were evidently newer than the elevation of the Weald.

Prof. HUGHES pointed out the difficulty of correlating unfossiliferous and variable beds when they were separated by considerable intervals. He thought that movements along the Weald-axis and affecting all East Anglia had occurred many times down to a late age. The Glacial beds rest quite irregularly on the higher- and lower-level gravels of Hertfordshire. The Hertford-Heath beds had, he believed, nothing to do with the Glacial deposits, but that between them there had been an elevation, denudation, and resubmergence of that area, and that the ingredients of these beds might have come from the north and west. The pebbles became smaller, tracing the stones from Hertford Heath to Hampstead, where he recognized two Pebble-beds, the upper with quartz being the equivalent of the Hertford-Heath beds, and the lower being the Bagshot pebble-bed. He had traced them along the top of Epping Forest also, and would look for them on the North Downs. The Sheppey gravel was an angular one, and different from that of Hertford Heath; whilst there was a gravel near Chatham on the mainland opposite Sheppey of different origin, being the deposit of a stream flowing northwards from the Weald. He shared the general regret that the Author was unable to be present, especially as he could probably have cleared up some of these difficulties either by reference to parts of the paper which had not been read or by supplementary remarks.

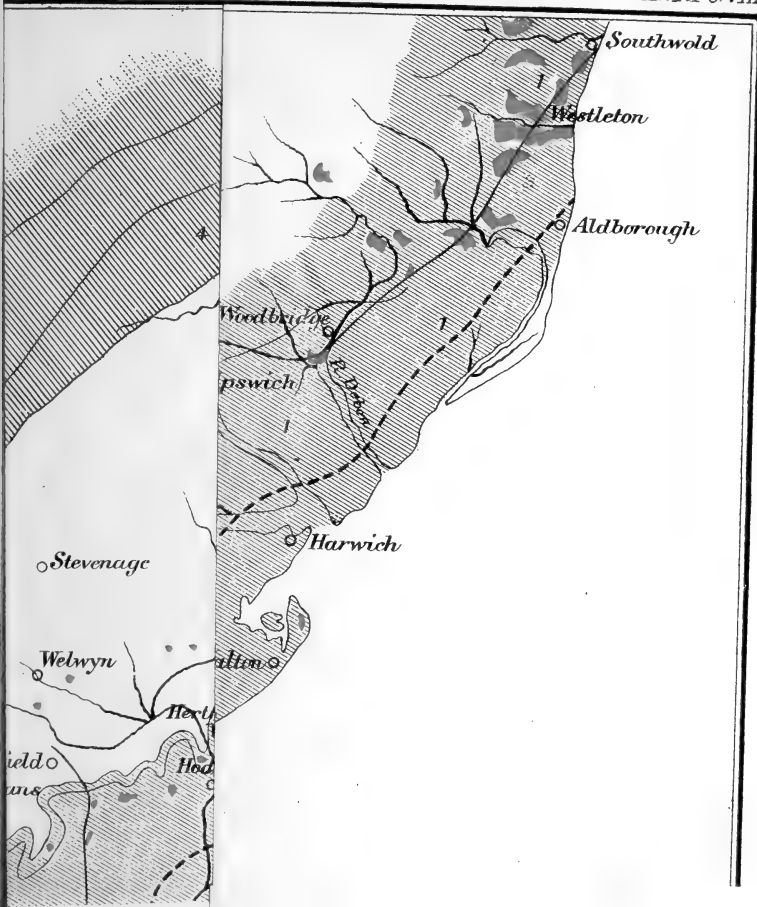
Mr. J. ALLEN BROWN had collected rocks from the high-level drifts of the Thames valley, and there was no doubt as to the occurrence of southern drift therein, though the northern drift preponderated.

Mr. MONCKTON agreed with the criticism of Prof. Hughes. There is a considerable break in the continuity of the proposed Westleton Beds north-east of High Beech, Essex.

The East-Berkshire plateau-gravels were shown in one of the diagrams; they were very different from the High-Beech gravels—quartz was, for instance, very rare in them, and he had placed on the table the only large block of quartz he had found in them.

Dr. IRVING was sceptical as to the identification of the Berkshire gravels with those of Essex and Suffolk. The Author appeared, since his York paper, to have altered his views as to the date of the upheaval of the Weald. He was in accord with Prof. Prestwich as to a certain amount of glacial erosion, by which he meant the work done by floating ice. He believed that the plateau-gravels were themselves fluvial and of much older date.

Mr. MARR stated that if the paper had been read in full many of the questions raised by the previous speakers would have been answered.



MAP OF THE PREGLACIAL DRIFT BEDS OF THE BASIN OF THE THAMES.

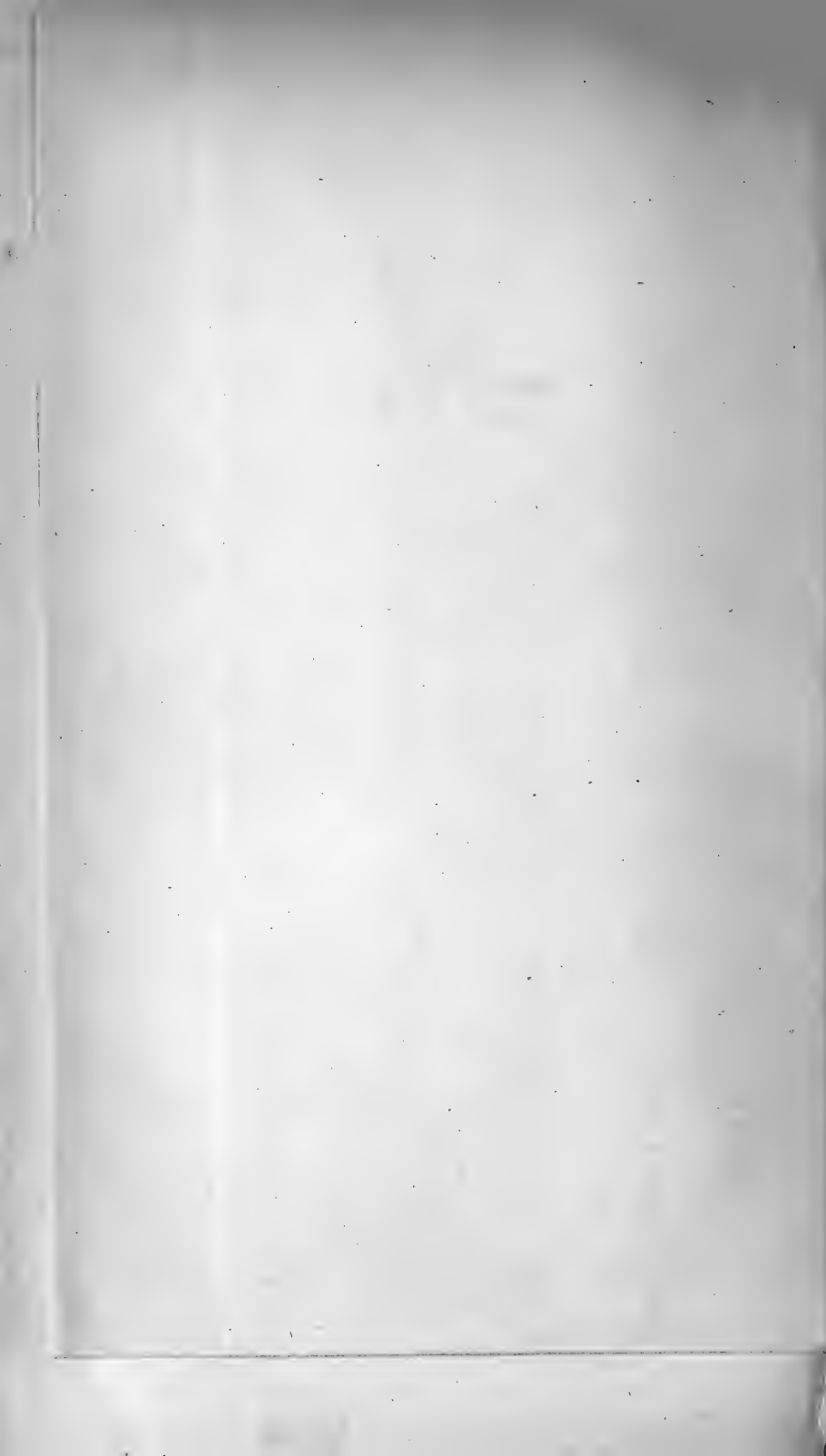
- Westleton Beds.
- ⊙ Brentwood Pebble Bed
- Southern Drift.

- 1. Crag Beds.
- 2. Tertiary (Eocene).
- 3. Chalk.
- 4. Upper Greensand & Gault.
- 5. Lower Greensand.
- 6. Wealden or Jurassic.

--- Southern boundary of the Boulder Clay.
 Lines of Section (Pl. VII)

Scale.
 1 inch = 5 miles





10. *On the RELATION of the WESTLETON SHINGLE to other PRE-GLACIAL DRIFTS in the THAMES BASIN, and on a SOUTHERN DRIFT, with OBSERVATIONS on the FINAL ELEVATION and INITIAL SUBAERIAL DENUDATION of the WEALD: and on the GENESIS of the THAMES.* By JOSEPH PRESTWICH, D.C.L., F.R.S., &c. (Read February 26, 1890.)

PART III.

THE SOUTHERN DRIFT.

[PLATE VIII.]

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1. *Distinctive Characters of the Southern Drift.*

TAKING the strata in their order of succession, this paper ought to have preceded the last, but for the fact that for the purpose of classification it was essential to have a base-line of which the position had been previously determined, such as that offered by the Westleton Shingle, before the relation of the other pre-glacial Drift-deposits in the Thames Valley to one another and their relative age could be established. It is for this object that I attach importance to the Westleton Beds last described; but besides these, which are confined almost entirely to the north side of the Thames, there is another closely allied hill-drift, which I propose to call the "Southern Drift," of more limited range and confined chiefly to the south side of the Thames. I at first thought it possible that they might be synchronous*, but now I have come to the conclusion that the Southern Drift is the older of the two, in the sense afterwards to be explained. Both of them are so restricted to outliers, often very small and far apart, and have been so much encroached upon by Glacial Drifts of later date, that the relation they bear to one another is generally much obscured.

The leading points on which we have mainly to depend are the relative levels and the differences in the character and origin of the rock-fragments and pebbles composing the two deposits, and in

* Much hinges upon their relative levels. These I had originally taken with an aneroid barometer, but the new 1-inch Ordnance Maps have now furnished me with the more accurate data required.

the proportion and condition of those which are common to both. For example, the Westleton Shingle is, as before mentioned, characterized by the constant presence of numerous pebbles of white quartz with a few small pebbles of Lydian Stone, Jasper, and others of old rock origin, and some peculiar larger quartzite-pebbles; whereas a similar abundance of quartz-pebbles is wanting in the Southern Drift, which, on the other hand, is characterized by a large though variable proportion of worn fragments of chert and ragstone—not that these are wanting in the Westleton Shingle, but they are in less abundance, more reduced, and hold a more subordinate position. The materials common to both, but present in different proportions, are subangular flints and flint-pebbles; while the absence of quartzite-pebbles derived from the Triassic rocks of Central England equally stamps both, and is one of the marks of distinction from the Northern Drift. The Westleton beds also had a marine origin, whilst the other seems to have been formed in great part under subaerial conditions.

The following are the component materials of the Southern Drift, taken in the order of their relative abundance, and with the sources whence derived:—

1. Angular and subangular fragments of flint, some retaining their natural colour, others much worn and stained uniformly of a deep warm brown colour. The former are derived directly from the Chalk, and the latter from an older Drift, the location of which is still uncertain (probably Diestian).
2. Pebbles of flint derived from the Lower Tertiary strata of Kent and Surrey, which formerly extended over the Chalk-area more generally and also further southward.
3. Subangular fragments in very variable proportions, and more or less worn, of chert and ragstone, derived from the Lower Greensand of Kent and Surrey.
4. Occasional small pebbles of white quartz (smaller and more opaque usually than those of the Westleton Shingle), derived, together with a few quartzites and some old rock-pebbles, from the Lower Greensand or from the Wealden.
5. A few subangular fragments of ironstone-grit and ironstone derived either from the Lower Tertiaries, the Diestian, or the Lower Greensand. No organic remains have been found in this Drift, of which the negative characters are the absence of the white and often chalcedonic quartz-pebbles of the Westleton type, of Triassic quartzite-pebbles; and of Jurassic débris.

2. *Distribution of the Southern Drift.*

This we will take, as in the former paper, in the order by counties.

Kent.—There is a considerable spread of very ferruginous sandy gravel on the Tertiary hills of East Kent, consisting of subangular flints with a small proportion of flint-pebbles. Although fragments of chert are wanting, or extremely scarce, I think it probable that the gravel on some of the higher grounds, such as Dunstead, the hills west of Canterbury (250 to 300 ft.), and a few other of the higher hills of the district, belongs to this Southern Drift, as it is

much above the level of the Post-Glacial Drifts, contains no organic remains, and is distinctly a plateau or hill-gravel.

It is not, however, until we reach the neighbourhood of Rochester that the Southern Drift is found well characterized. It there caps the wooded hill extending eastward, at a height of about 400 feet, from the mausoleum in Cobham Park to within a mile of the Medway (see Pl. VII. fig. 4). It is a coarse gravel, lying bare on the surface, and consists roughly of*—

- | | | |
|--|---|---------------|
| 1. Subangular flints but little stained, with others more worn and stained uniformly brown | } | $\frac{3}{5}$ |
| 2. Flint-pebbles, some of them broken and white, with abraded edges, and green-coated flints from the base of the Thanet Sands | } | $\frac{1}{5}$ |
| 3. Subangular fragments of chert and ragstone from the Lower Greensand, and a few pieces of iron-sandstone | } | $\frac{1}{5}$ |

There is an absence of white quartz-pebbles.

Traces of similar gravel occur a few miles to the south of the last, on the hills between Halling and Punish Farm, near the edge of the Chalk-escarpment.

On the high Chalk-plateau between the Medway and the Darent there is in several places, namely at Ash, Fairseat, Plastal Green, Wrotham Hill, Cotman's Ash, Bower Lane, and others, a thin sprinkling of this old flint- and chert-drift. But there is no bed of it, except on the isolated Tertiary outlier at Swanscombe Hill †, $3\frac{1}{2}$ miles north of the main Chalk-plateau, where it forms a small patch, 316 feet above the sea-level, and almost identical in composition with the gravel on Cobham Hill.

A much more important bed of this character is one which I met with long ago on the summit of Well Hill, near Chelsfield, a ridge from 550 to 600 feet high, *forming the water-shed* between the Darent and the Cray, and extending about one mile from south to north, with a width of only a few hundred feet. This bed of gravel is from 5 to 12 feet thick, very coarse and unstratified, and consists mainly of;—

1. Subangular flints, many of them very large and very much worn, and having the interior texture altered to an opaque white or brown colour; with a few smaller ones stained brown on the outside, and still more worn.
2. Numerous flint-pebbles (some of them broken and worn) from the Woolwich and Reading Beds, and a very few green-coated flints from the base of the Thanet Sands.
3. A very small number of subangular fragments of chert and ragstone.
4. A few rare flat ovoid white quartzites.

The whole imbedded in ochreous quartzose sand and clay. This Drift rests on an uneven surface of Lower Tertiaries, which forms an outlier rising above the surrounding Chalk-plateau, see fig. 7, p. 170.

* The relative proportions vary so much in different localities that it is not necessary to describe it very closely.

† I have described this bed in Quart. Journ. Geol. Soc. vol. xlv. p. 291 (1889).

Though Lower Greensand *débris* is extremely scarce in this gravel, there is, lower down (500 feet above O.D.) on the south side, and resting on the Chalk-plateau, at a spot above the railway-tunnel opposite Colegate Farm, a small patch of gravel composed in large part of fragments of chert and ragstone. Another small patch caps the hill with the clump of trees (366 feet) just north of Lullingstone Park.

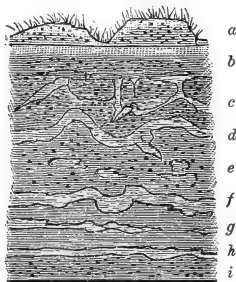
More recently, I have discovered a bank of this gravel, very coarse and with much chert and ragstone, some of large size, on the slopes of the hill on the left bank of the Darent, between Eynsford and Farningham. There it does not cap the hill, but extends on its slope from 250 feet nearly to the summit at 350 feet. It is not worked, but, being bare, is easily examined.

Thence westward to the borders of Surrey I know of no well-marked body of this gravel (unless a sprinkling of flint-gravel on the top of Red Hill near Chislehurst should be grouped with it), although here and there on the Chalk-plateau there is, as on the downs east of the Darent, an occasional thin sprinkling of chert-fragments and much-worn brown-stained flints.

Surrey.—Here it is on the Tertiary hills, and not on the Chalk-downs, that we find the best exhibition of this Southern Drift. A thin bed of it resting on London Clay caps West-Ho Hill, Norwood (see Plate VII. fig. 3).

The following is a detailed section taken some years since :—

Fig. 1.—*Section of Gravel-pit on West-Ho Hill*.*



	ft.	in.
a. Surface-soil	2	0
b. Loamy gravel	1	0
c. Fine ochreous gravel with veins of grey sandy clay	1	0
d. Grey sandy clay		6
e. Yellow gravelly sands	2	0
f. Grey sandy clay.....		6
g. Ochreous sand	1	3
h. Grey sand		3
i. Coarse ochreous gravel.....	2	0+

* This pit is now probably built over.

According to the one specimen I kept, this gravel consists of:—

1. Subangular flints, unstained and stained brown,—in largest proportion.
2. A considerable proportion of Tertiary flint-pebbles—some broken and worn.
3. About 10 per cent. of subangular fragments of chert and ragstone.

With one pebble of a hard sandstone or quartzite (Tertiary?) and one small pebble of quartz.

This gravel extends southward all along the top of this hill, at a height of from 360 to 380 feet above O.D.

From the Norwood hills we pass westward over a lower tract of country with gravels of later age, as far as Wimbledon Common, which rises to the height of 183 feet above the valley of the Wandle. It is capped by a Drift-gravel, about which I feel uncertain. It has all the elements of the Southern Drift, but in addition it contains quartzite-pebbles, which have the Triassic characters. It is therefore either of Glacial age, or else a Southern Drift invaded by a later Glacial Drift. It consists, in the order of their relative abundance, of:—

1. Subangular flints stained yellow.
2. Tertiary flint-pebbles.
3. Subangular fragments of cherty ragstone and of a yellow chert.
4. Pebbles of white quartz, of dark quartzite, sandstone, and ironstone.

Imbedded in a ferruginous matrix of coarse worn quartzose sand.

The next hill to break the uniform level of the later Thames-valley gravels is the isolated and conspicuous hill known as St. George's Hill, which rises $1\frac{1}{2}$ miles to the south of Weybridge to the height of 245 feet, and is capped by a Drift-gravel much like that of Wimbledon, but without the quartzite pebbles. I have less difficulty, therefore, in referring it to the Southern Drift, although it contains some small white quartz-pebbles, but these may be derived from the Lower Greensand or Wealden. The gravel is composed as under:—

	per cent.
1. White and yellow-stained subangular flints	44
2. Tertiary flint-pebbles, some broken	30
3. Subangular fragments of ragstone and brown chert	15
4. White quartz-pebbles.....	5
5. Pebbles of sandstone, ironstone, &c.	6
	100

in a matrix of quartzose sand.

The greater part of the Surrey Chalk-Downs are bare, with the exception of a few Tertiary outliers and the red clay with flints. But on Merrow Down, near Guildford, there is a gravel which seems to belong to this Drift. It consists in large proportion of Tertiary flint-pebbles and subangular flints, mostly white, of some subangular fragments of cherty ragstone, and of a hard sandstone (Tertiary), with a few small rough quartz-pebbles, imbedded in a

matrix of bright yellow and red sands. The Downs at this spot are from 400 to 500 feet high. The Hog's Back, which rises to the height of 500 feet between Guildford and Farnham, is bare of any Drift.

To the north of these Downs are the extensive heath-covered hills of the Bagshot, Chobham, and Frimley ridges, from 350 to 415 feet high. These are capped by the Southern Drift, with a certain proportion of ragstone and chert, imbedded in a coarse ochreous and ferruginous sand. The gravel is from 6 to 12 feet thick, roughly stratified, and becomes white on exposure. Large blocks of Tertiary sandstone* occur not unfrequently, and in places there are a few small quartz-pebbles (Pl. VII. fig. 2).

Berkshire.—The lower part of the valley of the Thames immediately adjacent to the river exhibits only Glacial and Post-Glacial Drifts. The higher hills which range from Windsor Forest to Sandhurst are covered in great part by the Southern Drift.

The most striking instance I know of is that exhibited on Cherry Down (named Burleigh in the new 1-inch Ordnance Maps), near Ascot. Subangular fragments of chert and ragstone are there so abundant that they almost equal in number the subangular flints, which, with flint-pebbles and a few fragments of iron-sandstone, constitute the other portion of this gravel. These are imbedded in a yellow quartzose sand with some black grains and quartz-grit: in the gravel there are a few intercalated grey and red argillaceous seams as at Norwood. This hill is about 300 feet above sea-level, and 220 to 240 feet above the plain of the Thames at Windsor and Slough (see Pl. VII. fig. 2).

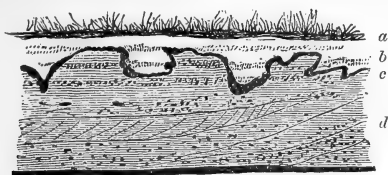
Further westward the ridges are less persistent, and isolated hills more frequent. Several of these are capped with this gravel. On one of them, called "Gravel Hill" on the map, 400 feet high, and 1 mile east of Cæsar's Camp Hill, near Easthampstead, the gravel consists of:—

	per cent.
1. Subangular fragments of flint, part not stained, and part stained yellow and brown	40
2. Tertiary flint-pebbles, of which about one fifth part are broken.	32
3. Much-worn fragments of light-coloured ragstone and yellow chert, and ironstone-grit	18
4. Small pebbles of white quartz	4
5. Pebbles of white sandstone and subangular fragments of Sarsen stone (Tertiary)	6
	100

Long exposure has bleached the upper part of the gravel, which is roughly stratified, as seen in the following section:—

* Some of these are 20 tons in weight. They mostly occur deep down at the base of the gravel, and are derived from the Upper Bagshot Sands on which the gravel rests.

Fig. 2.—Section of Gravel-pit, Gravel-pit Hill, near Easthampstead.



- | | |
|---|---------|
| a. Black peaty soil | } 5 ft. |
| b. Bleached gravel | |
| c. Irregular black carbonaceous band | |
| d. Ochreous gravel with sandy beds showing oblique lamination. | |

The same gravel caps Cæsar's Camp Hill, but is not worked there.

Hampshire.—Among the most conspicuous of the gravel-capped hills in this county are Hungary and Cæsar's Camp Hills near Farnham and Aldershot. They are respectively 577 and 600 feet high, and the gravel on the former consists of:—

	per cent.
1. Much-worn subangular fragments of flint weathered white	50
2. Tertiary flint-pebbles, of which about two thirds are broken and worn	36
3. Small subangular fragments of light-coloured cherty ragstone and of ironstone-grit (Lower Greensand).....	6
4. Pebbles of Tertiary sandstone and Sarsen stone, some with rude vegetable impressions	8
	100

Imbedded in a matrix of yellow loam with much-worn quartzose sand, passing into coarse quartz-grit the size of peas.

A tract of flat country intervenes between these last hills and the smaller ridges of Hartley Row, Bramshill, and Hazeley. The gravel at the first-named place is roughly stratified and disturbed at top, and is composed of:—

1. Subangular worn brown-stained flints.....	$\frac{5}{10}$
2. Tertiary flint-pebbles, some of them broken	$\frac{4}{10}$
3. Subangular pieces of ragstone and iron-sandstone with a very few small quartz-pebbles	$\frac{1}{10}$

Imbedded in an ochreous sand with veins of a greenish-grey clay. The whole is roughly stratified, and the upper part much disturbed.

The Confines of Hampshire and Berkshire.—Between Hazeley Heath and Reading the country is flat, with the exception of the hills at Heckfield and Farley, near Swallowfield (300 feet?). These are capped by a little flint-gravel, weathering white.

A low tract of bare London Clay then intervenes at Strathfieldsaye and on to Burghfield, where a bed of flint-gravel commences (on the

Common), and continues past Silchester, Tadley, and Brimpton Commons, to Greenham Common near Newbury. This gravel, which is sandy, roughly stratified, and weathers white, consists essentially of subangular flints with Tertiary flint-pebbles, and some much-worn fragments of a very fine-grained variety of Sarsen stone. There is also a certain number of small blocks of Sarsen stone, or so-called Druid Sandstone, scattered over the district; and one well-known large block (the Nymph Stone) of hard Lower Chalk lies on Silchester Common. Though there is in this gravel an absence or extreme rarity of Lower-Greensand débris, I think, from the level of these plateaux (330 feet on Silchester Common to 402 feet near Newbury), and from its relation to the valley-gravels, that it belongs to the period of the Southern Drift. The Wealden anticlinal did not bring the Lower Greensand to the surface to the south of this district; it only raised the Chalk.

Wiltshire.—Westward of this point there are few traces of this flint-gravel. I have found it capping Upper Kirby Green hill (573 feet), near Inkpen. A little also occurs on the high ground of Martinslee Hill, near Marlborough; but I have not recognized it further westward in this direction, though traces of it extend over some of the Oolitic hills.

3. *Other Pre-Glacial Hill-Gravels: the Warley and Brentwood Groups.*

Besides the two distinctive Pre-Glacial Drifts here described, there are two others not so easily assigned to a definite horizon, although there can be no doubt of their Pre-Glacial age. One has many of the characters of the Southern Drift; and the other, which is better known, has the essential characters of a Bagshot pebble-bed*.

The first of these groups caps Langdon and Rayleigh Hills in South Essex, and Hampstead and Highgate Hills in Middlesex. They are so few in number and are so nearly on the same plane as the other two groups, with which they possess many characters in common, that I can scarcely doubt that they belong to one or the other of them.

Rayleigh.—This range of hills, which is a little to the north-west of Southend, and rises to the height of 250 or 260 feet, is capped by a thin gravel consisting of:—1. Numerous flint-pebbles. 2. Some white subangular fragments of flint. 3. A very few small white quartz-pebbles. 4. Fragments of Tertiary Sandstone (one piece measured 18 × 9 inches). 5. Subangular fragments of brown chert

* See Mr. S. V. Wood, junr., "On the Pebble-beds of Middlesex, Essex, and Herts," *Quart. Journ. Geol. Soc.* vol. xxiv. (1868), p. 464; Mr. W. Whitaker's "Geology of the London Basin," *Mem. Geol. Survey*, vol. iv. (1872), pp. 320–328; and 'Guide to the Geology of London,' 5th edit. 1884, p. 55; and Messrs. H. W. Monckton and R. S. Herries, "On some Bagshot Pebble-beds and Pebble Gravel," *Proc. Geol. Assoc.* vol. ix. (1889), p. 1.

(one small block measured 4 inches each way) and ragstone imbedded in a bright ochreous clayey sand. I found no pebbles of the older rocks.

Bagshot Sands, 30 feet thick, and overlain by from 2 to 3 feet of a ferruginous pebble-conglomerate, cap Boyce Hill (200 feet), near South Benfleet*. Two to three feet of a Drift-gravel overlie the conglomerate.

Langdon Hill.—Eight miles westward of these hills, and separated by a low tract of nearly bare London Clay, is Langdon Hill the highest (373 feet) in South Essex. It is capped by some 40 or 50 feet of Bagshot Sands, over which is a thin sprinkling of gravel, composed almost entirely of flint-pebbles, with which are mixed a few subangular flints, and some very much weathered fragments of chert and ragstone (Pl. VII. fig. 4).

The Glacial Beds to the north do not approach within some miles of Langdon Hill, and then they are on a much lower level (150 to 200 feet), as they are also at Rayleigh.

Hampstead and Highgate.—On the Bagshot Sands at Hampstead there is in places a thin sprinkling of flint-pebbles (Bagshot), mixed with which I have found a few subangular fragments of flint and of a cherty ragstone, whilst at Highgate we can only surmise that similar traces occur; but the ground is too much built over for any sufficient observations to be made. The relation of this Drift to the Glacial Beds is here much the same as that of the Westleton Beds at Totteridge to the Glacial Beds at Whetstone—that is to say, that in both places the Glacial Beds are about 100 feet lower than the top of these hills. At Highgate the Boulder-clay comes in at the foot of the south slope of the hill (Pl. VII. fig. 3), and is not met with higher.

The summits of Hampstead Hill, and of Mill Hill near Totteridge, are nearly on the same plane, whilst the summits of Langdon Hill and Rayleigh Hill differ little from the height of Brentwood and Writtlepark hills. In the latter instances, the Westleton Shingle seems to be on a level somewhat lower, although it is at a sufficient distance for a slight alteration in the dip to lessen or annul the difference. The dip, however, of the Westleton Beds is in general southward, and not northward.

On the whole, these Drift-beds show more analogy with the Southern Drift than with the Westleton Beds. It is possible, however, that in the case of Hampstead Hill the two may have had the same floor and got intermixed. In the case of the Essex Hills, there may be a connexion with the Brentwood group, but further research is required to decide the exact relation of these drifts.

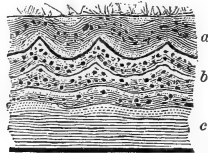
The Brentwood Group.—The other hill-drift of this section may be termed the Brentwood or Warley Group, from its being best developed in that part of Essex, where it forms a number of detached outliers. The most eastward of these hills are those which range from a little west of Chelmsford to near Brentwood,

* This would seem to indicate a fault between this spot and Rayleigh.

with a height of from 300 to 350 feet. These hills consist of London Clay, with remnants of Bagshot Sands on the summits of some of them. The Boulder-clay wraps round the east end of this range at a level of about 150 feet below its summit, but on the northern slope it rises much higher. The Pebble-beds which cap the hills at Writtlepark, Beggarhill, Mill Green, Fryerning, and Norton Heath seem to be little else than Bagshot Shingle more or less disturbed and mixed with a few subangular flints, quartzite-pebbles, and pieces of quartz.

A more conspicuous range of hills is that which extends a few miles further to the south-west, from Brentwood to Warley and Billericay (see Pl. VII. fig. 4). On Brentwood Common (352 feet) the Pebble-bed is thin and very much disturbed, as shown in the annexed section :—

Fig. 3.—Section of disturbed Pebble-bed, top of Railway-cutting, (west end) Brentwood Common.



- | | |
|---|--------------|
| a. Grey clay, with flints and pebbles | } 3 to 4 ft. |
| b. Pebble-bed disturbed | |
| c. Light-coloured sands | |

The railway-cutting exposed other features in connexion with the Bagshot Beds, which require some notice. The Warley Pebble-bed does not extend so far as the cutting, or rather it is there hidden by a bed of clay, which displaces the Bagshot strata, and soon acquires a thickness of 30 feet. As it increases in thickness its true Boulder-clay character is apparent; it becomes darker, and contains imbedded large subangular flints, flint- and chalk-pebbles, pebbles of sandstone, and fragments of Jurassic rocks, with specimens of *Gryphæa incurva* and a large Oyster. As this Clay trends further eastward, it passes into a sandy brown and bluish clay with only a few pebbles, and finally thins out as a greenish clay or marl (see A, Pl. VII. fig. 5, and p. 152).

At the base of this Clay is an irregular bed of sand and gravel, thickening as the overlying clay thins out, and consisting chiefly of flint-pebbles, while the way in which the Boulder-clay has mounted the hill and displaced the strata of the Bagshot Beds deserves notice.

The Bagshot Beds themselves, which are here 40 feet thick, will be found described in the explanation of the section (Pl. VII. fig. 5, p. 152). There are no Pebble-beds here *in situ*. They were

apparently disturbed and displaced on the north side of the hill and pushed southward.

At Warley Heath (378 feet) the pebble-gravel is thick and little disturbed. The flint-pebbles have a distinctive character of their own. They are unlike those of Blackheath or of the Westleton Beds. Dr. Mitchell speaks of them in his papers (MSS.) as the Warley pebbles. They are larger and less shapely than those of Blackheath, and are often weathered white. Of their derivation from the Bagshot Beds, with which these shingle-beds are in close association, there can be little doubt, for at Billericay there is a thin bed of flint-pebbles intercalated in the yellow sands of the Bagshot which cap the hill, and Mr. H. B. Woodward gives a section at South Weald Park, near Brentwood *, showing a bed of pebbles 15 feet thick *in situ*, and overlain by 6 feet of Drift-gravel. We have, in some cases, therefore, this Eocene Shingle *in situ*, whilst in others it seems to have been affected by the Southern Drift and by subsequent Glacial action.

This range of hills formed here, as did the Hampstead and Highgate on the north of London, and the Bushey and Stanmore Hills to the south of Watford, the boundary to the advance of the Boulder-clay; for though Glacial gravels and evidences of Glacial action are to be found further south, there is no Boulder-clay.

Stanmore.—An important mass of shingle-gravel spreads over Stanmore Heath (400 to 450 feet), from little Bushey to Bentley Priory. It is composed in large part of:—

1. Flint pebbles, a good many being white-coated.
2. Very few subangular flints, stained brown.
3. Some small white quartz pebbles.
4. A few worn green-coated flints, from the base of the Lower Tertiary sands.

Imbedded in a matrix of coarse yellow and ochreous sand, and resting upon an indented surface of London Clay, as though due to pressure (glacial) from above. Many of the pebbles also have their longer axes upright.

I did not notice any chert or ragstone in this shingle, and in other respects it resembles the Brentwood and Warley, more than the Westleton Shingle. The few quartz-pebbles may have been derived from the Lower Tertiaries, which in the Pinner district contain a few such pebbles.

The hill (380 to 400 feet) between Pinner and Watford, as well as Brockley (416 feet) and Elstree Hills (450 feet), on the other side of Stanmore, are capped by a small spread of similar shingle, but it is not worked.

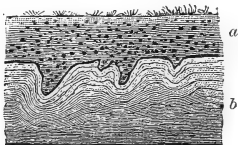
There is no Boulder-clay to the west or south of these hills; and

* "The Geology of the London Basin," Mem. Geol. Survey, 1872, p. 324; and 'Geology of London,' 1889, p. 273.

that at Bricket Wood and Aldenham on the north is on a level of from 150 to 200 feet lower.

The only outlier belonging to this group on the south of the Thames is that on the summit of Shooter's Hill, 424 feet high. The shingle is there composed essentially of flint-pebbles, with only a few sub-angular flints and a very few rare quartz-pebbles. The flint-pebbles closely resemble those of Warley Heath. The bed is only 2 or 3 feet thick, and is disturbed at the top like that on Brentwood Heath Common and Stanmore.

Fig. 4.—Section in the Brick-field to the West of Bentley Priory, Stanmore, Middlesex.



- a. Unstratified beds of shingly gravel 6 to 7 ft.
 b. Upper loamy bed of the London Clay disturbed by the pressing down of bed a.

It will be observed that on these hills there are either remnants of the Bagshot Sands, or else the London Clay is of such a thickness that little is wanted to bring them in; or, as the London Clay varies somewhat in thickness, it is quite possible that at Shooter's Hill, Havering Atte Bower, and Buckhurst, there were depressed areas in which the Bagshot Sands and pebbles gained at the expense of the London Clay, and that in these cases, as at Brentwood and Billericay, the Pebble-beds are nearly *in situ*.

That the Pebble-beds have been disturbed and partly reformed is, however, evident from the introduction of materials foreign to the Bagshots. This may have been effected at the time of the Westleton or Southern Drifts, though further changes in their condition seem to be due to ice-action in the Glacial period.

4. Early Physiographical Conditions of the Wealden Area.

To understand the relation which the Southern Drift bears to the other Pre-Glacial and Glacial Beds, it is necessary to go back to earlier times to see what were the physiographical conditions previously prevailing in the south of England and the adjacent continental area.

The denudation* of the great dome of the Wealden anticlinal commenced in the early Tertiary period†; but though the Chalk,

* On the general subject of the Denudation of the Weald see chapter 16 in Mr. Topley's 'Geology of the Weald,' pp. 270-301 (1875).

† The author in Quart. Journ. Geol. Soc. vol. xiii. p. 256 (1852).

which then extended possibly over the anticlinal, must have been largely denuded, in order to have furnished the mass of flint-pebbles in the Woolwich Beds, there is no evidence that the denudation reached down to the Lower Greensand and Wealden, as no débris from these sources has been found in the Tertiary strata. For our present object we need, however, only commence with the state of the area in Pliocene times.

It is obvious, as I have shown on a previous occasion*, that in an early Pliocene epoch, before the later denudation of the Weald, the North Downs from Folkestone to Dorking and possibly beyond, together with the adjacent area to the south, were submerged under a sea which extended probably from the North Sea to Brittany and so southward in one direction, and in the other, eastward, over parts of France and Belgium to the foot of the Ardennes. The Pebbly-sands, occasionally fossiliferous (Lenham), that occur at intervals on the edge of the North Downs are proofs of this submergence. On the continent beds of the same early Pliocene age and character are found capping, amongst others, the hills of Mont-de-la-Trinité, near Tournay, and the hills near Boeschepe in Belgium, and of Mont Noir near Bailleul, Mont Cassel near Dunkirk, and the Chalk-hills between Calais and Boulogne, in France, showing the same sea to have extended over that area also.

In these Beds, the Diestian of the Belgian geologists, the fossils have generally been removed by infiltration, and it is only occasionally that a few casts are met with. Where, however, they pass under the newer Crags of the Antwerp district they are very fossiliferous. This deposit, which does not exceed 50 or 60 feet in thickness, consists of pebbly sands, sometimes very ferruginous and passing into iron-sandstone, while the flint-pebbles are often so decomposed that they break under the pressure of the fingers into a white powder.

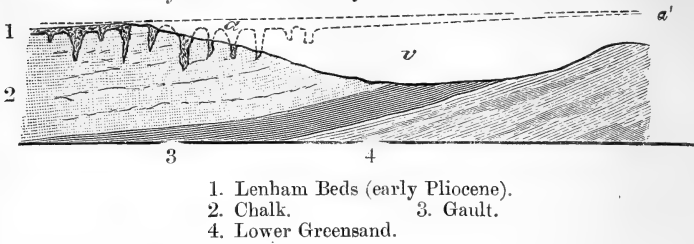
From the position of the Beds at Lenham, we may assume that they originally extended, together with the Chalk, further over the Lower Cretaceous and Wealden strata to the south, as remnants of the Beds are preserved in the sand-pipes, the ends of which occur in decreasing lengths on the bare slope of the Chalk-escarpment, showing that the deposit itself at one time spread over the now denuded area at the foot of the escarpment, as exhibited in the subjoined diagram (fig. 5).

It is clear from that section, that the valley *v* between the Chalk and Lower Greensand hills is of later Pliocene or Post-Pliocene date, and the same reasoning applies to the whole length of this great valley, and in all probability to the Wealden valleys in general.

There can be little doubt, also, that in the early Pliocene times of which we have been speaking, Belgium and the south-east of England and Western France (Normandy and Brittany) were separated, not by the present narrow strait, which was not existent at that time, but by a broad sea-channel extending across

* Quart. Journ. Geol. Soc. vol. xiv. p. 322 (1858).

Fig. 5.—Section of the Chalk-escarpments above Lenham, showing the former extension of the Lenham Sands.



a. Sandpipes in the Chalk.

a'. The dotted lines represent the former extension southward of the Lenham Beds over the Chalk and Wealden.

the Wealden area and over a part of North-western France and of South-western Belgium, before the elevation and denudation of those areas and the excavation of the Straits of Dover.

As neither the White nor the Red Crag of Suffolk extend over the Lenham Sands, while the sand-pipes could only have been formed after the emergence of the latter and a lengthened exposure to atmospheric agencies, it is evident that the east and west elevation of the Wealden area must have taken place at or soon after the White-Crag epoch, possibly at the insetting of the Red-Crag epoch. The effect of this emergence was to bar the Crag sea of the Eastern Counties on the south, and to establish a land-connexion with the continental area along the line of the Wealden and Boulonnais anticlinal, which then, with that of the Ardennes, probably formed a continuous range.

The final elevation of the broad anticlinal dome of the Weald was therefore subsequent to the deposition of the Lenham Sands, and it must have been after that time that the excavation of the valleys *v*, fig. 5, commenced. Hence we may conclude that the denudation of the Weald, as generally understood, is of a date subsequent to the early Pliocene period, that is to say, after the emergence of the Lenham or Diestian Beds, just as we have shown that the excavation of the valleys of the Thames district took place after the elevation of the Westleton Shingle, or subsequent to the early Pleistocene period.

5. *Origin of the Southern Drift.*

The foregoing conclusion respecting a Wealden barrier in Pre-Glacial and Glacial times is confirmed by the circumstance that the component materials of the Southern Drift consist exclusively of débris derived from rocks in the Wealden area, or from those which formerly extended over it. The deep valley (*v*, fig. 5) now separating the range of the Chalk-Downs from the range of the Lower Greensand could, for a long time, have had no existence, for otherwise the débris of chert and ragstone of the Lower Greensand could not

have been carried from the Greensand-range on to the Chalk-plateau on the north. The valley, *v*, must then have been bridged over by the Gault and Chalk to have allowed the transport across it of this débris by streams from the central Wealden area; for there is no reason to suppose it was effected by floating ice.

Let us now try to conceive the condition of the Wealden area at the period of this, its last, emergence. At present, the height of the anticlinal ridge at Crowborough does not exceed 803 feet. To realize the condition of the dome before denudation, we have to add the thickness of the strata removed, which may probably be estimated as under :—

	feet.
1. Chalk. <i>It is doubtful whether this extended to the centre of the Weald, for, as I have already shown*</i> , it had before this time been planed down at its edge to a thickness of 300 feet by Tertiary marine denudation. If that rate of wear were maintained, it is probable that the Chalk either did not extend to the central area, or else was greatly reduced in thickness	100
2. Upper Greensand and Gault	150
3. Lower Greensand.....	450
4. Weald Clay	700
5. Tunbridge Beds and Wadhurst Clay	400
	1800
Add present height of Central ridge (Ashdown Sands &c.)...	800
	2600†

There would thus have been, even supposing that there has been no subsequent subsidence, a low mountain-range extending into the Boulonnais, on the site of the present Wealden area. It is probable also that at this time the Ardennes were considerably higher than they are now (2800 feet), for MM. Cornet and Briart have shown that during their diverse upheavals some 12,000 to 15,000 feet of strata have been removed ‡. This, however, was at a date very long anterior to the Pliocene.

The Wealden range having been uplifted in late Pliocene times, it soon became exposed for a vast length of time to the heavy rainfall, snow, and ice of the Pre-Glacial and Glacial periods, when torrents scored the flanks of the hills, and carried down the harder débris to the lower grounds at their base.

Amongst the earlier results of these denuding agencies is, I conceive, the coarse and much-worn gravel of Well Hill. The large heavy flints with their angles greatly worn, and the unstratified character of this gravel, give it the appearance of having been brought down by a torrent, and of not having been spread out under water. This would account for its very local occurrence; for this stream of stones is confined to Well Hill, and the hill itself seems to result from the protection afforded by the mass of flints, while

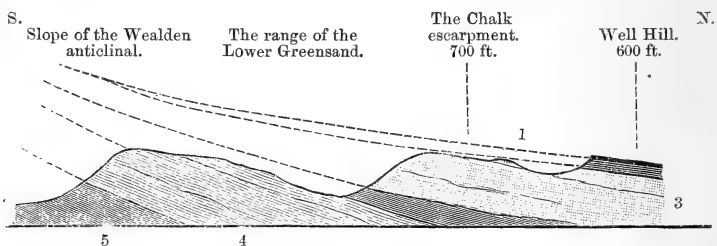
* Quart. Journ. Geol. Soc. vol. viii. p. 256.

† The estimate formed by Mr. Topley, supposing the whole amount of strata removed by denudation to be restored, varies at different parts of the axis from 1000 to 3000 feet ('Geology of the Weald,' p. 217).

‡ Mém. Soc. Géol. de Belgique, vol. iv. p. 71 (1877).

the soft unprotected Tertiary strata on either side have been removed by denudation. That the gravel is of great age is indicated by the extreme weathering of the flints, and by the alteration and discoloration of their substance; while although flint-pebbles from the Tertiary are abundant, débris from the Lower Greensand is extremely scarce, as though the denuding agencies had at that time scarcely reached down to the Lower Greensand, a state of things that may be represented by the following diagrams (figs. 6, 7):—

Fig. 6.—*Theoretical longitudinal Section along the summit of Well Hill (ante p. 157) to the flanks of the Wealden Range.*

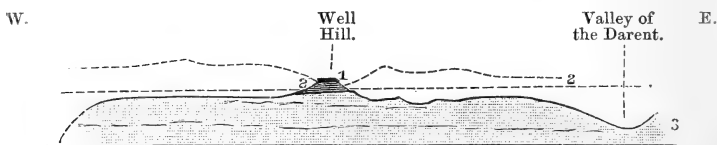


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|---------------------------|---------------------|--------------------|
| 1. Well-Hill gravel. | 3. Chalk and Gault. | 5. Wealden strata. |
| 2. Lower Tertiary strata. | 4. Lower Greensand. | |

The dotted lines show the prolongation of the beds before denudation.

The transverse section shows the position of the gravel in relation to the Tertiary strata formerly on either side.

Fig. 7.—*Theoretical Section across Well Hill and the old Gravel-stream.*



The upper dotted line shows the position of the removed Tertiary strata.

The conjecture that at this time much of the Wealden and Lower Greensand were still hidden under a mass of Chalk and Tertiary strata, finds corroboration in the analogous condition of the gravel on some of the other higher and earlier drift-covered hills, where flints from the Chalk, or flint-pebbles from the Tertiary strata, constitute the whole or nearly the whole of the mass of gravel, and Lower-Greensand débris is either absent or very scarce. Thus, for example, on Hungary Hill there are but few traces of Lower-Greensand débris, and in the flint-gravel of the hills near Canterbury it is absent or nearly so.

Later on, as the covering of Tertiary strata and of Chalk was removed, the Lower Greensand became more exposed, and its hard and indestructible siliceous débris was scattered more widely along the base of the old Wealden range of hills. Thus it is that on the Bagshot hills of Hampshire and Berkshire we find the chert and ragstone of the Lower Greensand occurring in quantity, and in Kent also scattered freely, though thinly, in places over the Chalk-plateau, having lodged there after the denudation of the Tertiaries and their removal around Well Hill.

Another and somewhat later phase occurred when the drainage of the Wealden Highlands became restricted to narrower bounds and more defined channels. It was then that some of the main transverse valleys received their first rudimentary channelling, as, for example, in the case of the Medway, where the flint- and chert-gravel above Halling and on some hills above Stroud point to old channels in the line of the present Medway valley, but at heights of from 200 to 300 feet above the existing river; or, in the case of the Darent, the bank of flints and chert on the slope above Eynsford, at a height of from 250 to 350 feet above that stream. Another instance is that of the Wey through the gorge of the Chalk at Guildford. On the east side of this passage, Lower-Greensand and flint-débris cover Merrow Down at a height of 400 feet, or of 300 feet above the Wey. In all these cases this old gravel is considerably above the Post-Glacial gravel more intimately connected with the existing valleys, though at the same time the Chalk around rises to still greater heights than this Drift.

In the foregoing instances, the valleys flanked by this old chert-drift pass through the Chalk-escarpment into the Wealden area, showing that there has been continuity of action along the same lines from the initial stages of the formation of these valleys to the present time, and therefore that it was not, as has been suggested, the present streams which have cut their way back through the escarpment.

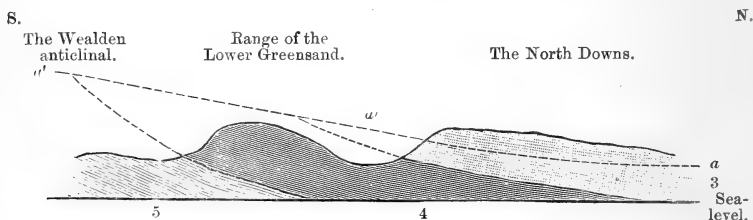
There are other instances where the continuity has been interrupted, and the original drainage diverted into other channels, leaving the valleys, as it were, half formed, and the old channels were left dry, but retaining a drift carried in from beyond their present precincts. A good instance of this is to be seen in the narrow valley of Smitham Bottom (fig. 8), which, commencing at Croydon, runs up to the Chalk-escarpment above Merstham, where it is cut off by the transverse valley draining into the Mole, and no longer passes into the Wealden area. At present it is a dry valley, excepting that during certain seasons there is an outbreak for about half its length of a bourne, which continues to run for a few months, but is in no way connected with the old drainage-area. Along the upper part of this valley, and extending to its end above Merstham, is a thin bed of gravel composed of subangular flints, and flint-pebbles, with subangular fragments of *chert*, *ragstone*, and ironstone derived from the Lower Greensand. It is clear, therefore, that this Drift was deposited before the strata beyond the escarpment

had been removed, and when the valley was prolonged in a southern direction into the Wealden area, and the drainage brought down the usual complement of Lower-Greensand *débris* from the hills beyond the Chalk-escarpment.

At this stage, some disturbance connected with the Central Wealden area diverted the drainage in another direction, cutting off the upper part of the valley, denuding the face of the Chalk-escarpment, and leaving the truncated end of the valley at a height of 174 feet above the stream at the foot of the escarpment (*b*, fig. 9) which now drains into the Mole. The bed of the valley at the point where it is cut off is 438 feet above O.D., while the hills on either side rise nearly 200 feet higher, showing the valley to have been in an advanced stage, but still 200 to 300 feet short of the depth subsequently acquired by that of the Medway or of the Darent.

The date of this old transverse valley is, however, far removed from that which has left its traces on the summit of Well Hill, inasmuch as at the latter date the Tertiary strata had not been denuded from the surface of the Chalk floor, whereas at this time not only had the Tertiary strata been denuded from the Chalk-plateau, but the Chalk itself had become channelled to a considerable depth. The position of the valley in its longitudinal course at the time of its arrested growth, when it had its origin in the Wealden area, is shown in the following diagram:—

Fig. 8.—*Course of the Valley of Smitham Bottom, restored.*



- a.* Level of the valley of Smitham Bottom through the Chalk-hills.
a'. The same prolonged beyond the chalk-hills southward before the denudation of the area.
 3. Chalk. 4. Lower Greensand. 5. Wealden.

The section transverse to the above showing the intersection of the valley in the face of the chalk escarpment is as under (fig. 9).

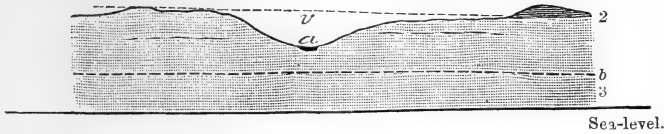
The gravel at Croydon, which belongs to the earlier stages of the valley, is not that on the lower levels, which is of Post-Glacial age, but that which forms the higher banks on Duppa's Hill on the west, and Park Hill on the east of the town.

We will now revert to the earlier streams of Lower-Greensand Drift, described in pages 156-162, and connected with the primary streams or torrents flowing from off the slopes of the Wealden highlands and over the Chalk-plateau. At this period the Wealden

Fig. 9.—Section in front of the Chalk-escarpment above Merstham.

W.

E.



- v. Valley of Smitham Bottom.
 a. Valley Drift.
 b. Level of valley at foot of escarpment.
 2. Lower Tertiary strata. 3. Chalk.

anticlinal may have formed a range from 2000 to 3000 feet high, with a drainage north and south.

As the channels of the early streams became deeper and larger, and the Lower Greensand more exposed, the mass of débris carried down increased, and the proportion of chert and ragstone became greater. It was then that were formed the extensive plateaux of gravel of the Chobham and Frimley Downs, and of the other hills we have named in Berkshire, Hampshire, and Surrey.

In the absence of organic remains of any sort in these plateau-gravels, we are without a clue as to whether fluvial or marine action had to do with their origin. It is not improbable that they are, in part, of subaerial origin; and to compare small things with great, they may have been formed in a manner analogous to the fan-shaped masses of débris carried down by torrents from the mountains bordering the plain of the Indus as described by Mr. Drew*. This would account for the localized form of these sheets of gravel, and for their absence on the intermediate Chalk-hills. It is also possible that the cone may have discharged under water, and so spread out to a greater extent and more uniformly, and with the rough sort of bedding this gravel sometimes shows.

In any case, whatever may have been the manner in which these hill-gravels were formed, there can be no doubt of the source whence the materials have been derived †. They clearly come solely from the Lower Tertiary, Chalk, and Lower Greensand, lying south of the area over which they are spread. Flints and flint-pebbles might have been brought from other directions, but the chert and ragstone are characteristic of the Lower Greensand of Kent and Surrey, and the peculiar character of some of the chert of the

* Quart. Journ. Geol. Soc. vol. xxix. p. 441 (1873).

† Prof. Rupert Jones arrived independently at the same general conclusions as myself with respect to the age and origin of the Bagshot plateau-gravels, though he ascribes more to marine action. I should have liked to give an abstract of his paper, but must refer the reader to the original work (Proc. Geologist's Association, vol. vi. pp. 437-443, 1880). The Rev. A. Irving has also written on the subject, and concluded that these beds were of estuarine origin and pre- or interglacial age (Proc. Geol. Assoc. vol. viii. pp. 161-171, 1883).

Folkestone Beds between Sevenoaks and Maidstone, spread over the Chalk-plateau to the south, renders a mistake impossible.

The time of the first appearance of the Lower-Greensand *débris* is significant. We have seen that the Wealden anticlinal was uplifted after the deposition of the Lenham Beds, while the first beds in which we find chert and ragstone of the Wealden area are those of the Red Crag—at least I found none in the single small exposure of the Pebble-bed at the base of the White Crag. Hence we may presume that the Wealden range was raised and became exposed to atmospheric waste at some time either towards the end of the White-Crag epoch, or very early in the Red-Crag epoch. But during the time of the Red Crag the waste was still small, and it was not until the time of the Westleton Shingle and Southern Drift, that it acquired larger dimensions—dimensions which had their climax in the plateau-gravels of the Thames Valley. These successive stages are, I imagine, coincident with the increasing cold of the period, and the increased disintegration and denuding action. If, on these limited premises—and we have none others to judge by—we might suggest time-equivalents for these several stages in the early denudation of the Weald, I would take the Well-Hill Drift to belong to the Red-Crag epoch, and the Plateau-Drifts to correspond broadly in time with the Chillesford, Forest Bed, and Westleton Shingle. A more definite concordance is hardly at present practicable; for nowhere are the hill-Drifts found in juxtaposition, and the extensive denudation of the subsequent Glacial period has swept away any connecting-links that may originally have existed, and left only the fragmentary remainders we have described.

While this glaciation was going on in the Thames Basin, it is probable that the Wealden Highlands were the centre of another snow- and ice-field, to which the denudation of that area is to be more particularly ascribed. It was this range of high land which obstructed the advance of the northern ice and the Boulder-clay, for the Tertiary hills of the Thames Valley were then only the outposts of that more important Wealden range. This ice-field may ultimately have been confluent in the Thames Valley with the great northern ice-sheet, though it may have yielded finally to it as the destruction of the Wealden range proceeded, and the obstacles to the further southward progress of the latter were removed.

6. *Relation of the Southern Drift to the Westleton Shingle and other Pre-Glacial Drifts.*

Let us now endeavour to follow the successive changes that took place from the time of the early Crag deposits down to that of the Westleton and Southern Drifts in South-eastern England and the adjacent continental area, and note the relation of these drifts one to another.

There can be but little doubt that a marine deposit of early Pliocene or Diestian age extended generally over a portion of the south-east of England and adjacent parts of France and Belgium, and

that the formation of this deposit was followed by an upheaval which brought it to the surface, and gave rise to a low mountain-range on the site of the present Wealden area. We are able to fix the time with tolerable accuracy, by the absence of the later Craggs in the upraised district, and by the presence of débris derived from that district in some of the deposits in the area which remained submerged.

Thus at the base of the White Crag, subangular flints, flint-pebbles, a few white quartz-pebbles, some light-coloured quartzite-* and a few sandstone-pebbles, of which one contained the cast of an *Astarte* (Oolitic?), have been found, and with these one considerable-sized boulder of red felspar-porphyr. These afford but little guide for the direction whence they drifted. There is an absence of chert and ragstone, such as might be expected to be present if the denudation of the Wealden anticlinal had commenced or been far advanced.

With the Red Crag, we have certain proof of denudation of the Lower Greensand and of the earlier Pliocene bed, for in the Coprolite-bed at the base of the Red Crag at Sutton there are found:—

1. Large angular flints from the adjacent Chalk.
2. Flint-pebbles from Tertiary or Diestian Beds.
3. Light-coloured quartzite-pebbles.
4. Pebbles of White or Coralline Crag.
5. Pebbles of white quartz.
6. Pebbles of iron-sandstone (Diestian?).
7. Pebbles of a light-coloured sandstone with impressions of *Pecten* and *Astarte* (Oolitic?).
8. Subangular fragments of *chert and ragstone* (Lower Greensand).

And at the base of the Red Crag at Frimley, in addition to the above:—

1. Pebbles of fossiliferous ironstone and box-stones (Diestian?).
2. Subangular fragment of a white felspathic sandstone.
3. A small boulder of red granite with green and black hornblende.
4. Subangular fragments of brown chert with sponge-spicules.

It is evident, therefore, that the denudation of the Weald had then commenced †, and that the Lower Greensand had been reached, although the quantity of chert- and ragstone-débris had not yet attained the proportions it acquired at a later period, when the Greensand-strata had become more worn down and exposed.

If, then, this Wealden range already existed at the time of the Red Crag, it follows that its denudation which then commenced must have been going on during the later times of the Chillesford Clay and of the Forest Bed. It was at that time probably that the winter snow and spring floods swept down the Lower-Greensand débris over the Chalk-plateau and Tertiary hills to the north. It was a period in all probability of great humidity and heavy rainfall, for there is some evidence that at no great distance to the south of the aforesaid range there were Pliocene seas with warm currents to furnish an abundant evaporation.

* In my earlier papers I used the term siliceous sandstone instead of quartzite.

† Quart. Journ. Geol. Soc. vol. xxvii. p. 353 (1872).

Following on this period, a tract extending from the east coast and reaching either as far as the district near Bath, or possibly as far as the Bristol Channel, was submerged and covered by the waters of the Westleton sea—a sea bounded by the highlands of the Weald on the south, but of which the northern barrier has yet to be defined. I am led, therefore, to conclude that the early stages of the Southern Drift preceded the Westleton Shingle (in its later stages they may have been synchronous), and either that the Westleton sea beating against a land over which the Southern Drift had spread, took up a portion of that Drift with its chert- and ragstone-fragments, or that the streams which still continued to run from off the southern hills carried down thence the Lower-Greensand débris into the Westleton sea. Superposition is wanting, and we have only the relative position and the peculiar composition of the two Drifts to guide us; for although the Southern Drift occasionally contains white quartz-pebbles, they are so few that they may have been derived from Lower Tertiary strata, or from the Lower Greensand and Wealden.

The Westleton Drift, as already explained, is, in the main, confined to the district north, and the Southern Drift to the south, of the Thames. But it is probable that on the southern slopes of the Wealden highlands and their prolongation westward, similar causes were in operation to those we have pictured on the northern slopes, that a similar Drift was there in course of formation at the same time, and that it was there subject to conditions analogous to those experienced by its equivalent in the London Basin.

As instances of such outliers, I may briefly mention Alderbury Hill, near Salisbury, the higher hills between Southampton and Winchester, and those in the New Forest between Lyndhurst and Wimborne; I have, however, now to confine myself to the Thames Basin. I would merely state further that in these districts this drift, like that on the opposite side of the dividing-range, contains a considerable proportion of *chert-* and *ragstone-*débris mixed with the angular and subangular flints of the Chalk.

7. *Main Lines of Elevation and Drainage of the South-east of England: Genesis of the Thames.*

Another point remains for consideration, and that is, the effect produced, not only on the configuration of the country, but also on the lines of drainage, by the elevation on the one hand, at an early Pliocene date, of the Wealden anticlinal, and, on the other hand, of the Westleton sea-floor in early Pleistocene times.

The east and west direction of the anticlinal of the Wealden axis necessarily gave rise to a drainage northwards into the area of the Thames Basin, and plotted broadly the direction of those valleys, which subsequently, with certain modifications, caused by minor disturbances, and by the action of glacial erosion, became the main lines of the transverse valley-system and rivers of the Weald.

The emergence of the floor of the Westleton sea was, on the contrary, effected not by any sharply-defined axis, but by flexures

ranging S.W. and N.E. through parts of central England, and of which the direction is coincident with the parallel ranges of the Chalk and Oolitic escarpments in that area. The Westleton beds, when raised, consequently dipped east and south-east on an incline at right angles to these elevation folds.

The result of this has been, that whereas on the Norfolk coast the Westleton Beds are close on the sea-level, they rise westward in Berkshire to the height of from 400 to 500 feet, and northward in Hertfordshire and Buckinghamshire to 500 and 600 feet. Thus a drainage from the raised area was established to the south-east, but diverted eastward as it approached the already raised Wealden area with its northward drainage.

The Thames necessarily resulted from these tributary lines of drainage; but the river must have been restricted at first to the Tertiary and Chalk Basin, with the Kennet (passing round the Tilehurst Hills) as the main stream and source of the river. The Chalk-escarpment was not breached by the Isis until later. This river before that time probably flowed to the north-east, parallel with and between the Chalk and Oolitic escarpments, and emptied itself into the Wash on the east coast*.

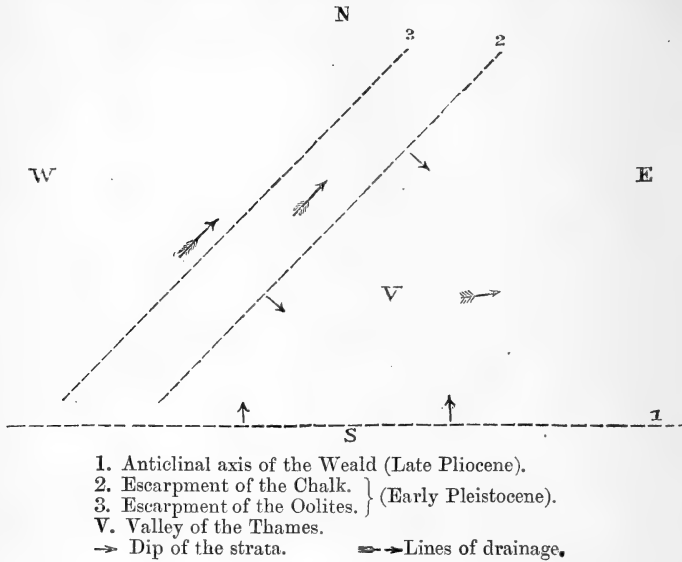
The old landmarks are, however, so obliterated by subsequent Glacial action and earth-movements that this requires confirmation. Of the fact, however, that for some time after the rise of the Chalk-escarpment, the pass of the Thames at Goring did not exist, and that the first breach through the belt of Tertiary strata and Westleton Shingle capping the Chalk-Downs was effected by a Glacial current coming from the direction of Warwickshire and Staffordshire, there can, I think, be little doubt. It was not until the gorge was enlarged by later glaciation, possibly aided by disturbances of the strata, that the Isis was diverted into this new channel, and so formed a junction with the Lower Thames and Kennet.

This may be illustrated by a diagram showing the two lines of elevation with the resultant conditions of drainage (fig. 10).

This is a branch of geology which opens some very large and interesting problems. I have treated it briefly. Owing to the vast erosion of the surface, the evidence respecting the older Drifts is generally very fragmentary, and has often been entirely swept away. Some speculation is therefore unavoidable, though it is essential that the consequences that may result from hypothetical assumptions should be in harmony with the results of observation. In putting together my notes, many new views have suggested themselves to me, and I should much like, as I have before said, to have gone over the ground again, with the object of confirming or, if necessary, correcting my early work; but that is no longer possible, and I must leave the task to my younger colleagues.

* The width of the Wash between Lynn and Boston, and the extent of the Bedford level and adjacent marsh-lands, convey the idea precisely of the estuary and alluvium of a large river, such as the Isis with its tributaries would, in the case here suggested, have been.

Fig. 10.—Diagram of the lines of Elevation bounding the Tertiary Basin of the Thames, showing their relative Age and Direction.



8. General Summary.

The results of the foregoing inquiry may be summed up under the following heads:—

1. That the Westleton Shingle ranges from the Crag in Suffolk inland to the Chalk-escarpment in Oxfordshire and Berkshire, rising gradually from the sea-level, until it attains a height of from 500 to 600 feet.
2. That the Tertiary strata were co-extensive with this Shingle at the time of its deposition, and that both extended to the edge of the Chalk-escarpment, where they have been cut off by subsequent denudation.
3. That the upraising of the floor of the Westleton sea, or of the Westleton Shingle, immediately preceded the advance of the Glacial deposits, so that while they are concordant or in conformable superposition in the eastern counties, they become discordant as they range westward, and the Boulder-clay occupies valleys formed, after the rise of the Westleton Shingle, by early glaciation.
4. That the belt of Tertiary strata and of Westleton Shingle on the northern borders of the Chalk-Basin, formed originally a continuous and unbroken zone, and that this was not broken through until after the elevation of the Westleton floor and the inset of the Glacial period.

5. That none of the valleys on the north side of the Thames Tertiary Basin date back beyond the Pre-Glacial epoch, and that the whole of the valley-system of that area is of later date.
6. That the escarpment of the Chalk, and probably that of the Oolites, in the Midland Counties, is of a more recent date than the Westleton Shingle, and therefore not older than late Pre-Glacial or early Glacial.
7. That there is a Southern Drift as well as a Northern Drift in the Thames Basin: and that this Southern Drift has been derived from the Lower Greensand of the Wealden area and from the Chalk and Tertiary strata formerly extending over portions of that area and the adjacent downs.
8. That during the early Pliocene (Diestian) epoch the Wealden area was partly or wholly submerged, and that a continuous sea extended thence over certain portions of France and Belgium, while the present Strait of Dover was non-existent.
9. That subsequently to this period, but before the in-setting of the Glacial period, the Wealden area and the Boulonnais underwent an upheaval, resulting in the formation of an anticlinal range 2000 or 3000 feet high.
10. That it was from the slopes of this anticlinal that the materials composing the Southern Drift were derived, and spread over the area now forming the southern side of the Thames Basin.
11. That this denuding action commenced at the time of the Red Crag, and was continued uninterruptedly through several successive geological stages.
12. That consequently, though the Southern Drift preceded the Westleton Shingle, the two must at one time have proceeded synchronously, though possibly at times on different levels.
13. That the valley-system of the Wealden area had its origin after the Diestian or early Pliocene epoch,—the initial direction of the transverse valleys dating from Pre-Glacial times, and of the longitudinal valleys from Glacial times.
14. That the formation of the Thames Basin is the result, on the one hand, of the elevation of the Wealden anticlinal, and, on the other, of the flexures of the Chalk and Oolitic strata in the midland counties, and dates therefore from a period subsequent to that of the Westleton Beds.
15. That the genesis of the Thames dates in like manner from late Pre-Glacial or early Pleistocene times, whilst its connexion with its upper tributaries and the Isis took place during the subsequent Glacial period.

EXPLANATION OF PLATE VIII.

This Map shows the position of the outliers of Westleton Shingle and of the Plateau-gravels in the Thames Basin, with the lines of section given in Pl. VII. A line marks the southern limits of the Boulder-clay, but the other Glacial and Post-Glacial drifts are not given.

DISCUSSION.

The CHAIRMAN remarked on the difficulties connected with the identification of gravels over large areas, and with the problems of Tertiary physiography.

Mr. WHITAKER noticed the wide range of the paper, and believed that there was no problem more difficult in the geology of the South of England than the classification of various deposits of gravel. Prof. Prestwich, he understood, put in the same class the gravels of Norwood, Hampstead, Rayleigh, and of the hills between Faversham and Canterbury. The geological surveyors had not felt that they could successfully correlate these various gravels. At Norwood, Mr. Spurrell considered the gravel was an old Wandle gravel, while he himself rather inclined to suppose it an old Thames gravel. The geological surveyors had coloured certain gravels as plateau-gravels, without any attempt to assign them to any definite age. He (the speaker) had noticed pebbles on end in many gravels. When Prof. Prestwich supposed that some gravel was synchronous with Crag-deposits, he could not follow his line of reasoning. As regards the supposed Wealden ice-field, he felt that the beds were not strong enough to carry much wear, and that the hills would soon be denuded. The pebbles in the Red Crag showed that the sea of that age extended to the Lower Greensand, pebbles of *Ammonites biplex* which had been phosphatized in Lower-Greensand times occurring in the phosphate-deposits of Red-Crag age. Between Southampton and Winchester he had seen hardly any high gravel which he was inclined to classify as Drift. He agreed with the Author as to the importance of insisting on the occurrence of a southern drift; but he pointed out the difficulties in identifying gravels by their included fragments. Whether the breaching of the escarpment of the Chalk was so late as the Author had considered it seemed to him doubtful.

Dr. IRVING said that he was in accord with the Author as to the age of the plateau-gravels of Berkshire. He had published his views as to the fluvial character of these gravels, and now brought forward evidence of glaciation at lower levels, proving their pre-glacial age.

Mr. TOPLEY was interested in the distinction between Southern Drift and Westleton Shingle. He had not altogether appreciated the distinction which Prof. Prestwich had endeavoured to draw, and thought that some of the materials of a river would be eliminated as it flowed further from its source. As regards the denudation of the Weald, the Author had shown that the denudation of the Chalk had extended so far that Tertiary deposits rested directly upon the Lower Greensand. He did not follow the Author's mode of estimating the height of the Wealden hill-range, for much denudation must have succeeded the deposition of the Tertiary beds previous to the formation of the Southern Drift. He thought changes of drainage in the Weald were frequently due to the cutting back of escarpments, and he gave an illustration of the method in which this might be done. He called attention to the important earth-movements which had

affected the Weald and surrounding districts, and referred to Mr. Poulett Scrope's views that during the elevation of the Weald the beds glided over others, which would account for the varying thickness of such deposits as the Gault.

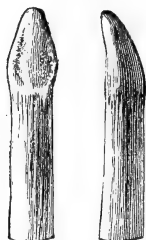
Dr. EVANS congratulated the Society and Prof. Prestwich on his having been able to sum the results of the observations of so many years in the series of papers which he had lately read. In taking samples of gravel, and attempting to correlate beds of gravel over a large area, mistakes might arise from local variations; but he thought that the facts brought forward by the Author went to a large extent to confirm his views. Possibly some further confirmation might be found in the country to the west of the axis of elevation that bounded the Westleton Beds. He hoped that Prof. Prestwich would allow a longer period of time to have elapsed for the production of the physical changes he had described than he had previously allowed for Postglacial changes. As one of the older Fellows of the Society, it would have been impossible for him to refrain from saying a few words in congratulation of one with whom he himself had laboured so long.

The AUTHOR, in reply, was not surprised at the difficulty speakers had experienced in following all the details of so intricate a subject. He acknowledged the assistance derived from the admirable Drift-maps of the Geological Survey. He had differed from them in venturing upon a chronological classification of the pre-glacial Drifts. He had attempted to describe three kinds of hill-drifts—the Westleton, Brentwood, and Southern Drifts. The Brentwood Drifts certainly originated with the Bagshot Beds, but showed differences which allied them to the other Drifts. He often found a sufficient number of ragstone- and chert-pebbles to show that the Bagshot Beds had been intruded upon and disturbed. In some cases, where infiltration had been suggested to account for the upright position of the pebbles, the pebbles rested upon clay-beds, where infiltration was impossible. He had felt the same difficulty as Mr. Whitaker as to the gravels of Well Hill, and could only suppose they had been derived from a destroyed hill-range. Amongst others Alderbury Hill, three miles from Salisbury, was capped by gravel full of chert and ragstone like the southern drift of the Thames Basin. No doubt, as Mr. Topley had said, the denudation of the Weald commenced in early Tertiary times; but he believed that the great upheaval to which he, the Author, referred took place after the spread of the Lenham Beds.

11. *On REMAINS of SMALL SAUROPODOUS DINOSAURS from the WEALDEN.* By R. LYDEKKER, Esq., B.A., F.G.S., &c. (Read December 4, 1889.)

[PLATE IX.]

AMONG the Dinosaurian remains from the Upper Jurassic of the United States, recently described by Prof. Marsh, none are perhaps more interesting than the vertebræ and teeth upon which the genus *Pleurocœlus** has been based, since they indicate a comparatively small form closely allied to the gigantic *Morosaurus*, and less nearly so to the still more huge *Brontosaurus*. In the type species of *Pleurocœlus* the teeth are said to be of the same general type as those of *Morosaurus*, but are not distinctly spoon-shaped, and are thus more like a compressed cone. The centra of the dorsal vertebræ, which are less than four inches in length, are elongated and very markedly opisthocœlous, with a long and deep lateral cavity, of which the upper portion gradually shelves towards the arch.



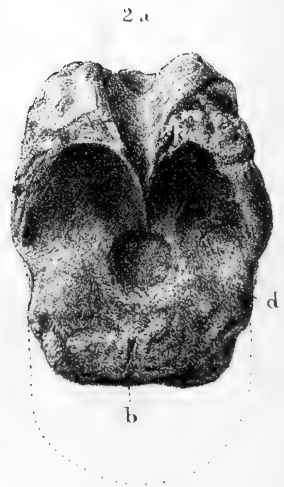
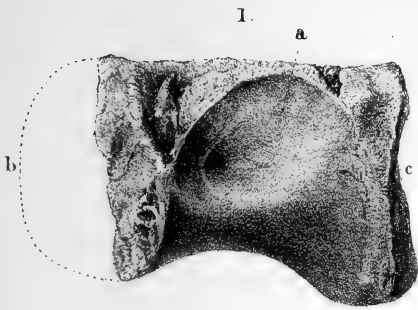
Outer and profile views of a tooth of *Pleurocœlus valdensis*;
from the Wealden.

Recognizing the Sauropodous nature of the teeth from the Wealden of Sussex and the Isle of Wight, provisionally referred by Mantell and subsequently by Sir R. Owen to *Hylæosaurus* (one of which is shown in the woodcut), I proposed † some time ago to regard them provisionally as indicating a European representative of the American genus, with the name of *Pleurocœlus valdensis*. These teeth indicate a very small member of the Sauropoda, and, although their crowns are subject to considerable variation in form, many of them show the absence of a decided spoon-shape, characteristic of those of the type species.

In the same notice I referred to the imperfect centrum of a dorsal vertebra from the Wealden of Cuckfield, preserved in the British

* Amer. Journ. ser. 3, vol. xxv. pp. 90-92 (1888).

† Geol. Mag. decade 3, vol. vi. p. 325 (1889).



Museum (no. R. 1616), which it was suggested might belong to the same species as the teeth. Of this vertebra two views are given in Pl. IX. figs. 1, 1*a*; and it will be seen from these figures that this specimen comprises the greater part of the centrum, with the exception of the anterior ball. The base of the neural canal still remains, but the surfaces for the articulation of the neural arch are destroyed. From the circumstance that the neural arch is lost, it is highly probable that the specimen is not fully adult; but the smooth outer surface of the bone indicates that it did not belong to a very young individual, being, in this respect, very widely different from the vertebræ from the Kimeridge Clay, described by Sir Owen as *Bothriospondylus suffossus*, which Prof. Marsh suggests may have belonged to a fœtal Dinosaur. I take it, then, that this vertebra indicates a comparatively small Dinosaur, and since it evidently belongs to the suborder Sauropoda, there is a strong presumption that it belongs to the same form as the above-mentioned teeth. When I say the same form I would, however, guard myself by adding that it is quite likely the teeth may indicate more than a single species. Compared with the figure of the dorsal vertebra of the typical *P. nanus*, it will be seen that this specimen agrees in the great depth of the posterior cup, and also (allowing for the loss of the anterior ball) in the comparative length of the centrum, and in the large size and shelving upper portion of the lateral cavity. Compared with the large dorsal of *Hoplosaurus (Ornithopsis)*, figured by Mr. Hulke in vol. xxxvi. pl. iv. of the Society's Journal, the greater proportionate length of the centrum and the larger size and more sloping boundaries of the lateral cavity are very noticeable in the present specimen. The approximate length of the entire centrum was probably some three inches, against 3·8 inches in the typical dorsal of *P. nanus*. So far therefore as I can see, the provisional reference of the Wealden teeth to *Pleurocœlus* is confirmed by this specimen, which appears to differ from the dorsal vertebræ of the type form by features of merely specific value.

The second specimen I have to notice is a somewhat larger imperfect vertebra, obtained from the Wealden of Brook in the Isle of Wight, and till recently preserved in the Dorsetshire County Museum at Dorchester. This specimen is represented from the left lateral and anterior aspects in Pl. IX. figs. 2, 2*a*. It is a dorsal vertebra, evidently referable to the Sauropoda, and, from the complete union of the arch with the centrum, clearly belonging to a fully adult individual. The neural arch is preserved in fair condition, as high up as the platform from which the transverse processes took their origin; and the union between the arch and centrum is so intimate that even the neuro-central suture cannot be detected, although its approximate position is indicated in the figure. The centrum has lost its lower half, the horizontal fracture extending through the plane of the central pit of the lateral cavity. The imperfect upper portion of the anterior articular ball remains, but the contour of the posterior cup has been entirely destroyed. The outer lamina of bone on the upper part of the sides of the centrum has

also been more or less completely destroyed, so that the contour of the shelving superior half of the lateral cavity has been lost. In the figure an approximate restoration of the lower half of the centrum has been made from comparison with the preceding specimen.

So far as its imperfect condition admits of comparison, the contour of the portion of the centrum now remaining appears to be very similar to that of the preceding specimen, the upper half of the lateral cavity having the same shelving form, while its central foramen was small and clearly defined. Moreover, when entire, the centrum must evidently have been of an elongated type, its approximate length being about four inches. There is accordingly no apparent reason why this specimen should not have belonged to an adult individual of the same species as the one to which the preceding vertebra pertained; although I would not deny that we may have to do with two distinct but allied species.

In the absence, however, of any evidence in favour of a contrary view, I propose to refer both these specimens provisionally to *Pleurocælus valdensis*. Their especial interest lies in the circumstance that, in conjunction with the above-mentioned teeth, they afford absolutely conclusive evidence of the occurrence in the English Wealden of a diminutive Sauropodous Dinosaur, which was the contemporary of the huge *Hoplosaurus*, and the still more gigantic *Pelorosaurus*; and they also serve to increase the evidence as to the similarity of the Dinosaurian fauna of the Upper Jurassic of North America to that of the Upper Jurassic and Lower Cretaceous of Europe.

EXPLANATION OF PLATE IX.

Vertebrae from the Wealden; referred to *Pleurocælus valdensis*.

a, lateral cavity of centrum; *b*, anterior ball of centrum; *c*, posterior cup of centrum; *d*, neural canal.

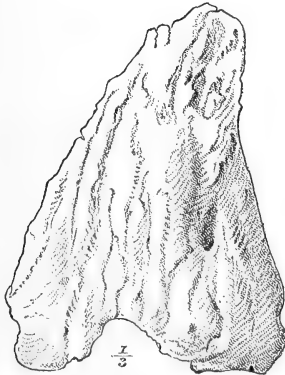
Fig. 1, 1 *a*. Left lateral and posterior aspects of the imperfect centrum of an immature dorsal vertebra, with a restoration of the anterior ball; from Cuckfield, Sussex. $\frac{2}{3}$ nat. size. (Brit. Mus. no. R. 1616.)

2, 2 *a*. Left lateral and anterior aspects of an imperfect dorsal vertebra, with a restoration of the lower half of the centrum; from the Isle of Wight. $\frac{1}{2}$ nat. size. (Brit. Mus. no. R. 1730.)

12. *On a PECULIAR HORN-LIKE DINOSAURIAN BONE from the WEALDEN.*

By R. LYDEKKER, Esq., B.A., F.G.S. (Read December 4, 1889.)

AMONG a small series of vertebrate remains lately sent from the Dorsetshire County Museum to the British Museum there is an imperfect bone from the Wealden of Brook, Isle of Wight, so unlike any specimen from those beds which has hitherto come under my observation that I deem it worthy of a brief notice. This specimen, which is represented on a reduced scale in the accompanying wood-cut, is a stout and short cone-like bone, of some $5\frac{1}{2}$ inches in length, with the larger basal diameter measuring 4 inches. The cone is somewhat compressed, with a distinct backward curvature, the summit being imperfect. The outer surface is rugged, with irregular longitudinal ridges; while the base is extensively hollowed, and has a smooth and mamillated surface, recalling that of the cancellous cavities found in the base of the horn-cores of the Bovidæ. In all these respects this specimen appears to present a close resemblance to the horn-cores of the Dinosaurian skull from the Jurassic



Horn-core(?) of a Dinosaur; from the Wealden of the Isle of Wight.
 $\frac{1}{3}$ nat. size.

of North America, described and figured by Prof. Marsh in the 'Amer. Journ.' ser. 3, vol. xxxvi. pl. xi., under the name of *Ceratops*. A less marked resemblance is also presented to the longer horn-like bone from the Greensand of Austria, figured by Prof. Seeley in vol. xxxvii. pl. xxvii. fig. 4, of the Society's 'Quarterly Journal,' under the name of *Crataomus*, which Prof. Marsh (Geol. Mag. dec. 3, vol. vi. p. 207) regards as a veritable horn-core. The dermal spines of *Hylæosaurus* and *Polacanthus* do not show a basal structure at all like that of the present specimen; and it certainly does not belong to *Iguanodon*.

I do not at present regard this curious specimen as affording conclusive evidence of the existence in the Wealden of a large Dinosaur furnished with horn-like projections on the skull like the American form to which the name *Ceratops* has been applied; but I do suggest that this may really prove to be its true nature, and I have accordingly brought it to the notice of the Society in the hope that additional evidence may some day prove whether this suggestion is right or wrong.

DISCUSSION.

The PRESIDENT commented upon the interest of finding a large number of Dinosaurs common to Britain and America.

Mr. HULKE thought the Author had done wisely in speaking cautiously concerning the supposed horn-core. He suggested that two different sorts of soft tissue had been implanted upon this bone.

The AUTHOR said that he had spoken very cautiously about the horn-core.

13. *On the CRYSTALLINE SCHISTS and their RELATION to the MESOZOIC ROCKS in the LEPONTINE ALPS.* By T. G. BONNEY, D.Sc., LL.D., F.R.S., F.G.S., Professor of Geology in University College, London, and Fellow of St. John's College, Cambridge. (Read January 22, 1890.)

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At the close of the year 1888 I read before this Society a paper "On two Traverses of the Crystalline Rocks of the Alps," in which I maintained that these rocks could be arranged in certain fairly definite groups, which exhibited a stratigraphical succession. On this communication only two criticisms of importance were offered. Of these one expressed a doubt of the value of the method which I had adopted in my work; the other affirmed that certain schists, regarded by me as members of a very ancient series, probably Archæan, had been demonstrated by the presence of Mesozoic fossils to be of the latter age; or, in other words, that, in the Alps, ordinary sediments deposited in the Jurassic epoch had been subsequently converted into true crystalline schists, a result of metamorphic action which I had implicitly affirmed to be incredible. The former criticism, which amounted to an assertion that the general succession of the Alpine rocks could only be ascertained by very detailed mapping, in my opinion, indicated an imperfect knowledge of the subject, while it was scientifically unsound and historically incorrect. It indicated an imperfect knowledge, because, as a matter of fact, a considerable part of the Alps has already been mapped, not by irresponsible amateurs but by official surveyors, and it was with the interpretation of these maps that I was largely concerned; and because it assumed that an impossibility could be performed. As I have had the honour to fill the same position in the Alpine Club that I have done in this Society, I may to affirm with-

out fear of contradiction that a very elaborate petrographical mapping of the Alps is impossible; for the most painstaking and conscientious of surveyors must assume much that is incapable of demonstration. A very large part of the whole area is concealed by snow, glaciers, débris, pasture, forest; and some one of these obstacles very frequently interferes, in the most provoking way, just at the most critical point. Further, no small amount of the rock which is visible can only be regarded from a distance. Many a cliff, many a ridge, is inaccessible, and the examination, even of every point which it would be possible to reach, would require the expenditure of such an amount of time, that I am certain it never has been, and believe that it never will be done.

But further, the criticism, in my opinion, was scientifically unsound and historically unjustifiable. Scientifically unsound, because very commonly the most important problems which are presented by the crystalline rocks receive a decisive answer from one or two sections only*. I have not the slightest desire to undervalue elaborate mapping, but we must be careful not to treat it as a fetish, as though it were the only means appointed for the discovery of geological truth. Its results more commonly are the removal of minor difficulties in a conclusion already attained, and the disclosure of the precise mode in which certain effects have been produced. The criticism was historically unjustifiable, because, so far as my knowledge goes, it is a fact that in regard to difficult petrological questions, infallibility has not been found to reside with the makers of geological maps.

My work, both in the Alps and in other regions, which has been carried on with a definite object and a fairly clear idea as to the needful evidence, has led me to the following conclusions, which, though they have been already expressed, I will venture to repeat for the information of the reader.

(i.) That a group of truly crystalline schists is always more ancient than any rock to which, on the evidence of fossils, a date can be assigned.

(ii.) That many such groups can be proved to be older than any Palæozoic rock.

(iii.) That though crystalline schists have often been claimed as metamorphosed sedimentary strata of Palæozoic or Mesozoic, if not of Tertiary age, the evidence in support of this claim has hitherto always broken down on careful examination, and in not a few instances has proved hardly worthy of the name.

(iv.) That in certain cases structures exist in the crystalline schists which must be indicative of sedimentation, and that in not a few instances a sequence can be detected which must be due to

* For instance, whether an igneous rock be interbedded or intrusive may be an open question in every section but one. Whether a group of slates forms part of a continuous series with a group of schists may be uncertain in most of the sections, but may be settled in the negative by the discovery, in a single section, of a conglomerate or breccia of the latter in some member of the former. I do not suppose that this statement will be questioned by any one familiar with this department of geology; but if it were, I could fill a page readily with examples of the proof or disproof of a theory by a single section.

successive deposition. Great as the modifications resulting from subsequent pressure very frequently are, these may often be separated, and the earlier record, as in the case of a palimpsest, be decyphered.

In the Alps there exists, as has frequently been pointed out by those who have preceded me*, a great group of crystalline schists, the bulk of which must be metamorphosed sedimentary deposits. This group can be traced, practically without a break, from one end of the chain to the other. These schists certainly overlie, sometimes it would seem unconformably, another great series of gneisses and schists †, generally coarser in texture. These seem to be divisible into two groups differing in lithological characters, of which the upper, though sometimes well developed, is not seldom wanting; so that instead of the gradual transition from it to the first-named group, which can sometimes be observed, we find the latter resting with marked discordance upon some part of the lower series. The present paper deals mainly with this highest group.

The oldest unaltered rocks in the Alps generally belong to the lowest part of the Mesozoic system, Jurassic or Triassic (possibly sometimes Permian), but in certain districts not inconsiderable deposits of Carboniferous age (quite disconnected from the last named) occur, and in the North-eastern Alps Palæozoic rocks of yet earlier date have been identified. All these are practically unaltered. An exceptionally wide experience enables me to affirm without fear of contradiction that, in the case of any large mass which would be referred without hesitation to the Jurassic, Triassic, or Carboniferous group, there will not be found, however great may have been the mechanical disturbances which it has undergone, any transition exhibited by it into one of the normal gneisses or schists; at most a microfoliation has been developed or a superficial resemblance set up. The crystalline schists also do not exhibit, as a rule, any tendency to pass into ordinary sedimentary rocks. Appearances suggestive of this transition are found on closer examination to be due

* I have made no attempt to compile, in accordance with a growing practice, a list of books on Alpine geology, because the greater part of them would have little real bearing on the subject of this paper. A list of those treating on the geology of the Lepontine Alps will be found in Von Fritsch's volume, to which and to such as I have used in writing this paper references are given in the text. Others there may be, for I do not pretend to have spent much time in searching; but if any one has come to conclusions identical with my own, I can assure the author that there is no plagiarism. At the present stage of the questions treated of in this paper, I find work in the field or with the microscope of far more value than "hours in a library."

† In the remainder of this paper I follow my invariable practice of using the term *schist* to express a foliated rock, and so as the equivalent of the "crystalline schist" of some authors. This is the restriction long ago insisted upon by Jukes. As I have frequently pointed out, the lax use of *schiste* and *schiefer* by continental writers, and of *schist* by some English geologists, has been a fruitful parent of confusion of thought and inaccuracy of expression. By a *foliated* rock I mean one which is crystalline and exhibits a certain parallelism in its constituent minerals, especially those like mica and hornblende. If in addition to this certain minerals predominate in certain layers, the rock is also called banded. Thus the terms schist and gneiss imply foliation, but not necessarily banding.

either to pulverization of the rock by pressure, or to the inclusion of a later series by folding or faulting.

But while there can be no doubt of the general truth of this statement, it has recently been asserted that in certain districts of the Alps there is a passage from Jurassic rocks into truly crystalline limestones, while in others fossils of that age occur together with garnet, mica, and a mineral resembling staurolite, in schists which cannot be distinguished from certain members of the above-named group*. If this assertion be correct, it must follow (1) that the Alps exhibit true schists which are metamorphosed sediments of Mesozoic age, and (2) that, inasmuch as these are undistinguishable from schists which by stratigraphical evidence can be proved to be very much older than any Mesozoic rock, a schist, like a granite or a dolerite, might belong to almost any geological epoch.

This last opinion can claim the sanction of antiquity and the authority of weighty names, but the progress of investigation had largely diminished the number of its supporters, when it seemed to receive a new life from a recognition of the amazing effects of mechanical forces in modifying rock-structures and from the above-named discoveries in the Alps. Specimens illustrative of the latter were exhibited at the International Geological Congress in September 1888. Those supposed to indicate the passage of an ordinary Jurassic limestone into a crystalline marble (from a district which I had already visited) did not appear to me convincing. But those exhibiting fossils in a rock resembling a true schist were certainly very remarkable, and seemed to afford considerable support to the opinion mentioned above. I was not, however, convinced by them, because though I had not examined the two localities in which the supposed "fossiliferous schists" occurred, I was fairly acquainted with the geology of the district, and had been very near, in one case within less than a mile, to each locality. I had also examined rocks identical, as I believed, with those in which the fossils occurred. The knowledge thus obtained, notwithstanding the apparent evidence of the specimens exhibited, suggested to my mind the possibility of a mistake, and a doubt whether the identity of the fossiliferous rock with the true schists of the district was not more apparent than real. Still so remarkable were the specimens, so great was the weight of authority, that when these cases were quoted against me in the discussion on my paper, I departed from that which has become almost a rule to me—viz., to pay no regard to criticisms founded on second-hand information—and stated that I accepted the challenge. A part of my last summer vacation was devoted to the study of the district. I had hoped to have been aided by my old friend and fellow-worker Mr. Hill, but his entry upon a new field of duty prevented him from leaving England. I had, however, the good fortune to obtain the company of Mr. J. Eccles, F.G.S., who joins to

* As the volume of papers presented at the Geological Congress has not yet been published, it will be better to refer, not to the copies then distributed, but to the translations by Dr. Hatch, printed in 'Nature,' Sept. 27 and Oct. 4, 1888: see especially p. 524.

an exceptional knowledge of the Alps much experience in field-work in England. For his constant, unwearied, and friendly help I can hardly adequately express my thanks. He was accompanied by his guide, Michel Payot of Chamouni, a shrewd observant man, who took great interest in our investigations and was often very useful.

We began our work, at Andermatt, by examining the crystalline limestone at the back of Altkirch and the rocks in that neighbourhood. Thence we crossed the Oberalp Pass to Dissentis, and walked therefrom to the summit of the Lukmanier Pass, where we halted to study the sections on either side (Alp Vitgira and Scopli), localities where fossils were said to occur in schists. Thence we crossed the Passo del Uomo to the Upper part of the Val Piora, where we examined (for the third time in my case) the sections around the Lago di Ritom. Descending thence to Airolo we investigated the section in the Val Canaria, described by Dr. Grubenmann; and then, in crossing the Nufenen Pass, examined another case of the occurrence of fossils in "schists," reaching the valley of the Rhone by the Eginenthal. This concluded the work specially described in this paper, but I may add that we afterwards visited the Binnenthal, in order to verify some points in my former work, and then proceeded to Zermatt. From both these localities some valuable information was obtained which bore indirectly on the general questions involved in the investigation.

The results of our work will, I believe, be made more generally intelligible by grouping them (irrespective of chronological or topographical order) under the following heads:—

1. The Andermatt Section.
2. The Schists of the Val Piora.
3. The Rauchwacké and its relation to the schists.
4. The Jurassic rocks containing minerals and fossils.

1. THE ANDERMATT SECTION.

At the base of the slopes leading from the upper valley of the Reuss to the Oberalp Pass, and not far from the southern opening of the Urnerloch, is a craglet of white marble, which is quarried near a chapel, Altkirch, and can be seen cropping out for some distance up the hill side. This rock is now considered by certain eminent Swiss geologists to be a limestone of Jurassic age, and is so represented on the Andermatt sheet of the Survey map. Specimens were exhibited at Burlington House, during the Geological Congress of 1888, to illustrate the supposed transition of this marble into the indubitably Jurassic limestone which occurs in the upper valley of the Reuss, not very far off the line of strike, at a minimum distance of about 3 furlongs, and can be followed for a long distance westward. The evidence of these specimens did not, however, appear to me satisfactory; for a very wide gap seemed to exist in the chain of demonstration which, from my knowledge of the locality, I believed would be difficult to fill. But as this identification had evidently been made a basis of correlations of crystalline with sedimentary

strata in the Alps,—correlations which were of the highest theoretic importance, and had affected the more recent geological maps published in Switzerland,—we began our work by carefully examining these slopes. Before giving the results it is necessary to preface them, for the sake of those unacquainted with the district, with a brief description of its physiography.

The upper waters of the Rhone, Reuss, and Rhine occupy an orographical trough between the range of the Lepontine Alps and that which prolongs the line of the Central Oberland. Through a narrow gap in the latter the Reuss escapes northwards; and the passes of the Furka on the west, and the Oberalp on the east, limit its basin, and form watersheds in the trough. This is bounded north and south by schists, gneisses, and gneissoid granites; but there is a rather marked lithological difference, as has often been pointed out, between the rocks of the two *massifs*. Enfolded between them and not reaching to so great an elevation above the sea, are various schists, sometimes more or less calcareous, which have a more modern aspect than the above-named rocks, though they are often so much crushed that any assertion as to their original condition demands great caution. Furthermore, a long strip of dark Jurassic rock, often calcareous,—sometimes a blackish limestone (not unlike one of those in the English Lower Carboniferous series),—extends from the valley of the Rhone over the top of the Furka Pass, is restricted after a time to the left bank of the Reuss, and finally dies out on the hillside about due north, so far as I can see, of the village of Andermatt, its disappearance being of course due to denudation. If then, as a glance at Von Fritsch's map will show, this Jurassic limestone is identical with the white marble of Altkirch, there must have been a displacement of the latter southwards of two or three hundred yards. This, however, would not be a difficulty of any real importance; I only mention it to show that the masses at present are not really in the same line of strike. Judging from the outcrops, the slopes up which the road winds to the Oberalp Pass are mainly composed of gneissoid rock, which obviously has been greatly modified by pressure*; between this (the "sericite gneiss" of the Swiss map) and the Urnerloch is the marble in question, with certain apparently associated rocks; while on the other side of the "sericite gneiss," between it and the Lepontine *massif*, is phyllite and black slate, referred by the Swiss geologists to the Carboniferous series †. According to Von Fritsch, the former group of rocks consists of a lenticular strip of marble, on the south of which is a band of Jurassic rock, which in one place is fringed by rauchwacké. Where the marble narrows to a point at its eastern extremity, a mark indicates the occurrence of fossils.

* More than one variety of rock is present, but I have thought it needless to enter upon details. The most conspicuous feature in the part nearest to the marble is a cleavage-foliation; but on examining a fractured surface at right angles to this, we see that the rock has been a granite or granitoid gneiss.

† Perhaps also some of the newer group of schists occur here, but I did not carefully re-examine this section last summer, no controversy existing in regard to it.

On the present occasion we chiefly devoted ourselves to the examination of the rocks lying between the "Urseren gneiss" and the "sericite gneiss." They are not very well displayed, for so much of the hillside is covered by turf. Briefly related, this is what we found. Beginning on the northern side, and keeping near the base of the slope, we passed over a crushed-looking gneiss. This, which (to quote from my note-book) "was examined again and again during the day, may be the 'Devil's-bridge' gneiss in a very crushed condition, still it has a more friable, saccharoidal aspect, and thus bears some resemblance to the gneiss of the St. Gothard Pass." After a brief interval of turf, we came to a very fissile, black, slaty or schistose rock, shortly followed by calc-mica schist*, which indubitably graduates into the marble quarried at the back of the chapel. This rock on its southern side passes back again into a calc-mica schist. Yet further to the south we came to the "sericite gneiss." Two other traverses made higher up the slope gave us the same succession, though certain changes presently to be described take place in the marble, which does not long retain the whiteness and comparative purity exhibited in the quarry. We failed to discover any fossils at the locality indicated on the map; and we could only find a very small patch of a friable cream-coloured limestone in the bed of a glen to represent the rauchwacké. At a rather higher level, however, we came upon a small outcrop of dark unaltered rock which bore a considerable resemblance to the ordinary Jurassic rock of the district. It is therefore possible that a small outcrop of this age containing fossils may occur on the right bank of the Reuss valley; but we failed to find it, though we searched carefully, and visited, as we believe, every outcrop between the "Urseren" and the "sericite" gneisses.

This section then exhibits rocks, which appear not highly altered close to a distinctly crystalline calc-mica group. Let us now subject them to a more minute investigation, taking first the crystalline group. The marble has a flaggy structure. The surface of the slabs exhibits frequently filmy flakes of white mica, and not seldom the superficial "flutings" which indicate earth-movements. In one part of the quarry the marble is banded with layers of mica, often about 1 inch thick, and it passes, as has been said, into a calc-mica schist. On microscopic examination we see that the rock gives some indications of pressure, but that in many parts it exactly resembles one of the ordinary white marbles which, in many other districts of the Alps, are associated with true crystalline schists. It is never quite free from flakes of white mica, and grains of quartz, obviously authigenous, are not rare. There is nothing to suggest that the crystalline structure of the rock is in any way the result of pressure; but we may confidently affirm that such modifications as can be attributed to this agent of change were produced after the rock had assumed a crystalline condition, and when it differed in no material respect

* In the field the calc-mica schist might be thought to exhibit a tendency to graduate into this phyllite. This, however, proves on further examination to be illusory.

from its present condition. There are, however, certain rocks outcropping higher up the hill, obviously in close relation with the above-mentioned marble, which demand careful study; for at first sight these might be supposed to retain traces of organisms. Some 300 feet above the level of the valley, we found that the marble (here rather more fissile and flaggy) shows on the southern side elongated markings of a lead-colour, bearing a rough resemblance to flattened tubes. These vary in size; the larger are a couple of inches or even more in length, a quarter of an inch wide, and perhaps one twentieth of the same in general thickness. They weather more rapidly than the rest of the rock, so as to be indicated on an old surface by irregular hollows. Higher up, about on the same horizon, the rock is obviously not quite so pure a limestone (having, at first sight, as is common with such rocks, a slightly gneissoid aspect), and is more distinctly "slabby" in habit. In this variety also the rudely tubular markings are very distinct; they are lighter in colour than the body of the rock (which here is greyish), and are occupied by a substance resembling a yellowish-white or greyish clay.

Specimens of these rocks have been studied microscopically, more especially with a view of determining the nature of these peculiar structures. The first one, with the lead-coloured streaks, is a fairly coarsely crystalline limestone (grains commonly about .03" in diameter) with a few flakes of white mica, grains (variable in size, but generally smaller than those of calcite) of quartz*, and a few black grains, probably graphite. The matrix does not appear to be generally crushed, but some grains exhibit the usual indications of pressure. The "tubes" (cut transversely in this specimen) are occupied by minutely granular calcite with occasionally a small flake of mica, which mineral seems slightly more abundant here. The sections are irregular in outline. They are streak-like masses, which have a tendency to die away in a string of granules; now and then a larger grain of calcite occurs in the dust-like mass, and the grains of the matrix on either side of the streak seem as if broken away. These streaks obviously lie, whatever be their significance, in surfaces roughly at right angles to the general direction of the pressure by which the rock has been affected. A specimen of the rock with light-coloured tubuli, in close relation with the last described, though a little further away from the more typical marble, does not exhibit any important difference under the microscope, but the grains of calcite are more dirty-looking. Sections of the tubuli are numerous, often very irregular and "inorganic" in outline, sometimes darkened as if by graphitic matter, either crushed up *in situ* or subsequently infiltrated. Another specimen, taken from higher up the section, obviously less calcareous, consists of calcite as before, quartz, in amount perhaps one third of the whole, with a little white mica and granules of graphite (?). Sections of the tubuli are numerous; they are very irregular in outline, "streaking" away into the matrix, and small ones occur which are hardly more than strings of

* I think it possible that a colourless silicate may also be present. Not seldom crystallites are enclosed.

granules. Indications of mechanical disturbances also are rather conspicuous.

What explanation are we to give of these markings? Are they organic or inorganic? At the first glance they look very like the former. But a tubular mollusc seems to be out of the question, since the forms under the microscope are so very irregular; further, so far as my experience goes, a calcareous organism generally crystallizes more readily and is thus coarser in structure than the matrix. Still this difficulty might perhaps be explained away; but the former, even allowing for subsequent distortion, seems to me insuperable. But they might be Annelid burrows. Here, however, is the difficulty that the matrix is often an almost pure limestone, and the contents of the tube also are calcareous, while the fact that they often "streak away" into the matrix and sometimes are mere "strings" in sections, seems fatal to the hypothesis. After a long and, I hope, unprejudiced examination, I can come to no other conclusion than that these markings are inorganic, and their appearance accords best with the hypothesis that they are the result of local crushing. This may sometimes be due to the accident of the rock being slightly less homogeneous at these places, but I venture to suggest the following as a general explanation. Suppose a pressure acting upon a rock, which if it were mainly composed of parallel folia of a mineral like mica, would produce in them a series of parallel undulations: parallel with the crests of these would be lines of maximum strain or stress which might produce local fracture in the calcite, and when a line of grains once yielded, these would give rise to a linear band of crushed material, which would obviously take a form roughly resembling a flattened-out tube.

The black schistose rock which occurs north of the marble is macroscopically very difficult to determine; its dominant structure at the present time is obviously due to pressure. Is it a dark micaeous schist which has been greatly crushed, or an ordinary shale similarly treated? In other words, is the development of mica, to which its schistose aspect is due, mainly anterior or posterior to the action of the pressure which has caused the present cleavage? I have seen, as, for instance, in the Tyrol*, in association with white crystalline limestone a dark mica-schist which has so yielded to pressure as to bear locally a very close resemblance to a phyllite, while the associated marble has been but little affected. Partly owing to the difficulty of obtaining good sections in so fissile a rock, and partly to the destruction of the original mica-flakes in the production of the cleavage, which is followed by a further development of minute filmy mica, a rock in this condition is sometimes locally not easy to distinguish, even under the microscope, from an ordinary phyllite or schistose slate.

My first impression in the field inclined me to think that this was probably a repetition of the Tyrol case, but a more careful study of the question leads me to the other conclusion. The difficulty of

* Q. J. G. S. vol. xlv. p. 91.

examination is increased by the abundance of a brownish to blackish material, ferruginous or carbonaceous, which, so to say, stains the rock; but the matrix itself appears to consist mainly of small flakes of white mica and granules, often elongated in form, of quartz or of some silicate. There are no signs of strain-slip cleavage. The present microfoliation seems due either to original sedimentation or to pressure acting on a material which has not possessed a very definite structure. Oblong crystals of a silicate, often about $\cdot 01''$ by $\cdot 003''$, are not uncommon, usually lying with their longer axes at a high angle with the structure of the matrix; these are posterior in date to the latter, because the dark lines indicative of it can be traced through them; sometimes they are rendered partially or wholly opaque by reason of the dark matter. When clear they give low polarization-tints, and are often twinned on the Carlsbad type; one section gives extinctions of $14^{\circ}25$ and $17^{\circ}25$ respectively on either side of the twin line, so they are probably monoclinic. I have seen similar crystals in other Alpine phyllites, and occasionally in much crushed schists, but am not able to identify the mineral with any species known to me by name. After comparison of the slide with specimens of typical phyllites from other parts of the Alps, the Ardennes, &c., I think we must refer the rock to the same group.

This identification is confirmed by an examination of specimens from the rocks pierced by the St. Gothard tunnel, which runs nearly under the marble-quarry. The section disclosed in this reveals a still more extraordinary state of things than has been just described. It is well illustrated by the collection of specimens procured for the British Museum from the late Dr. Stapf, which has been carefully described by him*. In the tunnel the space between the two gneisses mentioned above seems to measure about 270 yards. In this interval we find that the following rocks are present:—(1) phyllite, (2) marble and calc-mica schists, (3) phyllite, (4) calc-mica schists, in which occurs a curious brecciated rock, (5) phyllite, followed by soft rotten-looking calcareous rock (? representing *rauchwacké*). From the distances at which the specimens are collected, I conclude that the phyllites, &c., are not so thick as the crystalline calcareous rocks. The specimens of the former come from distances of 2562, 2637, and 2766–2790 metres from the north entrance. They seem to owe their schistose condition to pressure: the latter group are clearly ordinary calc-schists or calc-mica schists more or less affected by subsequent pressure.

Strange, therefore, as the association above described may be, I can come to no other conclusion than that we have in this section a newer argillaceous sediment and an older mass of crystalline (calcareous) schists faulted together (in process, doubtless, of folding), so that the apparent sequence is misleading, and that pressure, as is commonly the case, has affected the softer argillaceous sediment more than the more solid crystalline masses. I am, however,

* I am indebted to Mr. Fletcher for great facilities afforded me in the study of these, and to Mr. Miers for much kind help.

doubtful whether the phyllite which occurs at Altkirch, and presumably those pierced by the St. Gothard tunnel, of which the northernmost at any rate may be safely identified with the former rock, are of Jurassic age. The Swiss geologists consider (rightly, as I believe) the phyllites south of the "sericite gneiss" (above the village of Andermatt) to be members of the Carboniferous group, as also an infolded strip which crosses the Lukmanier road at Curaglia. Other like infolds occur (according to the older authorities, who, I believe, are correct) in the valley of the Rhone, as, for instance, at the north base of the Simplon Pass and elsewhere in the neighbourhood of Brieg; and a narrow strip of the same rock, in my opinion, is cut through by the Binnenthal, to the north of the great mass of dark crystalline schists, from which it is macroscopically not easily distinguished*. I am, of course, aware that in a case of this kind it is hazardous to rely on lithological resemblances, but it is at any rate remarkable that there is not only a strong family likeness, in such Alpine rocks as I have examined, among the phyllites of Carboniferous age on the one hand and those of Jurassic age on the other, but also a distinction between the two groups, due, as I believe, to an original difference in the materials, the former having been more directly derived from the older crystalline rocks. If this identification of the Altkirch phyllite be correct, the relation of the crystalline series, the Carboniferous phyllites, and the Jurassic rocks of the upper Reuss valley would very closely resemble that which I have already described, and which is universally admitted, in the valley of the Romanche †.

Be this as it may, whether the Altkirch phyllite be Carboniferous or Jurassic in age, if we place it in the same group with this marble and calc-mica schist, the section presents us with the following difficulties. The argillaceous members of a consecutive sequence are comparatively unaltered, while the calcareous are intensely metamorphosed; for in them not only have the calcareous constituents become completely crystalline, but also the argillaceous have been converted into flakes of mica of considerable size—a result of environment which is hardly in accordance with the general teaching of nature. Again, both rocks have been affected, though, as is usually the case in associated strata of unlike composition, to a different extent, by pressure. This has produced the usual effect upon the clay by converting it into a phyllite; but it has first of all (according to the hypothesis) converted the calcareous rock into crystalline limestone and banded calc-mica schist, and has then imprinted upon it the usual mark of dynamic change. Further, the section appears to prove too much for the advocates of theories of "pressure metamorphism," for the transition between the phyllites

* I twice walked over this strip without observing the distinction, but detected it on a third occasion, as the occurrence of fragments of a dark schistose rock in the adjacent rauchwacké led to a more careful examination of the underlying rock. The similarity is probably due to the "anthracit-schiefer" having been largely composed of fragmental mica, and having derived locally much of its material from the adjacent dark schist.

† Quart. Journ. Geol. Soc. vol. xlv. p. 73.

and the calc-mica schists seems to be too abrupt to be explicable by the difference in their chemical composition. In addition to these difficulties there is a further one, which to myself seems also of great weight. In the Alps crystalline limestones and calc-mica schists are anything but rare. These rocks differ in no respect of the slightest importance from those at Altkirch, and they are associated again and again, under circumstances which preclude the possibility of error, with other true crystalline schists (micaceous, chloritic, &c.). Such rocks, wide as is my experience, I have never seen in undoubted sequence or intercalation with true phyllites, nor have I found, even in the most highly disturbed regions occupied by Mesozoic strata, crystalline limestones and calc-mica schists (not even in the most restricted areas) which presented any real resemblance to those which abound in the other (and, as I believe, much older) series. Yet probably few geologists have had better opportunities of meeting with such rocks if they really did occur in the Alps. Surely, then, if the "upper schists" (as I have termed them) are merely Jurassic sediments, to which a crystalline structure has been given in the process of mountain-making, these cases of transition, these instances of resemblance, should be of common occurrence. There should be a frequent tendency among the sedimentaries to assume the crystalline character, among the crystallines to revert to the sedimentary. This argument will perhaps not appeal very strongly to those who have devoted themselves to a minute and elaborate mapping of a single district; but I am confident of its effects with those who have compared rock with rock, and section with section, from one end of the Alps to the other.

Thus the Altkirch section, a difficult and perplexing one in any case, presents us with such anomalies, if interpreted as a case of selective metamorphism in a group of Jurassic rocks, that it must not be made the basis of a theory which is to be applied with unquestioning confidence to every part of the Alps. As it seems to me, the evidence tendered on the spot demands a verdict of "not proven;" that obtainable in other parts of the Alps, as I now hope to show, will compel us to add "not provable" *.

* I ought to mention that Stapf, in his description of the rocks from the St. Gothard Tunnel, states that he finds in one rock (No. 43), about 2600 metres from the north entrance, organic remains like sponges, corals, or Polyzoa. One of these he figures and describes (*Zeitschr. d. deutsch. geol. Gesellsch.* xxx. p. 130, pl. vi.). He admits that in the same rock a network structure occurs which is due to the infiltration of graphite into the cleavage-planes of calcite. I have examined microscopically specimen No. 43 in the collection belonging to the British Museum, and cannot satisfy myself that there are any true remains of organisms, but think that the imitation structures (often very curious) are of mineral origin. A remarkable pseudo-organic structure is described by Prof. Hedde (*Min. Mag.* vol. v. p. 275), and the same epithet, as is well known, would be applied by many to *Eozoon*. The rock itself macroscopically and microscopically appears to me to be closely related to the crystalline limestone described above, and to differ much from any Mesozoic limestone known to me. After arriving at this conclusion, I found that Dr. Otto Meyer and Prof. Zirkel were of the same opinion (*Untersuchungen über die Gesteine des Gothardtunnels* (Inaug. Diss.), Leipzig, 1870). For the above references I am indebted to Mr. Miers. The rock which has furnished No. 43 lies just south of the schistose slate described above, and appears to pass into the white fissile marble.

2. THE SCHISTS OF THE VAL PIORA.

The Val Piora is a well-marked and fairly wide upland glen running roughly from east to west; at its lower end is the Lago di Ritom, a sheet of water about 2000 metres long by 500 wide. Formerly it must have extended about 880 metres further east, the upper end of the rock-basin in which it lies being now a level and rather marshy meadow. The water from the western end escapes through a narrow gap in the mountains and leaps down (at first in fine cascades) to the Val Bedretto. The lake is 1829 metres above the sea, and the range rises rapidly on either side of the gap, on the west to about 2200 metres, on the east to a long ridge, which varies from about 2000 to 2800 metres. On the northern side of the Val Piora the mountains rise steeply to the watershed parting the drainage systems of the Rhine and Rhone from that of the Ticino. As is shown on Dr. von Fritsch's map, the southern range consists of gneiss, the northern of a group of gneisses or schists. Of these the members which crop out nearest to the Val Piora are commonly characterized by the conspicuous presence of red garnets and green actinolite; they are lithologically identical and practically continuous with the well-known rocks displayed on the lower part of the southern slope of the St. Gothard Pass, for which (merely to avoid circumlocution) I have proposed the name of the Tremola schists. The Val Piora itself is occupied by the rauchwacké and its associated rocks*, and by the group of schists with which we have now to deal; this apparent trough, sometimes narrowing, sometimes widening, extends eastwards along the upper part of the southern slope of the Lukmanier Pass, and westward across the Val Canaria to Airolo in the Val Bedretto, and in both directions far beyond these limits.

At the first glance the map suggests that the last-named schists overlie the rauchwacké and occupy a trough between the two masses of gneiss. But a further study of it, and still more an examination of the terrain, indicates the existence of the gravest difficulties in this hypothesis. For the moment, I will place the rauchwacké on one side and confine myself to the mineral characters and relations of the schists: that these form one group of rocks of considerable thickness, but very closely related, cannot be doubted. They vary much in mineral character, but for the present minor details may be passed over in order to concentrate our attention on the more salient features. We will refer to them again, for the sake of brevity, as the Piora schists. They exhibit two fairly well-defined subgroups or types—one, the thickest and most persistent, being strong schists consisting of alternating bands (of variable thickness) of a brownish or yellowish quartzose rock and a dark, sometimes almost black, micaceous schist. Some members of the latter are characterized by the presence of numerous garnets, about the size of a pea, but sometimes rather larger, generally black. So far as

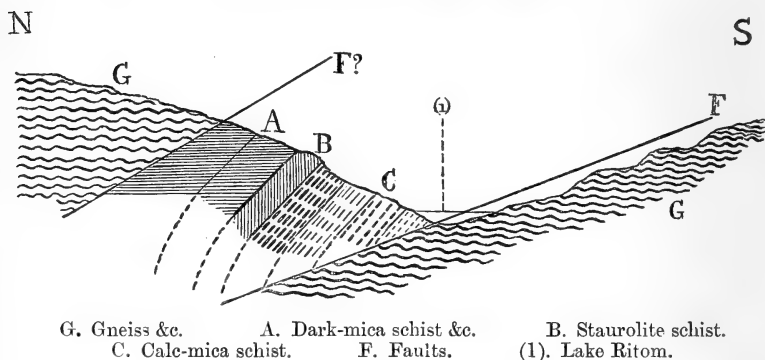
* For brevity and distinctness I will refer to this group, which consists of a peculiar limestone with dolomite, anhydrite, or gypsum, as the "Rauchwacké."

I have been able to ascertain, these, though occasionally very abundant, are rather impersistent in their occurrence. Apparently underlying these is a zone which, were it not still less persistent and much thinner, one would be disposed to regard as another subgroup; this is characterized by the presence sometimes of large staurolites, sometimes of kyanite (disthene).

The second subgroup consists of a number of calcareous and micaceous schists, occasionally quartzose, generally light in colour, frequently varying from calc-mica schists to a slightly micaceous marble, the latter usually of no great thickness. I will refer to the first as the Dark-mica schists ("Graue oder Bündner-schiefer in Glimmerschiefer übergehend," von Fritsch), the garnet-bearing variety as Black-garnet schists* ("Granatführende schwarze Schiefer, *id.*), the next as Disthene schists ("Disthen und Staurolith führende Schiefer," *id.*), and the last as the Calc-mica schists ("Kalkglimmer Schiefer," *id.*).

After examination of these rocks both in the field and with the microscope the following conclusions appear to be beyond any doubt:—(1) That the series originally consisted, mainly if not entirely, of sedimentary deposits; (2) that its members are now truly crystalline and generally rather coarsely crystalline; (3) that

Fig. 1.—Section (diagrammatic), with interpretation, across Lake Ritom and the Val Piora.



after they had become foliated rocks they were subjected to pressure, often great, which very commonly, but by no means always, has acted at right angles to the original foliation—that is, these rocks exhibit a cleavage-foliation as well as a stratification-foliation, though very often the two are coincident in direction.

What, then, is the geological position of these rocks? The annexed section (fig. 1) exhibits their mode of occurrence in the neighbour-

* I formerly spoke of it as melanite-schist, but from a partial analysis made by Dr. Grubenmann (Mitth. der Thurg. naturf. Gesellsch. Heft viii. 1888) the mineral appears to be an alumina-lime garnet, its blackness being due to impurities which prevented any precise determination.

hood of the Lago di Ritom. To a considerable extent it is diagrammatic, as it is designed only to indicate the relation of the principal types. The questions, then, for which we must seek an answer are these:—(1) Are we dealing with a simple fold? (2) What is the order of succession in the series? Omitting for the moment the rauchwacké from our consideration (as we shall presently see we are justified in doing) it is evident that these schists in the Val Piora do not form a simple fold. The Dark-mica schists with the Black-garnet schists are exposed on the Alpine pastures between the Lago di Cadogra and the Lago di Ritom. They form the cliffs overlooking the Ritom Boden, whence they sweep upwards in a westerly direction, and may be traced up the flanks of the Pian Alto and on the summit of Fongio, two mountains on either side of a pass west of the Lago di Ritom, leading into the Val Canaria. Beneath these (apparently) we find above the S.E. end of the Lago di Ritom some kyanite schists, and at the N.E. end the well-known schist with fine staurolites*, which overlies a white quartzite. The latter rocks I did not succeed in tracing very far, and could not find at the top of the above-named pass. The Calc-mica schists appear to rise from beneath this quartzite, and are found in great force on the hill-side leading to the pass. Commonly they are concealed beneath turf or débris, but a fair section is obtained in a gully near the N.W. corner of the lake. The neighbourhood of the col affords important evidence (fig. 4, p. 208). North of it rises the Pian Alto, a craggy mass of the Dark-mica schist. Just west of it, and a few dozen feet lower down, some rauchwacké crops out from the turf. The former rock occurs on the rounded summit of Fongio, on the S. and S.W. sides of which is the Black-garnet schist †. At the base of the actual summit and near the edge of the crags descending to the Val Piora we find schists of the Calc-mica group with some white marble, much crushed, and a little further to the south gneiss, also much crushed, crops out. It is therefore clear that the greater part of the Calc-mica-schist group is cut out by a fault.

If we follow the "Piora schists" eastwards to Olivone and westwards to Binn (and over all this distance they can be traced practically without a break), we find that the characteristic Black-garnet schist is repeatedly picked up and that this rock generally occurs very near to the gneiss or to the Tremola schists—that is, to some member of what I have termed the Lepontine series, which is unquestionably the more ancient. I think therefore that the apparent order of succession in the Val Piora is the reverse of the true one, and that it exhibits only a part of an overfold the remainder of which is cut out by thrust-faults (fig. 1). It is possible that the Dark-mica schist also may be divided from the Tremola schists by a

* Dr. von Fritsch gives 20 metres as its maximum thickness. I have never seen so much as this exposed.

† The whole of Fongio south of the rauchwacké is coloured in Von Fritsch's map as gneiss. This is one of the few errors which I have noticed in this excellent map.

fault; but on this matter I have not been able to come to a conclusion, and I regard it as subordinate in importance.

This Piora series, as already said, is very variable in mineral character. As I have previously noticed some of its members*, and as it has been described in this or that locality by Dr. von Fritsch, Dr. Grubenmann, and others, I shall pass very briefly over the macroscopic characters of all but the Dark-mica and Black-garnet schists, which alone have a direct relation to the main subject of this paper. Suffice it, then, to say that all the members of the Calc-mica-schist group are distinctly (and, if uncrushed, moderately coarsely) crystalline; and that they almost invariably exhibit a cleavage-foliation which often is very marked. Sometimes it seems to have obliterated the original "stratification-foliation," sometimes it coincides with it, sometimes it crosses it at high angles. The evidence for all this has been so often stated in detail by myself that I need not weary the reader by repeating it †. White mica is common, and generally glazes the "sheen surface;" but some specimens have a fair amount of greenish or brown mica. Light-coloured quartz-mica schists and a rather soft schist with two micas are found; but, as said above, in this district the rock is more commonly calcareous, varying from calc-mica schist to white slightly micaceous marble. Rocks with identical lithological characters occur at intervals from one end of the Alps to the other, and are connected by other schists which exhibit only varietal differences.

On the staurolite- and disthene-schists it is needless to dwell, for these also have been often described. It may suffice to say that I have examined microscopically specimens of both, and that they are true crystalline schists. Once, no doubt, they were sediments; but all trace of their original clastic structure has been obliterated. The crystals of staurolite and disthene are sometimes as much as a couple of inches in length, though this, so far as I have seen, is an exceptional size.

The Dark-mica schist, however, with the Black-garnet variety, demands a longer notice, because it is through these that a link is sought with the fossiliferous Jurassic rocks. It will suffice, however, to describe the latter schist minutely, because the description, when the garnets are omitted, will apply, in general terms, to the former. The Dark-mica schist with black garnets is rather fine-grained, of a very dark colour and graphitic aspect. The matrix, especially on slightly weathered surfaces, exhibits a fairly, sometimes very, distinct foliation, though the mineral constituents do not appear to be large. Though the rock in cross-fracture has a strong tough aspect, resembling that of one of the harder schists, it has a more or less fissile structure, doubtless the result of pressure subsequent to foliation, and the "sheen surfaces" exhibit a distinct lustre, which varies from one not very unlike that of "black lead" to that of a silvery

* Anniversary Address to the Geol. Soc. (Proc. Geol. Soc. vol. xlii. (1886), pp. 45-47).

† Quart. Journ. Geol. Soc. vol. xlii., Proc. pp. 36, 37, 69; see also vol. xlv. pp. 82 &c.

mica. On examining a cross-fracture with a lens many glittering minute black particles are seen to be thickly interspersed with the more micaceous constituents. Garnets are numerous; they are seldom more than one third of an inch in diameter, and commonly about the size of peas. Though somewhat distorted, evidently by pressure, they exhibit fairly definite crystal faces (dodecahedral) and the usual aspect of a dark garnet when fractured; but not unfrequently they are traversed by a rude cleavage coincident with the divisional planes of the rock, and obviously due to the same cause. Their crystalline form is often better exposed on weathered surfaces, and in this way sometimes fairly regular crystals may be obtained. It is rather difficult to detach them from the matrix. The faces are then lustrous, though corroded by the more rapid weathering of the enclosed impurities, which are abundant. The ordinary colour is black, but not seldom a slightly brown or reddish tinge may be noticed, and occasionally they are of a deep claret-red.

The folia in the matrix bend round them, and there is every indication that the rock has been subjected to severe pressure since they were formed and it was foliated. This dark schist is associated with layers of a light brown to greyish rather fine-grained quartzose rock, of somewhat felspathic aspect, apparently resulting from the alteration of a rather earthy sandstone. The one rock passes rapidly into the other; sometimes the two are closely interbanded, laminæ of black schist alternating repeatedly with those of quartzite, the thickness of either varying from that of a stout card up to about half an inch, now one now the other predominating; but sometimes the rocks occur in much thicker masses. Garnets are common in the dark layers, sometimes bulging out a little beyond the surface of a thin one, but are very rare and small in the quartzose layers. The pressure to which the cleavage-foliation is due has acted commonly (in the Val Piora) at right angles to this lamination, but there are occasional exceptions to the rule, and the rock then exhibits contortions.

Some details of the microscopic structures of these Piora schists are given in the Appendix (p. 224). It may suffice to say here that, after careful study of the rocks of this group in the field and with the microscope, the following conclusions appear to me fully established:—

1. This group was once a series of more or less banded sediments, not unlike some of our Coal-measure shales and sandstones.

2. By some agency these were completely metamorphosed, all traces of the clastic structure of the sandstones being obliterated, and a number of new minerals formed, among them (in the black bands) garnets of considerable size.

3. The whole mass was subsequently exposed to severe pressure, doubtless during one or more of the processes of mountain-making, which has produced the usual effects.

4. There is no evidence whatever to show that a pressure definite in direction had anything to do with the production of the garnets. So far as we can tell, they, as is usual with the garnets in the Alpine

schists, appear to have developed themselves with equal ease in all directions in the enveloping matrix, and any deformations which they may present have been subsequently impressed upon them.

3. THE RAUCHWACKÉ AND ITS RELATION TO THE SCHISTS.

(a) *Val Piora Sections.*

Rauchwacké is a name employed by the Swiss geologists to designate a peculiar rock which occurs, as a glance at their map shows, in a curiously irregular way, generally in elongated patches, over a large part of the Lepontine and Pennine Alps. Commonly it is a rather cavernous or carious-looking limestone of a yellowish, ochreous, or darkish cream-colour,—not unlike some rather soft varieties of tufa—which bruises under the hammer, is rather tough than brittle, and has a dusty surface. It is frequently associated with rather thick beds of anhydrite or gypsum or passes into a dolomite, in which condition it is usually, so far as I have seen, harder and more solid. But, as a rule, the rauchwacké is a rather soft, non-crystalline rock, and, even when dolomitic, is not so “metamorphic” in aspect as many of the “dolomites” of the Southern Tyrol. It frequently contains mica, usually more or less silvery. The irregular form, the variable size, the unequal distribution, and the occasional association in flakes of this mineral suggest that it is in great part if not wholly derivative, an idea which is confirmed by the fact that occasionally fragments of mica- and other schists are very abundant*. The Swiss geologists regard the rauchwacké† as a Triassic rock, and I see no reason for doubting the general correctness of the reference. There can be no doubt that in some cases it is overlain by Jurassic rocks‡. Though once or twice the rauchwacké, from the abundance of mica and the effects of pressure, superficially resembles one of the calc-mica schists, no one, after a study of the rock in the field or even of a fair series of hand specimens, would think of calling it a “metamorphic” rock in the ordinary sense of the word, or of suggesting a close relationship between it and one of the above-described schists. In the one a detrital or fragmental character, when it occurs, is perfectly retained; in the other, though doubtless the rock had a clastic origin, not a grain of the original constituents can be identified. If, then, we are required to regard this soft unaltered rock as the basis of the great series of crystalline schists described above, we should be involved in such serious theo-

* Dr. Grubenmann states that in the gypsum he found quartz, pyrite, mica, talc, tourmaline, disthene, and zircon, most of which are also mentioned by Von Fritsch (*loc. cit.* pp. 119, 120). He does not, however, appear to have thought it necessary to consider the possibility of their being derivative, but assumes them to be authigenous. I should have thought that the appearance of the rock would have suggested the need of rigorous demonstration.

† For brevity I use the term inclusively, the presence of dolomite, anhydrite, or gypsum being, for my present purpose, of subordinate importance.

‡ Von Fritsch (*loc. cit.* p. 3) says the Lower-Lias *Belemnites Oppeli* has been found on the Nufenen Pass.

retical difficulties that we are entitled to demand a very clear demonstration of its stratigraphical position. What instance, which has stood the test of careful examination, can be produced where a bed, practically unmetamorphosed, is intercalated in a thick series every member of which is highly crystalline? Making every allowance for differences of composition (though it might be observed that highly crystalline calc-schists, limestones, and dolomites are common enough among the supposed overlying series), we are still compelled to ask, What process of selective metamorphism can have produced such a result? I put this question in the interests of "a rational uniformitarianism." Accurate observation and scientific induction lead us to believe that Nature acts in accordance with laws, and that these are related to their results. This would be an anomaly without precedent, and thus cannot be accepted without very clear evidence.

But when we come to study the rauchwacké more closely (confining ourselves for the present to the Lepontine Alps) we find that to regard it as the base of the Piora series (as is done by some of the Swiss geologists) would lead to results which would be often perplexing and sometimes self-contradictory.

For instance, in the Lukmanier-Piora district a brief study of the map shows that the distribution of the deposit is very puzzling, and our difficulties grow the more minutely we examine the terrain. Below the mineral-bearing Jurassic beds of Scopi and Alp Vitgira the rauchwacké is thin and sometimes wanting, but it occupies a considerable area a little below the summit of the Lukmanier Pass, and the group* soon attains a thickness which can hardly be less than a hundred yards, and may probably be much more. This mass (which seems as if embayed between Scopi and the hill of gneiss facing it on the S.W. across the open basin traversed by the upper part of the road) is an offshoot from a broad strip which runs eastward to beyond the Val Greina †, and westward towards the Val Piora. The former part, I may remark in passing, is bordered on the northern side by beds indubitably Jurassic, on the southern by true schists ‡. The western strip of rauchwacké crosses a watershed, where, in the Pizzo Columbe, unless appearances are very deceptive, it can hardly be less than 700 feet thick. Thence it passes into the Val Piora. Here its distribution is very perplexing, on the hypothesis of its superposition to the Piora schists. On the northern side of the valley it appears to occur between these and the Tremola schists. West, and perhaps south of the lake it appears to divide the former series in one part from mica-gneiss, in another from ordinary gneiss; but the mass which extends westwards from

* There is a thick bed of anhydrite or gypsum.

† This joins the Val Levantina at Olivone.

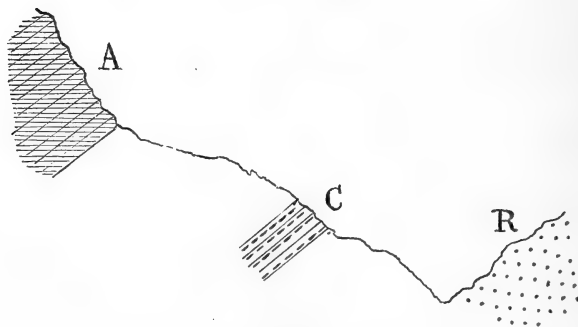
‡ This is the testimony of Dr. von Fritsch's map. Personally I can only answer for the Lukmanier road, which in descending crosses black-garnet schist, quartz-schist, and mica-schist with reddish garnet, staurolite, and kyanite—rocks which bear a general resemblance to those of the Val Piora. Lower down, at the opening of the Val Greina, in the strike of the same mass, calc-mica schists are abundantly developed.

the Pizzo Columbe narrows and disappears in the *middle* of the Piora schists. This, with the occurrence of one or two lenticular patches in like position, can only be explained, if the above hypothesis be correct, by very peculiar rolling and faulting.

Not less perplexing is the occurrence of another irregular isolated and probably interrupted strip on either side of the Pian Alto, west of the lower end of the Lake Ritom.

Our difficulties increase as we examine the sections in detail. Assuming the rauchwacké to be at the base of the Piora schists, let us direct our attention to two sections in ravines on the south side of the Ritom Boden. If we climb up the ravine traversed by the second stream (counting from the west) we find the rauchwacké resting upon gneiss. The upper part of the latter rock is tremendously crushed; its quartz-veins are rolled out and smashed; it is converted into a fissile silvery schist; above it comes a foot or two of rock, which is practically past identification. It may be crushed gneiss, friction- or basement-breccia, for it has been smashed beyond recognition. Then comes the rauchwacké, slabby and rather schistose. Here and there it contains a few fragments; but these, so far as I saw, were gneiss, so they prove no more than that the rock is much later than the Lepontine gneiss (which all admit) and is not highly metamorphosed. Here, then, the rauchwacké either rests directly upon the gneiss or is brought against it by a thrust-fault. Let us now pass on to the next ravine, which for a considerable distance runs almost along the other edge of the patch of rauchwacké. In the lower part we find the following section, not, indeed, continuously exposed, but indicated by crags and ridges outcropping from turf or débris (fig. 2):—(1) Dark-mica schist (well displayed);

Fig. 2.—Section in lower part of Ravine, south-east of Lake Ritom.



A. Dark-mica schist.

C. Calc-mica schist.

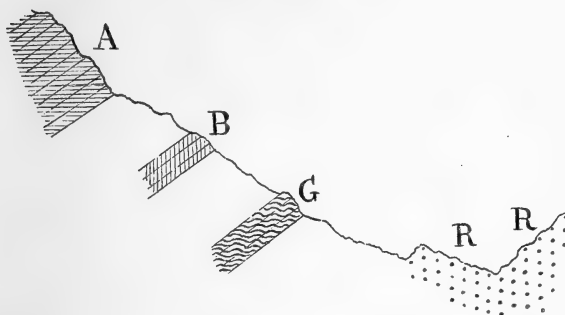
R. Rauchwacké.

The part left blank is covered ground.

(2) Calc-mica schist, parted by the stream from (3) rauchwacké. But about 400 feet above the lake we find (fig. 3):—(1) Dark-mica

schist (as before); (2) Disthene schist; (3) Gneiss rather crushed; (4) Rauchwacké.

Fig. 3.—Section in upper part of Ravine, south-east of Lake Ritom.



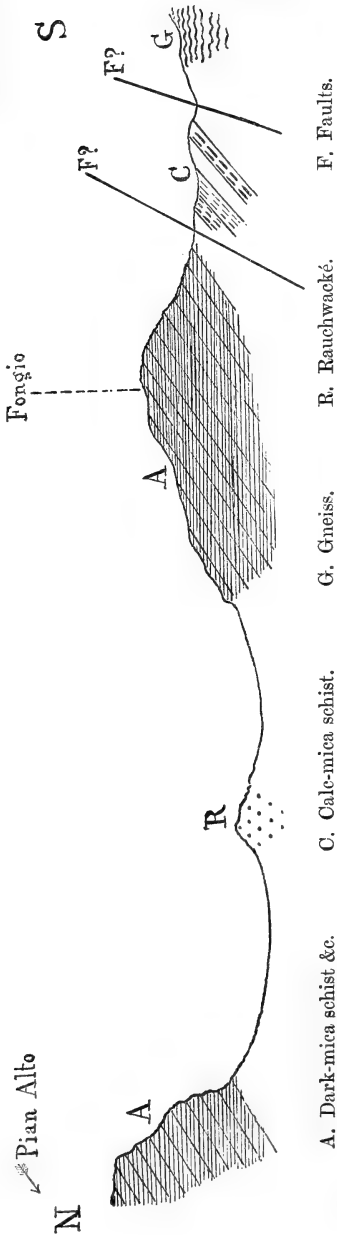
A. Dark-mica schist. B. Disthene schist. G. Gneiss. R. Rauchwacké.

The part left blank is covered ground.

In these sections (A) is a thick mass, well exposed in a line of crags; (B) in the latter is a thin band, the absence of which from the former section is of little importance, for it may be concealed by débris or have died out; but after this we find in the one case calc-mica schist in its ordinary position, and apparently overlying the rauchwacké, while in the other it is wanting, and its place is taken by a rather thin mass of gneiss (which ought to underlie the rauchwacké). If, then, we adopt the idea of a regular sequence and simple fold, we are involved in hopeless confusion; while an examination of the rocks in the field itself suggests that the rauchwacké is caught between two sets of thrust-faults, one of these being, very probably, the southern main fault already mentioned.

We pass on to the section already incidentally mentioned near and about the summit of Fongio (fig. 4). Here we find, apparently in descending order:—(1) Dark-mica schist; (2) Rauchwacké; (3) Dark-mica schist, with Black-garnet schist; (4) Calc-mica schist; (5) Gneiss (crushed). Here, then, the rauchwacké appears to be intercalated in the Dark-mica schist. These sections also, if read from the south side, would indicate that the Calc-mica schist was the lower rock, while if we read from the north side it would be the Dark-mica schist. Obviously, then, the idea of a simple trough is inadmissible. Furthermore, this strip of rauchwacké, where it is exposed in the ravine leading down from the alp between Fongio and the Pian Alto, contains numerous fragments of schists which, to our eyes, were undistinguishable from members of the calc-mica schist group, which crop out in the same ravine, as already stated.

Fig. 4.—Diagrammatic Section across Pass between Pian Alto and Fongio.

(b) *Val Canaria Section.*

A little west of the district just described is the Val Canaria with the noted section described by Dr. Grubenmann. His memoir is a careful and elaborate study in petrography, so that I may pass over the minor details and confine myself to the petrology—that is, to the inductive treatment of these details—where I cannot say that the author appears to me to have been equally successful. This section, as Dr. Grubenmann states, is best seen by climbing up a ravine which runs roughly from north to south*, and has been excavated by a small stream descending from the Alpe Pontina to the lower part of the Val Canaria. Here, on either side of the ravine, is a considerable mass of rauchwacké, with gypsum or anhydrite and some dolomite (fig. 5). Above this a thick mass of various schists is ascended, and then comes another thick mass of rauchwacké &c. followed by a small zone of schists similar to some of those below; above which we find representatives of the Tremola schist and the gneiss †. According to Dr.

* It is not a very easy climb in all parts. More than once, if we had not had our ice-axes to chip an occasional step in the débris, we should have had to make a détour.

† Thus far the section drawn by Mr. Eccles and myself agrees with that given in general terms by Dr. von Fritsch, and in greater detail by Dr. Grubenmann. Between our own section and that of the latter are some slight differences of detail, but they are insignificant; and as we went only once up the ravine (and the work is not easy) he may be more correct than ourselves.

Grubenmann and others we have here the two ends of a fold of rauchwacké enclosing the overlying schists, the axial plane of the trough dipping (as is so commonly the case) to the north. But when we come to study the annexed section (fig. 5) minutely we find that, though at first sight the Calc-mica schist seems to rest upon the rauchwacké and to be succeeded by the Black-garnet schist, we cannot make out any definite order in the upper portion of the fold (where, of course, the lower should be repeated). Again, as we pass over the outcropping beds in the ravine, we notice constant evidence of squeezing, sometimes of crushing, with gliding planes and other indications of thrust-faulting. But when we have passed through the upper mass of rauchwacké, we are confronted by a further difficulty: we find ourselves, after crossing a very few feet of a mica-schist or gneiss, separated from the mass of the Tremola schists by a comparatively thin zone of black-garnet schist and silvery mica- (? disthene) schist*, which are undistinguishable from those included in the fold below.

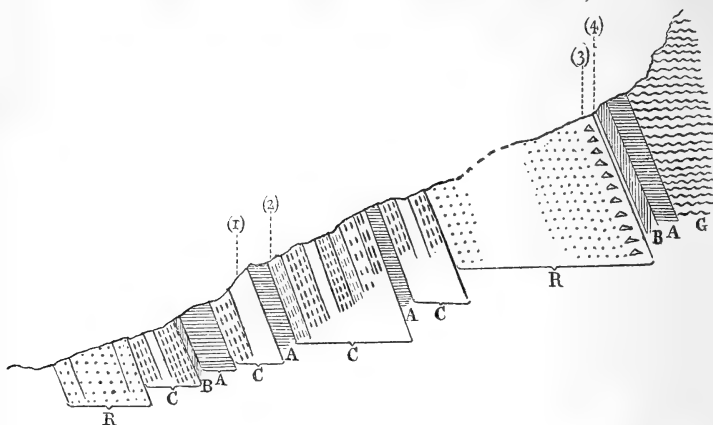
The identity of the latter, as a group, with the Piora schists cannot for a moment be doubted. If, then, the hypothesis that in some way or other we have the thick mass of the Piora schists compressed into a fold measuring only a few hundred feet across, be correct, what explanation is to be given of the occurrence of certain of its components below the rauchwacké, which is the basal member of the trough?

But this is not all. Let us now examine the rauchwacké on either side of the supposed fold. In the lower member mica, mostly silvery, is fairly common. This, in its form and distribution, suggests a detrital origin, and there are sundry small flaky bits which are curiously like fragments of schist. Similar mica occurs in the upper member, but here, near the top, we find that the rock becomes a true breccia full of angular fragments, sometimes more than two square inches in area, similar to schists which occur in the ravine below †. That these fragments were broken from members of the Piora series we had not the slightest doubt. It is therefore evident that in this Val Canaria section we are dealing not with a simple trough, but with an overfold broken up by a series of thrust-faults, as shown diagrammatically in the annexed figure (fig. 6),—that the apparent infolding of the Piora schists by the rauchwacké is wholly

* Dr. von Fritsch maps these two beds as identical with the disthene-schist and garnet-schist below and in the Val Piora. Dr. Grubenmann, though he says he did not see any disthene under the microscope, admits the identity of the former with the "two-mica" (disthene) schist below. To myself they are macroscopically undistinguishable. I was not fortunate enough to find a very characteristic exposure of the black-garnet schist, but scattered blocks are numerous, and I have no doubt of the accuracy of Dr. von Fritsch's mapping. I find, on examination, that the "disthene" schist contains grains of a mineral like staurolite, and I think I can detect disthene (see p. 227).

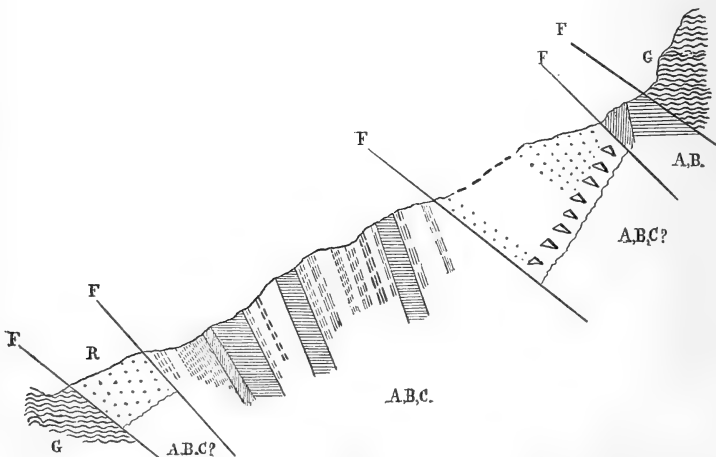
† We did not, indeed, discover the black-garnet schist, but found the so-called disthene schist and other silvery and greenish micaceous schists which occur in the Piora series; these fragments, however, appear to be less modified by subsequent pressure than the rocks *in situ* below.

Fig. 5.—Section in Ravine, Val Canaria.
(Relative thicknesses of the beds uncertain.)



- A. Black-garnet schist.
 B. "Disthene" schist ("Two-mica schist" of Dr. Grubenmann). (2). Thin band of same.
 C. Calc-mica schists, marbles left white. (1) forms a small cascade.
 R. Rauchwacké. (3). The breccia of schist-fragments. (4). Thin zone of variable schists.
 G. Gneiss or Tremola schist.

Fig. 6.—Diagrammatic interpretation of Section in Ravine, Val Canaria (fig. 5).



The letters indicate the general position of the beds mentioned in the explanation of fig. 5. F. Probable position of more important faults.

illusory,—and that the latter really overlies and is much later in date than the former.

The evidence in this locality appears to me decisive, and it is of a kind which would render it needless to pursue the investigation further; for the schists of the Piora group are so different from those of the Tremola group that there is little danger of confusion between a member of the former and one of the latter. Still it may be well to add that the above case is by no means an isolated one. For instance, near the top of the Nufenen Pass, as will presently be described, some rauchwacké occurs. This also contains fragments of a satiny mica-schist, resembling the so-called disthene-schist mentioned above. Again, in the lower part of the Binnenthal, the path to the village of Binn crosses some rauchwacké at the mouth of a ravine cut deeply into a mass of dark schists which can be traced up the valley above Binn, and ultimately passes eastward by the flank of the Ofenhorn to the Gries Pass, the neighbourhood of the Nufenen Pass, and the Val Bredretto. These schists are dark-coloured mica-schists, sometimes rather calcareous. In their lower part they include a mass of crystalline dolomite*, and the peculiar black-garnet schist occurs in the bed of the river a short distance above Binn †. The connexion of these schists with the Piora group cannot be doubted; both form part of the same great series which, as I have already said, can be traced from one end of the Alps to the other. Hence they ought, if the hypothesis which we are discussing be correct, to be more modern than the rauchwacké. But this contains fragments of a rock which has a remarkable resemblance to these schists.

One objection might, however, be made. These fragments are neither numerous nor large, and it is uncertain whether they represent the true Binn schists. While there can be no doubt as to the nature of the rock through which the greater part of the ravine is cut, there is some difficulty at the opening. A short distance higher up there are some indications of another bed of rauchwacké, and the rock, which south of this is an undoubted schist, suddenly assumes a more slaty character, and it is difficult to determine whether we have found the schist in a very crushed condition or a true slate. Such a rock in this part of the Rhone valley (as, for instance, near the foot of the Simplon Pass) is often found in contiguity with the schist and bears some resemblance to it (being probably largely derived from it), and might very well occur just in this position. After careful study of slides cut from two rather typical specimens collected in the neighbourhood of the rauchwacké, I incline to regard this rock as only a phyllite, not a true schist. Be this as it may, the same rock indubitably occurs as a fragment in the adjacent rauchwacké. This, however, contains other smaller fragments more closely resembling schists, besides mica corresponding

* A white saccharoidal rock resembling the marbles which elsewhere occur interbedded with schists and totally unlike any rock I have seen in the rauchwacké group.

† It was detected by Mr. Eccles as we were returning from an ascent of the Ofenhorn.

with that of the crystalline schists, quartz, rutile, &c. So if we pay no attention to the latter constituents, and claim the underlying rock and the included fragments as representatives of the Carboniferous series, then, if the dark-mica schists of the Binnenthal are to be regarded as Jurassic, how is it that these have been so completely altered, while a neighbouring rock, very similar in composition, which before Triassic times had attained to practically its present state of metamorphism, has been so much less changed*?

Again, some 25 miles away to the south-west near the side of the Gorner glacier and on the south flank of the Hochthäligrat, in a region consisting partly of calc-schist, marble, quartz-, chlorite-, and other schists † which lithologically resemble the most highly crystalline members of the Upper group of Alpine schists, partly of gneisses of the ordinary character, which appear to underlie the latter, we find a small mass of rauchwacké. It is the usual yellow, friable, non-metamorphic rock. At the first sight it appears to be interbedded on the mountain-side with the above-named schists and gneiss, but a closer examination indicates that it occurs in a very "patchy" way, and that its outcrop hardly coincides with that of the other masses. This rauchwacké contains not only scales of white mica, very detrital in aspect, but also indubitable fragments of the silvery gneiss with which it is apparently interstratified. Even if it be contended that these fragments only represent the gneissic series, the greater age of which is admitted, we have still to explain the anomaly of a rock which retains the characters of an ordinary sedimentary deposit, directly underlying a great mass (containing rocks of very different composition, but some of which are also limestones) which has become highly crystalline.

In short, this rauchwacké, wherever I have seen it ‡, is not a rock to which I should apply the term metamorphic. I have little doubt that it will be found, in many places, to contain fragments of the great group of schists to which the Piora schists unquestionably belong. But I always felt so convinced that it was a rock of comparatively late date, and that its apparent interstratification with the schists or gneisses was illusory, that until my last visit to the Alps I never took the trouble of searching for fragments.

It might, however, be suggested that in the above cases I have mistaken a consolidated talus of schist and rauchwacké—a formation of recent date—for an integral part of the latter rock. It may

* On referring to the 'Beiträge zur geol. Karte der Schweiz,' Lief. xxiii. pl. i., I find this objection is not likely to be advanced. The rauchwacké is represented as underlying all these dark rocks of the Binnenthal, which are marked as forming one mass, and thus are implicitly claimed as Jurassic.

† These, in the new edition of the Zermatt sheet of the Survey map, are coloured "Lias-Jura," while the older map simply indicated the lithological character of the deposits. This is one of the unfortunate changes which has converted the map from an accurate petrographical record into an expression of the hypothetical opinions of certain geologists, and thus has greatly diminished its value.

‡ I have often come across it, and have also examined typical specimens in the Berne Museum.

therefore save future trouble to say that the possibility of such an error was always present to our minds, and that we convinced ourselves, at any rate when the rock was *in situ*, that we were not making any mistake. On this point we were especially careful in the Val Canaria section, which alone would be sufficient for our case. But since my return to England I have obtained evidence which seems to me to place the accuracy of our observations beyond question. The upper band of rauchwacké in this section—that in which we found the fragments of schist—is continuous with the mass which at a little more than a mile distance along the outcrop is pierced by the St. Gothard tunnel at Airolo. In the British Museum is a collection of rocks illustrating the masses traversed by this great work, which by the courtesy of the authorities of the Mineral Department, I have examined. At the south end of the tunnel a considerable thickness of rauchwacké was pierced, and the collection contains several specimens of the rock. In at least three, taken from between 60 to 72 metres from the entrance, fragments of schist, like those in the Val Canaria, distinctly occur. Another, found at 78·5 metres, has similar fragments of considerable size. Another, at 83 metres, exhibits two parallel slabs of the “two-mica” (so-called disthene) schist, which I have described above, cemented by rauchwacké. This has been taken either from a mass of coarse breccia or from a very unequal junction-surface of the schist and rauchwacké. At 85 metres is the schist itself *in situ*. Thus this section and that in the Canaria ravine are as nearly as possible identical, and it is impossible to deny that the breccia occurs at the base of the rauchwacké.

4. THE JURASSIC ROCKS CONTAINING FOSSILS AND MINERALS.

(a) *Preliminary.*

The occurrence of fossils in the dark, slaty, sometimes schistose, but non-crystalline rocks of the Alps has long been well known. Most of these instances have no more bearing on questions of metamorphism than the occurrence of fossils in certain districts of Devonshire or North Wales. The rocks are slates, at most phyllites, not true schists, and probably no reference would ever have been made to them in the literature of such questions, had not so much confusion been produced by the vague use of the term schist. Studer, however, many years since spoke of finding Jurassic fossils in the same rock as garnets, and, as I have already said, specimens illustrative of this were exhibited by Dr. Heim at the meeting of the Geological Congress in 1888, which, through his courtesy, I was enabled to examine, so far as could be done with a lens. They were of much interest, and in one or two cases certainly bore a strong resemblance to the Black-garnet schist described above. Still I was not quite satisfied of the identity of the rocks, and some scepticism seemed more than justifiable, for it was very difficult to understand how such a fossil as a Belemnite could have retained

its characteristic form while molecular changes of such importance were taking place in the matrix of the rock. Such inferences as one could draw from the analogy of other cases in Nature seemed to render this one extremely improbable, though of course one could not say impossible*. The more I considered the question, the more I regarded it in the light of the evidence which I had obtained from my previous studies both in the Alps and in other regions, the greater appeared the difficulties involved in the hypothesis, the stronger the probability of some mistake.

I have already, I trust, shown that the Black-garnet schist of the Piora group underlies the rauchwacké, and therefore cannot be identical with these supposed granatiferous rocks of Jurassic age, which it is universally admitted overlie the rauchwacké and, like it, belong to the Mesozoic system. Still we have to consider the possibility that the fossiliferous rock has been converted into a schist undistinguishable from the former. My previous experience made this hypothesis appear very improbable to me, but I thought it ought to be fairly tested. After examining the sections near the Lukmanier and Nufenen passes I deemed it needless to carry my investigations further.

In describing the results of these I will not begin by giving a detailed description of the supposed garnet-bearing schist in which fossils occur, but will merely state that the mineral constituents appear either as flattened spheroidal or ovoid grains, about the same size as the garnets, or as somewhat rounded and occasionally rather elongated prisms. Before leaving the subject I shall endeavour to summarize the principal characteristics of these minerals in order to compare them with those of the Black-garnet schist and its associates. Meantime, in order to avoid prejudging the question, I will refer to the rock in question as "the spotted rock," a trivial name which I think expresses fairly accurately its most marked characteristic.

(b) *The Lukmanier Pass.*

The upper part of this pass, north of the mass of rauchwacké already mentioned and east of the highroad, is bounded by a mountain-mass of which the southern peak bears the name of Scopi and rises to an elevation of 10,500 feet. On the opposite side of the road is a lower mass called the Alp Vitgira, which, however, is a kind of spur from a group of peaks but little inferior to Scopi in

* We know that large and well-formed chiastolites are produced by contact-metamorphism in a rock (of somewhat similar mineral character) of which the matrix is but little affected. In the Bastogne also garnets of fair size and singularly regular crystalline form have been formed in a matrix but slightly changed. As reference is often made to the latter, I may say that though I have not visited the district, I am familiar (thanks to Messrs. Renard, Rudler, and Topley) with specimens of the rocks, and am convinced that they do not give us much help towards a theory of the formation of crystalline schists, as the garnets are of a very exceptional character. The metamorphism, such as it is, appears to me due to some unusual agency (certainly not pressure). Can it be the passage of hot water?

altitude. These, together with the peaks north of Scopì, are gneiss; it, with the Alp Vitgira, mainly consists of the "spotted rock," with slates and impure quartzites, in which occasionally Belemnites and other Jurassic fossils occur.

We began our examination of Scopì at the northern part of the steep slopes overlooking the Lukmanier road *, and worked southward over the area on which the map indicated the occurrence of fossils. The annexed section (fig. 7) represents diagrammatically the structure of the mountain †. At its northern end is gneiss of normal aspect. This, in the first little ravine, is followed by a rather fissile schist, which appeared to us to be probably only the gneiss in a very crushed condition. Be this as it may, there can be no doubt that this rock is a member of the crystalline series, greatly crushed. Apparently below it, a short distance up the northern bank of the ravine, is the first outcrop of a rock obviously of sedimentary origin.

* The upper part of the pass is comparatively level, rising from about 6000 to 6243 feet, the highest point.

† We can guarantee its general correctness; but to arrive at minute accuracy and give detailed measurements would be a long and, in my opinion, needless labour. We were moving along a curved line from the western to the south-western slopes of the mountain, and were constantly scrambling up and down over a band perhaps a hundred yards in vertical height, and from 500 to 800 feet above the grassy plain which forms the upper part of the pass, according as promising outcrops of rock were exposed on the steep turf slopes.

Q. J. G. S. No. 182.

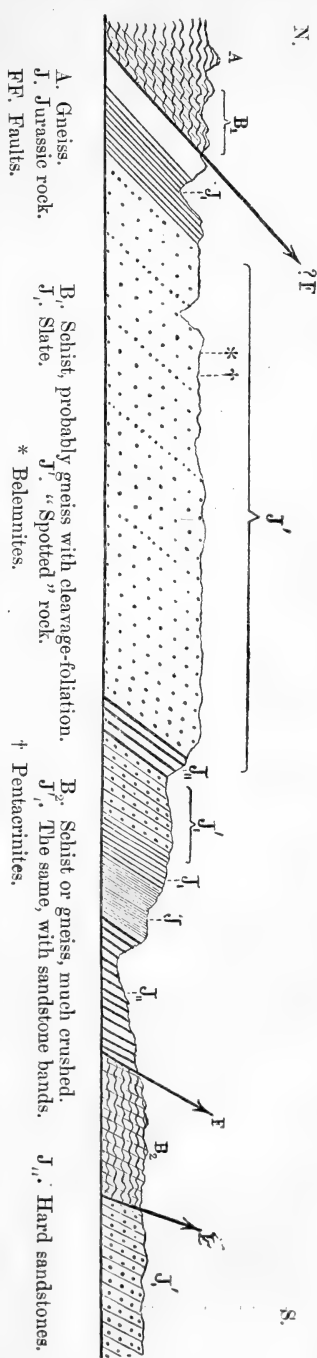


Fig. 7.—Diagrammatic Section on West Flank of Scopì. (Relative thickness of deposits not guaranteed.)

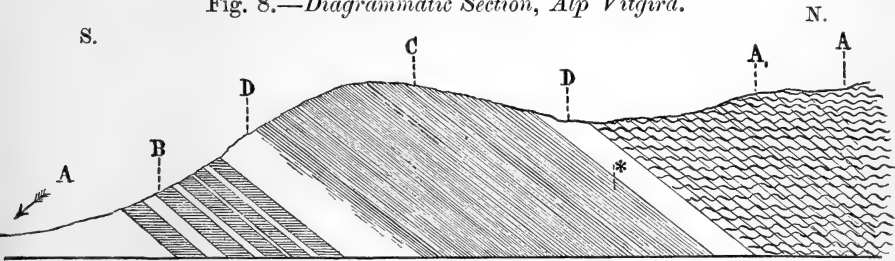
It is a dark-coloured, somewhat schistose rock, having a rude cleavage variably developed, and occasionally is quite an ordinary "bastard slate." The ground-mass has commonly a non-crystalline aspect, though the rock contains much mica, which appears on a weathered surface like tiny spangles, and frequently the minerals already mentioned are abundant. These at first occur rather sparsely, but soon become more numerous. After crossing a second ravine, at a height of some 800 feet above the pass, fossils are found in the "spotted rock." Belemnites, though not in very good condition, are readily recognized, and a little further on the joints of Pentacrinites can be identified. With both are found the round minerals—about as big as hemp-seeds—and the prisms up to full one third of an inch long. Fossils then for a time become rare or are absent, but the "spotted rock" continues, occasionally inter-banded with a hard sandstone or impure quartzite. Sometimes, however, the "spots" disappear, and the rock becomes quite an ordinary black "satiny" slate. We next cross a rather flaggy, fine-grained sandstone, which forms a crag more than 20 feet high; then comes another mass of "spotted rock" followed by sandstone banded with slate ("spots" rare); then a dark, rough, slaty "spotted rock" followed by sandstone; to this succeeds a great mass of an extremely fissile rock of variable mineral character. Evidently it has been intensely crushed, and is thus in a very unfavourable condition for examination; but this may be affirmed with confidence, that it is a member of the crystalline series. The upper part exhibits roundish spots like fragments of decomposing felspars, so that it may once have been a gneiss, or even a fine-grained rather micaceous granite. Parts, however, of the mass have possessed a stratification-foliation; for this occasionally can be seen to "wriggle" across the newer structural planes of the "cleavage foliation," which cut the former like a "strain-slip" cleavage.

To this mass, which I have no doubt is an upthrust portion of the old crystalline floor, succeeds another mass of "spotted rock" (the "spots" perhaps attaining a rather larger size than before) with sandstone bands, much twisted, crushed, and altogether in great confusion. This is succeeded by another mass of shivered schists, and that, again, by more "spotted rock," which appears to continue along the southern face of the mountain*. We had thus examined a large tract of the "spotted rocks," and to my eye, in the field, even the specimens richest in minerals were readily distinguishable from an average specimen of the Black-garnet schist of the Val Piora.

* Von Fritsch marks on his map a band of rauchwacké running up the flank of Scopi, apparently about in the position of the line of sandstone crags mentioned above. We, however, did not find any rock that we could identify with the rauchwacké group, except that a small crag at the base of the slopes overhanging the main stream consists of a pale fawn-coloured rock, which, though rather harder than usual, may be one of the dolomites in this group. If so, it would be an outlier of the great mass of rauchwacké which, as already mentioned, occurs near the top of the pass. We find that in this respect we are in accord with the more recent map published by the Swiss Geological Survey.

The Alp Vitgira affords the following evidence. Its southern slopes overlook a glen called the Val Rondadura: the floor of this is the gneiss of the district, over which, according to the map, rauchwacké occurs some distance up the glen; but there is no trace of this rock at the south-eastern angle of the Alp Vitgira. Here, at the base of the slope, we have Black-garnet or Dark-mica schist interbanded with quartzose rock (fig. 8). Except that these dark

Fig. 8.—*Diagrammatic Section, Alp Vitgira.*



- A. Gneiss. A₁. Gneiss with cleavage-foliation.
 B. Black-garnet schist, banded with quartzite.
 C. Jurassic rock. * Breccia. D. Covered ground.

schists are more squeezed and slaty in aspect than is usual near the Lago di Ritom, this group is very like the banded Black-garnet schist of the Val Piora; and microscopic examination fully confirms the impression, gained in the field, as to the identity of the two groups of rock. These banded schists form a craggy buttress, and the part exposed may be some 200 feet in thickness. Crossing this in a northerly direction, we find that everything for a short interval is concealed by turf. Then come outcrops of interbanded calcareous and slaty (rather fissile) rocks. These contain here and there (but, so far as we saw, less abundantly than on Scopi) the usual mineral spots and prisms. The more fissile layers exhibit sheen surfaces, but the matrix in which these minerals are imbedded looks, even to the unaided eye, very different from that of one of the true schists. Here also we found ill-preserved Belemnites, with indications of other organisms. One outcrop consisted of a dark grey sandy mudstone interbanded with layers, which suggested the presence of detritus from gneiss; below this was a phyllite, which might have obtained its materials from the Dark-mica schist; these contained Belemnites, &c. Shortly beyond this the usual gneiss crops out and continues away to the north.

(c) *The Nufenen Pass.*

The sections here are less accessible than those on the Lukmanier, but accommodation—though very rough—for the night can be found at All'acqua (5266 feet), on the eastern side of the pass, about 2½ hours below the summit (8006 feet). Between All'acqua and

Airolo the Val Bedretto follows very nearly the line of division between the Calc-mica schist group and the Lepontine group (including the Tremola schists). The path leading to the Nufenen Pass for a considerable distance runs near the right bank of the infant Ticino, over schists which belong to—and in many cases are very typical examples of—the calc-mica group, now one, now the other constituent dominating. They are particularly well developed near the entrance of the little hamlet called Fontana. Just after leaving Airolo the path crosses a considerable mass of rauchwacké. It exhibits the usual character, being part of the bed which occurs in the upper part of the Canaria ravine*. After an interval of about $1\frac{1}{2}$ mile the rauchwacké again appears in force near Villa, on the left bank of the stream, associated (unless our eyes deceived us) with gypsum. Beyond All'acqua, at the Cantine de Cruina, is another strip of rauchwacké †, and then blocks of the “spotted rock” become common.

In the upper part of the pass the section from north to south, according to Von Fritsch, is as follows:—(1) gneiss, (2) rauchwacké, (3) granatiferous rock, (4) Jurassic rock with fossils, (5) granatiferous rock, (6) calc-mica schist; the summit of the Nufenenstock (9400 feet) occurring at the junction of (5) and (6): the crags which fall steeply to the pass consisting of (4), while the actual “col,” with the greater part of the final ascent on the eastern side, is on (3). The track, from near the Cantine de Cruina to the summit, winds among scattered blocks, chiefly of the “spotted rock.” These commonly are of all sizes up to about 8000 cubic feet, but occasionally are still larger. The map is coloured as if the rock were *in situ*, but most of the blocks which we saw formed part of a sort of “trail” or scattered moraine. Some might be *in situ*, but it was only in a ravine coming from a tributary glen—the Val Corno,—and near the summit of the pass itself, that we were sure of the occurrence of “live rock;” the distinction, however, is immaterial: I have no doubt that for all practical purposes the map is accurate enough. But the great mass of the so-called granatiferous rock on the north side of the pass (3), and at the entrance of the Val Corno, the only place where we examined the other band (5), corresponds, not with the Black-garnet schist of the Val Piora, but, in all its essential characters, with the “spotted rock” of Scopi. Perhaps it is slightly more “crystalline” in aspect than the latter, but the difference from the former is marked, as will presently be seen. Fossils are by no means unfrequent, mainly Belemnites, even in the most crystalline-looking matrix, but good specimens are hard to obtain. The Belemnites are rather shattered; the rock also is rather harder and tougher than one would anticipate from its mode of

* It is continuous with that pierced by the St. Gothard tunnel.

† Von Fritsch maps part of this as dolomite. Doubtless he is correct, but we did not attempt to distinguish the dolomitic varieties (which are, I think, usually harder and somewhat more crystalline in aspect) from the ordinary rauchwacké, into which I believe they graduate, because for our purpose the difference was not material.

weathering: moreover the best specimens have a trick of occurring towards the middle of the flattish surface of a block, which may be about 16 square feet in area and a yard or so thick! These blocks are frequently very distinctly banded, layers of a grey calcareous mudstone alternating with dark layers full of rounded and prismatic spots: these minerals are rare and small in the former, but fossils occur in both. The "spotted" bands pass rapidly into the compact rock, and are sometimes split up by it, as when a grit is associated with a shale. The mineral "spots" are rather indistinct on a fresh-broken surface, but are very clearly displayed on a weathered one by projecting from the matrix. One block exhibited an interbanding of a fine-grained, hard mudstone and coarse micaceous layers, commonly two or three inches thick, curiously twisted, evidently by subsequent pressure. The rock, as a whole, has been subjected to considerable pressure and generally exhibits a rough imperfect cleavage, which is usually parallel with the bedding, but can occasionally be seen to cross the latter at a fairly high angle. Another peculiarity should be noticed. This rock in weathering breaks up—sometimes with considerable facility—into rude flakes—as it were "scaling" off—as is common with rather coarse mudstones in which a cleavage or bedding may be traced. This characteristic is very conspicuous just at the top of the pass* (where the rock is *in situ*). Here it reminded me of certain hard, gritty, Carboniferous shales, and it gives to the scenery a curiously dull, dirty, and generally untidy aspect. In this respect it differs markedly from the habit of the black-garnet schist. The unpropitious state of the weather prevented us from ascending the Nufenenstock to examine the section at its summit, or from devoting much time to a search for any true Black-garnet schist, and an examination of the rauchwacké to the north of the pass †. There is not, however, space for much of either, for the gneiss crops out abundantly at a very short distance to the north. Rauchwacké, however, is there, but most of it occurs as detached blocks. One of these contained pieces of a satiny schist like the "Disthene" schist of the Val Canaria. There must also be a remnant (as at the Alp Vitgira) of the Black-garnet schist, for we found a few loose blocks, in one of which the garnets were of a dark red colour.

If the rock on the top of the Nufenenstock is identical with that on the pass itself, as, from what I saw at the entrance of the Val Corno, I presume it is, the Jurassic rock may form a true trough, though it must rest upon rather than be intercalated in the Piora series as a whole. For on the north side of the pass there is certainly gneiss with at most a mere scrap of the Black-garnet

* A hard sandstone is interbanded in the series close to the top of the pass, the bands dipping roughly south at an angle of at least 70°.

† Perhaps I should state that this did not interfere with our examination of the eastern side. We were able to satisfy ourselves thoroughly as to the great mass of the fossiliferous and spotted rock, but just when we had completed the examination of this, a dull morning changed to heavy rain, and obliged us to hurry down into the Eggenenthal without minutely examining the short space between the "spotted rock" and the gneiss, or climbing the Nufenenstock.

schists, and at some little distance to the south a great mass of the Calc-mica schist. This accords with what I saw in crossing the Gries Pass*. This differs from the Nufenen Pass in running completely across the different rocks mentioned in the above description; for at the Tosa Falls we are again on gneiss. The summit of the Gries Pass is about a mile and a half, as the crow flies, from the "col" of the Nufenen. On the last part of the ascent to it, from the north side, we traverse "spotted rock" close to the top, and at the commencement of the descent is Black-garnet schist, followed by other schists of the Piora group †.

From the description given above it is obvious that even in the field the resemblance between the "spotted rock" and the Black-garnet schist, as a rule, is rather superficial. But on a closer study of the former the differences become yet more marked, as will be seen by comparing the following description with that given above of the schist. The description is chiefly founded on specimens from the Nufenen, which, as it appeared to me, are better imitations of crystalline schists than those from the Lukmanier, but *mutatis mutandis* it will apply generally. The "spotted rock," even in the most crystalline specimens that I could find, presents marked differences from the Black-garnet schist. For instance, on examining the fresh cross fracture of a slab we find it exhibits a much less definite foliation; sometimes, indeed, its structure hardly differs from that of an ordinary dark argillaceous limestone which has undergone considerable pressure, showing a rude cleavage with a dull glimmering surface. On these fresh fractures the eye less readily detects the included minerals, and instead of the fairly well-defined faces or the resinous lustre of the black garnet, we only detect not very clearly defined and but rarely lustrous spots. Instead of the rather bright "sheen-surfaces" of the schist, we find a dull glimmering surface, like imperfectly polished "black lead," which, on applying a lens, is seen to be a dead blackish mass powdered with glittering specks. When we study the included minerals (for which purpose we must select a well-weathered surface), we find that instead of garnets, presenting their usual crystalline form (though it be occasionally somewhat distorted or flattened), we have rounded bodies, seldom exceeding about a quarter of an inch in diameter, which in form are commonly rather flat oblate spheroids, and sometimes rudely ellipsoidal. The surface of a garnet projecting from the schist, except where corroded by the weathering-out of the included impurities, is fairly lustrous; the spheroidal bodies are dull and minutely granular in aspect. In the case of the associated prisms the external angles are generally ill defined, and they too are

* I examined it in 1883.

† My knowledge of this pass was one of the chief grounds of my scepticism as to the occurrence of "fossils in crystalline schists." Fortunately I had written careful notes (though then much perplexed by this "spotted" rock) and had brought away specimens. I think it probable that the whole of the "bulge" to the north shown on the Swiss Survey Map is the outline of the *Kalkhaltig Glimmer-schiefer*, roughly cut off by a line drawn from the Val Corno to the Mittaghorn, and will be found to consist of Jurassic rock.

occasionally somewhat rounded, as if waterworn. This, indeed, is so marked in many cases that at the conclusion of my field-work I was quite prepared to find that these minerals were derivative, and represented the garnets and staurolites of the schist in a rolled condition. But, as will be seen from the detailed account of the microscopic structure in the Appendix, the spheroidal minerals are totally different from the garnets, the prismatic minerals from the staurolites or kyanites of the Piora schists, and all have been formed *in situ**. It was, indeed, already evident from the analyses quoted by Dr. von Fritsch †, that the spheroidal mineral could not be a garnet unless it included a large number of grains of quartz; for it contains over 53 per cent. of SiO_2 , while the usual proportion for a garnet is from 38 to 42 per cent. ‡ The mineral also contains 6.06 of water, and there is more than 3 per cent. "loss." Thus it is very different in all respects from garnets in the Piora schists. Its analysis does not correspond with that of any mineral known to me. This is not surprising, because evidently so much impurity is present. One statement only may be confidently made, that whatever the cementing material may be to which the form is due, it is not garnet. The prisms, on microscopic examination, are seen to be less crowded with the detrital material, and the analysis, as Dr. von Fritsch points out, suggests that of couseranite §; and, as will be seen from the description in the Appendix, its microscopic characters fairly correspond with those of a mineral allied to dipyre. I have examined the specimens of couseranite (all from either Poujac or some other locality in the Department of the Ariège) in the British Museum collection and at University College, and find that though less perfect in external form and less pure, these Alpine specimens present a general resemblance to them. I think it possible that in the Lukmanier district a third hydrous silicate is also present.

Thus the resemblances of these fossiliferous "spotted" rocks to the Black-garnet schists are only superficial, while the differences both of the larger included minerals and of the matrix, as will be seen from the description in the Appendix, are marked and essential.

* It may be instructive to record my exact impressions. The evidence at the Lukmanier seemed to me on the whole to suggest a formation of the minerals *in situ*; that at the Nufenen seemed to accord better with a derivative origin. But in regard to the latter I was from the first conscious of a grave difficulty. If the minerals were detrital—rolled garnets and staurolites—if the bands in which they occurred were a kind of grit, how was it that I failed to find any other fragments, such as vein-quartz or the harder parts of some of the schists? As, however, one or two bands (without the minerals) do contain detritus of some crystalline "rock," I still thought it possible that something might be revealed on microscopic examination. This, however, as may be seen, places it beyond all doubt that the minerals have been formed *in situ*.

† *Loc. cit.* p. 127. I have quoted these on p. 233.

‡ Dana (*Mineralogy, s.v. Garnet*) quotes 84 analyses, in 82 of which the SiO_2 is less than 43 per cent., and it is more often below than above 40. One rises to 44, the other very exceptional analysis contains 52 per cent.

§ There is, however, too little both of silica and of alkalis.

5. CONCLUSIONS.

If, then, we accept the identification of the Andermatt marble with the Jurassic rock of the Urserenthal and of the Black-garnet schists with the Jurassic "spotted rock" of the Lukmanier and Nufenen Pass, and (as a necessary consequence of these admissions) of the upper group of schists with the Mesozoic rocks of other parts of the Alps, we find ourselves inextricably involved in the following dilemmas:—

(1) That this upper group of schists, which, in all sections free from suspicion, consists of highly crystalline rocks, overlies the rauchwacké, which, in the same region, is quite an ordinary limestone.

(2) That the rauchwacké, though underlying this group of schists, contains fragments of more than one characteristic member of it, identical in all essential respects.

(3) That, if the admissions be correct, metamorphism takes place in accordance with no principle and in obedience to no law. Rocks, in regions of intense pressure, are sometimes highly metamorphosed, sometimes, though with no appreciable mineral differences, are practically unaltered.

From these dilemmas I can see no way of escape, except by denying the facts stated in this paper. On their substantial accuracy I will stake my credit as a worker in science. Moreover I must confess myself at a loss to understand how some of them have been overlooked or ignored by previous observers, and feel justified in expressing my surprise that such slight and superficial evidence has been held sufficient to warrant the adoption and publication of hypotheses which, as a little reflection and some general knowledge of the geology of the Alps would have quickly shown, could not fail to land us in the gravest difficulties. It would be imprudent, in the present state of our knowledge, to prescribe arbitrarily limits to the powers of Nature; but it is justifiable to generalize from one's own observations, when these not only have been made with all possible care, but also are very considerable in number. So I will venture to end this communication, already perhaps too long, by stating that though I have been for years familiar with Palæozoic and still more with Mesozoic rocks of diverse mineral characters in many parts of the Alps, including districts where there have been great foldings, strange contortions, and severe crushings, I have never seen a limestone which presented any real resemblance to the marbles which are usually associated with schists and gneisses, or a slate which was much more than a phyllite, or which, if studied carefully, could not be distinguished from an ordinary mica-schist*. But I have always found that limestones, schists, &c., in the crystalline districts possessed characters, macroscopic and microscopic, in common, by which they could be distinguished from members of the Palæozoic and Mesozoic series. Cases of difficulty do, no doubt, occasionally occur, but, so

* I have seen numerous instances similar to those so well figured in Prof. Heim's classic work 'Mechanismus der Gebirgsbildung,' and have examined the specimens exhibited in the Berne Museum and elsewhere.

far as my experience goes, they are rare and very local; and these arise from one of two causes, viz.: sometimes the base of a sedimentary group is a kind of "arkose"—*i. e.*, is composed of fragments, rather uniform in size, of the underlying crystalline rocks. Such material, after pressure and the consequent development of minute filmy mica, is difficult to distinguish, especially when imperfectly exposed, from certain members of the crystalline series when they have been much crushed. Sometimes also a dark micaceous schist, when crushed, is locally difficult to distinguish from a dark argillaceous sediment in which severe pressure has developed a secondary mica. In short, so far as my observations go, the direct effect of pressure in promoting crystallization is not very great*, and the minerals which may be connected with it are usually minute. It appears to be most efficacious when acting upon a rock already crystalline, and especially in producing changes more or less of a paramorphic nature. But its result, even in the case of such a rock, is usually to diminish the size of the crystalline constituents, to convert coarse- into fine-grained rocks, and thus it causes a rock to recede from rather than advance towards what may be called a maximum stage of alteration.

In short, the result of my investigations differs widely from the conclusions announced to the Geological Congress and embodied in the following quotation †:—"That by the plication of the Alps the constitution of the rocks has been completely changed is most distinctly proved by an examination of the sedimentary rocks; because the latter can be studied in an unaltered condition in adjacent localities. The commonest changes met with in connection with folding are marmorosis of the limestones Development of new minerals (garnet, staurolite, mica) in places that have undergone crushing Even Liassic slates with fossils have been converted into garnetiferous mica-schists, &c. The boundary between the old crystalline schists and real sediments in the Alps has by such processes of dynamic metamorphism been obliterated, and the proper character of the rock is altered so as to render recognition impossible. When we see in true sediments new minerals developed by the progress of the mechanical metamorphism (magnetite in the crushed oolitic ironstone of the Windgälle, garnet in the Belemnite-slates of Scopi), the question arises for the crystalline schists of this and the neighbouring regions: Which minerals are original, and which have been produced subsequently by orogenetic processes?" It is, then, obvious that I dispute the accuracy of most of the statements on which this question is founded, and in so doing have endeavoured to show that it can be answered without the aid of a geological *Oedipus*.

* See, for a fuller discussion on this point, my note in the *Geol. Mag.* 1889, dec. iii. vol. vi. p. 483. It must be remembered also (a point which seems to be often overlooked) that the formation of new minerals takes place during the diminution, not during the increase of pressure. This matter cannot be discussed here, but I am preparing some notes on it for publication.

† 'Nature,' Sept. 27, 1888, p. 524. Passages are omitted to which I take no exception.

6. APPENDIX.

(a) *Microscopic Structure of the "Val Piora" Schists.*

The macroscopic aspect of this group has been described above; the microscopic structure of such members of it as appear in the Val Canaria Section (where most of the characteristic varieties can be recognized) has been studied by Dr. Grubenmann. As I have nothing important to add to his excellent descriptions of the mineral constituents, I shall content myself with quoting his results, incorporating with them some of my notes on specimens from the Val Piora and on the significance of the rock structures, a point to which Dr. Grubenmann appears to have devoted less attention than to their mineral composition*.

The Dark-mica schists, including those containing blackish garnets, are associated, as has been said, with bands of brownish quartzite of variable thickness and persistency. The dark schists consist of quartz, calcite, and two micas, with various other minerals, of which, in certain cases, garnet is the most conspicuous. Regarding those first named as the more essential components of the rock, we find that the ratio of the first two varies much, the calcite sometimes predominating over the quartz, while sometimes it is almost absent; dolomite also is probably present in some cases. The quartz is clear, occurring in subpolygonal or rounded grains; and does not retain any record of clastic origin. These grains, to some extent, and still more those of calcite, are interspersed, and sometimes even crowded, with a minutely granular blackish to greyish mineral (probably in part graphite). Of the two micas, which occur in flakes usually $\cdot 01$ to $\cdot 02$ inch long, one is colourless. This is identified by Dr. Grubenmann with margarite. The other is brown, dichroic, giving a rich brown for vibrations parallel with the basal cleavage, and a pale straw- or greyish green for those perpendicular, and is considered to be probably biotite. The garnets in thin slices appear of a very faint reddish colour, but the included "opacite" often renders them almost opaque. Pressure, subsequent to crystallization, has set its mark upon them. They are cracked or rudely cleaved; they are slightly distorted in form, or even somewhat irregular in outline; occasionally their edges are quite irregular, and the mineral passes into a fine-grained granular mixture of quartz and garnet †. The adjacent matrix is bent and disturbed by the resistance which they have offered; frequently it has gaped open a little "under the lee" of the garnet as the pressure again diminished, and the space has been filled up subsequently by secondary quartz, with perhaps some calcite or a flake or two of

* We have, in fact, approached the subject by different paths. I do not pretend to have investigated the mineral composition of these rocks so elaborately as he has done; for the history of a rock is to me of more interest than the exhaustive study of its mineral details; so that I am often content to leave questions relating to these unsettled. I find also that the use of high-power lenses and any delicate optical work proves very trying to my eyes, which are far from strong.

† See page 235.

mica. We find also, in some cases rather abundantly, a colourless mineral in moderately elongated prisms (ranging in length from about .02 inch to .06 inch). These, with crossed nicols, give apparently a straight extinction and low bluish tints in intermediate positions. They occur both when garnet is present and when it is absent. Dr. Grubenmann identifies this mineral with zoisite, and suggests the possibility of its having replaced garnet; but, so far as I have seen, it appears to me to have been formed independently, and to belong to the same period in the history of the rock. In certain cases, I note among these prisms a slight difference in aspect and some obliquity in extinction, so that kyanite may also occur. Tourmaline is present, being sometimes fairly abundant. Some of it, however, is rather peculiar in aspect, for it occurs not only in more or less definite prisms, but also in films. In the latter case it may have replaced brown mica, as it often appears to do in granite. The colour is a dull indigo or slightly greenish blue. Small prisms, and occasionally geniculate twins, of a honey-brown mineral, are not unfrequent; these are probably rutile. Sometimes they are locally very abundant. I have counted more than 30 in a field, measuring .04 inch in diameter*. Granules of magnetite, hæmatite, and pyrite are present. Every slide that I have examined of this rock indicates a crushing more or less severe, with probably a slight shearing movement. To this also I am disposed to attribute the brownish dust present in the slide, instead of regarding it as an original constituent. No one, I think, accustomed to the study of crystalline schists and of the effects of pressure can have the slightest doubt that the rock was a crystalline schist, containing sometimes good-sized garnets, anterior to its being exposed to the only pressure of which it has retained a definite record †.

* The following analysis of the *Granatführende Thonglimmer-Schiefer* has been made by Dr. Grubenmann. As rock analyses always have great value, and his paper appears in a publication not very accessible to English readers, I shall not hesitate to reprint them here. He states that the garnets were too impure to give a satisfactory result, but that a partial analysis showed them to be an alumina-lime garnet (thus corresponding with those in the Tremola schists). The large amount of TiO_2 shows that much rutile may be expected in the rock.—

SiO_2	72.24	
TiO_2	3.01	
Al_2O_3	11.79	
Fe_2O_3	2.99	
FeO	1.74	
CaO	4.06	Sp. gr. = 3.5667.
MgO	0.80	
K_2O	0.85	
Na_2O	0.97	
Combustion-loss (H_2O, CO_2)	2.30	

100.75

† See also President's Address, 1885, Quart. Journ. Geol. Soc. vol. xli., Proc. pp. 46, 47. No specimen in my collection gives clearer evidence in proof of the above statement than that which I obtained from the ravine (Val Canaria) which was examined by Dr. Grubenmann.

The "quartzite" interbanded with the dark schist consists, in the specimen which I have examined*, chiefly of two minerals in variable proportions. The one is quartz, in grains (often about .01 inch in diameter) of roundish but slightly irregular outline, like those common in many quartzose schists, except that they are rather full of microlithic enclosures and fluid-cavities. The other is a mineral, which at times is rather earthy-looking, like a decomposed felspar, at times is clear with a rather strong double refraction. The former seems to pass into, as if replaced by, the latter. This occasionally occurs in rude prisms, and presents some resemblance to an impure andalusite, having in one or two instances the brownish tint of staurolite. Their form is hardly regular enough to determine satisfactorily the extinction-angle, but I venture to suggest that they are a mineral allied to andalusite, and have been produced from a decomposed felspar. Zircon (?) and rutile occur occasionally. One of my slides exhibits a close interlamination of this rock and of the dark schists. Here the former contains a few grains which may be small reddish garnets, and the latter exhibits the tourmaline-like mineral in a form that suggests a replacement of the brown mica.

The Staurolite-schist from near the N.E. end of Lake Ritom has as its matrix a closely felted mass of white mica and quartz (both minerals being rather minute) in which are scattered grains of iron-oxide, flakes of brown mica, reddish garnets of fair size, and the large staurolites. The last mineral is a honey-brown colour in thin slices. It contains numerous microliths which I will not venture to identify, but flakes of an iron-oxide (? hæmatite) are not rare, and prisms of rutile are fairly abundant. The garnet here is "cleaner" than in the black schist, still enclosures are plentiful. The outline of the staurolites is sometimes fairly rectilinear, but sometimes rather irregular and broken-looking. On the whole the evidence seems favourable to the existence of this mineral anterior to the date of the mechanical disturbance which has affected the group.

A schist, with staurolites of smaller size, in a rather more micaceous matrix, occurs on the south side of the Lukmanier Pass, above Somascona. It appears to have been subjected to pressure after it had attained to its present mineral conditions †.

To the S.E. of the Lago de Ritom, apparently on nearly the same horizon as the Staurolite-schist described above, are outcrops of rock containing kyanites, which sometimes are full 3 inches in length, in a rather gneissose ground-mass. This, however, does not call for any special notice, because smaller kyanites are far from rare in the more micaceous bands of the Calc-mica-schist group. Kyanite occurs also plentifully on the south side of the Lukmanier

* From the ravine at the east end of the Ritom Boden. It seemed needless to have other specimens sliced.

† For a brief description of the group of rocks with which this schist is connected, and which evidently is a prolongation eastward of the Piora group, see my President's Address, 1886, Quart. Journ. Geol. Soc. vol. xlii. Proc. p. 47.

Pass, but here of only about .02 inch or .03 inch in length, together with a pale green hornblende, brown mica, and some quartz. This schist is much crumpled, evidently by the action of pressure subsequent to mineralization.

In this connexion it may be well to notice the rock in the Val Canaria mapped by Von Fritsch as "Disthen-schiefer," and fully described by Grubenmann, although the distinctive mineral is far less conspicuous than in the cases already mentioned, and in one instance he failed to find it. He describes this schist as "*zweiglimmerigen (sog. Disthen fùhrenden) Schiefer*;" and undoubtedly micas are the more conspicuous minerals. Its position in the supposed fold of the Val Canaria has already been described, and just above the upper mass of rauchwacké is a schist which, macroscopically, is identical, and only differs under the microscope by the absence of the disthene*. Dr. Grubenmann states that the rock also occurs in the ravine leading up from the Lake Ritom to the pass between Pian Alto and Fongio, and in this view I entirely concur. For a full description of the microscopic structure, I must refer to his paper; but it will suffice to say that the rock in the lower zone (where it is altogether about 6 feet thick) is of a grey-green to dark green colour, with a pearly lustre on the cleavage-surfaces, and occasional marked folia of a dark mica. Among these occur infolding layers of mica with a wavy cleavage, and with these are associated small blades of disthene, with quartz and calcite. Two micas are present, one colourless the other dichroic; they are associated with needles of rutile. Tourmaline occurs pretty frequently, with some zoisite, black grains of iron-oxide (doubtless magnetite), pyrite, and zircon. From a discussion of the optical properties of the micas, and their analyses (given below †), Dr. Grubenmann considers the colourless one to be a kind of margarite, and the dark one a meroxene. They occur roughly in the proportion of 20 : 9.

* As I follow Dr. Grubenmann in the description of the rock, I will retain in this part of my paper the name *disthene* instead of kyanite, which I am in the habit of using for this mineral. In my specimen, however, there are some small-bladed lamellæ which, I think, may be identified with disthene, and several rather irregularly formed granules of a honey-yellow mineral, which much resembles staurolite. These are about .01 inch long.

†	<i>The White Mica.</i>		<i>The Dark Mica.</i>	
	I.	II.	I.	II.
SiO ₂	34.90	34.82	SiO ₂	40.56 40.96
Al ₂ O ₃	48.92	48.85	TiO ₂	0.38 0.43
Fe ₂ O ₃	trace	trace	Al ₂ O ₃	21.84 22.10
CaO.....	10.88	10.83	Fe ₂ O ₃	6.02 7.25
Na ₂ O	2.33	2.69	FeO.....	5.91 5.27
K ₂ O	0.49	0.59	MgO	14.08 14.13
H ₂ O.....	3.05	3.30	K ₂ O.....	6.41 5.87
	100.57	101.08	Na ₂ O	3.07 3.19
			H ₂ O	2.31 2.25
				100.58 101.45

Sp. gr. = 3.1095.

Sp. gr. 2.9001.

Associated with the above rock, at its lower occurrence, is a quartzose calc-schist, of which Dr. Grubenmann gives a description and analysis*; these show, as will presently be seen, that in reality it differs little from some members of the Calc-mica schist division. Indeed, I feel some doubt whether this "*Disthen führender Schiefer*" ought not to be regarded rather as a member of that division than as an equivalent of the staurolite and kyanite rock near the eastern end of Lake Ritom.

The second zone of this *Disthen führender Schiefer* (about 5 feet thick) does not seem to differ materially in microscopic structure from the first one; and, like this, it is associated with quartzose and calcareous schists. The third zone (*above* the upper mass of the *rauchwacké*), according to Dr. Grubenmann, very closely agrees (*sehr weitgehend übereinstimmen*) with the last named, although he has not detected any disthene. For myself, I may say that the rocks appear macroscopically identical. I could only distinguish specimens by their labels, and agree with Dr. Grubenmann in not attaching much weight to the absence of the disthene, a mineral generally rather uncertain in its mode of occurrence. But, if identical, how is its presence *outside* the fold to be reconciled with his theories?

Calc-mica Schist Division.

The rocks included here vary from a fairly pure white or grey marble to quartzose or micaceous calc-schists. If attention be paid

Bulk analysis of the Schist containing two Micæ, Disthene, &c.

	I.	II.	
SiO ₂	40.20	39.98	
TiO ₂	2.00	2.30	
Al ₂ O ₃	26.72	26.20	
Fe ₂ O ₃	3.12	3.54	<i>The "Disthene."</i>
FeO.....	4.08	3.80	SiO ₂ 36.85
CaO.....	4.12	4.01	Al ₂ O ₃ 63.12
MgO.....	11.39	11.68	99.97
K ₂ O.....	6.12	6.02	
Na ₂ O.....	0.57	0.47	Sp. gr. = 3.6034.
Combustion-loss ...	2.22	2.18	

100.54 100.18

Sp. gr. = 3.0092.

* "*White aluminous Quartz-schist.*"

SiO ₂	25.99		
Al ₂ O ₃	8.95		
Fe ₂ O ₃	3.89		
CaO.....	29.70		
MgO.....	3.59		Sp. gr. = 2.5792.
K ₂ O.....	2.84		
Na ₂ O.....	0.84		
CO ₂	23.86		
		99.66	

This schist must accordingly contain about 57 per cent. (or, at any rate, more than half) of carbonates (*T. G. B.*).

to minute details, it would be possible to indicate many varieties both in the Val Canaria and in the Val Piora sections, but I agree with Dr. Grubenmann in regarding these as comparatively unimportant, except so far as they indicate (as we both agree in holding) that the rocks are of sedimentary origin. The principal constituents are calcite, quartz, mica, commonly white, but sometimes brownish or greenish (from alteration) with black grains—iron-oxides, and perhaps graphite—and more or less of dusty-looking material, which Dr. Grubenmann considers to be of organic origin. He also finds some zoisite, and rutile is occasionally present. The quartz-grains, often about $\cdot 012$ inch to $\cdot 025$ inch in diameter, are commonly very clear and give high polarization-tints. In no case do they retain any trace of a clastic origin, though they often appear to have been dislocated and again cemented. The mica flakes are commonly about $\cdot 03$ inch long, and the calcite grains about the same in diameter. Every specimen gives more or less an indication of mechanical disturbance; sometimes the pressure appears to have acted at right angles to the mineral layers, sometimes there is evident shearing, sometimes it has acted more nearly parallel with the layers, producing various flexures and foldings as I described on a former occasion. Dr. Grubenmann himself states that the mica flakes are often thrown into strong undulations (*sind oft stark wellig verbogen*) and that the calcite shows constantly twin structure parallel with $-\frac{1}{2}R$, and the twin lamellæ are frequently rather conspicuously bent. He remarks that this is evidence of severe pressure, but does not seem to perceive the necessary inference that the rock was already thoroughly crystalline when the pressure acted.

So far as microscopic evidence goes, these rocks of the Val Piora group present in many cases close resemblances to members of the "Upper schist group" (as defined by me) from other parts of the Western, Central, and Eastern Alps, though, of course, varietal differences are almost endless. Here dolomite may predominate over calcite, here mica may be much more abundant, here there may be a greater amount of this or that accidental constituent, but, as it seems to me, "a family likeness," both macroscopical and microscopical, is strongly marked, and the latter method of study does but accentuate the difference between these and the so-called "fossiliferous schists" of the Lukmanier and Nufenen Passes*.

* Dr. Grubenmann gives the following as a bulk-analysis of a typical example of the Calc-mica schist series of the Val Canaria, remarking that the rock must consist of about three fourths of calcite, and the remainder quartz, clay, and some mica:—

SiO ₂	21·96	
Al ₂ O ₃	1·43	
Fe ₂ O ₃ and FeO	0·78	
CaO	46·11	Sp. gr. = 2·7674.
MgO	0·61	
CO ₂	30·04	
	100·93	

(b) *The Rauchwacké.*

So far as concerns the mineral constituents, I have nothing to add to Dr. Grubenmann's petrographical studies. Indeed, I have had only a few slides prepared, because the question which I sought to determine was petrological, viz. whether the composition and structure of the rock permitted of its being placed at the base of a certain group of crystalline schists, a question which, to my mind, was decisively answered. Dr. Grubenmann describes the lower zone of rauchwacké in the Val Canaria section more minutely than the upper, but gives analyses of the latter*. I have only looked at this through the microscope, and have thought it needless to examine the anhydrite or gypsum, or one of the more dolomitic bands. But that the two zones belong to the same mass of rock there can be no doubt. Quartz, pyrite, mica, talc, tourmaline, disthene, rutile, and zircon are the chief minerals enumerated by Dr. Grubenmann and by earlier observers as accidental constituents of this series. In a specimen from the upper zone he obtained an insoluble residue of about 2 per cent., consisting of colourless flakes of a biaxial mica, with a small axial angle (margarite), and greenish flakes of a uni-axial mica (biotite), quartz-grains, and little crystals of tourmaline, rutile, and zircon. I selected for examination two specimens: one, a clear, fairly hard, cream-coloured rock, in which only a few tiny flakes of white mica and specks of some dark mineral could be seen

According to Dr. von Fritsch (*l. c.* p. 113), Escher von der Linth found in the calc-mica schists of the Lepontine Alps "*unbestimmte aber unzweifelhaft organische Reste.*" Of these I have never seen the slightest indication, and venture to think this evidence insufficient. Studer also states that he found belemnites in the *Knoten-schiefer*, at Fontana, in the Val Bedretto. I did not myself come across either this rock or the black-garnet schist at that locality, but it is not mapped there by Von Fritsch, and so, being anxious to spend my time on the important Nufenen mass, I made no search for it. Mr. W. Watts, however, informs me that he failed to find it, though he spent some time hunting about. I would venture to suggest that the mass examined by Studer was not *in situ*. The number of the erratics in the upper part of the Val Bedretto is enormous.

* Analysis of a saccharoidal white dolomite, from a quarry north of Villa (Val Bedretto):

	I.	II.	
CO ₂	46.01	45.97	
CaO.....	39.04	39.14	Sp. gr. = 2.8469.
MgO	15.04	15.16	
	100.09	100.27	

Also of a fine-grained, rather yellow-coloured dolomite from the ravine (Val Canaria):

CO ₂	44.96	45.15	
CaO.....	40.12	40.16	
MgO	11.96	11.98	Sp. gr. = 2.8303.
FeO.....	0.42	0.36	
Insoluble residue	1.96	2.05	
	99.42	99.70	

with the unaided eye—a sample of the purest and most crystalline condition of the rauchwacké; the other from the matrix of the basal breccia.

I recognize the above-named minerals, for a careful description of which I refer to Dr. Grubenmann's memoir. The structure, however, of the rock, which does not appear to have impressed him, appears to me of great importance. Taking first the specimen which is more crystalline in aspect, we find a minutely granular matrix*, which, owing to the interstitial presence of a greyish dust, is less clear and transparent than one would anticipate from the macroscopic appearance of the rock. In this matrix are scattered flakes of mica, mostly white, grains of calcite, of a colourless mineral, often stained earthy brown, of quartz (here not common), and of brownish or blackish iron-oxide. There is also one tiny flake of a quartz-mica schist. But without the evidence of this last, which is so small a fragment that I would not wish to rely upon its testimony, no one, I think, accustomed to the study of elastic and metamorphic rocks could have any doubt that this rock cannot be ranked with the latter group, that its matrix is not that of a true marble, that the above-named minerals have been derived from older rocks, and that these very probably were crystalline schists such as have been described above.

In the specimen taken from the breccia-bed (p. 209), the matrix resembles that of the last one, but is slightly coarser and dirtier. It is fuller of fragmental minerals; both micas abound; quartz is common, indubitably in fragments, which are clear and give bright polarization-colours like the grains in the schists; calcite, iron-oxides, &c. are present, with a few flakelets of mica-schist. These all are beyond doubt derived from an older series, as in the other case.

A specimen of the rauchwacké, containing fragments, from the ravine at the north-west end of Lake Ritom affords a matrix generally similar to the above, with like mineral fragments. Rutile is rather abundant in parts of the slide, and frequently occurs in "nests," which, with the associated material, suggest the presence of fragments. Be this as it may, chips of schist are undoubtedly present, and I can hardly doubt that some represent the adjacent Calc-mica series.

A specimen also has been examined from the base of the rauchwacké in the second ravine, south-east of Lake Ritom (p. 206). It was selected because it illustrated the rock in a crushed condition. Even here, though the effects of pressure are very marked and the rolling and crushing together of the matrix and included fragments, sometimes of not very different mineral composition, makes it more difficult to follow the precise outline of the latter, still the calcite of the matrix is but slightly more coarsely crystalline than in the cases described above, the clastic character of the rock is not destroyed, and it is very different from any specimen which I possess of the crystalline schists. Among the fragments, calc-mica schists,

* The granules rarely exceed .001 inch, and are often less.

including a quartzose variety, can be recognized; brown mica is abundant. Crystallites of rutile (maximum length about .01 inch) are numerous, often occurring in elongated nests in the flaky masses of brown mica or in a finely granular, rather dusty-looking mineral (? crushed calcite) and sometimes also with granular quartz. With these are a few grains of tourmaline and not unfrequently small blade-like prisms, about the same length as the rutile, which I would suggest may be kyanite. These rock-fragments appear to be exceptionally rich in microlithic constituents, just as I have noticed is the case with parts of the slides cut from the Piora schists.

(c) *The Jurassic Rocks.*

Under the microscope the specimens from both the Lukmanier and the Nufenen Passes present a strong family likeness. The matrix consists of calcite* in rather elongated and somewhat irregularly outlined grains (generally less than .01 inch long, not uncommonly about .005 inch), with a variable quantity of a clear mineral, part of which is quartz, but part is perhaps a silicate, with flakes of a colourless mica, which gives rather brilliant polarization-tints, and with granules, probably of the second mineral described below. Scattered through the matrix is a minutely granular, greyish to blackish, sometimes brownish, powder, the colouring-matter of the rock. There are also occasional grains of pyrite or an iron-oxide, more or less perfect prisms of rutile †, and (rarely) of (?) tourmaline, all of small size. It is very difficult to decide how far the constituents are derivative. The calcite, in its present condition, is probably authigenous, so also may be the quartz; but not seldom the form of a grain suggests the presence of a fragment as nucleus, which has only received a slight enlargement *in situ*. In the case also of the mica the evidence is inconclusive. Here, again, it is

* Mr. J. Chorley, of University College, has kindly determined the amount of CaCO_3 in a specimen in which the "knots" and "prisms" were not abundant; the first which I collected on the north side of Scopi. One estimate gave 82.72, the other 83.53. Of course, where the included minerals are numerous, the percentage of carbonate in the whole rock would be lower; but I should say that this was a fair sample of the matrix throughout, and that every specimen which I have examined probably contains over 50 per cent. of carbonate of lime. I have examined the residue of this rock under the microscope; it consists largely of generally minute granular graphitic matter, with small flakes of a colourless mineral of no definite outline and weak depolarizing power (? mica), sometimes "peppered" with the black dust, and rather numerous acicular microliths, not generally exceeding .002 inch long. Of these there appear to be two varieties—the stouter brownish yellow in colour, probably rutile; the other lath-like, colourless, extinguishing either parallel or at a very small angle with the sides (? kyanite). Also there are granules of quartz, felspar (?), and possibly zircon. I have not been able, from this study alone, to form any positive conclusion as to the history of the rock.

† The rutile-crystals occur sporadically, but two or three are in close proximity. Once or twice I found a large number of rutiles in what appeared to be a small fragment of another rock. This very closely resembles a portion of one of the layers rich in rutile in the Dark-mica series. I may add that one or two bits in the matrix resemble garnet, but these are almost certainly of fragmental origin, not authigenous.

possible that derivative flakes may subsequently have been slightly enlarged. Now and then a slide contains a little brownish mica which certainly has a derivative aspect. The larger minerals, present, as it were, porphyritically, and giving the spotted character to the rock, are certainly authigenous, and appear to have been formed after the rock had assumed a slightly schistose structure under pressure. At least three types can be recognized:—(a) The rounded grains (*Knoten*). These are found on microscopic examination to consist of the darker granular matter of the matrix with some quartz- or calcite-grains (smaller than in it) cemented together by a clear, rather wax-like material, which has occasionally separated itself from the other constituents in thin streaks. It has weak double-refraction, for with the two nicols its tints are low in the scale; certainly, as the analysis leads us to expect*, it is not garnet; but it is in a condition so unfavourable for examination that I will not venture to suggest an identification. Probably it is a hydrous silicate of alumina and lime, possibly orthorhombic, but it does not remind me of any mineral with which I am familiar. (b) The prism-shaped minerals (*Prismen*), of which there may possibly be two forms. The commoner are subangular to almost rounded prisms, with surfaces rarely lustrous, but often spangled with minute mica-flakes. These, in thin slices, exhibit a flaky-granular mineral affording moderately bright polarization-tints, cementing together a dusty-looking matrix (in this crystalline calcite cannot be discerned). The outline of the prisms is rather irregular, but, so far as one can judge, extinction takes place either parallel or at a small angle with their sides. With this mineral I provisionally include a somewhat shorter but decidedly more slender one (commoner, I think, on Scopi) which has a slightly fibrous aspect, with indications of cleavages parallel with and oblique to the axis: fractured surfaces having a rather resinous lustre. In thin slices, though the outline is rather irregular, the crystals are more free from foreign matter. The polarization-tints are rather low, whitish or yellowish. Though extinction not seldom takes place parallel with the sides (so far as they can be determined), it is, I think, more often oblique than would occur with an orthorhombic mineral. In thin sections some of the former prisms are very hard to distinguish from the first group, which seem sometimes to take an

* Analysis of the minerals in the "Nufenen Schiefer" (Fritsch, Beiträge zur Geol. Karte der Schweiz, xv. Lieferung, p. 127):—

	(I.) In den Knoten.	(II.) In den Prismen.
SiO ₂	53.09	40.07
Al ₂ O ₃	19.45	22.05
Fe ₂ O ₃	5.93	5.66
CaO.....	10.95	22.29
MgO.....	1.03	1.20
H ₂ O.....	6.06	8.89
Loss.....	3.49	—
	100.00	100.16

ellipsoidal form. I must leave these prisms also unnamed. The mineral sometimes presents a slight resemblance to andalusite, but the analysis seems to make this identification impossible. Naumann* appears to have regarded it as couseranite, for he names the Nufenen Pass as a locality for this mineral. But the identification appears to be doubted by Studer, who is quoted by Dr. von Fritsch in the passage from which the preceding analysis is taken. This, however, does not correspond well with those given by Dana, but comes nearer to some of those quoted under the head "Agalmatolite;" neither does the mineral exactly resemble any one known to me, though it is not very unlike couseranite, and has a slight general resemblance to dipyre. I suspect its relations are with this group of minerals. The analysis corresponds more nearly with some forms of scapolite. (c) A mica-like mineral which occurs in rather tabular small masses, usually not exceeding .05 inch in diameter, and perhaps .03 inch in thickness, presenting more or less rounded outlines and a very distinct basal cleavage, a silvery lustre and a slight tinge of green in colour. Under the microscope it is evidently authigenous, having developed after the formation of a schistose structure in the matrix, which can be traced through the crystal. Sometimes, however, it is fairly clean. It is colourless, very like a mica, but perhaps slightly more "waxy" in aspect. The polarization-tints are rather bright; it almost invariably exhibits polysynthetic twinning parallel with the planes (basal) of cleavage, and extinction which, if not simultaneous, is very nearly so (and parallel with the same). Both macroscopically and microscopically it seems to differ slightly from a mica. Mr. Teall, after looking at my specimens, suggested that the mineral might belong to the chloritoid group, and the more I examine them the more probable this suggestion appears to be.

Larger grains of pyrite are also common. These evidently have been crushed out, for they form rather elongated clusters or streaks. At each end, "under their lee," the quartz, calcite, and mica of the matrix occur in slightly larger grains.

Specimens cut from the finer bands, intercalated, as already described, with those of the "spotted" rock, consist of a matrix generally resembling that of the latter rock; but the grains are rather smaller, there is less quartz and mica, and the specimens more nearly resemble those of an ordinary impure fine-grained limestone. The characteristic minerals of the coarse bands are wanting, but there are grains of pyrite, and vein-like seams occupied by calcite, with a very little quartz, (?) dolomite, white mica, and perhaps a colourless silicate.

One of the specimens from Scopi contains numerous joints of a Pentacrinite. The matrix of this differs slightly from that of the other examples in being a little more calcareous, decidedly more carbonaceous and more irregular in its structure. Fragments of organisms are frequent, such as I can identify as being Crinoidal. In these the tubuli, infiltrated with carbonaceous matter, are often

* Elemente der Mineralogie, s. v. Couseranite.

preserved, but in proportion as the fine granular look of the calcareous organism is lost and a regular mineral cleavage set up, these structures tend markedly to disappear*. The slide contains one of the rounded mineral spots, but these and the prisms are not abundant in the hand-specimens.

Near the base (apparently) of the similar group of rocks on the Alp Vitgira is a curious-looking nodular rock, which, in the field, appeared to me as if it were mainly composed of fragments, were, in short, a conglomerate or breccia at the base of the Jurassic series, much crushed. It exhibits, under the microscope, a very peculiar structure. The chief constituents are calcite, quartz, white mica, brown mica, sometimes altered into a greenish mineral, and garnet. This is speckled with "opacite," which also is variably disseminated in the slide. A bit of the slide here and there resembles the ordinary matrix of these Jurassic rocks, and one small fragment resembles an organism (*Pentacrinites?*). The structure of crushed breccias in the Alpine Palæozoic and Mesozoic rocks is often peculiar, the ultimate result of the pressure being to render the fragmental structure less definite, probably by the direct effects on the fragments themselves and the "mashing up" of chips from their surfaces with the very variable constituents of the matrix. Thus it becomes difficult to discern the precise boundaries of the fragments and of the matrix, or to be sure in many cases whether we have (more especially in the case of quartz and calcite) minerals of primary or derivative origin. But in regard to this slide, I may say that the garnet, at any rate, appears to be distinctly derivative. It occurs in two ways. One piece resembles a garnet which has been partly broken up and recrystallized. There is a piece, like the remnant of a crystal, about 1 inch long and one third of this wide, which passes on both sides into a granular mass of garnet, quartz, and a little brown mica. The others exhibit a mass composed of garnet, calcite, and quartz, with a very little brown mica, the first mineral appearing to act as a kind of setting to the others, the interspaces composed of it being elongated in one direction, so that the garnet seems to form a kind of root-like growth among the other minerals. This structure I consider to be a record of pressure; it is a species of foliation; but I observe that, while usually it is parallel with the structure of the rock-mass which is due to the Post-Jurassic movements, at least in two specimens, which have a very fragmental aspect, it lies athwart the latter. This "foliation" accordingly appears to be of earlier date than the Jurassic epoch.

* I have observed the same thing in regard to the so-called canal-system in the supposed organism *Eozoon canadense*. [In the discussion it was stated that "marmorosis" had taken place in the organisms in these Jurassic rocks. In those described here there is just as much or just as little "marmorosis" as may be seen in any later Palæozoic limestone in Great Britain. The Belemnites, being larger and rather brittle, are a little more changed in appearance, but even these not seldom, on careful examination with a lens, are found to retain their characteristic structure. If these slides exhibit "marmorosis," so do hundreds of limestones to which no one would apply the term "metamorphic," using this in its ordinary sense.]

I admit that the evidence of this specimen is not such as would convince an ordinary observer, but after long familiarity with schists and derivative rocks, I am unable to come to any other conclusion than that the garnet, to say nothing of other minerals, has not been developed *in situ*, but occurs in derivative fragments*. If this be so, no stronger proof could be given of the independence and antiquity of the Piora-schist group—and this, coupled with that already obtained from the rauchwacké, if admitted, places the matter beyond dispute. This instance is only one out of many which indicate (as I have already more than once observed) that there had been “mountain-making” in the region of the present Alpine chain before any Mesozoic rock was deposited, and even in Pre-Carboniferous times.

DISCUSSION.

Dr. GEIKIE stated that he had sent an abstract of the paper by Prof. Bonney†, read to the British Association at Newcastle, to Prof. Heim, and the latter had favoured him with a *résumé* of his views on the subject of the present discussion, of which the following is a translation:—

“It appears to me that Professor Bonney starts from a misunderstanding. It has often been maintained that Mesozoic rocks can become crystalline; but no Swiss geologist has, so far as I know, *ever* asserted that the crystalline schists of the *Central massif* of the Alps are metamorphic Mesozoic rocks. In the printed abstract of his British-Association paper, however, which you have sent to me, Professor Bonney attacks this supposed assertion—one that has never been made.

“I am in perfect accordance with those who know the *Central massif* best (Baltzer, Fellenberg, &c.) in fixing the following points:—

“1. Crystalline schistose rocks of Mesozoic age exist at Scopli, in the Valsertal (Graubünden), in the Urserenthal, on Piora, at the Nufenen Pass, in the Val Canaria, in the Ganterthal, and numerous other places. Such rocks are:—

“(a) Clay-slates, with mica, garnets, zoisite, staurolite, rutile, and Belemnites, the latter being crystalline and granular.

“(b) Clay-slates, with mica, staurolite, &c., and garnet, alternating with the Belemnite-schists.

“(c) Green plagioclase-amphibole schists, alternating with the Belemnite-schists.

“(d) Micaceous phyllites and calcareous mica-schists.

“(e) Marble with mica, which has undergone linear stretching, going over into ‘Malm-kalk’ with crinoids.

“2. We have *never* given the name ‘crystalline-schists’ to these rocks, nor have we ever regarded them as such, but always as sedimentary metamorphosed zones (synclinal basins) *between* the central massifs. Professor Bonney is right in saying that they have not the aspect of true crystalline schists. It is true there are some varieties which it would be difficult to distinguish in the hand-specimen, and without stratigraphical evidence, from true crystalline schists. Stratigraphically, they always present themselves as ‘Mulden-zones’ accompanied by other sedimentary rocks.

* My specimen of the Black-garnet schists collected between the top of the Lukmanier Pass and Somascona (President’s Address, 1886, Q. J. G. S. vol. xlii., Proc. p. 47) in parts very closely resembles the fragment here described. The rock has evidently been much affected by pressure.

† Prof. Bonney states that the printed document sent to Prof. Heim contained the whole of the note communicated by him to the British Association.

"3. In the *Central massifs* occur rocks which exactly resemble true crystalline schists in mode of occurrence. Petrographically, they are related to them by passage-rocks; at least, the line of separation is not easily distinguished. Such rocks are *phyllites*, *chlorite-schists*, *felsite-schists*, *mica-schists*, and especially *sericite-gneisses*, all of which we regard with certainty as palæozoic. The proofs are the following:—

- "(a) In some places in these zones are found intercalated beds of graphitic and sometimes even anthracitic schists (Bristenstock, &c.).
- "(b) Traces of fossils have been often found (trunks of *Calamites* from Guttannen in the Haslithal, Carboniferous plants in strips wedged in on the Tödi, &c.).
- "(c) At the end of the Central-massif distinct zones of Carboniferous slates are often developed out of the zones of these sericitic gneisses; and the synclinal ('Mulden') nature of these zones, in comparison with the old granitic gneisses, is shown there by the wedging in of still younger unaltered sedimentary rocks.
- "(d) I have already shown in my Tödi-Windgällen group that even the Verrocano (Permian), when nipped in between crystalline schists, assumes a close resemblance to them, and appears as a part of the crystalline Central-massif.

"Fragments of these rocks are found in the Triassic Rauchwäcké, but this is not the case with the garnetiferous schists of Scopi, which are younger than the Rauchwäcké, and belong to the true sedimentary synclinal zones ('Mulden').

"A great unconformity exists in the Central Alps between Palæozoic and Mesozoic formations, but not between Palæozoic and Azoic.

"I. The *Palæozoic* formations mostly show an intimate tectonic relation to the crystalline schists, and have been converted petrographically into crystalline schists. The *central-massifs* consist, perhaps to the extent of two thirds, of true old crystalline schists, older than the Cambrian, in part, perhaps, the primitive crust (Erstarrungskruste, granite-gneisses, protogine); and to the extent of about one third of Palæozoic mica-schists, sericite-schists, amphibolites and other similar rocks which have been derived by dynamic metamorphism from Palæozoic slates, sandstones, and conglomerates; and Baltzer distinguishes between the old nucleus and the younger shell (slates) of the *Central-massif*. They are kneaded and pressed into one another.

"II. The genuine Mesozoic deposits follow, sometimes conformably, sometimes unconformably. In places they have become crystalline and schistose (*schiefrig-krystallinisch*); but they never occur as a constituent of the *Central-massif*, but always accompany the Mesozoic deposits, or are intercalated as 'Mulden' in, and especially between, the *Central-massifs*. They are never termed 'Crystalline-schists' in the geological sense of the word—at the most, only in its petrographical sense.

"The latest literature on these things is, above all:—

"Baltzer. 'The Aar-massif and a part of St. Gothard massif,' 'Beiträge zur geol. Karte der Schweiz, 24th Lieferung, 1888.

"Grubenmann (*Prof. Dr.*). 'The Sedimentary "Mulde" of Piora.'

"Baltzer furnishes, in the volume above cited, some excellent work on the rocks indicated under I, and gives a drawing of the *Calamite*-like trunk from Guttannen. Grubenmann does the microscopic work in connexion with the Mesozoic formations belonging to II., which have never been referred, by us, to the crystalline schists or to the *Central massif*.

"RESULT.

"Much of what have been regarded as genuine crystalline schists in the Alps is Palæozoic.

"The crystalline metamorphosed Mesozoic rocks always occur as sedimentary deposits, and have never been termed 'crystalline schists' in the stratigraphical sense" *.

* After reading once more Dr. Heim's essay, communicated to the International Geological Congress in 1888, I cannot hold myself to blame for misunderstanding it, and must contend that the sentences quoted above on page 223

In continuation of his remarks Dr. GEIKIE complimented the Author on his courage in returning to this difficult ground, but notwithstanding the arguments so skilfully brought forward that evening he was not convinced of an error on the part of the Swiss geologists. Even the Author's own sections gave some countenance to their views, since the dark garnetiferous schists might quite well be part of the same series as the Belemnite-schists. In metamorphic regions there must be some line, on one side of which fossils are recognizable, on the other not so. In the Alps, as Heim and his associates contend, the Belemnite-schists, which have become markedly crystalline, may be less altered portions of masses from which all trace of fossils has been generally obliterated.

Mr. ECCLES declined to say anything with respect to the Andermatt section. As to the Val-Piora schists, and their relations to the rauchwacké, he fully concurred with the Author's views thereon, and especially in respect of the frequently changing position of the rauchwacké in relation to these schists. He criticized the suggestions of Von Fritsch with reference to this series of beds, and pointed out the curious position of the calc-mica schists on this

(and the translation appears to me to represent accurately the sense of the original German) justify the position which I have taken up in this paper. Indeed, I find it very difficult to reconcile perfectly the present letter with that essay or the published statements of Swiss geologists; and if I might venture to put my view of the case rather bluntly, I should be obliged to say, "It is not so much that I have misunderstood you as that you have misunderstood Nature." Hence, to contend further on the point, whether Dr. Heim did or did not include rocks of Jurassic age among crystalline schists, is needless, for if I am right as to the following matters, the dispute is one "*de laná capriná*." I beg leave, then, to observe that:—

(1) Carboniferous rocks are only incidentally mentioned in my paper, so that I fail to see the full force of Dr. Heim's reference to such rocks in another part of the Alps. Some of these, however, I have examined, and think I know them well enough to demur to Dr. Heim's statements concerning them. I have seen, in the Berne Museum, the specimen with "the Calamite-like stem." When this rock is proved to be a gneiss I shall be prepared to consider the propriety of extending this name to the *Grès Felspathique* of Normandy, or that of mica-schist to some rocks of Carboniferous age at Vernayaz, in Canton Valais, or of calling the Torridon Sandstone of Scotland a granite.

(2) One of the main purposes of the present paper is to prove that a great group of true crystalline schists (some of which contain garnets, staurolites, &c.) does exist in the Lepontine Alps, and that in these Belemnites or other fossils never occur.

(3) Also to prove that the supposed infra-position of the Rauchwacké (Triassic) to this group is the result of misinterpretations of the stratigraphical evidence, and that this Rauchwacké (a comparatively unaltered rock) contains fragments of more than one member of the above-named group of schists.

(4) Also to prove that the *schistose* (Jurassic) rocks, in which Belemnites and other fossils occur, only resemble superficially the above crystalline schists, and do not contain (not to mention other minerals) authigenous garnets or staurolites, the minerals which have been taken for these being certain hydrous silicates, the presence of which does not indicate any extreme metamorphism.

Hence, in my opinion, Dr. Heim in his letter does not adduce any fresh evidence, but only reiterates the mistakes, as they appear to me, in correction of which my paper was written.—T. G. BONNEY.

supposition. If Jurassic here, they are also Jurassic in the Pennine Alps, and would carry with them the "grüner-schiefer" of Studer. He commented on the brecciated character of the Rauchwacké. He scarcely agreed with the Author as to the Jurassic schists resembling poor forgeries of genuine garnet-schists, since it might be easy to mistake some bands for parts of the calc-mica schists.

Mr. TEALL referred to remarks of his own on a previous occasion as possibly having had something to do with the production of the paper. We now had a further illustration that Prof. Bonney's views were at variance with those of the modern school of Swiss geologists. He had dealt with the age of the Val-Piora schists on stratigraphical evidence; but we must wait to hear what the Swiss geologists had to say to the criticisms of the Author.

Speaking of the petrographical relations of the two rocks, he agreed with Prof. Bonney that his specimens of the garnet-schists were quite different from those of the Belemnite-rock. With reference to the character of the Belemnite-bearing rock, the Belemnites themselves are marmorized; the rock itself is schistose, the planes glistening with secondary (developed) mica; the knots represented some silicate. The prisms gave distinct outlines. There had been much molecular change. In fact, he would term the rock a crystalline schist.

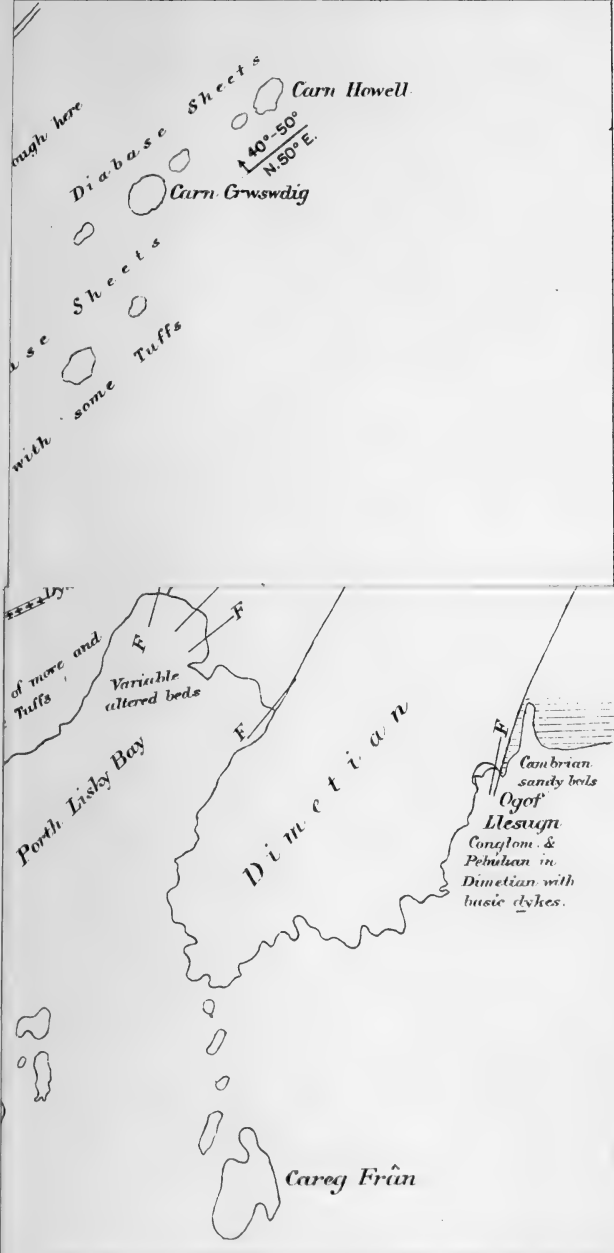
Dr. IRVING, from personal experiences of traverses in the Eastern Alps, could bear out the Author's views as to the succession of the calc-mica schists &c. in the Glockner region and the small degree of alteration of the rauchwacké in comparison with some of the dolomitic series of the Eastern Alps. He had studied Grubenmann's section of the Val Canaria, and criticized some of his deductions. He regarded his assumptions as untenable—such as that the schists are of Mesozoic age, chemically and morphologically altered by pressure, or that the "calc-glimmer-schiefer" are altered limestones. There was a third fallacy, viz. that of the two mica-schist series recurring three times in the Val-Canaria section, yet only once in such a position that their suggested origin would seem possible. Lastly, Dr. Grubenmann had overlooked the important evidence of the breccias in the dolomites.

Prof. HUGHES had been over the ground where the fossil-bearing altered rocks occur, in company with Prof. Heim. He thought the case one of evolution as far as the rocks are concerned. There was a tendency to approach extinction-point, and when at last the fossils disappeared alteration had gone so far that something altogether different was produced. But there were degrees of alteration, and many changes of known series, before we got to the Archæan.

Rev. E. HILL referred to the unlikeness of the Rauchwacké to the older schists.

The AUTHOR said that many of the objections proceeded from misunderstanding. Heim's work dealt chiefly with the Central Alps, of which he had not spoken, but he gave a complete contradiction to any statements that these fossil-bearing rocks in the Lepontine Alps are in any proper sense crystalline schists. There are, however,

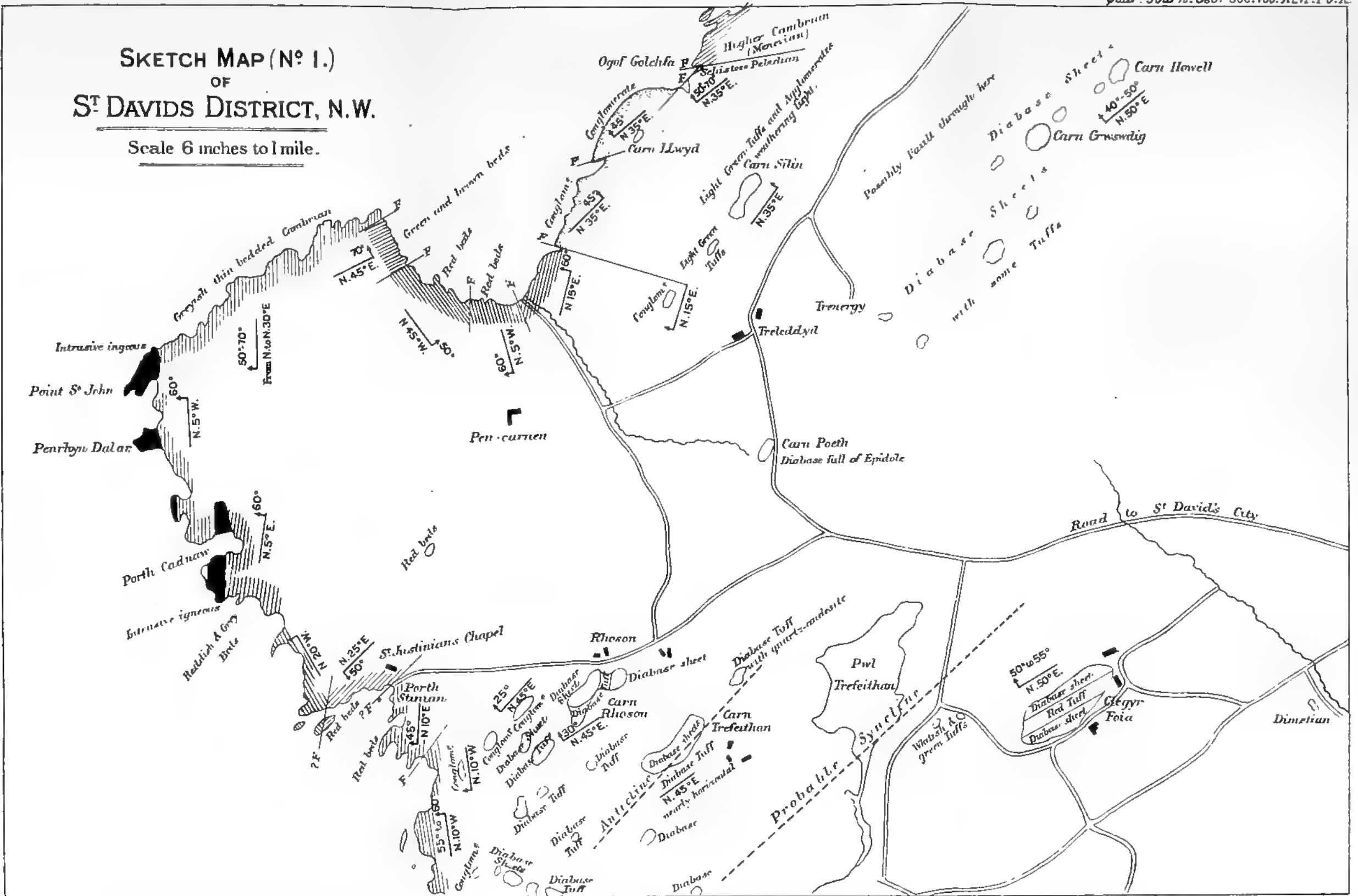
crystalline schists in this region; but to reply to the letter which Dr. Geikie had read would be merely to give a repetition of his paper. In this he had disproved (as he hoped, satisfactorily) the statements repeated in that letter. He admitted the similarity spoken of by Mr. Eccles, but it was only superficial; under the microscope the differences were at once visible. He complained that, in Mr. Teall's argument, words had been substituted for things. By this process of reasoning the Devonian and Carboniferous Limestones of Britain might be proved to be metamorphic, whereas truly crystalline marbles are quite different. In the Belemnite-series the minerals are not (where authigenous) garnets, staurolites, &c., but dirty hydrous minerals; it is possible to conjecture what these rocks were, and the organisms are scarcely altered. He could not quite understand Prof. Hughes's points; but in answer to the notion that we must have connecting-links, he asserted in the present case the totally distinct facies of the two series of rocks.





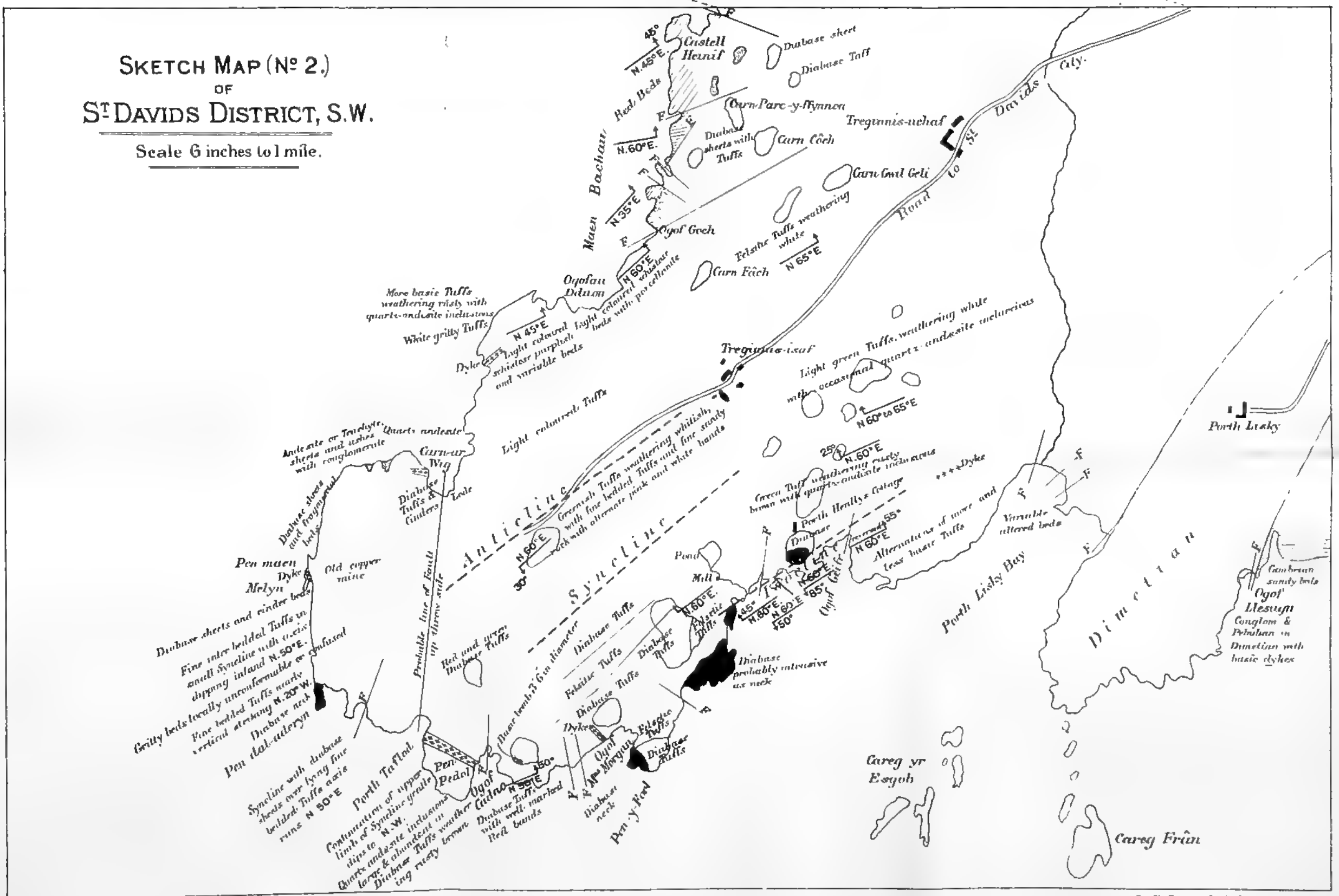
SKETCH MAP (No 1.) OF ST DAVIDS DISTRICT, N.W.

Scale 6 inches to 1 mile.



SKETCH MAP (No 2.) OF ST DAVIDS DISTRICT, S.W.

Scale 6 inches to 1 mile.



ST. DAVID'S HOSPITAL
DALLAS, TEXAS

14. *The PEBIDIAN VOLCANIC SERIES of St. DAVIDS.* By Prof. C. LLOYD MORGAN, F.G.S., Assoc.R.S.M. (Read January 8, 1890.)

[PLATE X.]

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1. INTRODUCTION.

Two strongly contrasted interpretations of the structure and geological genesis of the St. David's promontory are before geologists. The first of these is that advocated for many years by Dr. Hicks and finally summed up by him in 1884 (*Quart. Journ. Geol. Soc.* vol. xl. p. 507). On this view there are at St. Davids, besides the strata of Cambrian age, three distinct Pre-Cambrian systems—the Dimetian, Arvonian, and Pebidian. Each is unconformable to the others. The Dimetian was very much in its present state before the Arvonian was laid down. The Arvonian hälluffintas, again, were brought to their present mineral condition before the Pebidian series was deposited. The Pebidian volcanic beds, once more, were nearly as highly metamorphosed as they are at present before the Cambrian Conglomerate was formed. Each is therefore separated from the succeeding group by a *systematic* unconformity, and we have, on this view, to quote the words of Mr. Tawney, "a vista opened

up to us in the rocks of St. Davids of age behind age most pleasing to the imagination of the geologist."

The second interpretation is that advocated by Dr. A. Geikie (*Quart. Journ. Geol. Soc.* vol. xxxix. p. 261). According to this view the Pebidian constitutes a volcanic series at the base of and forming an integral part of the Cambrian system; the Dimetian consists of granite intrusive into the Cambrian and of much more recent age; while the Arvonian group comprises portions of the Pebidian volcanic breccias and tuffs, where these are invaded by quartz-porphyrries associated with the intrusive Dimetian granite.

To these two divergent interpretations Mr. J. F. Blake (*Quart. Journ. Geol. Soc.* vol. xl. p. 294) has added a third, first suggested by Mr. Hudleston. He contends that the Dimetian (granite), Arvonian, and Pebidian belong to one volcanic series, the age of which is anterior to and independent of the Cambrian epoch.

Not only is there this marked divergence of opinion as to the age of the Pebidian volcanic series and its relations to the other rock-masses of the district, but equally marked is the divergence of opinion as to the succession of the Pebidian strata and the mode of their stratigraphical arrangement. Dr. Hicks maps the Dimetian-Arvonian ridge as the ancient land-axis against which the Pebidians were unconformably deposited and from which they now dip away to the north and to the south. The series to the north of the axis is thus a continuous ascending series, the older beds, except where they are "dropped" by faults, flanking the ridge, the newest being those furthest from the axis found near Whitesand Bay to the north of St. Davids. Dr. Geikie, on the other hand, denies that the series to the north is a continuous series. He contends that they are repeated by an isoclinal fold "the axis of which must cut the coast-line somewhere between Pen-maen-melyn and Pen-y-foel." The beds to the south of the axis of this isocline are thus, on his view, repetitions of those to the north, and their northerly dips are reversed dips. Mr. Blake, however, examined the coast between Pen-maen-melyn and Pen-y-foel, and though he was "enchanted with the glorious confusion of the volcanic masses there exhibited," could find no sign of a regular fold, "which," he says, "among such rocks would be almost impossible to conceive."

It can hardly be said that our knowledge of the Pebidian volcanic series of St. Davids has yet reached a satisfactory position of stable equilibrium.

I have recently spent some seven weeks in the St. David's district, nearly the whole of which time I devoted to field-work*. I have examined every accessible portion of the cliffs and all the inland exposures, having the advantage of the 6-inch Survey map on which to record my observations. The discovery of some new facts and the formation of an independent opinion on some of the debated questions impels me, though not without diffidence, to enter the field of the St. David's controversy.

* During the greater part of the time I had the advantage of the assistance and companionship of Mr. J. G. Grenfell, M.A., F.G.S.

2. THE RELATION OF PEBIDIAN TO CAMBRIAN.

a. *General Considerations.*—The Cambrian conglomerate is a deposit of variable thickness, reaching in some places 100 feet. It is composed of rolled fragments, consisting in the main of quartz and quartzite. These are well rounded and sometimes of large size, as big as a man's head or larger.

The underlying beds, where direct contact is observable, belong to the Pebidian series. According to Dr. Hicks they formed shore-lines and were very much in their present mineral condition before any of the Cambrian sediments were deposited. The conglomerate itself is, he says, very largely indeed made up of fragments and finer materials derived from them by denudation, and constantly overlaps different members of the volcanic series, from which it is separated by a systematic unconformity.

Dr. Geikie denies the systematic unconformity, admitting only contemporaneous erosion; he denies that the included pebbles are "almost invariably for the most part" derived from Pebidian rocks, and he denies that they constantly overlap different members of the volcanic series.

Let us, before examining the evidence in detail, consider what we are entitled to expect on the one view and on the other.

On Dr. Hicks's view we should expect to find a more or less well-marked line of demarcation between the Cambrian conglomerate and the upturned and eroded edges of the more ancient strata. We should expect a varying discordance of strike between the unconformable systems. We should expect the included fragments, or at any rate a large proportion of them, to consist of well-rounded pebbles of the volcanic breccias similar to those which are abundant on the present shore-line where Pebidian strata are undergoing denudation.

On Dr. Geikie's view we should expect the conglomerate to lie on a current-swept surface of the volcanic tuffs and breccias which were then still soft. We might even expect a considerable thickness of the volcanic beds to have been in some places swept away by currents capable of rolling onwards such large masses of quartzite. Together with this local contemporaneous erosion we should expect systematic conformity and accordance in the main lines of strike. We should expect some shading of the conglomerate into the underlying volcanic beds at the point of junction and some inwashing of the volcanic beds into the conglomerate. We should expect to find occasionally, among the materials of the conglomerate, subangular fragments of the larger inclusions of the breccias and tuffs over which the current passed.

Such would seem to be legitimate expectations. What are the facts?

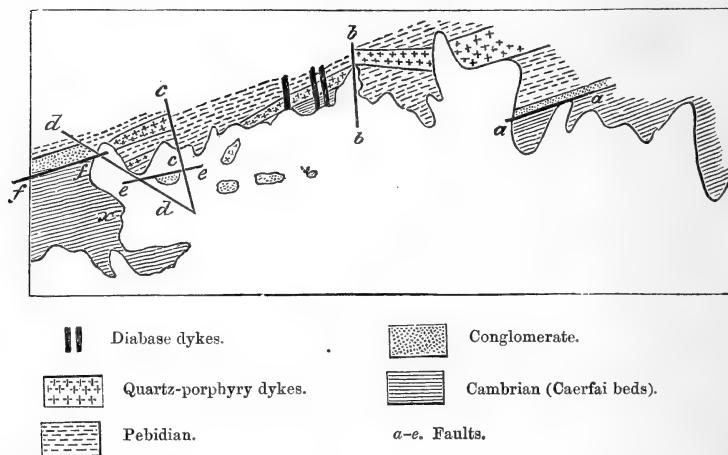
There are four localities where the Pebidian-Cambrian junction may be observed. Two (Caerbwdy Valley and St. Non's Bay) are to the south of St. Davids, two (Ogof Golchfa and Ramsey Sound) to the north. We will consider the stratigraphical evidence in each

of these localities severally and then the evidence afforded by the materials of which the Cambrian conglomerate is composed.

b. *In Caerbwdy Valley*.—This locality is situate about a mile to the south-east of St. David's city. The conglomerate is here seen crossing the valley, striking N. 65° E., and dipping seawards somewhat steeply. It is underlain by a close-grained red felspathic tuff. There is no sharp line of demarcation between the two, and a good deal of evidence that the felspathic tuff is inwashed into the conglomerate. Some three or four feet above the base of the conglomerate, for example, a very similar material occurs*. On the east side of the valley this tuff crosses the road, and associated with it there seems to be a more argillaceous fine-grained tuff of a pink colour. The strike here appears to be the same. Higher up the valley bedded porcellanites are well exposed in a quarry. Their strike can be accurately read; it is the same as that of the conglomerate, N. 65° E.

From Caerbwdy Valley westwards the conglomerate does not afford facilities for observation until we reach St. Non's Bay.

Fig. 1.—Sketch-map of St. Non's Bay. (Scale 1 foot to 1 mile.)

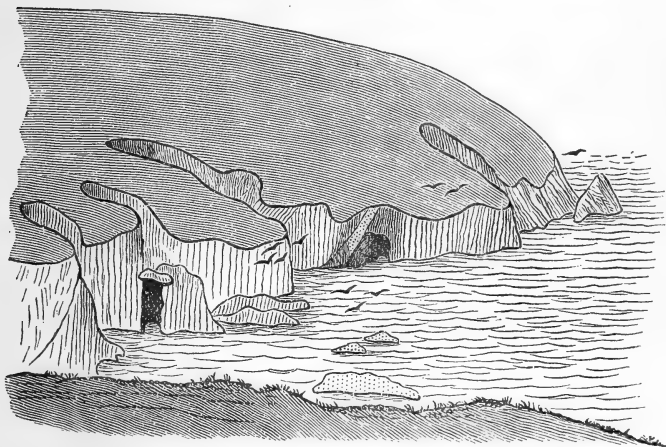






c. *In St. Non's Bay*.—This locality is situate south of St. David's city, about a mile west of Caerbwdy Valley. If we approach the bay from Bryn-y-garn, skirting the field in which St. Non's Chapel stands in ruins, we find ourselves at the head of the most westerly of the series of little creeks shown in the sketch-map, fig. 1. Skirting this and standing at the point marked *x* we obtain the view shown in fig. 2. Along the central line of vision runs the conglomerate, striking N. 75° E., and forming the northern side of an arch (St.

* Although the microscopic character of the rock is obscure, still the microscope only reinforces the macroscopic similarity.

Non's Arch we may call it), figured by both Dr. Hicks and Dr. Geikie. To the left, where four birds are placed, we have Pebidian porcellanites and breccias nearly vertical. To the right, where there are two birds, we have Cambrian greenish flaggy beds, also nearly

Fig. 2.—Sketch from Cliff, St. Non's Bay, looking east.



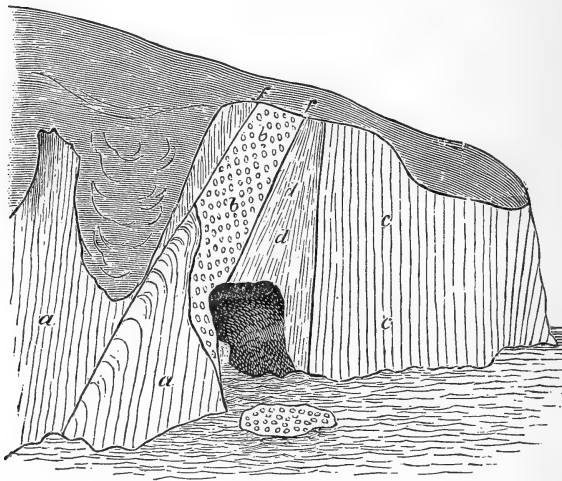
	Caerfai beds of Cambrian with seaward dip.		Cambrian conglomerate.
	Ditto, nearly vertical.		Pebidian.

vertical, but disturbed by faulting. Still further seawards purple Cambrian strata of Dr. Hicks's Caerfai group dip at an angle of about 45° . The strike of the Pebidian porcellanites and that of the green Cambrian sandstones both agree with that of the conglomerate.

Reference to fig. 1 will show that there are several little faults in this bay. To the east over St. Non's arch there are two faults. Both are omitted in Dr. Geikie's figure (*l. c.* p. 287), the more inland of the two by Dr. Hicks (*l. c.* p. 525). These omissions make the figures in each case incorrect. I have therefore redrawn the arch (fig. 3). The two faults are indicated by the single line *a* on the plan, fig. 1. Another fault, *b*, has slightly dislocated the strata in the middle of the bay. Further westward a fault, *c*, running $S. 30^{\circ} E.$, has shifted the line of the conglomerate about 70 feet inland and to the north; while in the next creek, the most westerly of the series which form St. Non's Bay, another fault, *d*, running inland $S. 70^{\circ} E.$, has again shifted the conglomerate inland and northwards about 90 feet. An east and west fault, *e*, has bevelled off the edges of the vertical conglomerate and caused red felspathic Pebidian to lie upon it; while in the western creek a similar fault,

f, probably originally continuous with this and with one of those over the arch, has shifted the conglomerate so as to cause it to rest on the bevelled edges of greenish-brown Cambrian sandstones. These faults are not of any magnitude; but they must be taken into consideration for the understanding of the stratigraphical relations in this bay.

Fig. 3.—*St. Non's Arch*.



aa. Pebidian.

bb. Cambrian conglomerate.

cc. Cambrian, Caerfai beds.

dd. Disturbed Caerfai beds.

ff. Lines of fault.

Matters are also complicated by the intrusion of massive quartz porphyry (+ +) and diabase dykes (firm dark lines). Concerning them, however, I have nothing here to say except that the intrusive nature of the quartz-porphyrines is unquestionable.

Both at the east end and at the west end of the bay the Pebidian-Cambrian junction can be studied.

The little bay to the north-west of *St. Non's Arch* is not difficult of access; a steep grass slope, overshadowed by the face of the porphyry-dyke, bringing one to the foot of the cliffs. Here the porcellanites can be studied in detail and are seen to be fine-grained sedimentary strata altered *in situ*. Fine lines of bedding are beautifully shown on their weathered edges. Between the porcellanite-beds are coarser, greenish, softer beds, which show diagonal cleavage, the cleavage-planes here, as elsewhere, in the district dipping to the N. at about 60°. Bands of brecciated tuff are here and there interstratified.

At low-water spring-tides it is possible to climb round under

the cliff into and through the arch, and the junction of the conglomerate with the underlying Pebidian may without difficulty or danger be followed up the cliff to within about 6 feet of the grass slopes.

The beds immediately beneath the conglomerate very clearly indicate the oncoming of sedimentary conditions, which is also indicated by the porcellanites. There are fine-grained pink and white beds, a red felspathic tuff with numerous rounded grains of quartz, greenish shaly bands, white quartzose beds, and a very close-grained, white, porcellanitic material. Upon the somewhat hollowed surface of these beds lies the conglomerate. There is about 8 or 10 feet transgression of the conglomerate across the Pebidian strata. Near the foot of the cliff, for example, the soft pink and white beds are about 6 feet below the conglomerate. Higher up the cliff the conglomerate rests upon this bed and it is washed in among the pebbles, large stones being well imbedded in this material. I examined this locality very critically and carefully. In my judgment the facts favour Dr. Geikie's view (contemporaneous erosion) rather than that of Dr. Hicks (systematic unconformity).

In the westerly creek at the foot of the cliff, below *a*, the junction of the conglomerate with the underlying Pebidian, here grey with small water-worn pebbles from $\frac{1}{4}$ to $\frac{1}{2}$ an inch long, may be seen. The line of junction is an uneven one, the conglomerate V-ing into the subjacent material. I could see no satisfactory evidence here of a systematic unconformity.

Nor is such evidence afforded by the detached conglomerate masses between this creek and the arch. The underlying beds are similar to the red sandy beds with rolled quartz pebbles found beneath the conglomerate at St. Non's arch, and well seen on the top of the little promontory which the archway pierces.

In St. Non's Bay, then, together with clear and unmistakable signs of local or contemporaneous erosion, I find the general parallelism of the strike most marked. There is no evidence of the bending round of the conglomerate against the strike of the Pebidians drawn by Dr. Hicks in his "Plan of Coast south of Nun's Chapel" (*l. c.* fig. 3, p. 536), while the unconformity shown in his fig. 2 (p. 525) is much exaggerated. The incoming of sedimentary conditions is also noteworthy.

The contact of the conglomerate with Pebidian is again seen further west at Ogof Llesugn; but a description of this locality may be advantageously deferred.

We come now to the junctions seen on the northern side of the axis.

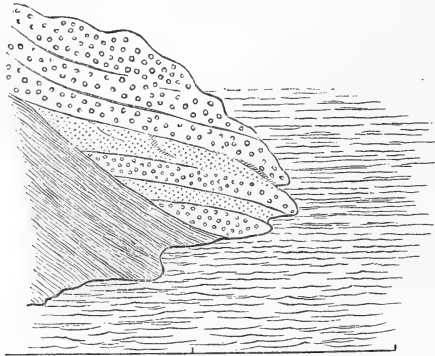
d. *At Ogof Golchfa*.—This locality is a mile and a half north-west of St. David's city, situate at the south end of Whitesand Bay.

Between Porth Sele and Whitesand Bay the conglomerate is well exposed and is here of considerable thickness. Tracing the cliff from Porth Sele northwards we have the flaggy sandstones of the Caerfai series striking N. 15° E. and dipping seawards at about 60°. These extend for two or three hundred yards, when the succession

is broken by a considerable fault, which brings the conglomerate to the shore-line. This fault is entered in Dr. Hicks's map; but I have not seen any evidence for the second fault he draws, making a V with this one. Inland of the fault and on its southern side the conglomerate is well exposed in the field, so that the amount of displacement, 175 yards, can be readily measured. North of the fault the well-developed mass of conglomerate then runs roughly parallel with the shore-line (though it is thrown seawards by one or two minor step-faults), striking N. 35° E., with a dip of from 55° to 45°. At the southern end of Whitesand Bay, at Ogof Golchfa, the underlying Pebidian are exposed for a short distance, when another strongly-marked fault brings in higher beds of the Cambrian series.

Dr. Hicks figures the junction at Ogof Golchfa as if it showed a marked unconformity (*l. c.* p. 543, fig. 15). The figure is, however, misleading. The conglomerate ends off against the Pebidian with a faulted junction, as noted by Mr. Blake. The edges of the conglomerate are truncated wedge-fashion, as shown in the accompanying sketch (fig. 4), taken from the cliff so as to look down on

Fig. 4.—*Faulted junction of Conglomerate and Pebidian at Ogof Golchfa.*



Sketched at high-water from the cliff, looking down in the direction of dip of the conglomerate.

the line of dip of the strata. Near the base of the cliff, however, the slip has taken place in such a manner as to leave some of the red Pebidian adherent to the conglomerate, and here they end off against the conglomerate, making with it an angle of perhaps 5°. A little further north, where the big fault brings in higher beds of the Cambrian succession, some of the conglomerate is in contact with the underlying Pebidian, and appears to be quite conformable with them.

The Pebidian strata at Ogof Golchfa, which are troubled by a basic igneous intrusion, show as clearly as, if not more clearly than, at St. Non's Bay the incoming of sedimentary conditions. They are, indeed, marked on Mr. Blake's plan (Quart. Journ. Geol. Soc. vol. xl. p. 298) as "Cambrian sandstone." They consist of red and purple and green sandy and very close-grained tuffs. In hand-specimens the finer red beds are scarcely if at all distinguishable from the red *Lingula-primeva* beds of the Cambrian of this district. They are, however, remarkably schistose, but *not more so than the finer beds of the conglomerate itself*. I cannot make 5° difference between the strike of the Pebidian strata and that of the overlying conglomerate. Both are N. 35° E. The dip of the conglomerate at the seaward low-tide face is 45° , near the faulted junction it is 55° ; that of the Pebidians is from 60° to 70° , or even somewhat higher.

Here, then, we have, together with some slight signs of local unconformity, a marked parallelism of strike, a continuous change of dip, and a common schistosity. I could find absolutely no evidence of the divergence of no less than 45° between the strike of the conglomerate and that of the Pebidian drawn by Dr. Hicks on his map. The strike of both can be readily observed at Ogof Golchfa, and they are practically identical.

e. *In Ramsey Sound*.—Near Rhoson the conglomerate may be seen in the first field going down to Porth Stinian, to the left of the path. The strike here is N. 45° E. No junction with the Pebidian can be seen, but these strata near the farm and on the flagstaff-hill appear to have the same strike. The Pebidian on Rhoson, moreover, and the conglomerate in the field both have a low dip of from 25° to 35° .

There are several field-exposures of the conglomerate between Rhoson and Maen Bachau, where it emerges on the coast-line. It is in close proximity to the outcrop of basic lava-flows, some of which may have been at or near the surface at the time when it was deposited around them. There is, however, much evidence of faulting, and as no direct junction can be seen, these exposures need not be further described.

The conglomerate is next seen on the coast at Maen Bachau, south of Castell, a spot readily recognizable, since this rock here forms the bridge of a conspicuous natural arch. The under surface of the bridge is a line of slip, the fault-line being indicated by quartz-spar. But the slip has taken place in such a way as to leave some red sandy Pebidian adherent on the northern side to the under surface of the conglomerate. These beds show at this spot some signs of ending off against and being washed in with the conglomerate. Beneath the fault, which makes an angle of about 45° with the vertical, and is probably of no great magnitude, the red Pebidians are seen ending off against the fault-face and resting on an uneven surface of basic igneous rock. Associated with the red beds are dark green tuffs with abundant small, black or, rather, very deep red specks.

To the north of the arch red Cambrian Caerfai beds form the

coast-line, and beneath them are green sandy shales. These are separated from Pebidian by a quartzose fault-line, broken fault-rock lying on the lower rock-surface. The conglomerate is here cut out. The Pebidians show the incoming of sedimentary conditions which is so noteworthy at Ogof Golchfa. The red and green Cambrian beds are invaded by a dyke of basic igneous rock.

In the little creek immediately to the south of the arch the conglomerate, here thick, has been thrown back by a little east and west fault, and rests upon the surface of green Pebidian tuff with the dark specks before mentioned. The beds in this creek are a good deal troubled, and the junction is somewhat obscure. I could, however, find no satisfactory evidence of anything like a systematic unconformity.

The included fragments in the conglomerate are here remarkable, as will be presently noticed.

In the next creek southward there must be more faulting; for the green sandy Cambrians are seen striking at the conglomerate.

The following creek shows the green sandstones (striking N. 25° E. and dipping about 40° seawards) overlying the conglomerate.

In the next creek there occurs a considerable fault. The northern cliff-face is conglomerate, against which the silky schistose Pebidians with associated porcellanites strike about N. 45° E. It is not difficult to clamber down here. At the base of the conglomerate is a cave (Ogof Gôch) following the line of the fault, which runs S. 70° W. The Pebidian in contact with the conglomerate is at first sight a dirty dark-green basic-looking rock. When polished, however, it is seen to be a rich green with lighter veins. I prepared a specimen for microscopic examination. The following is Mr. Grenville Cole's description of the slide:—"A rock probably composed of ferruginous clayey particles, with lava chips and tuff-fragments, washed into it. The sedimentary part—the clays—seem reduced chemically, and the iron separated, probably as magnetite dust. The whole has undergone squeezing." Although it is probable that the rock has undergone alteration, it is obviously very different from the silky beds and porcellanites on the other side of the displacement. But in the cave and so close to the fault the relations of Pebidian to Cambrian at the junction cannot be readily observed.

So far as I can ascertain, it is to this spot that Dr. Hicks's fig. 14 (*l. c.* p. 542) purports to have reference. I could find nothing here or elsewhere on this coast-line in any way resembling it. The Ogof Gôch fault, the effects of which are well marked here and inland, is not noticed by either Dr. Hicks or Dr. Geikie.

Pebidian strata form the coast-line for about half a mile beyond Ogof Gôch until we reach Carn-ar-wig, where another well-marked fault occurs. On the south-western point beyond this bay the last exposures of the conglomerate occur*. Speaking of this locality Professor Blake says:—"Though there is no fault here, all the rocks being laid quite bare, no better proof could be desired, derived

* These exposures are not mentioned by Dr. Hicks or marked on his map.

from one spot, of the perfect independence of the conglomerate and the volcanic series, and in particular the silvery schists." I approached this locality, therefore, in the full hope of finding satisfactory evidence in favour of one theory or the other.

The first (north-easterly) exposure of the conglomerate shows this bed resting upon the surface of a lava. Mr. Grenville Cole kindly examined my sections * of rocks from this locality, and the words placed within inverted commas in the following descriptions are from the notes he kindly sent me. Of this rock he says that it is an "Andesite lava, with veins of chloritic decomposition. The flow may result from squeeze, but was probably original when the rock was brown and glassy." There are certainly no marked signs of independence here. The appearance is as if the conglomerate were deposited in the somewhat concave surface of the lava.

This is, however, not the only exposure of the conglomerate. Further to the south-west there is the clearest and most unmistakable evidence of the interstratification of the conglomerate with Pebidian volcanic beds. In the most westerly exposure there is fair, but not perhaps convincing evidence that the conglomerate is succeeded by volcanic beds four or five feet thick, and these, again, by conglomerate overlain by fine tuff. The details here are, however, difficult of mastery and of description. But a little to the east of this the relations are more readily decipherable. Beneath the conglomerate is tuff or broken-up lava. In the midst of the conglomerate is a thin band of ashy tuff which, under the influence of squeeze, has a somewhat fluidal appearance. Above the conglomerate are ashy tuffs and perhaps lavas. Pebbles of quartzite are found in the ashy tuffs adjoining the conglomerate. The two so shade into one another that it is oftentimes difficult to tell where one begins and the other ends. The tonguing-in of one series with the other is complete. One seems to be in presence of an island or shoal in the sea in which the Pebidian volcanic series were accumulating. In the hollows on the surface of the lavas and tuffs tongues of conglomerate were formed by the currents that bore onwards the quartzose materials. Then followed other volcanic outpourings by which the conglomerate tongues were buried.

Above and inland of these exposures is a highly vesicular amygdaloidal rock (in which a quarry has been opened). This Mr. Cole describes as a "soda-trachyte or highly silicated andesite, with tendency to spherulitic and granophyric structure." It may be a lava, but is more probably a dyke—perhaps a volcanic dyke of contemporaneous origin.

I carefully considered on the spot two possibilities—(1) that the lavas and supposed ashy beds were dyke-material of long subsequent date which had enveloped the conglomerate. (2) That the ashy beds and supposed lavas were remade materials consequent on the denudation of neighbouring Pebidian beds on Dr. Hicks's hypothesis. The field-evidence and the microscopic evidence negative both

* Prepared by Mr. Thomas Ryley.

suppositions. I am therefore forced to conclude that Pebidian and Cambrian here interdigitate.

f. *The Materials of the Conglomerate.*—"The pebbles" [of the conglomerate] says Dr. Hicks, "almost invariably for the most part consist of the rocks upon which they lie, and when examined they tell distinctly that the underlying Pebidian rocks, after they were elevated, when these fragments were broken off, and before they were again depressed, were not only consolidated but nearly as highly metamorphosed as they are found to be at present." (Q. J. G. S. xxxiv. p. 162.) On the other hand, Dr. Geikie says (*l. c.* p. 288), "Of the component pebbles not less than about 95 per cent. are of quartzite or quartz." And, as the results of the examination of microscopic slides, Mr. T. Davies says (Q. J. G. S. xl. p. 556), "The contents of the Cambrian conglomerates of St. David's, found in the sections examined are:—quartz, both dirty and clear, small pebbles consisting of dirty quartz with two feldspars, individual feldspars both orthoclase and plagioclase, felsite, quartz-felsite, quartz-schists, quartzite, basic rocks, porcellanite, and mica much altered."

Now there can be no question that a preponderating number, I may say a very largely preponderating number, of the pebbles are composed of materials from a foreign source, and for the most part of quartz and quartzite. But there are, especially in some localities, other included fragments. These are particularly conspicuous at the Arch, near Maen Bachau, south of Castell. A goodly number of these may be fairly matched with undoubted Pebidian. This at first impressed me strongly in favour of Dr. Hicks's contention. But when I came to study the Pebidian beds more carefully and in greater detail, I found the fragments imbedded in the tuffs and agglomerates so numerous, in some cases so large, and so closely resembling the fragments included in the conglomerate that it seemed to me that the evidence afforded by them was by no means so clear as I had at first supposed.

These Pebidian fragments, if such they be, enclosed in the conglomerate on Ramsey Sound, are remarkable in that they are for the most part much softer than the more numerous quartzite- and quartz-pebbles, and that they are less well rounded. In some cases they form long flat subangular slabs, in others somewhat lenticular masses ending in fine points; occasionally they seem to be indented by the harder and rounder pebbles. Clearly they have not been brought from a great distance. Clearly they have not been rounded by long-continued wave-action.

During a second visit to St. David's for purposes of verification, I paid especial attention to the question of included fragments, both in the Pebidian and in the Cambrian conglomerate. In the former there are a considerable number of fragments, from whatever source they may have been derived, of a horny porcellanitic rock. Most of these are small, though fragments from half an inch to an inch in length are not unfrequent. Fragments of porcellanitic rock in the conglomerate may therefore be from this source. I was again struck with the number and variety of the fragments of

older tuff and more sedimentary-looking material in the upper beds of the Pebidian series.

Turning to the conglomerate, it appears that the fragments of Pebidian aspect differ from those contained as inclusions in the Pebidian tuffs chiefly in their larger size. I paid a good deal of attention to the Pebidian pebbles on the modern beach in the neighbourhood of cliffs of this age, and was forcibly impressed by the fact that no pebbles of similar form, structure, and aspect occurred, so far as I was able to observe, in the conglomerate.

I have no desire to underestimate the value of the evidence of these abnormal inclusions in the conglomerate. I hold no brief for either party in this controversy. My sole desire was to reach, if I might, the truth concerning the relation of Pebidian to Cambrian. The evidence of these fragments seemed at first to contradict the stratigraphical evidence. But further study tended to show that this contradiction might be apparent only, and that the Pebidian fragments might well be derived from inclusions in the tuffs washed out of these deposits by the current which bore onward the more numerous foreign materials of the conglomerate.

g. *Summary of the Evidence.*—The evidence as to the relation of Pebidian to Cambrian at St. Davids is, in my opinion, not such as to enable one to lay down the law with ease and precision. It is such that two geologists who were at one concerning the facts observed might nevertheless differ as to the exact position and value in the stratigraphical scheme to be assigned to the Pebidian series. On the one hand we have in the Cambrian conglomerate an apparently satisfactory base to a natural system of stratified deposits; we have in that deposit fragments derived from the underlying strata; we have evidence of some transgression of the conglomerate across the edges of the subjacent beds. On the other hand we have a marked parallelism of strike and a general uniformity of dip in the beds of both Pebidian and Cambrian; the included Pebidian fragments are such as might have been washed out of Pebidian tuffs; and the transgression across the subjacent beds is nowhere more than one has a right to expect where a current-borne material, such as a coarse conglomerate, follows upon soft beds of recent formation. It is remarkable that both to the south of the St. David's axis and to the north, where in each case the parallelism of strike is so marked that I could nowhere make 5° of difference, we have evidence of the incoming of sedimentary conditions in the Pebidian similar to those which are indicated by the Cambrian beds that succeed the conglomerate. And it is noteworthy that in those overlying Cambrians we have evidence of the continuance of volcanic conditions which characterize the Pebidian. Moreover, at Carn-ar-wig we seem to have satisfactory evidence of the interdigitation of Cambrian conglomerate and Pebidian ashes. Taking all the facts into consideration, I am led to the conclusion that the break between the two systems was not of any great magnitude, and that the change of conditions emphasized by the conglomerate was one which followed, after no great lapse of time,

on the volcanic condition of the Pebidian, the uppermost Pebidian beds already foreshadowing the sedimentary conditions of the Caerfai beds.

And here I think it well to draw attention to the amount of break for which Dr. Hicks contends. According to Dr. Hicks the Pebidians were (1) deposited as a volcanic series, (2) upheaved into dry land, and also (3) metamorphosed to very much their present condition before (4) they were denuded to form coast-lines of an Archæan land, which (5) once more sank beneath the sea and (6) were overlain unconformably by the beach-deposit of the Cambrian conglomerate. Such is Dr. Hicks's contention. But it is right to add that at times he writes as if he held a very different view. For example, in his answer to Dr. Geikie (*Q. J. G. S.* xl. p. 536), he says:—"Whether the volcanic fires had completely expended themselves or not before the conglomerates were deposited may be an interesting point; but it is virtually of no importance in regard to the questions at issue." On reading this I thought I must have misunderstood Dr. Hicks's previous statements. But no! They are quite clear. So also is the testimony of his map. And I therefore am in some doubt as to which statement represents Dr. Hicks's present view. Taking, however, the former, so distinctly formulated and reiterated, I must distinctly state that I could find no evidence to justify it. Coming to St. Davids fresh from a study of the beach-conditions of the Basement Beds of the Trias in the Bristol district, I was impressed with the very different nature of the break between Pebidian and Cambrian in Pembrokeshire.

The relation of Pebidian to Cambrian is therefore, in my opinion, that of a volcanic series, for the most part submarine, to the succeeding sedimentary strata which are introduced by a conglomerate formed in the main of foreign pebbles borne onward by a current which swept the surface of, and eroded hollows and channels in, the volcanic tuffs and other deposits.

The last question which arises on this head is whether we should, as Dr. Geikie proposes, abandon altogether the term Pebidian; and, further, if we retain it, what value we should assign to it. I think that to abandon it would be a distinct injustice to Dr. Hicks, who, notwithstanding manuscript evidence of Sir Andrew Ramsay's views, was the first to draw the attention of geologists to this interesting volcanic series, and to place on record a great number of valuable facts concerning it. The name Pebidian should therefore, in my judgment, be retained for the volcanic series of St. Davids.

What value shall we assign to it? On this there will doubtless be difference of opinion. For my own part I am clear that it should not be removed from the Palæozoic, that it cannot be regarded as Archæan. There remains the question:—Is it to be regarded as coordinate with Cambrian, Ordovician, Silurian, or coordinate with Harlech and Menevian within the limits of the Cambrian? I incline to the latter view. I am disposed to regard it as a volcanic series at the base of, but not beneath, the Cambrian system. But I should have no great quarrel with those who hold the other view.

3. THE PEBIDIAN SUCCESSION.

a. *The Results of previous Investigations.*—In his earlier paper (Q. J. G. S. xxiv. p. 15) Dr. Hicks divides the Pebidians into eleven groups. Subsequently (Q. J. G. S. xl. plate xxiv.) he maps five groups:—

- e. Purple and green schistose breccias.
- d. Diabase breccias and sheets.
- c. Quartz-felsite breccias and sheets.
- b. Felsite tuffs &c.
- a. Agglomerates, breccias, and porcellanites.

These are mapped in parallel bands, little disturbed by faults except where they adjoin the Dimetian and Arvonian axis. In describing the area to the north of the axis, Dr. Hicks says:—“Here, again, the evidence of a regularly ascending succession in the Pebidian, but broken by a few faults, is perfectly clear, and there is no indication of an isocline. The beds dip regularly in one direction at a high angle, and the alternations are well marked and easily traced.” (Q. J. G. S. xl. p. 544.)

Dr. Geikie divides the series provisionally into four groups:—

- 4. Fine tuffs and silky schists.
- 3. Diabase sheets with intruded quartz-porphry and hardened tuffs.
- 2. Compact green granular tuff.
- 1. Thick purplish-red, green-flecked tuff, with abundant small lapilli of felsite.

These beds, according to Dr. Geikie, are isoclinally folded, the axis of the isocline cutting the coast-line between Pen-maen-melyn and Pen-y-foel.

Professor Blake found only a glorious confusion, which enchanted him.

b. *General Results of the Author's Survey.*—Although the time at my disposal did not permit of anything like an exhaustive resurvey of the district, yet I was able to lay down on the six-inch survey map the evidence afforded by all the important inland exposures and that presented by the long coast-section. The main facts are indicated in the accompanying sketch maps on the six-inch scale (Plate X.), in which direct observations alone, and such inferences as are inevitable therefrom, are included. A short description of certain special features is also given in the pages which follow. Here I will describe the main results which I have obtained.

There can be no question that with the exception of some cinder-beds to the west which appear to be subaerial, the whole series was accumulated under water, many of the beds containing quartzose and other sedimentary material. The tuffs vary in colour from dark green, or dark green and red, through lighter shades to light green, light pink, and white. The former are decidedly basic, the latter acidic in appearance. Sometimes, as may be well seen in the Allan Valley, east of the cathedral, differing bands alternate somewhat rapidly. The lighter more acidic beds contain great numbers of often large felsitic and felspathic fragments. In the more basic

red and green tuffs there are many fragments of a red fluidal quartz-andesite. These fragments are sometimes of large size. One which I measured was four and a half feet in length. They also contain bombs of basic lava, some of which also are of large size, a yard or more in diameter.

In addition to these fragmental rocks there are contemporaneous sheets and intrusive masses of basic igneous rock, the olivine-dia-base of Dr. Geikie, dykes and sheets of felsite or quartz-porphry, andesite or trachyte, and perhaps sheets of quartz-andesite.

Concerning the subdivision of the series I do not think that the facts to be presently brought forward justify us in making any definite subdivisions or in going further than stating generally that the series consists of alternating beds of tuff of varying colour and basicity, but with prevailing tints of dark green, red and green, and light sea-green. In the upper beds the tuffs of different character alternate more rapidly, there are more rounded pebbles, and a larger and increasing amount of sedimentary material, together with porcellanite bands. Basic lava-flows occur for the most part in the upper beds of the series. I was quite unable to verify Dr. Hicks's five groups. Indeed their existence is negated by the folding of the district to be now described.

Great care, much detailed work, and not a little climbing are required to obtain anything like satisfactory evidence of dip and strike in these Pebidian rocks. Moreover a persistent shearage of the rocks along planes dipping at about 60° to the N.W., giving sometimes the appearance of a true dip, is often very troublesome. Careful observation of the rock-exposures foot by foot will, however, disclose the occasional interstratification of finer and coarser material or the alternation of tuffs of different colour, and will thus enable one to obtain reliable data for determining the nature of the folding which the beds have undergone.

Detailed work between the headlands of Pen-dal-aderyn and Pen-y-foel thus brings to light the fact that there is, in place of the continuous sequence advocated by Dr. Hicks, or the isoclinal fold suggested by Dr. Geikie, a well-marked syncline, the beds on the southern side of which are, however, repeated by small faults. The syncline is perhaps tilted inland, so as to form the lip or spout of an elongated basin.

Further inland there is again good evidence for the existence of this syncline, satisfactory southerly dips of the northern limb being observed on the prominent craggy exposure south-west of Treginnis Isaf farm. And I think it not improbable that the low-lying swampy ground between Trefeithan and Clegyr Foia marks the continuation of the same synclinal fold*.

North-west of this central syncline runs an anticlinal fold. The

* All along the south-east side of Trefeithan, near its base, the red and green "diabase" tuffs which underlie the igneous sheets are well exposed, and are found to be lying nearly horizontally, the dip being N.W. (about 10°) in one exposure and S.E. (about 5°) in another exposure at the south-eastern end of the hill. This looks as if we were near the somewhat flattened summit of the northern anticline, and that between Trefeithan and Clegyr Foia there runs a

evidence for this on the western coast is not satisfactory, but its existence is unquestionable. It would seem to flatten in the neighbourhood of Rhoson and Trefeithan.

South-east of the central syncline runs another anticlinal fold. Below Treginnis Mill the evidence of the normal anticline is satisfactory, the seaward dip of about 50° being readily observable even from a distance. Tracing the beds eastwards along the coast, the dip becomes higher, up to 85° , seawards, and then passes over to a landward (reversed) dip of 75° – 65° . The normal anticline passes into an isocline. The northerly dips in Porthlisky Bay are reversed dips.

The diagrammatic section (fig. 5) shows the structure of the western portion of the St. David's promontory as I read it.

The thickness of the Pebidian volcanic series exposed in the district, I estimate at about from 1200 to 1500 feet—a modest figure compared with the 8000 feet claimed by Dr. Hicks.

c. *Further Details.*—There are one or two points on which further details may be desirable.

(a) *The Fault at Ogof Gôch.*—A well-marked fault here brings basic beds against the more acidic schistose strata of Ogofau-Dduon (the Ogfeydd-duon of previous writers. I have adopted the spelling of the 6-inch survey map). Dr. Hicks is perfectly right in contending that these Ogofau-Dduon beds do not, as suggested by Dr. Geikie, immediately overlie the more basic beds; but by failing to take note of the Ogof-Gôch fault he erroneously made the conglomerate rest immediately and unconformably upon these beds. The fault is not only, as previously noted, perfectly obvious on the coast-line, but further inland it divides the more acidic crags of Carn Gwil and Carn Geli Fach from a triplet of basic crags of which Carn Côch is the most prominent.

(β) *The Porphyry Crags of Treginnis.*—The strongly marked rock-exposures of which Carn Gwil Geli is the most easterly

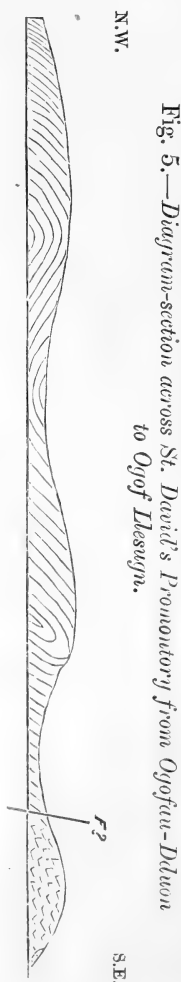


Fig. 5.—Diagram-section across St. David's Promontory from Ogofau-Dduon to Ogof Ileswyn.

perhaps faulted syncline. It may be, however, that the syncline has flattened out; that, as Dr. Geikie suggests, the Clegyr Foia sheets lie on the southern side of an isocline; and that the northerly dips there observable are reversed. I could not determine this point with certainty. But I lean to the view that the folding here is synclinal.

are described by Dr. Geikie as the "prominent and massive porphyry crags of Treginnis." That there is porphyry* I am not prepared to deny; but the main bulk of the crags is fragmental—a sea-green highly acidic andesite-tuff with quartz-porphyry inclusions of fair size and in great numbers. Some "adinole" concretions occur here; and, commenting on one of my slides, Mr. Cole asks "Has this rock been saturated (? with silica) so as to become so 'felsitic' and uniform in texture?" The beds apparently dip northwards at 60°. But I was led to look with much suspicion at a northerly dip of about this angle, since I frequently found it to be illusory and the result of shearage.

(γ) *The Red Quartz-Andesite*.—At Rhoson and Trefeithan, on the north side of Porthlisky Bay, at Pen Pedol and elsewhere, there are in the "diabase"-tuffs large fragments of a red fluidal quartz-andesite. They are for the most part angular. Near the landing-stage at Carn-ar-wig there is a band or bed of similar lavaform rock; and at Ogof Geifr a bed closely resembling it may be found. Mr. Grenville Cole, to whom I submitted it, calls it "a beautiful fluidal quartz-andesite (being ancient, a 'porphyrite' of German authors). It reminds me of one at Elfdalen, Sweden, and many in the Permian 'Bozen porphyries.'"

(δ) *Volcanic Bombs*.—The occurrence of large volcanic bombs in rocks of such high antiquity is worthy of notice. Such a "diabase" bomb, 3½ feet in diameter, may be seen in the tuff at the seaward foot of the craggy boss just inland of Ogof Cadno. Others may be found along this coast-line. They are rounded, vesicular, and often radially fissured.

(ε) *Pen-dal-aderyn and Pen-y-foel*.—I am inclined to regard the "diabase" masses at these two points as intrusive, but unquestionably of Pebidian age. They may almost be looked upon as volcanic necks. It may be that the extrusion of lava through them has produced the remarkable confusion in the neighbouring tuffs. Near both these points, too, the relations of the more basic and more acidic tuffs indicate local contemporaneous erosion.

North of Pen-y-foel, towards Porthlisky Bay, there is another great mass of "diabase" with well-marked trappean steps leading down to the sea-level. This may be a massive lava-flow; but I am more inclined to regard it also as an intrusive contemporaneous neck. The same may be said of the exposure to the south of Porthenhlllys Cottage.

d. *Faults and their Effects*.—The long stretch of coast-line between Ogof Golchfa on the north and Porthlisky bay on the south affords every facility for studying the faulting of the district. In the maps appended to this paper (Plate X.) I have entered all the faults of which there seems to me to be satisfactory evidence. The only displacement of any considerable magnitude is that which takes

* Dr. Geikie, with great courtesy and kindness, allowed me to examine about 20 of his St. Davids slides, and among others one of the quartz-porphyry from these crags.

place north of Ogof Golchfa, by which Menevian beds, as determined by Dr. Hicks, are brought down so as nearly or quite to abut on Pebidian. The other faults, though their effects are sometimes well marked, as at the Ogof Gôch, Carn-ar-wig, and north of Porth Sele, are of no great magnitude or importance. A glance at the map will show that the Caerfai beds (*e. g.* to the west of Porth Sele, and in the neighbourhood of Castell) are affected by faulting to as great an extent as the Pebidians which underlie them. In fact I failed to find any evidence of faulting special to the Pebidian, as opposed to the other Cambrian strata.

e. The Cambrian Overlap.—I have before stated that neither in Caerbwdy valley, in St. Non's Bay, nor at Ogof Golchfa, did I find satisfactory evidence for the overlap marked on Dr. Hicks's maps and plans. There is such erosion as is inevitable from the nature of the conditions under which the conglomerate was formed. More than this I failed to see.

Dr. Hicks, however, contends that between Rhoson and the exposure of the conglomerate on the coast-line beyond Porth Sele, "the facts prove that in this mile of country a quarter of a mile in thickness of nearly vertical Pebidian strata has been overlapped by the conglomerates."

The facts are these. Near Maen Bachau, south of Castell, the conglomerate is seen on the coast-line. Then it is occasionally seen in the faulted ground between this locality and Rhoson, where it is seen striking N.E. with a low dip. The underlying Pebidians at Rhoson are not "nearly vertical," but have also a low dip and a strike similar to that of the conglomerate. There is, then, no exposure of the conglomerate till it is seen in the field inland and to the east of Porth Sele, where its strike is N. 15° E. Here it has been displaced 175 yards by the fault before alluded to, on the north side of which it occupies the coast-line, with a strike N. 35° E. The faults between Maen Bachau and Rhoson and this fault are step-faults constantly throwing the beds to the N.E. The probabilities are that it is by step-faults between Rhoson and Porth Sele, and not by overlap, that the displacement of the conglomerate has been effected, and this view is borne out by the evidence of faulting west of Porth Sele and near Porth Stinian (see map). In any case it is incorrect (1) to speak of nearly vertical Pebidian, and (2) to neglect the probable effects of faulting.

But it may be said that the evidence of overlap is not merely a matter of the strike of the beds, it is the fact that the conglomerate is found resting upon different beds of the Pebidian series. Here again Dr. Hicks's map is misleading. Through missing the fault at Ogof Gôch he makes the conglomerate rest upon his C group of quartz-felsite breccia and sheets. It does not do so. It is faulted against them. Even if this piece of evidence be eliminated, however, we have the unquestionable fact that at Ogof Golchfa the conglomerate is resting upon schistose sedimentary-looking beds, at Maen Bachau it is in close proximity to "diabase" lava-flows, and at

Carn-ar-wig point it interdigitates with more acidic lavas and ashes.

I have no wish to undervalue these facts. They are, indeed, just such as I should expect upon the hypothesis that I adopt. I have already mentioned the great cinder-beds in the western part of the district which seemed to point to subaerial accumulation; I have also drawn attention to the tonguing-in of the conglomerate with the volcanic beds at Carn-ar-wig. These facts seem to point to subaerial conditions and shoals to the west. I think the facts point to deeper water and more sedimentary conditions to the east and south-east. But I believe that both near Pen-dal-aderyn and near Pen-y-foel there is evidence of local erosion, within the volcanic series, due to the fact that the tuffs were brought to or near the surface, and thus suffered some abrasion from waves and currents. And then, at the close of Pebidian times and the ushering in of the Harlechs, the powerful current which bore onwards the materials of the conglomerate could not fail to sweep away much of the superficial soft tuff in the shallows and shoals of the Pebidian sea. Its effect would be less marked in the deeper water to the east and south-east.

Let us try to realize the conditions. Volcanic tuffs are being formed around several, perhaps many, small volcanic centres, for it is probable that Cambrian volcanic efforts did not concentrate themselves on one focus. The volcanic centres are submarine, or perhaps form islands. As in the case of Graham's Island, they may have given rise to islands which were soon washed away by the waves, the materials being scattered around as tuffs, commingled perhaps with some sedimentary materials. Then as the volcanic fires are dying out (Carn-ar-wig tells us they are not quite dead), there comes a powerful current sweeping over the tuffs and bearing onwards rolled quartz- and quartzite-pebbles of altogether foreign origin. Whence came the pebbles, how was produced the current, who can say? There is the evidence of it in the conglomerate, which is no beach-deposit or anything like it. Now if this be anything like a true story of the sequence of events, and it seems to me the only view which fits the facts, is it to be expected that the conglomerate everywhere should lie upon the same volcanic beds? Would it not be in the highest degree surprising should it be found to do so? Is it not more probable that here in deeper water it should rest upon more sedimentary tuffs (Ogof Golchfa); there, in shallower water, it should be in close proximity to lava reefs (Maen Bachau); and elsewhere (Carn-ar-wig) it should tongue in with the later splutterings of the volcanic period? So it seems to me; and thus I would account for the apparent overlap of the conglomerate on the Pebidian beds.

f. *The "Felsitic" Dykes.*—Cutting through the Pebidian strata and well exposed at many points along the coast-line are igneous dykes. These are of two types, the one basic the other acidic.

Some of the basic dykes are seen in close proximity to or actually connected with the basic intrusions of Pen-y-foel and the neighbour-

ing coast-line to the east. They may be regarded as definitely connected with the volcanic series. Others, however, are of far more recent origin and are found cutting alike through Dimetian, Pebidian, and the overlying Cambrian sedimentary beds. Fine examples may be seen in the Dimetian in the Porthlisky promontory, in the Pebidian at St. Non's Bay, and in the Cambrian sedimentaries at Porth-y-rhaw.

The acidic dykes are the quartz-porphyrries of Dr. Geikie and the felsites of other authors. Some of these in the Church-school and Board-school quarries, for example, and in St. Non's Bay, are familiar to all who know the literature of St. David's geology. But there are other examples in many places along the Pebidian coast-section. One of these is mentioned by Dr. Geikie as occurring near Pen-y-foel. It is readily seen as one stands on this headland and looks westwards across the Ogof Mrs. Morgan inlet. Near the sea-line there are two converging limbs which appear to meet above to form a common mass. Between the limbs a triangular mass of tuff (basic) is enclosed, and similar tuff is seen on either side. I have had half a dozen slices cut from various parts of this dyke for microscopic determination. Mr. Grenville Cole has kindly afforded me much valuable assistance in this examination.

The rock is granophyric in structure, with abundant spherulitic aggregates in which the radial structure is well seen. Good porphyritic felspars occur, which Mr. Cole is inclined to regard as oligoclase. The banded structure along the edge of the dyke is beautifully seen some 20 or 30 feet above the water's edge, and in one part waving flow-lines are very noticeable on the weathered surface. Vesicular and amygdaloidal structure is well marked in parts. The vesicles are large, elongated, and oval, with their long axes parallel. This led me to suspect that the dyke was rather volcanic than plutonic in origin. For in plutonic dykes the vesicles are generally rounded and small. In one of my slides the rock shows much brecciation, which may, as Mr. Cole suggests, contain fragments from the adjacent tuffs or may have resulted from dragging and flow along the contact plane.

In the notes with which Mr. Cole was good enough to furnish me he describes the dyke in general as "a good granophyric rock like the wall of Cader Idris and many other British examples. The analysis ought to give some 70% of silica, and soda as the dominant alkali,—a quartz-andesite, or perhaps more nearly an oligoclase-trachyte had it erupted as a lava. It might well be an offshoot of a soda-granite or quartz-diorite."

I subjoin an analysis of this rock (I.), together with an analysis of the acidic tuffs (II.) of Pen-y-foel hard by for comparison. They are kindly furnished me by Mr. Cecil Gibbins, who carried out the analyses in the chemical laboratory of the University College, Bristol. I have added in the third column (III.) an analysis of Dimetian, quoted from Dr. Persifor Frazer by Dr. Hicks.

	I.	II.	III.
Ignition	1·69	1·31	1·38
SiO ₂	72·30	74·09	75·48
Al ₂ O ₃	12·09	14·98	9·60
Fe ₂ O ₃ }	2·16	1·80	{ 1·73
FeO } . . . . .				{ 4·26
CaO	trace.	trace.	·98
MgO	2·02	1·50	1·32
K ₂ O	4·80	1·27	·56
Na ₂ O	3·41	6·07	5·09
FeS ₂	·90		
	99·37	101·02	100·40

Allusion has already been made to the very vesicular rock at Carn-ar-wig. It is remarkably lavaform, but is more probably part of a dyke. Two strong beds of soda-trachyte or highly silicated andesite interstratified with the Pebidian may be lava, but perhaps it is best to regard them as sills. Still I should not be surprised if true lavas of similar character* to the dyke-material were to be proved at this spot. In any case I wish to suggest the possibility that the acidic dykes, such as those at Pen-y-foel, Carn-ar-wig, and others at Ogofau-Dduon, Pen-maen-melyn, Porth Taflod, Ogof Cadno, to the north-west of Porthlisky, and at Trefeithan, may be volcanic dykes intruded during the last phase of Pebidian volcanic activity. How far this view (merely advanced as a suggestion) would apply to the much larger dykes near the St. David's schools and in St. Non's Bay I am not at present prepared to say. There is no doubt, however, that all these dykes have the granophyric or spherulitic structure in common.

g. *The Porcellanites*.—That these beds have undergone alteration since their original deposition there can be no doubt. But whether this is due to the influence of the quartz-porphry dykes, as suggested by Dr. Geikie, is, I think, open to question. They are seen in Caerbwdy valley, in St. Non's Bay, and to a less extent at Ogofau-Dduon; while a porcellanitic bed is found in the Allan valley near the boundary-wall beyond the vicarage. In Non's Bay the weathered surface gives indication of the originally very fine sedimentary nature of at any rate some of the bands. Sometimes the beds are porcellanized in fine bands interleaved with softer scarcely altered material. In the Allan valley it is a tuff-like bed with largish included fragments which has been porcellanized.

Dr. Geikie has drawn attention to the concretionary masses (the so-called adinole) in St. Non's Bay; but Dr. Hicks regards them as included fragments. "That they are true fragments," he says (p. 548), "of some pre-existing rocks, and not concretions, is clear beyond dispute from microscopical and chemical evidence." I am surprised, however, that any one studying them on the spot in St. Non's Bay could doubt their concretionary character. Both the

* The undoubted lavas seem to be somewhat more basic in composition.

porcellanite bands and these adinole masses remind one of the occurrence of flint, or still more of chert in some of the older limestones. That they are all products of some mode of the segregation of silica is suggested by their appearance and mode of occurrence. But the microcrystalline structure of the matrix is no doubt puzzling on this view. It is probable that a fuller microscopical study of these rocks in different stages of porcellanization would yield results of considerable, and not merely local interest.

4. THE RELATION OF PEBIDIAN TO DIMETIAN.

a. *Dr. Hicks's Arvonian.*—It is right that I should here state why I omit any consideration of the relation of Pebidian to Arvonian. The reason is that I have been unable to satisfy myself of the existence of a separate and distinct Arvonian system in the area within which I restricted my observations. I do not deny the existence of such a system. But I saw no satisfactory evidence of it in the immediate neighbourhood of St. Davids.

b. *The Dimetian Question.*—Between the City of St. Davids and the Crow and Bishop Islands, off Porthlisky Point, there occurs a granitoid rock, well exposed at Bryn-y-garn and elsewhere. The question at issue concerning this rock is, whether, in relation to Pebidian, it is a subsequent granite-intrusion or a pre-existent Archæan formation. There are three kinds of evidence bearing on the question :—(1) that derived from the lithological character of the rock, (2) that based on the petrological and stratigraphical relationship with the surrounding rocks, and (3) that afforded by the presence or absence of Dimetian fragments or pebbles in overlying deposits.

Concerning the first point, the lithological character of the rock, I have no new facts to communicate. Had I been ignorant of the controversy on the subject, I should unhesitatingly have pronounced it a granite or an intrusive rock allied thereto. But since others of far greater knowledge and experience than myself have held and hold a different view, I do not presume to suppose that any opinion of mine will carry weight.

On the petrological and stratigraphical evidence I may be allowed to offer a few remarks.

c. *In Porthlisky Bay.*—In this locality there is no very satisfactory evidence of either faulting or intrusion. As before noticed, however, the strata in this bay have been much altered in some way, and if the Dimetian be intrusive, one naturally surmises that it may have a (possibly indirect) connexion with this alteration. It is therefore worth noting that the Cambrian conglomerate and overlying beds show a somewhat similar alteration in Porth Melyn, west of St. Non's Bay, and here the Dimetian is close at hand. Still, though this is naturally suggested if the Dimetian be otherwise proved to be granite, I do not think that by itself it can be taken as satisfactory evidence of intrusion.

The fault-line, if it exist, is obscured. I found, however, un-

doubted Dimetian some distance to the left of the fault-line as drawn by Dr. Hicks in his figure (Q. J. G. S. xl. fig. 13, p. 540).

d. *In the Allan Valley at Porth Clais.*—I have no new facts to bring forward with regard to this locality. I could find nothing to convince me of the intrusive nature of the granite in any of the sections exposed. I am not altogether satisfied with Dr. Geikie's mapping of the locality (Q. J. G. S. xxxix. pl. viii.). There has certainly been some faulting; but there is no sufficient evidence of the faulted patchwork shown in figure 5 of Dr. Hicks's paper (p. 532). Such a map, apart from its demonstrable errors (*e. g.* the anticline in the south-west corner, also shown in fig. 5, which has absolutely no existence in nature), is worthless as a guide on the spot, and misleading to the student in the study. I spent some time in endeavouring to map this locality on the hypothesis of a faulted junction between Dimetian and Cambrian. My complete failure may be due in part to the want of sufficient data; but it led me to suspect that the Dimetian is intrusive, notwithstanding the absence of any convincing evidence at the actual points of contact.

e. *At Ogof Llesugn.*—To this spot the easiest access is by the Cambrian beds a little to the east of the incoming of the Dimetian. Clambering down here by the sucking pool, one skirts the upturned strata—striking N. 85° W. and nearly vertical, but with a slightly reversed dip—and descends, at low water, by a cleft opposite the most easterly of the two faults described by Mr. Blake and Dr. Hicks. A long cave occupied by water even at low tide runs here some distance inland. To the west of this is a projecting spur of rock consisting of Cambrian, with massive conglomerate, and apparently some Pebidian. The beds strike about N.E. and show again the inverted dip. There is, to my eye, no indication of the upturning of the strata figured by Dr. Hicks.

Beyond this spur is the more westerly of the two faults, running inland about N.N.E. This brings the conglomerate against Dimetian. On the opposite or Dimetian side of the fault, about west of the spur, the conglomerate is again seen. It is in contact below with Dimetian, but there may be a slight slip here. It is overlain, owing to the reversed dip, by red Pebidian. Then follow eight or ten feet of green beds which are separated from the Dimetian by a "diabase"-dyke. It is difficult here and elsewhere at Ogof Llesugn to separate intrusive diabase from dark green altered Pebidian, and it may be that all the dark material here is "diabase."

South of this, the western shore of the Ogof Llesugn creeks or bays shows a bewildering confusion of rocks. There are two well-marked masses of conglomerate, much altered and indurated. On the outer face of the more southerly mass (that figured, to me quite incomprehensibly, by Dr. Hicks) there is what appears to be highly altered Cambrian fine-bedded strata. There is a very large amount of much altered Pebidian, red, green, and white. Lastly these rocks are seamed with "diabase"-dyke material. Here, again, it is difficult to separate this material from Pebidian. But even granting (what I am not prepared to admit) that all the dark green material

is "diabase" subsequently intruded, it is to me inconceivable that this alone should have produced the large amount of alteration and induration in the conglomerate and large masses of Pebidian strata. I am aware that Prof. Bonney says that he has seen nothing to lead him to suspect that the Dimetian was intrusive in the Cambrian, but much to induce him to consider the Dimetian far the older. I can only say that oft-repeated study of the locality left me unable to account for the phenomena there presented, by either faulted crushing or the influence of the "diabase"-dykes. The view that the Dimetian was intrusive was therefore forced upon me.

f. *General Considerations.*—I have already stated that my study of the Pebidian strata at St. Davids led me to dissent as widely from Dr. Hicks's classification and mapping of the volcanic series as from his conclusions as to their Archæan age. Quite apart from any Dimetian question, I am led to regard the Pebidian beds in St. Non's Bay and in Porthlisky Bay as very near the top of the series. This being so, it is quite impossible to map the Dimetian on the hypothesis of its Archæan age without so extravagant a use of faulting as to stagger any sober geological surveyor. In any case, even granting the correctness of Dr. Hicks's Pebidian conclusions, it is exceedingly difficult to realize the sequence of events which could possibly have given rise to the state of things depicted in Dr. Hicks's map.

I venture to think that Dr. Hicks himself, and some of those who accept his reading of the St. David's geology, have failed to realize what his map commits them to. At Ogof Golchfa, for example, the conglomerate is stated to rest unconformably on the highest visible beds of the Pebidian. These are not necessarily the highest existing beds. Other higher beds may, on this view, have been overlapped by the basal conglomerate of the Cambrian. In any case, however, these Ogof Golchfa Pebidians are, according to Dr. Hicks, some 8000 feet above the base of the system, which may have reposed directly on Dimetian, or may have rested on intervening Arvonian strata. Let us say that it rested on Dimetian, and that 8000 feet represents the thickness of the Pebidians. Now west of St. Non's Bay the Cambrian conglomerate rests (see Dr. Hicks's map) directly on Dimetian—that is to say, it has overlapped some 8000 feet of upturned strata. Here again I do not press the criticism that in St. Non's Bay the dip and strike of Pebidian and Cambrian are practically identical—a state of things hard to realize in connexion with such an overlap. What I wish to draw attention to is that such an overlap involves an enormous break in time,—uplift, folding, and vast amount of denudation—between Pebidian and Cambrian. And yet Dr. Hicks remarks in his reply to the Director-General: "Whether the volcanic fires had completely expended themselves or not before the conglomerates were deposited may be an interesting point; but it is virtually of no importance in regard to the questions at issue"! and Professor Bonney says, in a letter quoted by Dr. Hicks (*Q. J. G. S.* xl. p. 546), that "we do not efface the limits between Miocene and Pliocene

because, in a country where there has been great volcanic activity in the former, some feeble sputterings have occurred in the latter"—the implication being that there might be (though Dr. Bonney is not satisfied with the evidence of the fact), still there might be some sputterings of volcanic activity continued from Pebidian into Cambrian without being utterly and completely subversive of Dr. Hicks's Precambrian theory.

Even on Dr. Hicks's own hypothesis, then, his mapping of the district, and especially of the Dimetian with its nine-faulted boundary, is, I will not say an impossibility, but, to me, an incomprehensibility.

But great as is the difficulty of mapping the Dimetian as Precambrian, on Dr. Hicks's view of the Pebidian succession and orderly sequence, it becomes immensely greater if the existence of an isocline come to be regarded as an established fact. A glance at the diagram-section (fig. 5, p. 257) will show how considerable a fault there must be between Dimetian and Pebidian on the hypothesis of the Pre-Pebidian age of the former. I do not say that the Pre-Pebidian interpretation is thereby rendered impossible, but I do contend that the difficulties of this view are thus rendered exceedingly great.

g. *The Evidence from included Fragments.*—On this head I have nothing but negative evidence to offer. In Porthlisky Bay there are beautifully rounded pebbles of Dimetian, readily recognizable as such. Not a single pebble in any respect resembling these have I seen in the conglomerate or elsewhere.

Dr. Hicks lays a good deal of stress on the minute pebbles, supposed to be Dimetian, in the grit-beds at Chanter's Seat. Now from Dr. Hicks's own statement and from my own observations I conclude that these Chanter's-Seat beds are from 800 to 850 feet above the conglomerate. I find it very difficult to conceive, on Dr. Hicks's hypothesis, that any Dimetian—worn down as it had been by Pre-Arvonian, Pre-Pebidian, and Pre-Cambrian denudation—could have continued still to afford materials for Cambrian sedimentaries after 800 feet of these strata had already been accumulated. If the Dimetian origin of these pebbles be thus rendered improbable, we must search elsewhere for the source of the "dirty quartz."

5. CONCLUSION.

It only remains for me to state briefly the general conclusions that I have reached.

The Pebidian beds constitute a volcanic series, the base of which is nowhere seen, about 1200 to 1500 feet in thickness. Their age is anterior to the Harlech (Caerfai) conglomerate, which is, in many places, locally unconformable to them. I advocate the retention of the term Pebidian either as a sub-group of the Cambrian coordinate with Harlech, Menevian, &c., or as a distinct volcanic group coordinate with Cambrian, Ordovician, &c. (preferably the former),

but in any case to be included under the Palæozoic and not under the Archæan category.

These beds, in the western part of the district, where they can be best studied, are thrown into a series of three folds—a northern anticline, a central syncline, and a southern anticline folded over to form an isocline with reversed dips to the south-east. The axis of folding is roughly parallel with the axis of St. David's promontory.

There is no evidence in the district of an Arvonian system.

The Dimetian is intrusive in the southern limb of the isocline.

There are no Archæan rocks at St. Davids, unless some of the included fragments in the Pebidian tuffs are to be so regarded—in any case no Archæan rocks *in situ*.

EXPLANATION OF PLATE X.

Sketch Maps of the North-western and South-western portions of the District of St. Davids, on a scale of six inches to the mile.

The broken lines between the two Maps unite the points at which they fit together.

DISCUSSION.

The PRESIDENT commented upon the differences of opinion among those who had studied the geology of St. Davids, and pointed out that there were two points of primary importance—the relations of the Pebidian to the Cambrian, and those of the Dimetian to all the other rocks. The Arvonian question was of less consequence.

Dr. HICKS said that the Author had commenced his paper with a reference to the Caerbwdy valley, but had not referred to the great agglomerates at Clegyr, nor to the clearly bedded porcellanites. Now, there was nothing porcellanized in the Cambrian, and yet fragments of the Pebidian porcellanite abound in the Cambrian conglomerate. He proceeded to describe the different beds on which the conglomerate rests transgressively, showing how the Pebidians vary in character at different points; he also commented on the absence of a map, and the paucity of sections. As to that at St. Non's Arch, the unconformity on the porcellanites was clearly shown in both interpretations, and he exhibited photographs in proof of the correctness of his own reading of this section. At Ogof Golchfa the Author had shown the beds as almost conformable, but photographs were entirely against this interpretation. There might be a kind of crush here between the Cambrian and Pebidian, as would happen at the junction of such dissimilar beds; but there was no fault, only a shearing. At Rhoson and other places large fragments of Pebidian had been found, which showed that they had been cleaved before being enclosed in the conglomerate.

Criticizing the diagrammatic section exhibited, Dr. Hicks remarked that he himself had once given a similar section, but had found that such a simple interpretation was impossible, and that the beds of the Pebidian had been greatly broken and, in places, inverted, as the

result of great thrusts from the north-west, and that they had been folded over a crystalline axis (Dimetian) in Pre-Cambrian times. In Post-Cambrian times there had been a great fold of Cambrian and Ordovician rocks over the Pre-Cambrian axis, and immense dislocations of the strata had taken place, especially in the arch-limb of this fold. On the north-west side of the axis the beds have been intensely cleaved and sheared, and newer rocks have been thrust for great distances over older rocks; whilst on the south-east side they have been inverted and faulted so as to cause the older beds to overlie the newer. On this side the rocks are much less cleaved and sheared, and the overthrusts are of less magnitude. Faults were referred to in the fossiliferous strata showing displacements of from 500 to 12,000 feet. A great anticlinal arch bent over a core of Archæan rocks, and broken into a succession of sheared surfaces, could alone furnish any satisfactory explanation of these conditions.

The Pebidians themselves, both the volcanic and sedimentary portions, had also been sheared. Whatever might be the relations in other areas, here there was an immense unconformity. Where could all these pebbles have come from? He referred to the existence of large pebbles of various rocks in the conglomerates in different areas, and maintained that the Pebidian had been folded, altered, and cleaved before a stone of the Cambrian had been deposited.

As regards the Dimetian, he was not surprised at the difficulty the Author found in mapping it. He himself now admitted that the rock was originally, like the massive Archæan gneisses, of igneous origin. It was of Pre-Cambrian age; but he thought it had been too much crushed to assume a gneissic character. The pebbles at Chanter's Seat were undoubtedly fragments of Dimetian.

Prof. BLAKE thought the views of the two disputants were not so far removed in matters of fact; both agreed that there was a well-marked overlap or unconformity. In so far as details were concerned, he could verify the sections given by Prof. Morgan. The main question is the importance to be assigned to the unconformity. He formerly thought it very great; but later work in Caernarvonshire, and still more recently in Shropshire, had shown that there was a volcanic series more satisfactorily classed with the Cambrian than with the underlying series, and of this the St. Davids rocks might possibly be the equivalents.

Prof. HUGHES regretted the absence of the Director-General, as the paper seemed to be chiefly a re-opening of the old controversy in which he had ably expounded the same view as that now put forward. The paper secondly suggested corrections of details in the interpretation of the structure of the district, which, though valuable, were not of great importance in the general question.

He would have been glad if the six-inch maps on which the Author had drawn his lines had been produced, if only to be sure that they were speaking of exactly the same sections.

He gave diagrammatic illustrations of his own view that the Cambrian was unconformably transgressive across the Archæan, and that the constituents of the conglomerate varied according to the

various parts of the Archæan from which they were derived, though that might not be the immediately underlying part, as he had long ago pointed out in the case of the North-Wales sections.

Appealing to particular sections he explained the proofs, from the fluting and crushing of the rocks, &c., that the junction seen at Porth Clais was a fault; but at Ogof Golchfa evidence of the original unconformable junction could still be made out, though the Cambrian was much crushed and shifted by the coming together of beds of unequal texture, and the purple ash-like schist on which it rested was squeezed out during earth-movements by being in contact with the unyielding conglomerate. There seemed to be here, as at Nun's Well, signs of long and deep oxidation of the rock on which the Basement Beds of the Cambrian rested. At Ogof Llesugn he thought that an unconformable junction could be seen, though it was traversed by numerous step-faults, so that much depended upon the position of the observer when drawing the section; while the supposed passage or intercalations in the cliff-section close by he considered to be only a passage between the gneissic and porcellaneous felspathic rock, with local changes due to crush and consequent later alteration, the Cambrian conglomerate being quite distinct, and the supposed alternation of Cambrian and Archæan only an included fragment or "horse" of conglomerate caught in a fault and cut back by denudation.

Mr. H. W. WILLIAMS failed to recognize some of the Author's sections, although well acquainted with the locality.

The AUTHOR said that the main point between himself and Dr. Hicks was as to the relations of the conglomerate to the underlying Pebidian. He hoped to go over the ground some day with him and Mr. Williams. He had not worked the section in patches, but had traced it continuously throughout the whole district. He had listened with admiration to all that Dr. Hicks had said about the enormous faulting of the fossiliferous Cambrian, but failed to see how it bore on the subject. To please Prof. Hughes he was ready to admit any number of faults, and he also agreed with Dr. Hicks as to shearage. He was glad to find that Prof. Blake practically agreed with him as to the relations of Pebidian to Cambrian. He was well acquainted with the existence of step-faults, and thought that Prof. Hughes had misunderstood his meaning; the overlap of $\frac{1}{4}$ mile was due to step-faulting. He maintained that his reading of the Ogof Golchfa section was correct, and spoke of the bevelling-off of the edges of the beds.

The evidence of Carn-ar-wig neither Dr. Hicks nor Prof. Hughes had touched. It was perfectly clear that "tuff" ash and lavas might be seen overlying the conglomerate. He submitted a map, which was on the table; but in a volcanic region it was not easy to map systematically, since this was not a regular series of beds as maintained by some.

15. *On the Occurrence of the GENUS GIRVANELLA in OOLITIC ROCKS, and REMARKS on OOLITIC STRUCTURE.* By EDWARD WETHERED, Esq., F.G.S., F.C.S., F.R.M.S. (Read December 18, 1889.)

[PLATE XI.]

I. INTRODUCTION.

IN January 1888 I commenced a systematic examination of the oolitic rocks in the Carboniferous and Jurassic series. The subject was, of course, by no means new, but I was under the impression that there had been no systematic investigation of the structure of those rocks, though many authors had referred to the subject. My attention was subsequently called to Dr. Sorby's illustrated appendix to his Presidential Address to this Society, 1879, and I found that much of the work I contemplated was already done. I had, however, at an early stage of the work, discovered that the little-known genus *Girvanella* was of frequent occurrence in oolitic rocks, which appears to have escaped the notice of Dr. Sorby. My work then resolved itself into a search for that organism; but, as I had to make over 230 thin slides for microscopic examination, I have been able to work out the structure of the rocks in greater detail than Dr. Sorby has done, and I trust that an account of the observations deduced from those slides may prove a worthy supplement to his work.

The Genus GIRVANELLA, Nich. & Etheridge, jun.

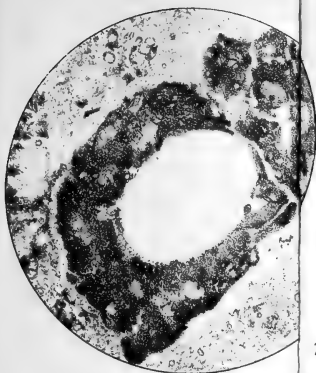
This apparently insignificant organism was first noticed by Prof. H. Alleyne Nicholson and Mr. Robert Etheridge, jun., in their 'Monograph of the Silurian Fossils of the Girvan District in Ayrshire' (Part I., 1878), and was described as consisting of "Microscopic tubuli with arenaceous or calcareous (?) walls, flexuous or contorted, circular in section, forming loosely compacted masses. The tubes apparently simple cylinders, without perforation in their sides, and destitute of internal partitions or other structures of similar kind" (p. 23). The one species established was *G. problematica*, which name was given for convenience' sake*.

In the Geol. Magazine for 1889 †, I have shown that *Girvanella* is not confined to the Silurian rocks, and that as a rock-forming organism it is of more importance than was supposed. In that communication I established a new species, *G. pisolitica*, which forms the Pea-Grit spherules near the base of the Inferior Oolite in the northern Cotteswold area of Gloucestershire. I also showed that a much smaller form built up the pisolite spherules which occur in the Coralline Oolite near Weymouth; but I did not see my way to establish a third species. Since then I have obtained in-

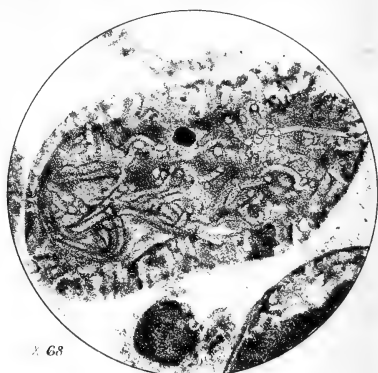
* See also Geol. Mag. 1888, pp. 22-24.

† Dec. iii. vol. vi. p. 196.

1a.



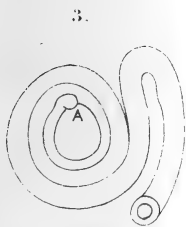
2c



2b.



3. 68



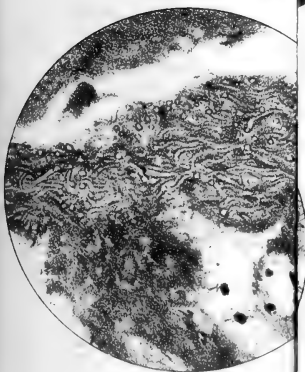
127

4.



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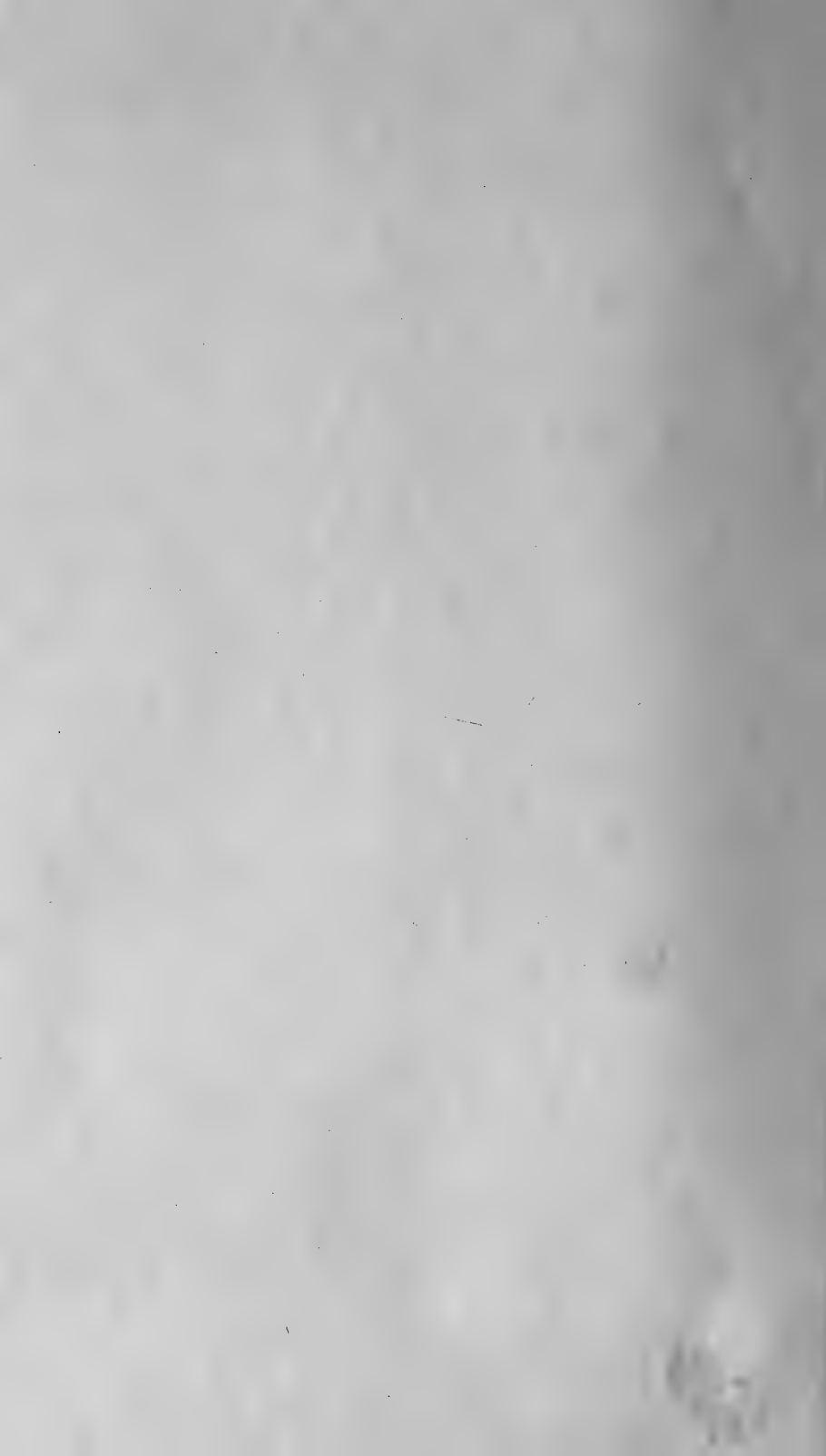
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8.



70



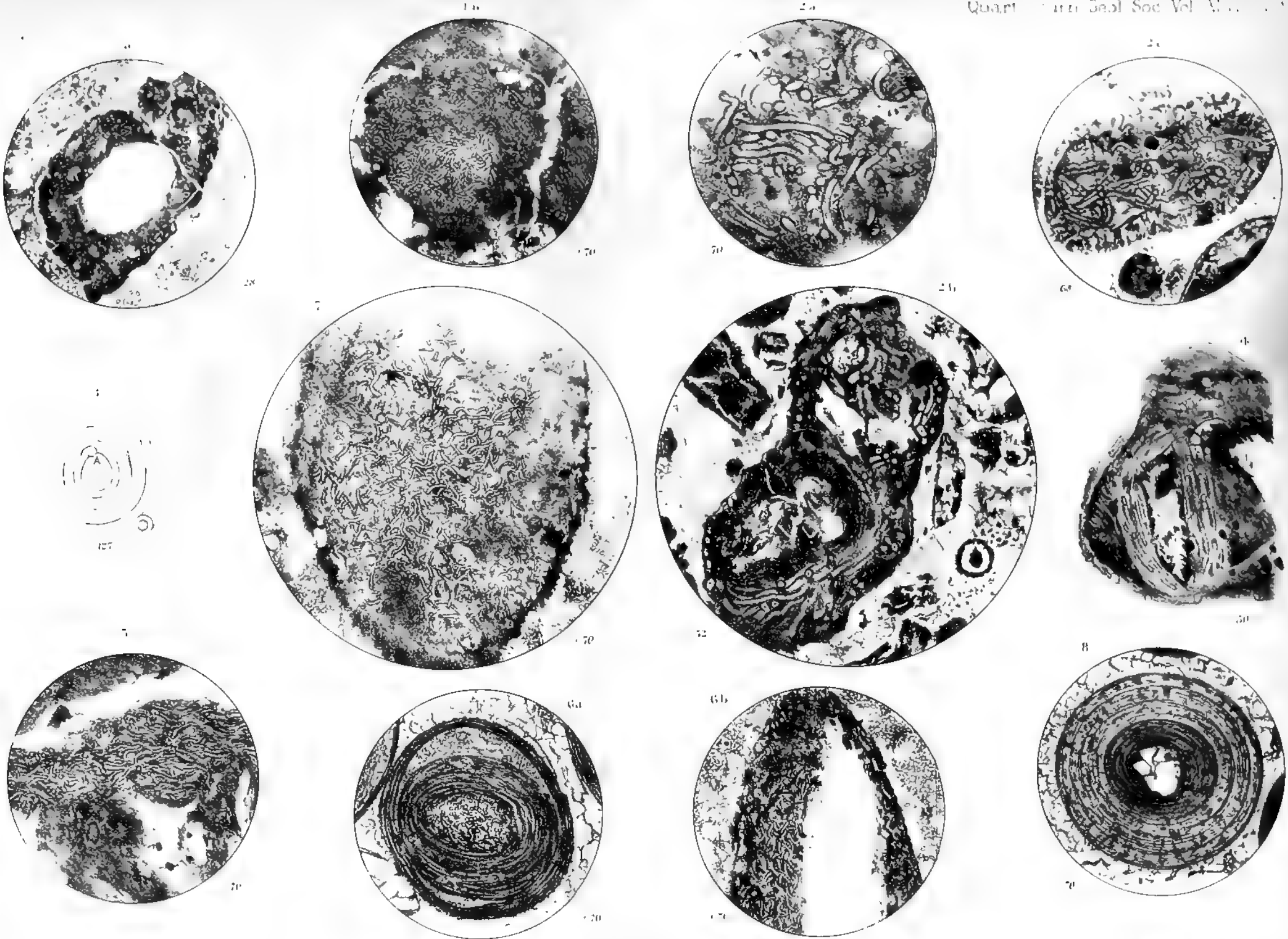


PLATE I.

formation which I think will justify me in drawing a distinction between the Coralline-Oolite form and *G. problematica*, to which I temporarily referred it.

II. THE CARBONIFEROUS OOLITIC LIMESTONES.

In the Carboniferous Limestone of Gloucestershire oolitic limestone is more common than is generally supposed. Taking the gorge of the Avon as the typical section, I find oolitic limestone to occur at four horizons in the middle series. It is also worthy of remark that in three instances out of the four the oolitic limestones rest on dolomitized limestone.

1. The first development of oolite occurs at the base of the Middle Limestones, and the following analysis shows the beds to be dolomitized:—

Insoluble residue	1·40
Organic matter	6·20
Magnesia	15·56
Lime	32·36
Carbonic acid.....	42·78
Oxides of iron and alumina	1·10
Alkalies, &c.	·60

100·00

2. About 100 feet of oolite follow above the dolomitized limestone, consisting of well-defined spherules of dark colour and granular crystalline structure. These stand out in relief against the clear calcite which occupies the space between the spherules, and average about ·6 millim., but occur as small as ·1 millim. in diameter. In some the main axis has been extended and a spheroidal form has been developed, which is usually larger than the others. In some spherules the crystalline radiate feature is seen, but the concentric arrangement can always be distinguished. In most instances the original nature of the nucleus cannot be determined, it having passed into calcite. When a nucleus is preserved in its original form it is usually a Foraminifer in the spheres, and in the spheroids a spicular object which could not be definitely distinguished, probably a portion of a small spine.

3. The next development of oolitic limestone is in what is known as the Great Quarry, and, like that previously mentioned, it rests on dolomitized limestone, as the following analysis of the beds shows:—

Insoluble residue	2·70
Organic matter	5·20
Magnesia	11·86
Lime	42·48
Carbonic acid.....	37·40
Oxides of iron and alumina	trace.
Alkalies, &c.	·36

100·00

This analysis shows that the amount of magnesia present is less than in the previous analysis. This is accounted for by numerous minute veins of calcite which traverse the rock. These are clearly of secondary origin, and in an analysis would, of course, increase the percentage of carbonate of lime. The oolitic spherules are very similar to those which I have described from the base of the middle series. They average about .52 millim., and are therefore slightly smaller than those previously described. No sign of *Girvanella* was discovered in these beds.

4. The next limestone which shows oolitic structure occurs a short distance below where the New Road from Clifton joins the road along the banks of the River Avon, and for convenience I will call it the "New-Road Oolite." The beds differ from those previously noticed; they do not rest on dolomitized limestone, and are not so crystalline. The following section shows the character of the beds:—

Section of the New-Road Oolite.

	ft.	in.
1. Oolitic limestone, with corals at the top	10	0
2. Dark nodular limestone with argillaceous material	0	9
3. Blue limestone with some oolitic spherules	2	6
4. Oolitic limestone	3	6
5. Grey limestone; oolitic in part	2	8
6. Base, Coralline Limestone.		

Commencing an examination from the top, the sections were made from specimens collected throughout the 10 feet of rock. The oolitic spherules are slightly ferruginous, and some of them are as large as 1 millim. in diameter, and the average may be put at about .8 millim. In some the nucleus is well preserved and consists of a Foraminifer, a joint of a Crinoid, a portion of a spine, or a fragment of shell. The nucleus is surrounded by a concentric arrangement, but the crystalline radiate feature is only slightly developed in a few instances.

A form of *Girvanella* was here discovered to which I propose to give the name of *Girvanella Ducii*, for reasons to be presently explained. It consists of an aggregation of tubules similar to those represented in Pl. XI. figs. 2 *a* and *b*; but in this instance the outlines are to a large extent obliterated by mineral changes; the centre of the granule has been converted into calcite, and the concentric arrangement now presents a dark granular crystalline structure. Throughout the whole of this the tubules of *Girvanella Ducii* can be seen. The concentric arrangement is similar to that of the other granules or spherules in the slide, and I have given it very careful examination with the object of determining whether it is of organic or of inorganic origin. Seeing it for the first time, an observer would be disposed to pronounce in favour of the latter view; but after the study I have made of the structure of oolitic spherules I am disposed to regard it as organic. The apparent concentric layers may be a series of tubuli, the outlines of which have become obliterated by mineralization. That some of the spherules in the

limestone originate from the *Girvanella-tubuli* there is proof, but in these the structure, though it can be made out, is almost obliterated.

Bed No. 2 consists of dark nodular limestone and argillaceous material. The sections of the former show it to be extensively crystalline, the calcite being slightly tinged with iron-oxide. Scattered here and there are some Foraminifera; but the most conspicuous feature is formed by some oolitic spherules which measure as much as 3 millim. in diameter (fig. 1 *a*). Viewed in a thin section of the rock, these are seen to be masses of tubuli (fig. 1 *b*), measuring only .01 millim. in diameter, forming a crust around a nucleus. This nucleus is usually calcite, and probably represents some foreign object which served as a nucleus to which the organisms attached themselves, and which has changed into calcite. I propose to distinguish this species by the name of *Girvanella incrustans*.

Bed No. 3 is a blue limestone largely made up of Foraminifera, associated with oolitic spherules. In this bed we again meet with the organism I propose to call *Girvanella Ducii*, occurring in loose aggregations, as represented in fig. 2 *a*. It is also found surrounding foreign objects, as in fig. 2 *b*, in which case an oolitic granule is made up. In fig. 2 *b* there may be said to be three nuclei, which serve as centres of growth. With the largest of these the very interesting question is again raised as to whether the concentric arrangement around the nucleus is of organic or inorganic origin. The original structure is, doubtless, much obliterated; but the outlines of tubes can be seen, and I am therefore disposed to regard it as organic. *G. Ducii* may be said to be numerous in this bed, sometimes in loose aggregations of tubules, at other times growing round some foreign object.

Bed No. 4 consists of an oolitic limestone in which the spherules are unusually dark in colour. In my slides, made from this bed, I obtained one specimen of a loose aggregation of *G. Ducii*, in which the tests were for the most part well preserved.

The next development of oolitic limestone occurs just above what is known as the "Great Fault," where the Millstone-Grit is thrown down against the Middle Limestone. These oolites rest on dolomitized limestone, and are like the others previously referred to, which rest on a like basis. That is to say, the nuclei of the spherules are seldom preserved, and the concentric arrangement is highly crystalline. The radiate crystalline structure is prominent and at times develops what Dr. Sorby calls the "fan-shaped arrangement of the small prisms of calcite" *.

The following analysis of beds on which the oolite rests shows them to be dolomitized:—

* Presidential Address, Quart. Journ. Geol. Soc. p. 71, plate x. fig. 1 (1879).

Insoluble residue	3·10
Organic matter	3·60
Magnesia	12·10
Lime	42·25
Carbonic acid	38·80
Oxide of iron and alumina	trace.
Alkalies, &c.	·15
	100·00

I have also found a good specimen of *Girvanella Ducii* (fig. 2 c) in oolitic limestone at Tortworth Park, Gloucestershire, the residence of the Right Hon. the Earl of Ducie. The horizon corresponds with the Clifton oolite at the base of the Middle Limestones; but at Tortworth the beds are not so crystalline. As to whether or not the beds rest on dolomitized limestone could not be ascertained, as the strata at the base were not exposed. This specimen of *G. Ducii* was the first I discovered in Carboniferous rocks, and I dedicate the species to his Lordship.

In this specimen the central tubuli are surrounded by a radiate and in part concentric arrangement, which also characterizes some of the other spherules in the rock; and in this there are the outlines of undoubted tubes, which seem to point to the structure being of organic origin.

So far, then, I have discovered two species of the genus *Girvanella* in the Carboniferous Limestone, and these only in rocks of oolitic structure.

It may at first appear strange that *Girvanella* has not been discovered in oolite resting on dolomitized limestone, and a connexion between the latter and the oolite may be suggested. I was at first disposed to believe that this was so, but the absence of dolomitized limestone at the base of the New-Road Oolite dispelled that idea. It is, however, noticeable that in the Forest of Dean there is a thick series of oolitic beds, and these also rest on dolomitized limestone. The only connexion between the two types of rock appear to me to be that both are highly crystalline; and it may be due to this fact that we find no reliable signs of *Girvanella* in the oolites which rest on dolomitized beds, the structure having been obliterated in the process of crystallization.

THE JURASSIC OOLITES.

All the specimens I have examined from the Jurassic rocks were collected in Gloucestershire or in the neighbourhood of Bath.

Commencing at the base of the Inferior Oolite in the northern Cotteswold area, we find coarse oolites of the Pisolitic type, which series are finally brought to a close by the fine development of large spherules known as the "Pea-Grit." These, as I have already stated, are not concretions but the organism I have named *Girvanella pisolitica* *.

* See my paper in the Geol. Mag. dec. iii. vol. vi. (1889), pp. 196-200, plate vi. figs. 8-11.

The organisms attach themselves to a foreign substance which finally becomes a nucleus in the centre of a mass of *Girvanella* tubules, and a spherule results, the exact shape depending upon the form of the nucleus. I am not sure that I should not be justified in making a new genus out of some forms which occur in the Pea-Grit. In some spherules the tubes have the appearance of branching, a feature which is absent in what may be considered the typical *Girvanella*. Professor Nicholson remarks* on what he considers to be a close comparison between *Girvanella* and the 'Challenger' Foraminifer, *Syringammina fragilissima* ('Challenger' Reports, vol. ix. p. 242, woodcut, fig. 9). In describing this organism Dr. Brady says (*loc. cit.*):—"Test free; consisting of a rounded mass of branching, inosculating tubes, radiating from a common centre, and arranged in more or less distinct concentric tiers or layers, which are marked by the formation at intervals of a network of lateral branches."

Dr. Brady, however, appears to take a different view from that of Professor Nicholson, for under the head of *Hyperammina vagans* he refers to *Girvanella problematica*; and, after quoting the description originally given by Professor Nicholson and Mr. Etheridge, jun., remarks (*op. cit.* p. 261):—"This description applies in every particular to such specimens of *Hyperammina vagans* as are represented in figs. 7 and 8; and the specific characters which follow agree equally well, except in a single point, namely, that the diameter of the tubes in *Girvanella* is from $\frac{1}{700}$ th to $\frac{1}{600}$ th of an inch, whereas those of the present species range from $\frac{1}{500}$ th to $\frac{1}{120}$ th of an inch. Some latitude must be allowed in estimating the characters of a minute fossil belonging to so very remote an age; but it seems scarcely worth while to recognize these trifling differences as a basis of generic distinction." Now, assuming that the genus *Girvanella* is rightly referred to the Foraminifera, some forms which I have included under the head of *Girvanella pisolitica* appear to correspond with *Syringammina fragilissima*; but on the other hand the Carboniferous forms I have mentioned, and some to be referred to further on, are allied to *Hyperammina vagans*. In reference to that organism Dr. Brady further remarks (*loc. cit.* p. 260) that it occurs "spreading in irregular tortuous lines over the surface of shells or stones, or, in the absence of foreign bodies, growing coiled upon itself in irregular masses." The coiling upon itself is also a feature in *Girvanella pisolitica*, as shown in fig. 3, where apparently we get the primordial chamber at A.

Passing now to the beds of the Inferior Oolite which follow the Pea-Grit series, we come to the Lower Freestones. There is a considerable amount of calcite present, and some of the spherules are granular, without any concentric or other structure. At Bull Cross, near Stroud, the beds appear not to have undergone molecular change to such an extent as at Leckhampton, near Cheltenham; and in my prepared section from these beds I have several spherules showing the structure of *G. pisolitica*.

* Geol. Mag. dec. iii. vol. v. p. 23 (1888).

Following the Inferior Oolite in ascending order, we pass from the Lower Freestones into the Oolite-marl, and above that we come to the Upper Freestones. What I have said with regard to the crystalline condition of the Lower Freestones also applies to the Upper Freestones, when taken as a whole; but a striking exception has been found to this in freshly exposed beds of this freestone near Chedworth, about eight miles from Cheltenham. In these beds there are patches of oolite, of blue tint, which is due to the iron in the rock being in the state of carbonate, the original condition in which it existed after the formation of the rock. In the yellow oolite the iron has been converted into ferric oxide. Where the original carbonate of iron has not been converted into the ferric condition the oolite-spherules show their original structure better than is the case where the iron has been converted into ferric oxide, and in this the *Girvanella-tubuli* are clearly made out. The tubes show a somewhat dark exterior; and, when cut in section, the interior is seen to be filled with crystalline calcite or dark argillaceous material. They are smaller than *G. pisolitica* as it occurs in the Pea-Grit spherules, but otherwise similar; and I therefore regard them as a variety of that species. In Pl. XI. fig. 4 I have represented a spherule in which tubes are clearly distinguished; but in parts the outlines have been obliterated by mineral changes, and we then get the identical structure which is characteristic of most of the oolitic spherules in the Upper Freestones. There are others which show a regular crystalline concentric arrangement, and they may possibly be of concretionary origin; but I am disposed to regard them as spherules in which the *Girvanella*-tubes have become crystalline and the outlines consequently obliterated.

Another form of *Girvanella* has also been met with in the Upper Freestones. It consists of a dense mass of tubes, measuring .01 millim. in diameter, which form a crust attached to foreign objects (fig. 5). It is very similar to the Carboniferous *G. incrustans*, and might perhaps be regarded as identical with that species. For reasons to be explained under the head of "new species," I think it best to regard it as a variety, with the name of *G. incrustans*, variety *Lucii*, after W. C. Lucy, Esq., the excellent President of the Cotteswold Naturalists' Field Club.

I now pass to the upper divisions of the Inferior Oolite. In the new railway now in course of construction between Cheltenham and Cirencester some fine exposures of the *Clypeus-Plottii* beds are seen. In these there are large oolitic spherules which measure as much as 4 millim. in diameter, though the average size may be stated at about half that. In most of these there is no structure except the dark granular and occasional streaks and circles of calcite, but in others the *Girvanella*-tubules are seen. I have therefore no doubt that the spherules in this division of the Inferior Oolite are not concretions, but due to a variety of *Girvanella pisolitica*.

THE GREAT OOLITE.

1. *The Stonesfield Slate*.—Specimens were collected from Eyford in Gloucestershire, on the eastern side of the Cotteswold Hills, where the so-called “slate” has been worked since the time of the Romans. Dr. Sorby describes the Stonesfield Slate thus* :—“This is a good example of a fine-grained shell-sand with small grains of quartz. Most of the fragments are of Brachiopods and Oysters, which are of flat shape, and thus cause the rock to split easily along the plane of bedding.” I find this description to apply only to the “Base Bed” at Eyford (*i. e.* the lowest which rests on the Fuller’s Earth) and not to those above. The beds which give the “best slate” are made up of broken valves of Ostracoda, a few Foraminifera, and a quantity of undetermined material, which, whatever it may be, does not consist of fragmentary remains of Brachiopod and Oyster-shells. There is a large amount of insoluble residue, which includes detrital quartz, zircon, tourmaline, rutile, and microcline. No oolitic structure was observed in these beds, nor any sign of *Girvanella*.

2. *The Bath Oolite*.—Of this rock it is most difficult to prepare sections for microscopic examination on account of its softness and the slight cohesion of the oolitic spherules with the crystalline matrix. My specimens were collected from Coombe Down, near Bath, and Cross Hands, in Gloucestershire.

The specimens from Coombe Down show a highly crystalline limestone, and consequently a large percentage of calcite. The oolitic spherules were so crystalline that in some cases the concentric structure had disappeared. All the specimens show fragments of shells, and in some cases Foraminifera are met with. The specimen from Cross Hands showed the same crystalline condition as those from near Bath, and only a few of the spherules were preserved, most having been detached during the process of preparing the slide. No reliable evidence could be obtained as to their origin.

3. *Forest-Marble*.—The specimens were collected from Langton Herring, near Weymouth, and from a boring at Swindon, Wiltshire. In both cases the limestone partook of the Bath-oolite character, but it is more shelly, and oolitic spherules are not so numerous. Like the former, too, the spherules are so crystalline that little can be said as to their origin.

Passing over the intermediate formations, I take next the Coralline Oolite. All my specimens were collected from near Weymouth, and reference has already been made to my communication to the ‘Geological Magazine,’ in which I have shown that the pisolite spherules in the Oolite near Weymouth and at Sturminster Newton are not concretions but a minute form of *Girvanella* †.

I find that preparations of this rock for microscopic examination are seen to most advantage when not covered with Canada balsam. It is best to simply polish the surface of the thin sections, and then

* Presidential Address, Quart. Journ. Geol. Soc. p 53, and Appendix, p. 70, plate vii. fig. 1 (1879).

† Geol. Mag. dec. iii. vol. vi. p. 196.

the structure can be easily made out. It is probably owing to the fact that slides are generally covered with balsam that the structures I am about to describe have not before been detected. I have myself rendered many of my slides almost useless by reason of the high refractive power of Canada balsam.

The best examples of oolitic structure are to be found in the "Osmington Oolite" of Blake and Hudleston*; but there may be said to be several types of oolitic spherules in the Coralline Oolite.

1. A spherule with a minute loosely aggregated form of *Girvanella* tubules as a nucleus, which are surrounded by an irregular sort of concentric arrangement (Pl. XI. fig. 6 a).
2. The same form of minute *Girvanella* occurs in loose aggregations or surrounding foreign objects (fig. 6 b); in these instances forming granules or spherules.
3. A spherule or granule made up of a mass of loosely-aggregated very vermiform tubuli which are larger than the last (fig. 7).
4. A spherule or granule in which the nucleus generally consists simply of calcite, and the concentric arrangement has a granular crystalline appearance, in which occasional outlines of tubuli may be seen. In short, we get in these spherules the same appearance that we see in those obtained from the Upper Freestones and *Clypeus-Plottii* beds of the Inferior Oolite, which I have represented in fig. 4.
5. A spherule with a clear and well-defined concentric arrangement around a nucleus (fig. 8).

With regard to the first of the above spherules or granules, in which the *Girvanella*-tubules occur in the centre (fig. 6 a), I regard the tubes simply as the nucleus, and the concentric structure as foreign to the nucleus. That this is so, is proved by the fact that *Girvanella*-tubules of the same form are met with apart from the concentric arrangement (fig. 6, b). It is then a question whether the concentric structure is of concretionary origin or a form of *Girvanella*. A casual observer would probably either give no opinion at all, or decide in favour of the concretionary origin. A careful examination, however, of other spherules in the slides shows that they exhibit the same structure; and in some there are unmistakable outlines of tubules. I am therefore obliged to come to the conclusion that the structure is organic, and the same may be said of other spherules in the slides which show similar structure.

With regard to the class of spherules which I have mentioned under the head of 3, they are simply an aggregation of a species of *Girvanella*, which I propose to call *G. intermedia*. Spherules of this type are fairly numerous in the bed of Coralline Oolite from which the slides were taken, and which occurs on the sea-shore at Wyke, near Weymouth. I have not found the tests of this species attached to foreign objects.

Spherules of the type represented by fig. 8, are quite different from those before described. They are more truly crystalline, and the granular crystalline feature is absent. Also the structure around

* Quart. Journ. Geol. Soc. vol. xxxiii. p. 265.

the nucleus is perfectly concentric. Viewed through a microscope, spherules of this type would be regarded, at all events at first sight, as of concretionary origin, and I am not prepared to say that such may not be the true interpretation. When photographed, however, what under the microscope are very obscure dark spots appear like the extremities of tubes which have been cut across. These objects occur throughout the concentric layers at short intervals; and it is impossible to resist the idea that the apparent concentric layers may really be layers of tubuli which were filled with dark material, and the walls of which have become crystalline.

PORTLAND OOLITE.

The beds of the Portland Oolite vary considerably in microscopical structure. I therefore found it necessary to take a section of a quarry and examine each bed separately.

Section of the Portland Oolite.

Imosthay Quarry, Portland.

Beds in descending order.

		ft.	in.	
	Roach Bed	2	6	Full of the casts of <i>Cerithium portlandicum</i> , <i>Trigonia gibbosa</i> . Chert at the top contains minute shells.
Whit Bed.	{ Portland Building-stone	6	0	Fine-grained limestone. Terminates in a layer of chert.
	{ Portland Stone with numerous cracks.	3	0	Inferior stone on account of liability to split.
	{ Portland Stone with Chert ...	3	6	Chert nodules most numerous at the bottom.
	Curf Roach	3	0	Mass of casts of shells: <i>Trigonia incurva</i> (2), <i>Ammonites giganteus</i> , <i>Cerithium portlandicum</i> .
	Base Bed.....	8	0	

Commencing at the "Base Bed," we find the rock made up entirely of dark oolitic spherules, which have been much altered by crystallization, and nothing can be said as to the original structure.

Curf Roach Bed.—Contains some rather large crystalline oolitic spherules, numerous granular nodules, and organic detrital material. The spaces between are filled with small crystals of calcite and a quantity of dark granular structure, which indicates altered organic calcareous remains.

Whit Bed.—The last, or top bed, is a mass of small crystalline organic fragments, with a few oolitic spherules. Dr. Sorby's* description and figure of the Portland Stone is not typical of the Portland Stone of commerce, namely the "Whit Bed," as it occurs in the above quarry.

* Presidential Address, p. 50, and Appendix, p. 70, pl. iv. (1879).

Roach Bed.—A mass of shell-débris; the structure is often well preserved in the fragments; no oolitic spherules appeared.

In none of the slides from the Portland Beds was *Girvanella* detected. As to the origin of their oolitic spherules, it is impossible to express any positive opinion, on account of the alteration they have undergone by crystallization.

The New Species.

To make distinctions between organisms such as the *Girvanella* is a task of considerable difficulty, but to do so is a matter of necessity.

I. *Girvanella incrustans*, Pl. XI. figs. 1 *a*, *b*.—Occurs only in the Carboniferous Limestone at Clifton, in spherules as large as 3 millim. in diameter. When cut in section, the organism is seen to consist of a dense crust of very tortuous minute tubuli, which measure .01 millim. in diameter. They are arranged in rude layers, formed around a centre, which is usually represented by calcite into which the original nucleus has probably been converted.

Girvanella incrustans, variety *Lucii* (fig. 3), is very similar to *G. incrustans*; but so far I have not found the tubuli to occur in layers, but as an irregular mass incrusting foreign objects. I have found *G. incrustans* only as spherules; but the variety *Lucii*, as represented in the figure, is not a spherule. The differences between the two varieties are slight; but as one occurs in the Carboniferous Limestone and the other in the Inferior Oolite, I think it better to give the varietal name of *Lucii* to the latter.

II. *Girvanella Ducii*, Pl. XI. figs. 2 *a*, *b*, *c*.—This species is confined to the Carboniferous Limestone, and has been found at Clifton and Tortworth Park in Gloucestershire. The test consists of a tortuous tube, with clearly defined walls of dark granular structure, and measuring .02 millim. in diameter. In some instances the tubes occur in irregular loose aggregations, at other times adhering to foreign objects, as represented in fig. 2 *b*, when a small nodule or granule results. In some instances *G. Ducii* assumes a more or less spherical form, and the inner tubes are surrounded by a concentric structure. Whether in this case the central tubes are nuclei and the concentric arrangement concretionary or organic is doubtful, and worthy of consideration by future observers. I have not as yet been successful in discovering a primordial chamber: but, seeing that in the living Foraminifer *Hyperammina vagans*, which *G. Ducii* resembles, the primordial chamber is "almost invariably wanting"* , it is not surprising that, in the fossil state, it should be still less easily detected.

III. *Girvanella minuta*, Pl. XI. figs. 6 *a*, *b*.—The test consists of a short minute tube, which measures .007 millim. in diameter. These tubes are enclosed by a thin dark granular wall, and occur in the centre of oolitic spherules (fig. 6 *a*), or in aggregations or around some foreign object (fig. 6 *b*).

* 'Challenger' Report, Zoology, vol. ix. p. 260.

IV. *Girvanella intermedia*, Pl. XI. fig. 7.—The test consists of a vermiform tortuous tube, which grows in nodular masses. The tubes measure .01 millim. in diameter, and have well-defined thin walls. I have not as yet found this form adherent.

In concluding this paper I should like to say, first, that it has been my object to produce evidence that oolitic structure is not always of concretionary origin. That it is all organic I am not prepared to maintain, but it may be.

DESCRIPTION OF PLATE XI.

- Fig. 1 a. Spherule of *Girvanella incrustans*; $\times 28$ diam. Seen in section. From the "New-Road Oolite," Middle Carboniferous Limestone, Clifton.
- Fig. 1 b. Portion of fig. 1 a; $\times 70$ diam. Showing the tubules of *Girvanella incrustans*.
- Fig. 2 a. *Girvanella Ducii* occurring as an aggregation; $\times 70$ diam. "New-Road Oolite," Middle Carboniferous Limestone, Clifton.
- Fig. 2 b. The tubules of *Girvanella Ducii* attached to foreign objects, which act as nuclei for the formation of an oolitic granule or spherule. $\times 52$ diam.
- Fig. 2 c. The tubules of *Girvanella Ducii* in the centre of an oolitic granule, and surrounded by a radiate and concentric structure of doubtful origin, but probably organic. $\times 68$ diam.
- Fig. 3. *Girvanella pisolittica*, coiling upon itself, with what is suggestive of the primordial chamber at A.
- Fig. 4. Portion of an oolitic spherule from the Upper Freestones of the Inferior Oolite, from near Chedworth. The spherule is passing into the granular-crystalline condition. $\times 50$ diam.
- Fig. 5. *Girvanella incrustans*, variety *Lucii*, attached to a foreign object. From the same beds as fig. 4. $\times 70$ diam.
- Fig. 6 a. An oolitic spherule from the Coralline Oolite at Radcliff Point, near Weymouth, with the tests of *Girvanella minuta* in the centre, surrounded by a concentric arrangement of doubtful origin, but probably organic. $\times 70$ diam.
- Fig. 6 b. *Girvanella minuta*, attached to a foreign object, which has been converted into calcite. The latter acts as a nucleus, and an oolitic granule results. On the left-hand side, and on the outer edge of the right, the tubuli have passed into the granular crystalline condition. $\times 70$ diam. From the Coralline Oolite, Wyke, near Weymouth. Only a portion of the granule is represented.
- Fig. 7. *Girvanella intermedia* forming an oolitic spherule. Coralline Oolite, Wyke, shore near Weymouth. $\times 70$ diam. Around the edge of the granule the tubules have passed into the granular crystalline condition.
- Fig. 8. A crystalline oolitic spherule, showing perfect concentric arrangement around a nucleus which has become converted into calcite. Coralline Oolite, Radcliff Point, near Weymouth. $\times 70$ diam.

[Most of the figures are represented imbedded in the limestone.]

DISCUSSION.

The PRESIDENT remarked on the importance of investigating the question whether these appearances are organic or not. We should take warning from *Eozoon* as to possible differences of opinion in the

interpretation of tubular structure, though these mystifying appearances seem more common in serpentine and chalcedony than in calcite. In the bodies depicted, the wall, the irregularity, and the manner in which the tubes curve round each other are in favour of their being organic.

Prof. RUPERT JONES thought that these forms were not due to mineral, but to organic laws. The surrounding enallostegian lines looked like tubuli (he was not prepared to ignore those of *Eozoon*), quite analogous to those mentioned by the Author, and perhaps to those of the small knots of *Serpulæ* in the Chalk; but whether the latter are continuous or not, is doubtful. As to difference in the size of the tubules there was not much in that. He referred to the views of Schafhäütl, who had given distinct names to oolitic granules from the Alps of South Bavaria. He suggested that some markings in flint had been due to thread-like Foraminifera in the chalk. He congratulated the Author on his successful research; also on his not claiming that all oolitic granules were derived from this one source.

Dr. EVANS, while disclaiming any special knowledge of the subject, suggested that the appearances might be interpreted on the supposition of an organism boring into a comparatively hard substance. He also referred to other difficulties in the way of the Author's interpretation, though there could be little doubt as to the organic nature of the structures.

Dr. HINDE, who had seen most of the known species of *Girvanella*, spoke of the wide distribution of these organisms. Dr. Bornemann had found them forming a bed of rock of Cambrian age in Sardinia, and he referred them to calcareous algæ; Prof. Nicholson originally noted their occurrence in the Ordovician rocks of Ayrshire; and he (the speaker) had found them in limestones of similar age in the Province of Quebec. They are undoubtedly organic; the tubes have definite imperforate walls of granular calcite, distinct both from the matrix and from the calcite infilling them, and they could not therefore be mere borings. The 'Challenger' Foraminifera, with which they were compared by Dr. Brady, are considerably larger and are also built up of arenaceous grains. *Girvanella* had been erroneously described as a Calcsponge, and compared to knots of *Serpulæ*, but we can hardly conceive that worms inhabited such small tubes.

Dr. HICKS referred to the walls of borings, in the Cambrian and Silurian rocks, giving an appearance of being distinct from having been lined with calcite.

Prof. BONNEY felt sure the specimens had no place in the mineral kingdom, and organic fragments were common in them, for there had been no great degree of molecular change in these beds. What organism the *Girvanella* might be he would not venture to say.

Prof. JUDD referred to the oolitic grains from the coral-reefs of the Bahamas, which had been described by De la Beche and Sorby. The study of these recent oolitic grains might be expected to lead to important results. He had found in them structures similar to those described by Mr. Wethered, but the structures are finer even

than that of *Girvanella incrustans*; the tubuli also anastomose greatly: the little tubuli are sometimes filled with calcite, at other times with calcareous mud.

Rev. H. H. WINWOOD congratulated the Author and the West of England on this piece of work. Stoddart, after examination, had failed to discover any organisms. He referred to Mr. Wethered's happy knack of discovery.

The AUTHOR said that he prepared his own slides, and that in some cases it was a mistake to mount them in Canada balsam, as its high refractive power obliterated the structure. Possibly it was for this reason that Dr. Hinde had not observed the structure of *Girvanella* to the extent he, the Author, had done in oolitic granules. Those Fellows who had seen his slides agreed with him that the *Girvanella*-structure was organic, but those who had not seen them doubted it; clearly those who had seen the slides were the best judges. To Dr. Hicks he replied that the walls were not formed of calcite; quite the contrary, it was only the interior of the tubules which contained it as an infilling mineral. The discovery made by Prof. Judd in recent oolite from the Bahamas was most important; and as the tubules were branching he suggested the possibility of their being allied to *Syringamma fragilissima*.

As to Dr. Evans's remarks, half an hour's examination of the actual slides would convince him that he was mistaken in the views he had expressed. The Author thanked the Fellows who had discussed his paper.

16. *On a CROCODYLIAN JAW from the OXFORD CLAY of PETERBOROUGH.*
By R. LYDEKKER, Esq., B.A., F.G.S., &c. (Read March 12, 1890.)

THE symphysis of the mandible of a Thecodont Reptile recently obtained from the Oxford Clay near Peterborough, by Mr. A. N. Leeds, and entrusted to me for description, affords evidence of a species new to the English fauna, and apparently belonging to a genus not hitherto recorded from the Oxfordian.

The specimen, which is represented of one third of the natural size in the diagram (fig. 2), belonged to a comparatively large reptile, and comprises the anterior portion of the splenial and dentary elements; that part of the dentary which still remains including the whole of the alveolar region. The symphyseal portion of the jaw is very broad and flat, with a rugose inferior surface; but the original flatness has been abnormally increased by pressure, which has crushed the oral floor into the dental alveoli, and has thus destroyed the original circular contour of the latter. The splenials enter extensively into the formation of the symphysis, reaching as far forward as the seventh tooth on the left side. No traces of teeth remain, and the empty dental alveoli are thirteen in number on the left, and twelve on the right side. The alveoli, in their original condition, must have been nearly circular; and none of them are markedly enlarged, or separated from one another by spaces in the neighbourhood of the muzzle. On the inferior aspect the dentaries and splenials are completely ankylosed together, this feature, taken together with the rugose surface of the bones themselves, indicating that the specimen belonged to a fully adult animal. The length of the symphysis on the oral aspect is close upon 8 inches, while the length of the alveolar portion of the dentary is some 9 inches.

The thecodont character of this jaw indicates that its owner belonged either to the Sauropterygia or the Crocodylia, and it is necessary, in the first place, to point out why I refer it to the latter Order. I do not, indeed, know what characters there are by which it is possible to say at once whether a given thecodont mandible is Sauropterygian or Crocodylian; and it is therefore necessary to rely upon empirical means of distinguishing between the two. Now it is quite clear that the specimen under consideration does not belong either to *Pliosaurus* or to *Peloneustes*; while in the other Sauropterygians of the Oxford Clay, which I have provisionally included in the genus *Cimoliosaurus*, the mandibular symphysis is very short, and the whole jaw very much smaller than in the present specimen. Compared with Crocodylians, the mandible before us agrees in the rugose character of its outer surface, and also in the relations of the splenials to the symphysis; and since, as will be shown below, it agrees in all essential features with an undoubtedly Crocodylian jaw, I take it for granted that the specimen really belongs to a Crocodylian genus.

Figs. 1-4.—*Mandibles and Teeth of Suchodus durobrivensis and Metriorhynchus Moreli.*

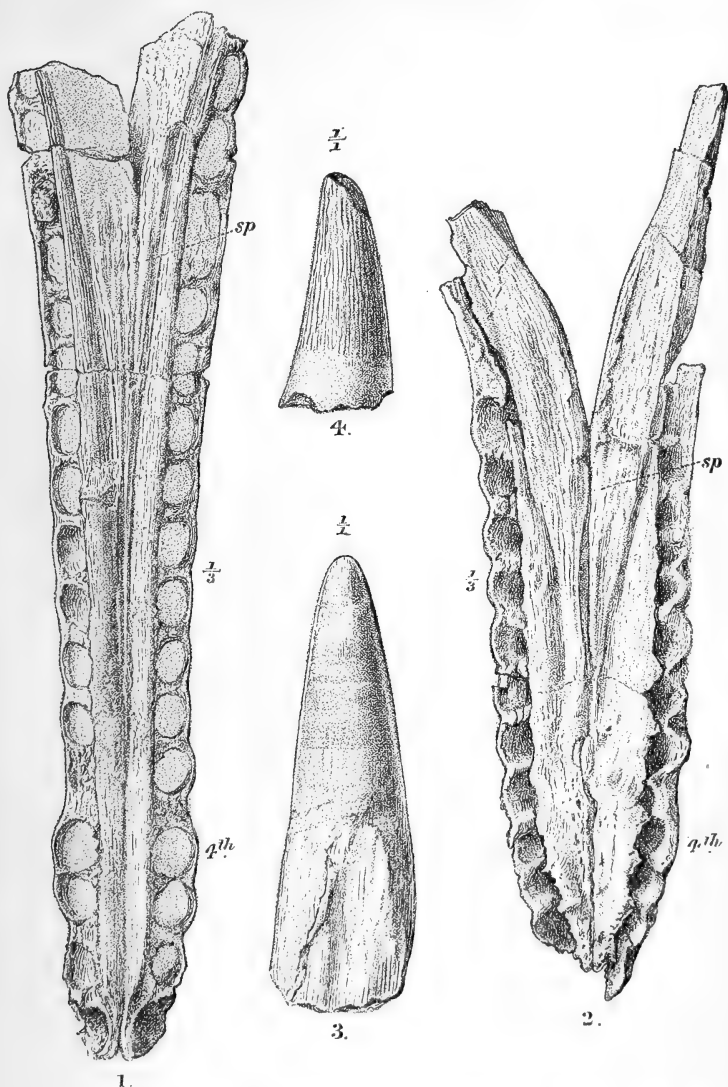


Fig. 1. Anterior portion of the mandible of *Metriorhynchus Moreli*; from the Oxford Clay of Wiltshire. (Brit. Mus. No. 46323.)
 2. Anterior portion of the mandible of *Suchodus durobrivensis*; from the Oxford Clay of Peterborough.
 3. Outer side of tooth of *Suchodus durobrivensis*; from Peterborough.
 4. Tooth of *Metriorhynchus*; from Willesden.

Compared with the Crocodilians from the Oxford and Kimeridge Clays described by Deslongchamps, in his 'Notes Paléontologiques,' under the names of *Steneosaurus* and *Metriorhynchus*, the present specimen differs, among other features, from all those species of which the mandible is known, by the smaller number of teeth, this character alone being quite sufficient to prove its generic distinctness from *Steneosaurus*. In the mandible of a typical species of *Metriorhynchus*, like *M. Moreli* (Deslongchamps, *op. cit.* pl. xxii., and fig. 1 of the diagram illustrating this paper), there are nineteen alveoli, of which the first four are larger than the others, and are separated from one another by considerable intervals, so that the anterior portion of the mandible is quite unlike the specimen before us. In *M. brachyrhynchus* of the Oxford Clay (*op. cit.* pl. xxiii.) the number of alveoli in the upper jaw was less than in *M. Moreli*; but if Deslongchamps is correct in his restoration of the muzzle, the extremity of the mandible must have been similar to that of *M. Moreli*, and in any case the number of lower teeth (judging from the relative number of upper and lower alveoli in the latter) can scarcely have been less than fifteen. It may therefore be safely considered that the specimen cannot be referred to the genus *Metriorhynchus*, and also that it is specifically distinct from all the forms which have been described under that name.

The genus *Teleidosaurus** of the Fuller's Earth (which in some respects connects *Steneosaurus* with *Metriorhynchus*) makes a decidedly nearer approach to the present specimen, as is shown by the reduction in the number of the teeth and the great width of the oral aspect of the skull. In *T. Calvadosi* and *T. Joberti* the number of lower teeth is, however, 20 or 21; and the anterior alveoli are spaced, with a very long interval between the 4th and 5th in *T. Joberti*.

If, however, our specimen be compared with the large Crocodilian originally described from the Kimeridgian of France under the name of *Machimosaurus mosce*†, and to which I have referred ‡ the mandible and part of the cranium from the equivalent beds of Dorsetshire figured by Sir R. Owen § as *Pliosaurus trochanterius*, we shall find a marked resemblance between the two. In both specimens the number of alveoli is very nearly the same, the Kimeridgian one having 14 on each side||, and the present one 13 on one side and 12 on the other. In both the splenial extends as far forward as the seventh alveolus; while the anterior alveoli in both are not separated from one another by longer intervals. The Oxfordian mandible is, indeed, rather more pointed at the extremity of the symphysis, and is perhaps more flattened at the symphysis. The total

* See Deslongchamps, *op. cit.* pls. xviii., xix.

† See Sauvage & Lienard, *Mém. Soc. Géol. France*, sér. 3, vol. i. pl. xxiii.

‡ *Cat. Foss. Rept. Brit. Mus.* pt. i. p. 104.

§ Reptiles of the Kimeridge Clay (*Mon. Pal. Soc.* for 1868), pt. 3, pl. iii. figs. 3-5.

|| In the British Museum Catalogue it is stated that there are 13 alveoli, but the anterior one is evidently broken away on either side.

length of the Kimeridgian mandible is 52 inches, the portion of the symphysis in advance of the extremity of the splenials being one fifth of the whole length. Calculating the dimensions of the present mandible on these proportions we should have a total length of about 25 inches.

The resemblance to the above-mentioned jaw which I have referred to *Machimosaurus mosæ* is, indeed, so close, that were it not for other evidence, I should have been inclined, in spite of its much smaller dimensions, to regard the present specimen as indicating another representative of the same genus.

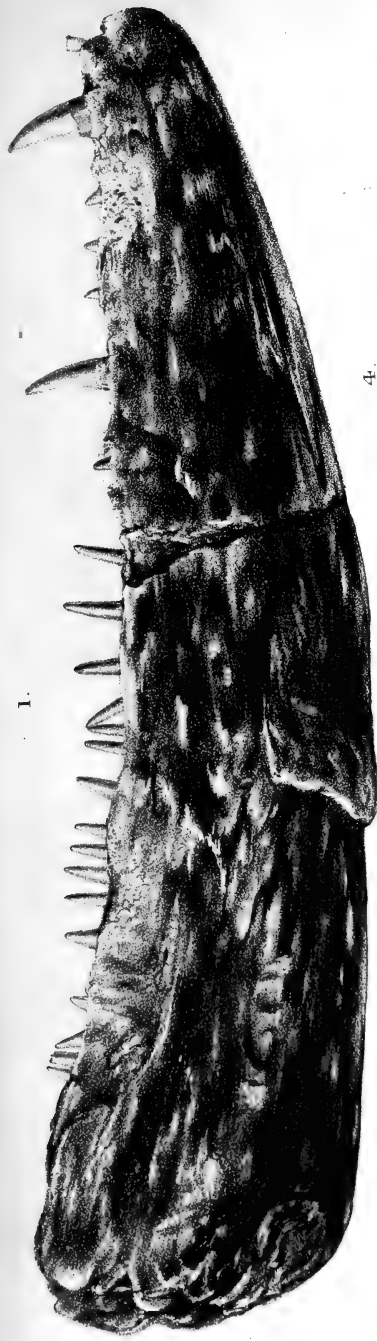
In his collection Mr. Leeds has, however, an imperfect crocodylian skull from the Oxfordian of Peterborough, which appears, both to him and to myself, to belong to the same form as the present specimen, and which certainly cannot be referred to *Machimosaurus*. The mandible of that specimen agrees precisely in size with the one before us, and has a symphysis of just the same length; unfortunately, however, it has been crushed in the opposite direction, that is to say, the symphyseal region has been compressed from side to side, so as to render comparison of details almost impossible. Ten alveoli can now be traced in the right ramus, some of which still retain their teeth; and it is quite probable that there may have been two or three more. There is no trace of a long interval between the 4th and 5th alveoli, and I have accordingly little or no hesitation in regarding this skull as specifically identical with the detached mandible. The cranium of the second specimen has the laterally placed orbits characteristic of *Metriorhynchus*, and it approximates in contour to the cranium from the Oxfordian of Normandy, figured by E. Deslongchamps in his 'Notes Paléontologiques,' pl. xxiii. as *Metriorhynchus brachyrhynchus*. The English cranium has, however, a broader muzzle than in the latter, the nasals are relatively shorter and wider, and do not reach the premaxillæ, and the number of teeth was evidently considerably less, although the exact number cannot be determined. If Deslongchamps is correct in his restoration of the missing muzzle of *M. brachyrhynchus*, there must have been at least 20 upper teeth, while in the present form, calculating from the lower jaw, there were probably only some 15 teeth in the upper jaw. The mandible and teeth of *M. brachyrhynchus* are unknown, and since the restoration of the muzzle is conjectural, it is quite possible that it may have differed considerably in these points from the more typical representatives of the genus, as it certainly does in the shortening of the rostrum. The teeth of the skull in the Eyebury Collection (diagram, fig. 3) are distinguished from those of *Metriorhynchus* (*ibid.* fig. 4) by their more compressed and expanded crowns, of which the enamel is nearly smooth, instead of having the strongly marked vertical striæ which are so characteristic of those of the latter. The teeth of the present form are, indeed, more like those of *Geosaurus* (*Dacosaurus*), although readily distinguished by the absence of serrations on the fore-and-aft carinæ. These teeth, it may be observed, agree precisely in size with the alveoli of the figured mandible.

If, then, I am right in regarding the skull in the Eyebury Collection and the figured mandible as belonging to one and the same species, we have evidence of the existence of a Crocodilian allied in cranial characters to *Metriorhynchus*, but with a shorter and wider skull, furnished with fewer teeth, which have smooth enamel and compressed crowns like those of *Geosaurus*, while the mandible has no long interval between the 4th and 5th teeth, and thus approximates to *Machimosaurus*. In the width of the palate and mandible this form also seems to approximate to *Teleidosaurus* of the Fuller's Earth, although the latter is at once distinguished by the greater number of teeth and the Steneosauroid type of cranium.

The foregoing comparisons indicate that we have to do with a Crocodilian allied to *Metriorhynchus*, but certainly distinct from all named forms with which I am acquainted. The characters pointed out as distinguishing it from the typical species of *Metriorhynchus* seem, moreover, to be sufficiently important to be regarded as of generic value, when we take into account the distinctions on which genera are based in the Crocodilian order. I propose therefore to regard the figured mandible as the type of a new genus and species to be named *Suchodus durobrivensis*, the characters of this genus being those given above.

I have said that the mandible of *Suchodus* differs from that of *Metriorhynchus* by the absence of a long interval between the 4th and 5th teeth, and of a distinct terminal expansion; and the interalveolar portion is also wider than in the typical forms of the latter (diagram, fig. 1). When the mandible was in its original shape, it is, however, probable that the interalveolar portion was raised in the same manner above the level of the alveoli.

1.



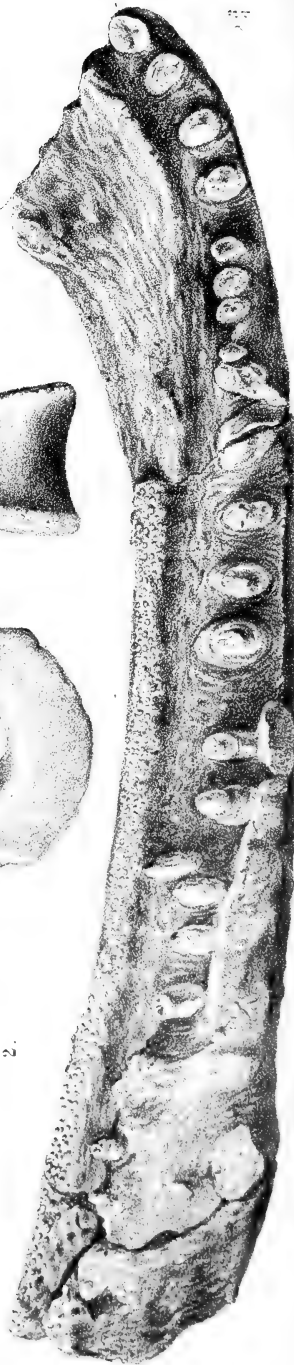
4.



3.



2.



NEW LABYRINTHODONTS

Mintern Bros. del et lith.

17. *On two new SPECIES of LABYRINTHODONTS.* By R. LYDEKKER, Esq., B.A., F.G.S., &c. (Read March 12, 1890.)

[PLATE XII.]

A. *Mandible from the Carboniferous of Scotland.*

EXCLUSIVE of the smaller forms like *Ophiderpeton*, *Ceraterpeton*, &c., the Labyrinthodonts hitherto described from the British Carboniferous comprise *Anthracosaurus*, *Loxomma*, *Pholiderpeton*, and *Pteroplax*. Of these the type specimen of *Anthracosaurus* was obtained from the Coal-Measures (Upper Carboniferous) of Lanarkshire *; while the types of the second and third genera come from the ironstone of Gilmerton, near Edinburgh, which is generally considered to represent the upper part of the English Mountain-Limestone (Lower Carboniferous). *Pteroplax* is from the Coal-Measures of Northumberland. Several other generic names have, indeed, been applied by Mr. T. P. Barkas † to remains of reputed Labyrinthodonts from the Coal-Measures of Northumberland; but such of these specimens as are truly referable to the group in question appear to belong to *Loxomma* and *Anthracosaurus*. It is important to observe that a jaw from the Lower Permian (Rothliegendes) of Bohemia has been referred by Dr. Fritsch ‡ to a species of *Loxomma*, thus indicating, if the determination be accepted, the persistence of this generic type from the Lower Carboniferous to the Lower Permian. The Northumberland specimens indicate the occurrence of *Loxomma* in the Coal-Measures; while a specimen in the British Museum leads me to conclude that *Anthracosaurus* dates from the Lower Carboniferous of Burdie House.

Of the four genera mentioned above, *Pteroplax* and *Pholidogaster* are represented by species of much smaller size than the others: and since it is quite evident that they have no affinity with the specimen I am about to describe, it will be unnecessary to make any further mention of them.

In *Loxomma* the teeth are characterized by the large size of the crowns, which are straight and laterally compressed, with very prominent fore-and-aft carinæ, so that they present a striking resemblance to some types of spear-heads. These teeth have a highly polished and nearly smooth surface; and in the lower jaw their arrangement is very irregular. Further, the outer surface of the mandible is entirely covered with a net-like sculpture, and the depth of the ramus is not very great.

In *Anthracosaurus*, on the other hand, the teeth (as described by Mr. Atthey) have subcylindrical crowns, without fore-and-aft carinæ, and with an oval transverse section at the base, of which the

* See Quart. Journ. Geol. Soc. vol. xix. p. 56, note.

† 'Coal-Measure Palæontology.'

‡ 'Fauna der Gaskohle,' etc. vol. ii. p. 16.

larger diameter is placed at right angles to the axis of the jaw. The mandible is readily distinguished from that of *Loxomma* by the slight development of the sculpture on the outer surface, and also by the great vertical depth of the hinder part of the dentary element, which causes the inferior border of the ramus to assume a highly arcuated contour.

Having thus briefly sketched the salient features of the teeth and mandible of *Loxomma* and *Anthracosaurus*, we may proceed to notice the specimen forming the subject of this part of the present communication. The specimen in question is a slab of shale, exhibiting the external aspect of the greater portion of the right dentary bone of a comparatively large Labyrinthodont from the Lower Carboniferous of Gilmerton; it is now preserved in the British (Natural History) Museum, where it bears the register-number R. 310, and was formerly in the collection of the late Earl of Enniskillen. That this jaw belonged to a Labyrinthodont is at once evident from the internal structure of the teeth, as shown by fractured specimens. It is figured on a scale of $\frac{3}{4}$ in Plate XII. fig. 1. The portion of the dentary remaining is about 8 inches in length and contains a number of teeth, some of which are entire, while others are more or less broken. The jaw is of moderate depth at the hinder portion of the dentary, and thereby approximates to *Loxomma*, from which, however, it is at once distinguished by the slight development of the external sculpture; so that in this respect it is more like *Anthracosaurus*. At the anterior extremity of the jaw there is the broken base of a large tusk-like tooth*, immediately followed by an entire tooth of similar type; then we have an interval of about an inch and a half, occupied by the bases of smaller teeth, which are again succeeded by the stumps of two large tusks. The remainder of the alveolar margin is occupied by a regular series of small teeth, many of which are well preserved. The whole of the teeth have a cylindrical section at the base, while their crowns are smooth, with a convex external and a somewhat flattened inner surface, and there are distinct, although not very prominent, fore-and-aft carinæ. Distinct grooves are visible at the base of each tooth, which tend to become obscure as they approach the smooth summit: and there is a more or less marked tendency to a backward curvature of the summit of the crown; while each tooth has a large pulp-cavity and strongly marked labyrinthine foldings at the base.

The above description is quite sufficient to indicate that we have to do with a form which is generically distinct (in the sense in which generic terms are employed in the Labyrinthodonts) both from *Loxomma* and *Anthracosaurus*, and therefore from all British Carboniferous representatives of the Order. Among the numerous forms described by Dr. Fritsch from the Lower Permian of Bohemia, the genus *Macromerion*† (or, more correctly, *Macromerium*), which was probably allied to *Anthracosaurus*, presents, however, such a marked

* These broken teeth are not shown in the figured aspect of the specimen.

† Fritsch, 'Fauna der Gaskohle,' etc. vol. ii. pp. 37-41.

resemblance in dental characters to the specimen under consideration as to lead to the conclusion that the latter cannot be generically separated. The teeth of the several Permian species of *Macromerium* are described as conical, with the crowns smooth near the summit but deeply grooved inferiorly, and bearing distinct fore-and-aft carinæ; while they have a well-marked pulp-cavity, and complex labyrinthic foldings at the base. The figures given by Fritsch, together with a cast of part of the jaw of the typical *M. Schwarzenbergi*, now in the British Museum, show that the outer surface of the teeth was markedly convex; while the summits of the crowns were more or less bent backwards. *M. Schwarzenbergi* was a much larger form than the one under consideration; but the fragmentary upper jaw represented in pl. lxxvii. fig. 15 of the work cited, under the name of *M. bicolor*, has teeth agreeing in size with those of the Gilmerton jaw. The magnified views of these teeth, given in plate lxx. of the same volume, show an internal structure which, so far as I can determine, is very similar to that of the Gilmerton specimen. The crowns of the upper teeth are, however, more curved backwards in *M. bicolor*; and if the same condition holds good in the lower jaw, we shall have a character by which the Carboniferous species can be readily distinguished from the Permian one. The lower geological horizon of the Gilmerton jaw is, however, of itself sufficient to indicate its specific distinctness from *M. bicolor*, and I therefore propose to make that specimen the type of a new species, which I refer (at least provisionally) to the genus *Macromerium*, with the name of *M. scoticum*. This species may be defined as agreeing in size with *M. bicolor*, but with the crowns of the lower teeth less recurved than the upper ones of the latter.

If I am right in the generic reference (and, in any case, the Carboniferous form must be closely allied to *Macromerium*), we shall have the same vertical range in the case of *Macromerium* as is given by Dr. Fritsch in that of *Loxomma*.

B. *Mandible and Intercentrum from South Africa.*

Among a series of specimens from the Karoo system of South Africa, presented to the British Museum by Sir R. Owen, is the greater portion of the right ramus of the mandible of a comparatively large Labyrinthodont, together with an intercentrum which, from its size and mineral condition, appears to have belonged to the same individual. The precise locality where these specimens were obtained is unknown; and there is likewise no evidence to show whether they were derived from the Beaufort or Stormberg beds of the Karoo system.

The mandibular ramus is in three fragments, which, when put together, indicate that its entire length was somewhere about 40 centimetres. The portions remaining comprise the entire articular region and the greater portion of the dentary and associated elements, together with a fragment of the missing intermediate portion. The anterior portion of this mandible is represented, from

the oral surface, on a reduced scale in Plate XII. fig. 2. The outer surface of the bone is ornamented with a coarsely reticulate and ridged sculpture, while the broken teeth show the labyrinthic internal structure characteristic of the Labyrinthodonts; so that there is no hesitation in referring the specimen to that group of Amphibians. The unfigured articular region is fairly well preserved, and shows that there was no postarticular process behind the glenoid cavity—a feature in which this jaw agrees with that of the North-American genus *Eryops* and the European *Loxomma*. In the dentary bone the bases of twenty-five teeth now remain, these bases having an ovoid section, with the longer diameter at right angles to the axis of the jaw. Externally to this row of teeth there is a well-marked bony parapet, forming the summit of this border of the jaw. The most remarkable feature displayed by the specimen is, however, the presence of a narrow band of about half an inch in width, situated on the bone of the jaw, immediately on the inner side of the alveolar area, and covered with a number of minute knob-like denticles, much resembling in appearance the so-called “shagreen” of the Elasmobranchiate fishes. Apparently this band of denticles stopped short of the symphyseal region. Each denticle presents the appearance of a veritable tooth, having a distinct pulp-cavity.

The intercentrum, already referred to, is figured of the full dimensions in Plate XII. figs. 3, 4. This bone presents the horse-shoe-like form characteristic of the “rhachitomous” Labyrinthodonts, and shows the presence of a distinct facet (*a*) for the articulation of the capitulum of the rib. The absence of ossification in the axial region of the bone shows that it belongs to a Labyrinthodont and not to an Anomodont, since in the latter group the intercentra always form complete wedges. This is confirmed by the presence of a rib-facet; since the only known Anomodont with an intercentral costal articulation is the American genus *Embolophorus*. I may take this opportunity of mentioning that the evidence appears to be absolutely conclusive as to the correctness of Prof. Cope's identification of the Labyrinthodont intercentrum (hypocentrum of Gaudry) with the Anomodont intercentrum, as may be verified by a comparison of specimens of the vertebral column of the Labyrinthodont *Eryops* and the Anomodont *Embolophorus*, acquired a few years ago by the British Museum.

With regard to the affinities of the form indicated by these two specimens, it may be observed, in the first place, that the only Labyrinthodont hitherto described from the Karoo system, which can be compared in point of size to the present form is the imperfect skull described and figured by Sir R. Owen in the Society's ‘Journal’* under the name of *Rhytidosteus capensis*. Assuming that specimen to be adult, the superior size of the mandible under consideration would of itself indicate the specific distinctness of its owner from *R. capensis*. A comparison shows,

* Vol. xl. p. 333, pl. xvii. (1884).

however, a well-marked generic distinctness in the presence of a postarticular process to the mandible of the latter. The oral surface of the mandible of *Rhytidosteus* is, moreover, characterized by the absence of the parapet externally to the dental series, which forms such a marked feature in the present mandible; while, in place of a band of denticles situated *internally* to the marginal teeth, *Rhytidosteus* has a similar band placed *externally* to the latter*. We have, therefore, decisive evidence of the generic distinctness of the form under consideration from *Rhytidosteus*.

I have hitherto been unable to find among the larger Labyrinthodonts any description of a band of denticles situated as in the figured mandible. In part of a mandible preserved in the British Museum (No. R. 570, a, b), from the reputed Permian of Texas, which appears to belong to *Eryops megacephalus* of Cope, there is, however, a precisely similar band of denticles. Now, as I have already mentioned, *Eryops* agrees with the present form in the absence of a postarticular process to the mandible, and also in having rhachitinous vertebræ; and since the above-mentioned mandible agrees with the African one in the presence of this band of denticles, and also presents no characters by which it can be generically distinguished from the latter, there is a presumption that the Labyrinthodont under consideration indicates either an African representative of *Eryops* or a closely allied form. The African mandible indicates, however, a somewhat smaller form than the typical *E. megacephalus*; and it also seems to differ from the latter in that the anterior teeth are less enlarged in proportion to the hinder ones. Again, the African intercentrum differs from the corresponding element of the American form in the absence of ossification of the axial region; but it does not seem to me that this feature is necessarily a generic difference. I therefore propose to refer the African form provisionally to the genus *Eryops*, with the name of *E. Oweni*, the mandible being taken as the type.

In conclusion, it may be observed that the reptilian and amphibian faunas of the reputed Permian of Texas and the Karoo system of South Africa are both remarkable for the abundance of more or less closely allied types of Anomodonts; while the first-named fauna also contains numerous forms of rhachitinous Labyrinthodonts. The remains of the latter group hitherto described from the Karoo system are less common; but it is not surprising to find among them a form which cannot at present be satisfactorily separated from one of the American genera. A connexion between the Mesozoic faunas of Africa and America is already known to us by the identification of the Brazilian genus *Stereosternum* with *Mesosaurus* from the Kimberley beds of the Karoo system; and the present form adds further evidence of this community of types. I have recently published † the description of a species of Labyrinthodont from the Karoo system, which is referred to the Australian genus *Bothriceps*;

* No mention of this band of denticles, nor of the similar denticles with which the palate is covered, occurs in Sir R. Owen's memoir.

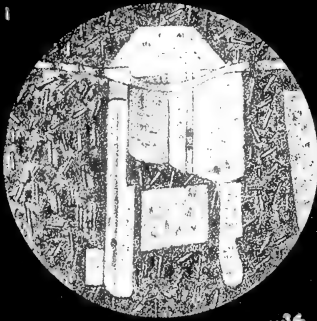
† Ann. Mag. Nat. Hist. ser. 6, vol. iv. p. 475 (1889).

and this, with the evidence previously recorded, serves to show that the Anomodonts and Labyrinthodonts of the Permian of Texas, of the probably equivalent beds of Brazil, and of the Karoo system of the Cape were closely related, not only to one another, but also to those of the Gondwanas of Central India and the Hawkesbury beds of Australia; while more or less closely allied types also occur in the Upper Permian of the Urals.

[Since the foregoing was written I have been informed by Dr. E. Fraas that the Munich Museum possesses some rhachitomous Labyrinthodont vertebræ from the Karoo system, which are probably referable either to the form described above or to *Rhytidosteus*.]

EXPLANATION OF PLATE XII.

- Fig. 1. Outer aspect of the anterior portion of the right ramus of the mandible of *Macromerium scoticum*; from the Lower Carboniferous of Gilmerton, near Edinburgh. $\frac{2}{3}$ nat. size. (Brit. Mus. No. R. 310.)
2. Oral aspect of the anterior portion of the right ramus of the mandible of *Eryops Oweni*; from the Karoo system of South Africa. $\frac{2}{3}$ nat. size. (Brit. Mus. No. R. 466.)
- 3, 4. Terminal and left lateral aspects of an intercentrum of *Eryops Oweni*; from the Karoo system of South Africa. Nat. size. *a*, facet for capitulum of rib. (Brit. Mus. No. R. 470.)



$\times \frac{32}{3}$



$\times \frac{40}{3}$



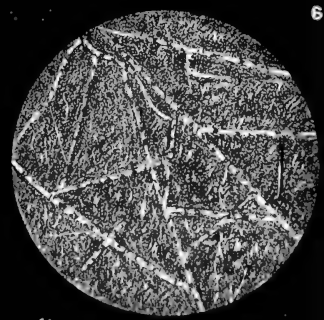
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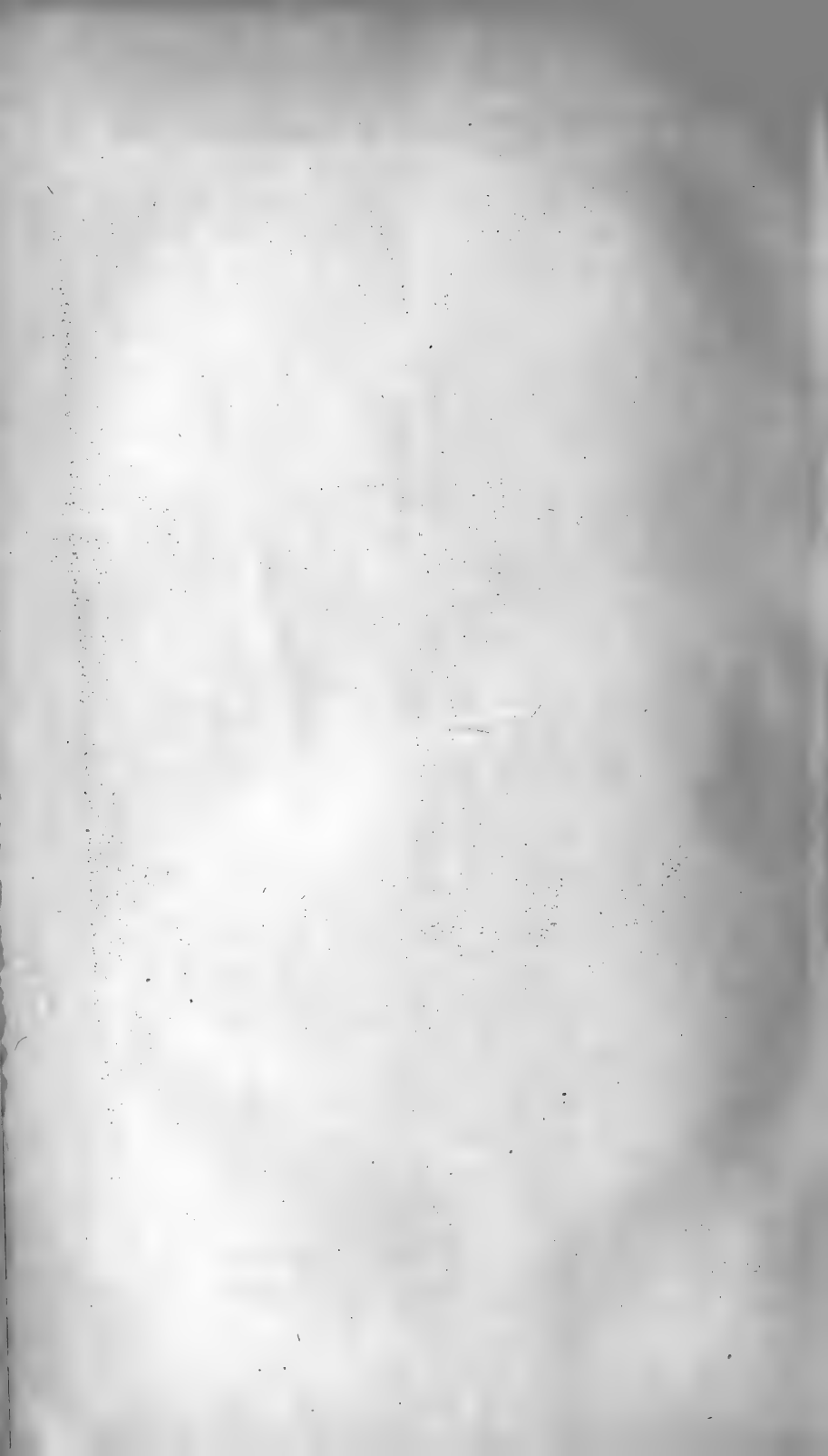
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$\times \frac{28}{3}$



$\times \frac{41}{3}$



18. *The VARIOLITIC ROCKS of MONT GENÈVRE.* By GRENVILLE A. J. COLE, Esq., F.G.S., and J. WALTER GREGORY, Esq., F.G.S., F.Z.S. (Read February 5, 1890.)

[PLATE XIII.]

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I. INTRODUCTION.

THOUGH the series of structures found in the acid igneous rocks has now an almost complete parallel in the basic group, a few gaps in the latter still remain unfilled. The spherulitic and perlitic structures of ordinary rhyolites are now well known in the basic lavas; but the only rock that seems homologous with the pyromerides of Jersey and North Wales is that known as the Variolite of the Durance, which has been described as the selvage of a compact euphotide. Impressed by the perlitic and other structures of this rock, one of us suggested in 1888* that it was a devitrified tachylite; while a few weeks later, the other attempted to settle the question of its true nature by an examination of the rock in the field. As a series of heavy snowstorms prevented anything being done on that occasion, we visited Mont Genève together last August, to examine the igneous mass to the south of the pass, which had been mapped by Lory as an intrusive euphotide, and from which it was probable that the variolites of both the Durance and the Dora had been derived.

II. PREVIOUS WORK ON THE VARIOLITE OF THE DURANCE.

Variolite is a rock that has been of interest since the time of the Romans on account of its supposed medicinal value; its European sources, however, were lost till it was found near Lucca, early in the 17th century; previously the supply had been drawn from America, where it had long been known as "gamaicu." Specimens of the "lapis variolatus" of Lucca were

* G. A. J. Cole, "On some additional Occurrences of Tachylite," *Quart. Journ. Geol. Soc.* vol. xlv. p. 307.

figured and described by Aldrovandus* in 1648, but no definite opinion as to the nature of the rock of this locality can be obtained from his work. A figure, however, given by Langius †, in 1705, of a "variolites Lucernensis" from the Emmenthal is unmistakable. The rock was subsequently described from other localities, as by Bruckmann ‡ in 1734 and by Demeste § from the bed of the Durance in 1779. Wallerius ¶ in 1747, and Bertrand ¶¶ in 1763, published classifications of Variolite, as by this time different rocks had been included under the same name. Hitherto pebbles only had been found, but in 1775 the Abbé Rozier's 'Journal' ** announced its discovery *in situ* in the "Servières" valley, by MM. Faujas de St. Fond and Guettard; the former, however, gave in 1781 †† an account of his observations, and from this it is obvious that he and his companion had only found fallen masses of rock on the talus-slopes; in the same contribution Faujas called the Durance rock "*lapis variolatus viridis verus*," to distinguish it from the amygdaloids that had been confounded with it. Valmont de Bomare's discovery of native silver in the Variolite of the same district led him to examine it, with the result that he contended for ‡‡ the common origin of varioles and ground-mass (or "variolin" as it was called by Delamétherie).

Though Buffon §§ had in 1786 clearly indicated Mont Genève as the source of variolite, Morozzo |||| threw doubt on its occurrence there. Fournet's elaborate "Mémoire sur la géologie de la partie des Alpes comprise entre le Valais et l'Oisans," ¶¶¶ contained an important addition to the knowledge of variolite: from his descriptions *** he seems to have collected, probably from the bed of the Durance, compact diabase, perlitic variolite, and porphyritic diabase. Elie de Beaumont probably found variolite *in situ*, but no record of his observations seems to have been published, and

* Aldrovandus, UL, 'Musæum Metallicum in libros iii. distributum;' Bononiæ: 1648: p. 883.

† Langius, Carl Nic., 'Historia Lapidum figuratorum Helvetiæ ejusque viciniae;' Lucernæ: 1705, pp. 40-1.

‡ Bruckmann, 'Centuria Epistolarum Itinerarium,' vol. i. ep. xxxi. Wolfenbuttelæ, 1742.

§ 'Lettres du Doct. Demeste au D. Bernard sur la Chymie, Docimasie,' &c. Paris, 1779 (quoted by Buffon).

¶ Wallerius, 'Mineralogia, Eller Mineral-Riket, Indelt och beskrifvit,' Stockholm: 1747, p. 409 (French edition, 1753).

¶¶ E. Bertrand, 'Dictionnaire raisonné universel des fossiles propres et des fossiles accidentels,' Le Hage, 1763, t. ii. pp. 238-9.

** "Observations sur la physique," t. xvi. (1775) p. 517.

†† Faujas de St. Fond, 'Histoire Naturelle de la province de Dauphiné,' Grenoble: 1781, t. i. p. 253. See also Faujas de St. Fond, 'Histoire Naturelle des Roches de Trapp,' ed. 2 (Paris, 1813), p. 26, footnote.

‡‡ 'Dictionnaire raisonné universel d'Histoire Naturelle,' t. viii. Lyon: 1791.

§§ 'Histoire Naturelle des Minéraux; sur la variolite du Piémont,' t. iv. (Paris, 1786) pp. 395-8.

||| Mém. Acad. Roy. Sciences (Turin), vol. v. 1793, pp. 165-72.

¶¶¶ Ann. des Sci. Physiques et Nat. Soc. Roy. d'Agric. Lyon, sér. i. t. iv. (1841) pp. 105-183, 483-560; ix. (1846) pp. 1-112; sér. ii. t. i. (1849) pp. 185-259, pl. i.

*** Fournet, *ibid.* sér. i. t. iv. p. 155.

his collection from Mont Genève was described by Delesse *; Scipion Gras certainly examined it *in situ*, and in consequence denied † the volcanic origin of either the variolite or any of the rocks associated with it.

Delesse's memoir "Sur la variolite de la Durance" ‡ was the first serious attempt to treat the rock from a modern point of view; the paper was illustrated by a coloured plate, which was supplemented by an exquisite lithographic drawing in the same author's "Recherches sur les roches globuleuses" §. Delesse was led by his examination of the collection and acceptance of the field-work of M. Elie de Beaumont to accept the passage from euphotide to serpentine, and to regard the variolite as a selvage to the euphotide.

Supplementing the laboratory-researches of Delesse, Lory made in the field a series of observations which have long appeared to be conclusive. In 1861 the Geological Society of France, under his guidance, spent one day in the variolitic area; visiting the Col du Gondran, they saw the largest gabbro mass, and having probably met with this rock again in the Chenaillet Valley, they greatly exaggerated its importance ||. Lory argued on that occasion, in opposition to M. Hébert, that the melaphyre-like rock was only an "euphotide porphyroïde, comme la variolite serait une euphotide globulaire," and that the latter was a structural modification of the gabbro on its selvages. These views Lory indicated clearly in 1863 in his map and sections of the Briançonnais ¶; in the latter he represented this igneous massif as composed of euphotide intrusive in the surrounding schists, and with a selvage of variolite on the west and of serpentine on the east. In 1864 he repeated these views in a rather detailed account of the area in question **; in his well-known memoir he reaffirmed the passage from euphotide to serpentine on the one hand and to porphyry and variolite on the other ††.

The first application of the microscope to the study of thin sections of the variolite of the Durance was made by Inostranzev in 1874, in his valuable paper "O Variolitye" ‡‡, in which he described in detail the variolite of a new locality, Yalguba in Olonetz, and devoted several pages and figures to the microscopic structure of that of

* Ann. Mines, sér. 4, t. xvii. p. 130.

† Gras, Sc., "Introduction à un Essai sur la constitution géologique des Alpes centrales de la France et de la Savoie," Bull. Soc. géol. France, 2^{me} sér. t. i. pp. 723-4.

‡ Ann. des Mines, sér. 4, t. xvii. pp. 116-131, pl. i. Compt. Rend. xxx. pp. 741-743; Bull. Soc. géol. Fr. 2^{me} sér. t. vii. pp. 427-431.

§ Mém. Soc. Géol. Franc, 2^{me} sér. t. iv. (1852) pl. xxiv. ff. 18-20.

|| "Réunion extraordinaire a St. Jean de Maurienne," Bull. Soc. géol. France, 2^{me} sér. t. xviii. pp. 779-784.

¶ "Carte et coupes géologiques du Briançonnais," Bull. Soc. géol. France, 2^{me} sér. t. xx. pp. 233-235, pls. iii. & iv.

** Lory, "Description géologique du Dauphiné," Bull. Soc. Statistique de l'Isère, sér. 2, t. v. (1861) pp. 1-240, pl. i.; sér. 2, t. vi. (1861) pp. 1-260, pls. ii., iii.; sér. 2, t. viii. (1864) pp. 7-252.

†† *Loc. cit.* par. 293; Bull. Soc. Stat. Isère, sér. 2, t. vii. p. 86.

‡‡ Verh. russ. k. min. Ges. St. Petersburg, ser. 2, Bd. ix. (1874) pp. 1-28, pls. i., ii.

the Durance. These include an excellent coloured drawing of the Durance variolite and a figure that illustrates the corrosion of the varioles by the ground-mass*. Inostranzev fully recognized that the varioles were closely akin to spherulites; he considered the two structures to be distinguished by the fact that in the variolitic the central sphere of radial fibres is enclosed by a series of concentric layers, which do not share in the formation of the black cross under polarized light.

Zirkel †, in 1875, made a detailed microscopic study both of the variolites of the Durance and of those described by Gumbel from the Fichtelgebirge; he corrected Delesse's statement that the ground-mass of the rock is a felspathic paste, and declared that microscopic study rendered untenable the view of the connexion of the gabbro and variolite that had been taught by Élie de Beaumont, Cordier, Scipion Gras, Roth, and others. In the next year, however ‡, he admitted variolite as a contact-product of diabase, and Senft §, in the same year, described it as a diabase-aphanite. In 1877 appeared Lévy's important memoir ¶, which embodies the most detailed study yet made of the microscopic characters of variolite. Relying on Lory's map and sections, he described it as a compact euphotide formed by the rapid cooling of the selvage of a great euphotide-dyke, thereby differing from Zirkel, and agreeing with Lory and Delesse. He described the fluidal structure, and made the important discovery that some specimens were perlitic, as is well shown in the figure given subsequently in the 'Minéralogie Micrographique' ¶¶.

In 1887, in the second edition of his 'Mikroskopische Physiographie,' Rosenbusch ** redrew variolite and accepted it as a selvage-product of a basic rock, analogous to the spherulitic structures so common in the glasses of the acid series.

In the same year Zaccagna ††, in describing some spherulitic diabases from the neighbourhood of Monte Viso, referred to the variolites of Mont Genève as a thin crust on decomposing diabase spheroids, and we regard this description as the truest that has yet appeared.

Finally, in 1888, the perlitic structure of the rock was again described and figured ‡‡, accompanied by the suggestion that the rock was a devitrified tachylyte.

* *Loc. cit.* p. 27.

† "Die Structur der Variolite," *Berichte d. k.-sächs. Ges. Wiss.* xxvii (1875) pp. 209-220.

‡ F. Zirkel, *Neues Jahrb.* 1876, pp. 279-280.

§ F. Senft, 'Synopsis der Mineralogie und Geognosie,' *Abth. ii.* 1876, p. 556.

¶ A. Michel Lévy, "Structure et Composition minéralogique de la variolite de la Durance," *Comptes Rendus*, t. lxxxiv. pp. 264-266; *Mémoire sur la variolite de la Durance*, *Bull. Soc. Géol. France*, sér. 3, t. v. (1877) pp. 232-266.

¶¶ Fouqué & Lévy, *Minéralogie micrographique*, (Paris) 1879, pl. xxiv. fig. 2.

** H. Rosenbusch, 'Mikroskopische Physiographie der massigen Gesteine,' ed. 2, vol. ii. 1887, pp. 227 *et seq.*

†† D. Zaccagna, "Sulla geologia delle Alpi occidentali," *Boll. R. Comit. geol. Italia*, xviii. (1887) pp. 387-8.

‡‡ G. A. J. Cole, *Quart. Journ. Geol. Soc.* vol. xlv. p. 306-7, pl. xi. fig. 6.

III. GENERAL FEATURES OF THE SURFACE.

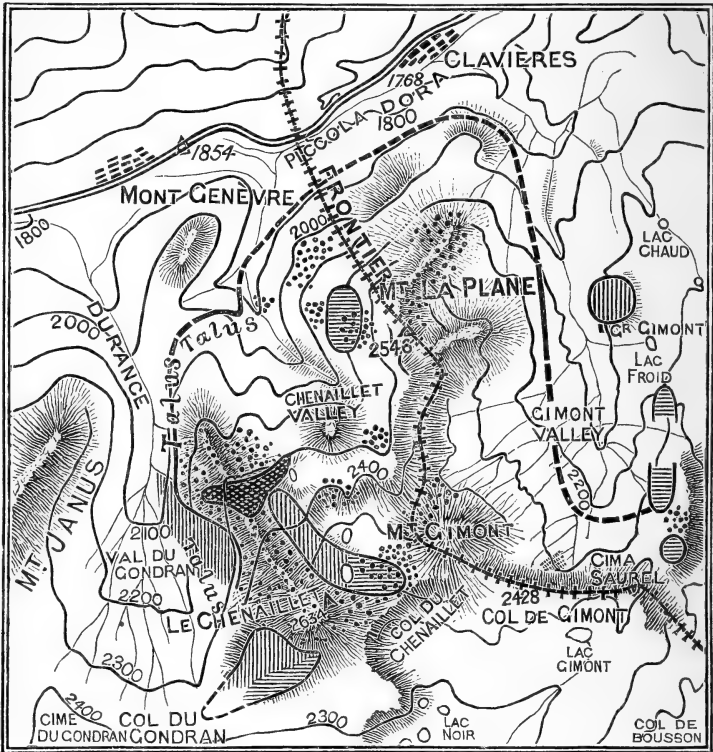
The area occupied by the rocks studied in this paper comprises some sixteen square kilometres immediately to the south of the highroad from Mont Genève to Clavières. By "Mont Genève" we indicate the village of that name, at the summit of the well-known pass, since the mountain or mountain-group once so designated is now known under other names. Our authorities in nomenclature have been the map on the scale of 1 : 80,000, published by the French Dépôt de la Guerre, and revised to 1887 (sheet 189), and that of the Italian Survey, 1 : 50,000, sheet 66, division 1, made by the Istituto topografico militare in 1880.

Three valleys open on the south side of the highroad at a level of 1800 metres, rising towards a line of hills that runs east and west, beyond which, again, the ground descends rapidly to the valley of the Cerveyrette, or Cervières. The westernmost of these is the *Gondran Valley*, in which the upper Durance rises; the floor is grassy, and covered with pine-woods at the lower end, the stream ramifying considerably in the more barren upland known as the *Près du Gondran*. On the west rise the grassy *Cime du Gondran* and the sheer crags of *Mont Janus* (2514 metres), formerly spelled *Juan*, *Jouan*, or *Joux*, and also styled sometimes *Mt. Genève*. On the east, above an intermediate platform used as cow-pasture, lie the rocky ridge and taluses that run north-west for $1\frac{3}{4}$ kilometre from *Le Chenaillet*. This peak, the highest point in the area (2634 metres, or 8642 feet), occupies, in fact, the south-east angle of the bounding wall, and sends out an important spur towards the *Col du Gondran* on the south. This col has an altitude of 2350 metres, lying between the *Cime du Gondran* and *Le Chenaillet*.






The second and central valley, which we term for convenience the *Chenaillet Valley*, is bounded on the west by the steeper and more rugged face of the *Chenaillet* ridge and, further to the north, by a long fir-clad promontory, the end of which is surmounted by pale limestone cliffs. On the south is an extremely picturesque col (2500 metres) which we here term the *Col du Chenaillet*, following the system adopted in the *Gondran Valley*. On the east a series of pinnacled crags, reminding one of the north of *Skye*, leads up to *Mont La Plane*; the valley-floor, at first undulating and containing several little lakes, falls rapidly on the right, the descent from the col being over terraced cliffs until the stream is encountered, running in a deeply-cut gorge. Above this gorge, on the east or right hand, the slopes are formed of steep taluses, with a smooth slate-blue exposure of serpentine; on the west rise the walls of rock that mark off the upper division of the valley.

This upper or western division, into which one looks from *Le Chenaillet*, falls much more gradually; it contains no stream in ordinary weather, and the cattle-track from the col descends along it over glaciated bosses of gabbro until it reaches a smooth grassy upland, from which one may cross to the *Durance*. We are here, in fact, on the watershed between that stream and the *Piccola Dora*, the waters of which fall into the *Adriatic*.

Fig. 1.—Map of the Variolitic Rocks of Mont Genève.

Scale about 1 : 50,000 ($\frac{3}{4}$ mile = 1 inch).

The area included by the broken line — — — — —, which is left open on the south, is occupied by the variolitic rocks.

-  Variolite-tuffs.
-  Intrusive porphyritic diabase of Le Chenaillet.
-  Gabbro.
-  Serpentine.
-  Brecciated serpentine.

(Heights in metres.)

If we follow the stream of the Chenaillet Valley, we find it turning east under a cliff-set mountain-side to Clavières; and here the third valley opens southward. This we have styled, for uniformity, the *Gimont Valley*, since Mt. Gimont forms its south-west angle and the Col de Gimont (2428 metres) is at its head. Here the dominant mass is Mt. La Plane, the cliffs and great taluses of which form the western wall. On the east the slopes are far smoother, with rounded gabbro-masses and blue serpentine showing unmistakably at a distance of some miles. The Col de Gimont is formed by an interesting ridge, scarped to the north, dipping smoothly and steeply to the south, the boundary between France and Italy running exactly along its crest. The rocky prominences of Cima Saurel (2453 metres) occupy the south-east angle.

From what follows it will be seen that the series of variolitic rocks lies mainly between the Durance and the branch of the Piccola Dora in the Gimont Valley, and may have an important extension outside our area towards Cervières on the south. Probably one of the most easily attained localities in which variolite may be studied *in situ* is the north face of Mt. La Plane, just within the Italian frontier, and a kilometre south of the highroad. The whole east front of the same mountain forms one of the most admirable fields for the collector.

IV. ROCKS FOUND IN THE GONDRAN VALLEY.

As it is from the bed of the Durance that the principal supply of variolite has been derived in the past, it is natural to make the first search for the rock in the upper reaches of this stream. Proceeding south from the village of Mont Genève among the boulders strewn over the bed, one soon finds plenty of material. Following the stream up the valley, one notices, scattered over the limestone floor, great blocks of coarse gabbro (euphotide) and variolite, some of the latter reaching to 5 feet in diameter and being spherulitic throughout. Amongst these, but numerically less important, are blocks of dense fine-grained diabase; porphyry, with green saussuritic feldspars; serpentine with or without diallage-crystals and cleavage-flakes; great masses of agglomerate containing variolite and diabase; and finally, dolomite, "cargneules," limestone, and limestone-breccia. A closer scrutiny of the gabbro-blocks shows that some of this rock is fine-grained, and some schistified with large diallage- and feldspar-eyes: it shows no signs of the asserted passage into variolite, but is traversed by many dykes of diabase as well as by felspathic segregation-veins.

Here in the stream we have specimens of all the rocks of the district spread out before us: the dykes and agglomerates are suggestive of volcanic origin, but of this there is no hint in the descriptions of Prof. Lory, who records neither of these two rocks. This author, moreover, regards the coarse gabbro, the fine-grained diabase, and the porphyrite with green feldspars, as only different degrees of coarseness of the same rock, which he describes as euphotide, and of which the serpentine and variolite are alike structural modifications.

Leaving the stream, then, as it breaks up into the numerous brooks which drain the peat-bog at the head of the valley, we turn to the ridges on the east from which the material has been derived, in order that we may see what light is thrown on the relations of the rocks to one another.

V. THE GABBRO AND ASSOCIATED SERPENTINES.

At the summit of the Col du Gondran, along the ridge that forms the watershed between the Durance and the Cerveyrette, the igneous rocks are seen *in situ*. We here find the gabbro as a series of rough crags forming the south-west spur of Le Chenaillet. The rock is usually coarse-grained, the crystals being in places as much as 60 millim. in diameter; the texture is truly granitic. The rock is a gabbro (euphotide of French and Italian authors), all the more typical because its constituents, plagioclase and augite, have been altered into "saussurite" and "smaragdite" respectively. Microscopic examination shows that the rock has undergone considerable change. In a less coarsely-grained specimen collected from near the junction with a diabase-dyke, the felspar is often brecciated and traversed by veins of secondary hornblende. The following analysis by Delesse* shows that the felspar is labradorite:—

Silica	49·73
Alumina	29·65
Protoxide of iron	·85
Oxide of manganese	trace
Lime	11·18
Magnesia	·56
Soda	4·04
Potash	·24
Water and Carbonic Acid	3·75
	100·00

The magnesia is to be attributed to the serpentine-veins traversing the felspar, and Delesse has also noted the presence of veins of calcite, which may perceptibly increase the percentage of lime. Boulanger † has also given an analysis of the felspar, and of what he describes as a felspathic "pâte blanche" in the euphotide; but the results of this early analysis differ considerably from that of Delesse, while the silica of the felspar is much higher than in those occurring in typical gabbro.

The pyroxene is still more altered. There is little of it remaining even in the form of diallage, since it has been changed into grass-green masses of "smaragdite;" these on closer examination are

* Delesse, "Recherches sur l'Euphotide," Bull. Soc. géol. France, sér. 2, t. vi. p. 549.

† C. Boulanger, "Mémoire sur la Composition des roches d'euphotide," Ann. Mines, sér. 3, t. viii. (1835), p. 163.

seen to consist of actinolite, uralite, and common hornblende. The hornblende forms long frayed-out masses, with the fibres bent and broken, and often surrounded by a zone of radiating needles of actinolite. As a rule, the green amphibolic areas are quite irregular in shape, and often consist of a felt, or of radiating masses of actinolite-needles.

The third constituent is titanite iron, and this also is decomposing and passing into leucoxene.

Neither olivine nor pseudomorphs after it appear to be present, and this forms another of the points of resemblance between this rock and the saussuritic Cornish gabbros, which rarely contain olivine*.

Along its western margins on this spur of Le Chenaillet the rock is of finer grain, and it has not only been altered by the development of microlites and decomposition-products, but by the mechanical rearrangement of the constituents. In the first stage the rock is schistified into an eye-gabbro, strikingly like that of Karaclews. The primary felspar is turbid and opaque, and both it and the pyroxene occur in eyes or lenticles drawn out along the plane of schistosity. Between these are layers of green hornblende and a mosaic of clearer secondary plagioclase. Actinolite-needles are greatly developed, and occur in lines sweeping round the felspar and pyroxene.

Still closer to the margin of the mass occurs an interesting fissile rock. The felspar, which largely predominates, is far less turbid; the pyroxene has all been altered to actinolite which, with the sphene associated with it, occurs in straight lines through the rock.

Ascending the ridge, we cross many diabase-dykes in the gabbro, and finally come to a sudden junction with the rocks of finer grain that form the main mass of the ridge. From Lory's description we had expected a gradual passage from one to the other; on the contrary, the junction is very sharp, and probably faulted. On the west side of a line that runs straight across the hill, the gabbro is at its coarsest; on the other side are the normal diabases with variolitic selvages. There is no sign whatever of a passage; the general appearance of the junction, which, however, is not well shown, and the extent to which the rocks have there been slickensided, both suggest a fault.

There are several other outcrops of the same coarse-grained gabbro in the area. Thus a little to the north, along the line of junction of the igneous rocks with the calc-schists, it forms the face of the slope of the platform that runs along beneath the ridge. It is the same coarse-grained mixture of "saussurite" and "smaragdite," traversed by diabase-dykes and serpentinous patches, which will be subsequently described. In the upper part of the west Chenaillet valley there is another exposure which extends from the lowest lake to the north bank of the dry basin of a former tarn, where it abuts against

* J. J. H. Teall, 'British Petrography,' London: 1888, p. 177.

a bank of serpentine. Round the margins of this gabbro-mass, except where it joins the serpentine, the texture is especially coarse, and there is not the slightest sign of a passage into the finer-grained rocks of which the variolite is a selvage.

The last outcrop of the gabbro is on the extreme east of the area, where it occurs running from the bottom of the Gimont valley up the east slope to the level of the platform, just north of Gr. Gimont. On the lower part of the slope it abuts against the calc-schists that form the floor of the valley; but the junctions higher up were not exposed, and no special attention was devoted to this mass, as it lies outside the area especially considered in this paper. The usual diabase-dykes and veins of green felspar occur in it.

Wherever the gabbro is exposed, it is found to be associated with dark green or black "serpentine." On the south-west spur of Le Chenaillet these occur in irregular patches in the gabbro, from which, by the elimination of the felspar and decomposition of the pyroxene, a gradual and complete passage to the "serpentinous" masses can be traced. In the gabbro on the west flank of Le Chenaillet true serpentine appears as a long dyke traversing the rock. In the upper Chenaillet valley a similar serpentine runs from the end of the gabbro on the north slope of the dry tarn-hollow across the Col du Chenaillet, where it is covered by tuff (see sketch, fig. 2), and here, as well as in the ridge that runs south, it is associated with brecciated serpentine. On the west flank of Mt. La Plane, that is, on the right slope of the lower part of the east Chenaillet valley, the serpentine occurs as a dome-shaped mass, irregularly underlying tuffs; both the face of the serpentine and the layer of vein-quartz that often marks the junction are greatly slickensided, and it appears as if the serpentine had been faulted up into the tuffs. Finally, looking east from Mt. La Plane across the Gimont valley, one recognizes, by the striking slate-blue tint of the talus-slopes of the upper part of the opposite bank, a still larger development of serpentine. From the north of Gr. Gimont it extends as a great band along the side of the ridge, at about the 2200-metre contour, for some distance to the south. This area is of interest, as it is that which, by its size and development, is most akin to the serpentines that crop out as elliptical patches throughout the range of the Cottian Alps.

It was doubtless on the black patches of "serpentinous" matter in the south-west spur of Le Chenaillet that Elie de Beaumont based his theory of the complete passage from the gabbro to the serpentine, a theory which was accepted by Delesse* and Lory †, and reaffirmed by Hébert in 1877 ‡. Microscopic examination of this "serpentine," however, shows that two very different rocks have been confounded together. The dark green masses of the spur of Le Chenaillet are

* Delesse, *Ann. des Mines*, sér. 4, t. xvii. p. 130.

† Lory, "Description géologique du Dauphiné," para. 292, *Bull. Soc. Stat. Isère*, t. vii. (1864), p. 83.

‡ *Bull. Soc. géol. France*, sér. 3, t. v. p. 266.

thus shown to be due to great aggregations of chloritic decomposition-products. Other patches in the neighbourhood are true serpentines formed from olivine, and contain areas of felspar, diallage, and bronzite. The structure exactly resembles that of the ordinary serpentines of the Cottians, one of which is well shown a little over two kilometres to the north-east, at the upper angle in

Fig. 2.—*The Col du Chenaillet, from the north.*



B.S. Brecciated serpentine.

S. Serpentine.

V. Variolite-diabase and Variolite-tuff.

X. Point where fragments of limestone occur in the brecciated serpentine.

the zigzag on the road between Clavières and Cesana Torinese. This rock was described last year by Prof. Bonney* as a schistified serpentine. Macroscopically it is almost identical with some from the variolitic area; under the microscope it is seen to consist of a light green serpentine with a well-marked "Maschenstruktur" and areas of altered diallage; secondary magnetite, either in the form of crystals or dust, and actinolite are both abundant, and the rock is traversed by a complex of chrysotile-veins.

We have thus to deal with a pseudo-serpentine formed from segregation-masses of diallage and a true serpentine with bronzite. In the case of the former, the junction with the gabbro is so irregular that the rock certainly does not result from the intrusion of a dyke richer in pyroxene than the surrounding gabbro. That the true serpentine was not formed from pyroxene seems clear, as it

* Bonney, "Notes on two Traverses of the Crystalline Rocks of the Alps," *Quart. Journ. Geol. Soc.* vol. xlv. (1889), p. 80.

contains an abundance of slightly altered flakes of that mineral, as in the Wildschönau serpentine discussed by Hatch* and Cathrein†. As, however, there is so little olivine in the gabbros and the diabases, the serpentine must have been formed from great segregation-masses of this mineral. The existence of such segregations in basic rocks is well known from the descriptions of Prof. Judd‡. But it is possible that one of the dykes of serpentine in the gabbro on the west flank of Le Chenaillet, containing as it does evidence of former felspar, may be due to the intrusion of a gabbro richer in olivine than is usually the case.

At several points round the margins of the serpentine is found a serpentine-breccia similar to that described by Prof. Bonney§. The most striking mass is that on the east slope of the valley that runs south from the Col du Chenaillet, while a little of it is well shown just to the north of the Col. A similar bed occurs above the slickensided serpentine on the east flank of the lower division of the eastern Chenaillet valley. Examined under the microscope, the rock is seen to consist of broken pieces of serpentine, the "Maschenstructur" in which indicates its production from olivine. Secondary hornblende in the shape of long wisps, forming light-green dichroic areas, indicates the former existence of pyroxene; flakes of altered felspar also occur. These three constituents, and a multitude of magnetite-granules, are scattered irregularly through a brown matrix. In several specimens there are many small grains of calcite and occasional lumps of limestone; the latter appear in sections as dusty areas traversed by veins of clear calcite with the usual irregular outlines and polysynthetic twinning. This rock, resulting from the breaking-up of serpentine with pyroxene and some felspar, may be named a picrite-breccia.

VI. THE DYKES.

Though earlier observers have accepted the gradual transition from euphotide to the variolite-diabase, we have, as has already been stated, found no sign of such a passage. On all the exposures examined, the gabbro ends abruptly against the more compact rocks. In all probability the gabbro was once a deep-seated mass that consolidated at the base of the volcano; but it now seems to form a platform under the diabase, exposed where dome-shaped masses have been pushed through the softer rocks, or where the valleys have cut down to it. This view is supported by the abundance of diabase-dykes traversing the gabbro in all its exposures. These vary in width from half an inch or less to about 4 feet. Their course

* F. H. Hatch, "Ueber den Gabbro aus der Wildschönau in Tirol und die aus ihm hervorgehenden schiefrigen Gesteine," *Tsch. Min. u. Pet. Mitth.* Bd. vii. (1886), pp. 75-87.

† A. Cathrein, "Ueber Wildschönauer Gabbro," *ibid.* pp. 189-194.

‡ J. W. Judd, "On the Tertiary and Older Peridotites of Scotland," *Quart. Journ. Geol. Soc.* vol. xli. (1885), p. 358.

§ T. G. Bonney, "Notes on some Ligurian and Tuscan Serpentine," *Geol. Mag.* 1879, p. 365.

may be irregular, as they may branch and enclose masses of the gabbro, or they may form long straight regular dykes, often marked on the denuded surface by a long gully in the more resisting gabbro.

The dykes are usually composed of a compact fine-grained rock, of a dull green colour; some, however, are more coarsely crystalline, and the feldspars are visible to the naked eye. Under the microscope the coarse-grained dykes are shown to consist of lath-shaped feldspars optically included in a ground of secondary hornblende. The feldspar is turbid and worn, and the crystals are often surrounded by a zone of fresh feldspar, which has restored the original crystalline form. In many cases a fresh feldspar-crystal has been developed, surrounding several turbid ones, which appear as if optically included in it. The titaniferous iron is passing into leucoxene, the white bands of which are very marked. Olivine appears to have been rarely present, and is indicated by dark brown decomposition-products. We may therefore fairly call this rock a diabase, using that ill-defined term in Hausmann's sense*, that is, for a labradorite-pyroxene rock with green decomposition-products. A more finely grained dyke traverses the gabbro on the slope below the west face of Le Chenaillet, and in this the rock is less altered; it is mainly composed of a granular aggregate of feldspar and pyroxene, with green decomposition-patches formed from the latter; titaniferous iron occurs in scattered grains, and there is a little olivine. In most of the dykes the rock is finer on the margins than in the centre, and there is a thin devitrified glassy selvage. This is well shown in a specimen collected low on the flank of the Col du Gondran; the junction is irregular, thin tongues of the diabase penetrating the gabbro, while broken fragments of the latter are enclosed in the diabase. The rock of which the dyke is composed is a finely crystalline mass of acicular feldspars in a basis coloured green by the predominance of the decomposition-products. Towards the margin of the dyke the texture becomes finer, till at the edge it passes into a glass, full of cumulites and some incomplete crystals of feldspar. Epidote-veins traverse the diabase in all directions near the margin (Pl. XIII. fig. 2). The dykes are usually not spherulitic, the only approach to this structure being the formation of the cumulites above referred to. But in one case a huge block of compact diabase has a distinct variolitic selvage; along the margin of the diabase there are many amygdules, some of which are elongated. Though this specimen was not found actually *in situ*, there can be little doubt from its position that it belongs to the dykes intrusive in the gabbro.

The rarity of the variolitic selvage in the diabase-dykes is remarkable, since it is so constant an accompaniment of the great diabase-masses about to be described. Since, moreover, the dykes are not seen to run from the gabbro into the upper diabase-series, they may possibly not be connected with the latter. The spherulitic and glassy selvages are, however, evidence that they are not mere

* J. F. L. Hausmann, 'Ueber die Bildung des Harzgebirges.' Göttingen: 1842.

segregation-veins, and the irregular nature of the junction and the inclusions of the plagioclase- and pyroxene-fragments from the gabbro speak unmistakably in favour of their intrusive nature. The rarity of the glass-selvage products is of interest, since it shows that even the small intrusive veins could only have solidified slowly; the gabbro, therefore, may have been in a heated condition at the time of the intrusion of the more compact rocks. The fact that the dykes do not run from the gabbro into the diabase, suggests that the former was more deeply seated at the time of their intrusion, and that it was subsequently forced up into the diabase-masses by earth-movements; if, indeed, these dykes entered the diabase-masses, the original junctions have been shifted and destroyed.

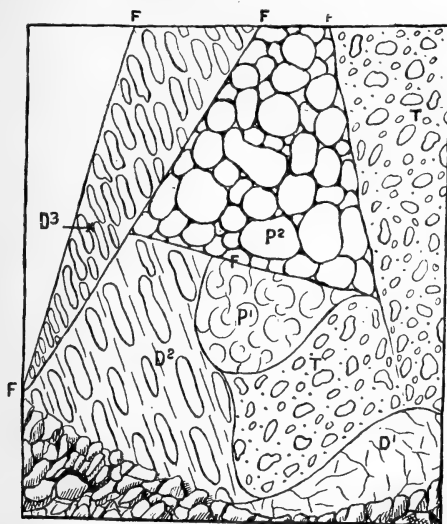
Dykes, however, do occur in the great variolitic diabases. They may be divided into three classes:—compact diabase; diabase-porphyrite or altered augite-andesite; and coarse-grained dolerite.

Commencing with the dykes of diabase, the most important is one that crosses the ridge of Mt. La Plane, just south of the summit and on the north side of the east hollow; it is probably continuous with a similar dyke seen in the corresponding position on the other side of the ridge in the lower part of the east Chenaillet valley. The rock is just macrocrystalline, and is jointed into bold columns which are not perpendicular to the edge of the dyke. Microscopic examination shows that the rock is composed of augite and plagioclase grouped optically; the augite is remarkably fresh, but the plagioclase is kaolinized. Patches of yellowish-green serpentine indicate by their structure that they have been derived from olivine. Biotite occurs as a few small, pale green, fibrous, and slightly dichroic areas. There is a good deal of titanite iron with leucoxene. The rock may therefore be called an olivine-diabase. It is markedly scoriaceous, and overlies a thin diabase-ash or mud, which is baked at the junction, and jointed into irregularly columnar blocks. This green to purple slate-like rock appears to be unique in the area under discussion. The dyke has cooled against the ash with a variolitic selvage, a fact important in showing the connexion between the diabase-dykes and the variolitic series. Immediately to the north of this is a similar but less interesting dyke in the north-east hollow of Mt. La Plane. A dyke of a similar but more finely crystalline rock runs up into the porphyritic diabase or diabase-porphyrite on the west slope of the middle of the Chenaillet ridge.

The "diabase-porphyrite" plays an important part in the formation of the Chenaillet ridge, which it crosses as a saddle-shaped mass running north-east and south-west. It faces the west as a steep and rugged crag, while it presents to the east a slope covered with spheroidal joint-surfaces. Along its northern margin it cuts sharply against a bank of tuff, but its relations to the diabase and tuff on the west flank are complicated. In fig. 3 the junction of the three rocks is shown; the diabase-porphyrite is exposed by the denudation of the diabase and tuff into which it has been faulted. It appears here and at other points that the porphyritic rock was intrusive into and partly faulted up through the diabase-series, of

which scattered patches occur plastered on to its western face. A little to the north of this a faulted junction of the compact and the porphyritic diabase is well shown. The latter weathers into great

Fig. 3.—*Rock-face showing relations of Variolitic Diabase (D^2 and D^3), Diabase Dyke (D^1), Porphyritic Diabase (P^2), and Tuff (T), on west slope of north ridge of Le Chenaillet.*



The spheroidal porphyritic diabase (P^2) is exposed from beneath the variolitic diabase (D^2 and D^3) and tuff (T), and shows faulted junctions with these; a fault parallel to the ridge, and giving a nearly horizontal trace, separates the spheroidal porphyritic diabase (D^1) from a small patch, broken by curved joints. The junction of D^2 and D^3 is faulted. The tuff overlies the variolitic diabase D^2 , and both are cut by an intrusive dyke of compact diabase.

F. Faults.

rounded spheroids, the faces of which appear to be surfaces of cooling, since the masses are often jointed within into radial prisms; the master-joints, however, often cut straight through the spheroids.

Microscopic study shows that the porphyritic diabase is composed of plagioclase, augite, and some decomposition-products, in a granular base that probably represents a devitrified glass. The plagioclase belongs to two periods of consolidation; there are the large saussuritic and porphyritic crystals, which are greatly corroded by the ground-mass, in one specimen all the angles being rounded. These crystals are traversed by veins of secondary feldspar, which are in optical continuity with the adjacent crystal (Pl. XIII. fig. 1) even when they extend a little distance beyond it. The augite is mainly present in the form of granules, which, with feldspar in a similar condition, forms the ground-mass of the rock. A large number of clear isotropic octagonal or rounded masses are to be attributed to the

pseudomorphs after augite. Some very similar bodies are, however, probably amygdules, filled with clear crystals, the single cleavage of which is suggestive of epidote. The alteration of the rock is marked by the development of epidote in the felspars, and of chloritic and epidotic areas, and minute grains of epidote, in the ground-mass. There is very little of the original glassy matrix preserved. The rock was, however, originally an augite-andesite. In most cases the only signs of radial structure are seen in the chloritic areas, but in some specimens long rays of felspar are grouped about a centre; by a gradual increase in this structure a passage from the ordinary andesite to a variolite-selvage can be traced (Pl. XIII. fig. 5). In other cases the selvage is full of porphyritic crystals which seem to have floated to the margin.

Another coarse porphyritic diabase-dyke, grey in colour, occurs crossing the south-west spur of Le Chenaillet in the diabase-tuff above the junction with the gabbro.

The last type of dyke is the dolerite that occurs in a mass on the south side of the summit of Le Chenaillet, on the side of the valley running to the Col du Chenaillet. It is a rather coarse-grained rock, and we considered it in the field as more allied to gabbro. Its microscopic structure, however, shows that it would be most appropriately named a dolerite; the texture is ophitic, and the augite is not schillerized. Its constituents are augite and plagioclase, with some green decomposition-products and scattered crystals of titanite iron and pyrites. The augite is in fairly large crystals, and, in contrast to the felspar, is remarkably fresh; it is, however, much cracked, and along these fissures decomposition has commenced in places. In some cases a complete passage can be traced from fresh augite at one end of a crystal into green decomposition-products at the other, while in the middle a zone of diallage has been caused by schillerization. Whether all the green areas are derived from augite is doubtful, since in some cases, the junction is sharp between a fresh augite crystal and the "viridite." The latter may have been formed from accessory bronzite. The green areas appear, however, to be mainly composed of actinolite, and a crystal of secondary magnetite often forms a nucleus from which radiates a group of actinolite-needles.

VII. THE VARIOLITIC DIABASES AND TUFFS.

We may now proceed from these dyke-rocks, on which variolite occurs *in situ* as a selvage, to the mass of the compacter diabases through which they were intruded. In 1861* Lory reports that, starting from near Le Chenaillet, "en avançant de quelques pas vers l'est, on trouve l'euphotide bien caractérisée, à éléments nettement séparés, qui continue de là jusqu'aux sommités et dans tout le vallon affluent de la Doire." The euphotide proper is certainly visible from this point, but occupies, as has been described, only a

* Bull. Soc. géol. France, 2^e sér. t. xviii. (1861), p. 782. "Descript. géol. du Dauphiné" paragraphe 293.

small part of the floor of the upper and western portion of the Chenaillet valley; while the summits immediately above, and the whole upland about the lakelets, as well as all the main walls of this "vallon affluent de la Doire," consist of rocks entirely different in their mode of weathering, colour, and degree of crystallization.

Finding serpentine on the eastern flank, Lory*, in his published section, filled in the intervening space as "euphotides," and thus unconsciously diverted the attention of observers from one of the richest areas where variolite may be obtained *in situ*. We must recognize, however, that the igneous masses extend some way towards the Cerveyrette, and euphotide may be there more prominent. We hope at some future time to examine this southern area; but from the contour we judge that Lory's section traverses the high ground near Le Chenaillet, to which his descriptions, as above quoted, undoubtedly apply.

Fig. 4.—*Variolite-d diabase. Spheroidal Masses with Variolitic Selvages. North end of Le Chenaillet Ridge, above the Durance.*



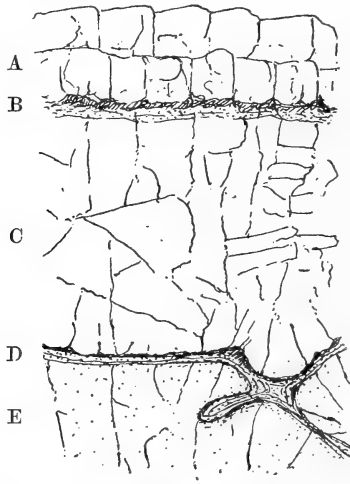
The prevalent rock of the whole district at present under discussion is a compact grey-green diabase. The dykes already described doubtless represent the coarser types of these widely spread masses. The most striking character of the compact series is a tendency to spheroidal jointing. Sometimes, as among the

* "Carte et coupes géol. du Briançonnais," Bull. Soc. géol. France, 2^e sér. t. xx. (1863) p. 233.

craggs forming the east side of the Chenaillet valley, south of Mt. La Plane, the spheroids appear piled regularly one above the other, forming walls as it were, which are divided by conspicuous vertical joints; but the structure is more commonly irregular, the masses resembling pillows or soft cushions pressed upon and against one another, each cliff-face thus exhibiting a number of swelling surfaces and curving lines of junction (fig. 4). Examined more closely, small vesicles are seen in these rude spheroids, especially towards the margins; and in some places, as on the east of Mt. La Plane, the whole rock becomes vesicular and slaggy. The surfaces of the masses are covered by a crust of variolite, from 1 to 7 or 8 centim. thick. The spherulites or "varioles" are grouped or drawn out in bands parallel to the surface, being in some places almost microscopic, in others 5 centim. in diameter.

The coarsest variolite that we are acquainted with occurs on a little plateau above the pine-woods on the north end of the ridge of Le Chenaillet. The ground here, with the large spherules projecting from the weathered surface, reminds one of the pyromeride-area of Digoed near Pennmachno in North Wales.

Fig. 5.—*Variolite-d diabase ; north end of Le Chenaillet Ridge.*



- A and C. Compact diabase.
 B. Variolite, 5 centim. thick.
 D. Variolite, bent and infolded, 3-4 centim. thick.
 E. Compact spherulitic diabase.

This, then, is the typical mode of occurrence of the famous Variolite of the Durance. It is everywhere a selvage to compact and ordinary basic igneous masses, just as tachylite so frequently borders the intrusive basalts of our Western Isles of Scotland*. But in

* See P. F. Kendall, "On some Occurrences of Tachylite in Mull," *Geol. Mag.* 1888, p. 555.

the Mt. Genève area the spherulitic selvage is found on every conspicuous surface of division throughout the rock, and often seems to have become infolded when still viscid by the pressure of adjacent masses (fig. 5). Often a subsidiary jointing has been set up, as is common in spheroids of contraction*, columns being produced which radiate from the centre, and produce a tessellated effect on the outside. This feature is best seen, however, in the globular masses found in the rocks styled by us variolitic tuffs.

Where very thin, the variolitic crust is liable to become lost by exfoliation and decomposition; and its outermost layer is commonly soft, and coated with dark-green alteration-products. But in the majority of instances the spherulites are easily recognizable, and hundreds of specimens might be collected in an hour which would show the passage from compact grey diabase to typical "variolite of the Durance."

The microscope shows us that the green matrix of the variolite becomes less and less in quantity as we proceed from the surface towards the centre of the spheroidal masses of diabase. The spherulites come into contact with one another, as in the similar "aphanite" of Liguria †; but even at some distance from the selvage they are still differentiated. In the interior of the rock their place is taken by beautiful stellar or brush-like groups of plagioclase, the rays of which are straight. These rays contain dark axes, occupying about a third of their bulk, formed of included or imperfectly crystallized material; they often bifurcate at the ends, branches are set on at intervals, and forms resembling skeleton-crystals are thus built up, though the individual little rods composing them have different optical orientations (compare Pl. XIII. fig. 5).

The spherules of the variolite itself are often of a translucent brown colour, the more characteristic grey appearance being due to alteration. The rays, moreover, of the brown examples are pleochroic, as in ordinary tachylytes. The matrix becomes also browner in the interior of the spheroidal masses of the rock, resembling thus the residual glass in the great porphyrite dykes.

Porphyritic crystals occur occasionally in the variolite. We have not detected olivine, but may record felspar, magnetite, iron-pyrites, and transparent little pseudomorphs after pyroxene. Not unfrequently, embryo prisms of felspar, with characteristic bifurcated ends, appear in the midst of the spherulites, as if developed at an earlier stage. We must mention also the "pseudocrystallites" so clearly distinguished by M. Lévy ‡, which occur in so many of the larger globules, and which we are inclined to regard as little fissures due to fracture or contraction. Much as they often resemble the constituents of a crystalline meshwork, there is evidence in many of our examples of a tendency to branch and become irregular. We do not find that the rays of the spherulites, as seen in polarized light, run on without interruption through these lighter areas; on

* See, for example, Serope, 'Considerations on Volcanos,' 1825, p. 140.

† Mazzuoli and Issel, *Boll. R. Comit. geol. d'Italia*, vol. xii. (1881), p. 330.

‡ *Bull. Soc. géol. France*, 3^e sér. t. v. (1877), p. 238.

the contrary, they are broken through, and the "pseudocrystallite" resolves itself into a minute rift filled with colourless secondary products. The dark granules that abound throughout the rock are frequently grouped along these transparent lines, so as to suggest that they also are developed as products of alteration. We feel that until a similar structure is found in other rocks, so that ample comparison may be made, the last word cannot be said on these interesting "pseudocrystallites;" but in a large spherulite, 2 centim. in diameter, which we have especially studied in reference to this question, all stages between the coarser and undoubted cracks and these little individualized and intersecting rifts can be determined without any hesitation (Pl. XIII. fig. 6).

While dealing with these structures in the variolite, we would note the great abundance of yellow epidote as a secondary constituent, whether in the occasional perlitic lines of separation, or in the more ordinary fissures, or irregularly developed in the matrix. M. Lévy's specimens appear to have been deficient in this mineral, the importance of which was insisted on by Delesse in 1850, and again in discussion in 1877. The epidote commonly forms a granular mosaic, but occasionally occurs in almost colourless prismatic forms associated with the chloritic areas. It is unnecessary to call attention to the little bunches and fibres, probably of actinolite, in the matrix, and to the other mineral features that M. Lévy has so admirably described.

The more we examine the interesting structures of the variolite, the more we are convinced that we are dealing with the altered and devitrified selvages of an ancient basic andesite or basaltic lava. The matrix of the rock, despite its epidote-veins and granules, and its action on polarized light, shows so often a perlitic structure that its former colloid condition seems placed almost beyond dispute*. The alteration of basic glass to palagonite and to fibrous recrystallized products, has been again and again described; and the "variolite of the Durance" received, indeed, a normal explanation if placed in the category of the tachylytes.

The varioles themselves have been already referred to as if they were ordinary spherulites; but this is a question that has received considerable attention. Setting aside the old discussions as to whether they were included pebbles or concretions subsequent to consolidation, we note that even Morozzo † compared them to the "taches variolitiques" of the lava of Vulcano, although he could see no proof of volcanic action in the locality of his variolite near Susa. In far later times, M. Michel Lévy ‡, while stating that the varioles have only a superficial analogy to the colloid globules of acid rocks, fully recognizes their spherulitic character, classing them as crystallized varieties. Geinitz § also insists that they should be compared

* Mr. Rutley has recently traced in certain "epidosites" the extreme phase of alteration of perlitic lavas. *Quart. Journ. Geol. Soc.* vol. xlv. (1888), p. 740.

† *Mém. Acad. royale des Sciences, Turin*, t. v. p. 171.

‡ *Bull. Soc. géol. France*, 3^e sér. t. v. (1877), pp. 257 and 263.

§ *Tscherm. Min. u. petr. Mitth.* Bd. i. 1878, p. 143.

with ordinary spherulites. Lœwinson-Lessing*, on the other hand, regards them in a similar rock as globular forms analogous to porphyritic felspars, a view calculated to lead the mind away from a number of most valuable comparisons. It is clear that the varioles are now largely composed of crystalline fibres; but it is doubtful if these are all of the same mineral composition. Delesse † has given the following analysis of globules brought by Scipion Gras from 2 kilometres south of the village of Mont Genève:—

Silica	56·12
Alumina	17·40
Oxide of iron	7·79
Oxide of chromium	0·51
Oxide of manganese	traces
Lime	8·74
Magnesia	3·41
Soda	3·72
Potash	0·24
Loss on ignition	1·93
	99·86

The globules from a similar specimen from the “ torrent de Cervières ” yielded M. Lévy ‡ results agreeing closely with the above.

With hesitation, Delesse classed the globules as triclinic felspar. Their specific gravity is given as 2·923; M. Lévy records 2·920; and we have found a large spherule which has a specific gravity as high as 2·96.

M. Michel Lévy § concludes that oligoclase-fibres form 60 per cent. of the globules, the remainder being composed of amphibole and pyroxene. It is equally impossible for us to refer our own materials to any one mineral, but rather to a mixture, in which felspar largely predominates. The varioles may have originally included only a small amount of glassy matter, and may even have been among the crystalline “ belonospherites ” of Vogelsang; yet we cannot on this account cut them off from kinship with the more familiar types of spherulites. Indeed we know how in modern tachylytes pleochroism and other effects of crystallization are observable in the fibres of bodies that are exactly comparable in mode of origin to the spherulites of pitchstone or obsidian. The whole of a basic rock, even to the vitreous selvage, becomes, under similar conditions, more crystalline than the corresponding acid type. The variolites of Mt. Genève have undergone, in addition, the very extensive secondary devitrification of which the epidote-veins and microlites of actinolite afford such abundant evidence.

* Tscherm. Min. u. petr. Mitth. Bd. vi. 1885, p. 298.

† Ann. des Mines, 4^e sér. t. xvii. (1850), p. 116. Also Comptes Rendus, t. xxx. (1850), p. 741.

‡ Bull. Soc. géol. France, 3^e sér. t. v. (1877), p. 248.

§ *Ibid.* p. 250.

If, then, the variolite represents a vitreous selvage-product, how comes it to be so widely diffused among the masses of the diabase-lavas? It is possible that the surfaces of ordinary spheroids of contraction, even in the heart of a cooling mass, may differ appreciably from the more central portions, and, consolidating more rapidly, exhibit a vitreous structure. Delesse * thus concluded, from a number of determinations of specific gravity, that the centres of prisms and spheroids in igneous rocks are denser than the external layers. If denser, even a glassy crust may occur outside while the core is fairly crystalline. But we prefer to read in the irregular shape and involuted surfaces of the diabase-masses of Mt. Genève evidence of the rolling over of lavas among themselves; and we are led to regard the presence of variolitic selvages throughout such great thicknesses of rock as largely due to movements taking place within a crater, a point to which we shall revert in Section IX. That the mode of occurrence of the variolite of Mt. Genève is paralleled at other places may be seen by the descriptions of Mazzuoli and Issel † of kidney-shaped masses of aphanite near Bonassola in Liguria, which have variolitic surfaces of junction. Zaccagna ‡ also records similar phenomena in a spheroidal diabase near Mte. Viso.

A glance at the sketch-map of the district (p. 300) will at once show the large area covered by the variolite-diabases. When we add that the thickness of these compact rocks often amounts to 300 metres, and appears to reach 500 metres in the neighbourhood of Mt. La Plane, some idea may be formed of the importance of the series. In places both folds and faults are traceable; but we believe that the thicknesses here stated are not the result of actual repetition.

Our map also indicates the occurrence, particularly upon Le Chevaillet, of rocks styled by us Variolite-Tuffs. These, as has been stated, readily attract attention among the pebbles in the bed of the Durance, though, with an exception in the Museum of Grenoble, we have not found specimens of them in any public collection. Delesse §, however, cites Elie de Beaumont as stating (probably in conversation) that “l'euphotide formant le massif central du Mont-Genève est encore accompagnée ou entourée par des roches brèche-formes variées, ainsi que par des roches probablement métamorphiques.” Cordier || has, moreover, in his classification the heading “Brèche variolitique,” and he describes one of his specimens as follows:—“*Brèche de variolite embryonnaire*. Cette roche, très-curieuse, ayant la même origine que toutes celles que j'appelle *Brèche de froissement*, sert d'éponte à la variolite qui forme des amas transversaux dans les serpentines des parties supérieures de la vallée de Servières (Hautes Alpes).” It is possible that the *pou-*

* ‘*Métamorphisme des Roches*,’ Paris, 1858, pp. 371-4.

† *Boll. R. Comit. geol. d'Italia*, vol. xii. (1881), p. 329.

‡ *Ibid.* vol. xviii. (1887), p. 387.

§ *Ann. des Mines*, 4^e sér. t. xvii. (1850), p. 130.

|| ‘*Description des Roches*,’ 1868, p. 173.

dingue with variolitic rocks recorded by Morozzo* from near Susa was a rock similar to those of Mt. Genève. We fail to see, however, that Geinitz † has established satisfactorily that the schistose variolite described by him from the Col de Sestrières is a tuff and not merely a metamorphosed portion of the diabase.

We have not mapped the boundaries of these fragmental rocks on account of their intimate association with the variolite-diabase. They may, indeed, be friction-breccias, or lavas broken up while viscid, or volcanic tuffs. Careful consideration inclines us to the last-named of these views, and we regard them, as will be seen in a later section, as the products of local explosive action. Against the view that they are friction-breccias, we would urge that slickensides are rare in their material, though common enough in the brecciated serpentines; that the dykes which must be practically contemporaneous with them have not suffered from any similar crushing; and that we have found no admixture of gabbro, serpentine, or limestone in these diabase-"breccias," even when they are hundreds of metres in thickness. The smaller particles appear, moreover, to represent the glassy types rather than the compacter diabase-lavas; while spherical "bombs" are abundant, which remain unbroken and are beautifully coated with uninjured variolite. Nor, on the other hand, do we think that the characters of the matrix in these fragmental rocks, when little altered, can support the suggestion that they are lavas which became brecciated during flow. In such a case at least some of the instances examined should betray, by spherulites or other signs of imperfect crystallization, the former molten nature of the ground-mass. The slaty bed against which the great dyke of Mt. La Plane has cooled is also some evidence of the existence of ashes and tuffs among the lavas at the time of their formation.

A striking feature of these fragmental deposits is, as we have hinted, the abundance of globose masses of compact diabase, their surfaces being thickly coated with variolite. Although only slightly vesicular, these appear to be of the nature of volcanic bombs. The smaller ones are spherulitic throughout, and in almost all cases the old glassy crust is exceedingly well marked. Some of these spheroidal specimens, with their concentric coats, resemble the well-known globes from the pitchstone of the Chiaja di Luna of Ponza. The largest that we have measured was on the western slope of Le Chenaillet, and was partly broken, showing within the characteristic radiating columnar structure. The dimensions of this imperfect mass were 70 centim. by 43 centim. by 45 centim. We believe that the large and beautiful specimens of variolite, spherulitic from one side to the other, which are obtainable in the upper Durance are residues from the breaking-up of the volcanic agglomerate rather than from the massive diabase-lavas. The blocks thrown out into the tuffs would naturally be at times completely vitreous.

The smaller fragments are often scoriaceous and very angular, and consist of variolite and more ordinary diabase in about equal

* *Mém. Acad. royale des Sciences, Turin*, t. v. (1793), p. 169.

† *Tscherm. Min. u. petr. Mitth.* 1878, pp. 146-152.

proportions. Microscopic sections reveal a number of transitional forms, with delicate radial groups of felspar and brown interstitial glass, such as have been referred to in our description of the diabase-lavas. We have also found fragments of the porphyritic andesite or diabase of the arête of Le Chenaillet—a fact that confirms the practical contemporaneity of the great dykes and these agglomerates. Of course, on the other hand, these fragments would by themselves support the view that the agglomerates are friction-breccias. The matrix of the tuff has generally been extensively altered, and a zone of epidote and other clear secondary minerals, accompanied by opaque granules, has often formed around the included fragments. Particles of basic glass, rich in globulites and minute stellar aggregates, are freely scattered; and many even of the stony-looking and darker fragments prove, between crossed nicols, to retain their original amorphous character (Pl. XIII. fig. 4).

Fig. 6.—*West Slope of Le Chenaillet, showing dyke-like forms of the Variolite Tuff.*



Le Chenaillet.

Gabbro of the
Col du Gondran.

The secondary mineralization of the matrix has given rise to a handsome rock on the west of Mt. La Plane, where dark-green particles of variolite lie in a ground of bright yellow epidote. Where, moreover, the tuffs come in contact with the serpentine, hydrous magnesian silicates have permeated the mass, and even the variolitic fragments have become softened and decomposed. The resulting serpentinous tuff is, on Mt. La Plane and at the Col du Chenaillet, difficult to distinguish from the breccia of the serpentine itself: but we have found no passage between these rocks, the variolite never occurring in the breccia, and the wisps of diallage or

bronzite being entirely absent from the tuff. The microscope easily distinguishes between the particles of serpentine, with their veins of magnetite, in the breccia, and the fragments of diabase in the green and metamorphosed tuff.

It is remarkable, indeed, that the serpentine should have thus yielded to earth-movement without a real intermingling of the rocks at contact. We presume that, at the period of brecciation, the variolite-tuff had become as tough and hard as its unweathered masses are to-day.

The great locality for the tuff is Le Chenaillet itself; and on the western slopes the characteristic mode of weathering is admirably displayed. The roughly piled masses are divided, not by stratification, but by vertical joints, and form, under denuding influences, great dyke-like spurs running out towards the valley at right angles to the ridge (fig. 6). As is common in ancient volcanic agglomerates, there is also a marked tendency to the formation of pinnacles and spires.

VIII. RELATIONS OF THE ROCKS TO ONE ANOTHER AND TO THE STRATIGRAPHICAL SERIES.

To summarize, then, the relations of these igneous rocks to one another, we may safely assert that the gabbros and serpentines, so intimately connected, form a floor or undulating platform on which the variolitic series has been piled. The gabbro is exposed at four distinct points:—above the forks of the Durance, at a height of 2250 metres; on the south-west angle of Le Chenaillet, at 2450 metres; in the floor of the upper Chenaillet valley (2350 to 2550 metres); and on the east flank of the Gimont valley, among the limestones, as low down as 2100 metres. Serpentine occurs independently at 2200 metres on the west slope of Mt. La Plane and along the ridge north of Cima Saurel, some 200 metres higher.

While, then, the true euphotide seems to have at the surface little of the importance assigned to it by earlier observers, it none the less forms a base to the eruptive series and is probably of similar age. But the original junctions of the highly crystalline rocks with the diabase-series, or the passages from one type to the other, have been lost during subsequent earth-movements, the gabbro being often most coarsely developed at its present margin, and exhibiting there the eye-structure of gabbro-gneiss. These facts, and the abundant slickensides in the gabbro, show that the upper series may have been shifted over the hard crystalline masses, leaving us in doubt as to their contemporaneous origin and connexion.

The gabbros, however, were broken through in places by eruptive rocks, which form numerous dark dykes and veins. We are led to regard these as representing either the last upwelling of molten material through the cracks of the consolidating gabbro, or as the lines of fissure through which the variolitic rocks attained the surface.

We have, however, been unable to detect the passage of these dykes, so numerous on the west flank of Le Chenaillet, into the

upper diabase series. Where the variolitic tuffs are in direct contact with the gabbro, such dykes ought to form prominent objects. The great porphyritic diabase, however, that crosses the ridge of Le Chenaillet is certainly intrusive in the tuffs, and probably has similar relations to the gabbro; but the gabbro does not reappear to the north of it, and thus even here the evidence is inconclusive. There are abundant dykes of diabase in the variolitic lavas and tuffs, and their characters link them closely with those traversing the gabbro. Yet we find no evidence of passage between the gabbro itself and this compacter group. An observer intent on establishing the sedimentary or metamorphic origin of euphotide and serpentine might, indeed, accept the eruptive character of the diabases without prejudice to his views of the more crystalline series.

The age of the variolitic group and associated gabbros has been generally accepted, on the authority of Lory*, as later than the Infra-Lias. We have observed something like contact-alteration where the variolitic diabase abuts on limestone north of the fork of the stream in the Chenaillet valley. Here, and also against the gabbro in the Gimont valley, the limestone is broken and traversed by abundant calcite-veins; but this brecciated condition of the rock precludes accurate determination of the existence of contact-metamorphism. Gastaldi† has, indeed, denied such alteration at the junction of the "pietre verdi" and the overlying limestone. Similarly, the interesting limestone-fragments in the eruptive rocks at the Col du Chenaillet occur, not in the massive serpentine, but in the brecciated variety; and it may therefore be urged that they have become included as the result of subterranean crushing. We think, however, that their distinct removal from the limestone of the lower valley is fair evidence that they were carried up during the intrusion of the igneous mass.

But doubts now arise as to the real age of the stratified rocks regarded by Lory as Liassic. The obscure fossils picked up on the talus of Mt. Chaberton appear to have formed the basis of this conclusion‡. Gastaldi and his collaborators, who believed in 1876 that they had found evidence here of Cambrian and Silurian strata, abandoned this view later, on the determination of their specimens as Mesozoic. But Gastaldi claims to have proved the existence of the Trias within the limits of Lory's "Calcaire du Briançonnais"§; while it is clear that he would sweep the whole of the euphotide and diabase group down into the "pietre verdi," and thus relegate them to the pre-Palæozoic. That this view was influenced by the generalization he had adopted with regard to serpentines in the abstract may be seen by his refusal to admit the Eocene age of any of these rocks in Tuscany||.

* "Descript. géol. du Dauphiné," paragraph 290, Bull. Soc. Stat. Isère, 2^e sér. t. vii. p. 79.

† Boll. R. Comit. geol. d'Italia, vol. vi. (1875) pp. 352-3.

‡ Bull. Soc. géol. France, 2^e sér. t. xviii. (1861) p. 770.

§ "Sui rilevamenti geologici fatti nelle Alpi piemontesi, 1877," Mem. R. Accad. dei Lincei, Rome, ser. 3. vol. ii. 1878, p. 959.

|| Letter in 1878 to Sterry Hunt, Geol. Mag. 1887, p. 536.

Zaccagna*, however, agrees that the "massa diabasica" of Mt. Genève is intercalated in the calc-schists below the limestones of Mt. Chaberton. He states that various authors have treated the mass as Permian; but against this view he urges that the calc-schists cover it upon the French or western side. It is clear, however, that this reasoning, and that of other Italian geologists, will only hold good if we regard the series as sedimentary. Moreover, Zaccagna himself would seem to assign an eruptive origin to the diabase-groups of the Val de Chabrière and of Mt. Genève.

The age of the calc-schists themselves has not been satisfactorily determined. As early as 1850 Fournet† pointed out the existence of this zone of the "roches pennines" at Mt. Genève, and suggested that they were of Carboniferous or earlier age. Lory‡, selecting the band of "Gypse et cargneules" below Clavières as the top of the Trias, included in that system the mass of the "schistes lustrés calcaréo-talqueux" and much of the "pietre verdi" of Gastaldi. Though strongly opposed by Italian writers, he issued a sketch-map in 1881, in which the base of the Trias is still carried out to meet the ancient gneisses along a line as far east as Susa§. This seems a logical consequence of the acceptance of any part of the "schistes lustrés" as Triassic; and in almost his latest scientific utterance he affirmed the accuracy of these views||.

Notwithstanding his great breadth of vision, the balance of recent evidence seems in this matter opposed to Lory. Zaccagna, for example, states that the zone which he regards as Permian, and which underlies dolomitic limestones with *Gyroporella*, was deposited in inequalities of the calc-schist series¶; and in his section of the Pointe de Mary he shows an unconformity of the most decided character between the two**.

Zaccagna and Mattiolo, indeed, in the beautiful map appended to the paper cited††, carry their Triassic rocks from the frontier to Briançon, entirely excluding the Lias from the neighbourhood of Mt. Genève. Strips of Permian appear above the diabase group and on Mt. Chaberton.

Gastaldi hesitated to divide up definitely the "Calcaire du Briançonnais" of Lory; but on the frontier itself his map‡‡, if more detailed, would probably agree with that of Zaccagna. We have

* "Sulla geologia delle Alpi occidentali," Boll. R. Comit. geol. d'Italia, xviii. 1887, p. 388. Cf. *ibid.* p. 377.

† "Notes sur une excursion dans les Alpes en 1849," Ann. des sciences phys. et nat. Lyon, 2^e sér. t. iii. (1850-51) p. 37.

‡ "Descript. géol. du Dauphiné," 1864, paragraphs 256 and 286, Bull. Soc. Stat. Isère, 2^e sér. t. vii. pp. 14 & 72; "Stratigraphie des Alpes Graies et Cottiennes," Bull. Soc. géol. France, 3^e sér. t. i. (1873) p. 278. Cf. *ibid.* p. 269.

§ Bull. Soc. géol. France, 3^e sér. t. ix. p. 655.

|| "Études sur les schistes cristallins," Congrès géol. internat. London, 1888, pp. 26 and 28.

¶ Bull. R. Comit. geol. d'Italia, vol. xviii. (1887) p. 389.

** *Ibid.* tav. ix.

†† *Ibid.* tav. xi.

‡‡ Mem. R. Accad. dei Lincei, ser. 3, vol. ii. tav. ii.

Fig. 7.—Part of Professor Lory's Map. (Scale 1 : 250,000.)

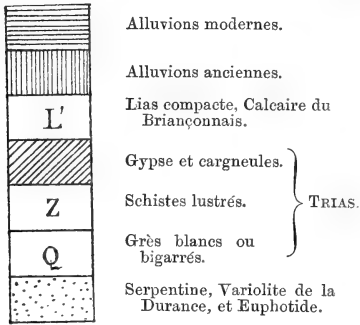
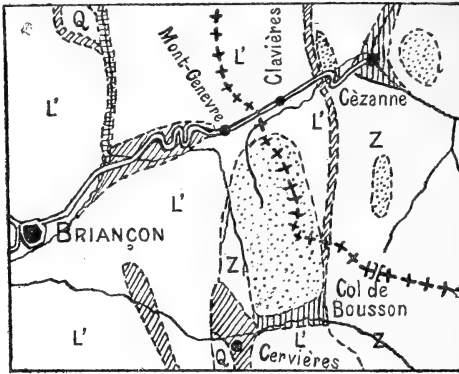
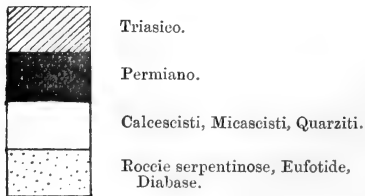
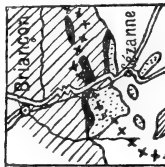


Fig. 8.—Part of Map by Zaccagna and Mattiolo. (Scale 1 : 1,000,000.)



here traced portions of the two first-mentioned maps, which will illustrate the position better than any words* (figs. 7 & 8).

Prof. Bonney † also declines to accept the “schistes lustrés” as Triassic. He regards them as schists which have retained their original stratification, and as forming the uppermost member of his three Archæan groups. If, then, the euphotides and diabases are subsequent to the “schistes lustrés,” they may still be of very considerable geological age.

At its northern end, however, the variolitic series of Mt. Genève abuts against a normal compact limestone, the “Calcaire du Briançonnais,” which is certainly above the horizon of the anthracitic Carboniferous strata. Accurate palæontological evidence being still wanting, even on Mt. Chaberton, we cannot state with certainty that this limestone is either Triassic or Liassic, but we believe with Lory that our series has been erupted through it, as well as through the dubious “schistes lustrés” or “calcescisti” of Zaccagna. The eruptive group has suffered from folding, faulting, and in some places from brecciation; but the earth-movements that took place in this area at the close of the Eocene period would amply account for these phenomena. In fine, we observe that throughout Liguria and the western Alps the distinction between the pre-Tertiary and Eocene serpentinous groups is becoming a matter of pure stratigraphy ‡. The existence of, at least, two groups has been again and again accepted; but, in the absence of the direct evidence afforded by the presence of derived pebbles of these rocks in subsequent formations, the age often assigned to the older masses may be looked upon with considerable caution. The admitted exact resemblance of the igneous rocks themselves at different horizons makes the most careful investigation all the more desirable before an age is affirmed in any instance. As long as the view that diorite, euphotide, and serpentine are formed by metamorphism from contemporaneous muds continues to be prominently put forward, so long must the true stratigraphical position of Italian and Alpine “greenstones” be involved in considerable obscurity. While we may accept with Lory a maximum age for those of Mt. Genève, we must in fairness merely style them *Post-Carboniferous* until further evidence is forthcoming.

IX. CONDITIONS OF FORMATION.

In dealing with the question of the physical conditions that gave rise to the variolitic series and its associated rocks, it is only fair to

* It is unfortunate for purposes of reference that the topographers have in Gastaldi's map written “Mt. Genève” in place of “Clavières,” while precisely the reverse mistake has occurred in that of Zaccagna and Mattiolo. In our copy from the latter the name is omitted, the frontier being sufficient guide.

† “On two Traverses of the Crystalline Rocks of the Alps,” *Quart. Journ. Geol. Soc.* vol. xlv. (1889) pp. 96 and 80.

‡ See, for example, Mazzuoli and Issel—“Sulla zona di coincidenza delle formazioni ofiolitiche eocenica e triasica della Liguria occidentale,” *Boll. R. Comit. geol. d'Italia*, vol. xv. (1884) p. 2.

bear in mind that, even at the present day, there are numerous authors who would question their eruptive origin. Scipion Gras* in 1844 went so far as to assert that dykes and veins were unknown in connexion with the variolites, spilites, euphotides, and serpentines of the Alps, which in Dauphiné and Savoy "particularly affect the anthracitic formation." A more detailed examination of the base of Le Chenaillet, however, would probably have modified this opinion. When the French Geological Society visited the area in 1861, M. Hébert†, supported by M. Studer, maintained that the compact rocks seen on the east side of the Val de Gondran (*i. e.* the variolitic diabases) were nearly horizontal sediments which had been metamorphosed by injections of serpentinous matter. This view, however, was strongly opposed by Lory, and was certainly held by only the minority of the members present in the field. We have already referred to the opinion of some geologists as to the stratified character of various "pietre verdi." It is not for us to enter into the vexed question of the origin of serpentine and euphotide or of other "greenstones"; and we must content ourselves with a passing reference to some of the more recent literature on this subject, selecting papers that deal with the area of the Apennines and the Alps.

Prof. Bonney‡, for example, has carried his studies on serpentine as far as the masses of Liguria, and strongly insists on their intrusive character. He also opposes the view that serpentine can be derived from gabbro. In 1880 Issel§ criticized these opinions, and shortly after published, with Mazzuoli||, a paper in which it is suggested that the serpentines were poured out as a warm impalpable mud on the sea-floor, where they underwent slow internal changes through the action of vapours and liquids. The authors hold that such changes would be competent to produce the diorites, euphotides, granitones, and variolites so constantly associated with the serpentines. Lotti¶, on the other hand, acknowledges and helps to demonstrate the igneous origin of euphotide, and recognizes this rock as the deep-seated type of diabase and basalt. But he differs from Prof. Bonney when he asserts that serpentine may be derived from ordinary basic rocks by alteration, through the permeation of magnesian waters from below.

In connexion with this point it will have been seen that the apparent passage from altered gabbro to serpentine at the Col du Gondran is deceptive, and that we regard the serpentine as resulting from an exceptionally basic mass formed in intimate association with the normal and felspathic igneous rock.

* "Constitution géologique des Alpes centrales de la France et de la Savoie," Bull. Soc. géol. France, 2^e sér. t. i. p. 723.

† Bull. Soc. géol. France, 2^e sér. t. xviii. p. 782.

‡ "Notes on some Ligurian and Tuscan Serpentines," Geol. Mag. 1879, p. 362.

§ Boll. R. Comit. geol. d'Italia, vol. xi. p. 183.

|| "Relazione degli studi fatti per un rilievo delle masse ofiolitiche nella riviera di Levante," *ibid.* vol. xii. (1881) p. 313.

¶ "Contribuzione allo studio delle serpentine italiane e della loro origine," *ibid.* vol. xiv. (1883) p. 281.

Turning to the compacter series, the abundant dykes show that considerable activity was going on during the formation of the variolitic lavas. In the field we pictured to ourselves a huge volcanic cauldron, its centre being most probably among the great intrusive masses of Mt. La Plane; in this basin, excavated in the calcareous schists, the viscid lavas would heave and seethe upon one another, the surfaces of junction between them becoming coated with spherulitic glass, the product of their more rapid cooling. A crust would form from time to time across the crater, to be torn through again by occasional explosive action. Hence agglomerates would be formed intimately connected with the lavas, and spherulitic glassy fragments would be abundantly thrown up, together with globular masses of compacter rocks. As the andesitic lavas became piled thickly upon one another, the new material would burst up through rocks already solid, and would form the more crystalline dykes of the Chenaillet ridge and Mt. La Plane. But even these would prove their affinity to the earlier lavas by consolidating against them with a vesicular and spherulitic selvage.

Indeed, it is this abundance of basic glass, now devitrified and furnishing the "variolite," that makes the area of Mt. Genève remarkable among volcanos old or new. While it is probable that many such centres may be recognized in Piedmont and the northern Apennines, similar occurrences are rare in other parts of Europe; and we believe that the best modern analogue is to be found in the great craters of Hawaii. Although we do not pretend that the compact andesites of Mt. Genève possessed the marvellous fluidity of the lavas of Kilauea, yet they must have borne, when fresh, a remarkable resemblance to the well-known *pahoehoe* of the Sandwich Islands. The engraving in Dutton's 'Hawaiian Volcanoes'*, and the exquisite photographic view of the lava-floor of Kilauea which accompanies a recent article by Prof. J. D. Dana†, restore for us, as it were, the surface of our "variolite-diabases;" while the vertical joint-faces in the foregrounds of these illustrations hint at structures precisely similar to those seen on the arête of Le Chenaillet. Prof. Dana's articles, indeed, considerably strengthen the impression made upon us in the field. At Kilauea the lavas have a glassy crust, which is often scoriaceous, and half an inch to two inches thick. "The crust is a *crater*-feature," writes Prof. Dana‡, "for I have not seen it on the lavas outside. . . . The lavas exuded through the crust from the liquid mass below, above alluded to as making seams, streamlets, and knobby surfaces, are covered sometimes with separable scoriaceous glassy crust, though commonly having a solid glassy exterior half an inch or so thick." At Mt. Genève, even allowing for the crushing and obliteration of delicate scoriæ during earth-movements, the more solid glassy selvages appear to have been everywhere predominant. But the scoriaceous character of the diabases, and even of the edges of the massive dykes, bears ample witness to the vapours that escaped throughout

* U.S. Geol. Survey, 4th Annual Report, publ. 1884, p. 98.

† Amer. Journ. Sci. vol. xxxiv. (1887) pl. iv. p. 364.

‡ *Ibid.* pp. 354 and 355.

the mass. Moreover, we probably find preserved for us only the lower layers of the volcanic cauldron, and any pumiceous matter of the final surface must have been removed by early denudation.

It is only natural that spherulites should occur in the glasses of the Sandwich Islands, although they may not be on so bold a scale as at Mt. Genève. Mr. E. S. Dana* has recently described spherulitic structure in a lithoidal lava from Mauna Loa; the rock contained olivine, and the spherulites were of two kinds, light-brown ones being set in a "nearly opaque spherulitic ground-mass." On pp. 451 and 459 of the volume quoted, Mr. E. S. Dana mentions similar structures in other rocks from Mauna Loa and Kilauea. Moreover, his beautiful "fan-shaped or feather-like" groups of augite in the "clinkstone-like basalt"† appear to be sections of interesting, if imperfect, spherulitic aggregations.

Cohen‡ has also described a tachylyte from Hawaii with a spherulitic ground-mass; and a specimen in the collection of the Normal School of Science and Royal School of Mines shows small brown spherulites, clustering more and more closely until the glass passes into the almost opaque matrix of the basalt.

It would have been a harmonious conclusion to this comparison if we could have classed our agglomerates as ancient *aa* lava-streams, that is to say, as brecciated, rugged, and scoriaceous flows. But neither the arrangement of the masses nor the globe-like bombs correspond with the features so clearly described and figured by Prof. Dana§, and we are led to treat these deposits as produced by true explosive action. The compact non-scoriaceous character of the vast majority of the ejecta is paralleled, curiously enough, in the "stones" of the tuffs on Kilauea||.

While the extent of these fragmental rocks does not seem to have been sufficiently insisted on in the past, authors have often stated their views as to the origin of the variolite itself. The great advance in the discussion of this question appears to us to have been made by Lory¶, when he so clearly recognized the variolite as a product of the rapid cooling of an igneous mass. After this statement the various accounts of its discovery as a selvage to diabase dykes in other districts have seemed in the highest degree natural, and have met with ready acceptance.

Finally, if it is granted that the variolite of Mt. Genève represents a glassy lava-crust which has been devitrified by slow secondary action, is there anything in the nature of the compact diabases that will explain its relative abundance? If the lavas were unusually fusible, the glassy condition might be retained over large areas; but it is unfortunately impossible to argue as to the exact original characters, chemical or physical,

* "Contributions to the Petrography of the Sandwich Islands," Amer. Journ. Sci. vol. xxxvii. (1882) p. 452.

† *Ibid.* p. 443.

‡ Neues Jahrb. für Min. &c. 1880, vol. ii. p. 51.

§ Amer. Journ. Sci. vol. xxxiv. (1887) pp. 362-364.

|| *Ibid.* p. 360.

¶ Bull. Soc. géol. France, 2^e sér. t. xviii. (1861) p. 782.

of rocks so highly altered. The analysis made by Delesse* of the variolite of Mt. Genève corresponds closely with the average composition of a number of Hawaiian lavas, as already quoted in this Journal from the work of Cohen†. But an average of twelve analyses by Silvestri‡ differs in many respects from that derived from Cohen's figures, the percentages of silica and magnesia, for instance, being distinctly lower. It seems, moreover, from the experiments of Silvestri, that ease of fusion or a refractory character cannot be ascribed to the predominance in these lavas of any particular base§. We quote these averages for comparison with the variolite, but fully recognize the extensive alteration of the latter. We have excluded the two most altered examples in dealing with the analyses of Silvestri.

	I.	II.	II
	Variolite. (Delesse.)	Average composition of Hawaiian lavas. (Cohen.)	Average composition of Hawaiian lavas. (Silvestri.)
Silica	52·79	51·71	48·25
Alumina	11·76	11·44	15·65
Oxides of Iron	11·07	12·62	16·59
Oxide of Manganese.	trace	—	—
Lime	5·90	10·75	8·40
Magnesia	9·01	7·59	3·70
Soda	3·07	3·47	3·62
Potash	1·16	0·67	1·57
Oxide of Chromium .	trace	—	—
Loss on ignition . . .	4·38	0·98	0·41
	99·14		

It is probable, then, that complete fusion, arising from abundant access of water|| or unusually high temperature, rather than any chemical peculiarity, will best explain the wide extension of glassy selvages in our area. But the occurrence of the variolite, with its detailed analogy to the tachylytes of the present day, forms the best proof, if proof were needed, of the igneous origin of the diabase-series of Mt. Genève.

X. THE CONCLUSIONS OF PREVIOUS AUTHORS AS TO THE NATURE OF THE VARIOLITES OF OTHER LOCALITIES.

Though variolite is rare and local, a fairly long list of its occurrences can be compiled. Of these, however, a considerable proportion may be at once dismissed, as there are several very different rocks

* Bull. Soc. géol. France, 2^e sér. t. vii. (1850) p. 430.

† Quart. Journ. Geol. Soc. vol. xxxix. (1883) p. 457; Cohen, Neues Jahrb. für Min. &c. 1880, vol. ii. p. 41.

‡ "Lave del vulcano Kilauea," Boll. R. Comit. geol. d'Italia, vol. xix. (1888) p. 194.

§ *Ibid.* pp. 135, 141, 171, &c.

|| See Prof. Judd, "The Natural History of Lavas," Geol. Mag. 1888, p. 11. Q. J. G. S. No. 182.

included under this name. Thus, according to Valmont de Bomare*, some of the specimens of West-Indian "Gamaicu" are pieces of madrepore; possibly it has an oolitic structure. A second group that must be removed is a series of hornblende and actinolitic schists; such are the variolites of the Varaita and Upper Po valleys described by Gastaldi †, those from the Pellice valley near Turin ‡, and the variolitic hornblende-schists of Transylvania §. The third group to be removed are those amygdaloids known as the "variolites of the Drac" ¶; they were rightly regarded as volcanic by Lamanon ¶¶, who, having been persuaded by Faujas and others that he was wrong, destroyed all but twelve copies of his work. Brongniart** has described from Pietra mala, and Mattiolo †† from Pria Borghese, other variolites that are apparently amygdaloids; in the latter case the rock contains globules of calcite and chlorite, without radial structure.

In most of the localities from which true variolite has been recorded only pebbles of it have been found, and these may be summarily dismissed as likely to throw little or no additional light upon the nature of the rock. Such are the pebbles at Le Chatelard, in Savoy †††; in the Emmenthal, in Switzerland §§; at Hausdorf and other localities in Silesia ¶¶¶; in the Remigiusberg, near Cusel in Bavaria ¶¶¶; in the valley of the Inn, at Braunau***. In Italy they have been discovered at Chaumont near Susa †††, at Fenestrelles*, Exilles †††, Frejus §§§, Sestri near Genoa*, Monte Catini near Volterra*, near Pietra Mala*, the Dora near Turin ¶¶¶, Sestrières ¶¶¶, near Monte Viso****, &c. In the collection of the Normal School of Science and Royal School of Mines there is a

* Valmont de Bomare, 'Dictionnaire raisonné universel d'Histoire Naturelle,' t. viii. Lyon (1791), pp. 272-4.

† B. Gastaldi, Boll. Com. geol. Italia, vol. vii. (1876) p. 106.

‡ Geinitz, Tsch. Min. u. petr. Mitth., Neue Folge, Bd. i. (1878) p. 152.

§ F. von Hauer and Guido Stache, 'Geologie Siebenbürgens,' Wien, 1863, p. 209.

¶ Gueymard, Ann. Mines, sér. 4, t. xviii. (1850) pp. 41-59.

¶¶ De Lamanon, 'Mémoire Litho-Géologique sur la vallée du Champsaur et la montagne de Drouvaire dans le Haut Dauphiné,' Paris, 1784.

** A. Brongniart, Ann. Mines, vol. vi. (1821) p. 198, pl. i. fig. 4.

†† E. Mattiolo, Rend. Accad. Lincei, Roma, ser. 4, vol. ii. pt. i. (1886) p. 646.

††† P. L. A. Cordier and Ch. d'Orbigny, 'Description des Roches,' Paris, 1868, p. 165.

§§ Longius, l. c.; J. F. Kaufmann, Beitr. z. geol. Karte Schweiz, xi. 1872, p. 375.

¶¶¶ E. Dathe, Jahrb. d. k. preuss. geol. Landesanst. für 1882 (Berlin, 1883), p. 228-62; "Variolite der Gabbrogruppe in Schlesien," Zeitschr. deutsch. geol. Ges. Bd. xxxiv. 1882, pp. 432-4.

¶¶¶ A. Leppla, N. Jahrb. 1882, Bd. ii. pp. 134-5.

**** Chierici, Ann. Mines, vol. v. 1820, pp. 397-400.

††† Morozzo, Mém. Acad. roy. Sci. Turin, vol. v. 1793, p. 165.

††† Fournet, Ann. des Sci. phys. et nat. Soc. roy. d'Agric. Lyon, sér. 1, t. iv. (1841) p. 156.

§§§ H. B. de Saussure, 'Voyages dans les Alpes,' t. v. (1796) pp. 415-417.

¶¶¶ Eug. Geinitz, Tscherm. Min. u. petr. Mitth. i. (1878) pp. 136-153.

¶¶¶ Ibid. p. 146.

**** Robilant, Mem. Ac. Roy. Sci. Turin, i. 1786, p. 242.

specimen of typical variolite, brought by the late Prof. Carvill Lewis from Masasco, in Liguria; and we have recently received from Mr. F. B. Parkinson, A.R.S.M., an excellent example from Monte Penna, on the western frontier of Emilia.

Though this does not exhaust the list of recorded localities of variolite as pebbles, there are but very few cases known of its occurrence *in situ*, viz.: the Fichtelgebirge*, Schönfels in Voigtland †, and the Harz ‡ in Germany; Yalguba, near Olonetz, in Russia; Mont Genève, Cesana Torinese §, Monte Loreto ||, the Rochers de Rioubrent ¶, south-west of Monte Viso, and a few other Italian localities.

Most authors agree that it is a structural modification of a basic rock, whether euphotide, as was maintained by many French geologists, as Fournet, Lory, Hébert, Gras, Cordier, d'Orbigny, and Lévy, or of aphanite or diabase, as was held by Haiüy, Lossen, Gümbel, Löwinson-Lessing, Rosenbusch, and others.

As to the nature of the modification, opinions differ materially. The most unsatisfactory modern theory is that which regards the varioles as included and metamorphosed fragments—a view advanced by Gümbel**, and still held by him †† in spite of the criticisms of Zirkel ‡‡ and others. Chierici §§ maintained that the varioles were formed by decomposition of garnets, which at first broke down into black granules, and these, in a later stage, were bleached into the typical varioles. The opinion, however, that is most generally received regards variolite as the product of contact-alteration—a view that has been accepted by, amongst others, Lory, Lévy and Fouqué, Dathe, Leppla, Zirkel |||, and Rosenbusch ¶¶. The last-named author concludes that the opinion that variolite arises as an “endomorphe Contactform der Diabase” hardly requires repetition. There can be no doubt that many variolites have been formed in this manner; but some, no doubt, have arisen as a crust on lava. Löwinson-Lessing clearly recognizes*** that both methods of formation have been in operation, as he divides the variolites into two classes. He includes among the first group, or contact-modification products, those of the Fichtelgebirge, Franken-

* C. W. Gümbel, ‘Die paläolithischen Eruptivgesteine des Fichtelgebirges,’ München, 1874, p. 31; N. Jahrb. 1876, pp. 42, 43; Geognostische Beschreibung des Königreichs Bayern, Abth. iii. (Gotha, 1879), pp. 213-8.

† F. Zirkel, Ber. d. k.-sächs. Ges. d. Wiss. xxvii. (1875) p. 211.

‡ K. A. Lossen, Jahrb. d. k. preuss. geol. Landesanst. für 1880, pp. 10-12.

§ B. Gastaldi, Descriz. della Carta geol. Italia, ii. pt. 2 (Firenze, 1874), p. 28.

|| Mazzuoli and Issel, Boll. Comit. geol. Italia, vol. xii. (1881) p. 329.

¶ D. Zaccagna, Boll. R. Comit. geol. Italia, xviii. (1887) p. 387.

** C. W. Gümbel, N. Jahrb. 1876, p. 42.

†† C. W. Gümbel, Geologie von Bayern, Th. i. Lief. 1, 1884, pp. 78, 79.

‡‡ F. Zirkel, Ber. d. k.-sächs. Ges. d. Wiss. xxvii. (1875) p. 211.

§§ Chierici, Ann. des Mines, v. (1820) p. 398.

||| J. J. H. Teall, ‘British Petrography’ (London, 1886) p. 134.

¶¶ H. Rosenbusch, ‘Mikroskopische Physiographie der massigen Gesteine,’ Aufl. 2, Bd. ii. (1887) p. 227.

*** F. Löwinson-Lessing, ‘Olonetzskaya Diabazovaya Formatziya,’ Trud. St. Peterburgskagho Obsch. Estest. xviii. (1888) p. 169.

wald, and Voigtland, and doubtfully those of the Durance; the second division, or the spherulitic augite-porphyrates, is constituted by the variolites of Yalguba and some described by Geinitz. As will have been seen by our previous description, the variolites of Mont Genève mainly belong to the second class.

Owing to the looseness with which the name "variolite" has been used, it will be advisable in this connexion to repeat our definition of the term, although from the modern point of view the rock would scarcely require a distinctive name. As the variolite of the Durance was the first scientifically studied and described, we think it ought to be regarded as the type, in preference to the obscure "Variolites Lucernensis," or the unknown Italian rock described by Aldrovandus. We therefore define "variolite" as a devitrified spherulitic tachylyte, typically coarse in structure.

The unaltered rock that is probably most closely related to variolite is the spherulitic augite-andesite of the Vashegy mountain near Telkibanya, in Hungary. For interesting information respecting this rock we are indebted to Dr. J. de Szádeczky, of Budapest.

The variolite of Yalguba, in Olonetz, also closely approaches that of the Durance, and is of interest from the occurrence in the matrix of small patches of a brown glass which have escaped devitrification. This rock has been described in considerable detail by Inostranzev* in 1874, by Lœwinson-Lessing† in 1884, and again by the latter author in his elaborate memoir "Olonetz-kaya Diabazovaya Formaziya"‡. Lœwinson-Lessing seems inclined to abandon variolite as the name of a rock-species in favour of spherulitic augite-porphyrate, retaining it, however, in the form of "variolitism" for that of a process§. As variolitization seems to have resulted from the same causes that have built up ordinary spherulites, we do not see the necessity for the new term, especially as its introduction would obscure the identity of the results that have been produced by the action of similar causes on both the acid and the basic rocks.

The above definition of variolite, however, excludes several rocks that have been regarded as variolite; thus, that found by Dathe|| in the Culm Conglomerate of Silesia contains 75 per cent. of silica, and certainly cannot be regarded as a basic rock, unless a considerable proportion of the quartz is secondary. The close association of this variolite with gabbro and gabbro-conglomerate suggests that such may be the case, though Dathe has abandoned his original view of the connexion of the variolite and gabbro. Neither do we see any

* A. Inostranzev, "O Variolitye," Verh. k. russ. min. Ges. St. Petersburg, 1874, pp. 1-28, pls. i. & ii.

† F. Lœwinson-Lessing, Tsch. Min. u. petr. Mitth. vi. (1884) pp. 281-300, pl. iv.

‡ Trud. St. Petersburgskagho Obshch. Estest. xviii. (1888) pp. 29-396, pl. i.-v.

§ *Ibid.* p. 169.

|| J. Fr. E. Dathe, Jahrb. k. k. preuss. geol. Landesanst. für 1882 (Berlin, 1883), p. 254.

reason for regarding the spherulitic tachylyte of Carrock Fell* as a variolite, since the basis is not devitrified. The minute size of the spherulites would also debar Sordawalite† from ranking among the true variolites‡.

XI. SUMMARY OF THE CONCLUSIONS ARRIVED AT IN THIS PAPER.

We believe, finally, that the discussion of the observations of others and of ourselves justifies the following conclusions:—

The gabbro or euphotide south of Mt. Genève is associated with serpentines, which were originally peridotites, and were not derived from the alteration of the gabbro. These coarsely crystalline rocks probably form a considerable subterranean mass, but have little importance at the surface.

They were broken through by dykes of dolerite and augite-andesite, and are now overlain by a great series of compact diabases and fragmental rocks, which has no direct connexion with the gabbro.

The variolite of the Durance occurs *in situ* as a selvage on the surfaces of these diabases among themselves; as blocks in the fragmental rocks, which are regarded by us as tuffs; and occasionally as a selvage to the diabase dykes.

This product of rapid cooling was originally a spherulitic tachylyte, and has become devitrified by slow secondary action. Variolite stands in the same relation to the basic lavas as pyromeride does to those of acid character.

The eruptive rocks in the Mt.-Genève area are probably post-Carboniferous; but their exact age cannot at present be determined.

There are several other areas of similar variolitic rocks among both the Alps and the Apennines of Piedmont and Liguria.

The best modern representative of the conditions that produced these rocks is to be found in the great volcanoes of Hawaii; and there is nothing, either in their fundamental characters or in their mode of origin, that cannot be paralleled among the products of causes now in action.

In the preparation of this paper we have been guided at many points by the kind advice of Prof. Bonney and Prof. Judd. We have thus also been able to avail ourselves of several specimens and sections in the collections of the Normal School of Science and Royal School of Mines. Our indebtedness to those who have preceded us on the classic ground of Mont Genève is, we trust, fully apparent in the paper.

* T. T. Groom, *Quart. Journ. Geol. Soc.* vol. xlv. (1889) p. 303.

† F. Læwinson-Lessing, "Die mikroskopische Beschaffenheit des Sordawalits," *Tsch. Min. u. petr. Mitth.* ix. (1887) pp. 61-76.

‡ [By the kindness of Prof. Blake we have been enabled to examine the variolite found by him near Careg Gwladys in Anglesey (*Brit. Assoc. Rep.* 1888, p. 11, pl. v. fig. 22); as this is the first discovery of the rock in the British Isles, we hope it will be more fully described.]

EXPLANATION OF PLATE XIII.

[The numerator of the fraction expressing the degree of enlargement of an object represents the magnifying-power of the objective with which it was viewed.]

- Fig. 1. Crystal of plagioclase in the great porphyritic diabase on ridge of Le Chenaillet, traversed by a crack and subsequently restored by material optically continuous with the original crystal. $\times \frac{3}{3}^4$.
2. Junction of diabase-dyke and gabbro, S.W. spur of Le Chenaillet. The diabase has a selvage of formerly glassy matter, green and somewhat altered, and showing black globulitic aggregates. $\times \frac{3}{3}^4$.
 3. Tuff containing fragments of altered scoriaceous glass and variolitic rocks. Val du Gondran. $\times \frac{2}{3}^3$.
 4. Tuff containing fragments of greenish altered glass and of compacter lavas with radial groups of plagioclase. East ridge of Gimont Valley. $\times \frac{2}{3}^3$.
 5. Porphyritic diabase of ridge of Le Chenaillet, some inches from its variolitic selvage, showing radial grouping of the plagioclase. $\times \frac{2}{3}^3$.
 6. "Pseudocrystallites" and curving cracks intimately associated in large spherulite in the variolite. North end of ridge of Le Chenaillet. $\times \frac{4}{3}^1$.

DISCUSSION.

Prof. BONNEY had been over the Mont-Genèvre, but had not reached the exact area described by the Authors, though he had seen some of the rocks mentioned. From his general knowledge of the district, he appreciated how careful their description had been, and believed with them that the variolites merely represented the pyromeride-stage—a feature which, in his experience, was very rare amongst the basic rocks. He stated that the Authors were correct in assigning the gabbros and serpentines of the region to the ordinary Alpine types, and was interested to learn that the variolite had nothing to do with the gabbros.

Prof. JUDD also congratulated the Authors on their thorough treatment of an interesting subject. He wished to correct a mistake of his own: judging from specimens of Hawaiian rocks which he had seen, he was led to suppose that the tachylytes of Kilauea occurred in extensive masses; but Dana had shown that the crusts of glass were never more than two inches thick.

Prof. BLAKE compared the variolite of the Durance with a rock in Anglesey occurring in a similar way.

Mr. GREGORY, in reply, said that though much of the old variolite came from the north side of the ridge, nevertheless some of the rock probably occurs in the valley to the south. It would be extremely interesting to find a true British variolite in Anglesey. One of the type-places in the Alps where there was supposed by E. de Beaumont and others to be a passage from gabbro to serpentine was this valley. The supposed serpentines which gave rise to this view were not really examples of that rock.

19. *On a DEEP CHANNEL of DRIFT in the VALLEY of the CAM, ESSEX.*
By W. WHITAKER, B.A., F.R.S., F.G.S. (Read March 12, 1890.)

FOR many years the rising-up of older rocks beneath the Cretaceous beds of the London Basin, and beneath the Jurassic rocks to the north and to the west, has been brought in evidence before us by means of deep wells and borings. It may therefore be a welcome change to notice an occurrence of an opposite kind, the evidence of which is, in like manner, almost wholly owing to the well-sinker.

In Scotland long and deep channels, filled with Drift, have been noticed, and have been referred to river-action*. In the northern part of England, too, the like has been observed †; but I am not aware of the occurrence of such channels in Southern England, except on a small scale, having been described. It is perhaps well, therefore, to bring before the Society evidence that shows a sudden and deep extension downward of beds of late geologic age, namely the Glacial Drift, which are usually of no very great thickness, and which, in the tract in question, occur chiefly on the higher grounds.

In the Geological Survey Memoir that treats of the part of Essex that borders on Hertfordshire and Cambridgeshire, there is an account of a well-section at Wenden, showing an unexampled thickness of Drift at a comparatively low level, and also a description of two railway-sections that show the Drift abruptly abutting against the Chalk ‡.

Although my former colleague, Mr. Penning, who mapped the tract in question, near Audley End, wrote that "The Drift hereabouts fills an old channel, one slope of which is shown in [one] section, whilst another slope in a different direction, and at a distance of half a mile, is exposed near the station," he did not then think the evidence clear enough to warrant further remark.

Lately, however, a good deal more evidence has turned up, for which we have to thank Mr. G. Ingold, well-sinker, of Bishop Stortford. It is not proposed, however, to lay before the Society the detailed accounts of the various new wells, these having already been more fitly given to the Essex Field Club §.

In the well-sections to be referred to there is, in some cases, a certain amount of Post-Glacial Drift at the top; but this is comparatively small (in no case, for certain, more than 20 feet thick), so that it may be disregarded as a separate feature, and may be massed with the underlying Glacial Drift. This latter consists

* A. Geikie, "Ancient River-courses underneath the Boulder-clay," *Trans. Geol. Soc. Glasgow*, vol. i. pt. ii. pp. 49-52 (1863). J. Croll, "River Channels Buried under Drift," *ibid.* pp. 330-345.

† T. M. Reade, "The Buried Valley of the Mersey," *Proc. Liverpool Geol. Soc. Session 14*, pp. 42-65 (1873), &c.

‡ "The Geology of the N.W. parts of Essex," &c., pp. 38, 39, 80 (1878).

§ See 'Essex Naturalist,' vol. iii. pp. 49-54 (1889).

mostly of loam and sand, more or less bedded, with clay (sometimes apparently a Boulder-clay, full of pieces of chalk) and gravel.

It will be convenient to take the localities in order from south to north, beginning at the head of the valley of the Cam, in the higher part of which they all are (with a range of little more than six miles), and working downward.

Quendon and Rickling.

Although the evidence here is of a far less striking character than at the places to the north, and, indeed, might be passed over did it stand alone, yet it may be well to note what has been proved by well-sections, namely, that there is a greater thickness than would have been expected of those beds of Glacial Drift that crop out from beneath the great sheet of Boulder-clay, the sandy and gravelly beds that Mr. S. V. Wood called Middle Glacial.

Thus, near Brick Kiln Cottages, N.W. of Rickling Green, just above the 300-foot contour, the Chalk seems to have been reached at a depth of about 83 feet, whilst it comes to the surface some 550 feet N.N.W. at about the same level. Again, in a well at the south-western end of the Green, the depth to the Chalk is 60 feet, at a level perhaps a few feet higher.

At the public well, by the side of the highroad opposite Quendon Farm, and just below the 300-foot contour, a depth of $79\frac{1}{2}$ feet did not reach the Chalk. An old well at "The Views" near by, but rather higher, is 100 feet deep, and about 3 feet in Chalk. On the eastern side of Quendon Hall Lane, some way below the 300-foot contour, and some 400 feet from the highroad, the Chalk was reached at the depth of only 18 feet; but at Quendon Hall, further north, the well ends in sand at 90 feet, the level of the ground being about 300 feet.

On the east of Quendon the Chalk crops out, rising, at one part of the western slope of the valley, to about the 300-foot contour.

Newport.

It is here that we have the greatest thickness of Drift hitherto recorded, not only in Essex, but in the South-east of England, and even there its base has not been reached.

At the southern end of the village, a well at Mr. Shirley's Malting, on the marsh just east of the stream, reached the Chalk at the depth of 75 feet. On the eastern border of the narrow marsh the Chalk seems to crop out at a distance of about 150 feet, so that the westerly underground slope of the Chalk-surface is not less than 1 in 2.

The most interesting well, of all that have to be referred to, is at the other end of the village, and was made for the Grammar School, on the site of the Castle, a little above the 200-foot contour on the north of the Wicken Water. This boring begins just below the boundary of the great sheet of Boulder-clay, and therefore we have here to deal only with beds beneath that division of the

Glacial Drift. Instead, however, of the usual comparatively thin sand or gravel being found, the boring-tool, after passing to a depth of 340 feet, chiefly through loamy beds, did not succeed in reaching the Chalk, and the work was abandoned. The Drift, therefore, must here go down to a depth of about 140 feet below the level of the sea; how much deeper we know not.

As on the other, or eastern, side of the main stream, the Chalk crops up at a distance of about 1000 feet, or a trifle more, and only a little below the 200-foot contour, we have here, allowing a difference of level of 15 feet between the two sites, an easterly rise of the underground Chalk-surface of at least 325 in 1000, on the presumption that the Chalk would be touched at once on deepening the bore, and that the Drift occurs right up to the eastern edge of the marsh. We may fairly, therefore, call this a slope of about 1 in 3, over a long distance, and it may, of course, be steeper.

Wenden.

Hitherto we have been dealing with tracts where the great sheet of the Drift spreads down to the bottom of the valley, though at last on the western side only. From Wenden northward, however, this sheet of Drift is cut through by the valley, the flanks of which are then chiefly of Chalk.

It is at and near this place that the abrupt way in which the Drift lies against the Chalk has been seen, in open sections, as figured by Mr. Penning; and turning again to the evidence from deep borings, we have here two sections showing a great depth of Drift.

One of these, at Mr. Collins', north-eastward of Audley End Station, and, measuring on the six-inch Ordnance Map, about 550 feet eastward of the "Neville Arms," reached the Chalk at the depth of 220 feet. The other, which is somewhat nearer to the outcrop of the Chalk, was made for some cottages belonging to Lord Braybroke, and is on the southern side of the road, a little north of the "Neville Arms," and about 650 feet W.N.W. from the former well. In this case the Chalk was not reached until the boring had been made to the depth of 296 feet.

As, by a measurement made by Mr. Ingold, the Chalk occurs at only 3 feet below the ground (the 3 feet probably being soil) at the railway, only 140 yards N.N.W. of the second boring, it follows that, between these two places, there must be a fall of the Chalk-surface of 293 feet. Presuming that they are at about the same level (the site of the boring is probably a trifle the lower), this is a slope of 1 in 1.43.

Mr. Collins' well, though at a slightly lower level, seems to show the beginning of the easterly rise of the Chalk, which rock is bare at the lower part of the slope on the other, or eastern, side of the valley, the Drift coming on again higher up, at about the 200-foot

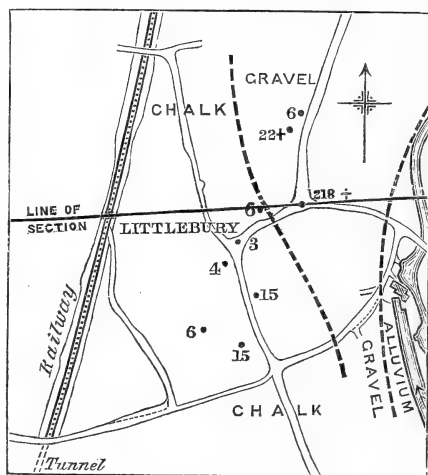
contour, whilst on the western side the mass of the Drift is at a higher level.

Littlebury.

According to the Geological Survey Map (Sheet 47) this village is on Chalk, capped in the eastern and lower part by River Gravel, which, in its turn, sinks below Alluvium close to the river. There was nothing, however, at the time when this map was made to show the presence of Glacial Drift, or of anything more than a thin narrow sheet of River Gravel over the Chalk; nor, indeed, is there now any sign at the surface; the mapping is right, for the narrow tracts of River Gravel and of Alluvium wholly hide the deep mass of Glacial Drift which has been unexpectedly proved.

The position of various wells in the village and their depth to the Chalk are shown in the map (fig. 1), which is from the new Ordnance Map (Essex, Sheet 8).

Fig. 1.—*Outline Map of Littlebury, with Sites of Wells.*
(Scale 6 inches to a mile.)



The figures stand for the depth to Chalk, in feet, at the wells.
The Geology has been indicated from the one-inch map (Sheet 47).

From this it will be seen that in five wells the depth to the Chalk is from 3 to 6 feet only, that being taken up merely by such top-earth, soil, or trace of gravel as might be expected. In two other wells, however, the Chalk was not touched for 15 feet, perhaps from the occurrence of a pipe or small hollow of gravel. Another well, the second to the north, ends in sand at a depth of 22 feet, and therefore gives little information.

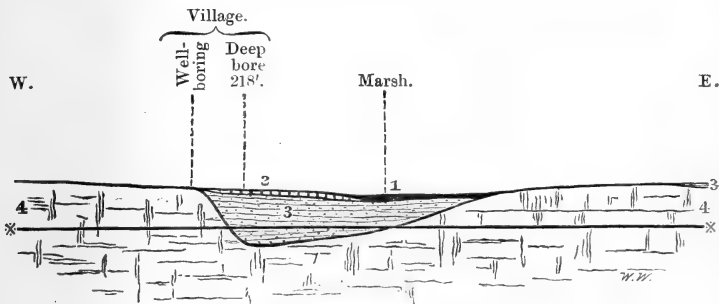
When, however, we turn to the one at about the centre of the village, where the road to Saffron Walden leaves the highroad, we

find that, after boring to the depth of 218 feet, the Chalk was not reached, the whole being in Drift. Now, as in the next well to the west, only 60 yards off, and at a slightly higher level, Chalk was touched at the depth of 6 feet, it follows that there must be a fall of the underground Chalk-surface of more than 212 feet in a distance of 180, or about a slope of 1.2 in 1 (adding only 4 feet to the 212).

As the last well was only carried 6 feet into the Chalk, it may be thought that this might be merely a boulder; but it should be noted that its evidence to the presence of Chalk in place is supported by the other wells. Thus the one where the road to Royston branches off, and which is only 125 yards from the deep Drift boring, reaches the Chalk in 3 feet, and is carried 121 feet into that rock. Again, the most northerly well, which is probably at much the same level as the deep boring, reaches the Chalk in 6 feet, and has been carried 19 feet into it, and this shows a fall of the Chalk-surface of more than 212 feet in 270.

Turning to the other side of the valley, we find that the Chalk rises up from beneath the Alluvium, and is bare of Drift until reaching the higher ground, from which it follows that the underground Chalk-surface must again rise abruptly eastward. A section, therefore, through Littlebury from east to west would be as in fig. 2, presuming that the Chalk would soon be met with by

Fig. 2.—Section across Littlebury, from a little S. of W. to a little N. of E. (Scale 6 inches to a mile, or 880 feet to an inch *.)



1. Alluvium (and River Gravel).
2. River Gravel.
3. Glacial Drift.
4. Chalk.

* * Ordinance datum.

deepening the 218-foot boring, and giving the greatest possible lateral extension to the channel of Drift: in other words, the slopes of the underground Chalk-surface cannot be less than as shown, but may be greater; and it should be remarked that the vertical scale is not exaggerated.

* Ordnance Datum (mean sea-level). The thickness of 1 and of 2 exaggerated slightly, of necessity.

This section has been taken to about the 200-foot contour on either side of the valley, and it should be noted that, whilst the boundary of the high mass of Glacial Drift just touches that contour on the east, and then only just by the spot to which the section has been taken, on the west that boundary is above the 300-foot contour, far beyond the limit of the section.

Nature of the Channel.

It may be well to notice three explanations of the channel that certainly suggest themselves. These are disturbance, sinking-in of the Chalk, and erosion.

As to the first, there seems to be strong imagination wanted for the acceptance of the idea of a fault of the throw and extent needful, and that must have been brought about during or since Glacial times. Moreover, there are no signs at the surface of such a fault, which must affect the Chalk. The Drift beds, too, that fill the channel are not such as occur on the higher ground around.

On the other hand, Mr. Ingold, to whom we owe our information about the borings, asks "If the Chalk at Wenden has been ploughed-out, how do you account for the soft white Upper Chalk with flints being found at from 300 to 350 feet below the level of the same kind of chalk at the outcrop near by? It seems to me more like a settlement." As, however, the Middle Chalk has a few flints in part, there is some doubt whether Upper Chalk is present beneath the thick Drift in the Wenden borings, though this division probably goes down some depth in that neighbourhood.

To explain the occurrence of so deep a hollow over such a length of country by sinking-in of the gravel from dissolution of the Chalk, is open to the objection that the infilling Drift differs from that on the neighbouring hills, which, too, in most cases comes near or close to the borings. Deep pipes in the Chalk we know to occur, but these are very different things.

I can see therefore no other explanation than a cutting-out of the channel by erosion of some sort, the effect being perhaps strengthened by later dissolution of the Chalk, which might take place more readily here than elsewhere. It is this explanation only that gets over the difficulty of the peculiar character of the Drift in the channel.

It would seem that the channel was cut out before the deposition of the Boulder-clay over the higher ground, for we have no such beds as those in the borings anywhere above the Boulder-clay, and, on the other hand, they are more like the loams, &c. that occur beneath the Boulder-clay elsewhere. The deepest boring of all, too, at Newport, begins just at the base of the Boulder-clay.

Mr. Ingold thinks that the channel reaches northward to Whittlesford, the loam of the deep Newport boring being like that at Whittlesford Bridge, near the station. This would add about 5 miles to the length of the channel, making it 11 miles. It is to be noted, however, that on the Geological Survey Map (Sheet 47) there

are two breaks in the continuity of the Glacial and River Drift along the valley, bare Chalk being mapped between Wenden and Newport, and again south of Littlebury. Whether further examination, with fresh evidence, may show the Drift to be continuous is a question to be decided. If the Chalk in the parts mentioned be really bare of Drift, then the channel is not continuous, or, at all events, was in parts so shallow as to have been destroyed in the erosion of the present valley. Between Littlebury and Whittlesford Bridge, a narrow channel, filled with Glacial Drift, may occur beneath the River Drift and the Alluvium, and may be proved by future wells; but we may perhaps have a set of long narrow basins instead of one more even and continuous channel.

[POSTSCRIPT.—A well-section at Whittlesford has been given on page 20 of the Geological Survey Memoir, "The Geology of the Country between and south of Bury St. Edmund's and Newmarket" (1886). Specimens, since seen, show that the bed described as blue clay is a hard grey calcareous band, like some of the loams in the borings alluded to above.]

DISCUSSION.

Dr. EVANS thought the Author's conclusions would generally commend themselves to Fellows. He gave reasons for rejecting the supposition that these particular depressions were due to chemical solution of the Chalk, and believed that, at the time the depressions were formed, the district was more elevated than it is at present. Under such conditions valleys would be rapidly denuded with an increased rainfall. There was one curious feature, viz. that the old configuration of the country was sufficiently distinct for the existing valleys to follow the same lines as those of an earlier age. This elevation of the country to some extent corresponds with that required by Mr. Prestwich in connexion with the Westleton Beds, and the axis might well have taken the direction which that Author had inferred.

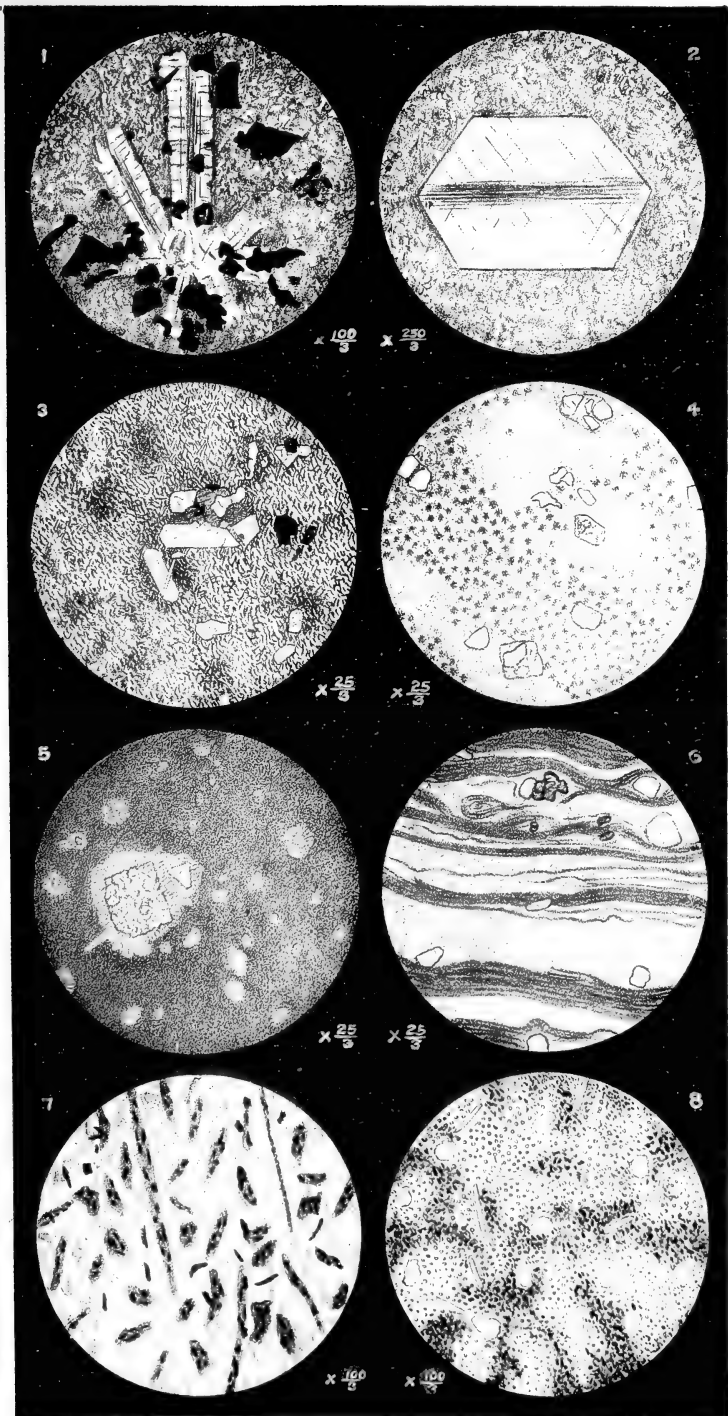
Mr. CLEMENT REID had found several of these old valleys in the North of England, but felt some diffidence in comparing an old valley in hard rocks with one in soft rocks. He suggested as a possibility that the Essex depression might not be a river-channel but a lake-basin, and was desirous of knowing whether it corresponded with the general direction of movement of the ice.

Mr. TOPLEY was inclined to think that the Preglacial-channel explanation was the most likely one. In Northumberland, the Blyth was, in Preglacial times, a tributary of the Wansbeck, and a deep Preglacial valley, which was filled with Glacial drift, occurred between the present valleys.

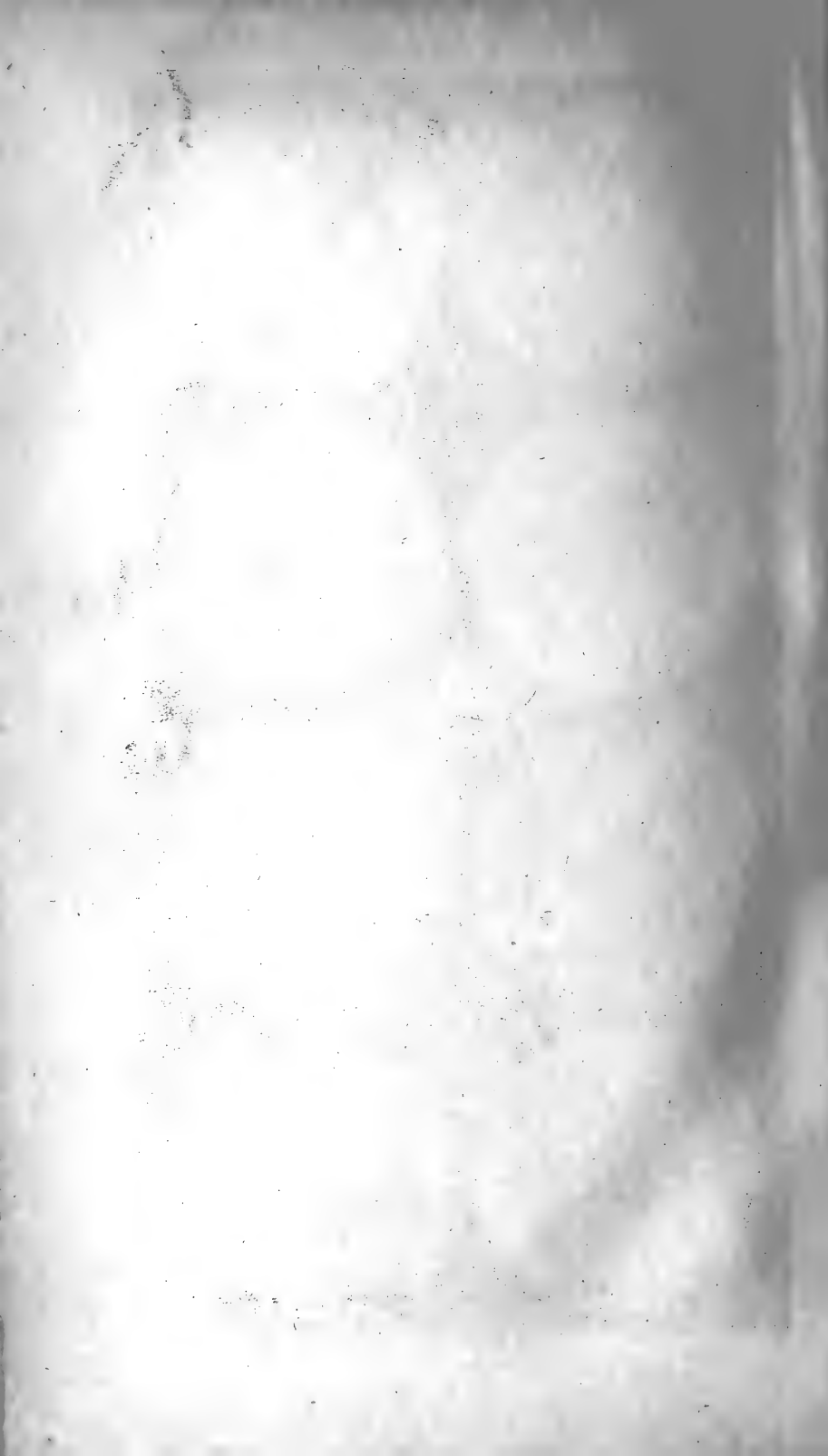
Mr. J. ALLEN BROWN asked why such hollows were called Preglacial, rather than Glacial.

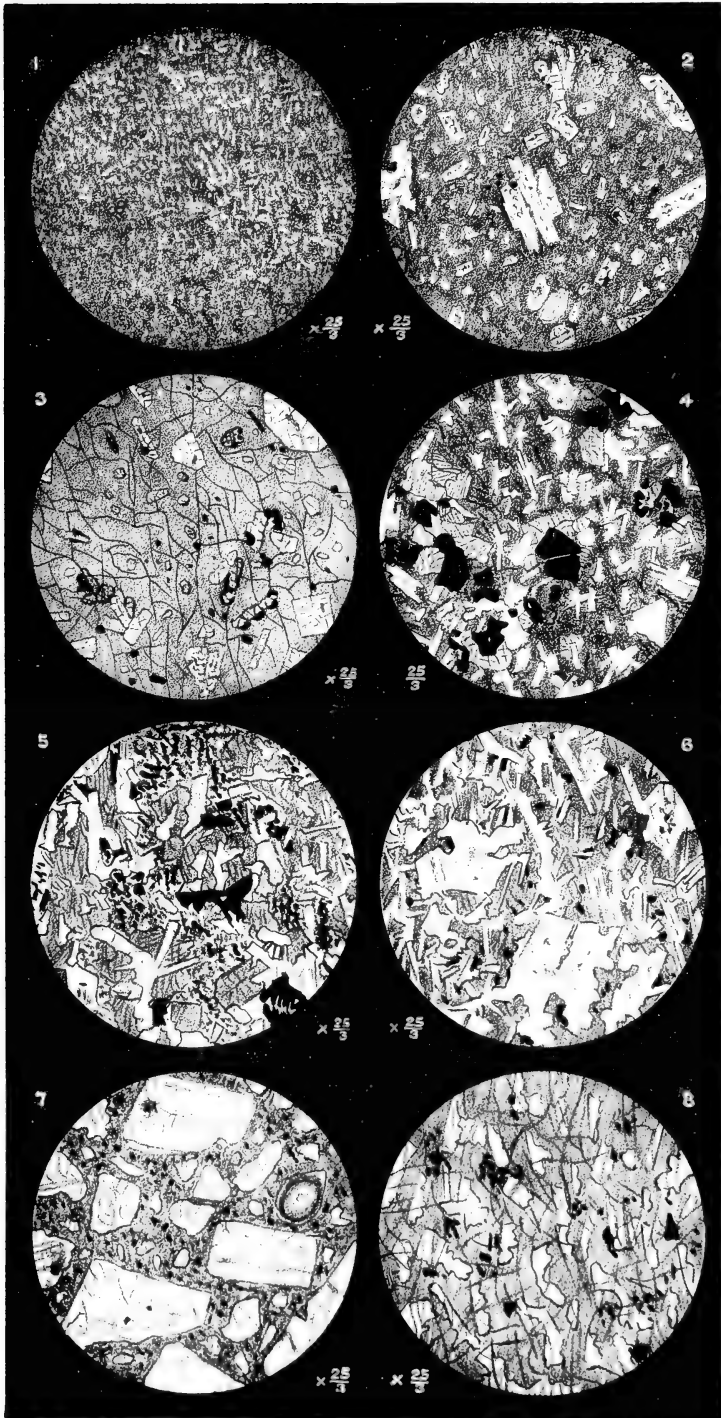
Dr. G. J. HINDE asked whether there were any striated or foreign pebbles to be met with in the lower beds of the Drift in the depression.

The AUTHOR, in reply, maintained that the occurrence of deep Drift at various places along the valley-bottom pointed to the existence of a more or less continuous channel or line of basins with the longer axis along the valley. He had not asserted that the hollow was Preglacial, but that it was either Preglacial or early Glacial. There was no evidence of striated pebbles, which could hardly be expected in the materials brought from a small bore-hole; still the deposits were of the nature of Glacial accumulations.



Scottish Andesites and Propylites.







20. *The PROPYLITES of the WESTERN ISLES of SCOTLAND, and their RELATION to the ANDESITES and DIORITES of the DISTRICT.* By Prof. JOHN W. JUDD, F.R.S., F.G.S. (Read February 5, 1890.)

[PLATES XIV. & XV.]

- I. Introduction.
- II. Previous Literature.
- III. Physical Characters and Chemical Composition of the Scottish Propylites.
- IV. Microscopical Characters.
- V. Relations of the Scottish Propylites to the other Rocks of the District.
 - A. *Geological Age.*
 - B. *Structure.*
 - C. *Nature of Rock-masses.*
 1. *Lava-streams.*
 2. *"Cupolas."*
 3. *"Laccolites."*
- VI. Nature of the Original Rocks from which the Propylites have been formed.
 - A. *Amphibole- and Mica-andesites and Diorites.*
 - B. *Pyroxene-andesites and Pyroxene-diorites.*
- VII. Causes by which the Propylitic Modification of these Rocks has been brought about.
 - A. *Solfataric Action.*
 - B. *Contact-Metamorphism.*
- VIII. Light thrown by the Study of these Tertiary Lavas on some of the Older Volcanic Rocks (Porphyrites, Felstones, &c.).
- IX. The Younger Augite-andesites ("Tholeites," "Pitchstones," &c.) of the Western Isles of Scotland.
- X. Summary of Results.

I. INTRODUCTION.

THERE exists in the Western Isles of Scotland a great series of lavas which, for the most part, underlie the ophitic olivine-basalts, and constitute the oldest of the ejections of the great Tertiary volcanoes of that district. These rocks were distinguished by me in 1874 under the old English field-name of "Felstones," and it was stated that they "vary in colour from black, through various shades of green and grey to white; but in almost all cases their surfaces acquire a white crust in consequence of weathering action"*.

In attempting, at that date, to define more exactly the characters of these lavas, by studying them microscopically in thin sections, I was confronted by two difficulties. In the first place, it soon became manifest that these more acid lavas of the Western Isles include a great variety of types—differing widely from one another in mineralogical constitution and in structure; and in the second place it was found that the minerals of which these rocks were built up were in a remarkably altered condition.

In both these respects, the "felstones" present a very striking contrast to the overlying series of ophitic olivine-basalts. The latter, as I have shown †, are remarkable for their uniformity of composition

* Q. J. G. S. vol. xxx. (1874) p. 236.

† *Ibid.* vol. xlii. (1886) p. 49.

and character, and, except where influenced by surface-agencies, seldom present any great signs of alteration; they are indeed, as a rule, singularly fresh and unchanged in their appearance.

But in the "felstones" which underlie the basalts the most extreme metamorphism is seen to have taken place; the feldspars are found to be so completely kaolinized that it is sometimes impossible to decide whether they should be referred to orthoclase or to plagioclase; the pyroxenes, amphiboles, and micas are converted into isropic mixtures or into minerals of the chlorite group; while in many cases the formation of epidotes and other secondary minerals at the expense of the original constituents of the rock has gone on to such an extent as to completely obliterate their distinctive characters. It may be safely asserted of many of these rocks that they are at the present time entirely made up of *secondary* minerals, the porphyritic constituents being represented by pseudomorphs, while the ground-mass has been completely recrystallized.

In 1874 I had been able to study only a few of the leading types of these rocks microscopically, and consequently did not feel justified in attempting a complete diagnosis of their varieties; therefore I contented myself with the grouping them under a convenient field-name.

During the last fifteen years, however, I have devoted much time to the study of these rocks both in the field and in the laboratory. The result of these studies is to show that among these "felstones" there are presented to us many interesting types of rhyolites, dacites, and sanidine-trachytes, intercalated with which are a few basalts, some of them of the same ophitic type as those so abundantly poured out at a somewhat later date. With these there also occur certain rocks which are so remarkable in their mineralogical constitution and structure that they do not seem capable of being referred to any of the accepted petrographical types; and these anomalous rocks I hope to describe on a future occasion.

But the great majority of these Hebridean "felstones" prove to belong to the family of the andesites, and to that "pathological variety,"* to use Rosenbusch's expressive term, to which the name of "propylite" has been given.

The delay in publishing the results of my researches upon these curiously altered rocks has not been unattended with advantage. Many interesting details concerning the propylitic rocks of other areas have been published in the interval both in Europe and in America; and during the same period there have appeared several very important memoirs on the rocks of the Faroe Isles, Iceland, and Greenland—districts in which the Tertiary igneous rocks present the most marked analogies with those of our own Western Isles †. The comparison of the much altered Scottish rocks with the very fresh examples in these several districts has often afforded valuable aid in the interpretation of the former.

* Rosenbusch, 'Massige Gesteine,' 2nd ed. p. 691.

† See Q. J. G. S. vol. xli. (1886) p. 53.

II. PREVIOUS LITERATURE.

In his great work on the Geology of Hungary, Beudant, as early as 1822, distinguished a series of rocks presenting very well-marked features, to which he gave the name of "porphyres trachytiques"*.

In 1860, Baron von Richthofen proposed to separate these rocks from the ordinary trachytes (andesites) of Hungary and Transylvania under the name of "greenstone-trachytes" †; and this term—indicating their analogies both with plutonic and with volcanic rocks—was very generally accepted by von Hauer, Stache, and the other geologists of Austria.

In 1868, however, von Richthofen was led by his study of the volcanic rocks of California and Nevada to abandon the term "greenstone-trachyte" in favour of that of "prophyllite;" he was induced to make this change from his conviction that, in Hungary and Transylvania, as well as in the western districts of the North-American continent, the rocks in question were the earliest erupted of the whole series of Tertiary lavas ‡.

In 1875 the late Mr. Poulett Scrope, who was well acquainted with the Hungarian rocks, pointed out to me the close similarity between many of the features exhibited by the volcanic rocks of that country and those which I had described in the Western Isles of Scotland. In consequence of his advice, and with his friendly assistance, I visited Hungary and Transylvania in that year, and some of the general results of the comparisons then made were submitted to this Society shortly afterwards. The conclusion at which I arrived with respect to the "greenstone-trachytes" or "prophyllites" of Eastern Europe was that, while they have intimate relations on the one hand with the andesites, and on the other hand with the diorites of the same district, yet many of their peculiarities are certainly due to their having undergone great alteration, especially in consequence of having been acted upon by acid vapours §.

The name "prophyllite," as distinctive of a well-marked group of rocks, was adopted by Mr. Clarence King and other members of the United-States Geological Survey engaged in the exploration of the Western Territories, and the term thus became familiar to all students of American geological literature, while its use in Europe still continued to be very restricted.

In 1876, however, Prof. Zirkel published the results of his microscopical study of the North-American rocks; and in this work he endeavoured to define the particular characters which seemed to justify the retention of the "prophyllites" as a distinct type of rocks ||. Dr. Zirkel pointed out that, while in their geological relations the prophyllites are clearly associated with the Tertiary

* Voyage Minéralogique et Géologique en Hongrie, tome iii. p. 344.

† Wien. Geol. Verhandlungen, xi. (1860) pp. 91-94, and Jahrb. k.-k. geol. Reichsanstalt, Wien, xi. (1860) pp. 154-276.

‡ Mem. California Acad. of Sci. vol. i. (1868).

§ Q. J. G. S. vol. xxxii. (1876) p. 298.

|| Microscopic Petrography, vol. vi. of the U. S. Geol. Expl. of the Fortieth Parallel (1876), pp. 110-121.

lavas, yet in the characters of their constituent minerals and in the enclosures which these minerals exhibit they present the most remarkable analogies with some of the older dioritic rocks. Vom Rath also adopted the same view as Zirkel as to the close relations existing between the propylites and plutonic rocks and their distinction as a group from the andesites.

In the first edition of his very valuable work 'Mikroskopische Physiographie der Massigen Gesteine,' published in 1877, Professor Rosenbusch not only refused to accept the term "propylite" as distinctive of a group, but classed many of the rocks that had been described under that name by other authors among the andesites. In 1879, Dr. Doelter showed that the Hungarian rocks which present the peculiar features held by von Richthofen and Zirkel to be characteristic of the propylites, could be seen to pass by insensible gradations into ordinary andesites*; and the view that the propylites were really altered forms of the andesites, was very forcibly upheld by Rosenbusch in a review of Doelter's memoir, published shortly afterwards †.

In the same year Dr. Wadsworth strongly insisted that the distinction between propylites and andesites could not be maintained in the case of the North-American rocks ‡.

Dr. Szabò of Buda-Pest, Dr. Anton Koch of Klausenburg, and Dr. E. Hassak of Gratz, have all expressed the opinion that the propylites of Eastern Europe are really altered forms of the andesites.

The publication in 1882 of Mr. George F. Becker's "Geology of the Comstock Lode and the Washoe District" marks an important epoch in the history of the propylite controversy §. Mr. Becker, while still continuing to classify the diorites and other plutonic rocks as Pre-Tertiary, maintained that the propylites could not be regarded as a distinct group of rocks, but only as a distinct "facies" or "habitus" of the andesitic lavas. As the result of a microscopic study of a large series of specimens obtained during the construction of the Sutro Tunnel, and the numerous deep workings of the Comstock Lode, Mr. Becker was able to show how, by the gradual alteration of their constituent minerals, the hornblende- and augite-andesites could be seen to gradually acquire those peculiar characters which had been held to be distinctive of the propylites.

Not less important as a contribution to this interesting question is the very remarkable memoir of Messrs. Arnold Hague and J. P. Iddings, "On the Development of Crystallization in the Igneous Rocks of the Washoe District" ||. The authors of this memoir, while fully accepting the conclusions of Mr. Becker that the propylites of the Washoe district are simply altered forms of the andesitic lavas, went much further, and proceeded to show that the

* Verhand. d. k.-k. geol. Reichs. 1879, p. 27.

† Neues Jahrb. für Min. &c. 1879, p. 648.

‡ Bull. Mus. Comp. Zool. vol. v. (1879) p. 285.

§ United States Geol. Surv. Monograph iii. (1882).

|| Bull. of the U.S. Geol. Surv. No. 17 (1885).

distinction between the Tertiary hornblende- and augite-andesites and the supposed older diorites and diabases could no longer be maintained. This conclusion they were able to establish by a careful examination of the extensive materials collected by the officers of the United-States Geological Survey. They proved that the diorites are only deep-seated portions of the rocks, which are poured out at the surface as hornblende- or mica-andesites, and that both alike are of Tertiary age; the differences between them were shown to be due, not to the *period* of their formation, but to the more perfectly developed crystallization in the deeply seated masses. The "diabases" of the district were also proved to be similarly related to the augite-andesites.

In the second edition of his 'Massige Gesteine,' published in 1886 and 1887, Professor Rosenbusch admirably summarizes the results which have been obtained by the study of both the European and the American propylites. Admitting, with von Richthofen and Zirkel, the extreme modification of the constituent minerals, and the frequently well-developed crystallization, that recall so strikingly the characters of the diorites and diorite-porphyrates, he shows that the former characters are unquestionably due to the *peculiar kind of alteration* that the rocks have undergone. The term "propylite" is therefore accepted only as serving to distinguish a well-marked and interesting facies of the andesitic type of rocks—"a pathological variety," employing Rosenbusch's apt designation. Used in this way, the term propylite may still be of great service to petrographers and field-geologists as a descriptive name; just as the terms shale, melaphyre, and porphyrite are convenient, and even necessary to us, for describing peculiar modifications of clay, basalt, and andesite respectively. It is in this sense that I propose to use the term propylite in the present memoir.

I shall be able to show that a careful study of the oldest Tertiary igneous masses in the Western Isles of Scotland makes us acquainted with a series of rocks presenting all the distinctive features of the "greenstone-trachytes" of Hungary and Transylvania, and of the "propylites" of California and Nevada.

I shall endeavour to illustrate the exact nature of the processes by which ordinary andesites (and rocks which in their structure and degree of crystallization are intermediate between andesites and diorites) have been converted into the curious varieties that present all the characters of the "greenstone-trachytes" or "propylites"; and it will be my especial aim to investigate the exact *causes* to which these peculiar modifications must be assigned.

III. PHYSICAL CHARACTERS AND CHEMICAL COMPOSITION OF THE SCOTTISH PROPYLITES.

In colour these rocks vary from a very dark grey, almost black tint, through many lighter shades, to varieties that are nearly white. Usually, however, more or less marked green tints are exhibited by them, and in some cases this colour becomes very pronounced.

Though often very dark-coloured, their lustre is usually dull, and they seldom if ever exhibit the jet-black tint and velvety aspect so often found in the olivine basalts of the district. The rocks are usually, though by no means invariably, of porphyritic structure, and the crystals of felspar have the opacity and the absence of vitreous lustre so often seen in the more ancient and plutonic rock-masses. Not unfrequently rocks that appear at first sight to be perfectly compact are shown by their mode of weathering to have been originally made up of angular or rounded fragments, a conclusion which is confirmed by microscopic study. Under the microscope, indeed, many compact and seemingly homogeneous rocks are seen to present all the characters of volcanic agglomerates and tuffs, and are found to be composed of a great variety of ejected fragments.

On freshly fractured surfaces or on faces that have been weathered, these rocks often exhibit evidence of possessing a strikingly banded and fluidal structure, and, under the same conditions, the porphyritic habit which is so general in these rocks becomes very conspicuous. It is very remarkable to find that many rocks which are of a uniform dull grey colour, and apparently quite homogeneous or compact in texture, must originally have presented all the characters which distinguish flowing lava-streams or beds of scoriæ and lapilli. These conclusions as to the original characters of the volcanic materials are fully confirmed, as we shall see when we come to study their microscopical characters. It is evident that the alteration, attended in many cases with an almost complete recrystallization of their materials, has effectually masked their original characters.

Many of these rocks were evidently originally scoriaceous; and, as the result of weathering, these often assume at the surface their pristine slaggy appearance. In many cases the cavities are occupied by aggregates of epidote- (pistacite) crystals usually enveloped in zeolites; and these clusters of green crystals, by the weathering-out of the surrounding zeolites, stand up in relief on the exposed surfaces of the rocks. Veins and nests of epidote also abound in many of these rocks. In other cases the black enclosures (originally green) to which Macculloch gave the name of Chlorophaeite are very conspicuous.

Vitreous varieties of these rocks sometimes occur, and such perfectly glassy parts of the rocks often exhibit but little alteration. The same fact is illustrated in the andesites of the Cheviot Hills, where the glassy portions are far less altered than the associated stony portions of the same mass. It would seem that these glassy varieties resist the percolation of solvents through their mass to a much greater extent than rocks made up of aggregates of dissimilar particles, and thus remain in a comparatively unaltered state.

The white crust which covers the weathered surfaces of the Scottish propylites has been already referred to as one of their most distinguishing characteristics. The origin of this white crust appears to be as follows:—by changes, which will be hereafter described, much of the iron has separated as secondary magnetite. Almost

everywhere in the Western Isles the rock-surfaces are acted upon by peaty waters; and just as brown sandstones and other ferruginous rocks become bleached by this action, so do the igneous masses, which have been rendered more permeable by the extensive alteration of their constituent minerals, become bleached to the depth of a few millimetres from the surface. That this is the true explanation of the phenomenon is confirmed by a microscopic study of these white crusts themselves, and of the parts of the rock where they graduate into the dark-coloured mass.

Another distinguishing characteristic of the Scottish propylites is the presence of considerable quantities of pyrite and other sulphides diffused through their mass. Certain rocks about Salen in Mull, and in Ardnamurchan, for example, when broken, are seen to be studded all through their mass with pyrite-crystals. In other cases marcasite and chalcopyrite are found, and these sulphides are often present in such quantity as to constitute an important constituent of the rocks. All who are acquainted with the "greenstone-trachytes" of Eastern Europe and the "propylites" of the Western Territories of the United States will recognize this as a feature which they present in common with the Scottish rocks. In one case I have found metallic copper forming thin plates scattered through the rock.

One of the readiest means of distinguishing the dark-coloured, much-altered andesites from the overlying olivine-basalts is by a determination of their specific gravity. While the gabbros, dolerites, and basalts have a density which always approaches to and sometimes exceeds 3, the propylites and their deep-seated representatives have a distinctly lower specific gravity, ranging from 2.4 to 2.9*.

During the last fifteen years, I have been able to compare the results of a great number of determinations of the specific gravities of the Scottish propylites, which have been carried out by various methods, in the geological laboratories of the Normal School of Science and Royal School of Mines. Some of these determinations have been kindly made for me by Mr. Grenville Cole, F.G.S., or by students working under his supervision; others have been contributed by Mr. W. B. D. Edwards, Mr. T. H. Holland, Mr. J. W. Evans, F.G.S., and Mr. W. F. Hume, F.G.S., working in the Research Laboratory of the school, and these gentlemen have spared no pains in obtaining and verifying their results.

A comparison and analysis of the great mass of specific-gravity determinations thus placed at my disposal shows that the propylites of the Western Isles of Scotland may be roughly classed in two great groups—those in which the specific gravity ranges from 2.4 to

* Shortly after the appearance of my first memoir on these rocks in 1874, Mr. W. Walker, F.G.S., wrote to inform me that, having visited the district described by me, in company with Mr. James Durham, he had been led to devise a portable balance for the purpose of obtaining rapid and approximately accurate determination of the specific gravity of rock-specimens. This balance proves to be of great service, as it can be employed by the geologist when he is far away from the resources of a laboratory. (See *Geol. Mag.* dec. ii. vol. x. p. 109, and *Proc. Geol. Assoc.* vol. viii. p. 278.)

2·7, and those in which the limits are 2·7 and 2·9. As a general rule (though colour is often a very unsafe guide) the former group comprises pale-coloured rocks, while the latter are generally dark-coloured.

The less dense, pale-coloured rocks, we shall presently see, were originally hornblende- and mica-andesites, and the heavier dark-coloured rocks are, for the most part, pyroxene-andesites.

Looking more closely into the results, we find that differences in specific gravity in each of these classes of rocks is dependent *first*, on the degree of development of crystallization in them, and *secondly* on the amount of chemical alteration which they have undergone.

As an example of difference of density in the more acid types, I may cite the case of the hornblende-propylite of Beinn Talaidh (Beinn Talla) in Mull. In the deep Corry of Tomsléibe the rock is highly crystalline, and, indeed, approaches a diorite, having a specific gravity of 2·68; while in the upper and superficial portions of the mass the rock is compact, and has a density of 2·60. Glassy varieties of the amphibolic rocks have a density of only a little over 2·4.

Among the more basic types, I may cite the pyroxene-propylites of Mingary Castle in Ardnamurchan. Highly crystalline forms of this rock have a density of 2·88, while the specific gravity of the compact varieties of the same rock is only 2·75. At Bealach a' Mhàim, in Glen Brittle, we find a rock of this type with a specific gravity of 2·89, which passes locally into a glass with a density of only 2·63.

The effect of the processes of alteration upon these rocks is generally to lower their specific gravity. Thus the much altered hornblende-propylites, with abundant chlorite and epidote developed in their mass, are found to have a density of 2·5, or even less, while the similarly altered pyroxene-propylites have a density which seldom much exceeds, and sometimes does not reach 2·7.

In cases where it is not practicable to make a complete chemical or microscopical study of the rocks, a determination of specific gravity affords a much safer criterion for their discrimination than colour. Some of the hornblende-propylites are of a very dark grey, and indeed almost black colour, though seldom exhibiting the lustrous jet-black of the olivine basalts; while, on the other hand, extreme alteration may sometimes cause the pyroxene-propylites to assume a pale grey and almost white colour.

The distinction of the Scottish propylites into two groups is borne out when we examine their chemical composition. A number of chemical analyses have been made for me by Mr. T. H. Holland in the Geological Research Laboratory of the Normal School of Science, and for some silica determinations I am indebted to Mr. Grenville Cole, F.G.S., and Mr. J. H. Power. I am also under great obligations to my colleague Professor Thorpe, F.R.S., for allowing a number of analyses of these interesting rocks to be carried out under his direction in the chemical laboratories of the same Institution. These analyses enable us to make comparisons between the different types

of propylites of the Western Isles of Scotland and those of Hungary and Transylvania, on the one hand, and of the Western States of North America, on the other, the chief districts in which they have been studied.

As a type of the analyses of the more acid varieties of the Scottish propylite we may cite that of the rock of Beinn Talaidh—a hornblende-andesite passing into a diorite—placing side by side with it a European and an American rock of analogous constitution.

	I.	II.	III.
Silica	62·89	63·05	63·13
Alumina	14·84	14·18	16·00
Ferric oxide	9·20	....	4·34
Ferrous oxide ....	....	6·71	1·52
Manganic oxide ..	trace		
Lime	3·61	5·40	4·45
Magnesia	0·37	1·12	2·07
Soda	4·01	5·65	3·87
Potash	2·91	3·49	2·65
Loss on ignition ..	1·41	2·04	2·00
Total	99·24	101·64	100·03

I. Analysis of highly crystalline hornblende-propylite from the deep Corry in Beinn Talaidh, Mull, made by T. H. Holland, 1889.

II. Analysis of hornblende-andesite (propylite) from Tokay (Banhof), Hungary, by K. v. Hauer, Verh. k.-k. geol. Reichsanst. 1869, p. 146.

III. Analysis of hornblende-mica-andesite (propylite) from Cross Spur Quarry, Washoe, made by R. W. Woodward, 1875.

A good type of the more basic pyroxene-propylites of the Western Isles of Scotland is found in the much altered rocks exposed on the western slopes of the Beinn More in Mull, and between that mountain and A Chioch. Analyses of European and American rocks are added for comparison with it.

	I.	II.	III.
Silica	58·07	59·56	58·44
Alumina	17·62	20·38	18·17
Ferric oxide	4·97	5·87	
Ferrous oxide	3·09	....	6·03
Manganic oxide ..	traces		
Lime	5·23	6·82	6·19
Magnesia	1·46	3·71	2·40
Soda	3·31	1·49	3·20
Potash	2·15	1·25	1·97
Loss on ignition ..	4·15	1·85	3·63*
Total	100·05	100·93	100·03

* Including 2·87 per cent. of Carbonic Acid.

I. Analysis of much altered pyroxene-propylite from Beinn More, Mull. Made by G. H. Perry in the Chemical Laboratory, Normal School of Science.

II. Analysis of augite-andesite, Gyetva, Hungary, by Wymietal in Tschermak, Min. Mittheil. 1868.

III. Analysis of pyroxene-andesite (containing hornblende) from the north-east of American Flat, Washoe. Made by W. G. Mixter, 1875.

While, however, it is convenient to make a broad general distinction between the usually pale-coloured and lighter amphibolic varieties and the dark-coloured and heavier pyroxenic forms of these rocks, it must be confessed that the division into acid and basic types of propylite is of no great value. Even when there is no free quartz present, either of primary or secondary origin, the variations in the proportion of porphyritic crystals to base lead to wide variations in the ultimate chemical composition of the different rocks. In this way we often find that pyroxenic rocks are of more acid character than amphibolic ones. The extreme modification, too, which many of these lavas have undergone leads to most remarkable changes in their colour, specific gravity, and chemical composition, and still further leads to breaking down the distinction between the two types which, for convenience of description, we have sought to institute.

IV. MICROSCOPICAL CHARACTERS.

The microscopical characters presented by these lavas may be summarized as follows:—

Although many of the rocks must have originally contained much vitreous or uncrystallized material in their ground-mass, yet in almost every instance this glassy substance has disappeared through secondary devitrification. In the majority of cases, the development of secondary minerals in the substance of the ground-mass has completely obliterated the original micro-structure of the rock; but in some instances we find traces of spherulitic, fluidal, and perlitic structures; while in others the structures known as “granophyric” can be detected—such as the micro-pegmatitic, the centric, and the pseudo-spherulitic.

As a general rule, it may be said that the ground-mass is the most highly altered portion of these rocks, this being doubtless due to the fact that the glassy matrix is less stable than the crystallized constituents of a rock. The matrix frequently acquires a green colour from the development of minerals of the chlorite group, and is sometimes studded with crystals of the metallic sulphides.

The porphyritic crystals of felspar, though so greatly altered, can usually be found to show, here and there, traces of the plagioclastic twinning. They are never, however, in the vitreous condition of the felspars of ordinary andesitic rocks (microtine), but exhibit the opacity and dull lustre characteristic of the diorites and other deep-seated rocks. It was this condition of the porphyritic felspars, with the state of the ground-mass and the features

presented by the ferro-magnesian silicates, that led von Richthofen and Zirkel to insist on the analogies of these rocks with plutonic rocks, which were, at the time when these authors wrote, generally believed by Continental petrographers to be of Pre-Tertiary age. Any glass-inclusions that the felspar-crystals may once have contained have, of course, like the glass in the matrix, undergone devitrification, while, as Zirkel has shown in similar rocks in North America, bands of cavities containing liquids are abundant. This character is also conspicuously exhibited by the quartz, which either as a primary or secondary constituent is not unfrequently found in these rocks. I have already stated the grounds that lead me to conclude that these bands of liquid-inclusions are of secondary origin. In many cases, however, the felspar-crystals, while preserving their outward form, have been completely transformed, and now only exist as pseudomorphs. The minerals which replace the original substance of the plagioclase felspars are pistacite, zoisite, and other minerals of the epidote group, with some new felspars of secondary origin. Occasionally quartz and calcite have resulted from the extreme alteration which the felspars have undergone.

The ferro-magnesian constituents of these rocks,—whether pyroxenes, amphiboles, or micas,—are almost always in a more or less altered state. A fibrous structure and a green colour have been developed in them, and, as this change goes on, curious modifications of the optical properties of the minerals are brought about. Frequently we find, as the result of this action, green isotropic materials are formed to which the name of “Viridite” may be properly applied. But, in most instances, we find that from the products of the decomposition of the original ferro-magnesian silicates, various minerals of the chlorite group are developed, and crystallize out from the mass. A still further change is marked by the destruction of these chlorites, and the formation at their expense of various epidotes, among which the varieties known as pistacite and a lime-epidote with a little manganese are conspicuous.

The pyroxenes of these rocks are usually the monoclinic forms or augites; the rhombic enstatites, though not unfrequently present, being, as in the case of the associated basic rocks of this district, usually subordinate and seldom, if ever, a predominating constituent of the rocks. The amphiboles were probably hornblendes, long acicular and tufted forms abounding. It is clear that in the unaltered rocks these crystals of amphibole and those of biotite were surrounded by zones (resorption-halos) composed of pyroxene and magnetite grains, the latter mineral only remaining in the altered state of the rock. Many of the rocks contained biotite as an original constituent; but I shall show in the sequel that much biotite has been developed in these rocks as a secondary constituent.

That titanoferrite was often present in these rocks, as well as magnetite, is shown by the forms of the opaque crystals and by the way in which, as the result of alteration, they become surrounded by the dense white product and the colourless substance derived from it, known as “leucoxene.” Sometimes the abundant magne-

tite, much of which is of secondary origin, has been converted into various forms of hydrous brown oxide, and not unfrequently we find great quantities of pyrite and marcasite developed, doubtless at the expense of the magnetite and ilmenite. In the thin white crust that so constantly covers these rocks the iron has been reduced and, in some cases, removed in solution by the action of water containing organic matter, as already pointed out. In some cases this removal of iron-oxides has gone on throughout the whole substance of the rocks, which become completely bleached.

While in most cases the alteration of the ground-mass and the conversion of the porphyritic constituents of the rock into pseudomorphs has not wholly destroyed its original aspect, yet, under certain circumstances, as I shall point out, the whole structure and character of the mass is found to be completely transformed. This is effected by the crystallizing-out of different minerals (among which the epidotes and chlorites are the most conspicuous) at the expense of the various secondary minerals that have been developed in the mass by the alteration of the felspars and ferromagnesian silicates. These excessively altered varieties frequently constitute rocks of very great beauty and interest*.

From this general account of the chemical, macroscopical, and microscopical characters of these Scottish rocks every one familiar with the accurate descriptions given by von Richthofen, Zirkel, Doelter, Becker, and other petrographers of the "greenstone-trachytes" of Hungary and Transylvania, and of the "propylites" of California, Nevada, and Utah, will at once perceive their complete identity†.

[Since this paper was read I have had an opportunity of showing Mr. J. P. Iddings, of the U.S. Geological Survey, a series of specimens and sections of the Scottish propylites. He was able to satisfy himself of the close similarity between these rocks and those of the Washoe district in Nevada, which he has so carefully studied; and he has permitted me to state his conviction of their identity in character.]

I shall show that, as in the districts mentioned, the curiously modified propylites of the Western Isles of Scotland have been produced from dacites and andesites, and from the deeper-seated and more highly crystalline representatives of those rocks, by the operation of certain well-defined agencies.

* Dr. Hatch, to whom a number of sections cut from these rocks were submitted by Dr. A. Geikie, has fully recognized the completely altered character of the materials he examined. Unfortunately he had no means for judging of the real nature of the rocks from which these were derived (Trans. Roy. Soc. Edinb. vol. xxxv. 1888, pp. 77, 167).

† See the excellent summary of these results given by Rosenbusch, 'Massige Gesteine' (1887), pp. 690-693.

V. RELATIONS OF THE SCOTTISH PROPYLITES TO THE OTHER ROCKS OF THE DISTRICT.

A. *Geological Age.*

That the great mass of "felstones" or propylites (as I have now shown they ought properly to be called) were the earliest erupted of all the rocks in the Western Isles of Scotland, I have already pointed out in my memoir of 1874.

That the propylites are older than the granitic masses of the district ("granophyres" of Dr. A. Geikie) is shown by the fact that the latter are seen to send off numerous veins into them, and to enclose portions of them in their mass, producing all the phenomena of contact-metamorphism where in apposition with them. These are all facts that I strongly insisted upon in the memoir referred to.

That the gabbros are younger than the propylites is equally obvious. Sheets and dykes of gabbro and dolerite connected with the mountain-like masses can be traced traversing the propylites in all directions, and also giving rise to the phenomena of contact-metamorphism.

That the "felstones" of the Western Isles of Scotland are invaded by the extrusions of granite ("granophyre") and of gabbro is confirmed by many sections described by Dr. A. Geikie*: but, in considering the descriptions given by this author, it must be borne in mind that under the same general name "bedded basalts" he has confounded two totally distinct petrographical types, namely, the ophitic olivine-basalts of the plateaux, which I described in detail before this Society in 1886, and the andesites and associated rocks of the central areas, of which I am treating in the present memoir. He has supposed that the rocks which we are now considering are really basalts which have acquired their peculiar and distinctive characters as a consequence of the metamorphism they have been subjected to through contact with great intrusive igneous masses †.

It will thus be seen that the great cause of the conflict of opinion between Dr. A. Geikie and myself, concerning the relations of the igneous masses of the Western Isles of Scotland, is to be found in the different interpretation we place on these propylitic rocks. Dr. Geikie has clearly noticed these propylites, which he describes in such a way as to avoid possibility of doubt concerning what he refers to. He states that they weather, not like the basalts, but with a "thin white crust, beneath which the rock appears dull, black, and splintery. They are generally veined with minute threads and strings of calcite, epidote, and quartz, which form a yellowish-brown network that projects above the rest of the weathered surface. Where they are amygdaloidal, the kernels no longer decay away or drop out, leaving the empty, smooth-surfaced cells, but remain as if they graduated into the surrounding rock by an interlacing of their crystalline constituents" ‡. Unfortunately, however, Dr. Geikie

* *Trans. Roy. Soc. Edinb.* vol. xxxv. pp. 151-181.

† *Ibid.* pp. 167, 168.

‡ *Ibid.* p. 167, and pp. 77 & 168.

appears to have left all exact petrographical study of the materials till after the completion of his field-work, and this led him to the erroneous conclusion that the propylitic rocks were simply the plateau-basalts altered by contact-metamorphism. Two dozen slices made from specimens collected by Dr. Geikie were placed in the hands of Dr. Hatch for microscopical study, and that gentleman's notes are characterized by his usual accuracy and acumen. He noticed the extreme alteration of the originally glassy base with the development of secondary feldspars, the complete change of the porphyritic crystals, and the development of chlorite, epidote, and other secondary minerals in the rock at the expense of the original constituents. But Dr. Hatch's notes afford no support whatever to the idea that these rocks are simply the plateau-basalts altered by contact-metamorphism.

B. *Structure.*

That the rocks which in their altered form we now refer to the propylites were, some of them, effusive (lavas and cupolas), while others were intrusive (laccolites, sheets, and dykes) there cannot be the smallest doubt. No warrant can be found from the study of these rocks for making a fundamental distinction of certain petrographic types, as belonging to the effusive or volcanic series (Ergussgesteine), and others as belonging to the intrusive or Plutonic series (Tiefengesteine). On the contrary, the central portions of some of the very thick lava-currents poured out at the surface are more highly crystalline than the rock of many eruptive masses. Still less ground can I find, in this district, for instituting a class of "dyke-rocks" ("Ganggesteine"); for while dykes and veins are sometimes found exhibiting very coarsely crystalline texture, others finely grained and even glassy may be seen side by side with them.

C. *Nature of Rock-masses.*

The rocks of the Western Isles of Scotland now referred to the group of propylites are found exhibiting three kinds of relations to the surrounding rock-masses:—

1. *Lava-streams.*—That these rocks often constituted ordinary lava-currents there cannot be the smallest doubt. Flat masses covering considerable areas and presenting at their upper and under surfaces the most strikingly scoriaceous and slaggy appearance abound, and are found piled one upon another to the depth of many hundreds or even thousands of feet. As a general rule, to which, however, there are a few exceptions, the lava-currents composed of porphyritic rocks are short and bulky, and they can seldom be traced to a distance of many miles from their point of emission. In this respect they present a most striking contrast to the olivine-basalts, which, as a rule, must have been poured out as lavas of great liquidity, and probably flowed distances of twenty, thirty, or even forty miles from their points of emission.

Professor J. D. Dana, in his suggestive memoirs on the Hawaiian

volcanoes, has clearly pointed out the important consequences which follow from the extreme liquidity of certain types of basalt; and in the Western Isles of Scotland, as in Iceland, we find many illustrations of the contrast between the features arising from the outflow of viscous lavas of acid and intermediate composition, on the one hand, and extremely fluid basic lava-currents on the other.

There is every reason for concluding that the ejection of the more acid lavas which constitute thick and bulky currents, and surround the five great centres of igneous action in the Western Isles of Scotland, took place, as a whole, before the appearance of the mass of the ophitic olivine-basalts which form the mass of the great plateaux. But, as I have already pointed out, we have evidence on the one hand that occasional streams of olivine-basalt were poured out during the earlier eruptions of the andesites; and, on the other hand, we find that occasional but very interesting outflows of andesite occurred during the ejection of the olivine-basalts; and such sheets of andesite-lavas are now found intercalated among the basalts of the plateaux. One such outflow of andesitic lava was referred to by Dr. A. Geikie in 1871 as occurring in the Island of Eigg, and I have noticed several similar in the same island. In Mull they also occur; and in the district of Mishnish, which I have somewhat closely studied, a very considerable number of such andesitic lavas have been detected by me intercalated with the basalts of the plateaux. The same is also the case in Skye, and about the other centres of igneous activity.

2. "*Cupolas*."—Under the name of "*Quell-Kuppen*," Dr. E. Reyer* and other authors in Germany are in the habit of describing more or less dome-shaped masses of lava, like the domitic-puys of Auvergne, the phonolite-hills of Bohemia, and the Chodi-Berg and similar andesitic masses in Hungary. Such "*cupolas*," "*domes*," or "*mamelons*" may vary in size from mere hummocks with an area of only a few square yards, to mountain-masses of the grandest dimensions. Externally such masses may have entirely lost the scoriaceous covering with which, in all probability, they were originally invested. But internally they often exhibit a markedly concentric structure; and there is a striking gradation from the true lava-type ("*hyalopilitic*" texture of rock) in the exterior portion to highly crystalline ("*hypidiomorphic-granular*") varieties, approaching Plutonic types, in the interior. Dr. Reyer has shown by plaster models how such masses were probably formed by a kind of endogenous growth. Dr. A. Geikie refers to some of those masses under the term "*bosses*."

Among the largest and most striking of these "*cupolas*" is that which constitutes the grand mountain of Beinn Talaidh (Beinn Talla) in Mull, which, rising to the height of 2496 feet above the sea, is remarkable for its smooth and graceful outlines. Specimens taken from the flanks and summit of this mountain show the rock to be a hornblende-andesite in a more or less altered condition. But examples

* *Theoretische Geologie*, pp. 79-99.

obtained in the deep Corry of Tomsléibe, on the north-western side of the mountain, are found to be a true diorite; and a series of specimens can easily be obtained exhibiting every gradation from the one type to the other. Some of the intermediate types exhibit the various kinds of "granophyric" structure in a very beautiful manner. The composition of this dioritic mass, which, in its upward development, gradates into a hornblende-andesite, is illustrated by the analysis given at p. 349.

3. "*Laccolites*."—In 1874 I described acid, igneous rocks as being intruded among the strata of the Western Isles, and stated that they tend to form thick, lenticular masses, which are generally confined to within moderate distances from the great centres of eruption*. Mr. Gilbert has since proposed to call intrusive masses of this type by the name of *Laccolites* †. Like the "cupolas" they are much more highly crystalline in their central than in their peripheral portions; the outside of such masses may be a true andesite, while the central portions exhibit the holocrystalline or granitic structure of a diorite. Where the country has undergone much denudation, it may often be impossible to state if a particular mass should be referred to the class of "Quellkuppen" or of "*Laccolites*," but that both types occur in the Western Isles of Scotland, there cannot be any doubt.

VI. NATURE OF THE ORIGINAL ROCKS FROM WHICH THE PROPYLITES WERE FORMED.

In endeavouring to determine the exact nature of the rocks grouped under the general name of "felstones," in the Western Isles of Scotland, very great difficulty is experienced owing to the excessively altered state both of the "phenocrysts" (to use Iddings's useful term) and of the ground-mass in which they are imbedded. Determinations of specific gravity and the partial or complete analysis of the rocks are, of course, of much value in deciding the place of the several varieties in a classificatory system, yet it is chiefly upon other methods that I have been led to rely in making a study of these very obscure rocks. The alteration which has gone on in them, though often extreme, is not unfrequently found to be more more or less *local* in character; and, in the same mass, portions exhibiting very different stages of the change may often be found. It has been my object, in the repeated visits I have paid to the district during the last fifteen years, to trace the much altered and obscure rocks to points where their phenocrysts and ground-mass can be studied in a less altered form; and although in some instances it has been long before I was able to resolve all the difficulties that have presented themselves, yet in the great majority of cases this method has led to more or less satisfactory results.

Fortunately, too, several very able investigators have been engaged, during the same period, in the investigation of the very

* Quart. Journ. Geol. Soc. vol. xxx. (1874), p. 268.

† Geology of the Henry Mountains, U.S. Geol. Survey, 1877.

similar rocks which occur in the Faroe Isles, in Iceland, and in Greenland,—districts in which the volcanic products present such remarkable analogies with those of the Western Isles of Scotland. The results of some of these researches have afforded me invaluable aid, for they deal with materials some of which are almost absolutely unaltered, belonging to the same types as those which we find in such an altered condition in our own country.

In 1874 K. Vrba described some rocks from Southern Greenland, and among them certain diorites of somewhat remarkable character, which may not improbably be of the same geological age with rocks to be referred to in the present paper*.

In 1882, P. Schirlitz published the result of his studies, in the Petrographical Laboratory of Leipzig, of the Icelandic rocks collected by Professor Zirkel in 1860. In addition to the basalts and rhyolites, a number of very interesting rocks, called by Zirkel augite-andesites, was described by this author. He rightly insists, however, on the distinction between these and the Santorin lavas and the glassy andesites of Java (the vitrophyric augite-andesites of Rosenbusch), and is in favour of grouping them with the basalts †.

In 1884, Dr. A. Osann undertook an examination of the series of specimens from the Faroe Islands contained in the collection of the University of Heidelberg. He showed that, besides the black lustrous olivine-basalts, there exist dark grey rocks of very different aspect, containing an augite of a somewhat remarkable character, and he is disposed to place these among the andesites ‡. The distinction of these dark grey rocks, poor in olivine, which Osann pointed out in the case of the Faroe Isles, and Schirlitz in the case of those of Iceland, was also made by H. Reusch in the case of the Jan-Mayen rocks §, and by Nauchoff in the case of the Greenland lavas ||.

Last, and most important of all, must be mentioned the very valuable researches made upon the rocks of Iceland and the Faroe Islands by M. René Bréon¶. These researches were carried on in the Laboratory of Prof. Fouqué in the Collège de France. M. Bréon has described a number of lavas of intermediate composition which present the most striking analogies with some of the rocks now found in such an altered condition in the Hebrides. The wonderful freshness of the Icelandic rocks enables us to explain many points of difficulty which confront us in the case of their greatly altered British representatives, and I am much indebted to M. Bréon for his kindness in sending me a series of specimens of his Icelandic types for comparison with the rocks of Scotland.

* Sitzungsber. Wien. Akad. lxi. (1874), pp. 109–115.

† Tsch. Min. und Petrogr. Mittheil. iv. (1812), p. 414.

‡ Neues Jahrb. für Min. &c. 1884, i. pp. 45–49.

§ 'The Norwegian North-Atlantic Expedition of 1876–78' (Christiania, 1882).

|| Min. Mittheil. 1874, pp. 109–176.

¶ Notes pour servir à l'étude de la Géologie de l'Islande et des Iles Féroë, par R. Bréon, 1884.

Without laying any great stress upon the value of the distinction, it may be convenient to group the propylites of the Western Isles of Scotland in two series. In one of these, the prevailing ferro-magnesian silicate was originally hornblende or biotite, and this we may speak of as the "Amphibolic Series." In the other group a pyroxene (augite or enstatite) was the predominating ferro-magnesian silicate in the original rock, and this may be called the "Pyroxenic Series."

The rocks of the Amphibolic Series include most of the types already spoken of as being distinguished by a paler colour, a lower specific gravity (ranging from 2·4 to 2·7), and a higher silica-percentage. The rocks of the Pyroxenic Series are usually darker-coloured, have a higher density (2·6-2·9) and a lower percentage of silica. But many varieties occur in which both pyroxenes and amphiboles or mica are present, and in the case of the very highly altered forms it is difficult and sometimes impossible to refer the rock to either of these series.

In both of these series we find rocks of highly crystalline character (true diorites) passing through various hypocrystalline ("pilotaxitic" and "hyalopilitic") varieties, into perfectly vitreous rocks. Both the amphibolic and pyroxenic rocks sometimes contain free quartz, and then pass into quartz-andesites and quartz-diorites.

The chief types of the andesites and their Plutonic representatives in the Western Isles of Scotland may be conveniently grouped as follows:—

A. AMPHIBOLE- AND MICA-ANDESITES.

Hornblende-andesites.
Hornblende-mica-andesites.
Hornblende-mica-andesites with enstatite.

Diorites and Quartz-diorites.

B. PYROXENE-ANDESITES.

1. "Vitrophyric" Pyroxene-andesites.
2. "Trachytoid" Pyroxene-andesites.
 - a. Stikkisholmur Type.
 - b. "Diallage-andesites."
 - c. Labradorite-andesites.

Pyroxene-diorites and Quartz-pyroxene diorites.

A. *Amphibole- and Mica-andesites and Diorites.*

The hornblende- and mica-andesites are perhaps more numerous in the Western Isles of Scotland than the pyroxene-andesites. While the former most commonly exist as quellekuppen and laccolites, the latter more frequently constitute lava-schists and intrusive sheets ("sills" of the miners of the North of England); but this distinction is far from being an absolute one, there being not a few lava-streams, some broad and far-spreading, composed of hornblende- and mica-andesites, at the base of, or intercalated among, the plateau-

basalts. It is among these lava-sheets, at a considerable distance from the great eruptive centres, that these rocks can be studied in their least altered condition. Around the great igneous centres the extreme of alteration is seen to have taken place, not one of the original minerals of the rocks being recognizable except as pseudomorphs. The felspars are usually completely kaolinized, the ferromagnesian minerals represented by chlorites, while even the titanoferrite is converted into white opaque products, and finally into the transparent leucoxene or titanomorphite (sphene?).

Rosenbusch has proposed to divide the amphibole-andesites into two groups—those which in addition to the amphibole or mica, also contain a pyroxene, and those in which pyroxenes are absent. Both of these groups appear to be well represented in the Western Isles of Scotland. Rosenbusch has also proposed to divide the amphibole- and mica-andesites containing pyroxene into two groups—those in which the pyroxene is an augite or monoclinic variety, and those in which it is an enstatite in rhombic form. The latter type, which is so abundantly represented in the recent volcanic rocks of the Western Territories of the United States, and southward in the Republic of Salvador, according to Hague and Iddings*, is beautifully illustrated in the district which we are describing.

In the *Hornblende-andesites* proper we find a "microplitic felt" of felspar needles, through which are scattered groups of green hornblende crystals, often assuming sheaf-like and tufted groupings. In most cases it is clear that each hornblende crystal or group of crystals was originally surrounded by a resorption-halo, that is, a sheath composed of pyroxene and magnetite, the result of the action of heated magma on the hornblende. But in most cases the pyroxene has been converted into isotropic viridite or into a chlorite of feeble double refraction, while the granules of magnetite still surround the more or less altered hornblende. In many instances, the hornblende can be seen to have been completely changed into a chlorite, with the separation all through its substance of granules of magnetite. These chlorite-pseudomorphs after hornblende, with granules of magnetite crowded along their sides and also scattered through their midst, are very characteristic of the propylites which are derived from the hornblende-andesites (see Plate XIV. fig. 7).

One of the best types of this group is found in the rock of Beinn Talaidh (Beinn Talla) in Mull. This rock varies in specific gravity from 2.60 in the least crystalline types to 2.68 in those more highly crystalline. In the deeper corries of the mountain, andesites are found exhibiting a distinctly dioritic habit. The chemical composition of this rock is shown by the analysis given at p. 349.

The hornblende-andesites of the Western Isles of Scotland exhibit the widest diversity in the proportions of their constituent minerals. Some of the rocks of this class, good examples of which may be seen near Salen, Mull, consist very largely of felspar crystals

* Amer. Journ. Sci. vol. xxvi. (1883) p. 233, vol. xxvii. (1884) p. 460, vol. xxxii. (1886) p. 28.

and a little glass, with only a few scattered crystals of ferromagnesian silicates. These rocks are usually pale-coloured or nearly white and have a low specific gravity (2·55). Other hornblende-andesites, like those of Mhàim Clackaig in Mull and of Glen Brittle in Skye, exhibit a dark green, often nearly black colour, and have a much higher specific gravity (2·7 to 2·8).

I have not detected any completely glassy forms of these rocks, nor any examples in which primary quartz occurs. Some of the more highly crystalline types, however, exhibit the granophyric structure and contain free quartz, which I believe is of secondary origin.

Hornblende-mica-andesites, with or without pyroxenes, are very abundant in the district. They constitute rocks of a pale grey colour and a more or less fissile character, which form well-marked lava-streams, some of which are found intercalated among the basalts of the plateaux.

In some of the best-preserved of these rocks, crystals of unmistakable enstatite (bronzite) make their appearance; and, as what may be the products of alteration of this mineral are seldom absent in the more altered varieties, it may probably be assumed that the majority of the rocks of this type in the Western Isles of Scotland must be referred to the hornblende- and mica-andesites containing enstatite.

Some of these rocks exhibit a character lately referred to by Dr. Osann* and by Mr. Teall†. Gas-cavities are found filled with glassy matter that seems to have oozed out of the ground-mass of the rocks into these empty cavities. In the case of some of the Scottish rocks it is curious to find that the glass in these cavities exhibits a markedly banded structure.

Mica-andesites.—While there are probably some examples of true mica-andesites it must be remembered that a dark brown biotite is among the commonest of the secondary minerals in these propylitic rocks. Good examples of true mica-andesites occur at certain points at Mull and also in Eigg. These biotite-andesites pass by insensible gradations into the hornblende-andesites; in some cases the amphibole being the predominating constituent, in others the mica. As a rule among the altered rocks, the hornblendes tend to disappear by passing into chlorites, with or without the separation of magnetite, while the biotite seems to increase in amount, either by the growth of original crystals of the mineral or by the development of new secondary crystals.

Diorites.—Of the common or hornblende-diorites we cannot find better examples than those which occur in the deep Corry exposing the central mass of Beinn Talaidh in Mull. From an almost perfectly holocrystalline rock every gradation can be traced, through beautiful granophyric varieties, into the lava constituting the peripheral portions of the mass, which is, as we have seen, a typical hornblende-andesite.

* Zeitschr. d. deutsch. geolog. Gesellsch. xli. (1889) p. 304.

† Geol. Mag. dec. iii. vol. vi. (1889) p. 481.

Quartz-diorites have a tolerably wide distribution in Mull and some of the other centres of eruption; the rocks in it, frequently exhibited granophyric structures and other peculiarities, recalling in the most striking manner the quartz-diorite of Doire na Each and other bosses in Arran so well described by Professor Zirkel*.

B. *Pyroxene-andesites and Pyroxene-diorites.*

These rocks contain as phenocrysts (or minerals of the first consolidation) feldspars which are always plagioclastic, and which, by their characteristic extinctions, their specific gravity, and their flame-reactions, are shown to belong to labradorite or to a variety between labradorite and anorthite. These porphyritic crystals are noteworthy as very constantly displaying a zoned structure, and are usually full of glass and stone-enclosures, for the most part arranged parallel to the sides of the crystals. The crystals often exhibit the evidences of growth after the consolidation of the rock, a phenomenon which has been already described. Sometimes in addition to porphyritically developed feldspars we find large crystals of augite, belonging to a variety very rich in magnesia and iron, and often exhibiting the structure to be hereafter described as the "pseudo-diallagic;" enstatite not unfrequently accompanies the augite, a ferriferous variety—between bronzite and hypersthene—being the most common form of the mineral. Olivine is either entirely absent or is so rare in these rocks that it must be regarded as an accessory or accidental constituent only. Magnetite, however, is always present, though in very varying quantities.

The minerals of the ground-mass, or those of the second period of consolidation, consist of feldspars (usually showing lath-shaped sections and more or less lamellar twinning), which by their extinctions are referable to oligoclase, but may sometimes be orthoclase; intercrystallized with the rod-like feldspars is a pale brown variety of augite, usually occurring in more or less rounded granules, and many opaque magnetite grains.

The glass, which sometimes is almost absent in these rocks, and at other times forms the greater part of their mass, is usually full of crystallites, and in the arrangement of bands and flecks of different colours, or the distribution of the crystallites, shows striking evidence of flow-structure. This is especially manifest in the varieties which contain porphyritic constituents and much glass. Skeleton crystals and rods of magnetite are very abundant in these glassy bases of the andesite-rocks.

The pyroxene-andesites of the district fall naturally into two groups, between which, however, many connecting-links may be found.

Those rocks in which the quantity of glassy base is reduced to a minimum, and which consist largely of the minerals of the second period of consolidation, with or without porphyritic constituents, undoubtedly approximate to the basalts. But their real analogies,

* Zeitschr. d. deutsch geol. Gesellsch. vol. xxiii. (1871) p. 30.

as I shall show in a subsequent part of this paper, are so clearly with the vitrophyric pyroxene-andesites, that it is quite impossible to remove them from the group of the andesites. We must regard them therefore as the most basic type of the andesite series,—forms which constitute a real connecting-link between the andesites and the true or olivine-basalts. I am still inclined to follow Zirkel's original rule of confining the name basalt to those rocks of which olivine forms are essential constituents. This plan is followed by Rosenbusch in the case of the leucite and nepheline-bearing rocks, though of late years he has departed from it in the case of the felspar-bearing types.

Augite-andesites of the vitrophyric type of Rosenbusch appear at many points in the Western Isles of Scotland, and are particularly abundant about the north-western part of Beinn-à-Ghraag in Mull.

In these we find crystals of augite and enstatite, of a felspar allied to labradorite, and of magnetite, embedded in a glassy ground-mass, which may be large or small in quantity compared with the crystalline constituents of the mass. As in almost all similar rocks, we may notice that the crystals are often by no means uniformly scattered through the glassy base, but are collected into groups which often appear like portions of a holocrystalline mass.

At Mhàim Clackaig in Mull I have found a vitrophyric augite-andesite in which crystals of labradorite (usually much rounded on the angles and sometimes corroded), of a brown augite, and of magnetite are somewhat sparsely scattered through a glassy base. This glassy base is crowded with black rods (trichites), much twisted and bent, which in places become so abundant as to render the glass nearly opaque, except in very thin sections. This rock has a specific gravity of 2.64 (see Plate XIV. fig. 3).

In Beinn-à-Ghraag similar glassy rocks are highly spherulitic, the spherulites being arranged in definite bands, evidently produced during the movement of the viscous mass (see Plate XIV. fig. 4). One of these spherulitic rocks has a specific gravity of 2.49. In other cases, the fluidal structure, indicated by the way the micro-lites of the second period of consolidation are arranged around the porphyritic felspar and pyroxene crystals (see Plate XIV. fig. 6), is very strikingly shown.

For the determination of the specific gravities of a series of the vitrophyric augite-andesites I am indebted to my assistant, Mr. F. H. Hume, F.G.S.

Although no augite-andesites with free quartz have been detected in the district, yet some of these very glassy varieties must have a silica-percentage as high as that of the quartz augite-andesites or augite-dacites.

The best type of the more basic, stony pyroxene-andesites ("trachytoid andesites" of Rosenbusch) is afforded by the rocks which exactly resemble the lavas of Stikkisholmur and other points in Iceland, and are so well described and figured by Bréon*. The rock

* *Loc. cit.* pp. 23 & 24, pl. iii. fig. 1.

consists essentially of a mesh of oligoclase and perhaps of anorthoclase microlites entangling granules of augite (with some enstatite) and of magnetite, glass being present in small quantities only and quite inconspicuous.

This *Stikkisholmur* type is well represented at many points in the Western Isles of Scotland. Good illustrations of the type occur in the promontory stretching out to Salen Pier in Mull, at Beinn Uaig, and Creagach Beinn, in the same island, in Ardnamurchan, and in many other places.

Like the Icelandic rocks, those of our Western Isles are "compact and dark-coloured . . . the fracture is often nearly conchoidal, and certain specimens present a semi-vitreous appearance" (Bréon, *loc. cit.* p. 23).

In his reference of these rocks of the *Stikkisholmur* type to the augite-andesites, Bréon is supported by Rosenbusch, who, in the last edition of his 'Massige Gesteine' (p. 682), refers to these rocks as presenting some analogies with the augite-andesites described by Foerstner as occurring in Pantellaria, and containing anorthoclase and the triclinic amphibole—cossyrite (ænimmatite).

Some of the augite-andesites of the *Stikkisholmur* type contain large scattered crystals of anorthite or labradorite, and thus pass into the labradorite-andesites.

Another variety of the "trachytoid" pyroxene-andesites is presented when, in addition to the porphyritic crystals of felspar, large phenocrysts of augite make their appearance. These augites appear to belong to a variety rich in iron and magnesia, but which, considering their composition, are of remarkably stable character, often remaining comparatively unaltered when all the crystals in the rock have been profoundly changed. Such porphyritic augites often show a tendency to assume the form of stellar aggregates, and sometimes are of such dimensions as to be quite conspicuous on the fractured surfaces of the rocks. Beautiful examples of lavas of this type are found about Mingary Castle in Ardnamurchan, and I have also detected them at many other points in the Western Isles.

The porphyritic augites in these rocks present a character of very considerable interest, which it is necessary to notice here, though I have discussed it in detail in another place (*Min. Mag.* vol. ix.).

The augite-crystals exhibit lamellar twinning and subsequent schillerization parallel to the basal plane (001). Similar varieties have been described by William Phillips, Osann, and by Mr. Teall. The forms found in the Western Isles of Scotland differ from those described by the first and last-mentioned authors in not exhibiting simple twinning parallel to the orthopinacoid (001), but in showing some traces of lamellar twinning and subsequent schillerization parallel to that plane. (See Plate XIV. figs. 1 & 2.)

The occurrence in certain andesites of augite crystals exhibiting lamellar twinning with schillerization has led to a group being established by some authors bearing the name of "Diallage-andesites." It is probable that, in many, perhaps in all, of the cases in which diallage is stated to exist in andesitic lavas, augite twinned and

altered on the basal plane has been mistaken for true diallage with schillerization on the orthopinacoid.

The rocks called by the French geologists labradorites, and which I propose to term "labradorite-andesites," consist of a base which is, in all essential respects, identical with that of the last-described rocks; but they contain numerous and sometimes very large porphyritic crystals of labradorite, or of a felspar which is intermediate between labradorite and anorthite.

Good types of such rocks may be found at Dun-da-Ghaoith (Dun-da-Gu) in Mull, around the southern flanks of Glamaig in Skye, and at Beinn Suardil in the same island. They agree in every respect with the Icelandic varieties so clearly described by Bréon. The general features of these rocks, and the evidence they afford of the growth of the felspar crystals subsequently to the consolidation of the rock, have been discussed in a previous communication to this Society*.

In their altered condition these labradorite-andesites present the most complete analogy with the labradorite-porphyrates, such as the *Verde antique* of Greece, and the Lambay-Island porphyrite so well investigated by Von Lasaulx.

Occasionally rocks of the "trachytoid" type are found passing locally into a perfect glass. An example of this was discovered some years ago by the late Mr. Grieve, and I am indebted to my friend Professor Bonney for calling my attention to it. The locality where this is found is at Bealach a' Mhàim, at the head of Glen Brittle in Skye. The mode of occurrence of this glass is somewhat obscure, but it appears that the glass does not exist like the tachylite-selvages to basalt-dykes, but as local patches in the midst of the andesite. Probably in this, as in cases to be more fully described in a later portion of this paper, a separation has occurred between the glassy and the crystalline portions of the andesite. The glass has a specific gravity of 2.63, while that of the labradorite-andesite in which it is enclosed is 2.89.

By the kindness of Prof. Thorpe I have been supplied with analyses of the glassy portions of this rock made in the Chemical Laboratory of the Normal School of Science and Royal School of Mines.

	I.	II.	III.
Silica	31.51	62.10	61.80
Alumina	14.83	15.00	14.91
Ferric oxide	8.41	8.14	8.27
Lime	3.58	3.07	3.33
Magnesia	0.28	0.27	0.27
Soda	6.58	6.42	6.50
Potash.....	5.17	5.21	5.19
Loss on ignition ..	0.88	0.86	0.87
	101.24	101.07	101.14

* Quart. Journ. Geol. Soc. vol. xlv. (1889) pp. 175-186.

I. Analysis of glass in labradorite-andesite from Bealach a' Mhàim, Skye, by S. Parrish.

II. Analysis of second specimen of the same rock by H. J. Taylor.

III. Mean of these two analyses.

It appears from these analyses that this glass is richer in silica than the andesite (a labradorite-andesite) in which it occurs.

Studied microscopically, this vitreous rock is found to consist of a glassy base, less black and opaque than ordinary tachylyte, through which porphyritic crystals of plagioclase (labradorite) are somewhat sparsely scattered. The glass often contains incipient and sometimes well-formed spherulites, and the arrangement of these and of darker streaks of glassy material give it a marked fluidal structure. The felspar phenocrysts are remarkable for the amount of corrosions by the fluid magma which they have undergone, and spherulitic fringes have often been developed all round the edges of the crystals. Sometimes the incipient spherulites are seen to yield to weathering influence much more readily than the enclosing glass, and a peculiar banded appearance then becomes very conspicuous on weathered surfaces (see Plate XIV. fig. 5).

The Augite-diorites.—In 1866 Zirkel* proposed the use of this term, and in 1877 Strong described an important class of rock of this type as occurring in Minnesota†. Mr. Cole has also strongly advocated the use of this term ‡, which has, moreover, been adopted by Rosenbusch, in the last edition of his 'Massige Gesteine.'

The type is beautifully exemplified, especially in Ardnamurchan, where great mountain-masses, like that of Meal nan Con, are made up of it. The augite often exhibits, partially or throughout, the diallagic striation, and the rocks differ from the gabbros only in the absence of olivine and magnetite. Every gradation can be followed from rocks with a glassy magma, though various granophyric types, into a perfectly holocrystalline rock.

Quartz-augite-diorites occur at several points, as in the great sheets under Beinn More. They contain both rhombic and monoclinic pyroxene, and also quartz, both primary and secondary.

As it has been asserted that the "felstones" or propylites of the Western Isles of Scotland are really nothing more than basalts altered by contact-metamorphism, I may point out that, associated with the andesites and more acid rocks, are a few ophitic-olivine-basalts, which have been subjected to the same kind of modification as the propylites. These are found to exhibit characters very strongly contrasted to those of the rocks in question. In all, or nearly all, these cases the distinctive characters of the basalts can still be clearly recognized, namely, the olivine grains, reduced to pseudomorphs, and the ophitic structure, traces of which can be detected even when both the felspar and the pyroxenes have undergone the most profound change.

* Lehrbuch der Petrographie, vol. ii. p. 7.

† Neuer Jahrb. für Min. &c. 1877.

‡ Geol. Mag. dec. iii. vol. iii. (1886) p. 225.

VII. CAUSES BY WHICH THE "PROPYLITIC" MODIFICATION OF THESE ROCKS HAS BEEN BROUGHT ABOUT.

In studying the relations of the propylites to the other rocks of the Western Isles of Scotland no fact strikes the observer more forcibly than that of their being constantly invaded by igneous intrusions, composed of granite and felsite on the one hand, and of gabbro and dolerite on the other hand. Beautiful examples may be studied, at many points, of the ramification of granite veins through the propylites, and portions of the propylite may even be seen caught up in the midst of granite. On the other hand, the currents of propylite may be seen to be broken up by numerous sheets of gabbro and dolerite, which are generally intruded between them; and from these sheets numerous veins and dykes of dolerite and basalt can often be traced intersecting the propylite masses. In places the intrusions, indeed, outbulk the rocks among which they have been thrust. These relations were fully explained by me in 1874*, and have been confirmed by numerous illustrative examples given by Dr. A. Geikie in 1888 †.

Impressed by the number of these intrusions among the propylite- ("felstone"-) lavas I was led, in 1874, to refer the remarkable alteration which they have undoubtedly undergone to contact-metamorphism ‡, and the same view was adopted by Dr. A. Geikie in 1888 §.

But subsequent and more detailed study of the propylites has convinced me that contact-metamorphism, while producing very striking results close to the planes of junction of the lavas and the intruded sheets, has seldom operated to any great distances from the latter, and that the widespread modifications which have been effected in the minerals and the ground-mass of the propylites must be referred to a widely different cause. In the case of the analogous rocks of Eastern Europe and North America, it has been abundantly proved, by the researches of geologists in these districts, that the cause of the curious alteration of the andesitic and dioritic rocks and their impregnation with metallic sulphides (some of which are of great commercial value in those two districts) must be referred to the action of steam and of various acid gases, which have permeated the whole substance of the lava-masses, giving rise to profound chemical alteration of their constituents.

At the same time the contact-metamorphism, to which I called attention in 1874, has undoubtedly been a noteworthy and, in some instances, an important contributory factor in bringing about the results. I showed that "in proximity to the gabbros, these felstone-lavas are seen . . . to have acquired a peculiar platy structure and splintery fracture, combined, in many cases, with the development of a probably preexisting banded coloration" ||. I particularly dwelt

* Quart. Journ. Geol. Soc. vol xxx. p. 246.

† Trans. Roy. Soc. Edinb. vol. xxxv. (1888) pp. 165-171.

‡ Quart. Journ. Geol. Soc. vol. xxx. p. 251.

§ Trans. Roy. Soc. Edinb. vol. xxxv. (1888) p. 167.

|| Quart. Journ. Geol. Soc. vol. xxx. p. 251.

upon the evidence of the contact-metamorphism produced around the intrusive mass of S. Airde Beinn (Sarsta Beinn), and the facts then pointed out have been confirmed by Dr. Geikie and Dr. Hatch*.

In many cases the solfataric action and the invasion of the lavas by great molten masses of rock can be shown to have produced effects which are strikingly contrasted. The effect of the contact-metamorphism is to induce a remarkable splintery fracture and jointed structure in the rocks affected. But this effect is only seen to extend to the distance of a few inches, or at most feet, from the actual planes of junction. As the result of the contact-metamorphism the rocks acquire, in a very remarkable manner, a power of resisting denudation; and in consequence of this, we find sheaths of altered rock standing up above the general surface, and enveloping the intrusive masses †.

The more widely spread changes which have affected the oldest Tertiary andesites and diorites are of a totally different kind. The action appears to have taken place in a sporadic and seemingly capricious manner. Highly altered rocks may sometimes be found to pass into comparatively unaltered rocks, within a few feet or yards, and no direct relation can be detected between the greatly altered masses and any particular intrusions of either acid or basic rock. The effect of the chemical changes in the rock is usually to disintegrate its constituents, and thereby render it less able to withstand the action of denuding agents upon the mountain-sides. The chemically altered rocks, rendered soft and porous and coated with a friable white crust, are often covered up and concealed by peat and vegetation, while the intrusions among them, and their surrounding sheaths produced by contact-metamorphism, retain the marks of glacial action, and stand up prominently above the peat and heather.

In many places it can be clearly shown that the widely spread chemical action has preceded the action of contact-metamorphism, while in other instances the opposite may perhaps have been the case. As might be expected, the results of these two kinds of action are often curiously complicated and involved. Microscopical and chemical study enable us, however, in most cases to define and explain the exact nature of the results which follow from either kind of action, and these I now propose to consider.

A. *Effects of Solfataric Action.*

To this cause must be assigned the alteration both of the phenocrysts ("Einspreninge") and the ground-mass of the propylitic rocks already described.

The order in which the several changes take place is often capable of exact definition, when a large series of sections made

* Trans. Roy. Soc. Edinb. vol. xxxv. (1888) pp. 103, 104.

† Q. J. G. S. vol. xxx. (1874) pp. 265-266, figs. 4, 5, & 6.

from carefully selected specimens, and taken from different portions of a propylite-mass, are examined microscopically.

We are able to see how clear plagioclase with vitreous lustre (microtine) becomes gradually clouded and opaque, and in the end completely kaolinized; the changes being, in the first instance, developed along the planes of chemical weakness between the twin lamellæ; but the extension of this action very frequently results in the complete obliteration of all traces of the original twin-lamellation. In some instances the felspar substance then breaks up into a mosaic of different minerals, among which zoisite and a secondary felspar usually appear to play the most important part. But in other, and perhaps the majority of instances, the results are modified by the impregnation of the products of the felspar alteration with ferro-magnesian secretions derived from the decomposition of other minerals in the rock. The consequence of this is that the necessary materials for the formation of an epidote are brought together and tufted masses of pistacite, or some other variety of that species, are formed and replace a part or the whole of the felspar crystal.

The ferro-magnesian silicates at the same time lose their distinctive character, and green isotropic products (viridite) are formed at their expense. Out of these decomposition-products various chlorites are formed with the separation of secondary magnetite. These, in turn, yield to further chemical action, and pistacite and other epidotes are produced, forming more or less distinct pseudomorphs after the pyroxene, amphibole, or mica*.

The ground-mass is often one of the earliest portions of the rock acted upon. Any glassy matter that may be present disappears as the result of secondary devitrification, and the whole matrix of the rock is frequently converted into a mass of secondary minerals. Among these, various metallic sulphides are often very conspicuous.

When steam-holes abound in the rock the epidotes and other secondary minerals crystallize out freely; and in these situations they are conveniently displayed for careful study and determination. Beautiful amygdules, composed of epidote and other secondary minerals, and filled in with still later deposits of zeolites, calcite, and chalcedony, are, indeed, among the most conspicuous features presented by the surfaces of such of these propylitic rocks as have originally possessed a scoriaceous character.

There are localities in which the kind of change which I have been describing seems to have been carried to its farthest extreme. In these cases epidote has been developed to such an extent, at the expense of the other constituents, that it is now quite impossible to determine the original mineralogical constitution and structure of the rock. The most marked example of this is seen in the eastern spurs of the great mass of Beinn More in Mull, and around 'A Chioch. Here the epidotization of the rock-constituents and the formation of numerous volcanic minerals has gone on to

* Compare Q. J. G. S. vol. xlii. (1886) pp. 430, 431.

such an extent that it is often impossible to distinguish between* lavas and tuffs.

The characters of the propylites of this particular district, as we now see them, are most remarkable, not one of the minerals of the original rock being present in it. The ground-mass has been completely altered, all traces of glass having disappeared by secondary devitrification, and many secondary minerals being developed in it. The *outlines* of the original felspar-crystals can sometimes be made out, but this is all. Their substance has been converted into aggregates, among which epidote, zoisite, secondary felspar, and even quartz, play the most important part. The ferro-magnesian silicates usually appear as pseudomorphs in isotropic "viridite" or in some species of chlorite. The resorption-halos of the hornblendes and micas can often be detected by the clustered magnetite grains; and certain forms of biotite may be seen developed at the expense of the secondary chlorites. Lastly, in addition to the original magnetite grains of the rock, we find enormous quantities of the same material produced during the breaking up of the ferro-magnesian silicates, a process which is so frequently attended with the separation of magnetite grains (see Plate XIV. fig. 7).

As "epidotization" is the ulterior and most marked change of which the propylite rocks exhibit evidence, it may be well to consider the nature of the mineral species which result from the change.

From one of the extremely altered augite-andesites of Beinn More, in Mull, Mr. W. B. D. Edwards isolated, by means of Klein's solution, a considerable quantity of the beautiful green epidote, the material proving, on microscopic examination, to be remarkably free from foreign admixture. The specific gravity of the mineral proved to be 3.42, and a partial analysis made by Mr. Edwards showed it to be a lime-iron-epidote or pistacite. I find that all the optical characters confirm the identification of the epidote in question with this variety.

Besides the beautiful deep green epidote which is most abundant, pale-coloured lime-epidotes occur, and some which have a pale pink colour, probably due to manganese. The highly coloured withamite, however, has not yet been detected in these rocks.

It is a most suggestive circumstance that this solfataric action is found to have been developed around each of the five great centres which I have identified as the sites of the great volcanoes of the Western Isles of Scotland. In most cases where this action can be shown to have taken place intrusive masses of granite and felsite can be shown to be in tolerably close proximity to the altered rocks.

In a very interesting memoir, M. de Lapparent has insisted on

* I believe that there cannot be any reasonable doubt that the district lying immediately to the east of the summit of Beinn More must have existed underneath what was the great central active crater of the Mull volcano, and in this way the excessively altered condition of its rocks and the production of the remarkable volcanic minerals described by me in 1874 is accounted for.

the close connexion that always appears to exist in different volcanic regions between solfataric action and eruptions of rock of acid composition*. The same fact has also been pointed out by Schmidt †. While the ejection of basaltic lavas is followed by actions that lead to the formation of carbonates, the extrusion of great masses of highly silicated materials is attended and followed by the escape of steam containing sulphurous and other gases, which give rise to the phenomena of solfataric action.

The rocks of the Western Isles of Scotland afford a very striking illustration of this connexion between solfataric action and the ejection of highly silicated rocks.

B. *Contact-Metamorphism.*

Studied microscopically, the sheaths of altered "felstone" that surround the intrusion of granite or gabbro enable us to understand the succession of changes which place as the result of the contact of these rocks with great bodies of fused materials. As already pointed out, these effects are strikingly contrasted with those resulting from solfataric action.

We are, in the first place, forcibly reminded of the resorption-halos which are seen surrounding hornblendes, micas, and other minerals as the result of the action of a heated magma upon them. But this action, instead of being confined to the immediate proximity of the crystals affected, may extend to the distance of some inches or even feet from the planes of contact.

All the ferro-magnesian silicates—pyroxenes, hornblendes, and micas—break up into finely granular aggregates, which seem to consist of an almost colourless pyroxene and of magnetite grains, though other minerals may not improbably be present. In some cases, however, the very minute granules appear to have the colour, pleochroism, and other optical properties of melilite (see Plate XIV. fig. 8).

In the midst of these granular aggregates we sometimes find scales of a deep brown, highly pleochroic biotite making their appearance; and these increase in size and in number as the igneous mass is approached. Clear colourless needles can also be detected, and these may not improbably be referred to some species of secondary felspar.

In these greatly altered rocks it is only possible to state what was the nature of the original rock, by tracing the alterations step by step from the comparatively unchanged mass at a distance from the intrusions right up to the planes of contact.

VIII. LIGHT THROWN BY THE STUDY OF THESE TERTIARY LAVAS ON SOME OF THE OLDER VOLCANIC ROCKS (PORPHYRITES, FELSTONES, &c.).

It was pointed out, in my former memoir, that in Scotland we have brought close together remarkable masses of volcanic materials

* Bull. Soc. Géol. Fr. sér. 3, vol. xvii. pp. 282-290.

† Zeitsch. d. deutsch. geol. Gesellsch. 1885, p. 737.

of very different geological ages. We can readily compare the altered or unaltered rocks of the Tertiary periods with Palæozoic lavas like those of Lorne, and of the great Central Valley of Scotland. At the time when I wrote, all these Palæozoic lavas were generally considered by geologists to be of Devonian age; but since the publication of my paper in 1874 I have had the opportunity of studying the remarkable volcanic rocks and conglomerates of Ballantrae in Ayrshire, and I cannot help thinking that a part at least of the Lorne rocks may prove to be of the same age. I am at all events fully prepared to subscribe to the opinion so clearly expressed by Mr. Dugald Bell, namely, that the question of the age of the Lorne lavas is still *sub judice* *.

Among these Palæozoic lavas we find just the same contrast between almost wholly unaltered and greatly altered rocks, as in Skye, Mull, or Rum in the case of Tertiary volcanic rocks. Mr. Teall has shown that the glassy rocks of the Cheviot Hills are really enstatite-andesites, which differ in no essential respect from the recent lavas of Santorin and Krakatoa. Mr. Durham and I have described in Fifeshire enstatite-andesites and glassy dacites, which, though as old as the Carboniferous, are as fresh and unaltered as the modern enstatite-andesites of Japan. In the Garlton Hills near Haddington there occur sanidine-oligooclase-trachytes, of Pre-Carboniferous age, which are strikingly analogous with those of the Siebengebirge.

On the other hand, we find in the Pentland and Braid Hills rocks, which, while of the same general ultimate chemical composition as the modern andesites, are remarkable for their obscure structure and peculiar mineralogical constitution. A comparison of these with the Tertiary propylites of the Western Isles of Scotland is most instructive, for it shows that some of the "porphyrites" are really andesites that have been subjected to the propylitic modification, and then further modified by surface-agencies. It may, indeed, be asserted of many of the propylites of Mull that, if their abundant magnetite-granules, some of which are original and others secondary, were changed to a red colour by peroxidation, they would be quite undistinguishable from the obscure porphyrites to which I have referred. These latter have such a peculiar constitution that they have been classified by Dr. A. Geikie as "felspar-magnetite rocks."

IX. THE YOUNGER AUGITE-ANDESITES ("THOLEITES," "PITCHSTONES," &c.) OF THE WESTERN ISLES OF SCOTLAND.

While the older Tertiary andesitic rocks which we have been describing are remarkable for the extraordinary and often extreme changes which they have undergone, there exist other lavas of similar composition in the district, which present the most marked contrast with them, by the wonderful freshness of their appearance. That these lavas are younger than all the plateau-basalts is shown

* Trans. Geol. Soc. of Glasgow, vol. viii. (1886) p. 116.

by the fact that they are found intersecting the basaltic sheets as veins or dykes, while at other times they can be shown to lie upon their greatly eroded surfaces, as lava-currents. Of the same late age are certain other rocks, some of more basic and others of more acid composition, which will be considered in greater detail hereafter. The whole of these rocks belong to the latest of the three periods to which, as I showed in 1874, the Tertiary volcanic rocks of the Western Islands must be assigned.

The lavas in question are of very considerable interest as having been undoubtedly the latest-erupted volcanic masses in the British Islands. A careful study of them shows that they present the most striking resemblances to some of the recent volcanic rocks of Iceland. Dykes and veins of these lavas are found traversing the thick ophitic olivine-basalts of the Western Isles of Scotland and of Antrim. But other dykes of remarkably similar rock occur cutting through the Palæozoic rocks of the lowland districts of Scotland, and these reappear in the north of England, where some of them can be shown to intersect Jurassic strata. Some of the Scottish examples of these rocks have been well described by Dr. A. Geikie*. The English examples have been admirably studied by Mr. Teall†.

I have already pointed out‡ that along these lines of fissure now occupied by dykes there is evidence of the outburst of a volcanic material giving rise to lines of volcanic cones, which bore the same relation to the great volcanoes of the Western Isles, that the chains of "pys" in Auvergne did to the great volcanic mountains of Mont Dore, the Mezen, and the Cantal.

At two points only, so far as I know, have the lava-currents and tuffs of this period been preserved. This is accounted for by the fact that the amount of denudation in the district since the formation of these small, subsidiary volcanic cones has been excessive; and only where the lava-currents were of unusual dimensions, or were of such a character as to resist the action of denuding agencies in an exceptional manner, was there any chance of their being preserved for our study at the present day.

The first case of the kind noticed was that of the Sgùrr of Eigg, which was so well described by Dr. A. Geikie in 1871§. His explanation of the mode of preservation of several successive lava-sheets, by their being poured out into a valley that had been eroded in the basaltic plateau, is one that must commend itself to every one who has studied the district. Equally convincing is the evidence he adduces of the enormous amount of denudation that has taken place since the formation of these lava-flows, seeing that the basalts forming the sides of the valley have all been removed, leaving the later lavas as a mass crowning the summit of a long ridge.

* Proc. Roy. Phys. Edinb. vol. v. (1878-80) pp. 219-254; and Trans. Roy. Soc. Edinb. vol. xxxv. (1889) pp. 24-73.

† Q. J. G. S. vol. xl. (1884) p. 209.

‡ Q. J. G. S. vol. xxx. (1874) pp. 260-272.

§ Quart. Journ. Geol. Soc. vol. xxvii. (1871) pp. 303-309.

Not less interesting and remarkable are the sheets of lava with the great masses of underlying tuffs that form the mountain of Ben Hiant (Beinn Shiant) in Ardnamurchan. The general structure of this mountain will be understood from the accompanying map and section, which have been constructed on the basis of the recently published 6-inch maps of the Ordnance Survey (figs. 1 & 2), see pp. 374 and 375.

Lying in part upon the much eroded basalt of the plateau, in part on the underlying Jurassic strata, and in part on the fundamental crystalline schists, we find thick masses of volcanic agglomerate. These volcanic agglomerates can be especially well studied on the northern face of the mountain, and on the southern sea-washed promontory known as Sron Mhor, or Maclean's Nose. They vary in character from ordinary andesitic tuffs, to very coarse breccias made up of fragments derived from all the underlying rocks (crystalline schists, liassic shales, sandstones, and limestones, and andesitic and basaltic lavas), with varying quantities of other volcanic materials.

The preservation of these agglomerates has been clearly due to the fact that they were covered by currents of a peculiar lava, often of a columnar habit, which cap all the spurs of this singularly outlined mountain; only the lower and more crystalline portions of these lava-currents having in most cases escaped removal by denudation. These lavas are found by careful study to be an andesite presenting many remarkable varieties, to which I propose to call especial attention in the sequel*.

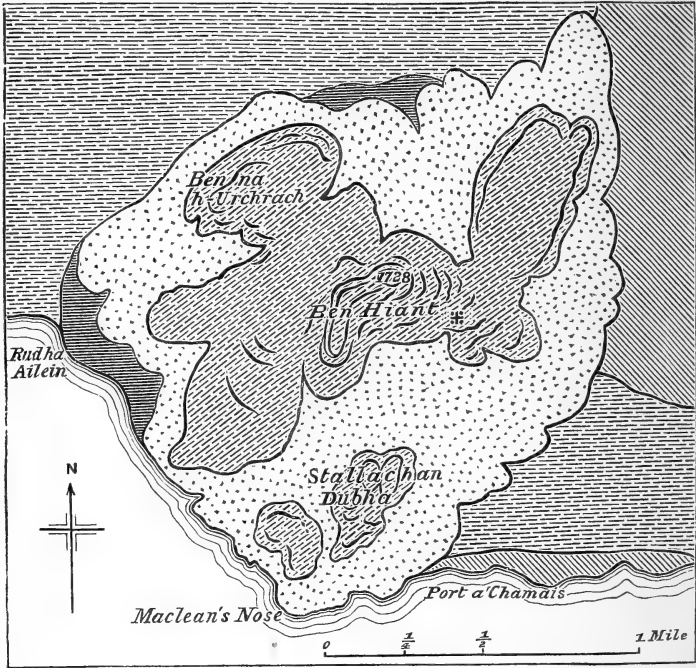
The rocks of Ben Hiant find their closest analogues in the augite-andesites of the Tertiary dykes of the north of England ("tholeites" of Rosenbusch), so well described by Mr. Teall, and in the rock of Eskdalemuir, for a very careful and accurate account of which we are indebted to Dr. A. Geikie. Mr. Grenville Cole, F.G.S., has kindly supplied me with a series of specimens collected by him from the Eskdalemuir rock, which have proved of great service to me in my comparisons.






Dr. A. Geikie has shown that in the case of the Eskdalemuir dyke a marked separation has often taken place between the more acid, vitreous parts of the rock and the more basic, crystalline materials. In consequence of this, as shown by Mr. Grant Wilson's analyses, different portions of the dyke come to present wide divergencies in composition and appearance †.

* The main features of the remarkable mass of Ben Hiant were accurately described by me in 1874. Dr. A. Geikie, as the result of what must surely have been a superficial examination of the locality, asserts that the lava of Ben Hiant is a single intrusive sheet, and that it consists of the ordinary ophitic dolerite of the "sills" that were erupted at the same time as the plateau-basalts. My statement of 1874 that the rocks consist of a very remarkable augite-andesite is borne out by the microscopic study of a very large series of specimens derived from various parts of the mountain; and the statement that the rock is neither glassy nor vesicular is contradicted by the study of this large series of rocks (see Plate XV.).

† Proc. Roy. Phys. Soc. Edinb. vol. v. (1880) p. 256; and Trans. Roy. Soc. Edinb. vol. xxx. (1888) pp. 40-44.

Fig. 1.—Sketch-map of Ben Hiant, Ardnamurchan.



- | | | | |
|---|--|-----------------|--------------------|
|  | Augite-andesite lavas, passing into glassy varieties
("pitchstone-porphyrries") at *. | } | NEWER
TERTIARY. |
|  | Volcanic agglomerates. | | |
|  | Basalts &c. overlying propylites. | OLDER TERTIARY. | |
|  | Sandstones and clays (altered). | JURASSIC. | |
|  | Crystalline schists &c. | | |

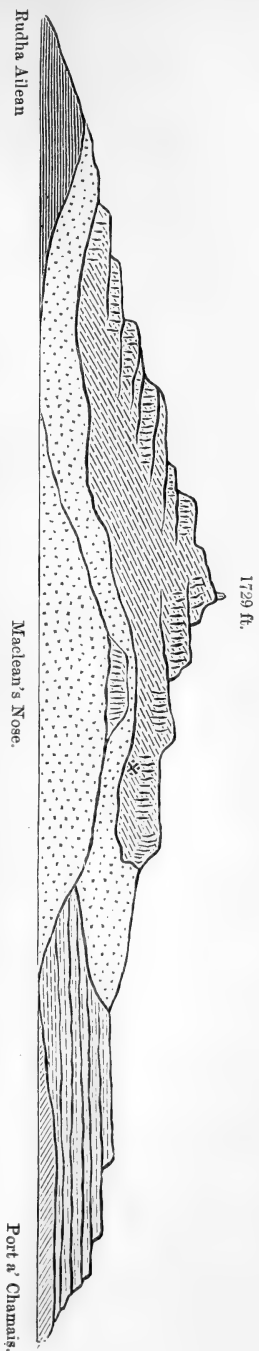


Fig. 2.—Profile Diagram, illustrating the Structure of Ben Hiant, Arduaraichan.
(Viewed from the South.)

The shading of the different rocks is the same as in the Map (page 374).
* The glassy varieties of andesite ("pitchstone-porphyrries") are well seen at this point.

Now the separation that has taken place within the Eskdalemuir dyke, on a small scale, has evidently gone on on a grand scale beneath Ben Hiant. The result of this has been that, while in some of the lava-sheets of the mountain we find a glassy lava through which porphyritic constituents are somewhat sparingly distributed (the result being a "pitchstone-porphry" similar to that of the Sgùrr of Eigg), in other cases masses of crystals with only a comparatively small matrix of glass have been poured out, giving rise to a rock of far more basic character than the pitchstone varieties.

In studying the Krakatoa lavas I was led to point out the remarkable differences in the composition and appearance of rocks resulting from variations in the proportion of acid ground-mass to basic phenocrysts in a rock. My examples in illustration of this principle were taken from Santorin, the Cheviot Hills, and Krakatoa*. But here in Ben Hiant we find, among the ejections of the same vent, the most wonderful illustrations of the same principle, one that has been too much overlooked in our petrographical studies.

I shall show that among the lavas of Ben Hiant we have varieties that are distinctly basic in composition, with a specific gravity of over 3 and a silica-percentage of a little above 50. But among the same rocks are others with a distinctly acid character, having a density of only 2.45 and a silica-percentage of over 65. Yet the minerals in all these rocks are identical; the same felspars, the same pyroxenes, magnetite, and a similar glass, are found in all; it is the *variation in the relative proportion* of these several mineralogical constituents which gives rise to the very wide diversity alike in the aspect and in the ultimate chemical composition of these rocks.

Mineralogically these rocks exhibit, as I have said, a remarkably uniform character. They consist of:—

1. *Felspar*, which is almost always either anorthite or labradorite, or some form intermediate between these species. This is proved by the extinctions which they give in the several zones, and is confirmed when we examine specimens of them, isolated by the use of heavy liquids, for their specific gravity, and the flame-reactions which they give by Szabó's method. The felspar-crystals are often zoned, the different zones giving evidence of being of different composition, the more basic being in the centre. Inclusions are often arranged parallel to these zones, and the first traces of schillerization are sometimes exhibited. Although the twin striation is often very marked, cases of simple Carlsbad-twinning are not uncommon.

2. *Pyroxene*, an augite, sometimes of a green colour, at other times brown. There is almost certain evidence that the brown augite is an altered form of the green; indeed every gradation from the one kind to the other can be found, and crystals occur which are in one part green and one part brown. The original colour is certainly

* 'The Eruption of Krakatoa and subsequent Phenomena' (1888), pp. 30-35; and Geol. Mag. dec. iii. vol. v. pp. 1-11.

green, and the brown tint is the result of alteration. Only the faintest trace of pleochroism can be detected. Some of the crystals show the beginning of the development of a structure like that exhibited by the augites in the older andesites of the district, which is described at page 363. Osann has described and analyzed a very similar augite from the augite-andesite of Kolter, in the Faroe Islands*. Its composition is as follows:—

Silica	50·21
Alumina	3·24
Ferrous oxide	17·40
Lime	13·92
Magnesia	14·05
	<hr/>
	98·82

Rhombic pyroxene occurs in these rocks, but in small quantities, and it must be regarded as an accessory constituent.

3. *Magnetite* occurs in distinct individuals, as skeleton-crystals, or in roundish grains, and is in some cases remarkably abundant.

Olivine, like enstatite, is an accessory constituent and is very variable in quantity. In some varieties of the rock it is not rare, while in most cases it is wholly wanting.

Brown glass containing microlites of different minerals and often corroding and forming enclosures in the felspars is usually present. Sometimes, when it is present in considerable quantities, this glass exhibits traces of both the spherulitic and the perlitic structure.

The best way of illustrating the remarkable varieties of structure and chemical composition which can be produced by combining the same mineralogical constituents in varying proportions, and with modification of internal arrangement, will be to describe some of the leading types of the Ben Hiant rocks, and show how they pass into one another by insensible gradations.

1. *Typical Pyroxene-andesites*.—These consist of a more or less perfectly glassy ground-mass crowded with microlites of felspar and augite, and grains of augite, the whole forming a “microlitic felt.” Through this base are scattered crystals of plagioclase, usually abounding with glass-inclusions, and with remarkable zoned structure. Pyroxene is represented by both augite and enstatite, the former being always the most abundant, though the latter mineral is sometimes by no means rare. Magnetite grains also occur scattered through the base (see Plate XV. fig. 2).

This rock not unfrequently contains vesicular cavities, which are usually filled with concentric deposits of various secondary minerals. The whole rock presents the most remarkable analogy with some of the well-known pyroxene-andesites of Hungary. Indeed, if some of my Ben Hiant and Hungarian sections were accidentally mixed, I know of no characters by which I should be able to separate them.

* Neues Jahrb. für Min. (1884), i. p. 48.

2. At some points, especially near the east side of the mountain, lava-currents composed of a compact rock are found. These, when studied microscopically, are seen to consist of a microlitic felt, in which the large porphyritic crystals are wholly wanting. The rock is vesicular, and the contents of the vesicles appear to be an altered glass. The specific gravity of this rock was found to be 2.89 (see Plate XV. fig. 1).

3. *Glassy (Vitrophyric) Andesite*.—At certain points, especially on the eastern side of the mountain, the rock is found to become perfectly vitreous and to pass into a “pitchstone-porphry.” In this the proportion of the glassy base to the porphyritic crystals is sometimes very great, but the latter present all the characters of the minerals found in the stony types of the rock (see Plate XV. fig. 3).

It is interesting to note that in these glassy forms of the rock the plagioclase crystals only show slight lamellar twinning in many cases, and some of the types of the rock appear to approximate very closely to the pitchstone-porphry of the Sgùrr of Eigg.

The glass sometimes exhibits the perlitic structure, and it varies in density from 2.52 to 2.62.

4. When the glassy or microlitic felted base becomes small in amount, it forms isolated masses which are caught up between the crystals, and the rock exhibits the “intersertal structure” of Rosenbusch in a very striking manner, the rock becoming a typical “tholeite” of that author. In many cases the glass of these “tholeites” is crowded with skeleton-crystals of magnetite, as in the case of the rocks figured and described by Mr. Teall* (see Plate XV. fig. 4).

5. *Highly Crystalline Andesites*.—In places, especially in the great central mass of the mountain, in some of the dykes, and in the deepest part of the thick lava-streams, the rock loses almost all trace of glass, and passes into a holocrystalline mass. These holocrystalline varieties sometimes exhibit the *ophitic* structure; while, as in the case of the ophitic basalt of the same district, the breaking up of the augite and felspar crystals into rounded granules, leads to a more or less perfectly developed *granulitic* structure (see Pl. XV. figs. 5 & 6).

6. New varieties make their appearance in consequence of differences in the proportion of the several porphyritic constituents to one another. These varieties are especially seen in the dykes, some of which contain the plagioclase felspar almost to the exclusion of the pyroxenes and magnetites; while in other cases the augite and magnetite are present in preponderating quantities, and a rock of abnormal density and basicity is the result. (See Pl. XV., compare figs. 7 & 8.)

The wonderful variation in chemical composition which may result from admixture in varying proportions of the same mineral constituents is illustrated in the following table of analyses:—

* Quart. Journ. Geol. Soc. vol. xl. (1884) pp. 209–246, pls. xii. & xiii.

Analyses of the Later-Tertiary Augite-andesites (Pitchstone, Tholeites, &c.).

	I.	II.	III.	IV.	V.	VI.
Silica	52·68	57·57	58·67	65·49	66·62	65·81
Alumina	12·66	14·42	14·37	14·66	14·02	14·01
Ferric oxide	17·34	6·04	1·64		5·73	4·43
Ferrous oxide .....	...	3·95	6·94	5·44		
Manganic oxide ...	trace	0·27			trace	
Lime	11·45	6·87	7·39	3·72	2·74	2·01
Magnesia	0·93	4·24	4·65	1·57	0·33	0·89
Soda	2·49	2·98	3·01		6·93	4·15
Potash	1·91	1·08	1·42		1·51	6·08
Loss in ignition ...	0·70	1·55	2·02		2·83	2·70

I. Analysis of augite-andesite (tholeite) with very little glass, from N.W. spur of Beinn Hiant, by W. Tate. Made in the Chemical Research Laboratory of the Normal School of Science, 1888.

II. Analysis of Cleveland Dyke (tholeite), made by Stock.

III. Analysis of crystalline portion of the Eskdalemuir dyke, by Mr. Grant Wilson, 1880.

IV. Partial analysis of kernels of glassy rock in the Eskdalemuir dyke, by Mr. Grant Wilson, 1880.

V. Analysis of glassy andesite from west side of Ben Hiant, made by Mr. T. H. Holland in the Geological Research Laboratory of the Normal School of Science, 1889.

VI. Analysis of the glassy andesite of the Sgùrr of Eigg, made by Mr. Barker North in the Chemical Research Laboratory in the Normal School of Science, 1888.

These younger augite-andesites seem to be remarkable for the tendency of the crystalline to separate from the glassy portions of the mass. This is illustrated in the several ejections from the same volcano, as in the case of Ben Hiant, and even in different parts of the same dyke as shown by the interesting observations of Dr. A. Geikie on the Eskdalemuir dyke, and in those of Mr. Clough in the case of other dykes in Scotland. According to Professor Ditmar's analyses, the mass of the Dunoon Dyke contains only 47·36 per cent. of silica, while the glassy segregation-veins contain 68·05 per cent. of silica*. The contrast in chemical composition between some of the Ben Hiant rocks, which are composed almost wholly of crystals, and others made up almost entirely of glass, must be equally great.

The tendency of the ground-mass in rocks of this kind to ooze out from among the crystals and fill up vesicular cavities in the rock has already been pointed out, and has been remarked upon by Osann † and Teall ‡.

The dykes of pitchstone which traverse the basalt of Mull, near Carsing and elsewhere, and also of the well-known dykes with the same relations in Eigg, are usually glassy andesites, the porphyritic

* Trans. Roy. Soc. Edinb. vol. xxxv. (1888) p. 44.

† Neues Jahrb. für Min. &c. 1889, vol. i. p. 304.

‡ Geol. Mag. dec. 3, vol. vi. 1889, pp. 481-483.

crystals being plagioclase. In this connexion it may be mentioned that recent researches show that many of the rocks of Iceland formerly regarded as rhyolites must really be referred to the group or the very acid andesites.

We have seen that the most glassy varieties of the Ben Hiant rocks have a very close analogy to the so-called "pitchstone-porphry" of the Sgurr of Eigg. This latter rock, from the presence of Carlsbad-twins, has usually been regarded as a purely orthoclastic rock. But careful examination in polarized light often proves that some of these feldspars show undoubted evidence of plagioclase-twinning. I have already remarked upon the fact that in the glassy variation of these rocks the lamellar twinning of the plagioclase often remains undeveloped. The quantity of glass present as enclosures in these feldspars would vitiate any result obtained by their isolation and analysis.

Nowhere can we find such clear evidence as in the rocks of Ben Hiant of the truth of the conclusion that the phenocrysts of such lavas as these were formed under Plutonic conditions, and that there is no direct and necessary relation between the porphyritic crystals of a volcanic rock and the magma by which they are enveloped.

In the case of the glomero-porphyrific rocks, I have shown that the evidence points to the existence of a holocrystalline mass having been broken up and its fragments enveloped and carried up in a magma of different composition. In certain pitchstones from Colorado, for specimens of which I am indebted to Mr. Louis, I have found fragments of micro-pegmatitic rocks enveloped in a perfectly glassy magma. In hornblende-andesites from Auvergne I have found glomero-porphyrific fragments of an enstatite-andesite, and in the case of the Krakatoa lava I have shown that the crystals are not scattered at random, but really form groups derived from a preexistent nearly holocrystalline mass.

Now some of the porphyritic crystals of the Ben Hiant rocks show all those features which I have already pointed out as being characteristic of deep-seated rocks. Both the feldspars and the augites show incipient schillerization, and this is found to be the case even in crystals enveloped in a perfectly glassy and vesicular matrix.

In the face of all these facts, I believe that it will be found impossible to maintain that the porphyritic constituents of such rocks as these could have been formed except under Plutonic conditions; and their present condition of corrosion and partial resorption proves that, in the volcanic masses as poured-out on the earth's surface, these materials of the Plutonic consolidation are in a condition of instability—very different indeed from that in which they were originally formed.

[Since the reading of this paper I have had the opportunity of studying the remarkable work of Mr. G. F. Becker on the rocks of California. He has shown that, closely associated with the andesites and basalts of the district, are great masses of glass, containing few crystals or none at all, and presenting therefore a higher

silica-percentage and lower specific gravity than the rocks with which they are associated. These cases, though on so much grander a scale, seem comparable to those of the Eskdalemuir and Dunoon dykes and the rocks of Ben Hiant. (See the Quicksilver Deposits of the Pacific Slope, U.S. Geol. Survey, Monograph xiii. pp. 153-162.)]

X. SUMMARY OF RESULTS.

The oldest of the Tertiary volcanic rocks of the Western Isles of Scotland (which were provisionally classed as "felstones" in 1874) prove on closer study to belong, for the most part, to the group called by von Richthofen "propylites." This term is used in the present memoir in the sense proposed by Rosenbusch, namely, as a "pathological variety" of the andesites and of their Plutonic representatives.

The rocks from which these "propylites" of Scotland have been formed find their exact analogues among the andesites of Iceland and the Faroe Islands, which have been so well described by Zirkel, Schirlitz, Osann, Bréon, and other authors. But in their present condition the Scottish propylites agree in all essential respects with the altered andesites of Hungary and Transylvania, which have been described by Dölter, Szabó, Koch, and other petrographers, and no less strikingly with the rocks bearing the same name in the Western Territories of North America—the rocks which have been so well illustrated by the researches of Zirkel, Wadsworth, Becker, Hague, and Iddings.

These Scottish propylites are distinguished by their dioritic aspect, the alteration which their minerals have undergone, and the development of metallic sulphides in their mass. In this way the original characters of their constituent minerals is often completely lost; various epidotes and chlorites with much secondary magnetite, biotite, and other minerals being formed at the expense of the original constituents. In their general aspect, in their specific gravity, and in their chemical composition, the propylites of Scotland strikingly agree with those of Europe and North America.

The propylites are shown to be the oldest of the Tertiary lavas of the district; as a mass, they underlie the ophitic olivine-basalts of the plateaux, though a few lava-currents of andesitic type are found intercalated with the latter. These propylite rocks form lava-currents, which are generally short and bulky as compared with the basaltic flows; they also constitute "cupolas" or "quellkuppen," and lenticular intrusions ("laccolites").

By tracing these much altered rocks to points where the changes produced in them have been less extreme, it can be shown that they represent various types of andesite and of the deep-seated representatives of those lavas, the diorites. Among the amphibolic and mica-rocks, we find hornblende-andesites, hornblende-mica-andesites containing enstatite, mica-andesites, and also true diorites and quartz-diorites. Among the chief types of the pyroxenic rocks described are glassy augite-andesites, labradorite-andesites, stony

augite-andesites, the so-called "diabase-andesites" with augite diorites and quartz-augite-diorites.

The causes by which the "propylitic *modification*" of these rocks has been brought about are two-fold; namely, *solfataric action*, which produces widely spread results, and *contact-metamorphism*, which is strictly local in its effects. By microscopic study of the rocks, the actions produced by each of these causes can be discriminated and severally studied. The solfataric action appears to have accompanied the intrusion of the highly acid masses (granites and felsites) of the district, and is shown to have taken place at each of the five great volcanic centres previously described.

The study of these greatly altered Tertiary rocks throws much light upon the mode of origin of some of the most obscure among the Palæozoic lavas—rocks to which the names of "felstone" and "porphyrite" have been applied. It is shown that while in some cases these rocks are simply andesites which have undergone slight alteration from the action of surface-waters, in other instances the rocks in question must have been profoundly changed by solfataric action and converted into propylites before the alteration from the surface commenced.

In striking contrast with the older Tertiary and much altered andesites (propylites) of the district are the remarkably fresh volcanic rocks which are everywhere seen to intersect and overlie the eroded masses of the plateau-basalts, and are therefore of much later age than those rocks. These younger rocks which are only preserved as surface lava-flows at the Sgùrr of Eigg and at Ben Hiant in Ardnamurchan are of much interest, as constituting the most recent volcanic rocks of the British Islands. They are shown to have the most striking correspondence in their petrographical characters with the rocks of the Tertiary dykes that traverse the south of Scotland and the north of England, which have been described by Dr. A. Geikie, Mr. Teall, and other authors. These rocks, which were in 1874 referred to the augite-andesites, are shown, both at Ben Hiant and in some of the dykes, to illustrate in a remarkable way the influence produced on the characters and chemical composition of rocks *when the same mineralogical constituents are united in varying proportions*. In this case we find every gradation from highly basic holocrystalline rocks, through various "ophitic," "intersertal," and "pilotaxitic" types of augite-andesite, into quite acid "vitrophyric" andesites (pitchstone-porphyrries).

EXPLANATION OF PLATES XIV. & XV.

[The system of notation here adopted to indicate the magnifying-power used for the rock-sections is explained in the Quart. Journ. Geol. Soc. vol. xlii. (1886), p. 88.]

PLATE XIV.

In this Plate an attempt has been made to illustrate the chief characters of the Older Tertiary Propylites, and of some of the Andesites, of which they are the altered representatives.

Fig. 1 shows a twinned group of Augite-crystals, exhibiting partings, produced by schillerization, along planes parallel both to the orthopinacoid and the basal plane. The crystals occur in a type of rock to which the name of "Diallage-Andesite" has been given by some authors. It is from Mingary Castle, Ardnamurchan. The specimen is shown as seen with a magnifying-power of 100 diameters. (See p. 363 and 'Mineralogical Magazine,' vol. ix.)

Fig. 2. Transverse section of a prism of the same Augite, showing the cleavage and the secondary twinning parallel to the orthopinacoid, the planes of the latter being crowded towards the centre of the crystal. Showing, as magnified, 250 diameters.

Figs. 3, 4, 5, and 6, represent a few of the most striking types of the Older Tertiary Andesite Lavas, as seen in parts of the rock-masses that have undergone a minimum amount of chemical alteration. (See p. 356.)

Fig. 3. Vitrophyric Augite-andesite, showing groups of crystals of plagioclase, augite, and magnetite (with some apatite), sparsely scattered through a glassy base, which is crowded with beautiful trichites. The latter are in many cases resolvable into globulites. The rock is from Mhàim Clackaig, in Mull, and is shown as viewed with a magnifying-power of 25 diameters. (See p. 362.)

Fig. 4. Spherulitic Augite-andesite, from Beinn-à-Ghraag, Mull. Crystals of plagioclase, augite (much altered), and magnetite are scattered through a glassy base, showing incipient spherulites. These spherulites are seen to affect a parallel arrangement, due to the movement of the mass. Magnified 25 diameters. (See p. 362.)

Fig. 5. Glassy Andesite, from Bealach a' Mhàim, Skye. The black glass is almost as opaque, in thin sections, as that of the basalts (Tachylite). There are many spherulites, consisting each of two concentric zones; and also spherulitic fringes around the much-corroded plagioclase crystals. This glass is associated with a "labradorite-andesite." Magnified 25 diameters. (See p. 364.)

Fig. 6. Banded Augite-andesite, from Beinn-à-Ghraag, Mull. The fluidal structure in the base of this rock is very beautifully exhibited, and is rendered conspicuous by the manner in which the bands of microlites are seen to curve around the porphyritic crystals. Magnified 25 diameters. (See p. 362.)

In figs. 7 and 8 an attempt has been made to show the characteristic differences in the effects of solfataric and contact alteration.

Fig. 7 is the Hornblende-propylite of Beinn Talaidh, in Mull. Scarcely a trace of the original glassy base and plagioclase crystals can now be seen in it; the colourless ground-mass consisting of secondary felspars and epidotes, in which only occasionally the outlines of the pseudomorphs of original constituents of the rock can be detected. The hornblende has been converted into mixtures of chlorite and magnetite; but in these pseudomorphs traces of the "resorption-halos" originally formed of pyroxene and magnetite, and constituting sheaths around the crystals, can still be detected. The section is shown as magnified 100 diameters. The peculiarities of the alteration of this rock are undoubtedly due to *solfataric* action. (See p. 369.)

Fig. 8 is the Augite-andesite from a point near its junction with the intrusive granite ("granophyre") of Beinn Uaig, in Mull. Scarcely a trace of the original crystals of the rock can be detected. In a colourless and structureless base, which is anisotropic but not individualized, we find numerous minute rounded granules of a colourless mineral, usually taken for Augite, with many grains of magnetite. A little, strongly pleochroic, brown biotite makes its appearance, and increases rapidly in quantity as we approach the intrusive rock. Magnified 100 diameters. (See p. 370.)

PLATE XV.

In this Plate an attempt has been made to illustrate some of the varieties of the Pyroxene-andesite of Ben Hiant. In these rocks the minerals and glass composing the different masses are identical; but the proportions in which they are combined and their structural relations are so different as to give rise to some very strikingly contrasted rock-types. They are shown as seen magnified 25 diameters. (See pp. 373-380.)

- Fig. 1 is a compact Augite-andesite from the south side of the mountain, and under the microscope is seen to be a "microlitic felt," consisting of lath-shaped feldspars, with granules of augite and magnetite, imbedded in a glassy base. The rock contains numerous small vesicles, which are sometimes filled with glass, as described by Osann and Teall. (See p. 378.)
- Fig. 2 is a rock with a similar ground-mass, through which numerous porphyritic crystals of plagioclase, with some of augite and magnetite, are scattered. The plagioclase crystals contain many glass- and magnetite-inclusions; and in the ground-mass there are a few vesicles filled with secondary products. In all its essential characters the rock is quite undistinguishable from the Augite-andesites of Hungary. (See p. 377.)
- Fig. 3. "Pitchstone-porphyr" from the east side of the mountain (at the point marked * on the map and section). In this rock the quantity of glassy base becomes very large, and the crystals of feldspar, augite, and magnetite occur in sparsely scattered groups. The feldspar-crystals are sometimes much corroded. The brown glass of this rock is traversed by many cracks, showing a distinct approximation to a perlitic arrangement. (See p. 378.)
- Fig. 4. Augite-andesite with portions of glass full of magnetite needles caught up between the numerous crystals, giving rise to the "intersertal" structure of Professor Rosenbusch. (See p. 378.)
- Fig. 5. Augite-andesite in which the "intersertal" structure of the last type is combined with the ophitic structure. (See p. 378.)
- Fig. 6. Rock differing from the last by the almost complete disappearance of the glassy material, so that the ophitic structure dominates throughout the whole mass. (See p. 378.)
- Fig. 7 is a rock in which a glassy base (with a few vesicles in it) encloses numerous large crystals of labradorite (or of a feldspar near that species). Augite and magnetite are present only in comparatively small quantity and as minute individual granules in the ground-mass, and the whole rock becomes a good example of a "Labradorite-andesite." (See p. 378.)
- Fig. 8 forms a striking contrast to the last. There is little glassy matter and the feldspar is present in small proportions. The bulk of the rock consists of augite and magnetite, and, though so closely related with the other types, is remarkable for its low silica-percentage and high density. (See p. 378.)

DISCUSSION.

The PRESIDENT said that papers like the present were difficult to discuss. They required to be read and reflected upon.

Mr. BARROW, referring to the amphibole- and pyroxene-andesites, remarked that, in mapping some of the dykes in Scotland, he had come across cases where amphibole prevailed in an acid matrix; secondly, where the prevailing mineral was mica; thirdly, pyroxene; and fourthly, that the three minerals would occur together. All these dykes were parallel to one another, and often formed double dykes with the apophyses of the Dee-Side granite.

He inquired if it were possible to get a connecting-link between the amphibole- and pyroxene-andesites.

Mr. COLE, speaking of the dykes and sheets traversing the plateau-basalts, inquired whether those with selvages of tachylyte might be related to the later andesitic eruptions.

The AUTHOR, in reply to Mr. Barrow, said that the existence of true amphibole-andesites was shown, even when the change was most complete, by the chlorites &c. occupying the place of the original hornblende-crystals showing traces of the "resorption halos" so characteristic of that mineral. He had described rocks which contain amphibole, mica, and pyroxene; but in the district under consideration the distinction between amphibole- and pyroxene-andesites may be fairly made out. In reply to Mr. Cole, he was not aware of any andesitic dykes traversing the basalts which put on a selvage of tachylyte.

21. *On the MONIAN and BASAL CAMBRIAN ROCKS of SHROPSHIRE.* By Prof. J. F. BLAKE, M.A., F.G.S. (Read March 12, 1890.)

[PLATE XVI.]

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1. General.
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3. Constitution of the Western Part of the Longmynd Massif.
4. The Western Boundary of the Longmynd Massif, with the supposed Archaean Masses.
5. Summary of the Stratigraphy of the Longmynd.

§ III. STRATIGRAPHY OF THE VOLCANIC HILLS.

§ IV. POSSIBLE MORE ANCIENT ROCKS IN THE DISTRICT.

§ V. RELATIONS OF THE OVERLYING FORMATIONS.

1. The Quartzite.
2. The Succeeding Formations.

§ VI. GENERAL CONCLUSIONS.

§ I. INTRODUCTION.

IN my memoir "On the Monian system" as developed in Anglesey*, I suggested that the Longmynd rocks might belong to the Upper Monian, on account of their general similarity to those of Bray Head, and that the Uriconian rocks of Dr. Callaway might be Middle Monian, because they were at once Precambrian and Volcanic. As these suggestions, which would be of some importance if true, were matters of conjecture only, I have taken the first opportunity to examine the district with care in order to arrive at a definite conclusion.

At the time of my writing, it was the universal opinion that the Longmynd series were essentially, even if not typically Cambrian; but about the same date Dr. Callaway was suggesting to the local geologists of Shropshire that in view of the break that existed between his "Hollybush Sandstone," which he regarded as Menevian, and the Longmynd series, it was doubtful if the latter were really Cambrian, and he proposed that till this was decided, they should be called Longmyndian †. The same argument was more strongly enforced last year ‡ by Prof. Lapworth, who writes, "the presence of

















* Quart. Journ. Geol. Soc. vol. xlv.

† Trans. Shrops. Archæol. Soc. 1887.

‡ Geol. Mag., Nov. 1888.

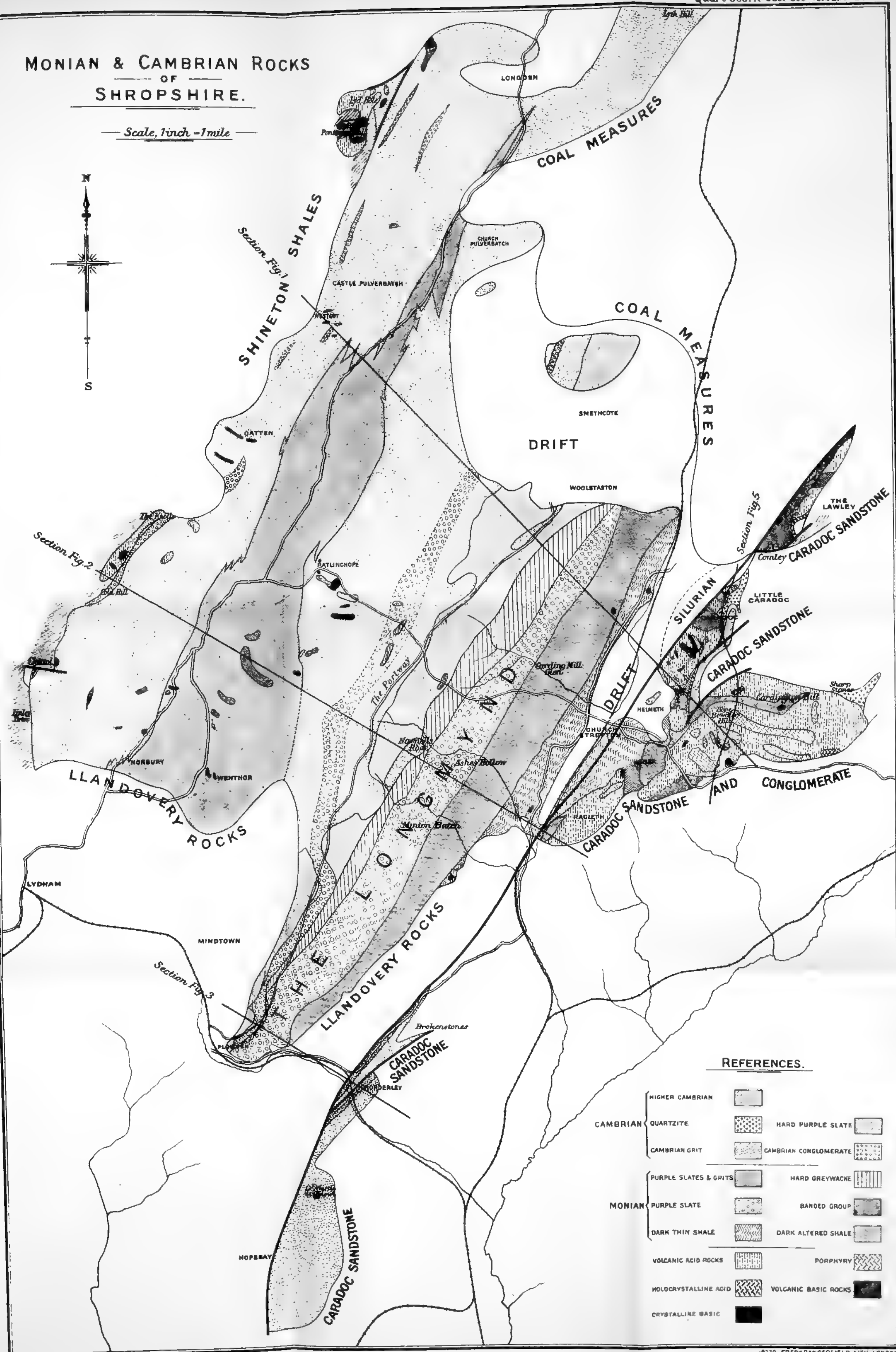


REFERENCES.

HIGHER CAMBRIAN			
QUARTZITE		HARD PURPLE SLATE	
CAMBRIAN GRIT		CAMBRIAN CONGLOMERATE	
PURPLE SLATES & GRITS		HARD GREYWACKE	
PURPLE SLATE		BANDED GROUP	
DARK THIN SHALE		DARK ALTERED SHALE	
VOLCANIC ACID ROCKS		PORPHYRY	
HOLOCRYSTALLINE ACID		VOLCANIC BASIC ROCKS	
CRYSTALLINE BASIC			

MONIAN & CAMBRIAN ROCKS OF SHROPSHIRE.

— Scale, 1 inch = 1 mile —



REFERENCES.

HIGHER CAMBRIAN		HARD PURPLE SLATE	
CAMBRIAN QUARTZITE		CAMBRIAN CONGLOMERATE	
CAMBRIAN GRIT		HARD GREYWACKE	
PURPLE SLATES & GRITS		BANDED GROUP	
MONIAN PURPLE SLATE		DARK ALTERED SHALE	
DARK THIN SHALE		VOLCANIC ACID ROCKS	
VOLCANIC ACID ROCKS		PORPHYRY	
HOLOCRYSTALLINE ACID		VOLCANIC BASIC ROCKS	
CRYSTALLINE BASIC			



Olenellus in the (Comley) Sandstone appears at first sight to fix distinctly the Precambrian age of the so-called Uriconian rocks of the Wrekin and their English equivalents, and even to render the Precambrian age of the Longmynd a matter of fair probability." It will be seen that in both these cases the age of the Longmynd rocks was made to depend solely on their relations to the fossiliferous sandstone; my suggestion, on the other hand, had arisen from entirely different considerations.

In any definite attempt to determine the age of a group of rocks like those of the Longmynd, it appeared to me to be a necessary preliminary to obtain a thorough knowledge of the rocks themselves; but I had not the slightest idea where their examination would lead me.

In their original description by Sir R. I. Murchison, in his 'Silurian System,' they are treated as forming a continuous sequence, whose base is to the east and whose summit is to the west, where they are said to pass up into Lower-Silurian rocks. In this description the lower part of the series is treated with care, but on the horizon of the grits and conglomerates being reached, the remainder is lightly dispatched in the following words:—"These conglomerates and grits form the central masses of the Longmynd, and are succeeded on the west by alternations of similar strata. They are again followed on the N.W. by various alternations of strata identical with those described. Still further to the west, the purple-coloured grits and sandstones and slaty schists prevail. The red grits are evidently of regenerated origin, and often contain many small fragments of older slate in a quartzose cement."

It is the same with Mr. Salter in 1857*. He divides the beds below the red grit into eight groups, but the entire remainder is classed as No. 9. His eight subdivisions are not very easily made to fit with the six of Sir R. I. Murchison; but this is not to be wondered at, both are quite true and are a matter of more or less arbitrary grouping. He also shows in a section a perfect conformity from the bottom to the top and a passage upwards into Lingula-flags. The Survey section is practically identical with this.

But geologists have been staggered at the enormous thickness that such a section indicates—some 26,000 feet, the beds being, in the lower part at least, highly inclined. And this result it has been hoped to avoid by introducing one or more synclinals. But whether such synclinals exist or not, no evidence has been adduced except by Dr. Callaway. In a paper by that author entitled "The Precambrian Rocks of Shropshire, part ii." †, a series of supposed Archæan masses along the western boundary of the Cambrian grits is described. From their occurrence it is presumed that we are here at the base of the Cambrian instead of its summit, and it is stated that on the east side of the line the Longmynd rocks dip easterly, of which one example (but one only) is given near Lyd's Hole.

As far as I can gather, the memoirs and maps above referred to

* Quart. Journ. Geol. Soc. vol. xiii.

† *Ibid.* vol. xxxviii.

constitute the sum total of our available knowledge of the Longmynd group of rocks. It will be observed that they present us with two views, partly discordant and partly concordant. According to Murchison, Salter, and the Survey, these rocks form the base of a continuous series, and are of Cambrian age. According to Dr. Callaway they are isolated by faults from every succeeding rock (below the Ordovician), and, if of Precambrian age, are at least younger than the Uriconian, of which they contain fragments. Both views agree in considering them as a single series, and in denying that there is amongst them anything older than both Cambrian and Uriconian.

Now the totally unexpected result of my examination is to show that within the Longmynd area there are two unconformable groups, one of which is older than the Uriconian, and the other of basal Cambrian age. I must admit at once that this result is by no means immediately obvious, and that there are many difficulties to be overcome, principally arising, I think, from the way in which the rocks have been squeezed together; but while the many points which make against this view can all be explained away, those which make for it can in no wise be accounted for in any other way that is in the least degree acceptable. To a very large extent the whole question is one of detailed stratigraphy.

§ II. STRATIGRAPHY OF THE LONGMYND HILLS.

1. *General*.—It has been noted above that in describing the Longmynd rocks Murchison and Salter made respectively six and eight subdivisions of the rocks below the red grits, which form the upper part of the series. In taking a single section, such as that of Carding-Mill Glen, or the Ashes Hollow, we might, if we pleased, make twenty or thirty subdivisions. The whole series consists of well-stratified rocks in conformable succession, made up of various-coloured slates and grits, and greywackés of various hardness and coarseness. But I have not found it possible to trace across the country more than five groups, and even with these it would in many cases be impossible to say of an isolated exposure to which group it should belong. In all of them there are bands of hard grit, which may occur anywhere, in most there are small masses of purple-looking slate, which, if more abundant, would indicate perhaps another group (see figs. 1, 2, 3).

The five groups I have adopted are as follows:—On the eastern side we have (1) a series of dark thin shales, which are usually very soft, and contain bands of calcareous matter, corresponding apparently to Nos. 1 & 2 of Salter. To the west of these succeed (2) a series of more solid rocks, many of them hard greywackés, but many pale-coloured slates. When these are seen well preserved, as in Minton Batch, they show a beautiful banding, being composed of innumerable small beds, 2 or 3 inches in thickness, with a fine ripple-drift lamination; but very often they seem so compacted together that bedding is difficult to perceive at all. These I call the “banded series.” Further west comes (3) a mass of purple

slate of very schistose character, but soft. There are some bands of grit, but on the whole it is very free from them. This is No. 4 and part of 5 in Salter's list. Following on we find (4) a large quantity of hard and often micaceous greywacké, seen in Carding-Mill Glen to contain many intermediate bands of slate, but the greywacké, being in greatest abundance, almost always forms the isolated exposures. This is Salter's No. 6. Lastly we find (5) a pale greenish slate which weathers purple, and is easily taken for No. 3 till a fresh fracture is obtained. Associated with this are bands of purple grit and greywacké, often micaceous. There is so intimate a mixture in some places of these two kinds of rock, and such a segregation in one place of slates and in another of greywackés, that I cannot separate them into two. They correspond to Nos. 7 and 8 of Salter, and 5 and 6 of Murchison, whose descriptions of them, no doubt taken in different glens, do not coincide in details, because they both are true of particular sections.

Practically the above description is the same as Murchison's, with the exception of the last item.

The subdivisions in the lower part of the Longmynd rocks, which I have here enumerated, are given in geographical succession, because it may be doubtful which is their order of succession in time. This, however, is the first point to settle. Murchison and every one else reckons No. 1 the lowest, and I think it is so, but it requires definite proof. In the first place there is a pretty uniform dip towards the west, only locally disturbed, and then so very irregular as to be obviously accidental. Thus if the rocks do not succeed in time as we pass west, they must be throughout inverted. Again, there are numerous surface-markings in some of the groups, especially in the purple and pale slates, the best known of these are the little hollows referred to the borings of Annelids. Now wherever these are seen it is the hollows that face west and the elevations which fit into them that face east. If they were really Annelid-burrows, it would prove the point, but this is by no means certain. However, the specimen in the Museum of Practical Geology collected by Mr. Salter, and figured by him in his second paper (Q. J. G. S. vol. xiii. pl. v. fig. 1), supplies the required evidence. On this there are at the same time ripple-marks, rain-spots, and the minute depressions. Now of rain-spots we can be in no doubt, the concavity must be on the upper side, and in the specimens the depressions are on the same side as the rain-spot concavities. Hence the upper side of the rock faces west. A third reason for believing this arises from the nature of the rocks. Those on the east are entirely unlike the overlying purple grits; but the group which lies most westerly is so like the succeeding beds, as to give rise to great difficulties, and suggest in some places almost a passage between the two. It is far more probable that this is a true appearance than that the basal beds of two groups should be so much alike; and if it should be accepted that the overlying grits are unconformable to the whole of the series, we may expect the included fragments at the base to have been derived from the uppermost rocks. Now

these fragments are of purple slate, such as the western part of the series alone will yield.

These considerations make it, I think, pretty certain that in going from east to west we are passing over an ascending sequence. Nor is there the slightest trace of a synclinal, anticlinal, or any other folding. There are disturbances here and there, but they have very little effect, and are mostly confined to the eastern slopes. Except for being compressed and hardened, they are very little altered, and if there is any cleavage it must affect the slates only, and be there confounded with the bedding; only in one place, in Stony Batch, did I observe an oblique cleavage.

The distribution of the various groups on the surface is indicated on the map. It is very possible that the lines of separation there marked do not always indicate the same horizon in the series as they should do, but the general tendency of all the rocks in one direction, wherever their strike can be observed, and the remarkable scoring of the hill-sides by the parallel crests of the harder strata, leave no doubt that the whole is an ordinary sedimentary series, simply turned up on end so as to dip at an average of about 80° , the lowest dip being seen generally on the west, though it is seldom if ever lower than 60° . This will give the series a total thickness of not less than 3 miles.

The careful lithological description given of the series by Salter relieves me from the necessity of saying much on this point, which is pretty familiar to geologists; but there are one or two observations of importance.

It is plain that the oldest member of the series in this locality is not a basal deposit. Its uniformity, the fineness of its material, and its calcareous bands, all give it great resemblance to the higher Welsh Cambrians, and show it to be the product of very settled conditions, and to represent the most tranquil portion of the period of the general formation. It must in fact be the upper part of a series whose lower part is not revealed within the district. It could not possibly be derived from the washing down of such volcanic rocks as are found on its eastern border, nor without many intermediate siftings from any series of gneissic or granitic rocks. If therefore these rocks be Monian, as I hope to show, they must belong to the upper part of it. The gradual coming on of coarser rocks indicates a rising of the area of deposition, with the denudation of new and less distant masses. First we have the fine banding which indicates perhaps a littoral condition of things, and then an alternation. The greywackés and grits are at first of a finer character, with very little mica, but the upper parts of groups 4 and 5 are often coarser and more micaceous, and they gradually put on a purple hue, but are invariably well bedded. As we approach the top, this last fact is about the only reliable character, and it is extremely hard, if not impossible, to distinguish some hand specimens of the hard greywacké from the overlying grits. One well-marked band at the top of Ashes Hollow is far coarser than these grits, and contains abundance of small purple fragments, as though it had been derived

from the denudation of the slates amongst which it lies. This is one of the difficulties, but the bedding is very clear, and there is no proof that these apparent slate elements were ever hardened and formed into rock before being imbedded with the other ingredients to form a grit. The same similarity is seen in an outlier near Smethcott; and near one south of Woolstaston the red grits of the underlying series are indistinguishable in hand-specimens from those of the overlying. In the absence of any other evidence, this might well be thought to indicate a passage, but it is equally well accounted for by the latter being derived from the former and redeposited.

With regard to fossils, the lowest beds look by far the most promising, but the only evidence of life I have seen is some impressions of *Lingule* found near the Church-Stretton Gasworks, but which were unfortunately broken in removal. The purple slates of No. 3, and the pale slates of No. 5 also look hopeful, and it is from these that Salter obtained his best specimens. Rain-spots and ripple-marks are undoubted, but it does not seem to me certain that the small depressions were burrows made by Annelids, they certainly have no signs of such burrows underneath them. They may, however, have been hollows occupied by coiled-up worms. In examining the large specimen figured by Salter (Quart. Journ. Geol. Soc. vol. xiii. pl. v. fig. 1) with me, Mr. E. T. Newton made a curious discovery. The surface of the slab is covered with very fine discontinuous curling tube-like bodies, which resemble exactly the castings of minute worms; indeed I cannot doubt that such is their character. In these then we have good evidence of the presence of minute Annelids. As to the supposed Trilobites, the evidence is hostile. The slates from whence they are derived are divided by irregularly undulating, overlapping, intermingling surfaces along which they split. These surfaces are remarkably smooth when compared with one produced by fracture. In breaking open the slates, these smooth surfaces come to be bounded by their junction-lines with old fracture-surfaces, and these have often a pseudo-regularity. This, combined with the peculiar undulation of the smooth surfaces, gives rise to a hundred fantastic shapes, and it is one of these surfaces that has produced the specimen figured by Salter as the tail of *Palæopyge*, and another the specimen referred by him to the head of *Dikelocephalus* (Mus. Pract. Geology). No Trilobitic remains have as yet been made known. What has given rise to these curious smooth surfaces of separation it is difficult to say; possibly it may be an excessively fine sediment coating a series of ripple-surfaces, or possibly, but not probably, fragments of some kind of laminarian alga. They may even be structural surfaces produced after the consolidation of the rock.

The area assigned to these rocks in my map extends a less distance to the north than is indicated on that of the Survey, because I have taken notice of the thick masses of drift which conceal what may lie beneath; and, though the underlying rocks may belong to the same series, it is impossible to draw the lines between subdivisions where nothing is seen. The mass exposed to the North of Smethcott

thus appears as an outlier. The eastern portion of this is composed of mixed masses of purple-weathering slate and purple greywacké, very much in the same way as No. 5, whose strike it continues and to which it is referred. Several miles to the North-east is the small inlier of Pitchford, surrounded by basal Carboniferous rocks. This inlier is exposed along a stream, and consists of well-bedded vertical glistening purple slates with hard greywacké bands. It is not remarkably like any of the subdivisions; but of all of them it is most like the banded series whose line of strike it continues. Further North still, but more to the West, stands the great inlier of Haughmond Hill. Dr. Callaway has shown that the long line of "greenstone" marked on the Survey map is really a conglomerate; the rocks to the East of the line consist mainly of hard greywackés, but with occasional masses of pale slate. These alternations and bedding are well seen in a quarry on the eastern slopes, where the rocks are more micaceous than usual. This series represents No. 5 extremely well; and, as in the Longmynd and by Smethecott, is easily confounded with the overlying rocks.

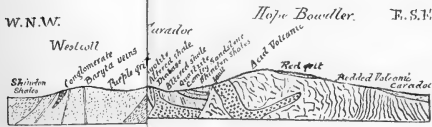
2. *The Junction-line between the two Series in the Longmynd.*—

We now pass to consider the junction of this lower series of five groups with the conglomerates and grits which form the upper part of the Longmynd massif. This is one of the most critical matters in the whole question. As just noted, we may often think we see a passage from one to the other, and if without due care we assign an isolated exposure of purple grit to the overlying beds instead of to No. 5, we may well believe they are interbedded.

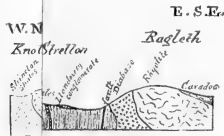
The first point to be noted is that the great conglomerate, which lies towards the base of the upper series, seldom forms the actual basal bed, there is almost always a mass of reddish-purple grit below it (see figs. 1, 2). The true basal bed seems to be that referred to by Sir R. I. Murchison, as containing small masses of purple slate. These, usually about $\frac{1}{2}$ inch in diameter, are angular and very distinct from the enclosing grit. These fragments are very like the underlying slates, and suggest immediately a derivation from them, which seems to be what Murchison means by saying the grits are of regenerative origin. This special slate-conglomerate is not always present at the base, but is found nowhere else within the eastern band of grit with which I am now dealing. The second point to be noted is that these Eastern grits never show any bedding,—a mark of distinction, when the exposure is large enough, between them and any similar grit belonging to No. 5 of the lower group.

Coming now to the line of junction between the two series, the main feature in its great irregularity. The subdividing lines between the groups of the lower series are not quite straight, but they have a remarkable general parallelism. This will be much impressed on the observer's mind if he fix their limits in each valley independently, and discover that when these points of division are joined, they form nearly uniform lines. But when we come to the line of junction now under consideration, it is wholly different. This was first seen by me in the patch marked as an outlier to the south of Woolstaston (see fig. 1).

Finch to a mile.)



Finch to a mile.)



Finches to a mile.)

The Morle Slate," "Banded Series,"
and "Dark S



Fig. 1.—General Section across the Northern Part of the Longmynd and the Volcanic Hills. (Scale 1 inch to a mile.)

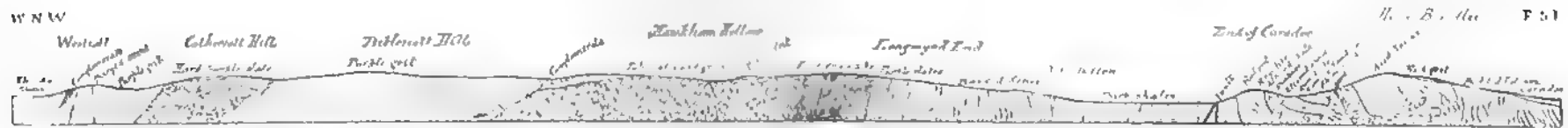


Fig. 2.—General Section across the Southern Part of the Longmynd and the Volcanic Hills. (Scale 1 inch to a mile.)

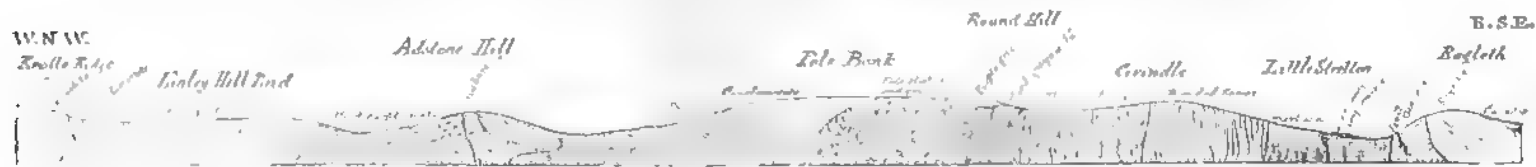
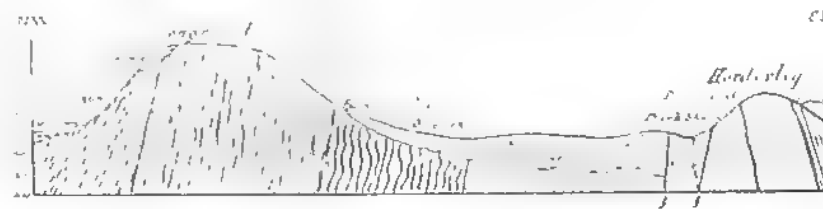


Fig. 3.—Section across the extreme South Part of the Longmynd to the Horderley Inlier. (Scale 1½ inches to a mile.)



The Monian Rocks in these Sections are those named "Pale Slates and Grits," "Hard Greywacké," "Purple Slate," "Banded Series," and "Dark Shales."

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On leaving the Drift, west of Colliersley, we come upon some rugged masses composed of purple-weathering slate in a nearly vertical position, and with the usual N.N.E. strike. On reaching the summit of the crest, the purple slate suddenly gives place to a great mass of purple grit without bedding and full of large fragments of slate. The line of junction is not very clearly seen, but seems to be a little transverse to the line of strike in the slates. Other beds of slate, however, in the road to the south strike directly at this mass. There is slate on the other side of it in the road to the west, and only a feeble indication of the grit is seen at the cross roads, apparently superficial. Thus if the purple grit be not here unconformably overlying the slate beds, it must be a local band within them. But this last appears impossible, as it lies across their strike. From this point it seems obvious that the junction sought is to be traced at the base of the mass of purple grit.

From the cross roads the purple grit may be traced towards the S.W. by the farm of Queensbounty by the entire covering of the fields with its fragments, till we reach the eastern slope of High Bank Hollow, where quarries are worked in it, and crags of it are exposed for a certain distance along the slope; while to the base to the south and on the western slope, there is nothing but the purple-weathering slate, which lies below, many of the strikes of which, if continued, would cut through the purple grit. These strikes are everywhere nearly the same, and yet *not* in the direction of the band of purple grit, which here is seen only on the higher parts of the ground. The mass of purple grit, which we have thus traced from near Colliersley, thus appears to be an isolated patch, not, indeed, actually seen lying on the edges of the slate, but whose main direction crosses the line of their strike; it dies out along a nearly horizontal line at a high level, and is without any stratification, and its basal portion, if it be horizontal, contains many slate fragments. I cannot see how such a mass can be anything than unconformable.

From this outlying patch it is some half a mile west before we reach the main mass of the purple grit, on the western slope of Hawkham Hollow. Here the line of junction, if not actually seen, is strictly limited for a long distance within a yard or two of breadth. It is not, however, a straight, but a crooked line, though the bedded slates, as seen, are everywhere nearly vertical, and parallel to each other. If part of the line of junction coincides with the strike, as it seems to do, the rest does not and cannot; and in one place there are two crags not many yards apart of which one is slate, striking directly at the other which is unbedded grit. There is here no evidence of either twisting or interbedding, but the junction appears to be an irregular surface both vertically and horizontally.

In these localities which lie on the valley-worn northern slopes, the exposures are pretty clear; but, when we get upon the rolling summit of hill-country, the relations of the beds become obscure. From the sigmoid curve depicted on the map, it might be thought that the irregularity of junction is thereby demonstrated, but it is not so; the necessity for this curve is one of the difficulties. All that can be seen is on the surface of the road. As we walk along

towards the west, we pass from irregular grits of the older series to purple grits with fragments of slate, thence to well-bedded vertical pale slates, exactly like those of No. 5, and then on the descending slope of the hill to the grit with slate fragments again. As far as this spot would show, there might therefore be an interbedding, but evidence elsewhere necessitates another reading which is indicated by the curve on the map.

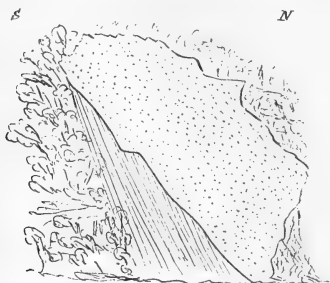
A little to the south of this the line of junction becomes very nearly parallel to the Portway, along which for a couple of miles there are occasional exposures of the purple grits and fine conglomerates. If this line were continued northward, it would nearly coincide with the eastern boundary of the patch of purple grit south of Woolstaston,—a fact which certainly suggests that the great area of purple slates and greywackés now exposed to the west of this patch has been laid bare by the denudation of a superficial continuation of the purple grit.

On and near the roads into which the Burway branches on reaching the hill-summit, are seen other exposures requiring explanation. On the western slope of a small depression at the bend of the northern road is seen a crag of purple slates and greywackés, with the usual high dip and ordinary strike, but on the eastern slope of the same depression is a mass of unbedded conglomerate, seen in several crags on about the same level, and this is followed by coarse purple grit, till the line of the regular junction is reached $\frac{1}{3}$ of a mile to the east. What happens to this patch of slate and greywacké to the north is not seen, but it is cut out by purple grit on the south, and reappears a little further on in surface-exposures over a limited area. The great regularity of the slates and greywackés, and their numerous alternations in the crag, forbid the idea of a local deposit in the midst of the conglomerates and grits. The very limited development and absolute absence of any indication negative the notion of a fold; but all of this combined with the fact that the relations are not here with the basal grits, but with the higher conglomerates, point to an unconformity and an irregular surface, in other words that these two patches of the older slates are ordinary inliers.

About $\frac{3}{4}$ of a mile to the south of these inliers, we have the converse phenomenon to deal with,—the conglomerate and grit form a well-marked outlier (see fig. 2). The northern end of this is seen in Ashes Hollow, along the south-western slope of which it forms near Narnells rock, which is also composed of purple grit, a horizontal crag. Now if we work along the valley-bottom of the Ashes Hollow, and examine only the rocks which are abundantly exposed all along the stream and pathway side, we shall emerge on the Portway, by Pole Cottage, without seeing anything else than purple-weathering pale slates and greywackés, or having any notion afforded of the presence of massive purple grits or conglomerates. It is only when we climb to the crag which overhangs the southern slope, and which has an unusual appearance even at a distance, that we find these grits, so far away from where we should expect them. On the northern slopes there are numerous exposures of rock, but not one of them is of

the purple grit, all are of banded greywackés. This shows first that the outlier is here at its end, and secondly that it lies, not upon No. 5 but upon No. 4 of the older series. In this locality, on the S.E. of Narnells rock the actual junction of the purple grit with the underlying rocks is seen (see fig. 4). This line of junction has

Fig. 4.—*The Junction of Slate and Grit South of Narnells Rock.*



here itself a dip towards the west of about 75° , showing that the outlier is more or less folded in with other rocks. The surface is somewhat slickensided, and the line is slightly irregular and cuts the edges of the underlying slates very obliquely. This grit is therefore here seen to lie unconformably, but the evidence is scarcely satisfactory or conclusive. If it had been conformable, the motion which is indicated by the slickensides might easily have produced the amount of unconformity apparent.

The eastern boundary of this outlier can be fairly well traced, but the western which runs across heath-covered moorland is entirely conjectural. But in the next depression we get its southern termination, and the same phenomena are repeated. Here in Callow Hollow, as before, if attention is confined to the stream-section where almost every yard of rock is exposed, we find nothing but a succession of bedded slates and greywackés, with the usual constant dip and strike, carrying them straight across the valley, but the moment we climb the slopes we come upon conglomerate. On the northern side this may be traced in a horizontal line trending S.E., each exposure facing a different rock in the series below. On the southern side the same thing is observable. So too in the next hollow to the south, *i. e.* Minton Batch, the boundary of the purple grit, some of which has the purple-slate fragments, follows the contour of the country, but the purple slates below are vertical and cross the valley. If there is such a thing as local field-evidence for an unconformity, I think we have it here.

Passing still to the south, we find ourselves approaching the western slopes of the Longmynd proper, and no more dependent on stream-sections and valley-sides. As soon as we descend these slopes we come again upon purple slates and greywackés, and the line of junction is seen to rise gradually towards the south, so that

near Asterton we walk round an amphitheatre, crossing all the while the strike of anything that has a strike, and always with the slaty series below and the conglomerate occupying the crest of the hill. The meaning of this still seems pretty plain. From hence to the south all that is seen of the upper beds is a long tongue of conglomerate, with minor beds of grit, which except at one point persistently keeps to the top of the hill. At the one point, however, where it descends to the level of the road, there is the greatest difficulty that anywhere may be felt about the unconformity. There is here a great quarry opposite Mindtown Farm, and in this there are vertical beds of slate with the usual strike, showing beautifully ripple-marked surfaces, but far more solid than anywhere else. In the higher portion of the same quarry is seen the conglomerate; in one part it is evidently disturbed, but in the least disturbed portion the two rocks have a great appearance of conformity, the conglomerate being to the east of and therefore below the slate. Still further up the slope of the hill slate is seen again, and finally the continuous mass of conglomerate. This appearance of conformity is very staggering, but we know how easily such an appearance is produced when rocks have been squeezed together, and this, I think, is the only interpretation available in face of the facts already adduced. It is the more easy to accept, because the conglomerate is not usually the base of the series, it is nowhere else followed by purple slate, and disturbance and squeezing have evidently taken place. The purple slate here is much more like the upper mass of that rock to be presently described, and it continues to have this resemblance for some distance to the south, so that I am by no means sure that it does not belong there. Yet in the same direction the rocks become gradually more like the series No. 5, till at the turn of the hill by Hill Cottage there is no mistaking them. It is, however, quite possible that the map may be here tinted wrong, especially as the band of hard greywackés No. 4 cannot here be recognized. Whichever way it is, it will scarcely affect, I think, the main conclusion as to the unconformity of the conglomerate.

On the other side of the tongue matters seem clearer. Along the crest of the hill the hard greywackés are well seen in numerous crags, till they are cut out by the crossing of the conglomerate, and from thence the neighbours of the latter are the purple slates of No. 3, well cleaved, in thin masses and very characteristic. Finally along the southern margin we find the same phenomenon (see fig. 3) as is so conclusive further north. Taking the low path, the innumerable exposures manifest an apparently continuous sequence with constant strike of purple and pale slates, with occasional greywacké bands, without a sign of conglomerate; but mounting the hill the conglomerate is seen again, and the line that must be drawn to separate its exposures from those of the slates is approximately horizontal and entirely transverse to the strike of the latter*.

* It may be noted that the conglomerate seen does not resemble the Llan-doverly conglomerate of the neighbourhood, which has a special character of its own.

Such is the evidence that may be obtained from the Longmynd hills themselves of unconformity between the two series. It will be seen that the upper series has relations in different spots to 3 distinct members of the lower series No. 3, 4, and 5. It would be still more satisfactory if similar relations were established with Nos. 2 and 1. There is little hope of this with regard to No. 2, but the great outlier which lies to the south by Horderley shows the grit and No. 1 in contact. On the side of the road from Horderley to Marsh Brook, there is a long cliff of dark shale of exactly the same character as No. 1 at Church Stretton, and at Horderley we find in it the same calcareous bands. Behind this and above it comes the purple grit as seen at the two ends of the mass. Capping all is a cliff of Caradoc grit, which often by its scree obscures the beds below. This sequence is repeated a second time to the east by means of a fault as represented on the map. Passing south the dark shale is soon lost sight of, and the purple grit swells out into the bulky hill which stretches from Wartle Knowl to Aston. The actual present position of these rocks in their relation to each other, is doubtless due to faults (see fig. 3), but the presence of the purple grit at all in this neighbourhood in association with the lowest member of the lower series, is inconsistent with its being conformably situated above No. 5. The only question is, are these rocks rightly identified, seeing they are isolated in a faulted outlier? As to the dark shales, they lie in the continuation of the same band; and, though on the opposite side of a fault, this fault near Church Stretton is seen to make no difference in their horizontal position, because the beds are nearly vertical. Moreover there is no other known rock below the Caradoc which they can possibly be. As to the purple grit, there is nothing to distinguish it lithologically from the western mass, the nearest exposures in the two areas are less than $1\frac{1}{2}$ miles apart, and when last seen it was creeping eastwards. It does not correspond to any other known bed below the Caradoc, and the only alternative is that it is lower even than No. 1. This, I think, would be a very rash hypothesis, resting absolutely on no proof, and rendered extremely improbable by the phenomena of the Caradoc and other volcanic hills, as will be seen in the sequel. Rejecting this, then, the proof of unconformity between the purple grit and the underlying series is complete.

I have gone into full details with regard to this point, because it seems to me to furnish the key to the whole problem of the relations of the various Pre-Ordovician rocks of Shropshire.

3. *Constitution of the Western Part of the Longmynd Massif.*—I must now pass on to the questions raised by the western part of the Longmynd massif, viz., that which lies between the series already described and the Stiper stones. This western part is constituted by three members,—a lower series of grits and conglomerates, a middle mass of slate, and an upper mass of grit. In the lower mass of grit it has already been noticed that the conglomerate does not usually lie at the base, but towards the southern part of its range in the Longmynd it does. So it does also at the extreme

northern end at Houghmond Hill, though at Lyth Hill it lies in the middle, and a smaller conglomerate band and a mixed series of grits and slates form the base. In the southern outlier, near Hopesay, there is an almost entire absence of conglomerate; the only places where I have seen it being the summit and slopes of Wartle Knowl, where it is apparently at the base. From these facts I conclude that the conglomerate has no chronological significance, but is a mere accident in the formation of the purple grits, dependent on the part of the surrounding country which at different epochs supplied material to different districts. Even where the conglomerate does not occupy the nearest position to the line of junction, and there seems to be a great mass of purple grit between it and the lower series, we cannot assume that this underlies it, since the inliers in the middle of the Longmynd, unless brought up by faults, have nothing between them and the conglomerate. Moreover, the absence of bedding prevents our knowing anything of the dip, while the fact of the purple grit overlapping the slates and greywackés seems to show that it is, on the whole, not far from horizontal. It was therefore laid down subsequently to the primary disturbances which set the slates on end.

With regard to the contents of the conglomerate, we have already a valuable account from Dr. Callaway*, who, in association with Prof. Bonney, describes eight examples, together with two specimens from Haughmond Hill, belonging to the lower series, which are not described in the same terms as the others, but are supposed to have been derived from the denudation of mica-schists. Four others are from the grits, in which it is noted that many fragments are those of volcanic rocks, a conclusion which I can confirm.

The nature of the conglomerate at Haughmond Hill scarcely requires the microscope to demonstrate, the bulk of the pebbles being of purple rhyolite. Dr. Callaway also notices a pale green felsite, and I can add a fine-grained altered ash. But this conglomerate, so obviously derived from the ancient volcanic rocks of the neighbouring Wrekin, is exceptional. So also is the conglomerate of Wartle Knowl, which is largely derived from an associated rhyolite.

The main conglomerates of the Longmynd are, on the contrary, principally composed of quartzite. The bed which lies to the east, whose range I have been hitherto describing, contains, I should think, about 95 per cent. of quartz- and quartzite-pebbles. The question is, whence were these pebbles obtained? There is, to my knowledge, absolutely no quartzite in the volcanic series (the overlying quartzite is obviously of later date than the conglomerate), nor do granitic rocks readily yield such fragments. Yet, from their abundance, we are certain that there must have been a large mass of quartzite, or quartz-veins, in the neighbouring Pre-Cambrian rocks. The only indication of such rocks that I have met with has been the abundant quartz-veins which render some portions of No. 4 and 5 almost a breccia. If the quartz-pebbles were not derived from

* Quart. Journ. Geol. Soc. vol. xlii.

these, they must have come from some mass of quartz now hidden from view. Now we know that the Monian rocks of Anglesey and Ireland are richly provided with masses of quartz; and these abundant quartz-pebbles may indicate, I would suggest, the presence of similar masses in the neighbourhood, now hidden by later deposits. With regard to the remaining 5 per cent., Dr. Callaway has described two, one a devitrified rhyolite, and the other a perlitic quartz-felsite. I have examined thirteen of these pebbles, in fact an example of every variety which I could recognize as distinct in the field, in hopes of finding amongst them some of the underlying greywackés or slates. Most of them were so much altered before they were imbedded that they are now difficult to recognize. The first group consists of granitoid and gneissoid rocks; a specimen from Lyth Hill is a typical gneiss, apparently resulting from the deformation of a granite; another, from Pole Bank, is a typical mica-schist, also very much pressed, and showing everywhere micro-spectral polarization as in some of the more altered schists of Anglesey; a third, also from Pole Bank, is a holocrystalline rock of large elements, of which only quartz and felspar are now recognizable, though there are dark patches which from their shape suggest a derivation from mica. It is brecciated in parts and generally calls to mind some of the more altered granites of Anglesey or the curite of the Wrekin.

A second group consists of felsitic or rhyolitic rocks. One is a very typical rhyolite, showing flow-structure to perfection. Another is darker in aspect, but is full of well-marked spherulites, and its insets are mostly of felspar. A third is also obscurely spherulitic, but the secondary crystallization is carried so far as to make it almost a macrofelsite. A fourth has decayed spherulites of irregular outline now marked by irregular radiating lines of dark dust, and between them are numerous irregular cavities as in an amygdaloid, now filled with radiating zeolites (?). A fifth is nearly black, and the numerous spherulites are almost entirely obscured by the abundant dark amorphous dust which colours the rock. Different as these rocks are to the naked eye, their insets in every case declare them to be essentially quartz-felsites which had suffered much alteration before they were imbedded.

A third group consists of the doubtful rocks, whose external aspect suggests that they are bedded; one of these is a fairly coarse quartz-felspar grit, obviously derived from a granitic rock, and which may in fact be a fragment of greywacké. A second is a finer-grained, more quartzose grit full of dust, and with nothing to suggest its connection with a rhyolite. The other three are very plainly banded; one, which to the naked eye looks exactly like a slate, has broad parallel bands of dark amorphous dust, the clearer spaces being excessively fine polarizing material, which resembles very closely the material of a slate from near All Stretton. There are, however, in this rock several large isolated fragments of quartz and felspar which resemble insets, and it is possible therefore we have here only a banded ash. Another also contains irregular bands of dust, and

innumerable grains of uniform size following more or less the apparent stratification, but it contains too some larger crystal fragments of felspar and zircon. A third, which is very dark, has the uniform grains still better stratified in the midst of diffused dust. The grains appear to be of felspar rather than quartz. This group does not, as I expected it would, leave absolute conviction on the mind that it is derived from the neighbouring underlying series; but this much may be safely said, that no such rocks have been found as yet forming part of the volcanic series of the neighbourhood, and they are very like the neighbouring slates and grits. Certainly the evidence of these contained pebbles is favourable rather than otherwise to the unconformity observed in the field.

To return to the stratigraphy proper. After passing the conglomerate in a journey towards the west, we come again to a vast mass of purplish grit, which, as before, shows little sign of stratification, but is much intruded upon by masses of greenstone. Wherever any bedding is seen, as east of Church Pulverbatch, the strike is still to the N.N.E., and the dip nearly vertical. After passing a varying breadth of this grit, we come upon the mass of rock which forms the middle portion of the series. This, though mentioned by Murchison as "alternations of strata identical with those described," seems generally to have been overlooked. If we make a traverse in various latitudes, we find towards the south more than two miles' breadth of solid purple slates, always dipping at a high angle towards the west, and with an average N.N.E. strike. The whole hill on which Wentnor stands is composed of this rock, and it may be traced in numerous exposures as far as Norbury. The breadth is little less in the traverse through Medicott farm and Gravenor, though many thin bands of grit are hereabouts intercalated. Near Ratlinghope the breadth is reduced to about a mile, but the rock is admirably seen in the highroad at Bridges, and a little further N. on the hill above Stitt Farm, though everywhere within its range it may be easily traced. In the neighbourhood of Cothercott it is reduced again to about a quarter of a mile, which it never again exceeds. No exposures of the slate are seen north of Castle Pulverbatch, but the last relic of it may be recognized in the quarry north of Longden Common. This slate may be easily distinguished from those of the older series (except in the neighbourhood of Mindtown) by its greater massiveness, and by the absence of the numerous subdividing, cleavage-like planes. Its occurrence in the middle between two masses of grit may seem to indicate a synclinal, but the dips observed give no countenance to this idea; there is not a single reversed dip in the whole area. We may perhaps think of an isoclinal, but in such a case we should expect the boundary to be more regular than it is; the eastern boundary, in particular, is by no means a straight line. In tracing these boundaries, however, a new feature occurs which is very instructive when contrasted with the inferior limit of the grit, where, as has been seen, it is also in contact with slate. On both sides of this upper mass of slate there is abundant evidence of its intercalation with the grit, so that the

boundary has to be drawn as a zigzag-line. This is best seen near Norbury and Cothercott on the western boundary, and near Church Pulverbatch on the eastern, and many sections show intermingling of the two kinds of rock. The phenomena are thus quite distinct from those of the unconformable junction, and I judge they are entirely due to an intercalation of deposit which thickens rapidly towards the south, and dies out towards the north. It is obvious that if there were here a synclinal and it actually died out, we ought to be getting to its base, in which case the isoclinal explanation fails, in face of the still nearly vertical position of the alternating strata.

The western purple grit, which constitutes the third member of the upper series, is very similar to the eastern, and, like it, contains sporadic bands of conglomerate. As every available exposure has been examined, I am prepared to say that the extent of its conglomerates cannot well be much greater than is marked on the map, which indicates that they are less continuous and narrower than in the other, and occur on several distinct horizons. I have sought in this conglomerate also for fragments other than of quartz, but they are far more rare, only three specimens in all the exposures having tempted collection. These are all quartz-felsites, one of them very spherulitic. The contents are therefore not so various as in the lower bed; and the upper one may be properly termed a quartz-conglomerate. In the grit itself there are more signs of bedding, and in most places the dip is still high towards the west. However, at the northern end, in the neighbourhood of Pontesford Hill, we find the only examples of reversal of dip in the whole area. Thus in the great crag of conglomerate in Oaks Hill, though the beds are nearly vertical, they do incline towards the east; and in the river-section above Lyd's Hole there is an undoubted easterly dip of about 60° . It is very tempting to consider these to be the true dips as Dr. Callaway has done, and to infer that the rocks which succeed them to the west are of an underlying series. But we are here in the presence of a large mass of igneous rock, which at least *may* be intrusive, and therefore we should be cautious, and take our observations, as far as may be, away from such possible disturbers. Leaving, then, this Lyd's Hole district for the moment, we will go to the extreme south,—to the other end of the range. Now here we may observe numerous dips throughout the whole extent of Linley Hill, and they are always rather low and to the west, no dip being above 60° , and one as low as 20° . It is in this district also that we meet with other rocks which, from their intercalation with the purple grit, seem to follow it in regular sequence. This, I take it, supplies us with the true reading, and proves that there is no synclinal.

It may seem remarkable that the beds of the upper series, if it be unconformable to the lower, should nevertheless have the same approximate strike. But this is easily accounted for. Where the grits and conglomerates mount on to the summit of the Longmynds, they do not possess the same strike; but when developed in the already denuded valley to west, the subsequent pressure has pushed them up

into a nearly vertical position against the buttress formed by the older Longmynd rocks, and the directions of the earlier and later pressures have been approximately the same.

4. *The Western Boundary of the Longmynd Massif with the supposed Archæan Masses.*—We now come to consider the western margin of the Longmynd grits. If the account already given of the rocks of this massif be accepted, and an upward succession broken by an unconformity be traced all the way from Church Stretton, we are here well up in the Cambrian, as represented by Murchison, Salter, and the Survey, and this western margin has little interest in relation to the older rocks. But Dr. Callaway has here described a “second area of Archæan rocks,”* and his proofs of their occurrence must therefore be examined. He states that the eastern margin of the Longmynd grits is formed by a fault, indicated on his sketch-map by a straight line; and immediately to the west of this, and in contact with the fault, come the masses referred to the Archæan. If there were really Archæan exposures here, with the Longmynd rocks dipping away from them, as stated, it is essential to the proof of their age that they should be thus in contact. This, therefore, is the first point to examine.

In the extreme north of the range is Pontesford Hill. All of this, with the exception of the central dolerite, is referred by Dr. Callaway to the Archæan, the proof assigned being the similarity of the rocks to the Wrekin lavas, and particularly that of Lea rock. There is, indeed, a remarkable pyromeride on the north-western border, as noted by Murchison; but, as we are scarcely justified in assuming that all such rocks, even in the same district, are of the same age, the question must be determined by the stratigraphy. The igneous portion of the hill consists of two masses of acid rock everywhere separated by a mass of basic rock. Now this igneous portion is *not* in contact with the purple grits. These latter are limited to the eastern slopes of Habberley Brook, while the whole of the western slope, which is formed by Pontesford Hill, is occupied by well-bedded, soft, compact pale slate with a moderate dip of about 30° to the west. It is above these slates, on the higher slopes of the hill, that the igneous rocks are met with. On the other, or western, side of the hill only part of the slopes is occupied by a spur of decomposed basic rock; the rest of the ground between the two masses of acid rock shows numerous exposures of pale slates and grits of varying coarseness, with the usual high dip and strike of the district. As we descend the hill from the doleritic summit we cross the strike of these rocks, and at a lower level come upon the pyromerides. In the neighbouring Lyd's Hole section we obtain further information. Of the section here seen we have had two descriptions, of which that by Sir R. I. Murchison seems to me to render the true interpretation. The slates and grits which here alternate above the falls are very much altered as they approach the igneous rock, the grit being rendered micaceous and the slates

* Quart. Journ. Geol. Soc. vol. xxxviii.

chiasmolized, and both are indurated. Below the falls there is another mass of micaceous altered slate; and irregularly related to this is seen a mass of pyromeride on its western side. The igneous rocks appear to have run in among the slates along their bedding, and their flow-lines, like the crystals in many dykes, are naturally parallel to the sides of the path. The whole of the grit that is seen in Radlith is also very much altered. In any case the acid igneous rock is in association here with purple slates and grits, which are recognized as Cambrian. On the other, or eastern, side of the hill, the associated slates and grits are of a different character. The area is certainly a faulted one, and the unusual dip of the conglomerate and grit may be thus accounted for, if the igneous rocks are of later date. Rhyolite pebbles are doubtless found in the conglomerates, but not abundantly, and they do not specially resemble and need not have been derived from the rock here exposed. I can find, therefore, no Archaean rock here, but conclude we are altogether far above the base even of the Cambrian.

In the next locality referred to, near Gatten Lodge, there is nothing very peculiar to be seen. The western side of the Longmynd grit in many parts of its range is marked by veins of baryta, sometimes associated with copper, as at the old workings at Westcot; and Gatten Lodge is a spot where these veins are abundant and have been worked. Their presence indicates doubtless some disturbance, and the grits do put on a very compact and irregular appearance; but under the microscope they are grits still, as will be seen by Prof. Bonney's description of the rock submitted to him, and which I entirely confirm. There is nothing Archaean here.

The locality referred to as Knolls Ridge and Cold Hill is particularly instructive (see fig. 2). On the north of the Farm of Squilver commences an acid igneous rock, of rather varying character, but mostly of grey felsite, which can be traced uninterruptedly as far as Cold Hill Farm. At first it is in contact with a bed of conglomerate; a little further south there is a mass of grit intervening in the valley-sides between the felsite ridge and the conglomerate ridge, which come together again at the southern end. The felsite ridge then leaves the conglomerate, and is separated from it by a valley of pale slate. At Cold Hill Farm the conglomerates are seen dipping westerly at 60° . They are followed by the pale slates seen in the road to dip at the same angle, and further to the west comes the exposure of felsite. This proves that the felsite ridge is transgressive across the edges of the strata, which are here pretty nearly in their natural succession. This conclusion, perhaps, is made more certain by the occurrence of two masses of similar compact felsite in the heart of the Cambrian grits, as marked on the map. Here, then, there is nothing Archaean.

As we trace the pale slates to the south, we see them rise at last into a conical elevation called Chittol Hill. Here they are more compact and greener, and the bedding is somewhat difficult to make out. They appear to be not far from horizontal. The cause of their elevation and compact appearance may be connected with some

copper vein in the neighbourhood, as the fragments are all tinged with the green salts of that metal. But the rock is unquestionable; it is the ordinary follower of the grits throughout the district. This, then, is not Archæan.

At the southern base of this hill there is a transverse fault bringing up the conglomerate alongside of the slate. This conglomerate is followed to the west in the south end of Chittol Wood by a mass of compact felsite, very like that of the Knolls Ridge, whose relative position it occupies, and whose interpretation it will therefore follow.

On the western banks of the West Onny river, by the side of Linley Drive, we have a series of very instructive sections. All the rocks have a dip of about 60° to the W. by N., and the river crosses them successively. They consist of a series of alternations of rock, some of which exactly resemble the purple grits, and others the compact Chittol slates, and others are of intermediate character; we could not desire a better illustration of the passage upwards from the grits into the slates. But these beds, though quite conformable in their strike with the grits of Linley Hill itself, are so situated that if continued either way they would run into the masses of felsite exposed in the neighbourhood. They would equally run into the associated greenstones, and we have no reason in either case to assume these igneous rocks to be anything than intrusive. Whatever, therefore, the exposures of acid rocks at Knolls Wood and Oldmoor Wood may be, there is no reason to call them Archæan, unless we are prepared to maintain that every acid rock of volcanic origin, or composed of volcanic fragments, is *ipso facto*, Archæan. The supposed ridge of Pre-Cambrian rocks in this district is therefore non-existent; the whole is of Lower-Cambrian age.

5. *Summary of the Stratigraphy of the Longmynd.*—The results obtained up to this point may be summarized as follows:—There are two series of rocks in the Longmynd; the lower series is divisible into five portions, which may be traced across the country and into the outliers. The upper series lies on this unconformably, and is seen in various parts in relation with four out of the five subdivisions of the lower series. It consists of three main members, which are reduced to one in the north by the dying-out of the middle one. There is no sign of a synclinal in the whole range, but the normal dips get smaller to the west. The rocks succeeding this tripartite series are pale hard slates, whose normal succession may be seen in the south, but elsewhere may possibly be obscured by a fault, near which several masses of acid igneous rock have intruded transversely. The pebbles in the conglomerate may possibly have been partly derived from some portions of the older series, but it certainly contains pebbles not only of quartzite unseen in the neighbourhood, but of acid volcanic rocks also.

Now Dr. Callaway has irresistibly argued from finding such acid igneous rocks in the neighbouring hills of the Wrekin, Caer Caradoc, and others, that we must regard the conglomerates as derived from them, and therefore as of later date than they, provided the stratigraphy permits it.

If the Longmynd conglomerates are Cambrian, the volcanic hills themselves must be in some sense Pre-Cambrian, so must they be also if the conglomerates are Pre-Cambrian. To use Dr. Callaway's names, so long as the Longmynd series was undivided, it was certain that the "Longmyndian" must be younger than the "Uriconian." But now that I have shown that there are two unconformable series, this argument only applies to the upper series which contains the conglomerates; and the relation of the older series to the Uriconian is left entirely undecided, and must, if possible, be determined by details of stratigraphy. To this I now apply myself.

§ III. STRATIGRAPHY OF THE VOLCANIC HILLS.

It is not my intention to go into all the details of these hills; they have been already described by Dr. Callaway, and are now receiving the attention of Prof. Lapworth. To him the many points of general interest in their structure may be left, and those only attended to which have some bearing on the age of the rocks. The place to commence our examination of these hills in their relation to the Longmynds is obviously where the two come closest together in the neighbourhood of Church Stretton.

The first question to deal with has relation to the fault that is there drawn between the two. In the south of this district, from Aston-on-Clun by Hopesay, Hordeley, and Marsh Brook, this fault may be traced without a shadow of doubt. It has here a remarkably straight course with only a general curvature to the east. Leaving it now for the moment from the southern end of Ragleth to that of Caer Caradoc, we find the western boundary of the latter a remarkably straight line, as is that of the Lawley; and the succession of beds on the west proves this to be a continuation of the fault. Thence it is traced on the Survey Map as far as the Severn, near Cound Villa, and if still continued it would form the approximate western boundary of the Wrockwardine mass. It is therefore a very continuous fault. But it does not appear that its throw is very great; Professor Ramsay estimates it at 2000 feet; but, considering the overlap of the Llandovery which reaches the Longmynd slopes, and must be thinning out, this would appear to be a maximum. If now we continue the line of this fault across the interval omitted, *i. e.* from Ragleth to Caer Caradoc, we must either assume that it zigzags about just here in an unaccountable manner, and as it does nowhere else, or we must leave some of the Longmynd shales on the eastern side of it, as is done by the Survey. With the high dip of these dark shales to the west, an upthrow of 2000 feet on the east would not cause a loss of more than 200 feet on the surface, so that we should still be probably in the dark shales on the eastern side of the fault. Now all the slopes of Ragleth are in the dark shales. They are seen very near the line of fault at the crossing of Watling Street and the Church-Stretton road, from which spot there is an almost continuous section exposed up two

roads to Ragleth Wood and Hazler, over a horizontal breadth of 2000 feet. Further north, on the road from Church Stretton to Caer Caradoc, they are exposed with their usual dip and strike beneath the Drift; and on the southern slopes of Caer Caradoc, they occupy a band running transverse, and almost perpendicular, to the line of fault. All these exposures being to the east of the fault, it is obvious that this last has no connection here with the relations of the dark shales to the igneous rocks, and we cannot solve the question by saying that the junction is a faulted one. It does not, of course, follow that the great fault is the only one; indeed, we know that there are several others on the N.E. side of Caer Caradoc, and the whole area on the eastern side of the main fault is greatly disturbed and dislocated. This fact is of use in accounting for certain difficulties, but will not solve the question as to the relation of the rocks before they were locally faulted.

Eliminating, therefore, the influence of the main fault, we must now inquire into the relative age of the adjacent volcanic group and dark shales. If the dark shales be the younger, and are merely displaced by local disruptions, we ought somewhere to find their basal beds. They are not at all the sort of rock to show basal beds or to be derived from volcanic débris—indeed the actual result of the denudation of the rhyolites is seen in the Longmynd conglomerates. There *are* indeed grits and conglomerates which may be considered basal on these hills, but their relation to the igneous rocks and shales is nowhere such as to indicate that they lie between them, being usually found remote from the junction, so that they are the basal beds of *another* formation. On the other hand, if the volcanic rocks be the younger, however much elastic material they may contain, they must somewhere break through the dark shales and alter them. The very faulting of the district would make the contacts scarce, and mingle up adjacent rocks confusedly. Yet almost all the puzzling rocks, that may be either altered slate or banded compact lava, are found at the lines of junction, and each one examined with the microscope has turned out to be a slate. Such rocks are well seen on the north-eastern slope of Ragleth. Their bedding is here across the hill, and makes an angle of quite 45° with the normal strike of the slate. This is only natural, if it be pushed aside, as it must have been, by the igneous rock.

From Hazler Hill we can learn nothing, as there is only dolerite in it, which may be of later date; but Helmeth is full of interest. All along the lower path on the western side we walk on slightly altered slate; but along the crest we find the southern half is all rhyolite, and the northern half yields successive exposures of rhyolite, slate, and dolerite. The boundary of the slate must therefore zigzag amongst the igneous rocks, and in fact at one spot a coarser rock than usual, almost like a eurite, is seen intruding into a true slate. Most of the southern slopes of the hill are also occupied by slaty rocks. The character of these slates does not, indeed, remain absolutely constant, but there are bands of hard greywacké, seen at Hazler, and inferred from fragments here.

In Caer Caradoc the unaltered adjacent patch at the south-west is very probably faulted. On the southern slopes is a band which we should call either halleflinta or altered slate, according to the series to which we supposed it to belong; and near the summit is another band which can hardly be anything but the latter; but the most remarkable is in Little Caradoc. Here, crossing the hill between the rhyolite on one side and the dolerite on the other is a very clear band of not much altered slaty greywacké, clearly bedded, and impossible to imagine to be in its natural position. Under the microscope it is seen to be marked with transverse cleavage-lines of sericite, parallel to which the long axes of the quartz fragments have been turned so as to lie across the bedding. From its position and outcrop it is rather difficult to get it here by faulting, but easy to explain as the solid underlying rock on either side of which the igneous extrusions have been made. A very similar band, about which the same may be said, occurs in the Lawley.

It is a remarkable circumstance that all the localities of these altered slates are connected with the western margin of the range; and there is nothing like them in the whole of Cardington Hill. The same may be said of the Wrekin area. Nothing that can be thought to be altered slate is found in the Wrekin itself, and the only rock of the kind is at Wrockwardine village, near the western border of the exposure of old rocks.

The first conclusion, then, at which I arrive is, that the volcanic rocks are younger than the slates, and have been extruded from their midst.

The next point to be considered is the age and character of the masses of coarse crystalline rock, of acid type, called granitoid by Prof. Bonney and Dr. Callaway. The principal mass of this type occurs in the Wrekin, where the former author says of it "there can be no doubt that it is far older than the rhyolite, and thus we may regard it as, in general terms, a representative of the Dimetian series." The distribution in the district, however, of this class of rock, presuming it to be all of one age, is very much against its being older than the rhyolite. Besides the main mass in the Ereal there are two small patches of it in the midst of the rhyolites near the south-eastern end of the Wrekin, whose mode of occurrence suggests intrusive bosses. At Primrose Hill it is likewise entirely surrounded by the rhyolite, into which, indeed, it almost seems to pass, and strongly suggests a neck, to which other phenomena point. Holocrystalline rock also occurs at the extreme N. of the Lawley, where it passes gradually into the rhyolite. Similar rock is referred to by Dr. Callaway near Wallsbank, Cardington Hill. It is here at the edge of the rhyolite, and is cut off by a fault from the Caradoc shales. Some connection may here perhaps be suggested with the porphyry to be presently noted in this hill.

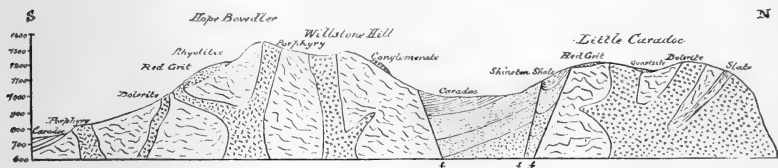
These isolated occurrences only *suggest* intrusion on the part of the eurite (as we may call it), and not on the part of the rhyolite; but in the Ereal Quarry there is a pretty long line of junction, and this ought to tell us whether there is any intrusion or not, and by

which rock. Unfortunately it leaves the matter doubtful after all. The line runs in general along the face of the quarry, turning westwards towards the southern end; but slips, for the most part, cover it. The rhyolite below has irregular flow-lines, and contains clastic portions, so that it does not look like intruding on anything. In one spot beneath a tree the solid eurite and compact rhyolite are brought side by side with a vertical dividing line, but the line is so decayed that nothing can be made of it. Hard by are soft bedded shales, evidently of rhyolitic material, which rest on and enter the wide cracks of the eurite, and contain numerous nodules of the latter of all sizes and shapes, which have evidently decayed *in situ*. If we could only persuade ourselves that these shales are rhyolite tuff, the question would be settled; but they are not in the least like the rocks anywhere else, and are scarcely consolidated. I take them therefore to be merely stratified débris, probably first formed within the fault, and therefore proving nothing. I did, however, obtain a specimen on a former visit, under the guidance of Dr. Callaway, which seemed to me an intrusive junction of the eurite, but I cannot confirm the observation. From all available evidence, it would, on the whole, appear that it is highly improbable that the eurite is the older, and highly probable that it is, on the contrary, intrusive in the rhyolite, but I cannot absolutely prove it.

I must next pass to the conglomerates and grits which are met with in these hills, the age of which is of supreme importance in connection with the general interpretation of the district. In several spots they have been noticed by Dr. Callaway, but have been taken by him to be part of the volcanic series, and to prove the clastic origin of the latter. If we commence on the south, we must probably consider the conglomerate and grit of Hopesay Common the first member of this group, for the summit of Wartle Knowl, at its termination, is composed of a mass of rhyolite, with which a dolerite is associated after the manner of an intrusive rock. This association of two kinds of igneous rock, which recalls what we see universally in these volcanic hills, and the position of this elevation in relation to them and to the boundary-fault, indicate that we have in Wartle Knowl the summit of a hidden Caradoc, enveloped by undenuded Cambrian grit. The next hill is Ragleth; along the western slope of this is seen a red grit of rather mixed character, but recalling very closely the Cambrian purple grit. It does not run transversely to the hill, as the dark shales do when pushed aside, but forms a longitudinal patch, which, from its easily determined limitations, must be superficial and deposited where we find it. On Cardington Hill there are two patches; one is noticed by Dr. Callaway on the slopes of the Gaer Stones, and the other is a large one at a lower elevation, situated to the east, where the hill is crossed by the footpath. The exposures of this and of the surrounding rocks are numerous, and the exact limit of the red grit can be easily traced. It is seen to be superficial. Besides these two masses of grit, there is on the same range, near the summit called Willstone Hill (see fig. 5), a very small and local patch of conglomerate occupying

part of the western slope. It has a dirty-looking muddy matrix, and contains various fragments, quartzose, micaceous, and rhyolitic. On *Caer Caradoc* there are two patches of red grit. One is at

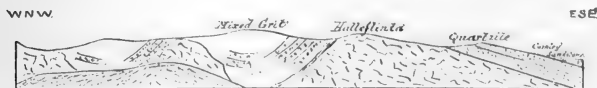
Fig. 5.—Section across the Volcanic Hills near Church Stretton. (Scale $1\frac{1}{2}$ inches to a mile.)



the southern end, where it is noticed by Dr. Callaway and described microscopically by Prof. Bonney, who says it contains fragments which closely resemble the *Wrekin* rhyolite, and that its material has probably been derived from this and the granitoid rock, which is exactly the character of the Cambrian conglomerates. The other is on the north side, where only fragments are found, but their position is such as to suggest, though not to prove, that the rock is overlain by the Cambrian quartzite. On the summit of the *Lawley* there is also an entirely isolated patch of grit, which may belong to the same group, but it is not very like the other exposures.

If we pass on to the neighbourhood of *Wellington*, there are again conglomerates and also grits, but it does not appear that their age is necessarily the same as those already mentioned. There is first the conglomerate of *Charlton Hill*, which Dr. Callaway regards as of *Uriconian* age, on account of the stratigraphy of the spot. By the aid of the 6-inch map, and the numerous exposures, I have been able to lay down pretty accurately the actual position occupied by the conglomerate and associated beds on the surface, and to show that it is entirely isolated and surrounded on all sides by igneous rocks. There is also a second patch at the northern-road junction, whose relation to the other rocks is not made out. On *Charlton Hill* itself the conglomerate is quite local (see fig. 7, p. 410). Towards the north-eastern end, where the band crosses the roadway, there

Fig. 6.—Section seen in *Charlton Lane*, showing the Relations of the Grits. (Scale about $\frac{1}{2}$ inch to 90 feet.)

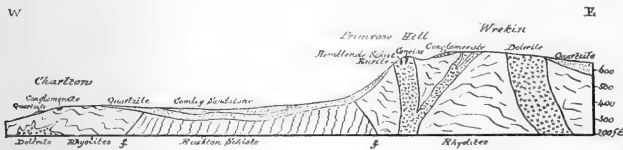


are some slaty grits, with high dip striking N.W. and pointing directly on one side to diabase, on the other to rhyolite. In the road-section, which Dr. Callaway regards as conclusive (see fig. 6), we find in the northern bank two masses of grit, each with a dip

in certain parts towards the west, but becoming almost horizontal through disturbance. The compact halleffintas show no bedding, but lie on all sides of the masses of grit, some of whose beds, if continued, would run into them. No grit is visible on the other side of the road. These masses seem to be portions of later deposits caught up and folded in with the older rocks, both here and on the summit of the hill. They do not, therefore, form part of the volcanic series. Nevertheless, since these foldings took place before the deposition of the quartzite, these grits must be older than the latter. On the next bare boss to the west there is another mass of grit intervening between rhyolite breccias and quartzite on the surface, but the relations of this are not very clear.

On the southern end of the Wrekin, east of Primrose Hill, there is a considerable mass of conglomerate rock forming an elevation and bearing considerable resemblance to that on Charlton Hill. It also appears to lie between the quartzite and the rhyolite (see fig. 8). It has, however, so mongrel a matrix that we seem to be

Fig. 8.—Section from Charlton Hill to the South end of the Wrekin. (Scale about $1\frac{1}{2}$ inches to a mile.)



approaching the agglomerates of Lawrence Hill. With these latter, however, we should have to compare, not the red grits of Cardington, but the great breccias there exposed at Woodgate quarry and fully described by Dr. Callaway, who ascribes them and, I think, justly, to the true volcanic series; but which, it must be noted, occur only on the edge of the mass, and may therefore be the youngest, in spite of their actual dip.

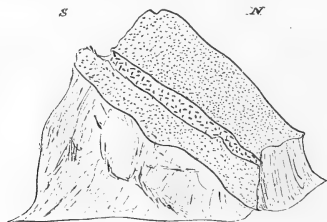
I think we may reconcile all these observations by looking on the Lawrence Hill and Woodgate deposits as the earliest results of denudation of the volcanic products, and almost belonging to their epoch. Then come the Charlton-Hill and South-Wrekin conglomerates, and possibly that on Willstone Hill, which is very like them; and lastly, at a later stage, the conglomerate of Wartle Knowl, followed by the red grit of all the localities that have been mentioned. We must conclude also that all this took place before the deposition of quartzite. The explanation involves, however, three conclusions, which rest, of course, on independent evidence, which will be strengthened, if this be accepted as reasonable. These are:—1. That the Cambrian grit lies unconformably, not only on the slates and grits of the Longmynd, but on the volcanic rocks on the east of the fault. 2. That these volcanic rocks are younger than the Longmynd rocks. 3. That all of these are anterior to the quartzite.

I pass next to the porphyry of Hope Bowdler and Cardington

(see fig. 5). This occurs in isolated and irregular masses of considerable size, and might at first be thought to form only an integral portion of the volcanic series of the hill. It is red in colour and has abundant felspathic inlets. There are three reasons for considering it intrusive. First, the character of the rock is different from any rock met with in the other volcanic hills, and is therefore not an ordinary constituent of the series; but it resembles more a superficial form of the eurite, which has already been regarded as intrusive, and, moreover, porphyries are more naturally intrusive than more glassy rocks. Secondly, because in the Gaer Stones plantation we find the ordinary grey and pink rhyolite becoming very much discoloured on approaching it, turning to a bright red hue owing to the oxidation of the iron. And thirdly, because one of the masses of red grit already described, as seen in a crack on one side of a valley, actually has a large vein of this porphyry intruded into its midst (see fig. 9). If, therefore, the porphyry was of the same age as the whole of the acid rocks of the hill, this grit would be earlier in date than the hill on which it rests, which would be very difficult to conceive of.

Lastly we come to the basic rocks, which seem to be everywhere present, mixed in the most intimate manner with the acid types.

Fig. 9.—*Porphyry intrusive in Red Grit at Cardington.*



There is seldom anything to indicate whether these are of later date or contemporaneous with the acid rocks. They are usually less in quantity than the latter; but in the Lawley the proportion is reversed. The great majority show no crystals, but are decayed into a dark irregular mass. There are other associated rocks, as at the north of the Lawley and in Hazler Hill, which appear to be the unstratified ashy representatives of this kind of rock, such as I have called pelite in Anglesey, and which would indicate that these basic rocks are not in the form of intrusions, but are eruptive. If all the basic rocks of the district are of the same age, they must be later than the agglomerates of Lawrence Hill, and therefore one of the last to be formed. Negative evidence to the same effect is afforded by the fact that the conglomerates and grits, wherever known, always lie upon the rhyolites and never on the basic rocks (unless Wartle Knowl be an exception). Even at the spot where the porphyry intrudes in the grit on Cardington Hill there is a crystalline dolerite which is

close at hand, but is not overlain by the grit. They may have once been overlain by grit, but have afforded it a less secure foundation, so that it has been more readily denuded. The absence of pebbles of this rock in the Cambrian conglomerates is not conclusive, since there is nothing in the majority of exposures that could produce a pebble; and the crystalline portions may be of a different and later date. We can thus get no nearer to the date of the basic rocks than that they are anterior to the quartzite which lies upon them, and that some of them, at least, are posterior to all the acid rocks. Their position at the present moment in relation to the rhyolites is very complicated; but this is due quite as much to later foldings and squeezings, possibly subsequent to the formation of the quartzite, as to the location of their original eruptive centres.

§ IV. POSSIBLE MORE ANCIENT ROCKS IN THE DISTRICT.

The rocks already dealt with form the principal portion of the Pre-Cambrian rocks of the district; but there are two other groups to which Dr. Callaway has already assigned a similar antiquity, viz. the Rushton schists and the gneiss of Primrose Hill (see fig. 8). With regard to the former there is little or no stratigraphical evidence available, and I have nothing to add to Dr. Callaway's petrographical descriptions*; I must only remark that the mica-schists and associated rocks are more altered by pressure than any other rocks of the neighbourhood, and call to mind many of the schists of the eastern district in Anglesey. Such strike as they show is more or less concordant with the strike of the Longmynd rocks; but they lie on the eastern side of the fault. It is very possible, considering the great exposure of the quartzite and the higher elevation of the Wrekin on the one side, and the coming in of the Trias on the other, that the throw of the main fault may be increased before reaching Rushton, and therefore that there may be a greater interval between the lowest accessible rocks. The Rushton schists may therefore be far lower in the series than the dark shales of the Longmynd border, and may actually represent some of the rocks of Anglesey, and this, at all events, is their most probable position; and if this correlation is correct, it would indicate a continuous development of the Monian series in the district.

The second mass, the gneiss of Primrose Hill, is intimately associated with the eurite and is considered by Dr. Callaway as forming part of the same group. This is not very likely to be the case if the latter is an eruptive rock, as I believe it to be; but independently of this the mode of occurrence of the gneiss is very peculiar. Towards the bottom of the western slope of the hill there is a small mass of it not many yards square, and there is another narrow patch of it, about 2 feet broad and a few yards in length, quite close to the summit, and this is all that can be called true gneiss, though some portion of the eurite is slightly gneissose. There is

* Geol. Mag. 1884.

also a narrow band of hornblende-schist of about the same size as the gneiss on the summit, and near and parallel to it, in connection with which may be mentioned a non-foliated diorite on the slope. These patches are so small and so isolated that it is impossible to regard them as exposures of bands in a gneissose series, especially as they are surrounded by non-foliated eurite; but if the latter be of the nature of a neck, these fragments may very well represent the underlying rocks, pieces of which have been torn off and carried up with the eruptive rock. The gneiss is foliated on a large scale, after the manner of the most mylonized gneisses of Anglesey, and the hornblende-schist is practically identical with the foliated diorite of that island. The occurrence of pebbles of gneiss and schist in the Longmynd conglomerates proves that there were large masses of such rocks exposed at the time of their formation; and the other interesting varieties recorded by Dr. Callaway * prove that other rocks which might belong to the same series accompanied them. The hornblende-schists, however, which would perhaps decay before forming pebbles, have not as yet been recognized.

These observations therefore tend to show that, as in crossing the Longmynds from west to east we come on ever lower rocks, so if the country still further east could be laid bare, we should find still lower rocks of the same system following in their proper order, the western and all other of the volcanic hills being later outbursts from the uptilted ground and having their own independent bedded pyroclasts.

§ V. RELATIONS OF THE OVERLYING FORMATIONS.

1. *The Quartzite.*

Leaving on one side the Cambrian conglomerates and grits as already dealt with, the oldest of overlying formation is undoubtedly the quartzite. With regard to this rock, the first point to be noticed is that it never occurs on the west side of the fault. It is, moreover, limited on the south by Cardington Hill, so that it occurs, as it were, only in a bay on the north-east side of the district. It does not even mount on to the extreme west of the volcanic hills. It climbs up the sides of Caradoc and occupies the summit of the crest between this and little Caradoc. It laps round the eastern side of the Lawley. It overpasses the Wrekin, it is true, but this hill is not in a geological line with Caradoc, but with Cardington Hill; and, though it reaches Charlton and is found as a capping on the slopes of this elevation, it neither reaches the western boundary nor appears at all in the Wrockwardine mass, which has the main fault on its western side. The extreme edge, therefore, of these volcanic hills appears, as far as we can tell, to have formed also its boundary, and they must therefore have been erected into a barrier at the time of its deposition. The occurrence of the Cambrian grit to the east of this boundary, and in fact to the east of the quartzite itself, on Cardington Hill, shows that the barrier

* Q. J. G. S. vol. xlii.

did not exist when the grit was being formed. This grit must, therefore, antedate the quartzite, and the elevation of the hills into a barrier must have occurred during the interval between them. And this is consonant with what we find elsewhere. Much of this grit lies below the conglomerate of the Longmynd, which was derived from the volcanic hills when first they came under the action of the denuding forces. As they rose they supplied the materials for the deposits on the west and formed the boundary of a quiet sea on the north, where organic life began to flourish. The fauna of the quartzite and the Comley sandstone, which everywhere succeeds it, and which is, therefore, probably only its continuation, is believed to be the oldest in the British Isles, except the fauna of the Monian rocks; but this does not necessitate its development at the earliest portion of the Cambrian period, when we remember how vast an amount of unfossiliferous Cambrian there is in North Wales, and how far above the base the *Paradoxides*-zone is at St. Davids.

2. *The Succeeding Formations.*

This barrier, once established, continued to be an important feature in the district through many subsequent ages. Now it is the character of Cambrian rocks, whenever we find them, to form the base of a continuous series which succeeds in regular order in the same district. On the other hand it is the character of Pre-Cambrian rocks to form the nuclei down to which the denudations of later ages have cleared away the rocks, so that they constantly form limits to later formations. This they do in Anglesey, at Charnwood, and here. For example, the next group above the primordial beds is the Caradoc. Towards the north this is separated from the volcanic hills by an expansion of the former; but it reaches them at the Lawley and Caer Caradoc, where it is faulted again, then on the other side of Cardington Hill the conglomeratic and gritty base of the Caradoc Series may be traced running nearly east and west in bay-like curves as far as Hope Bowdler, and showing large rhyolite pebbles where it crosses the Church-Stretton road. Another conglomerate, probably referable to this series is seen at the south end of Ragleth; coarse Caradoc bounds also all the southern inlier towards the east, but it never crosses the main fault. This fault, then, must lie also near the boundary of the Caradocian sea, since the beds of the same age in the Shelve district have not the same character. The existence of this boundary is probably connected with the Post-Cambrian squeeze which gave the dip to the purple grits and slates and placed them in a position for denudation.

The next formation which comes up to the nucleus is the Silurian with its basal Llandovery beds. The much wider range of these indicates that a depression had set in. Nevertheless the nucleus appears to have formed their northern boundary. They commence at Little Stretton and may be traced continuously, clinging to the Longmynd rocks, all the way to Plowden. They are mostly lost sight of in the succeeding valley, but are clearly seen all the way

from Wentnor to Lydham, dipping at a gentle angle from the Cambrian rocks on which they rest.

Many changes doubtless took place in this district during Devonian times, but these changes did not result in its submergence, since the Old Red Sandstone is only found in the south. More probably they resulted in its greater elevation; and the main fault, which did not exist during Silurian times, may now have been produced. The area of deposition was then transferred to the north; and from this direction came the later Coal-measures to abut naturally against the old rocks with an outline produced by denudation. In the same direction followed the Permian, then the Trias, which envelops the still remaining peaks of the ancient rocks, by Haughmond and the Wrekin; and even the Lias at Whitechurch is tending towards the same point: and none of these rocks have any representatives south of the Longmynd. Finally, even in the Glacial epoch, there appears to have been no submergence. The lower valleys on all sides are filled with Drift, but there is none of it on the surface of the hills; only on the northern side, whence the boulders travelled, do we find it, as it were, forced up-hill in the direction of its course. Here the boundary rises from a level of about 700 feet near Lebotwood to as much as 1050 feet on Picklescott Hill, descending to about 600 feet again to the east of Church Pulverbatch. In this direction a few boulders have even reached the summit of the hills, as at Church Pulverbatch itself and on Cothercott Hill. The boulders, as far as I have seen, are all of northern origin. None of them are of the Longmynd rocks, and the ice which thus pushed forward up a hill has left its striæ on the rocks of Charlton Hill, at a height 340 feet above the sea.

We thus perceive that the ancient rocks of the Longmynd have been exposed to denudation ever since the middle of Lower-Cambrian times, and the valleys we now see cutting across the vertical strata of the hardest and most insoluble grit, and carrying water remarkable for its clearness and purity, are the end result of its work.

§ VI. GENERAL CONCLUSIONS.

We are now in a position to determine how far my suggestion that the Longmynd rocks are not Cambrian, but Upper Monian, was correct. It is obvious that here, where the succession of the later rocks is so well made out, we are in the most critical locality for settling the existence or not of a system of ordinary stratified rocks subjacent to the Cambrian.

In the first place, in the face of the fact that the rocks hitherto comprised under the term Longmynd are not homogeneous, but consist of two distinct and unconformable portions, every statement made up to this time regarding them must be modified. Thus it is no longer permissible either to say the Longmynd rocks are Upper Monian or to give one name, such as that of Longmyndian, to the whole. Again the proofs that have hitherto been given that

the Longmynd rocks are derived from, and therefore later than, the Uriconian, will now only hold good for the upper of its two series.

We shall find it best, in considering what must be the result of the present observations, to commence at the top of the succession. The lowest beds that are continuous throughout the area, *i. e.* those found on both sides of the Longmynd hills, are the Shineton shales, and these have been determined to belong to the Upper Cambrian. Below these on the east there is the Comley sandstone and quartzite, enclosing a fauna which does not elsewhere characterize the beds immediately below the Upper Cambrian, but which forms the lowest fossil group of that system. Whether the Cambrian series is here complete and the intervening fauna lies yet hidden in the rocks, whether there is a yet unrecognized break between them, or whether such intervening fauna ever existed, it is not for me to decide. It is certain, however, from what is known elsewhere, that we cannot expect to discover here any truly Cambrian fauna below that of the Comley sandstone. On this side, therefore, of the Longmynd Hills we are at the base of the ordinary Cambrian development. On the other side we find an enormous thickness of grits and slates bearing no resemblance to the quartzite* and totally devoid of fossils. These grits and slates, though doubtless deposited with much greater rapidity than the rocks on the eastern side, must yet have required an enormous length of time for their formation, and starting at the top in Upper Cambrian, the base must belong to a very early, if not the earliest possible, portion of that series. The series must therefore, to some extent, be synchronous with, and to some extent earlier than, the quartzite, and have been formed in a different basin.

It is to be regretted that the relations of the two groups of rocks to one another are not as yet indubitably settled. Nevertheless such indications as there are, and which have been enumerated above, point with some force to the conclusion that the lower part, at least, is anterior to the quartzite, and is therefore the oldest representative of the stratified Cambrian rocks in the whole district. For these rocks, inasmuch as they still form the bulk of the Longmynd Hills, whose highest summits they actually occupy, the name of the Longmynd series can still be retained, and this series will therefore, in this district, be the base of the Cambrian.

On the eastern side of these hills, however, we must now recognize a comparatively narrow band, which belongs to an older series.

It is this band, and not the conglomerates, grits, and western band of slates, which has been studied by Salter and in which he discovered organisms totally unlike, so far as they go, the fauna of the Cambrian. It is this that shows a resemblance to the rocks of Bray Head, containing somewhat similar organisms, and it is this that has been compared with the schists of S. Lo, which are admitted to be unconformably overlain by the "conglomerat pourpré"

* The only exception to this is a reef of quartz running fairly parallel to the bedding at "Roch," near Medlicott, in the midst of the purple slates; but this appears to be rather of the nature of a vein.

of Brittany, referred by French geologists to the Cambrian. This band must therefore belong, by all the tests at our disposal, to a system which is at once of considerable thickness and wide distribution, and I venture to suggest that this can be none other than that system whose lower parts we see in Anglesey, in other words the Monian; and the portion of that system that is here represented must certainly be an *upper* part. So far, then, my original suggestion has been justified.

But, in view of what is seen in this locality, my former suggestion that the Uriconian rocks were Middle Monian cannot be adhered to. If there be any Middle Monian in this district it must be the Rushton schists; and if any Lower Monian, the fragments of gneiss and hornblende-schist caught up in the outburst on Primrose Hill. In fact, the proof that these volcanic hills are of later date than the Longmynd slates has entirely nullified all my previous conclusions as to the age and position of this and other volcanic Pre-Cambrian groups, which have been too rashly assumed to belong necessarily to the underlying subdivision called the Middle Monian.

What, then, are we to do with these Uriconian rocks? We have three alternatives to choose from. Either we must class them with the Monian, or we must assign them to an intermediate system, or we must class them with the Cambrian.

The uptilting of a group of rocks and the formation of fractures in its base, out of which a volcanic eruption may take place, indicates a great change of physical conditions, and probably a lapse of time equivalent to an unconformity. Can rocks formed after all this still belong to the same system? Moreover, the various conglomerates which cap them, some forming actually part of their mass, others worked up with them, show a gradual change of character into those which lie upon the surface, and which resemble the Cambrian grits. These considerations seem to associate these rocks, in spite of the unconformable quartzites, more with the rocks above than with those below.

Again, to class them as a separate system under the title of Uriconian is little more than a confession of ignorance. Such a system has been nowhere worked out, and we might have to create a new system on the same principle for every locality. Probably, however, this is what we shall have to do temporarily till more is known of the relations of these old rocks.

But if neither of these alternatives be acceptable, can they be classed with the Cambrian? I shall not, with our present information, attempt to answer this question definitely, but only throw out a few suggestions. In the first place, the behaviour of the overlying quartzite does not prove that they cannot properly be called Cambrian. On the one hand, it is very probable that the grits which lie upon them are also overlain by the quartzite, and yet that this grit is Cambrian. On the other hand, these conglomerates and grits, though derived in part from them, need not be of much later date, considering the rapidity with which volcanic rocks consolidate and are broken up, and considering the connection, as noted above,

of some of them with the actual volcanic débris. Again, if we go further afield, in North Wales, as I have shown *, the rocks which overlie the Monian unconformably, and are so well developed between Bangor and Carnarvon, are very volcanic in character, yet they form the base of the Cambrian and have several well-marked conglomerates in their midst, up to the one that overlies the felsites of Llyn Padarn. It may be that the Uriconian rocks are of the same age as these,—they have both been thought to be the same as the Pebidian. And this takes us to St. Davids. There is certainly there an entire unconformity and independence between the Cambrian conglomerates and the underlying series, and therefore I so unhesitatingly classed the volcanic group of St. Davids with the Middle Monian, that I gave as an alternative name for that subdivision “the St. Davids group.” But there is no special similarity between the rocks there and the Middle Monian of Anglesey; there is quite as much resemblance, if not more, to the rocks between Bangor and Carnarvon. It is possible, therefore, that Dr. Geikie may be right after all, and that sufficient allowance has not been made, in estimating the significance of the unconformity, for the volcanic nature of the underlying rocks. Again, in the Midlands, the Nuncaton quartzite lies upon the volcanic rocks of Caldecott: and at Charnwood the Swithland slates have great conglomerates associated with them and pass down, without any discovered break, into the volcanic ashes and lavas of the western portion of the Forest. If, on further knowledge, it should turn out that all these must be referred to the Cambrian, it would be certainly a remarkable circumstance, amounting to a generalization, that wheresoever we reach the base of that formation we find it formed of volcanic débris, which is not, perhaps, an unnatural commencement of a system formed under new physical conditions.

And if this should turn out to be the case, which as yet is far from proved, then would the Monian system be entirely cleared from the Pebidian and its associated Arvonian and Dimetian, and stand firmly as a distinct system founded entirely on independent observations.

EXPLANATION OF THE MAP, PLATE XVI.

The Monian and Cambrian Rocks of Shropshire.

This Map is traced from the 1-inch Ordnance Survey Map; the geological lines being reduced from the 6-inch Survey Map. Consequently, if this Map be retraced on the Ordnance Map, the exact positions of all lines will be found.

DISCUSSION.

Dr. Hicks said it was greatly to be regretted that Dr. Callaway, who had done so much in unravelling the geology of the district referred to was unable to be present to reply to the Author's remarks. In his absence, he (Dr. Hicks) desired to say that, in the

* Q. J. G. S. vol. xliii.

main, his own views were much more in accord with those of Dr. Callaway than with those of the Author. He failed to see any reason why the Author should call any of the Longmynd rocks (which already had local names given to them) by the name "Monian," especially since they were entirely unlike the rocks in Anglesey, which the Author had recently called by that name. Dr. Hicks had examined most of the sections, referred to by the Author, last autumn. He believed the Longmynd rocks to be mainly Cambrian, and the two series to represent the Caerfai and Solva groups of St. Davids, which contained similar fossils to those of the Longmynd rocks. Between the Caerfai and Solva groups there were well-marked grits and conglomerates. The materials composing the Lower Longmynd series had undoubtedly been derived by denudation from volcanic rocks, such as those now forming the Pre-Cambrian rocks of Caer Caradoc, hence the Longmynd rocks were clearly newer than the Uriconian (Pebidian) rocks of the area. The sections, on careful examination, showed that the Lower Longmynd rocks had formed an arch over the Caer Caradoc rocks, that the limb on the west side had been greatly broken by reversed faults, and that the limb on the east had been broken by great thrusts which had caused newer beds to be pushed over and hide the older. The Author, Dr. Hicks believed, had here, as he had done at St. Davids and in Caernarvonshire, entirely failed to realize the true interpretation by overlooking the effects due to thrusts and faults. In those areas he had also attributed contact-changes to Pre-Cambrian rocks, when entirely due to dykes which penetrated the Pre-Cambrian and overlying series. There was no evidence to show that the Bray Head rocks were of the same age as the Pre-Cambrian rocks of Anglesey.

Mr. WHITAKER asked whether the Author's results were in accordance with those of Prof. Lapworth.

Mr. MARR objected to the use of the term Monian for a system whose upper and lower limits were not defined. He pointed out the discrepancy between the supposed basal Cambrians on either side of the ridge.

The AUTHOR replied that the Bray Head rocks followed naturally upon the Howth Head rocks which were continued into Anglesey. The statement that the purple slates were derived from older acid rocks might be equally true of any other slates, and did not prove that they were derived from any definite volcanic series. He had seen no evidence for any of the thrusts imagined by Dr. Hicks nor had he seen any of the dykes. He admitted that the summit and base of the system were not defined, but the system itself was there. The beds below the Shineton Shales on the west side were continuous to the base of the Cambrian.

22. *On a new Species of CYPHASPIS from the CARBONIFEROUS ROCKS of YORKSHIRE.* By Miss COIGNOU, Scholar of Newnham College, Cambridge. (Read March 26, 1890.)

(Communicated by Prof. T. M'KENNY HUGHES, F.R.S., F.G.S.)

DURING the visit of Prof. Hughes's geological party to the Craven district in June last, I was fortunate enough to find in the Pendle-side limestone* at the base of Butterhaw, near Cracoe, a fairly perfect head of a Trilobite which appears to belong to the genus *Cyphaspis*. Hitherto this genus has not been recorded above the Devonian, and its discovery in rocks of Carboniferous age seems worthy of notice.

Description.—Head small, semicircular, very convex, 3·5 millim. in length and 5 millim. in width. Frontal border broad, flattened, minutely granulate. Its margin produced into a number of equidistant, horizontal, cylindrical spines, ·5 millim. long. In our specimen they are visible on the right antero-lateral portion of the border, and one near the left genal angle. They are ·4 millim. apart from each other, and as the frontal border is 9·6 millim. in length, there must have been 24 spines present. Genal angles invisible, probably prolonged into short spines. Glabella very prominent, ovoid, narrow behind, and widening gradually for four fifths of its length. Slightly constricted at the two glabella-furrows on each side, much raised above the cheeks; covered with small granules and bearing four tubercles, a pair near the upper part of the anterior sloping surface, a large unpaired one near the centre, and a smaller median one behind. Of the glabella-furrows the anterior one is short and, seen from the side, is directed backwards, while looked at from above it appears as a pit in the axial furrow, marking off an imperfectly defined narrow oblong lobe. Posterior furrow deep, extending backwards to the neck-furrow and bounding the postero-lateral lobes, which are elevated and pyriform. Neck-furrow broad and shallow. Neck-lobe short, convex, badly preserved. Cheeks subtriangular, elevated, sloping abruptly along the inner and posterior sides, finely granulated, continuous in front of the glabella. Facial suture invisible. Eyes sessile, reniform, at the summit of the cheek, opposite the centre of the glabella.

Thorax and tail unknown.

Affinities.—The specimen is provisionally referred to *Cyphaspis*, but it differs from the typical species of that genus in possessing two pairs of glabella-lobes. Barrande mentions the occurrence of two transverse furrows on each side of the glabella in *C. novella* and *C. depressa* †. From both of these our species is clearly distinguished

* "Explications des Excursions," Congrès géologique International (1888), p. 80.

† Syst. Sil. de la Bohême, vol. i. p. 479.

by the frontal border being produced into spines. It closely resembles *C. Davidsoni*, Barrande, and agrees with it in having:—

- (1) The frontal border produced into spines.
- (2) Two or four tubercles on the glabella.
- (3) The granulated ornamentation of the head.

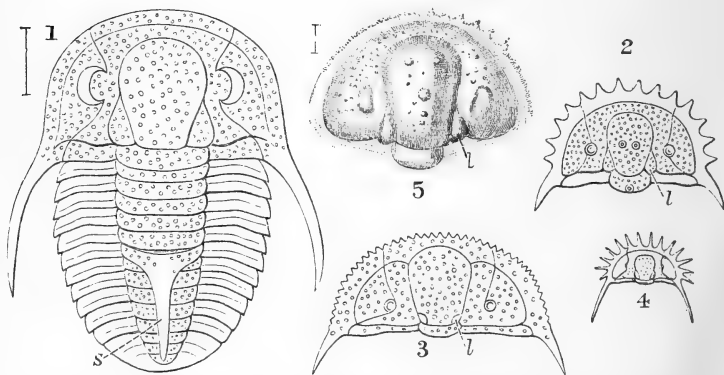
In our specimen, however, the frontal spines are longer and further apart, and the granules are finer than in *C. Davidsoni*. Further, the anterior glabella-furrows appear to be absent in the Bohemian species.

As it appears to be distinct from any species of *Cyphaspis* hitherto described, we propose to name it *Cyphaspis acanthina* on account of its thorny appearance.

Barrande records nine species of *Cyphaspis* from Bohemia, three only of which have the body-segments preserved, the other six species being represented by heads only.

All those with body-segments preserved have smooth borders to their cephalic shields, and all have the 6th axial ring prolonged into a strong median spine (see woodcut, fig. 1, *s*). It is possible that the species with spinose borders to the head-shield may belong to another genus or subgenus. The pair of lobes (*l*) at the base of the glabella are, perhaps, the best diagnostic character to rely upon in dealing with detached head-shields.

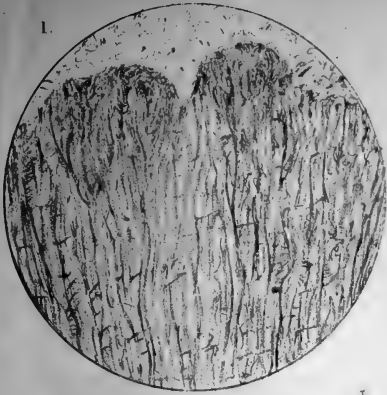
Outlines showing the Structure of some Cephalaspides.



Woodcuts are here given of a typical example of the genus *Cyphaspis*, and of those species which are most nearly allied to the specimen under consideration.

EXPLANATION OF FIGURES.

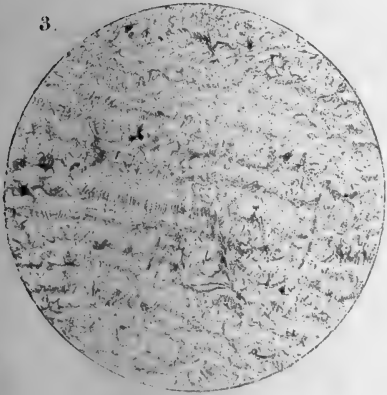
- Fig. 1. *Cyphaspis megalops*, M'Coy. Wenlock Limestone; Dudley, Staffordshire.
2. — *Davidsoni*, Barr. Etage F. Mniénian, Bohemia.
 3. — *Cerberus*, Barr. Etage F. Mniénian, Bohemia.
 4. — *coronata*, Barr. Etage G. Moulin de Vavrovitz, Bohemia.
 5. — *acanthina*, sp. nov. Carboniferous series; Yorkshire.



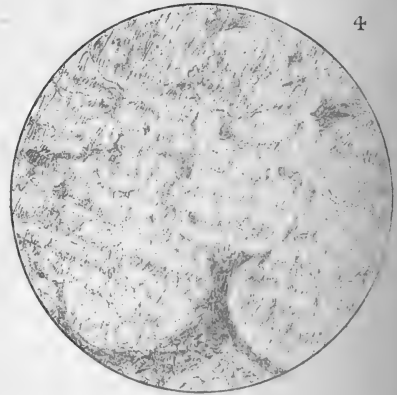
x 45



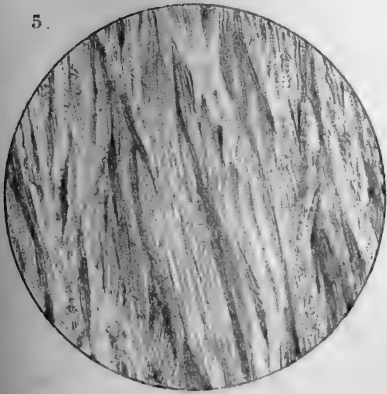
x 195



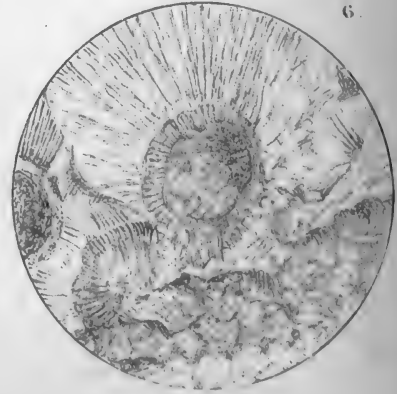
x 45



x 45



x 195



x 18

Frank Rutley del. F.H. Michael lith.

Mirrern Bros. imp.

COMPOSITE SPHERULITES IN OBSIDIAN.
Hot Springs near Little Lake, California.

23. *On Composite Spherulites in Obsidian, from Hot-Springs, near Little Lake, California.* By FRANK RUTLEY, Esq., F.G.S., Lecturer on Mineralogy in the Royal School of Mines. (Read March 26, 1890.)

[PLATE XVII.]

IN a paper read before the Royal Society in 1885*, allusion was made to certain greyish or yellowish-white spherulites occurring in a specimen of black obsidian which was given me by the late Mr. John Arthur Phillips, F.R.S.

These spherulites (portions of two occur in the specimen) are about an inch in diameter and are seen to consist of numerous spherulites of very much smaller dimensions. In the paper referred to it was suggested "that the smaller spherulitic structure was set up in the large spherule after its formation, the vestiges of a radiating crystalline structure tending to confirm this view." This opinion was based merely upon what could be seen on a fractured surface by the help of a pocket-lens. The microscopic examination of a section made through one of these bodies seems, however, to show that the smaller spherulites were formed first, and that after they had assembled together in spheroidal aggregates, a radiating crystallization was set up within the mass, travelling stage by stage from the centre to the periphery.

As I have not yet met with any account of precisely similar spherulites, even in Mr. Iddings's monograph †, it seems to me that the following notes may prove of some interest to petrographers.

In reflected light, but better when dark-ground illumination is employed, the entire section of the spherulite is seen to be composed of much smaller spherical or spheroidal bodies, so closely packed that they are usually in contact, the matter occupying the interstices appearing darker than the spherical or spheroidal bodies themselves, which latter, by dark-ground illumination, appear brightly lighted, fig. 4, Pl. XVII. In ordinary transmitted light these bodies are scarcely to be recognized, except in a few parts of the section, where they are somewhat darker than the remaining portions, although they are more or less translucent (fig. 1, Pl. XVII.). These are the small pellets which, by the help of a lens or even by unassisted vision, may be seen to compose the large spherulites in the hand-specimen. In the following description these smaller bodies will be termed primitive spherulites.

The general aspect of the section, when viewed in ordinary trans-

* "On the Microscopic Characters of some Specimens of Devitrified Glass, with Notes on certain Analogous Structures in Rocks," by Douglas Herman and Frank Rutley. Communicated by Prof. T. G. Bonney, D.Sc., F.R.S. Proc. Roy. Soc. vol. xxxix. p. 106.

† "Obsidian Cliff, Yellowstone National Park," Seventh Annual Report, U.S. Geol. Surv. Washington, 1888.

mitted light, is that of a portion of a large spherulite composed of anastomosing flexuous rods or fibres diverging from an approximately common centre. The rods or fibres are traversed transversely to their length by delicate cracks, which are very numerous but interrupted (fig. 2, Pl. XVII.). Between the rods or fibres there is more or less isotropic matter with minute globulites. The latter appear to be ranged in irregular linear aggregates following the direction of the crystalline rods. Trichites and granules and minute crystals of magnetite are somewhat plentiful in this fibrous mass.

When viewed between crossed nicols the fibres or rods composing the spherulite polarize, but not vividly, and the extinction, so far as it can be made out in the matted mass of fibres, appears frequently to be parallel and at right angles to their length, at other times it seems to make an angle approximating to 21° with the long axis of the rod, which would correspond to the extinction seen on (010) in orthoclase. It would therefore appear that the divergent rods which constitute the main bulk of the spherulite are orthoclase, as in the cases described by Iddings in his work on "Obsidian Cliff." There is, however, little dependence to be placed upon the measurement of the extinction-angles, since the confused and branching character of the rods (fig. 5, Pl. XVII.) is, I believe, due to the fact that the entire mass is made up of a succession of divergent bundles of rods, similar to those met with in artificially devitrified glass. Where this structure is strongly marked the section shows a well-defined concentric banding (fig. 3, Pl. XVII.), each band occurring at the terminal boundary of one zone of bundles of divergent rods, which boundary forms the floor from which the divergent crystalline fasciculi of the next zone grew.

The most interesting point is that *these concentric bandings pass completely through the primitive spherulites* already alluded to, as shown in fig. 4, Pl. XVII., which represents the same part of the section given in fig. 3, the different appearances being due to the methods of illumination respectively employed. It may therefore, I think, be safely assumed that the divergent crystalline structure of the large spherulite was developed subsequently to the massing together of the small (primitive) ones, which are also traversed by the divergent structure proper to the large or secondary spherulite.

The small or primitive spherulites show no fibrous or crystalline structure of their own. What appears to be tridymite is present in a small cavity situated at a little distance from the margin of the spherulite, and it is probable that some of the isotropic matter occurring between the divergent fibres of the spherulite may also be referred to this mineral, as in some of the cases described by Iddings*.

Colourless microliths may be detected in the section, but they do not appear to be numerous.

Some of the dark specks which, in reflected light, are seen to be of a reddish or brownish colour, may be regarded as iron-oxides.

* *Op. cit.*

To sum up the history of these spherulites, I think we may assume that in the first instance small spherulitic bodies (the primitive spherulites) were developed in the obsidian before it assumed a condition of rigidity. Secondly, that these small spherulites floated towards certain points in the still viscid lava and segregated in more or less spherical groups, although what determined their movements, whether mutual attraction or some other cause, there is no evidence to show. Thirdly, that from a point or points, situated at or near the centre of each group, crystallization was set up, giving rise to a radiating fibrous or rod-like structure, which gradually developed zone after zone of divergent tufts or fibres, until the entire mass of primitive spherulites was permeated by this secondary structure, a structure engendering a molecular rearrangement of the mass such as would obliterate any trace of structure which the primitive spherulites might have originally possessed.

There are two or three small spherulites visible in the section, which apparently arrived too late to be incorporated in the general mass and which occupy conspicuous positions on the margin of the crowd, and an independent divergent crystalline structure has been developed about them as shown in fig. 6, Pl. XVII.

It was not until the foregoing notes were made that I had the good fortune to see Mr. Iddings, whose work has already been alluded to, and to converse with him upon the question now under consideration.

Mr. Iddings has examined the specimen and section now laid before the Society, and kindly given me his opinion upon them.

He considers that the bodies which I have here ventured to term primitive spherulites are of secondary origin, and that they probably consist to a large extent of tridymite, although from his cursory examination of the section he could not speak positively as to the presence of this mineral.

In this case he stated that he reasoned from analogy, and that he had seen very similar phenomena in the spherulites and lithophysæ occurring in the obsidians of the Yellowstone National Park. From an examination of a vast amount of material collected in that district, he had been able to trace out structures of this class ranging from some very obscure or minute to others occurring on a sufficiently large scale to admit of more accurate determination.

In the present case he considered, 1st. that the spherulites or lithophysæ (he regarded them as the latter) originated in the development of a radial crystallization, in which felspar microlites were developed in a succession of twins which gave rise to delicate ramifying growths; 2nd, that diminution of volume resulted from this action of crystallization, and that vacancies were thus produced between the twigs, if one may so term them, of this divergent crystalline structure, so that the mass of the spherulite or lithophysa was thoroughly cavernous or spongy in texture; 3rd, that within these spaces tridymite was subsequently developed in small spherical bodies consisting of aggregates of minute scales or plates of tridymite, and

that between these small spherical pellets of tridymite vacuities still remained. In such empty spaces he finds that in most cases emery or other grinding-material has collected during the preparation of sections. In the central portion of one of the fractured spherulites in the specimen now described, he detected one or two small crystals of altered fayalite.

Although it is not very easy to give the results of a conversation accurately, without having taken notes at the time, yet I think that I have here expressed the opinion with which Mr. Iddings favoured me, clearly and correctly, and he kindly gave me permission to make this statement.

That it is difficult, if not dangerous, to question the opinion of a careful observer who has had such unparalleled opportunities for the study of spherulitic structures as Mr. Iddings has enjoyed, is a fact of which I am fully cognizant; yet there appear in this particular instance to be certain matters of detail which seem to support the conclusions expressed by me in the foregoing paper.

They may be summarized in the following manner:—

1st. That although diminution in volume is attendant upon crystallization in cases such as that with which we are now dealing, would it occur to an extent so appreciable that a cavernous or spongy structure would be thus developed throughout the entire mass of a spherical body an inch in diameter, or would it not rather result in the production of one or two appreciably large fissures or cavities such as are met with in lithophysæ, assuming that those fissures or cavities would not be developed through other causes than contraction?

2nd. That if such a spongy condition of the spherulitic body were induced, so that the entire spherulite consisted merely of divergent and anastomosing filaments composed of felspar microliths, forming a kind of delicate network, the interspaces of which were filled neither with vitreous matter nor with any other solid, would tridymite deposited within such interspaces be developed in the form of closely-packed, well-defined, spherical pellets, or would it tend to crystallize out along the twigs of the divergent microlithic structure of the spherulite, thus filling all the interspaces completely?

3rd. That tridymite is in the habit of forming more or less spherical groups is well known, but would such spherical groups be formed in a closely matted aggregate of crystalline rods, since each small pellet (primitive spherulite) would consist as much of felspar as of tridymite? Furthermore, would not these minute feldspathic rods afford surfaces along which crystallization would be set up, and thus seriously impede the crystallization of the tridymite in spherical aggregates, if, indeed, it would not render such spherical development impossible?

4th. The small spherical pellets have well-defined boundaries such as ordinary spherulites might have. Examination in polarized light reveals the presence of comparatively little, if any, isotropic matter, the pellets appearing to consist to a very large extent

of doubly refracting fibres or matted microliths. From this fact alone it is evident that it would be useless to attempt to determine the presence of tridymite, either by solubility of the pellets in a solution of an alkaline carbonate or by specific gravity.

5th. Where spaces occur between the small pellets or primitive spherulites, they are filled with crypto-crystalline matter associated with isotropic matter, which may be glass or which may be tridymite.

6th. On comparing what I here regard as the secondary structure developed in this spherulite with the structures produced by the devitrification of artificially formed glass, there appears to be a very strong resemblance in most cases, making allowance, of course, for differences in texture. The ramifications of the crystalline rods here indicate the existence of divergent crystalline bundles, which are probably bounded by radial planes of arrest, planes which in this instance evade detection by reason of the delicate nature of the rods composing each bundle, and the consequently confused appearance caused by the overlap of several fasciculi within the thickness of the section; whereas, in a more coarse phase of devitrification, a single bundle would occupy the entire thickness of the section, so that, in such a case, the arrest-planes would be well defined.

Now it is evident that if the initial points of divergent groups originate very close to one another along one of the circumferential bands of a spherulite (which band may be taken to represent a pause in the crystalline development) those rods which diverge most strongly from any radius of the spherulite will be quickly arrested by the development of similar rods in the adjacent bundles, and such rods will be excessively short, while those which approximate more closely to radii of the spherulite will be comparatively long. Under such circumstances, the crystalline rods belonging to successive zones will exhibit an apparent continuity. This seems to support the view that the divergent crystalline structure in these spherulites differs in no essential respect from the structure commonly observed in manufactured glass which has been artificially devitrified.

Taking all these points into consideration, I am inclined to think that the conclusions arrived at in this paper are substantially correct; but, on the other hand, the wide experience of Mr. Iddings in connexion with obsidians and the structures developed in them, renders his opinion worthy of the most careful attention.

I trust that I have in no way misinterpreted his views, and I would gladly substitute them for my own if, in this instance, I felt that they offered a more satisfactory explanation of the phenomena here described.

EXPLANATION OF PLATE XVII.

- Fig. 1. Border of composite spherulite in black obsidian, from Hot-Springs, near Little Lake, California, $\times 45$. Ordinary transmitted light.
The light upper portion of the drawing represents the obsidian. The boundary of the spherulite is here seen to be irregular, owing to the partial reception of two smaller spherulites. The latter were traversed

by the radial fibrous structure of the large spherulite with which they are incorporated.

Fig. 2. Ditto, $\times 195$. Ordinary transmitted light.

The radial structure is here seen to be crossed by short and delicate circumferential shrinkage cracks. The crystals and specks are magnetite.

3. Part of the same spherulite, $\times 45$. Ordinary transmitted light, showing concentric banding.
4. The same part of the section shown in fig. 3, $\times 45$, dark-ground illumination. By this method of illumination the composite nature of the spherulite becomes clearly demonstrable, and it may be shown that it is composed of a number of small, closely packed, primitive spherulites, through which the concentric banding is seen to pass.
5. Radial fibrous structure of the same spherulite, as seen between crossed nicols, the principal sections of the latter being situated at 45° to the general direction of the fibrillation. The fibres are felspars, apparently orthoclase, $\times 195$.
6. Marginal portion of the same spherulite, showing smaller outlying spherulites, around which an independent radial crystallization has been set up, $\times 18$. Oblique ordinary transmitted light.

DISCUSSION.

The CHAIRMAN said that the sequence of the different portions brought forward with so much care by the Author is one which admits of much discussion.

Rev. E. HILL said that the explanation of the divergence of these crystallizations was extremely interesting. As to which structure came first, it is difficult to determine. In the section exhibited under the microscope he agreed with Mr. Rutley as to the sequence. The question of molecular motion after consolidation in igneous rocks is a subject of great importance.

24. *On ORNITHOSAURIAN REMAINS from the OXFORD CLAY of HUNTINGDONSHIRE* *. By R. LYDEKKER, Esq., B.A., F.G.S. (Read April 16, 1890.)

My friend Mr. Thomas Jesson recently forwarded to me a few small associated bones obtained from the Oxford Clay of St. Ives, Huntingdonshire, which are of a certain amount of interest as being the only specimens referable to a Pterodactyle hitherto described from these deposits in England, or, indeed, so far as I am aware, in any other part of Europe. The specimens comprise seven vertebræ, portions of the ilia and ischia of both sides; one femur and the distal portion of the corresponding bone of the opposite side; part of a bone, probably from the shaft of the tibia; and two undetermined fragments. When they came into my hands they were partially bedded in their native clay, and their broken surfaces show the pyritous impregnation so characteristic of Oxfordian specimens.

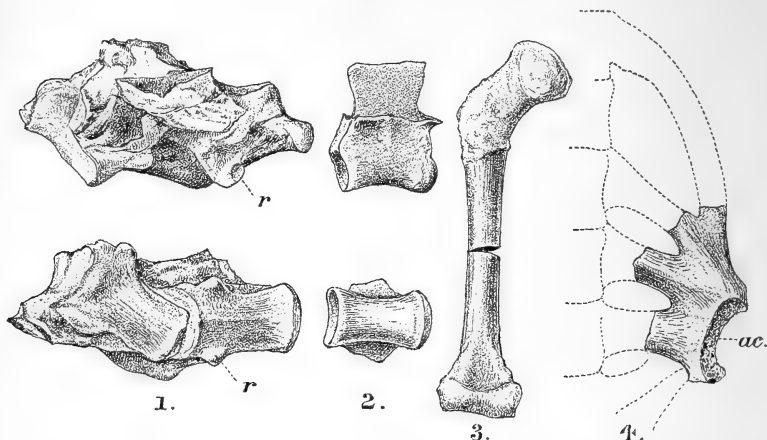
The Ornithosaurian nature of the specimens is at once shown by the hollow shafts of the long bones and the structure of the vertebræ, the latter having procœlous centra, with complete obliteration of the neuro-central suture. The two fragments of the femur (fig. 3), which I have placed in apposition, do not exactly fit together, so that there may be a portion missing from the middle of the shaft, and it is quite possible that I have not put the proper distal half in apposition with the proximal one. The bones indicate an individual of somewhat smaller size than the examples of the Lower-Kimeridgian *Rhamphorhynchus Gemmingi* figured by Professor von Zittel in the 'Palæontographica,' vol. xxix. pl. xii.

The portions of the pelvis (fig. 4) now remaining are of the peculiar type characteristic of *Rhamphorhynchus*, as is so well displayed in the specimen represented in fig. 2 of the plate cited. The peculiarity of this type of pelvis is that the ischium is connected with the hinder portion of the ilium to form a large expanded plate; while the ilium itself is united with the sacrum by means of four broad and flattened sacral ribs, which are anchylosed to the ilium, of which they appear to be mere processes. On the other hand, so far as I can gather from Meyer's figure of *P. spectabilis*, the pelvis of *Pterodactylus* is constituted on quite a different plan; which alone justifies our regarding the two genera as referable to separate families. Now, although the conjoint ilia and ischia of the Oxfordian Pterodactyle are far from perfect, yet such of the several processes of the ilia as remain so exactly accord with those of *Rhamphorhynchus* that I think the English form may be safely referred to that genus.

Of the vertebræ we have two, in apposition, which from their

* When the paper was read the author was under the impression that the specimens came from Northampton.

large size are evidently cervicals. They are somewhat smaller than those of the specimen represented in fig. 1 of Zittel's plate. The arches and spine are not well preserved, but the inferior aspect of the centra (fig. 1) is entire. These exhibit a feature which at the



Rhamphorhynchus Jessoni.—1. Left-lateral and ventral aspects of two cervical vertebrae; *r*, rib-facet. 2. Left-lateral and ventral aspects of a dorsal vertebra. 3. Ventral aspect of the left femur. 4. Ventral aspect of the left innominate; *ac*, acetabulum. (All the figures are twice the natural size.)

time Professor Huxley wrote his 'Anatomy of Vertebrated Animals' had not been observed, but which has subsequently been recorded by Dr. Baur in the genus *Rhamphorhynchus*. This feature is the presence of a distinct rib-facet at the lateral border of the inferior surface of the centrum, thus proving the existence of cervical ribs at least in this genus of Pterodactyles.

Another vertebra which calls for notice is an entire dorsal. The most noticeable feature of this specimen (fig. 2) is the lowness and length (antero-posteriorly) of the neural spine, which strikingly recalls that of a bird. There is no rib-facet on the centrum, and apparently none on the arch, so that the rib was probably supported entirely on the transverse process, as in crocodiles. An imperfect sacral vertebra shows the widely expanded sacral ribs ankylosed to the centrum, and corresponding in size with the sacral processes of the ilium.

The femur, as I have placed the two fragments, measures about one inch in length. The globular head is set very obliquely to the shaft by means of a long 'neck;' there is no inner trochanter, although the posterior surface of the shaft shows a distinct *linea aspera*.

The specimens under consideration are of interest, not only as the first recorded evidence of an Ornithosaurian in the Oxford Clay, but

also as showing the natural contour of the bones, which are generally more or less flattened in the specimens from the Lithographic Limestone. They do not afford characters by which the species to which they belong can be definitely distinguished from *Rhamphorhynchus Gemmingi*; but since they come from a lower horizon than the latter, I venture to regard them as the type of a provisional species, for which I have proposed the name *R. Jessoni*. The genus *Rhamphorhynchus*, as now restricted, has been hitherto known only from the Lower-Kimeridgian Lithographic Limestone.

25. NOTES on a "WASH-OUT" found in the PLEASLEY and TEVERSALL COLLIERIES, DERBYSHIRE and NOTTS *. By J. C. B. HENDY, Esq. (Read April 16, 1890.)

(Communicated by Dr. W. T. BLANFORD, F.R.S., F.G.S.)

THE Top Hard Coal-seam of the Midland Coal-field is being worked at these collieries at a depth of 217 yards at Teversall, and 514 yards at the Pleasley pits; the average thickness of the seam is 5 feet, with a band of cannel in the middle, varying from 4 to 14 inches. The general dip of the coal-seam is 1 in 12 to the N.E.

The "Wash-out" was first met with in the Teversall workings, about half a mile east of those pits, and from this point it has been proved to run for a distance of a mile and a quarter in a north-easterly direction, as shown in the plan, fig. 1.

The coal has now been worked off on each side of the "Wash" for a length of over 600 yards in the Teversall mine, and for 200 yards in the Pleasley workings, the boundary of the "Wash" being shown on the plan by strong lines where actually proved. Headings have been driven through the "Wash" at five different places, four of these from the Teversall and one from the Pleasley colliery. In each case these headings were driven next the ordinary sagar-clay floor of the mine; this under-clay is about 18 inches thick, and contains numerous nodules of ironstone. Careful sections of these "headings" have been taken, plans of which are given.

Section No. 1 (fig. 2).—At a distance of about 60 yards from the "Wash" the coal commenced to thicken; this continued until immediately adjoining the "Wash" the seam reached a height of 9 feet. On nearing the "Wash" a thin layer of soft sandstone is met with in the middle of the seam; this sandstone thickens like a wedge until the "Wash" is reached, the coal running out above and below, as shown in the section. The width of the "Wash" is here about 34 yards; and after heading this distance the coal was again met with next the floor, at first a thin band, but gradually increasing, until at 10 yards from the sides of the "Wash" it reaches a height of 7 feet,—from this point returning to the ordinary section of the seam. The edges of the coal next the "Wash" in this section are dull and smooth, it being difficult in some places to separate the sandstone from the coal, several thin layers of sandstone and earth-like impurities running from the "Wash" into the joints of the seam, and permeating the coal for a distance of from 2 to 3 feet. The "Wash" itself consists of a hard, yellow, stratified

* In Quart. Journ. Geol. Soc. vol. xlv., Proceedings, November 6, 1889, pp. 1 and 2, a short notice of this paper with the Discussion was published. Further particulars then asked for having been supplied, the present paper has been communicated.

sandstone, the lines of stratification being horizontal, but slightly inclining at the edges of the "Wash" to the top of the coal-seam, as shown by the lines in the Section No. 1. The ordinary surface of the clay floor of the mine is smooth and level; but in crossing the "Wash" this floor becomes uneven, presenting a series of furrows and ridges, the general line of these being at right angles to the course of the "Wash." The ironstone balls are exposed and stand, in many places, from 2 to 3 inches above the clay, their surfaces being rounded and apparently worn. In many places the floor is finely streaked or striated, the striæ running generally parallel to the course of the "Wash." The whole presents every appearance of having been subject to the action of a strong current.

Section No. 2 (fig. 3).—In this section the "Wash" has divided into two branches, the width of the northern branch being 40 yards, and that of the southern 50 yards; the two being separated by about 46 yards of coal, 9 feet thick. Several layers of sandstone run from the north "Wash" into the sides of the coal-seam for from 10 to 15 yards, these layers turning soft and friable as they leave the "Wash." In this section the thick coal is found almost entirely between the two "Washes," there being also a marked difference in the stratification of the sandstone in the two branches, that of the north branch being horizontal, as in Section 1, whilst that of the south bears

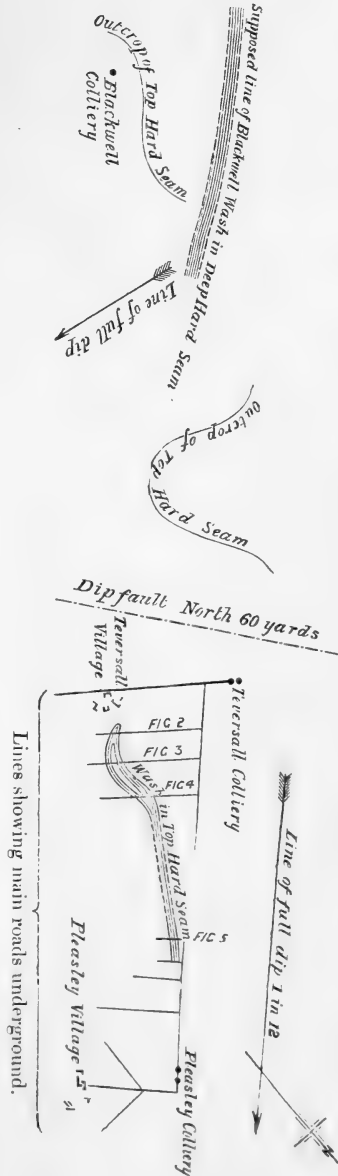


Fig. 1.—Plan of the Teversall and Pleasley Collieries, showing the Wash-out. (Scale 1 inch to a mile.)

Figs. 2, 3, 4, 5.—Sections of the Wash-out in the Teversall and Pleasley Collieries. (Horizontal scale 1 inch to 10 feet; vertical scale 1 inch to 3½ feet. Reduced ⅓ of original.)

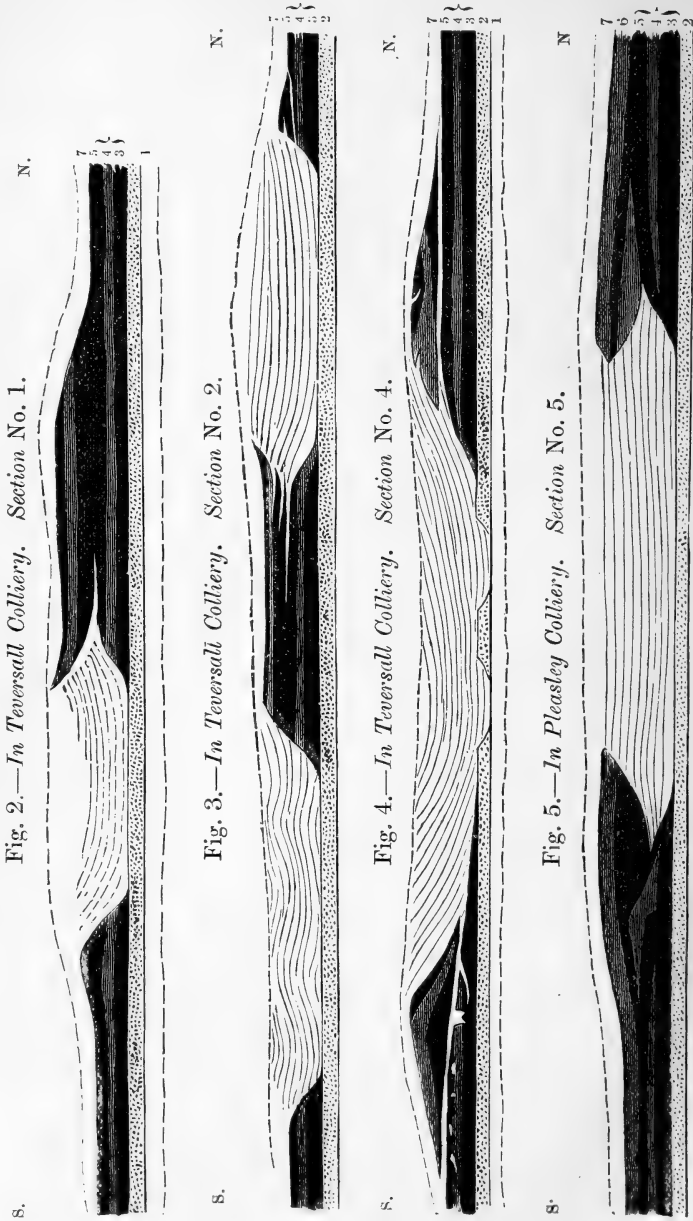


Fig. 2.—In Teversall Colliery. Section No. 1.

Fig. 3.—In Teversall Colliery. Section No. 2.

Fig. 4.—In Teversall Colliery. Section No. 4.

Fig. 5.—In Pleasley Colliery. Section No. 5.

evidence of lateral movement and pressure, being curved and contorted, as shown by the lines in the section. The same peculiarities were found in the floor of this section as described in Section 1.

Section No. 3.—This section is very similar to No. 2, the only difference noted being, that there are not so many layers of sandstone running into the sides of the seam, and that the coal for a length of 23 yards under the northern "Wash" has not been entirely denuded.

Section No. 4 (fig. 4).—Here the two branches of the "Wash" have again united, and in this locality the denuding force seems to have been strongest, for not only is the coal absent but in two places the clay floor has been entirely removed, in one instance for 7 yards, and in the other for a width of 10 yards, laying bare the sandstone below, there being a thin smooth parting between the sandstone of the "Wash" and that of the floor. On examining this sandstone floor it is found to be furrowed and, in some places, distinctly ripple-marked, the wave-lines being more or less at right angles to the course of the "Wash." The line of denudation is made apparent in the coal-seam on either side of the "Wash" by a layer of sandstone, of from 3 to 6 inches thick, which divides the upper from the lower coal (see fig. 4). The upper coal has evidently been re-deposited, being in many places impregnated with sand and earthy matter, whilst the lower coal retains its ordinary appearance and quality. On the south side of this section several blocks of isolated sandstone appear in the middle of the seam, these doubtless being the result of cavities formed in the coal about the time of denudation, and afterwards filled with sand, &c. The width of the "Wash" here is about 75 yards.

Section No. 5 (fig. 5).—This section is taken in the Pleasley colliery-workings. There is here a shale 2 feet thick, immediately overlying the coal, and forming the "roof" of the mine, instead of sandstone as in the Teversall colliery. On approaching the "Wash" this shale disappears with the coal, the overlying sandstone and that of the "Wash" taking its place. There is the same thickening of the seam on each side of the "Wash." On the north side the cannel gradually runs out in the lower coal, whilst in the upper coal it increases to a thickness of over 3 feet. The sandstone of the "Wash" is here harder and more compact, its stratification not being so well marked as in the other sections; but, as in several other instances, it penetrates the sides of the coal-seam like a wedge, this peculiar shape no doubt being due to the subsequent vertical pressure. The clay floor here maintains its ordinary appearance, there being none of the signs of denudation noticed as described in the other Sections, figs. 2, 3, 4.

Most careful examination has been made of all these headings, but in none of them have any fossils been found in the "Wash." There are, however, several "threads" or thin layers of coal running throughout the "sandstone" of the "Wash," varying in thickness from 1 to 3 inches, and from 4 to 20 inches in length, these being

in most cases more numerous near the edges of the "Wash." Several *Stigmariæ* have been found in the under-clay.

In every section examined, where there is evidence of lateral pressure, the sides of the "Wash" are more or less "slickensided"; in other cases the sandstone of the "Wash" is found in immediate contact with the coal, it being difficult sometimes to separate the two, both being in a state of transition; in other places the two surfaces are dull and smooth, as in the ordinary bedding between two strata.

It is impossible to say how far the "Wash" extends upwards; but, as the sandstone of the "Wash" is similar to that overlying the shale, in all probability it does not reach beyond that bed. Future workings in the Pleasley colliery will doubtless further prove its course, but evidently it either disappears or takes a sharp turn to the east, as shown by the present workings in the Pleasley pit.

It has frequently been suggested that these "Wash-outs" are due to "faulting"; there is, however, little evidence of this here, the only signs of "faulting" being the partly "slickensided" edges and in some few places the distortions of the coal next the "Wash"; these, however, are evidently due to lateral pressure and movement, subsequent to the denudation of the coal and the deposition of the "Wash" itself. Moreover it is difficult to conceive how any "faulting," in the ordinary sense, could have taken place in the coal or the measures above, without the sub-strata, or at any rate the clay-floor, being at the same time to a certain extent dislocated or disturbed; yet in all these sections the under-clay and the sandstone below are found in their normal condition, excepting as shown in Section 4 (fig. 4), where the clay has been denuded at the same time as the coal.

The most striking peculiarity of the "Wash-outs" found in this district is doubtless the thickening of the coal at the edges. Several "Washes" or "Drifts" have been found in the Durham coal-field. The writer remembers examining a "Wash" at the Middle Beechburn colliery in the west of Durham, which was first proved at the outcrop of the coal-seam, and followed by the workings on each side for a distance of $\frac{3}{4}$ of a mile into the hill-side. The peculiar feature of this "Wash" was, that whereas that near the outcrop consisted of sand and fine gravel, as the distance from the outcrop and the depth of the superincumbent strata increased, the sand gradually changed, first to a soft sandstone, and ultimately, when a depth of 230 yards from the surface had been reached, to a hard and compact sandstone, the change evidently being due, to some extent, to the increased pressure, &c., of the overlying strata. In the Teversall "Wash-out," however, there is no thickening of the coal, the measures having been simply denuded and carried away in suspension by a powerful current. In the case of the "Wash" at these pits from one third to one half of the coal has been re-deposited in different places on the sides, the remainder having evidently been carried away. It seems probable, therefore,

that these "Wash-outs" may be due to quite different kinds of aqueous action:—first, as in Durham and elsewhere, by a current flowing at a high rate of speed in one direction, denuding and carrying away the whole of the denuded material; and secondly, as in the Derbyshire "Wash," by a series of inundations or overflows of water, each in-rush denuding a certain amount, and on subsiding depositing part of the material at a higher level, whilst the remainder was carried away in suspension. Such action may have been the result of the periodical overflowing of a lake, or the more regular rise and fall of water in an arm of the sea. At the time this action took place the surface would doubtless be a soft, pulpy mass of vegetation in a state of decomposition, which would easily be removed by a current of water, however slight.

A "Wash-out" similar to the one described in these notes has been met with in the Blackwell and other collieries, and described in a paper read by Mr. G. E. Coke before the Chesterfield and Midland Institute of Mining Engineers. This "Wash" has been proved by the Blackwell coal-workings to run within $2\frac{1}{2}$ miles south-west of the Teversall pits (see the plan, fig. 1), and an impression seems to exist in the minds of several interested in the subject, that the Teversall and Pleasley "Wash" is a portion or continuation of that at Blackwell, &c. The writer submits that this cannot be so; for, whereas the Teversall "Wash" is found in the Top Hard-Seam, that at Blackwell has been proved in the Deep Hard Coal, some 200 yards below; and as the Deep Soft and other coal-seams lying between the Deep Hard and Top Hard have not been influenced by either "Wash," it seems certain that they must have occurred at vastly different periods:—the Blackwell "Wash" after the deposition of the Deep Hard Coal, but before that of the Deep Soft; and the Teversall and Pleasley "Wash" at a very much later period, viz., after the formation of the Top Hard Seam.

26. *On CERTAIN PHYSICAL PECULIARITIES exhibited by the so-called "RAISED BEACHES" of HOPE'S NOSE and the THATCHER ROCK, DEVON.* By D. PIDGEON, Esq., F.G.S., Assoc.Inst.C.E. (Read April 30, 1890.)

(Abridged.)

THE so-called "Raised Beaches" of Hope's Nose and the Thatcher Rock, near Torquay, have been so often discussed by eminent geologists that no attempt will be made to add anything by way of description in a paper proposing to deal exclusively with certain physical peculiarities exhibited by the "beaches" in question.

The word "beach" may be defined as an accumulation of sandy, shelly, and pebbly materials brought together, by the action of waves, upon the shore; while "raised beaches" are similar accumulations which since their formation have been lifted above the present level of the sea.

These definitions being granted, the author proposes to show, in the first place, that certain physical considerations, applicable to both of the "raised beaches" in question, make it impossible to consider them as beaches at all; and, in the second place, to suggest a possible explanation of their origin.

The considerations in question first struck the writer while working out the Conchology of the beaches for his friend Mr. A. R. Hunt, of Torquay, who has embodied the results thus obtained in a speculative paper on "The Raised Beach on the Thatcher Rock: its Shells and their Teaching"*. He gives a list of 43 species, with notes on their distribution in the present seas.

Referring, in the first instance, to the stony constituents of the beach, it will be observed—

1. That all the hand-samples exhibited to the Meeting are composed of fragments of rock and shells, both of which, with scarcely an exception, exhibit sharply fractured edges and are without any stratification.
2. That the rock-fragments consist, almost exclusively, of limestone derived from the cliffs overhanging the so-called beach; and that they are exactly such splinters as would fall, under the influence of weather, and particularly of frost, from those cliffs.
3. That the number of pebbles, properly so-called, in the beach is quite insignificant; and that, of these, very few are composed of the local limestone, chips of which constitute nearly the whole of the stony component of the deposit.
4. That stones other than limestone occur very sparingly and consist of quartz, Triassic trap, Devonian sandstone, and flint; and that, of these, very few are rounded, although some were once pebbles, which had been fractured before finding their way into the "beach."
5. Of the very few rounded stones of any kind, one here and there is incrustated with Annelidan tubes, acquired under water, and not since removed by

* Trans. Devon Assoc. vol. xx. pp. 225-252.

the attrition of a beach. 6. The limestone chips are entirely free from Annelidan incrustations and borers' holes. 7. On the other hand, *fragments* of what were once small limestone pebbles, riddled by borers, occur in some numbers; no bored limestone *pebbles*, however, are found.

Turning now from the stony to the shelly components of the deposit, these latter demonstrate—

8. That about half the mass consists of shelly matter. 9. That the shells, with scarcely an exception, are fractured, exhibiting peculiarly sharp and sometimes razor-like edges. 10. That the bulk of the shelly component consists of rock-dwelling shells, such as *Litorina* and *Purpura*, derived from the Laminarian and higher zones; and that a large proportion of these rock-dwellers are unbroken. 11. That, on the other hand, all the sand-dwelling Bivalves in the deposit are broken into fragments. 12. Whether whole or broken, however, all the shells retain their sculpture to a very remarkable extent, some allowance being made for chemical erosion. There is hardly a beach-rolled shell, and very few beach-rolled fragments of shell, in the collection. 13. No Annelidan incrustations occur on the unbroken shells, and very few on the fragmental Bivalves—another indication that both came, for the most part, into the beach as "live" shells. 14. While the facies of the forty-three shells obtained by Mr. Hunt is generally that of the present Molluscan fauna of Torbay, one decidedly Northern shell (*Trophon truncatus*, and one less decidedly northern (*Pleurotoma turricula*) occur in the list. These two shells might, perhaps, be taken to indicate a rather colder sea in the era of the raised beach.

Nothing could be more unlike a true sea-beach than the breccial deposit thus characterized. As to its stony constituents, nothing need be said; the splinters of local limestone speak for themselves; but, with regard to the shelly components, it may be remarked:—

1. The shells most abundant in this breccia, namely the rock-dwellers, are usually rare on the shore, and a beach of which *Purpura* and *Litorina* form an even appreciable proportion is unknown. Further, such rock-dwellers, when found on beaches, are always beach-rolled. 2. Bivalves, which are generally much more numerous than Gasteropods on beaches, are usually found with parted valves, but otherwise unbroken; and a beach upon which all the Bivalves are fragmental, while most of the Gasteropods are whole, does not exist. 3. Such broken shells as occur on existing beaches have their fractured edges always waterworn; but many of the beach shells, the *Purpura* especially, exhibit almost razor-like edges.

Before attempting any explanation of the origin of the Hope's Nose and Thatcher Beaches, it will be well to formulate certain questions which any such explanation must answer under pain of being inadequate.

As to the stony constituent of the beaches, it must say:—

1. Why are the limestone chips, which constitute the chief component of the deposit, sharply angular? 2. Why, if they be portions of a true beach, these fragments exhibit no signs of beach-

rolling, and why are none of them bored or encrusted by Annelidan tubes? 3. Why, on the other hand, do certain *fragments* of limestone pebbles which have been riddled by borers occur in the deposit? 4. Why do Annelidan incrustations occur only on the pebbly stones in the deposit, and how have such incrustations escaped destruction from beach-rolling? 5. How, the bulk of its stony component being local in character, were the few small foreign stones in it brought into the deposit? 6. Why is there no indication of stratification in these raised beaches *?

Again, as to the shelly components of these beaches:—

7. Why does *half* the deposit consist of shells, while these (except in the case of beaches composed entirely of shells and their fragments, not in question here) form such an insignificant proportion of existing beaches? 8. Why are the shells for the most part broken, and why do their fragments preserve sharp edges? 9. Why are there so few beach-rolled shells or shell-fragments in the deposit? 10. Why are none of the unbroken, and scarcely any of the broken shells either incrusted by Annelidan tubes or perforated by marine borers? 11. Why are *all* the Bivalves broken? 12. Why has the group of shells (see Mr. Hunt's list referred to above) a somewhat northern aspect?

The answers to these questions must, in the author's opinion, be sought in the study of certain Arctic phenomena, to which the attention of geologists was first drawn by Feilden and De Rance. They say † "there is no point of greater interest in Arctic geology than the occurrence of water-margins at successive elevations in Smith Sound, rising to heights of from 200 to 300 feet, in situations where wave-action was impossible. These ancient sea-margins are most persistent in bays, inlets, and narrow arms of the sea; and are still in process of formation."

During the short Arctic summer, upon the first signs of thaw, masses of rubbish fall from the cliffs and form immense scree, which not only reach, and cover, the "ice-foot," but are often carried, in part, by the impetus of their fall, on to the floes beyond it. Towards the close of the thaw episode, the sun's rays, being rapidly absorbed by the dark surface of the "scree," melt the uppermost layers of the ice-foot at its point of contact with the hill-side, thus producing a deep trench, filled, as soon as it is formed, by water which, at this season of the year, pours from the uplands.

The overflow from the trench in question, escaping over the ice-foot, cuts deep channels within a few hours across the latter, draining the ditch at low-tide, while at high-tide the sea pours through these transverse gullies into the trench and, sweeping right and left, with more or less violence, assort and reassorts the stony chips which it contains.

Meanwhile, the waves throw all sorts of "jetsam" both upon the surface of the ice-foot and into the ditch, mingling shells, weed,

* There is none seen in the lumps of beach exhibited.

† Quart. Journ. Geol. Soc. vol. xxxviii. p. 563 (1878).

crustacea, &c. confusedly with the stony chips which have already accumulated there.

Attempting now to apply the observations of the Naturalists who accompanied the Nares Expedition to the phenomena of the Hope's Nose and Thatcher beaches, it will be presumed that the British Channel was encumbered by floe-ice, and its bays margined by an ice-foot, at a time when the so-called beaches were accumulated,—and that they are composed, partly of chips of local limestone falling into an ice-foot-formed trench, such as that already described, and partly of such shells and fragments of shells as were thrown into the trench in question by the sea.

If that be so, the following answers may be given to the questions already proposed:—

1. The limestone chips which constitute almost the entire mass of the stony deposit are sharply angular because they were weathered out by frost from the cliffs above the so-called "beach."
2. These chips have not lain long enough under sea-water to become either rolled, bored, or incrustated by Annelids. Such sea-water as, entering the trench, rushed this way and that, with more or less violence, at every tide, might give the contained mass a rude stratification, but could not convert the chips into pebbles or afford time for the growth of borers and Annelids.
3. Such *fragments* of bored limestone pebbles as occur in the deposit were thrown into the trench by the sea, after the pebbles from which they were derived had been triturated by floe-ice.
4. The stones on which Annelidan incrustations occur were probably thrown by the sea into the "trench"; and there, protected from attrition by their sheltered position, they preserved such incrustations as would have been almost immediately lost on a beach.
5. The bulk of the stony constituents of the deposit is local, having fallen from the cliffs above, under the influence of frost. The few foreign stones it contains have been thrown in by the sea.
6. There could be no real "stratification" of its contents in a trench, now full and now empty of water, into which chips from the overhanging cliffs were continually falling, and to which every tide and every storm furnished each its quota of "jetsam."
7. The contribution which the sea in rough weather would make to the deposit in the "trench" would consist for the most part of shells derived, in a more or less triturated condition, from the Laminarian zone and somewhat deeper water.
8. After being broken by the action of floe-ice on the shore, these shells were quickly thrown into the trench; and some of the rock-dwellers would be more, and others less damaged by the floes before the waves took them in hand.
9. These, forming part of the "jetsam" thrown during storms into the trench from comparatively deep water, were insignificant in quantity relatively to the stony matter always falling into it, and to the rock-dwellers which the floes were always crushing and putting at the immediate disposition of the waves.
10. Whether broken or unbroken, nearly all the shells were thrown into the trench "alive," in which condition shells are seldom found either bored or incrustated.
11. Coming

from deeper water than the rock-dwelling Gasteropods forming so large a proportion of the deposit, they were sure to suffer more trituration than the latter from flocs on their way from comparatively deep water to the "trench." 12. If *Trophon truncatus* proves anything, it must be that the climate was colder during the accumulation of the deposit than it is to-day.

All the foregoing remarks, together with the speculation founded upon them, apply solely to the "raised beaches" of Hope's Nose and the Thatcher Rock. About the physical peculiarities of other raised beaches the author does not here pretend to speak; but if it should be admitted that the two raised beaches in question are not "beaches" at all, it is probable that other similar deposits will profitably bear re-investigation. Meanwhile, if the writer's hypothesis should stand the strain of criticism, it would appear probable that the "raised beaches" of Hope's Nose and the Thatcher Rock are phenomena marking the close of the Glacial Period in England.

DISCUSSION.

The PRESIDENT remarked that anything which might throw light on what took place in Glacial times in the non-glaciated regions of Southern England would be welcomed by geologists.

Mr. USSHER asked if the Author would not expect the stones in the beach to show some traces of glaciation if his explanation were correct. He was glad to hear that the Author considered that colder conditions prevailed during the formation of the beaches, though he himself did not think that the climate was Arctic. He instanced the occurrence, on a pinnacle 30 yards from the main cliff, of a fragment of raised-beach platform which was originally talus from the high ground behind the beach.

Prof. HUGHES was glad to hear that these were not exactly beaches, but subaerial accumulations with shells and pebbles thrown up in storms, as he had supposed from an examination of the Braunton beach, and did not therefore necessitate any considerable changes of level. He, however, saw no necessity for glacial action to account for the phenomena. *Trophon clathratus* and *Mangelia turricula* were elsewhere associated with Scandinavian shells, but he considered them to be last survivors from former colder conditions. He did not understand how the materials were thrown over the ice-foot. The materials were comparable with those of modern talus. Isolated pebbles were thrown to a great height above sea-level.

Mr. CLEMENT REID maintained that the shells were common British species. The fact that *Purpura* was less worn than the bivalves was paralleled on the ledges above modern beaches. He could not agree with Prof. Hughes as to the "raised beaches" of the south of England having been accumulated by the sea at its present level: for in Goodwood Park, 7 miles from the coast, they are found up to a height of 130 feet. The fauna of these is distinctly not Arctic.

The PRESIDENT had seen these beaches. It never occurred to him at the time that they afforded evidence of glacial conditions, though

he thought the shells showed them to be tolerably old. He thought the deposits might have been formed by agents now in operation along the same coast, though they certainly differed from any other "raised beaches" with which he was acquainted.

The AUTHOR, in reply, stated that evidence of extreme glaciation was not to be expected. He thought the "head" was formed during the passing away of glacial conditions, and referred, in corroboration of his views, to Dr. J. Geikie's work. He had seen sand and shingle thrown to a great height, but never fragments of broken shells such as those exhibited. Col. Feilden and Dr. Moss distinctly stated that materials were thrown over the ice-foot. Mr. Reid had touched the true difficulty; for there were several Southern shells, such as *Adeorbis*, present, and the general assemblage was not a northern one; but too much might easily be made of this, while he had himself relied chiefly upon the physical evidence to show that the deposit was not a true beach.

27. *On some NEW MAMMALS from the RED and NORWICH CRAGS.*

By E. T. NEWTON, Esq., F.G.S. (Read May 14, 1890.)

(Communicated by permission of the Director-General of the Geological Survey.)

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Introduction.

NOTWITHSTANDING the many additions which within the last few years have been made to our knowledge of the Pliocene Mammalian Fauna, by Mr. Lydekker, in the Quarterly Journal of this Society, in the 'Geological Magazine,' and in the British-Museum Catalogues (1885-87), several species new to the British Crags, and others altogether new to science, have come to light during a critical investigation of the Crag Vertebrata, which it has been my official duty to undertake.

As it is likely to be some time before the results of this investigation can be published, it is hoped that an account of the new forms will be acceptable to the Fellows of this Society.

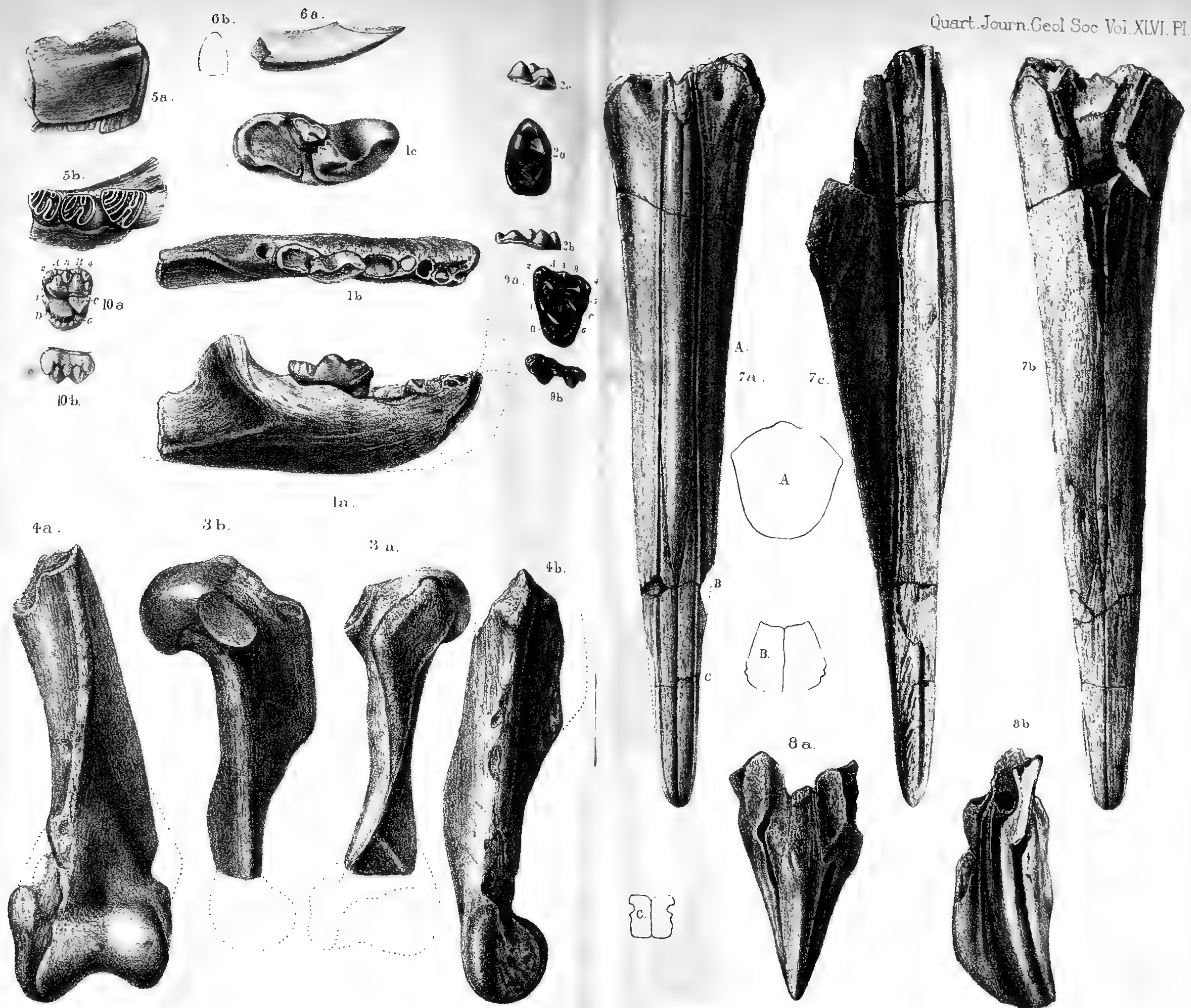
For several of the specimens here described I am indebted to the kindness of Mr. E. C. Moor, of Great Bealings, Suffolk, who has most courteously placed these and many other fossils at my disposal. Mr. James Reeve, of the Norwich Museum, has likewise been good enough to lend me many specimens, and among them the unique tooth which is now to be named after him. For the opportunity of studying the rostrum of *Mesoplodon Floweri** I am under obligation to the genial Curator of the Ipswich Museum, Dr. Taylor. To all these friends of science I tender my best thanks for their kindly assistance.

*Description of Species.*1. *LUTRA DUBIA*, Blainville. (Pl. XVIII. figs. 1 a-1 c.)

Within the last few years Mr. E. C. Moor, of Great Bealings, has obtained from the nodule-bed of the Red Crag, near Woodbridge, a right ramus of a lower jaw of an otter-like animal (fig. 1),

* Since this paper was read, the author has altered this name to *M. floris*, see p. 448.

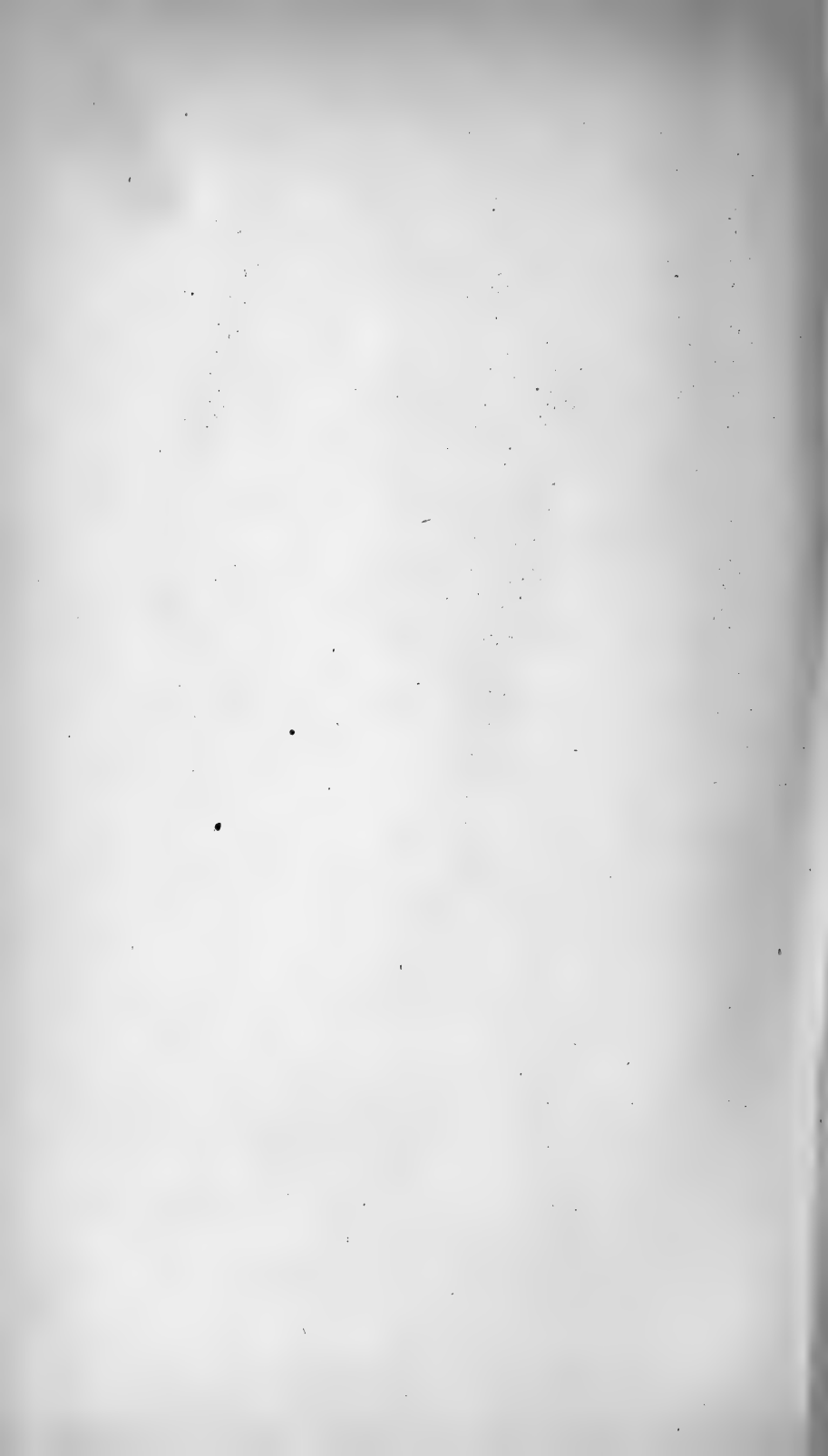




R. Minter del. et lith.

BRITISH PLIOCENE MAMMALS.

Minter Bros. imp.



which differs from *Lutra vulgaris* in having the carnassial tooth longer from before backwards, and proportionately narrower, while its inner cusp is smaller than in this recent species. The entire alveolar border is preserved, excepting that for the incisors, and measures from the back of the canine to the back of the hindmost molar 40 mm. The depth of jaw below the middle of the carnassial tooth is 17 mm. The carnassial itself is 16 mm. long, 6 mm. wide, and the crown is 5 mm. high. The number of cheek-teeth is apparently the same as in *L. vulgaris* (c. 1, pm. 3, m. 2); but the front premolar seems to have been smaller and placed more obliquely, while the hinder premolar was larger than in *L. vulgaris*. The fangs of the premolars also differ from those of *L. vulgaris* in that each tooth has the hinder fang much larger in proportion to the front one, and this is especially the case in the tooth immediately in front of the carnassial, the piece of fang remaining in the hinder alveolus of this tooth being nearly three times the size of the anterior fang. These differences prevent the Red-Crag specimen from being referred to *Lutra vulgaris*.

Lutra Valetoni, as figured by M. Filhol*, shows the alveolar border a little longer than it is in our specimen; but the carnassial tooth is proportionately smaller: moreover *L. Valetoni* has four premolars, and these approximately equal in size.

Lutra affinis, Gervais†, seems to have little to distinguish it from *L. vulgaris*.

Lutra Bravardi, Pomel‡, corresponds in size with the Red-Crag specimen; but, as the species is only represented by an upper jaw, it cannot be compared with our example of a lower jaw.

Lutra dubia, Blainv.§, from the Miocene of Sansan, bears a very close resemblance to our specimen; and I have been able to compare it more closely, as Prof. A. Gaudry has kindly sent me a cast of the type, which is preserved in the Muséum d'Histoire Naturelle at Paris. The length of the alveolar border is the same in both specimens; the carnassial teeth are as nearly as possible of the same length; the premolars have similar large posterior fangs, and decrease in size towards the front in the same manner: also the depth of the jaw below the carnassial is the same. The greatest differences observable are—that the Paris specimen has the ramus deeper below the premolars, the carnassial tooth not quite so narrow at its hinder part, and not so much curved from before backwards. The last molar also seems to be somewhat larger than the tooth could have been which occupied the hinder alveolus of the Red-Crag specimen. These differences, which are to some extent due to wearing and rolling, are not sufficient, as it seems to me, to prevent this British Red-Crag lower jaw being referred to De Blainville's *Lutra dubia*.

* Ann. Sci. Géol. vol. x. pl. vii. (1879).

† Zool. Pal. Fr. edit. 2, p. 244 (1859).

‡ Gervais, *loc. cit.* p. 243.

§ 'Ostéographie,' Genus *Mustela*, p. 76, pl. xiv.

2. *LUTRA REEVEI*, sp. nov. (Pl. XVIII. figs. 2 a-2 c.)

One of the most remarkable teeth which I have seen from the British Crags was found by Mr. James Reeve, in the lower beds of the Norwich Crag at Bramerton. This tooth (fig. 2), though small, is in a most perfect state of preservation; and, being a germ-tooth, the cusps are entirely free from facets of wearing; it consists of the enamel cap, with a layer of dentine supporting it within, and consequently the crown may have a less altitude than it would have had in the completed tooth. The length from before backwards is 20 mm., the width 10 mm., and the height 4 mm. In general contour the tooth is nearly parallel-sided; one end is flattened and the other bluntly pointed; the half corresponding to the pointed end is occupied by three cusps of nearly equal size, while the other and somewhat smaller half has a broad depressed space, with a cusp on one side and a ridge on the other; the cusp being a little smaller than either of those at the opposite end of the tooth.

The various species of Otters exhibit considerable differences in the form of their teeth; some, such as the Indian clawless Otter (*Lutra cinerea*), having broad and low-crowned teeth, of a type somewhat similar to the fossil now under examination; while others have narrower teeth, with the anterior cusps higher, and sometimes, as in the *L. hessica* lately described by Mr. R. Lydekker*, the three anterior cusps are equally developed.

Mr. Lydekker has kindly examined the Norwich-Crag specimen, and is of opinion that it belonged to a Lutrine species of a very brachyodont type, probably nearly allied to the *Lutra sivalensis*†, which also has broad-crowned teeth. Unfortunately, however, the only known example of a lower jaw of this Sivalik species has a very imperfect carnassial.

It would seem, therefore, that this Norwich-Crag tooth is a right lower carnassial of an extremely low-crowned type, with strong Lutrine affinities; and, accepting Mr. Lydekker's opinion, it is provisionally placed in the genus *Lutra*. I propose to name the species *L. Reevei*, as an acknowledgment of the services rendered to science by the worthy Curator of the Norwich Museum.

3. *PHOCA MOORI*, sp. nov. (Pl. XVIII. figs. 3 a, 3 b.)

Mr. E. C. Moor has a small left humerus of a Seal (fig. 3), wanting the lower articulation, from the nodule-bed of the Red Crag near Woodbridge. It agrees in form most nearly with the corresponding bone of *Phoca vitulinoides*, described by Prof. Van Beneden‡; but differs in being much smaller and of more slender proportions, the shaft just below the deltoid crest being especially small. Since there is no reasonable doubt that this humerus represents a new specific form, I propose to associate it with a name which has for

* Proc. Zool. Soc. 1890, p. 3.

† Pal. Indica, ser. 10, vol. xi, p. 195, pl. xxvii., and pl. xlv. fig. 3 (1884).

‡ Ann. Mus. Roy. Belg. vol. i. pt. 1, p. 72, pl. 15 (1887).

many years been connected with the preservation of Crag fossils, and to call it *Phoca Moori*.

4. *PHOCANELLA MINOR*, Van Beneden. (Pl. XVIII. figs. 4 *a*, 4 *b*.)

Prof. Van Beneden has given the above name to certain specimens from the Belgian Pliocene*, and Mr. E. C. Moor has a humerus from the nodule-bed of the Red Crag, near Woodbridge (fig. 4), which agrees so closely with the corresponding bone of *P. minor* that I have no doubt as to its belonging to the same species. The upper portion of Mr. Moor's specimen is wanting, and it is much rolled; but the general form and remarkable triangular section of the shaft agree precisely with the cast of this species preserved in the British Museum; but the peculiarities of this humerus are not so well seen in the figures given by Prof. Van Beneden †.

5. *TROGONTERIUM MINUS*, sp. nov. (Pl. XVIII. figs. 5 *a*, 5 *b*, 6 *a*, 6 *b*.)

Another interesting specimen in the possession of Mr. E. C. Moor is a right maxilla (fig. 5) of a beaver-like Rodent, also from the nodule-bed of the Red Crag, near Woodbridge. Three teeth are preserved in this fossil, the enamel-folds of which so closely resemble those of *Trogotherium Cuvieri* that I have no doubt as to its belonging to this genus; but the teeth are much smaller than in any known specimen of *T. Cuvieri*, and I do not feel justified in placing it in the same species, more especially as it comes from a lower horizon than any at which *T. Cuvieri* has yet been found.

The three teeth preserved are premolar 4 and molars 1 and 2. The grinding-surface of each of these is more or less triangular, one angle being directed backwards and outwards, while the rounded base is turned forwards. The front surface of premolar 4 is exposed, and is 18 mm. long, 8 mm. wide, and the grinding-surface is 8 mm. from back to front. Molar 1 is 16 mm. long, 6 mm. wide, and the grinding-surface 6 mm. from front to back. The length of molar 2 cannot be seen; it is 5 mm. wide and 6 mm. from front to back. Each tooth has had three enamel-folds on the outer side and one on the inner, as in *Castor* and *Trogotherium*; but they resemble those of the latter genus in being connected with the exterior of the tooth for only a short distance downwards from the summit; indeed, in each of these teeth the three outer folds have already become isolated, and the single inner fold is nearly in the same condition.

This specimen can hardly be a young example of *T. Cuvieri*, the teeth of which increase in size towards their bases, for the alveolar portion of the largest one (pm. 4) is closing in at the base to form fangs, and its greatest width is much less than in *T. Cuvieri*.

I propose to name this species *Trogotherium minus*, and in it to

* Ann. Mus. Roy. Belg. vol. i. pt. 1, p. 71 (1877).

† Loc. cit. pl. xiv.

provisionally include the incisor tooth from the Norwich Crag of Sizewell Gap, near Southwold (fig. 6), alluded to by Sir R. Owen as "Beaver"*. This incisor, preserved in the Society's Museum, has the front rounded and its enamel rugose, thus agreeing with *Trogontherium* and not with *Castor*.

6. *MESOPLODON FLORIS*, sp. nov. (Pl. XVIII. figs. 7 a-7 c, and A, B, C.) (= *Mesoplodon Floweri*, Canham, MS.)

The Rev. H. Canham, whose collection of Red-Crag fossils is now preserved in the Ipswich Museum, gave the name of *Mesoplodon Floweri* to a new form of Ziphioid rostrum which he had obtained from the Red Crag of Trimley, Suffolk. A cast of the specimen is in the Museum of the Royal College of Surgeons, and the name given by Mr. Canham is there retained for it (Flower, Cat. Vert. Mus. R. Coll. Surg., part ii. p. 562, no. 2915, 1884). This species is also noticed by Mr. Lydekker (Quart. Journ. Geol. Soc. vol. xliii. p. 15, 1887), but no description has hitherto been published. Unfortunately the specific name *Floweri* has already been used by Julius von Haast † for a recent species of *Mesoplodon*; but as the form thus designated has been shown by Prof. Flower to belong to a species previously described, it seemed to me very desirable to keep the name *M. Floweri* for this fossil Ziphioid. Since, however, the present paper was read, the Referee has pointed out that it will be far better at once to establish a new specific term; and, as by the use of Latin instead of English, the same honoured name may be kept in association with this Cetacean fossil, I propose to call the species *Mesoplodon floris* [July 1, 1890].

By the kindness of Dr. Taylor of Ipswich, I have had the opportunity of examining the original specimen (fig. 7), and propose now to give some details of its structure. In general appearance this rostrum is slender and regularly tapering, something like *M. tenuirostris* or *M. medilineatus*, but exhibiting important differences, its most striking peculiarity being the flattening of the anterior part of the upper surface, which gives to the transverse section of this region a quadrate appearance. The length of this specimen is about 420 mm. (16½ inches). The ossified mesethmoid (fig. 7 a) occupies about 285 mm. of the upper surface, and is about 23 mm. wide towards its hinder part; but it becomes narrower towards its front, the anterior third tapering away more rapidly, to end in an acute point. In front of this is a deep median groove which extends to the end of the rostrum. The mesethmoid narrows somewhat posteriorly, and its outer surface seems to consist of denser bone than the interior, probably because it is an ossification of the epichondrium, while the more cancellous interior is an ossification of the mesethmoid cartilage itself. And further, the ossification of the perichondrium is not complete towards the hinder part of the upper surface; but a median groove is left similar to

* Brit. Foss. Mamm. p. 192 (1846).

† Proc. Zool. Soc. 1876, p. 478.

that seen in *M. medilineatus*. Indications of this mode of ossification are also seen in examples of other species of this genus.

On each side of the mesethmoid there is a distinct channel, running along the upper surface of the rostrum, for about 190 mm.; it then gives off a much smaller channel, which, passing inwards, follows the tapering point of the mesethmoid, to end with its fellow of the opposite side in the median groove already noticed. Passing forward from the origin of the smaller channel, the outer wall of the larger channel becomes stronger, forming a distinct angle, which continues to the front of the rostrum, and gives it the characteristic flattened aspect, while the channel itself gradually dies out. Towards the hinder part of the specimen the maxillary region on each side is produced into an obtuse lateral angle (fig. A), which gradually subsides as it passes forwards and downwards (fig. B). At about 150 mm. from the front a channel takes the place of the ridge (fig. 7 c), and passes quite to the lower surface of the specimen. A little above and in front of this point, a much larger channel is seen issuing from under the bone and extending to the front of the rostrum; and below it there is a roughened area from which the anterior extension of the maxillary has been broken away. In the present condition of the specimen the front of the rostrum is formed solely by the two premaxillæ, which, although in contact with each other, are distinctly separated by a fissure clearly seen on the upper and under surfaces; moreover, the line of division is clearly shown on the surfaces where the snout has been broken across (figs. B, C). The boundary separating the maxilla from the premaxilla is seen on the upper surface towards the hinder end (fig. 7 a) as well as in front (fig. 7 c); but in the intermediate region no such boundary can be traced.

The openings of the premaxillary canals are on the upper surface (fig. 7 a) near the posterior extremity of those bones; and in a hinder view of the specimen the apertures of two other large canals may be seen on each side.

Near the middle of the rounded lower surface (fig. 7 b) there is a lenticular area, which is probably an exposure of the vomer, and on each side of it is the opening of a canal; while towards its front part may be seen the sutures separating the maxillæ from the premaxillæ.

The end of a rostrum figured by Van Beneden and Gervais* as *Ziphiopsis servatus*, Du Bus, bears some resemblance to Mr. Canham's specimen in the flattening of its upper surface; but the narrowing of the hinder part of this region is an indication of important structural differences. Moreover, *Ziphiopsis* or *Choneziphius*, with which it is now included, has the mesethmoid more or less unossified, and not appearing on the upper surface of the rostrum.

None of the specimens of *Mesoplodon*, either recent or fossil, so far as I can ascertain, present the same peculiar conformation of

* Ostéogr. Cétacés, pl. xxxvii. bis, fig. 8.

the front of the rostrum as that which is seen in Mr. Canham's example, and he is no doubt right in regarding it as a new species.

7. *MESOPLODON SCAPHOIDES*, sp. nov. (Pl. XVIII. figs. 8 a, 8 b.)

The Ziphoid rostrum from the nodule-bed of the Red Crag, near Woodbridge, now to be described is preserved in the Museum of Practical Geology, and is one of the most aberrant forms yet known from this deposit. The rostra hitherto described from the Red Crag are more or less elongated forms, some being very long and attenuated; the present specimen, however, is remarkable for being extremely short and proportionately deep. When seen from above (fig. 8 a), it has the form of a triangle, the hinder part forming an irregular base, about three inches wide; and the sides passing almost straight to the front to meet in a sharp edge.

The greatest length of this specimen is about five and a quarter inches. In a side view (fig. 8 b, $\frac{1}{3}$ nat. size) the hinder part is seen to be about one inch and three quarters deep; but it increases anteriorly to about two and a quarter inches; the front margin curving upwards like the prow of a boat. The mesethmoid is completely ossified, and in a back view its outline is clearly defined: its hinder end having a deep fossa which may have lodged the front of the internasal septum; its lower margin is received into a trough of what is doubtless the vomer. Anteriorly the vomer itself seems to be covered in by downward processes of the maxillæ; but all the bones of the front part of this rostrum are so completely coëssified that the divisions between them are entirely obliterated. At the hinder part of the upper surface there are some indications of a division between the mesethmoid and the premaxillæ; also on the right side there is a line which may indicate the junction of the hinder part of the maxilla and premaxilla.

On the upper surface posteriorly are the apertures of two large, covered canals, which evidently correspond with those in Professor Huxley's figures of *Belemnoziphius compressus**, marked with the letters *a, a*. On the right side the covering is broken away, but it is retained on the left. These canals, passing downwards and forwards, soon become open channels, running along the sides of the premaxillary region, and turning a little upwards they become wide and shallow at the front of the rostrum. If one of these premaxillary canals, as they may be called, is followed backwards under the bony covering, it will be found to bifurcate; one of the branches passing upwards and backwards is the canal already noticed, which issues at the aperture, and may be further traced as a shallow depression passing backwards over the premaxilla; the second branch is directed downwards and backwards, and after a short course opens, fig. 8 b, into a large cavity, partly preserved on the right side (seen in fig. 8 b), but better defined on the left. From each of these

* Quart. Journ. Geol. Soc. vol. xx. pl. 19.

cavities, which seem to be situated in the maxillary bones, issue several canals. The most clearly defined of these is the one alluded to above as the premaxillary canal; a second (as seen in fig. 8 *b*), passing almost directly forward on the outermost edge of what seems to be the maxilla, may be termed the maxillary canal, and is best seen on the left side; from the lower part of the cavity a third channel may be seen passing forwards; and, then curving upwards, it extends as a shallow groove to the end of the rostrum; this may be termed the submaxillary canal; and from about the middle of this latter canal a subsidiary groove may be seen branching off below it. These three canals, seen on the sides of the specimen, evidently correspond with those described by Prof. Huxley in *Belemnoziphium compressus*, and seem to be present, more or less covered in by bone, in all the rostra referable to *Mesoplodon*.

From the cavity on the right side of the specimen another large canal passes upwards and backwards; but on the left side a much smaller canal seems to occupy a similar position in the maxilla.

Each of the large cavities in all probability lodged a ganglion of the fifth nerve, the branches of which passed out through the various apertures and canals.

When first examining this specimen I thought it might be a much denuded portion of the more elongated rostrum of another species; but a closer attention has convinced me that, although much abraded (as indeed are almost all the fossils from the same deposit), it is as much to be relied upon for its main features as are most of the forms hitherto described.

The complete ossification of the mesethmoid being one of the chief characters of *Mesoplodon*, this specimen must be placed in that genus; and the short rostrum, with its sharp boat-like anterior extremity, is so entirely different from any form yet described that it becomes necessary to give it a specific designation by which it may in future be known, and it is proposed to name it *Mesoplodon scaphoides*.

8. *AILURUS ANGLICUS*, Dawkins. (Pl. XVIII. figs. 9 *a*, 9 *b*.)

Prof. Boyd Dawkins described before this Society in 1888* a portion of a lower jaw with the carnassial tooth in place, from the Red Crag of Suffolk, which he referred to the genus *Ailurus*, and named *A. anglicus*. In the discussion which followed the reading of the paper, Dr. Blanford called attention to the restricted distribution of this genus, and to its affinities with the American Racoons; he thought Prof. Dawkins's reference was possibly correct, but that one tooth was scarcely sufficient to go upon, and on the whole the determination would require confirmation. I am happy to say we have now some additional evidence.

Mr. Percy H. Browne, of Reigate, has recently presented to the Museum of Practical Geology a perfect upper molar tooth, from the

* Quart. Journ. vol. xlv. p. 228.

lower part of the Red Crag (nodule-bed), near Boyton. This tooth being unlike anything hitherto known from the Crag, was awaiting determination, when Mr. Lydekker saw it and, recognizing its resemblance to the tooth of *Ailurus fulgens*, kindly lent me a skull of this recent species for close comparison; it is to Mr. Lydekker, therefore, that we are indebted for the first identification of this tooth. On comparing the specimen with the left, upper, first true molar of *Ailurus fulgens* (see Pl. XVIII. figs. 10 a, 10 b), the resemblance between them in the form and position of all the cusps and tubercles is most striking. On the outer side are two cusps (A, B, the front one being the larger of the two), which have a strong ridge running down their anterior and posterior surfaces; a third cusp, c, placed within and near to the hinder one, is flattened on the outer aspect and rounded on the inner, while ridges pass from its summit downwards and outwards towards the outer cusp. The inner portion of the crown is occupied by a cusp, d, larger than either of the others, from which a ridge extends forwards and outwards to join a large tubercle, 1, situated upon the front of the tooth. This tubercle, in common with all those now to be mentioned, forms part of a strong cingulum, which may be traced round the crown. On the outer side of the tooth are three large tubercles, one (2) before, one (4) behind, and one (3) between the two cusps; and at the back of the tooth, between the outer and inner cusps, is another smaller tubercle (5). The inner part of the tooth is rounded, with the cingulum particularly well marked, and towards its hinder part developed into one or two small tubercles (6). In all these particulars the fossil and recent teeth are precisely similar; with only such trifling differences as might be due to individual variation, the greatest being the absence, in the recent tooth, of the small tubercle marked 5 in the fossil.

It will be remembered that the lower tooth of *Ailurus anglicus* was described as about one third larger than that of *A. fulgens* (i. e. 70 mm. and 48 mm.); and the upper tooth, now described, has the same proportion to the first upper molar of that species; its length from before backwards, however, is greater in proportion to its width, as will be seen by the following measurements:—

	<i>A. fulgens.</i>	<i>A. anglicus.</i>
Upper m. 1, length from before		
backwards	9·5	14·5 millim.
Upper m. 1, width	11·5	14·5 millim.

The height of the crown and cusps in the fossil is proportionately less than in the recent form, and in this particular corresponds with the lower tooth described by Prof. Boyd Dawkins. Another peculiarity of the upper tooth is that the bases of all the cusps are strongly grooved or striated, a character which is only seen to a very slight extent in *A. fulgens*.

This tooth is of itself sufficient to establish the presence in the Red Crag of a species closely allied to *Ailurus fulgens*; and, as it

agrees in size with *Ailurus anglicus*, we can scarcely do otherwise than associate it with the latter species.

A portion of a lower jaw, which, like the type, is in the Reed Collection, York Museum, and from the Red Crag near Woodbridge, is also referred to *A. anglicus*. The high position of the articular condyle, the deeply curved lower margin, and the high and large coronoid process agree with *A. fulgens*; while the flattened alveolus for the hinder fang of the last molar is like what is seen in the type specimen of *A. anglicus*.

EXPLANATION OF PLATE XVIII.

- Fig. 1 *a*. *Lutra dubia*, Blainv. Right ramus of lower jaw: natural size. From the nodule-bed of the Red Crag near Woodbridge. In the collection of Mr. E. C. Moor, of Bealings.
- 1 *b*. Same, seen from above.
- 1 *c*. Carnassial tooth, seen from above, and enlarged.
- 2 *a*. *Lutra Reevei*, sp. nov. Right lower, carnassial tooth, seen from above: natural size. From the Norwich Crag of Bramerton. In the collection of Mr. James Reeve, of Norwich.
- 2 *b*. Same, seen from outer side.
- 2 *c*. Same, seen from before.
- 3 *a*. *Phoca Mocri*, sp. nov. Left humerus, front view: natural size. From the same horizon and collection as fig. 1.
- 3 *b*. Same, side view.
- 4 *a*. *Phocanella minor*, Van Beneden. Left humerus, front view: natural size. Same collection and horizon as fig. 1.
- 4 *b*. Same, side view.
- 5 *a*. *Trogotherium minus*, sp. nov. Right maxilla, outer surface: natural size. Same horizon and collection as fig. 1.
- 5 *b*. Same, grinding-surface of teeth.
- 6 *a*. *Trogotherium minus*, sp. nov. Lower incisor: natural size. From the Norwich Crag, Sizewell Gap, near Southwold; in the Museum of the Geological Society. Provisionally referred to this species.
- 6 *b*. Same, transverse section.
- 7 *a*. *Mesoplodon floris*, sp. nov. Rostrum, seen from above: one third of the natural size. From the Red Crag of Trimley, Canham Collection, Ipswich Museum.
- 7 *b*. Same, seen from below.
- 7 *c*. Same, right side view.
- A, B, C. Transverse sections at points indicated in fig. 7 *a*.
- 8 *a*. *Mesoplodon scaphoides*, sp. nov. Rostrum, seen from above: one third of the natural size. From the nodule-bed of the Red Crag near Woodbridge. In the Museum of Practical Geology.
- 8 *b*. Same, right side view.
- 9 *a*. *Ailurus anglicus*, Dawkins. Left upper, first true molar: natural size. From the nodule-bed of the Red Crag near Boyton. Presented to the Museum of Practical Geology by Mr. P. H. Browne.
- 9 *b*. Same, outer view.
- 10 *a*. *Ailurus fulgens*, F. Cuv. (Recent.) Left upper, first true molar: natural size. From specimen in possession of Mr. R. Lydekker. For comparison with *A. anglicus*.
- 10 *b*. Same, outer view.

28. A MONOGRAPH of the POLYZOA (BRYOZOA) of the RED CHALK of HUNSTANTON. By GEORGE ROBERT VINE, Esq. (Read March 26, 1890.)

(Communicated by Prof. P. M. DUNCAN, F.R.S. &c.)

[PLATE XIX.]

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 - § II. Cheilostomata, *Busk*.
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- Explanation of Plate XIX.

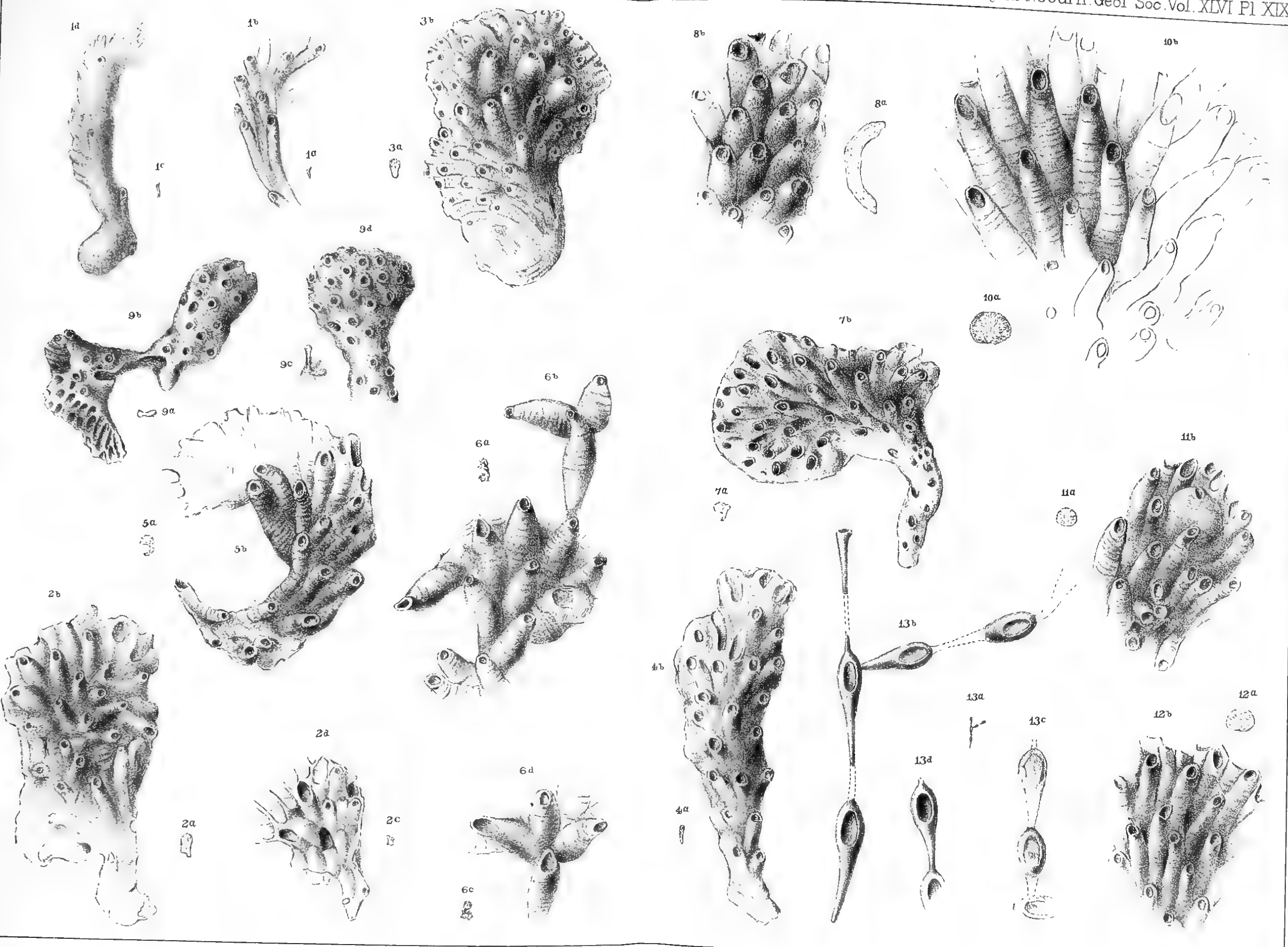
I. INTRODUCTION.

It is not my intention in this monograph to discuss any of the stratigraphical questions raised by authors who have written about the Red Chalk of Hunstanton. I have to deal with one group of fossils only; but, before entering on my investigations, it was necessary to make myself familiar with the views of others, and more especially with the palæontological evidence afforded by the study of the fossils from the various zones of the Chalk. One source of information has been, however, more helpful to me than all the others. When compiling material for my British-Association Reports on Fossil Polyzoa*, I was allowed to examine all the type series in the Museum of Practical Geology, from the Cambrian to the Upper Chalk; and recently (September 1889) I have re-examined, for the purpose of this and another paper on the Polyzoa of the Upper and the Lower Greensands (Bibliographic List, 21; see page 458), all the Cretaceous forms mentioned in the Catalogue of that Museum (Bibliogr. 12). Besides the examination of these forms Mr. Alfred Bell has placed in my hand for study and description a fine series of Polyzoa preserved on flints, as well as free examples,

* Brit. Assoc. Reports, 1880-1885.







POLYZOA OF THE RED CHALK.

Geo West & Sons del lith et imp.

from the Upper Chalk at Chatham. Thanks to the kindness shown towards me by Prof. Judd, F.R.S., and Dr. Pergens, of Belgium, I have been enabled to study the Polyzoa of the Faxoe Limestone and Maastricht Beds, by the gift of beautiful examples derived from these typical horizons of Cretaceous Polyzoa.

In the 'Catalogue of the Cretaceous Fossils in the Museum of Practical Geology,' 1878, we have lists of a fair assortment of British examples from several horizons, but there are many unavoidable blanks. Out of nine Cretaceous divisions given in the Catalogue, in four important sections there is no mention of a Polyzoan fauna. In the Neocomian (Lower Greensand) division (pp. 6, 7) much of the material is still unworked; but at least twenty-one forms are named specifically. These belong to the following genera: *Stomatopora*, Bronn; *Proboscina*, Audouin; *Diastopora* and *Entalophora*, Lamouroux, together with species of *Ceripora*, *Heteropora*, and *Radiopora*. The locality from which most of these Polyzoa were derived was Faringdon, but other localities are mentioned. In the Gault (pp. 26 *et seq.*) there is no record of Polyzoa; but in the Blackdown series (p. 39) there are four entries under the head-line "Polyzoa." In the Upper Greensand (Cenomanian, pp. 49-50) there are fifteen species named, besides references to others, most of which are from Warminster. In the Cambridge Greensand, Chloritic Marl, and Red Chalk there is likewise no mention of Polyzoa. In the Lower Chalk (p. 83) two references are given; and in the Upper-Chalk division of the Catalogue (p. 95) twelve species are named in full.

It is hard to account for this poverty of a polyzoan fauna in many of our own Cretaceous beds otherwise than by supposing that probably it arises from other causes than mere absence, and one of the chief may be that of British workers on the group being so few. In foreign localities the Cretaceous beds have been well worked, the upper divisions especially, and the number of species described by Goldfuss, von Hagenow, d'Orbigny, von Reuss, and others, though considerable, are still being added to by persistent and careful research, whilst our own strata are at present characterized as poor in Polyzoa.

Independently of the species catalogued as existing in the Museum of Practical Geology, or referred to by Morris in his 'Catalogue of British Fossils,' lists of Polyzoa from certain British Cretaceous horizons below the Upper Chalk are extremely rare, and I am not aware that any exist except those mentioned below. Mr. Etheridge, F.R.S., gives* the following summary of known Cretaceous Polyzoa:—

Upper Chalk . . .	38	genera,	50	species.
Lower Chalk . .	6	"	6	"
Chalk-marl . . .	1	genus,	1	"
Cenomanian . . .	15	genera,	24	"
Gault	3	"	4	"
Neocomian . . .	21	"	34	"

* Philips, 'Manual of Geology and Palaeontology,' vol. ii. 1885, p. 581.

The four Gault forms are distributed thus:—

Genus <i>Berenicea</i> . . .	two species.
„ <i>Ceriacava</i> . . .	one „
„ <i>Retepora</i> . . .	one „

With a catalogue like this it is impossible to give satisfactory ranges of species in British Cretaceous rocks.

The Rev. T. Wiltshire, in his paper on the Red Chalk of England (Bibliography, 3), names only one species, *Diastopora ramosa*, as found by him in the Hunstanton Chalk, and two other forms, *Idmonea dilatata*, d'Orb., and *Ceripora spongites*, Goldf., from Speeton. Neither Prof. Seeley (Bibliograph. 14 and 15) nor Prof. Judd (Bibliograph. 16), in any of their papers on the Hunstanton rocks, mention Polyzoa in their lists of fossils; and the same remark will apply to the two more recent papers on the lower beds of the Upper Chalk, by Messrs A. J. Jukes-Browne and William Hill (Bibliograph. 38 and 39). My own papers on *Lichenopora? paucipora* (Bibliograph. 18) and Notes on the Polyzoa of the Cambridge Greensand (Bibliograph. 19) called the attention of palæontologists to the probable existence of many undescribed forms in the cabinets of collectors. Some additions I was enabled to make through the kindness of T. Jesson, Esq., F.G.S., who overhauled his cabinet of Gault and Cambridge-Greensand fossils for that purpose; and the forms now to be described and illustrated I owe to the same careful collector. Already Mr. Jesson has placed in my hands over 1000 fossils, from the Red Chalk of Hunstanton, on most of which encrusting forms of Polyzoa are found; whilst others from the Gault and Chalk-marl still await special attention. The groups of fossils submitted to me for examination belong to the following:—

- Nautilus and Ostrea species;
- Ammonities, several species;
- Echinodermata and Belemnites;
- Inoceramus, *I. concentricus* and *I. Crispii*;
- Terebratula, *T. biplicata*, Sby., and *T. capillata*, d'Arch.

On the Inocerami and Ammonites, the best *Diastopora* and *Proboscina* are found; but the most abundant of all the individuals examined are the *Stomatopora*, on *Terebratula biplicata* chiefly. Species of *Entalophora*, *Idmonea*, and *Ceripora* are very rare, while Lichenoporidae are either rare or badly preserved. Cheilostomatous forms, individuals or species, are also very rare.

In the present monograph, on account of the peculiarities of the Cretaceous fauna, I have been obliged to limit or redefine the generic terms employed. Since the publication of Mr. Busk's British-Museum Catalogues (1854), the Polyzoa, both recent and fossil, have been studied much more systematically than previously, and the names of Reuss, Manzoni, Novák, Marsson, Pergens, Waters, Walford, and many others are especially suggestive of arrangements in grouping, more or less advantageous in a palæontological sense. Since the publication of the Rev. T. Hincks's 'British Marine

Polyzoa' his family-arrangement of the Cyclostomata has been accepted, either intact or modified in the smaller divisions, by competent authorities working on fossil groups more especially. Thus, Dr. Pergens, while working along the lines of Hincks, generally adds to or modifies the family-arrangement according to circumstances; so also Mr. Waters, working along the same lines, suggestively leaving out the family grouping, arranges genera only, and formulates two convenient sections, in either of which fossil and recent Cyclostomata can be appropriately placed. The family-arrangement of the Cyclostomata, as adopted by Dr. Marsson*, is both novel and peculiar, but cannot be dealt with so fully as I could wish in the present memoir. The author established two divisional types to include the Rügen species of Cretaceous Polyzoa:—I. The SOLENOPORINA, Marsson, embracing six well-known Family-groups; and II. The METOPORINA, Marsson, in which he places, in the Family CEIDEA, the genus *Filicea*, d'Orb., and in the Family ELEIDEA the heretofore much misunderstood genera, *Melicertites*, Römer, and *Nodelea*, d'Orb.

I am aware of the nomenclatural difficulties which Mr. E. A. Walford had to encounter in his Liassic paper (Bibliograph. 29), and also in his more recent memoir on the "Inferior-Oolite Bryozoa" (Bibliograph. 30). It is not only difficult, but almost impossible to arrange fossil Polyzoa occurring in and below the Chalk under the modern family-grouping. The Tubuliporidae of Hincks include *Stomatopora*, *Tubulipora*, *Idmonea*, *Entalophora*, and *Diastopora*. In one sense certainly this grouping is convenient, but the difficulty referred to above is in making *Stomatopora* a multiserial as well as a uniserial group. By accepting the genus *Proboscina*, I find that I can arrange the biserial *Stomatopora* of the Red Chalk, and keep in accord with the Liassic and Jurassic features of typical forms: whereas by accepting recent biserial *Stomatopora* as typical expressions we altogether ignore facial differences that ought to be recognized, palæontologically at least. Undoubtedly in Mesozoic rocks generally uniserial *Stomatopora* gradually glide into *Proboscina*, as *Proboscina* in some few cases fades into *Diastopora*. To formulate mere arbitrary divisions, therefore, in the present state of our knowledge is useless; yet the study of fossil Polyzoa will be greatly facilitated if, understanding these peculiarities, the student accepts certain generic terms as expressions of growth rather than as fixities. The uniserial *Stomatopora* of the Red Chalk are, however, a distinct group of fossils, and they very rarely, if ever, pass into biserial forms. The *Proboscina*, as a matter of course, begin their existence as uniserial *Stomatopora*; but very early in their development they pass into bi- and multi-serial varieties. The *Diastopora* of the Red Chalk also have the occasional Proboscinal features; but the disc-like character of the genus is very constant in all those forms which I place in that division. I have studied these varied and varying changes in all the forms indicated, on

* Die Bryozoen der weissen Schreibkreide der Insel Rügen, 1887, p. 8.

account of the multiplicity of the material placed in my hands ; but it would be impossible for students to formulate for themselves other than the arbitrary divisions given by Busk and Hincks.

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1845 }
-46. } 4. VON REUSS, Verstein. böhm. Kreideform.
1847. } 5. VON REUSS, Polyp. Wiener Tertiärbeckens.
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Other works have been consulted for special details, but the above (chiefly the Palæontological) have been constantly referred to for description of species and the ranges of particular fossils.

III. KNOWN RANGES OF POLYZOA IN THE RED CHALK.

	Cambridge Gault.	Cambridge Greensand.	Chalk Marl.	Upper Chalk.	Red Chalk.	Middle Bed.	Top Beds.
Order POLYZOA, <i>Bush.</i>							
§ I. Suborder CYCLOSTOMATA, <i>Bush.</i>							
Genus STOMATOPORA, <i>Bronn.</i>							
1. gracilis, <i>Edwards</i>	*		
2. divaricata, <i>Reimer</i>	*		
3. granulata, <i>Edw.</i>	*		
4. —, var. A (<i>S. incrassata</i> , <i>d'Orb.?</i>)	*		
5. ramea, <i>Blainville</i>	*		
6. longiscata, <i>d'Orb.</i>	*	...	*?
7. linearis, <i>d'Orb.</i>	*		
Genus PROBOSCINA (<i>Audouin</i>), <i>d'Orb.</i>							
8. angustata, <i>d'Orb.</i> & varr.	*	*		
9. rugosa (?), <i>d'Orb.</i>	*	*		
10. irregularis, sp. nov. & var. A	*	...	*
11. uberrima, sp. nov.	*		
<i>gracilis</i> (?), <i>Reuss.</i>	*		
12. —, var. <i>Reussii</i> , nov.	*		
13. subelegans, <i>d'Orb.</i>	*		
14. hunstantonensis, sp. nov.	*	* ₃	
15. —, var. <i>ampliata</i> , nov.	*	*	
16. <i>Jessoni</i> , sp. nov.	*		
17. <i>gigantopora</i> , <i>Vine</i>	*?	*		
<i>bohemica</i> (?), <i>Novák.</i>	*		
18. —, var. nov.	*		
19. <i>Toucasiana</i> (?), <i>d'Orb.</i>	*		
20. <i>ramosa</i> (?), <i>d'Orb.</i>	*		
<i>dilatata</i> (?), <i>d'Orb.</i>	*		
21. —, var. <i>cantabrigiensis</i> , <i>Vine</i>	*	?		
Genus DIASTOPORA, <i>Lamx.</i>							
22. <i>hunstantonensis</i> , sp. nov.	*	...	*?
23. —, var. A, nov.	*	...	?
24. <i>fœcunda</i> , <i>Vine</i>	*	*		
25. <i>regularis</i> , <i>d'Orb.</i>	*		
26. <i>radians</i> (?), <i>Novák</i> , var. ?	*		
27. <i>papillosa</i> (?), <i>Reuss</i>	*		
28. <i>Jessoni</i> , sp. nov.	*		
Genus UNITUBIGERA, <i>d'Orb.</i>							
29. <i>papyracea</i> , <i>d'Orb.</i>	*		
Genus ENTALOPHORA (?), <i>Lamx.</i>							
30. sp.	*		
Genus HETEROPORA (?), <i>Blainv.</i>							
31. sp.	*		
Genus CERIOPORA (pars), <i>Goldf.</i>							
32. <i>micropora</i> (?), <i>Goldf.</i>	*	*	

TABLE (continued).

	Cambridge Gault.	Cambridge Greensand.	Chalk Marl.	Upper Chalk.	Red Chalk.	Middle Bed.	Top Beds.
Genus REPTOMULTICAVA, <i>d' Orb.</i>							
33. simplex (?), <i>d' Orb.</i>	*		
34. collis (?), <i>d' Orb.</i>	*		
Genus ZONOPORA, <i>d' Orb.</i>							
35. irregularis (?), <i>d' Orb.</i>	*
36. variabilis (?), <i>d' Orb.</i>	*
Genus MULTICRESCIS, <i>d' Orb.</i>							
37. variabilis (?), <i>d' Orb.</i>	*
Genus UNCICAVEA, <i>d' Orb.</i>							
38. collis, <i>d' Orb.</i>	*		
§ II. Suborder CHEILOSTOMATA, <i>Busk.</i>							
Genus MEMBRANIPORA, <i>Blainville.</i>							
39. gaultina, sp. nov.	*	...	*	...	*		
40. fragilis (?), <i>d' Orb.</i>	*		
41. elliptica (?), <i>v. Hagencw</i>	*		
42. obliqua, <i>d' Orb.</i>	*		
Genus HIPPOTHOA, <i>d' Orb.</i>							
43. simplex, <i>d' Orb.</i>	*		

IV. DESCRIPTION OF SPECIES.

POLYZOA, *Busk.*§ I. Suborder CYCLOSTOMATA, *Busk.*= *Bryozoaires centrifuginés* (in part), *d'Orbigny.*§ A. PARALLELATA, *Waters.*

Zoaria encrusting, dendroid, or anastomosing. *Zoarium*, to a large extent, formed of the walls of the *Zoecia*.

Genus STOMATOPORA, *Bronn.*1821. *Alecto*, *Lamouroux* = *Aulopora* (part), *Goldf.*1825. *Stomatopora*, *Bronn.*1852. *Stomatopora* (for uniserial species), *d'Orbigny.*

The uniserial *Stomatopora* of the British Cretaceous rocks have been variously identified and treated of by different authors. In the earlier days of palæontological investigation only a limited number of works, dealing with the Polyzoan group of fossils, could

be referred to with any degree of authority. Lamouroux and Goldfuss, however, were soon followed by Bronn, Michelin, Blainville, and Milne Edwards; and as these writers professedly dealt with Cretaceous Bryozoa, among others, names established by them gradually found their way into British scientific (paleontological) literature. The earlier names for the *Stomatopora* were *Alecto*, Lamx., and *Aulopora* (in part), Goldf., and for a long time these had precedence over the now generally accepted term *Stomatopora*, Bronn. Amongst foreign authors antecedent to d'Orbigny the names of v. Reuss, Rømer, and v. Hagenow are justly remembered as specialists who have materially advanced our knowledge of Cretaceous Polyzoa. The publication of d'Orbigny's 'Paléontologie Française,' with an atlas of 200 plates, inaugurated a new epoch in the history of Polyzoan groupings, and any one who undertakes to describe British Cretaceous Polyzoa should be familiar with d'Orbigny's beautiful illustrations of the French Cretaceous species, however independently his elaborate, but almost unmanageable, classification may be criticized or disregarded.

As regards British Cretaceous *Stomatopora*, Prof. Morris (1854), 'Catalogue of British Fossils,' records two species only—*Alecto gracilis*, Edw., and *A. ramea*, Blainville. Mr. Woodward, in his 'Geology of Norfolk,' records *A. gracilis*, Edw., from the Norfolk Chalk; and Lonsdale, in Dixon's 'Geology of Sussex,' *A. gracilis* and *A. ramea* from the Upper Chalk of Kent and Sussex. Since the publication of these names very little has been done, specifically, to increase the number of forms, but in the 'Catalogue of the Museum of Pract. Geol.' 1878, *Alecto reticulata*, d'Orb., is adopted as the name of a Lower-Greensand Polyzoan. In Mr. Etheridge's summary, however, of the Organic Remains of the Cretaceous Strata (Bibliography, 26, p. 589), only two species of *Alecto* are recorded, both in the Upper Chalk.

In working out the uniserial *Stomatopora* of the Red Chalk, I have, to a large extent, followed the leading of d'Orbigny. In some few cases I have not been able to adopt his names wholly for other groups; and to prevent confusion, or misconception even, as to the value of the Red-Chalk fauna generally, I have created a few new names, varietal or specific, for forms which merited this distinction.

D'Orbigny describes, and illustrates by a number of figures, the following species of *Stomatopora* as belonging to the French Cretaceous series. British species are marked with *.

- *1. *Stomatopora granulata*, Bronn, p. 836, pl. 628. f. 5-8.
- *2. — *incrassata*, d'Orb., p. 837, pl. 628. f. 9-11.
3. — *subgracilis*, d'Orb., p. 838, pl. 629. f. 1-4.
- *4. — *linearis*, d'Orb., p. 838, pl. 629. f. 5-8.
- *5. — *longiscata*, d'Orb., p. 839, pl. 629. f. 9-11.
6. — *plicata*, d'Orb., p. 839, pl. 629. f. 12-15.
- *7. — *divaricata*, Rømer, p. 840, pl. 629. f. 16-18.
- *8. — *reticulata*, d'Orb., p. 841, pl. 630. f. 1-4.
9. — *calypso*, d'Orb., p. 841, pl. 630. f. 5-8.
- *10. — *ramea*, Blainville, p. 842, pl. 630. f. 9-12.
- *11. — *gracilis*, Edwards, p. 843, pl. 758. f. 17-18.

1. STOMATOPORA GRACILIS (Edwards).

1838. *Alecto gracilis*, Edw. Ann. Sc. nat. (9) p. 207, pl. 46. f. 2.

1848. *Stomatopora gracilis*, Bronn, Index Palæont. p. 1202.

1850. *Alecto gracilis*, Lonsd. in Geol. Sussex, p. 269, pl. xviii. A, f. 1.

1852. *Stomatopora gracilis*, D'Orb. Terr. Crét. v. p. 843, pl. 758. f. 17, 18.

1883. *Stomatopora gracilis*, Vine, Brit. Assoc. Rep. Foss. Polyz.

Zoarium delicate, wholly adherent; branches dichotomizing irregularly, and rather variable in breadth. *Zoecia* uniserial, originating from a disk-like base, from which two cells are generally thrown off, and these form the nucleus of two distinct branches; cells slightly lateral at their points of juncture with the parent cell, aperture circular, occasionally oval, even when not worn; turning alternately to the right and left, but sometimes pointing upwards. *Gonæcium* — ?

Habitat. On *Terebratulula biplicata*, Sow., *Inoceramus*, &c. *Fossil* No. 1 A. There are several other colonies and species on this specimen.

Horizon. Red Chalk, Hunstanton.

This is by far the most delicate and most abundant of all the uniserial *Stomatopora* in the Red Chalk of Hunstanton. It is not always possible to make out the *zoecial* details, or ramifications, of this interesting species on account of the secondary incrustations, which very often obscure the delicate branches. I have, however, been rather successful in defining several small colonies (one with the basal originating disc), which were adherent on a variety of fossils. The fossil marked No. 1 has on it many other colonies; and the same fossil bears the type species of *Diastopora hunstantonensis*, described further on. It may be well to keep the Red-Chalk *S. gracilis* separated, as a variety, from the more robust form found in the Upper Chalk. D'Orbigny characterizes the species as the least in dimensions of all the uniserial *Stomatopora* known to him, and he states that the diameter of the branches is $\frac{1}{5}$ millim. The branches of the Red-Chalk examples are, generally speaking, of about the same dimensions, but others are more delicate.

2. STOMATOPORA DIVARICATA (Rœmer).

1840. *Aulopora divaricata*, Rœm. Ool. ii. p. 15, pl. 17. f. 3.

1841. *Aulopora divaricata*, Rœm. Kreid. p. 18.

1847. *Alecto divaricata*, d'Orb. Prod. ii. p. 175.

1848. *Stomatopora divaricata*, Bronn, Index Palæon. p. 1201.

1850. *Alecto brevis*, d'Orb. Terr. Crétac. v. pl. 629. f. 16-18.

1852. *Stomatopora divaricata*, d'Orb. Terr. Crét. p. 840, pl. 629.

1872. *Stomatopora divaricata*, Reuss, Pläner*, p. 112, pl. 28. f. 1, 2.

Adherent to a large number of fossils, many of them species of *Inoceramus* and *Terebratulula*, is a blunt or stunted *Stomatopora*.

* Bibliographic List, No. 10, p. 458.

The forms are not altogether unlike the *Hippothoa inflata*, Hall, a Silurian species referable, says Dr. H. A. Nicholson, to *Stomatopora*, as this genus is usually understood*. In the Jurassic rocks there are similar stunted forms; but, as these have not been described as yet, I cannot refer to them more minutely. The example that I have selected for description is adherent to one of the smaller fossils; but some of the best examples are found on those that are larger. *Zoarium* rarely bifurcating, branches linear or twisted, occasionally anastomosing. *Zoecia* short and plump, with aperture considerably less than the diameter of the cell; length of zoecia generally about $\frac{1}{2}$ millim., and rather less in breadth.

Habitat. Type, on *Terebratula biplicata*. Fossil No. 2.

Horizon. Red Chalk, Hunstanton.

This little Polyzoon is one of the most peculiar that I have met with in the Red Chalk, and for a long time I was inclined to regard it as belonging to some other group of fossil organisms. In the type form I have been able to detect the small orifices in some of the cells, and, in an example on one of the larger fossils, a more perfect cell.

3. STOMATOPORA GRANULATA (Edwards).

1838. *Alecto granulata*, Edw. Sur les Cris. &c. pl. xvi. f. 3, 3a.

1852. *Stomatopora granulata*, Bronn, 1848; d'Orb. Terr. Crét. v. p. 836, pl. 628. f. 5-8.

1875. *Alecto granulata*, Busk, Brit. Mus. Cat. pt. iii. pl. 32. f. 1.

1880. *Stomatopora granulata*, Hincks, Brit. Marine Polyzoa.

1889. *Stomatopora granulata*, Waters, Quart. Journ. Geol. Soc. vol. xliii. p. 341.

Zoarium variable in shape and in the general arrangement of its anastomosing branches. *Zoecia* uniserial, nearly uniform in breadth, oral extremity occasionally erect and free; surface of zoecia punctured in the younger, granular in the older colonies. *Gonæcium* (?) a cell rather more inflated beneath the aperture than ordinary *zoecia*. Diameter of branch from $\frac{2}{3}$ to 1 millim.

This species is not abundant in the Red Chalk, but I have met with some good fragmentary examples. It is almost useless to compare the fossil with recent examples of the species, or even with New-Zealand Tertiary species and variety †. Mr. Waters (Bibliogr. 24), however, includes in his synonymy of *S. granulata* a large variety of forms that may be facially united. If I were to do the same with the fossils before me, my labours would be less irksome, for it is indeed difficult to keep *S. ramea* and *S. incrassata*, d'Orb., apart if we study the illustrations only. In dealing with the fossils the case is different, and in all my descriptions it must be understood that I describe and illustrate the Red-Chalk fossils

* See Ann. & Mag. Nat. Hist. ser. 4, vol. xv. Feb. 1875, pl. xi. f. 1-3; and 'Manual of Palæontology,' edit. 1890, vol. i. p. 637.

† Mr. Waters's variety, before me while I write, has been lent to me by Miss E. C. Jelly.

only, using the illustrations and descriptions of other authors as key-notes to a proper interpretation of the species indicated.

Habitat. On *Terebratula biplicata*, Fossil No. 3, and *Inoceramus*:
Horizon. Red Chalk, Hunstanton.

4. STOMATOPORA GRANULATA (Edwards). Var.* A.

1852. *Stomatopora incrassata* (?), d'Orb. Terr. Crét. v. p. 837, pl. 628. f. 9-11.

Zoarium much more stunted, compressed, and broader than the normal form; branches short, generally from two to three cells (more frequently the first) before each bifurcation; the length of the branch in this interval about 1 millim. *Zoecia* stunted, occupying the whole width of the branch, punctured in horizontal lines; length of each $\frac{1}{2}$ millim.

Habitat. On *Terebratula biplicata*. Fossil No. 4.

Horizon. Red Chalk, Hunstanton.

5. STOMATOPORA RAMEA (Blainville; non d'Orb.).

1834. *Alecto ramea*, Blainv. Man. d'Actinol. p. 464, pl. 78. f. 6.

1850. *Alecto ramea*, Lonsdale, Dixon's Geol. Sussex, p. 268, pl. xviii. f. 35-40.

Good examples of this species are rare in the Red Chalk, though fairish examples are found in the Upper White Chalk.

Zoarium uniserial, branches irregular and of nearly uniform breadth, but bordered in this case by a very narrow band, probably a slight development of a basal lamina similar in some respects to the basal lamina of *Diastopora obelia*, Johnst. †. *Zoecia* nearly uniform in width throughout; peristome inclined upwards; aperture circular (normal), slightly oval when worn.

Habitat. On *Terebratula biplicata*. Fossil No. 5.

Horizon. Red Chalk, Hunstanton; White Chalk, Sussex.

6. STOMATOPORA LONGISCATA, d'Orb.

1852. *Stomatopora longiscata*, d'Orb. Terr. Crét. v. p. 839, pl. 629, f. 9-11.

There are several examples of *Stomatopora*, adherent to *Terebratula biplicata* especially, that I cannot place with either *S. granulata* or *S. ramea* on account of the peculiarities of the zoecia. These may be placed, I think, under the above name. Generally the cells are of one width throughout; but there are several fragments in which the proximal extremities are thinner than the distal; this, however, cannot be accepted as a rule. On "Fossil No. 8" are apparently two colonies, differing slightly from each other, yet I cannot separate them so as to make two

* This variety is not common, for I have met with only two examples, the finest of which I have taken as the type. Whenever I can, I prefer working along the lines of Mr. Waters and Dr. Pergens, so as to reduce the nomenclature of species, rather than increase the difficulties of the palæontologist by the introduction of new names unnecessarily.

† Busk, Brit. Mus. Cat. pt. iii. p. 28, pl. xxvi.

species. In one colony some of the cells are long and pointed at the proximal extremity, while others are thick at both extremities of the cell. In one colony many of the cells are less robust, but of a character similar to those in the other. On another fossil a small delicate colony (only a few cells) is preserved, which comes very near to d'Orbigny's type species. The dimensions of the cells (length and breadth in all these examples), in some parts of the colony at least, are similar to the dimensions given by d'Orbigny (*op. cit.* p. 839).

Habitat. On *Terebratula biplicata* and *Torynocrinus manon*, Seeley. *Fossils*: No. 6, two colonies; and No. 8, two colonies, much better preserved.

Horizon. Red Chalk, Hunstanton.

7. STOMATOPORA LINEARIS, d'Orb.

1852. *Stomatopora linearis*, d'Orb. Terr. Crét. v. p. 838, pls. 629-658.

The species described and figured by d'Orbigny represents a free-growing Polyzoon, with peculiarly irregular branches. The principal branch is long and flexuous and contains eleven cells; afterwards the branching is thrown off at right angles rather freely, and not dichotomously, as in other species of *Stomatopora*.

I have met with only one unbranched example of this species in the Red Chalk, and the differences between the Cenomanian form (d'Orbigny) and this are slight indeed. The zoecia of the British form are rather less oval than the French, and there are indications that these were delicately punctate.

Habitat. On *Terebratula biplicata*. *Fossil* No. 7.

Horizon. Red Chalk, Hunstanton. French example—Havre (*d'Orb.*).

GENUS PROBOSCINA, Audouin.

1838. *Criserpia*, Edw.; 1847. *Idmonea*, d'Orb.; 1852. *Proboscina*, d'Orb. Terr. Crét. v. p. 844.

The genus *Proboscina* is a convenient, rather than a natural division of the *Stomatopora* group. Partially accepted and defined by d'Orbigny, the genus loses much of its individuality, for many of his species have been variously located by other authors. Mr. Hincks says (*Bibliogr.* 33, p. 432), "I do not venture to identify *Stomatopora expansa* with d'Orbigny's *Proboscina ramosa* (= *Idmonea cenomana*, d'Orb.), though it bears a strong general resemblance to it;" while *Tubulipora fimbria*, Lamk. (p. 448) = *T. flabellaris*, Busk (*Bibliogr.* 31, p. 25), is identified, though doubtfully, by both authors as *Proboscina latifolia*, d'Orb. Both Mr. Busk* and Mr. Hincks disallow the genus for recent species; the latter author bracketing the *Stomatopora* whose zoaria are partially erect and free as the subgenus *Proboscina*, Smitt. *Stomatopora incrassata*, Hincks, thus absorbs *Tubulipora (Proboscina) incrassata*, Sm., *Alecto retiformis*, Hincks, and ? *Filisparsa incrassata*, d'Orb. From

* 'Challenger' Report, pt. ii.

this it is evident that, unless the genus is more rigidly defined than it has been previously, it would be impossible to accept it for the purposes of this memoir. By Reuss (Bibliogr. 10, 11) and Novák (Bibliogr. 34), and recently by Mr. Walford (Bibliogr. 30), the genus has been accepted as a kind of passage-form between *Stomatopora* and *Diastopora*. There is, however, one peculiar species, *Proboscina spatiosa*, in examples of which Mr. Walford traces varietal characters so abnormal that, if disconnected fragments were found, and if growth only was a consideration in the definition of a species, it could be placed as a *Tubulipora*, as a *Diastopora*, and even as an erect *Entalophora*. Such instances, however, are rare, but I had already noticed some of these abnormal features in material given to me by Mr. Walford derived from the same locality (Inferior Oolite, Shipton). In my new Cambridge-Greensand material I have seen a similar *Proboscina* (Entalophorian growth), but I have not noticed examples similarly constituted in the Red Chalk, except in one case that will be referred to again further on.

Jules Haime, in his admirable memoir on "Jurassic Bryozoa," accepts *Proboscina* as a passage-group, and suggests that probably *Cellepora echinata*, Goldf. (= *Tubulipora echinata*, Hag.), and *Siphoniotyphlus plumatus*, Londs., are really Proboscinal species; and *Diastopora ramosa*, Mich. (Londs. Bibliogr. 35) is undoubtedly another.

Mr. E. O. Ulrich, examining some of Prof. Nicholson's species*, places two of them in the *Proboscina* group. Thus *Alecto confusa*, Nich., and *Aulopora frondosa*, James, become *Proboscina* respectively; and Mr. Ulrich remarks that the Silurian forms are like *Stomatopora*, but with cells in two or more series †. As yet I have not found the multiserial *Proboscina* in our own Silurian rocks, but the antiquity of the genus is sufficiently established by the citation given above.

In determining new species and varieties for Red-Chalk forms, I have been desirous of not increasing the difficulties of the Palæontologist; and in every case where I have called a species by a new name, I have previously examined all the attainable illustrations and descriptions by other authors before committing myself; but in the interests of truth I have preferred this course to promulgating false identities, which, to me, would be far more obnoxious.

8. *PROBOSCINA ANGUSTATA*, d'Orb. Varieties. (Plate XIX. figs. 1 \bar{a} -1 *d*.)

1852. *Proboscina angustata*, d'Orb. Terr. Crét. v. p. 852, pl. 632. figs. 7-9.

1872. *Proboscina angustata*, Reuss, "Bryoz. Unteren Pläners," p. 113, pl. 28. figs. 3, 4.

1885. *Stomatopora gracilis* (?), Vine, Proc. Yorksh. Geol. Polytech. Soc. vol. ix. p. 4, pl. 2. fig. 7.

* Ann. Mag. Nat. Hist. ser. 4, vol. xv. 1875.

† Journ. Cincinnati Soc. Nat. Hist. 1882, p. 149.

1889. *Proboscina angustata*, Vine, Proc. Yorksh. Geol. Soc. vol. xi. p. 265.

Small colonies belonging to this species are found on several of the fossils in the Red Chalk, and generally associated with other forms. In the Cambridge Greensand a rather ill-preserved example was found (the only one—adherent to a small phosphate nodule), which I placed originally as *Stomatopora gracilis*. I believe, after a re-examination of the fossil, the proper location ought to be here. D'Orbigny, in his description of the species, refers to it as being composed of two lines of longitudinal alternating cells, and this, generally, is the character of the Red-Chalk fragments. Reuss figures his species as partly uni- and partly bi-serial, and the Cambridge-Greensand form more closely resembles that of the "Pläner" than d'Orbigny's form from Le Mans.

Habitat. On *Terebratula biplicata*. Fossil No. 1 B. Also on *Inoceramus* and *Ammonites*.

Horizon. Cambridge Greensand; and Red Chalk, Hunstanton.

9. PROBOSCINA RUGOSA (?), d'Orb.

1852. *Proboscina rugosa*, d'Orb. Terr. Crét. v. p. 853, pl. 633. figs. 6, 7.

Amongst the rarer Polyzoa of the Red Chalk there are a few examples similar to the beautiful species figured by d'Orbigny quoted above. In only one small specimen are the cells in the branch arranged in three rows; and in this only some of the cells are rugose, as in the form from Le Mans. There are, however, a few examples of a branching Polyzoon encrusting *Terebratule* in the Red Chalk that may be regarded, if not identical with d'Orbigny's species, at least as belonging to a variety of the same. The arrangement and character of the cells are similar, and the rugose markings on one cell (many of the others are broken or abraded) are very perfect. The diameter of the branches in the British form is fully 1 millim. against the "1 demi-millimètre" of the Le Mans form.

Habitat. On *Terebratula biplicata*. Fossils No. 9 A and No. 11 B. Also on *Inoceramus* and *Ammonites*.

Horizon. Cambridge Greensand; Red Chalk, Hunstanton.

10. PROBOSCINA IRREGULARIS, sp. nov. (Plate XIX. figs. 2a, 2b; Variety A, figs. 2c, 2d.)

Zoarium repent; very irregular in its mode of growth and general habit. The zoarium is unbranched, but made up of many divergent cells, which, springing from a central or semi-central nucleus, diverge in a variety of ways from that point. The *zoæcia* are slightly ventricose in the originating cells and in the more fully developed zoarium; but the *zoæcia* here also are very irregular. *Gonæcium* double-celled; having the bust-like aspect of a pouter-pigeon in the type species, but generally speaking the gonæcium is a largely inflated cell.

Habitat. Type on *Terebratula biplicata*; var. A, on a Belemnite. Fossils No. 10 and 10*.

Horizon. Red Chalk, Hunstanton.

This species is only known to me by a few rather imperfect examples beside the type form, and some of these may easily be mistaken for other species. In the type (on Fossil No. 10, figs. 2 a, 2 b) the originating point of the colony is situated in the midst of a clustered mass at the base of the *zoarium*. From out this mass another colony (or branch?) passes off to the right, and towards the upper right-hand side is apparently the nucleus of another. Altogether, the general habit of the Polyzoon, the peculiar mode of development, and arrangement of cells in the colony, justify my characterizing this form by a new name. A very simple form of the species is found on one of the larger fossils. In this example the largely-clustered zoarium, as found in the type form, has apparently not been reached.

11. PROBOSCINA UBERRIMA, sp. nov. (Plate XIX. figs. 3 a, 3 b.)

The *zoarium* of this beautiful species is similar in many respects to that of *P. irregularis*, except that the *zoecia*, which are feebly punctate, could not be consistently described as "irregular" in the same sense as with that species. The distinctive features of this, however, are the well-developed ovicells (three in number) right across the middle of the *zoarium*. Each *gonœcium* (ovicell) is separated from its near neighbour by the proximal extremity of an intervening cell. The aperture of each ovicell is small, and in one, in the area below the aperture, there is a circular dotted (punctured?) patch which occupies the greater portion of the facial surface of the ovicell. This is the only example of the species that I have met with in the Red Chalk.

Habitat. On *Inoceramus? sulcatus*. Fossil No. 11 A.

Horizon. Red Chalk, Hunstanton.

12. PROBOSCINA GRACILIS, Reuss, var. REUSSII, nov. (Plate XIX. figs. 4 a, 4 b.)

Zoarium adherent, simple or branching; branches originating from a single cell, and gradually widening towards the distal extremity. *Zoecia* smooth (?), arranged alternately in the older part of the branch, clustered and contiguous in the upper; peristome circular, slightly raised.

Habitat. On *Terebratula biplicata*. Fossils No. 12 A, type; branching form No. 12.

[Since this paper was read, a separate copy of Dr. E. Pergens's "Revision des Bryozoaires du Crétacé figurés par d'Orbigny," première partie : Cyclostomata †, has come to hand. Without enter-

† [Bull. Soc. Belge Géol. Paléont. Hydrol. vol. iii. (for 1889), 1890, pp. 305-400.]

ing on other particulars, I may mention that one of the species which Dr. Pergens has redrawn and redescribed should be referred to here: thus, instead of my proposed *Proboscina claviformis*, n. sp., the following is substituted:—

13. *PROBOSCINA SUBELEGANS* (d'Orb.).

Stomatopora subelegans, d'Orb. Terr. Crét. v. p. 853, pl. 759. figs. 8–13.

Stomatopora subelegans, Pergens, Rev. Bryoz. Crét. p. 332, pl. xi. fig. 3.]

Zoarium wholly adnate, branches rounded and slightly elevated in the centre: clavate. *Zoecia* decumbent or partially depressed; in the older part of the zoarium the surfaces of the tubular cells are delicately punctured while in the younger, or growing portion, the prominent peristomes only are noticeable.

Habitat. On *Inoceramus*. *Fossil* 13 A.

Horizon. Red Chalk, Hunstanton.

At first sight this species may be easily mistaken for a British example of Novák's *Proboscina Suessii* (Bibliogr. 34), which, in its clavate character, it closely resembles; but the number of zoecia, and their peculiar character, entirely exclude the possibility of confounding what I believe to be two distinctly characteristic forms.

14. *PROBOSCINA HUNSTANTONENSIS*, sp. nov. (Plate XIX. figs. 5 a, 5 b.)

Zoarium multiform or irregular; branches originating from a small discoid body, and then spreading in various directions. *Zoecia*: originating cells simple, and generally unlike the zoecia in the more fully developed colony. Here the zoecia are flask-like, rugose, and very variable in their general outline; orifice contracted and of less diameter than the cell. *Gonæcium* a peculiarly flask-shaped cell, contracted towards the aperture.

Habitat. On *Inoceramus*: *Terebratula biplicata*. *Fossils* No. 17 A t (type); No. 16 A; A², slightly varying in the character of the cells.

Horizon. Red Chalk, Hunstanton.

This peculiar species is rather common in the Red Chalk; but the colonies are often found in such out-of-the-way places, and on the larger fossils, that it is by no means easy to get a form suitable for drawing, either of the species or of its variety mentioned below; and it is impossible to get a whole colony under the microscope at once.

15. *PROBOSCINA HUNSTANTONENSIS*, Vine; var. *AMPLIATA*, nov. (Plate XIX. figs. 6 a–6 d.)

This well-marked variety is similar in many respects to the foregoing species; but, as there is a difference in the character of the "ovicell"

and the cells surrounding the "ovicell," I have decided to keep the forms separated.

Habitat. On *Inoceramus*. *Fossil* No. 16 B.

Horizon. Red Chalk, Hunstanton.

16. *PROBOSCINA JESSONI*, sp. nov. (Plate XIX. figs. 7 a, 7 b.)

Zoarium fan-like. Colony simple, originating from a disc-like cell, and between this and the base of the zoarium there is a simple intermediate branch about 1 millim. in length. Out of the upper part of this connecting "link," which may be, really, only a portion of the "egg-cell" (d'Orb.), the true zoarium is developed. The first formed zoecia are in pairs, alternately placed, and then, after a small interval, the colony widens out, fan-like. *Zoecia* tubular, depressed towards the proximal, raised slightly near the distal extremities; walls contiguous, and towards the outer margin of the zoarium only the upper portion of the cells is visible. Several of the middle cells of the colony have their orifices closed, and the "closure" is delicately perforated. These probably are the gonæcia or "ovicells" of the colony (?).

Habitat. On *Terebratula biplicata*; unique. *Fossil* No. 15.

Horizon. Red Chalk, Hunstanton.

After I had received from Mr. Jesson by far the larger portion of the one thousand fossils previously referred to, he sent me a small parcel of selected examples, especially drawing my attention to them. "On some of the fossils," he wrote, "unless I am greatly mistaken, you will find some new forms." *Proboscina Jessoni* was one of the forms in this batch; and, as species bearing "closure-cells" are very rare in the Red Chalk, I feel a pleasure in dedicating this species as above.

Reuss (Foss. Polyp. Wiener Tertiärbeck. pl. vii. fig. 9) figures and describes a species with a zoarium similar to that of *P. Jessoni* as *Diastopora flabellum*, from the marine limestone of Eisenstadt in Hungary. I do not think that the two forms, though apparently similar in habit, could be easily confounded; for Reuss shows in his figure, and refers to it in the text, that the cells are well separated in the zoarium, whereas in *P. Jessoni* the walls of the tubular cells are contiguous, not separated, though at first sight they may appear to be so.

17. *PROBOSCINA GIGANTOPORA*, Vine. (Plate XIX. figs. 8 a, 8 b.)

Reference: *Entalophora gigantopora* (Proboscidian stage), Vine, Camb. Greensand Polyzoa, Proceed. Yorksh. Geol. Polyt. Soc. vol. ix. 1885, p. 8, pl. 1. fig. 3, and vol. xi. 1889, p. 262, footnote.

Zoarium wholly repent, unbranched. *Zoecia* very large, tubular, but Escharoidal; depressed, with large circular apertures, rarely raised above the surface of the zoarium; surface punctate; closures occasionally.

Habitat. On *Terebratula biplicata*. *Fossil* No. 20 A.

Horizon. Red Chalk, Hunstanton; and Cambridge Greensand.

I have only one example of this very interesting species, and this being slightly abraded, has the apertures of several of the cells broken; but sufficient perfect cells remain to enable me to give the diagnosis as above.

I have already (1885, Bibliogr. 19) described from the Cambridge Greensand a peculiarly flattened *Entalophora* with large cells, which I named *E. gigantopora*. Later still (1889, Bibliograph. 21), I referred an example, similar in many respects to the present one, to the *Proboscina gigantopora* group. I have no evidence that the Red-Chalk form ever assumed a bi-diastoporan or Entalophorian stage, consequently I cannot write so fully of this habit in the present as in the Greensand form; but, as this species ought to find a resting-place in the *Proboscina* group, I prefer to give it the same specific name as the *Entalophora* already referred to, and to figure it as perfectly as possible.

18. *PROBOSCINA BOHEMICA* (?), Novák. Variety. (Plate XIX. figs. 9 a-9 d.)

1877. *P. bohémica*, Novák, Bryoz. böhm. Kreidef. p. 101, pl. v. figs. 24, 25.

1852? *Idmonea radiolitiorum*, d'Orb. Terr. Crét. v. pl. 633. figs. 8-10.

This beautiful little Polyzoon more closely resembles *P. bohémica* of Novák than *P. radiolitiorum*, d'Orb., which probably is an ally of Novák's species; but ours differs from both in the general habit of the zoarium, but less so in the arrangement and disposition of the zoecia.

In the British form the branching is very irregular, but is unlike the *Idmonea*-character shown in the figure of d'Orbigny's species. In the early stage of the form the branch is thin, and from this nucleus two, or even more, diverging, rounded branches are developed. The general character of the zoarial habit is unlike any other species described from these strata. The *zoecia*, though tubular, are rarely wholly exposed, and only the apertures with rather thick peristomes are seen. From an abraded fragment (figs. 9 a, 9 b) it seems that the tubular *zoecia* are short; but this feature is what one would naturally expect from a delicate *Proboscina* like this.

Habitat. On *Terebratula biplicata*. Fossil No. 21.

Horizon. Red Chalk, Hunstanton.

19. *PROBOSCINA TOUCASIANA* (?), d'Orb.

1847. *Idmonea Toucasiana*, d'Orb. Prodr. ii. p. 265.

1847. *Idmonea elegans*, d'Orb. Prodr. ii. p. 265.

1852. *Proboscina Toucasiana*, d'Orb. Terr. Crét. v. p. 856, pl. 634. figs. 1-6.

[1890. *Stomatopora Toucasiana*, Pergens, Revis. Bryoz. Crét. p. 331, pl. xi. fig. 8.]

The species described by d'Orbigny under the names cited above

form a peculiar group of *Proboscineæ*. The habits of the whole may be characterized as follows:—*Zoarium* creeping, dendroid, with narrow depressed branches, which nearly anastomose at the tips. These branches are narrow at the base, enlarging towards the tops, and bearing from two to six or seven rows of alternately disposed cells. In his fig. 1, pl. 634, d'Orbigny figures a form of the natural size, and enlarged in fig. 2. Taking this form, *Proboscina (Idmonea) elegans*, cited by d'Orbigny as *P. Toucasiana*, as above, the British form which I place here resembles the habit of the more robust part of the colony, where the branches anastomose. The *zoecia*, however, differ slightly. In a portion of the zoarium the cells are arranged similarly to fig. 4, pl. 634; but the surface is rather rugose; in other portions of the zoarium the cells are depressed, rugose, and stunted like the cells on the branches of *P. fasciculata*, d'Orb., fig. 11, pl. 634. On the whole, rather than make a new name for the British form, I think it will be wise to leave this unique example under d'Orbigny's name, without any additional varietal term.

Habitat. On *Terebratula biplicata*. *Fossils* Nos. 28 B and 19.

Horizon. Red Chalk, Hunstanton; Senonian Stage, d'Orbigny.

20. *PROBOSCINA RAMOSA* (?), d'Orb.

1845. *Diastopora ramosa*, Michelin, Icon. Zoophyt. pl. 52. fig. 13.

1847. *Idmonea ramosa*, d'Orb. Prodr. ii. p. 175.

1852. *Proboscina ramosa*, d'Orb. Terr. Crét. v. p. 851, pl. 632. figs. 1-3, pl. 633. figs. 1-3.

Mr. Hincks (Brit. Mar. Polyz. p. 432) says "I do not venture to identify *Stomatopora expansa* with d'Orbigny's *Proboscina ramosa*, though it bears a strong resemblance to it." There is certainly no affinity between the present form, which I believe to be identical with d'Orbigny's *P. ramosa*, and the recent *Stomatopora expansa*, Hincks. Indeed the more closely that I study these Cretaceous fossils, the less inclined I am to identify any of the species found in the Red Chalk especially with recent forms.

In the list of references given above I have followed d'Orbigny, but the Red Chalk example now being described is more closely allied to *Idmonea cenomana* of that author than to either Michelin's *D. ramosa* or *Idmonea ramosa*, d'Orb.; but I believe that the whole of the forms indicated are inseparable, the slight variation in the habit being of little consequence.

Habitat. On *Inoceramus*. *Fossil* No. 14 A.

Horizon. Red Chalk, Hunstanton; French horizon, Cenomanian; Le Mans.

21. *PROBOSCINA DILATATA* (?), d'Orb., var. *CANTABRIGIENSIS* (?), Vine.

In my second paper on the Cambridge Greensand Polyzoa (Bibliogr. 21) in describing the above variety (p. 261) I refer to an impression of a species similar to, even if not identical with, the Greensand form, on an *Inoceramus*. No zoarium nor zoecia being

preserved on the fossil referred to, I cannot give further details, and I only place the species or variety as doubtfully present in the Red Chalk. I have mislaid the fossil, but probably it will be found, marked "cast," in Mr. Jesson's Collection.

Specialists working both on recent and fossil encrusting Polyzoa have noticed that certain of the recent species apparently leave behind them an impression on shell or stone, when all trace of cell or cell-arrangement was destroyed. On fossil No. 23 is the basal outline of a fine colony of *Proboscina*, but of what species I cannot say. The *P. dilatata* variety referred to was one of these, and on the fossil referred to is another.

Habitat. On *Terebratula biplicata*. Fossil No. 23.

Horizon. Red Chalk (one "colony").

Genus DIASTOPORA, Lamouroux.

The genus *Diastopora*, as now accepted by authors, has had a peculiar history. By Lamouroux, d'Orbigny, Haime, and others, and even by M'Coy, the term *Berenicea* was used for adherent discoid forms, and the term *Diastopora* was reserved for foliaceous forms. When, however, it was found that adherent *Bereniceæ* occasionally put on the habit of foliaceous species, the former term was, to some extent at least, abandoned; while d'Orbigny in the interval between lithographing the plates of the 'Paléontologie Française' and writing the description of his figures, was evidently undecided which term to use; for some of the figures in the plates are named *Diastopora*, and in the text the same figures are described as *Berenicea*. Since the publication of Busk's 'British Museum Catalogue,' pt. iii., and Hincks's 'British Marine Polyzoa,' the one term *Diastopora* has been more frequently used; but this practice is by no means general; even so lately as the new edition of Phillips's 'Manual of Geology' in 1885, Mr. Etheridge still clings to the old term. In the present paper, and in my writings generally, I make no distinction between the adherent and the foliaceous forms. In the Red Chalk, however, there are none of the latter; but in the Jurassic rocks, both British and foreign, the two groups are pretty evenly balanced. Mr. Hincks gives the following as his definition of the genus:—

"*Zoarium* adnate and crustaceous, or foliaceous, usually discoid or flabellate, less commonly irregular in form. *Zoecia* tubular, with an elliptical or subcircular orifice, crowded, longitudinally arranged, in great part immersed" ('Brit. Mar. Polyzoa,' p. 457).

The *Diastoporaæ* now to be described are peculiar. Most of them are altogether unlike any known British Cretaceous forms; but some of them are evidently allied to species, described by d'Orbigny and others, derived from foreign Cenomanian or Senonian horizons; while others, such as *D. hunstantonensis* and its allies, are quite distinct and new to science.

22. *DIASTOPORA HUNSTANTONENSIS*, sp. nov. (Plate XIX. figs. 10 a, 10 b.)

Zoarium wholly adnate, forming a thin irregular discoid crust on a variety of fossils, without marginal lamina or stunted marginal cells. *Zoecia* irregular both in breadth and length, but disposed in series, and generally radiating from a central point; robust and strongly wrinkled or punctate on the surface. Central or nuclear cells, short or stunted, consisting ordinarily of an "egg-cell" from which other cells branch off in opposite directions; these are swollen in the middle, slightly compressed towards the orifice; orifice circular, raised; peristome rather thick. *Gonæcium* either a double or triple combination of cells or a single large cell. Breadth of ordinary colony from 12 to 16 mm.

Habitat. On *Terebratula*, *Inoceramus*, *Ammonites*, and almost on every class of fossils previously referred to. *Type* on *Terebratula biplicata*. *Fossils* No. 1 (type) and 17 B t.

Horizon. Red Chalk, Hunstanton.

This is by far the most abundant and most prevailing form of all the Red-Chalk Polyzoa. The larger fossils, especially the *Ammonites*, have adherent to their exterior surfaces a number of colonial growths; while many of the smaller fossils, *Inocerami* especially, have occasionally from one to three. The type form, however, on *Terebratula biplicata* is one of the most beautiful examples of the species. The double character on the surface of the zoecia, wrinkled and punctate, is more noticeable on this than on the other forms; some of the cells being marked in regular transverse dotted lines, while others are most irregular; and on one edge of the zoarium is an overlap of another colony, very strongly wrinkled, bearing the peculiar *gonæcium*, with its triple combination of cells, referred to in the diagnosis.

23. *DIASTOPORA HUNSTANTONENSIS*, Vine; var. A. (Plate XIX. figs. 11 a, 11 b.)

There are a few examples of this species, which, bearing most of the characters of the typical form, differ sufficiently from them in the disposal and markings on the surface of the cells to merit varietal distinction. These varieties are not abundant on the Red-Chalk fossils, but they have, nevertheless, well-marked characters. *Zoarium* irregular, rarely discoid. *Zoecia* less wrinkled than in the type, and more regular in their disposition or arrangement. Central cells similar to those of the type-form.

I have met with several forms of *D. hunstantonensis* which, under ordinary circumstances, would be justly regarded as varieties and, in one case, as a new species; but, being able to trace in most of these particular features which seem to ally them to the type form, or to var. A, I think it useless to load the text unnecessarily.

Habitat. On *Inoceramus* and *Terebratula*. *Fossils* No. 17 c t, ordinary variety, and No. 22, var. A.

Horizon. Red Chalk, Hunstanton.

24. *DIASTOPORA FÆCUNDA*, Vine.

1885. *Diastopora fœcunda*, Vine, Proc. Yorks. Geol. Polytech. Soc. vol. ix. p. 9.

1889. *Diastopora fœcunda*, *ibid.* vol. xi. p. 266.

In the last of these two papers I have given a bibliography of species allied to the above; and at one time I was inclined to place the present species under d'Orbigny's name *Reptomultisparsa glomerata*, Terr. Crét. v. p. 877; but, as Reuss includes this form in his list of synonyms of *Berenicea confluens* (Römer), I cannot identify this with any of the forms indicated by him, Tertiary or Cretaceous.

The Red-Chalk form is rather larger than the one previously described from the Cambridge Greensand; but its general characteristics are similar. *Zoarium* discoid, and more or less proliferous in habit. The present form is rare in the Red Chalk and very badly preserved.

Habitat. In a water-worn piece of Red Chalk. *Fossil* No. 24.

Horizon. Cambridge Greensand (= Phosphate-beds); Red Chalk, Hunstanton.

25. *DIASTOPORA REGULARIS*, d'Orb.

1850. *Diastopora regularis*, d'Orb. Terr. Crét. v. pl. 636. fig. 10 (only).

1851. *Diastopora densata*, d'Orb. *ibid.* pl. 637. figs. 1, 2.

1851. *Diastopora orbicula*, d'Orb. *ibid.* pl. 637. figs. 3, 4.

1852. *Berenicea regularis*, d'Orb. *ibid.* p. 265, pl. 636. figs. 9, 10; pl. 637. figs. 3, 4.

The species included in the synonymy by d'Orbigny, as above, differ materially in their mode of growth. The *D. regularis*, pl. 636. fig. 10, has the flabellate character of a *Proboscina*, rather than that of a *Diastopora*, the discoid form of the species not having been reached; but in *D. densata*, pl. 637. fig. 2, we have a completed discoid form with the originating cells slightly excentric. *D. orbicula*, pl. 637. f. 4, has an entirely different form of cell and cell-arrangements. The Red-Chalk form is more like *D. regularis* (pl. 636. fig. 10), and I restrict my identification to this figure only. The *zoarium*, though in an advanced Proboscinal stage only, is a true *Diastopora*; but it is not wholly discoid. The *zoœcia* originate from a primary "egg-cell" at the base of the *zoarium*, which, unlike that of d'Orbigny's species, is soon enclosed by the early *zoœcial* growth, after which the growth is upwards and outward, to the right and left, until a disc-like form is reached. The orifices of the originating *zoœcia*, which are short and stunted, are circular; but on two of them these are covered by perforated opercula ("closures"), and some of the cells in other parts of the *zoarium* bear "closures" as well. The *zoœcia* are broad towards the orifices, narrow towards the base, contiguous, depressed for nearly the whole length; surface faintly punctate.

Habitat. On *Terebratula biplicata*. *Fossil* No. 28 A.

Horizon. Red Chalk, Hunstanton. Cenomanian Stage of Le Mans (*d'Orb.*).

This is the only example of the species that I have found in the Red Chalk.

26. *DIASTOPORA RADIANUS?* (Novák). Variety?

1877. *Berenicea radians*, Novák, Bryoz. böhm. Kreidef. p. 98, pl. iv. figs. 15-18.

The example which I place under Novák's name, as a variety of his species, is the only one that I have found among the Red-Chalk fossils. The identification of unique forms is always difficult; and this is especially so, because some of the characters in the British species seem to ally it more closely with *D. pilosa* of the same author than with *D. radians*. The Red-Chalk form, however, is similar to fig. 16, both in the general outline of the zoarium and in the arrangement of the cells; but the partly formed marginal cells of the British example are more abundant. *Zoecia* not contiguous, interspaces and cells finely punctate, disposed in linear series radiating from excentric originating cells. About the middle of the *zoarium* there is a raised gonocyst, which embraces several cells, similar in character to the one depicted by Novák as the "ovicell" of *D. (Berenicea) folium*, Novák (p. 96, pl. iv. fig. 14, *op. cit.*).

Habitat. On *Terebratula biplicata*. Fossil No. 26.

Horizon. Red Chalk, Hunstanton; Chalk-marl, Bohemia (*Novák*).

27. *DIASTOPORA PAPILLOSA* (?), Reuss.

1846. *Diastopora papillosa*, Reuss, Verst. böhm. Kr. p. 65, pl. 15. figs. 44, 45.

1847. *Diastopora papillosa*, d'Orb. Prodr. ii. p. 266.

1847. *Diastopora oceanica*, d'Orb. *ibid.*

1851. *Diastopora disciformis*, Hag. Bryoz. Maastr. Kreid. p. 16, pl. 10. fig. 7.

1852. *Berenicea papillosa*, d'Orb. Terr. Crét. v. p. 866, pl. 639. figs. 6, 7.

D'Orbigny describes and illustrates a series of *Diastopora* having very diverse habits, but the whole of them are very closely related, if we consider the cell and cell-arrangement of the forms. Thus the *zoecia* of *Diastopora tuberosa*, *D. grandis*, *D. oceanica*, and even *D. congesta* and *D. littoralis* (pls. 639 and 640) are strikingly similar, but the habits of nearly all are different. The example that I place here resembles *D. disciformis*, Hag., *D. tuberosa*, and *D. oceanica*, d'Orb.; but the prolific habit of *D. tuberosa* is so very peculiar that I think it would be unwise to place it under that name. As *D. papillosa* is accepted by d'Orbigny, under which he places his own *D. oceanica*, Reuss's name has a prior claim to our notice. The Red-Chalk form is disciform, one colony overlapping another; originating cells central.

The wonderfully wide range of this species as given by d'Orbigny

(Terr. Crét. p. 867) shows how very common the *Diastopora* with simple non-characteristic zoæcia are. It is, indeed, as Dr. Pergens very wisely suggested in a recent letter, a most unsatisfactory group to deal with and distinguish. I have been, however, so far very successful with the Red-Chalk species; but duplicates of all the forms indicated in the text are by no means easy to get, even out of the abundant series submitted to me.

Habitat. On *Terebratula biplicata*. *Fossil* No. 27.

Horizon. Red Chalk, Hunstanton.

28. *DIASTOPORA JESSONI*, sp. nov. (Plate XIX. figs. 12 *a*, 12 *b*.)

Zoarium adnate, without marginal lamina or partially formed cells on the edge, orbicular. *Zoæcia*: originating cells central, very short and compressed; radial cells either linear or slightly oblique where the lines reach the edge from the centre; these linear series widen out towards the margin, so as to admit an intermediary series between the radii, by which the *zoarium* is enlarged; zoæcia, either elongated tubes, of about the same diameter throughout, or flask-like, narrow towards the proximal and bulging at the middle or at the distal extremities; orifice circular or oval (?), raised, with very thin peristomes; surface of cells punctate in fine and closely transverse series, which give a rugose appearance to the zoæcia if only examined under a low power of the microscope, or by the hand-lens. Closure-cells occasional, with very finely perforated "opercula," which form a slightly rounded covering over the orifice of the cells. These closure-cells are probably equal to the ovicells in other species; anyhow they are very characteristic in certain species of *Diastopora* in the Red Chalk.

Habitat. On *Terebratula biplicata*, *Fossil* No. 25; and on *Nautilus albensis*, d'Orb., in Mr. C. D. Sherborn's collection.

Horizon. Red Chalk, Hunstanton.

The general outline of *Diastopora Jessoni* is similar to that of *D. gracilis* (d'Orb. pl. 635. fig. 9), and it is about the same size (natural) of fig. 8 on the same plate. In d'Orbigny's text (Terr. Crét. p. 864) I find that the author includes under *Berenicea gracilis*, d'Orb., both *D. intermedia* and *D. vassiacensis*, d'Orb., of the same plate; in any case it would be impossible to place the Red-Chalk form under any of these specific names, whether we regard them as synonyms of Milne Edwards's *D. gracilis* or not. The next species, somewhat similar as regards the flask-like cells, is the *Berenicea pilosa*, Novák (Bibliogr. 34, pl. iv. fig. 10, only); besides these, I know of no other species with which I can compare *D. Jessoni*.

I have already dedicated a *Proboscina* to Mr. Jesson, so as to connect his name with these Red-Chalk fossils, and, in my remarks on *Proboscina Jessoni*, I made reference to the small special collection which came after the larger mass of fossils had been placed in my hands; and the fossils to which *P. Jessoni* and *D. Jessoni* were adherent were in this parcel. Mr. Jesson has, therefore, a double claim to remembrance in the distribution of specific names.

Genus UNITUBIGERA, d'Orbigny.

1852. *Unitubigera*, d'Orb. Terr. Crét. v. p. 759.

D'Orbigny founded this genus to include a very peculiar group of fossil Polyzoa. The *zoarium* was fixed (parasitic?) on a large number of fossils; the *zoecia* were disposed in primary rays, radiating from the centre, with intermediate rays between the primaries in the wider parts of the zoarium. On the border, or outer edge, of the zoarium were a number of "germes de cellules," probably remains of former colonial (?) growths. D'Orbigny gives a list of eight species of *Lichenopora* and *Defrancia*, from other authors, that may be placed under this generic head, and one of these is the peculiar *Cerriopora disciformis* of Goldfuss. In the Paléont. Franç. Terr. Crét., d'Orbigny describes and illustrates two species only, *Unitubigera discus*, d'Orb., p. 760, pl. 763. figs. 4-6, and *Unitubigera papyracea*, d'Orb.; and to this latter species a single Red-Chalk Polyzoon seems to be related. In Mr. Etheridge's list (Bibliograph. 36, p. 590) he uses d'Orbigny's generic name for a Lower-Greensand species.

29. UNITUBIGERA PAPYRACEA, d'Orb.

1850. *Actinopora papyracea*, d'Orb.

1852. *Unitubigera papyracea*, d'Orb. Terr. Crét. v. pl. 643. figs. 12-14.

The example which I place under the above name is almost unique. The *zoarium* is disciform, slightly raised above the surface of the fossil to which it is attached, and is wholly adherent. *Zoecia* disposed in linear rays, radiating from the centre of the zoarium, with intermediary rays when the zoarium begins to widen out towards the margin; short, punctate, contiguous. The raised and slightly slanting border is composed of what d'Orbigny calls "germes de cellules," already referred to.

Habitat. On *Terebratula biplicata*. *Fossil* No. 29.

Horizon. Red Chalk, Hunstanton; Meudon, in 22 stage Senonian (d'Orb.).

The following two species (?), which I do not attempt to classify, are placed here temporarily:—

30. ENTALOPHORA (?), Lamouroux, sp.

This and the following species (?) I cannot attempt to identify with any known Polyzoa; but, because of their rarity, they ought to be recognized here, in the hope that better examples may be sought for and found.

Habitat. On *Spondylus*. *Fossil* No. 30 I.

Horizon. Red Chalk, Hunstanton.

Re-examining some of Mr. Jesson's fossils, I find another obscure specimen rather better preserved.

31. HETEROPORA (?), Blainville, sp.

In fragments of Red Chalk two different species (?) of Polyzoa are embedded, and I should hesitate to place them anywhere except that I have met with *Heteropora tenera*, in the Faringdon rock, having characters as obscured as these until fragments were sectioned, when their true character was revealed.

Habitat. In pieces of Red Chalk. *Fossils* No. 30 II. and No. 31.

Horizon. Red Chalk, Hunstanton.

§ B. RECTANGULATA, Waters.

Genus CERIOPORA, Goldfuss.

1826. *Ceriopora* (pars), Goldfuss; 1834. Blainville; 1847. D'Orbigny; 1852. *Ceriopora*, Goldfuss, d'Orb. Terr. Crét. v. p. 1029.

In establishing the genus *Ceriopora*, Goldfuss took for his type *Alveolites*, Lamarck; altogether Goldfuss described and admitted in the group about 37 species. The group has since been very much broken in upon by Blainville and others, and at the present time it is impossible to accept the genus for any considerable number of Polyzoa. D'Orbigny admits (Terr. Crét. p. 1030) the following Cretaceous species as *Ceriopora*:—

1845. *Ceriopora truncata*, Mich. Icon. pl. 51. fig. 7.

1830. *Ceriopora tubiporacea*, Goldf. Petrefact. pl. 10. fig. 13.

1830. *Ceriopora milleporacea*, Goldf. Petrefact. pl. 10. fig. 10.

1830. *Ceriopora micropora*, Goldf. Petrefact. pl. 10. fig. 4.

He also describes a new species from the Senonian stage as *Ceriopora digitalis*, d'Orb. I have only two examples of *Ceriopora* from the Red Chalk, which I prefer to place in this genus rather than in the *Ceriocava*, d'Orb.

32. CERIOPORA MICROPORA (?), Goldf.

1830. *Ceriopora micropora*, Goldf. Petrefact. p. 33, pl. 10. fig. 4.

1852. *Ceriopora micropora*, d'Orb. Terr. Crét. v. p. 1030.

1872. *Ceriopora micropora*, Simonowitsch, Bryoz. des Essen Grünsands.

The two examples, which I place here doubtfully, are difficult to separate, except by slight variation in their form. *Ceriopora* are rare in the Red Chalk, and the present specimens differ in the characters of the cell-orifices, so much so that Dr. Pergens, who has examined most of the Red-Chalk Polyzoa, made the following note respecting them:—

“*Ceriopora* (*Heteropora* ?), n. sp.; the orifices are 0·14–0·16 millim.” The forms seem to me, however, closely related to *C. micropora*, Goldf.

Habitat. Embedded in fragments of Red Chalk. *Fossils* Nos. 34 and 35 (variety ?).

Horizon. Red Chalk (middle bed *), Hunstanton; Essen (*Goldfuss*).

* The ranges in the several zones are shown in the Table at p. 460.

Genus REPTOMULTICAVA, d'Orb.

1826. *Ceriopora* (pars), Goldfuss ; Blainville.

1852. *Reptomulticava*, d'Orbigny, Terr. Crét. p. 1032.

Under the above generic name d'Orbigny places a considerable number of fossil forms. The colony is fixed by the whole of the inferior surface, and the general character of the superior face would be sufficient in itself to characterize species as *Ceriopora*, Goldfuss, previous to the rigid separation of that group by Blainville and d'Orbigny. Many of the flattened discoid *Monticulipora* of the older rocks are to some extent similar to these Cretaceous forms.

33. REPTOMULTICAVA SIMPLEX (?), d'Orb.

1852. *Reptomulticava simplex*, d'Orb. Terr. Crét. v. p. 1041, pl. 793, fig. 5.

The *R. simplex*, d'Orb., resembles, by its flattened figure, the Red-Chalk fossil placed here. The zoarium is simple, or disc-like, without any elaborate detail other than the small openings in the surface, which are very fine and characteristic, as in figs. 5 and 8 of plate 793, Terr. Crét.

Habitat. On *Terebratula biplicata*. Fossil No. 32.

Horizon. Red Chalk, Hunstanton.

34. REPTOMULTICAVA COLLIS (?), d'Orb.

1852. *Reptomulticava collis*, d'Orb. Terr. Crét. v. p. 1036, pl. 792, figs. 1-3.

1854. *Reptomulticava collis* (?), d'Orb.; Morris, Cat. Brit. Fossils, p. 128.

On several fossils of the Red Chalk are small colonies of a species similar to the forms described and figured by d'Orbigny as *Reptomulticava collis*. The general character and markings of the surface of the little dome-like zoarium are more like the species which d'Orbigny calls *R. cupula*, d'Orb., pl. 792, fig. 10 ; but this form is only partially attached at the base (figs. 8, 9), whereas the Red-Chalk examples are wholly attached. I have met with several examples of these little forms, but I am unable to follow d'Orbigny in establishing, even suggestively, other than these two species. Even those indicated vary slightly in their colonial growths.

Habitat. On *Terebratula*, *Inoceramus*, *Belemnites*. Fossils Nos. 33 and 36.

Horizon. Red Chalk, Hunstanton. Neocomian, Fontenvoy (d'Orb.)

Genus ZONOPORA, d'Orb.

1847. *Zonopora*, d'Orb. ; 1851. *Plethopora* (pars), Hagenow ; 1852. *Zonopora* (Fam. *Caveidæ*, d'Orb.), Terr. Crét. v. p. 928.

D'Orbigny, in his 5th family *Caveidæ* (Terr. Crét. p. 922), has brought together no fewer than twenty-seven genera, all of which, to say the least, are peculiar and characteristic. The author includes

in this family, among others, *Zonopora*, *Ditavia*, *Lichenopora*, *Domopora*, and *Radiopora*.

The *Zonopora* group may be regarded, judging from one of its species (*Z. variabilis*, d'Orb.), as a *Heteropora*, but not so with the other forms. As I have met with two or three examples in the Red Chalk that may be placed here, rather than elsewhere, I provisionally refer them to this genus, hoping that other and better examples may be brought to light.

35. *ZONOPORA IRREGULARIS* (?), d'Orb.

1849. *Zonopora irregularis*, d'Orb. Prod. ii. p. 87.

1852. *Zonopora irregularis*, d'Orb. Terr. Crét. v. p. 390, pl. 771. figs. 4-6.

Two small fragments of a species either allied to, or identical with, the above have been found in the top beds of the Red Chalk of Hunstanton. D'Orbigny shows in his fig. 6 two sorts of orifices: 1st, in raised cells, with thick peristomes, distributed in zones, but irregular; 2nd, very fine intermediary openings, similar to those found in *Heteropora*. Small sections, worked up to view as semi-transparent, show *Heteropora*-like intermediary "cells" in the centre, while the produced thick orifices of the larger cells, or true zoecia, of the species appear like those found in sections of *Heteropora* also. My material is far too limited to warrant further research at present.

Habitat. This is possibly a derived Polyzoon embedded in Red Chalk. *Fossil* No. 45.

Horizon. Top beds of the Red Chalk, Hunstanton. D'Orbigny's species was found in the Neocomian, 17th stage.

36. *ZONOPORA ? VARIABILIS*, d'Orb.

1852. *Zonopora variabilis*, d'Orb. Terr. Crét. v. p. 931, pl. 771. figs. 9-13.

There are only minute fragments, which I place here doubtfully.

Fossil No. 46.

Horizon. Top Beds, Red Chalk, Hunstanton. D'Orbigny's species was found in Senonian strata, 22nd stage.

GENUS *MULTICRESCIS*, d'Orb.

37. *MULTICRESCIS VARIABILIS* (?), d'Orb.

1852. *Multicrescis variabilis*, d'Orb. Terr. Crét. v. p. 1077, pl. 800. figs. 3-7.

In some respects the zoarium of the present species is similar to the example that I have placed under the *Ceripora micropora* (?), Goldfuss; but careful examination of the orifices of the two forms shows that the two are specifically distinct.

Fossil No. 47.

Horizon. Top Beds, Red Chalk, Hunstanton. D'Orbigny's species is found in the 20th Cenomanian stage at Le Mans.

In Mr. Etheridge's list of Cretaceous Polyzoa (Bibliograph. 36,

pp. 589, 590) he cites *Zonopora* (probably *Z. undata*) as occurring in Cenomanian strata; and five species of *Multicrescis*, three from the Neocomian, but the other two are not located; and also one species of *Ceriocava* from the Gault.

Genus UNICAVEA, d'Orb.

1826. *Melobesia*, Aud. (non Lamouroux); 1839. *Tubulipora* (pars), d'Orb.; 1848. *Defrancia*, Reuss (non Bronn); 1852. *Unicavea*, d'Orb. Terr. Crét. v. p. 970.

The genus *Unicavea*, as founded by d'Orbigny, embraces a most peculiar group of fossils (*Lichenoporidæ*, Hincks). The colony is a very simple, discoid, dome-like zoarium, fixed by the whole of its under surface to some foreign body, sometimes surrounded by a basal lamina, which is not always apparent in some of the species of the genus. The *zoœcia* are disposed in primary and intermediary rays, each of which bears the orifices of depressed tubular cells. Between the rays are cancellated interspaces, with a depressed, cancellated, non-zoœcial space in the centre of the zoarium. *Unicavea radiata* (Audouin), one of d'Orbigny's species, is cited by Busk as *Discoporella* (Catal. Mar. Polyz., Cyclostom. Polyz. 1875, p. 32), and by Hincks as a *Lichenopora* (Brit. Mar. Polyz. p. 476); but as none of the figures compare favourably with the Red-Chalk forms, which I shall place in the genus *Unicavea*, I make no apology for passing over the recent species, ignoring at the same time some citations by d'Orbigny and others.

38. UNICAVEA COLLIS, d'Orb.

1850. *Actinopora collis*, d'Orb. Terr. Crét. v. pl. 643. figs. 1-4.

1852. *Unicavea collis*, d'Orb. *ibid.* p. 973, pl. 778. figs. 1, 2.

There are a few forms in the Red Chalk that may be regarded as allies of the French Senonian species, even if they be not identical. The *zoaria* are dome-like and fully attached by the under side to foreign bodies. The *zoœcia* are disposed in primary and intermediary rings, which begin to form a little beyond the central cancellated centre. The examples are too badly preserved to allow me to discuss the Lichenoporidal features, ovicells or cancellæ, entered into by Mr. Waters*; but the characters, so far as I can make out, are more in accord with the Cretaceous (Senonian) forms than with any recent example of *Lichenopora radiata*, Aud., known to me.

Unicavea collis, d'Orb., must not be confounded with *Reptomulticava collis*, d'Orb., already described. The species are quite distinct.

Habitat. On *Terebratula*, *Inoceramus*, and *Bourgueticrinus*. *Fossils* Nos. 37, var. A, on *Terebratula*; 38, var. B, on *Bourgueticrinus*.

* A. W. Waters, 1884, pp. 694-5, Quart. Journ. Geol. Soc. vol. xl.; 1887, pp. 345-347, vol. xliii.; "On the Ovicells of some Lichenoporidæ," Journ. Linn. Soc., Zoology, vol. xx. pp. 280-285 (1888).

§ II. Suborder CHEILOSTOMATA, Busk.

Celloporina, Ehrenberg.

Genus MEMBRANIPORA, Blainv. See Hincks's Brit. Mar. Polyz.

Eschara (pars), Pallas; *Flustra* (pars), Linné, Lamarek, Fleming, Lamouroux, Audouin; *Membranipora*, Blainville, Johnston, Busk, Smitt, Hincks; *Cellepora* (pars), *Marginaria*, *Dermatopora*, v. Hagenow; *Cellepora*, d'Orb. †

"Generic Characters.—Zoarium encrusting. Zoecia quincuncial, or irregularly disposed, occasionally in linear series; margins raised; front depressed, wholly or in part membranaceous" (p. 128, *op. cit.*).

The few species that I place in this group are very characteristic, and likewise very rare in the Red Chalk.

39. MEMBRANIPORA GAULTINA, sp. nov. (Plate XIX. figs. 13 a-13 d.)

Zoarium very simple and uniserial. Zoecia elongate, sub-ovate, produced or attenuated below; area oval, occupying nearly the whole front, area-walls smooth (?), occasionally crenulated; the produced portion of the wall just below the area folded or puckered. Zoecia linked together in linear series; branches lateral, sometimes from every cell, at other times three cells apart, and occasionally from both sides of the same cell; three of the longest zoecia together measure one quarter of an inch.

Habitat. On *Inoceramus*, *Terebratula biplicata*, *Terebratula capillata*. Fossils Nos. 38 and 39*.

Horizon. Gault, Cambridge; and Red Chalk, Hunstanton.

This very peculiar *Membranipora* I have been obliged to describe as new, but not until after an examination of the illustrations of all apparently similar forms known to me; even then I should have hesitated to do so, had not a fine series from the Gault of Cambridge been sent to me for examination by Mr. Jesson.

At first I thought that the species described above may be placed as an ally of either *Hippothoa elegans* or *H. laxata*, d'Orbigny (Terr. Crét. pl. 711. figs. 1-4 and 12-15); but a reference to the figures is sufficient to show that no identity can be established between these forms. Novák (Bibliogr. 34) described two species of *Hippothoa*, *H. desiderata* and *H. labiata*, both of which, certainly in some of their characters, closely resemble *M. gaultina*; but among at least one hundred zoecia examined, not a single attenuation of the cell-wall exhibits the wavy outline indicated in Novák's figures. Then, again, the *Membranipora*-like area shown by Novák is an accidental breakage of the once covered portion, judging from some of the perfect cells depicted, whereas in the present

† In reproducing these names, Mr. Hincks says in a note (p. 128), "I have not thought it necessary to swell this list of synonyms by referring to all d'Orbigny's genera which include species of *Membranipora* as now defined. The groups to which they belong are given in the Family synonymy" (p. 126, *op. cit.*).

species the area-opening appears to me to be perfectly normal. The folding-in of the wall below the area also precludes the placing of the form here described even as a variety of *Membranipora catenularia*, Jameson (Hincks, Brit. Mar. Polyz. pl. xvii.).

I have figured the Red-Chalk form of *M. gaultina*, but I have had the better-preserved Gault examples before me when drawing up the characters. It is in the Gault form that the puckering of the wall below the area is found.

40. MEMBRANIPORA FRAGILIS (d'Orb.).

1852. *Flustrellaria fragilis*?, d'Orb. Terr. Crét. v. p. 545, pl. 723. figs. 5-9.

I have met with two or three examples of a form closely resembling the *F. fragilis* of d'Orbigny. Very rarely more than from 3 to 6 cells are preserved; and the fossil cited below contains the best-preserved colony that I have found. As the Red Chalk, so far as my experience goes, is very poor in Cheilostomatous forms, I have done my best to preserve every record of their existence, hoping that other workers will be able to add to the meagre list.

Habitat. On *Terebratula biplicata*. Fossil No. 41.

Horizon. Red Chalk, Hunstanton.

41. MEMBRANIPORA ELLIPTICA (?) (Hagenow).

1839. *Cellepora elliptica*, Hag. Neues Jahrbuch &c., p. 268; *Marginaria elliptica*, Rømer; *Membranipora elliptica*, d'Orb.

1877. *Membranipora elliptica*, Hag; Novák, Bryoz. böhm. Kreid. p. 89, pl. 2. fig. 16.

Hesitating to identify this species with von Hagenow's *C. elliptica*, I refer the student to the long list of synonyms given by Novák, and to his reasons for adopting that course. I have only one example; and as Novák's fig. 16, pl. ii., closely resembles its general features, his identification is adopted. I should have been more inclined to place this unique example under *M. tuberosa*, Novák, but the cells of that species are not elliptical, like the British Red-Chalk form. The avicularian cells in the intermediary space between the ordinary zoecia are very conspicuous and abundant on the Fossil No. 42.

Habitat. On *Pentacrinus Fittoni*. Fossil No. 42.

Horizon. Red Chalk, Hunstanton.

42. MEMBRANIPORA OBLIQUA (?) (d'Orb.).

1852. *Filiflustraria obliqua*, d'Orb. Terr. Crét. v. p. 513, pl. 723. figs. 1-4.

If we are to regard d'Orbigny's species mentioned above as a *Membranipora*, then the present form is allied to, if not identical with, it. The British example, the only one that I have met with, is adherent to a fragment of a Belemnite, and is apparently much larger than the fragment figured by d'Orbigny. The zoarium

branches dichotomously. The *zoecia* are oval, but attached; area oval; walls thick. This is a poor and unique example of the species; I cannot follow d'Orbigny in the other characters drawn up by him.

Habitat. On *Belemnites*. *Fossil** No. 44.

Horizon. Red Chalk, Hunstanton.

Genus HIPPOTHOA, d'Orb.

43. HIPPOTHOA SIMPLEX (d'Orb.).

1851. *Hippothoa simplex*, d'Orb. Terr. Crét. v. p. 385, pl. 711. figs. 5-8.

The forms that I have been able to identify are certainly not members of the *Hippothoa* group as now understood; but, as a set of four cells appear to belong to *H. simplex*, d'Orb., or a close ally, I place them here provisionally. They are all that I have met with adherent to Red-Chalk fossils, and are too characteristic to be overlooked.

Habitat. On *Inoceramus*. *Fossil* No. 40.

Horizon. Red Chalk, Hunstanton.

EXPLANATION OF PLATE XIX.

Polyzoa from the Red Chalk of Hunstanton, Norfolk.

(The objects enlarged are magnified about 15 or 20 diameters.)

- Fig. 1. *Proboscina angustata*, d'Orb. Variety: 1 *a*, natural size; 1 *b*, enlarged. Var.: 1 *c*, nat. size; 1 *d*, enlarged.
2. *P. irregularis*, sp. nov.: 2 *a*, nat. size; 2 *b*, enlarged. Var.: 2 *c*, nat. size; 2 *d*, enlarged.
3. *P. uberrima*, sp. nov.: 3 *a*, nat. size; 3 *b*, enlarged.
4. *P. gracilis*, Reuss, var. *Reussii*, nov.: 4 *a*, nat. size; 4 *b*, enlarged.
5. *P. hunstantonensis*, sp. nov.: 5 *a*, nat. size; 5 *b*, enlarged.
6. ———, var. *ampliata*, nov.: 6 *a*, nat. size; 6 *b*, portion enlarged; 6 *c*, nat. size; 6 *d*, portion enlarged.
7. *P. Jessoii*, sp. nov.: 7 *a*, nat. size; 7 *b*, enlarged.
8. *P. gigantopora*, Vine, var.: 8 *a*, nat. size; 8 *b*, portion enlarged.
9. *P. bohémica*, Novák, var.: 9 *a*, nat. size; 9 *b*, enlarged; 9 *c*, nat. size; 9 *d*, portion enlarged.
10. *Diastopora hunstantonensis*, sp. nov.: 10 *a*, nat. size; 10 *b*, portion enlarged.
11. ———, var.: 11 *a*, nat. size; 11 *b*, portion enlarged.
12. *D. Jessoii*, sp. nov.: 12 *a*, nat. size; 12 *b*, portion enlarged.
13. *Membranipora gaultina*, Vine, var.: 13 *a*, nat. size; 13 *b*, enlarged; *c*, *d*, portions enlarged.

DISCUSSION.

Dr. HINDE commented on the imperfect preservation of the specimens exhibited, and the difficulty of satisfactorily determining species from such specimens.

* The fossil No. 43 (*Terebratulina buplicata*) has attached to it several examples of *Webbina* (?), which seem to simulate the characters of *M. obliqua*; but a careful examination of the two forms will be sufficient to disprove any supposed relationship between the polyzoan and the protozoan.

29. *The DEVONIAN ROCKS of SOUTH DEVON.* By W. A. E. USSHER, Esq., F.G.S., of the Geological Survey of England and Wales. (Read April 30, 1890.)

By permission of the Director-General of the Geological Survey of the United Kingdom.

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§ I. INTRODUCTION.

“IN South Devonshire the rocks are greatly disturbed, broken by faults, standing at various angles, folded, and distorted; eruptive rocks frequently cut through them, and beds of volcanic ash are interstratified with them. Hence has arisen great dispute and uncertainty as to the true order of succession of deposits, although their fossils were referred to the Devonian age nearly fifty years ago. It will be seen without comment that the South Devonshire sections, from which most of the Middle- and Lower-Devonian fossils have been obtained, are valueless for determining the order of sequence of the faunas. There are many places (I saw such near Newton-Abbot) where limestones, appearing very similar in colour and structure, and within a stone's throw of each other, hold distinct faunas. In fact, the interpretation of the order of the beds is a matter of the greatest difficulty, even when occasional fossils appear.”

Here is the geology of South Devon as epitomized by Professor H. S. Williams, of Ithaca, N.Y., in a paper read before the American Association for the Advancement of Science as lately as Aug. 30, 1889. Explorations in the rocks of Devonshire gave rise to the Devonian System; explorations in France, Belgium, Germany, Russia, and North America have made us acquainted with the succession of

the Devonian faunas, and the extraordinary persistence of homotaxous horizons, such as those characterized by *Stringocephalus*, *Rhynchonella cuboides*, and *Goniatites*, at the same time presenting us with the varied evidences of stratigraphical succession.

The disturbances to which Prof. Williams refers, the distortion of fossils in consequence, and the paucity of localities rich in characteristic fossils, renders South Devon a most unprofitable field to the casual investigator, whilst depriving the stratigraphist of the only means of piecing the scattered details into a connected whole.

The late Mr. J. E. Lee's* discoveries of the Budesheim and Adorfer-Kalk faunas at Saltern Cove and Chudleigh proved that the Goniatite fauna had extended to Devonshire; but the faulted occurrence of the beds containing it precluded the observation of their true position in the formation.

The South-Devon limestones were, with two or three exceptions, regarded as Middle Devonian, and the presence of Lower Devonian was only proved in the Torquay Promontory.

The old 1-inch Ordnance Map on which De la Beche, Godwin-Austen, and subsequently Dr. Harvey Holl and Champernowne, were compelled to record their observations on the stratigraphy of South Devon is much too small to note minutiae which have the most important bearing on the question.

Dr. Holl †, in 1868, placed both the Plymouth and Paignton sections in the wrong sequence, through the acceptance of inverted dips as natural evidences of superposition; yet his sections account for the position of many of the types which he correlated by inverted plication. The succession he advocated in descending order is:—Staddon and Cockington grits, slates, limestones. He likewise endorsed Godwin-Austen's view that the limestones of Ashburton were a lower series than those of Newton and Ipplepen.

During a re-survey of portions of the country around Newton-Abbot and Torquay in 1874-75, my colleague, H. B. Woodward ‡, arrived at the conclusion that the Devonian rocks occurred in descending order as follows:—

Limestones.

Slates.

Red Sandstone (of Cockington).

When this general succession was published in 1876, it was adopted by Mr. Champernowne as affording "the clue to unravel the country."

Mr. Champernowne §, in "Notes on the Devonian and Old Red Sandstone of North and South Devon," gave the true succession in sections of the Mudstone-Bay coast. "This," he says, "brings the Red Sandstone into direct and natural relation with those of Cockington, the Warberry, Lincombe, &c. at Torquay, which are

* Geol. Mag. 1877, p. 100, and 1880, p. 145.

† Quart. Journ. Geol. Soc. vol. xxiv. p. 400.

‡ Geol. Mag. 1876, p. 576.

§ *Ibid.* 1878, p. 193.

beneath the limestones." Unfortunately, subsequent investigations near Cockington, Marlton, and Paignton induced Mr. Champernowne to abandon his previous views and to endorse, on stratigraphical grounds, the erroneous succession given by Dr. Holl. The independent observation of the Plymouth section led me to adopt the same views. We were both under the impression that the Cockington beds were unfossiliferous, and in ignorance of the discovery, by the Rev. G. F. Whidborne, of Lower-Devonian fossils in them, no detailed account of which had been published beyond incidental reference to it in Dr. Davidson's Supplement to Devonian Brachiopoda, Pal. Soc. Mon., note by G. F. W. at p. 4.

Thus, through a mere accident, the geologist whose painstaking devotion has furnished the first detailed map of the Devonian rocks of South Devon, and vastly increased our knowledge of that formation, was deprived of reaping the results of his exhaustive labours.

For the publication of the erroneous succession given in Proc. Geologists' Assoc. vol. viii. pp. 442 &c., I am alone responsible, Mr. Champernowne's views having, at my request, been promptly reduced by him to their simplest form in spite of the uncertainty he entertained respecting them.

The existence of contemporaneous volcanic action,—the definition of the Ashprington series and of sporadic evidences of local vulcanicity outside its borders,—the correlation of the Ashburton limestone with that of Newton and Ipplepen,—and palæontological contributions, adding to our knowledge of the Middle and Lower Devonian, stand prominently forth amongst the labours of my deceased friend. Had he lived, the task I briefly and inadequately undertake would have fallen into better hands.

During our friendship I became so thoroughly conversant with the special difficulties he encountered, and with the doubts he entertained, that, when it devolved upon me to carry on his work on the six-inch Map, I started already equipped with the results of his experience, and was stimulated to researches in quest of fossils in beds before regarded as unfossiliferous in character and anomalous in position. So the present communication must be taken as the outcome of my friend's life-work in Devonian geology, and will, I trust, form a not unfitting tribute to his memory.

After the London Meeting of the Geological Congress in 1888 I had the advantage of conducting MM. Gosselet, Kayser, Tschernyschew, Holst, and Frech over the North-Devon section and over those parts of South Devon near Newton-Abbot, Chudleigh, and Torquay, which would in a short time best show the different varieties of rock and evidence of their fossil contents.

Dr. Kayser embodied the results in a pamphlet entitled "Ueber das Devon in Devonshire und im Boulonnais," Neues Jahrbuch für Mineral. &c. Bd. i. (1889). The identification of the Cypridinen-Schiefer, by the Lewell-Path road and at Whiteway Farm, was of immense service to me. The identification of the Hope's Nose thin limestone with the Calceolen-Kalk, and the correction of *Rh. cuboides* to *procuboides*, were also important.

M. Frech kindly furnished me with the names of fossils found in the different localities visited.

I have great pleasure in acknowledging my indebtedness to MM. Gosselet and Barrois, and subsequently to Dr. Kayser, for their kind and prompt assistance in identifying fossils sent to them from time to time in 1889.

I am indebted to M. Tschernyschew for the assistance afforded me, by the presentation of his admirable contributions to the Devonian geology of Russia; and to MM. Gosselet, Kayser, and Barrois for similar favours.

My friend Prof. Gosselet devoted a week last September to conducting me over the typical sections of the Ardennes rendered classic by his investigations. His kindness supplied me with more information and encouragement than I can hope to repay.

§ II. GENERAL DESCRIPTION.

The area to which this paper more particularly refers lies north of the River Dart and East of Dartmoor, and comprises the most complex and lithologically varied tract in South Devon.

We naturally turn to the limestone districts to obtain evidence of structure. Owing, however, to crushing, it is impossible to obtain persistent and reliable dips beyond the actual exposures; and the acceptance of apparent superposition of limestone on slate, or *vice versa*, in any one place must lead to endless confusion in its general application, as inversion is rather the rule than the exception.

Evidences of stratigraphical relations are often so dubious as to suggest alternative explanations, such as anticlinal or synclinal inversion or consecutive sequence. Moreover the sharp plications often displayed in a single quarry, in beds otherwise exhibiting low dips, inspire caution.

When, however, we regard the district as a whole, the local development of limestones in the Kingsteignton, Ipplepen, King's-Kerswell, Torquay, Yalberton, and Brixham districts,—the prevalence of slates in the Berry-Park and Staverton districts,—and of volcanic materials north-east of Bickington, south of Totnes, and east of Yalberton, compel us to ascribe the anomalous distribution of the limestones to very irregular accumulation dependent on locally favourable conditions. Thus, in the area south of Totnes the formation of limestone has been restricted, owing to a long-continued period of volcanic activity; whilst near Bickington, Dartington, and Yalberton its accumulation has been partially arrested from a similar cause. Again, in the Broadhempston district the limestones are clearly impersistent; and the Plymouth and Ycalmpton masses, although equivalent to the Ipplepen and Denbury limestone, and to that of Ashburton, are, in the intervening district, represented by slates with very occasional, insignificant patches of limestone.

Without such a broad interpretation as the above it is found that

Fig. 2.—Map of the Distribution of the Devonian Rocks in the District between the River Teign and the Haldon Hills; showing the Kingsteignton Succession and the new Fossil Finds.

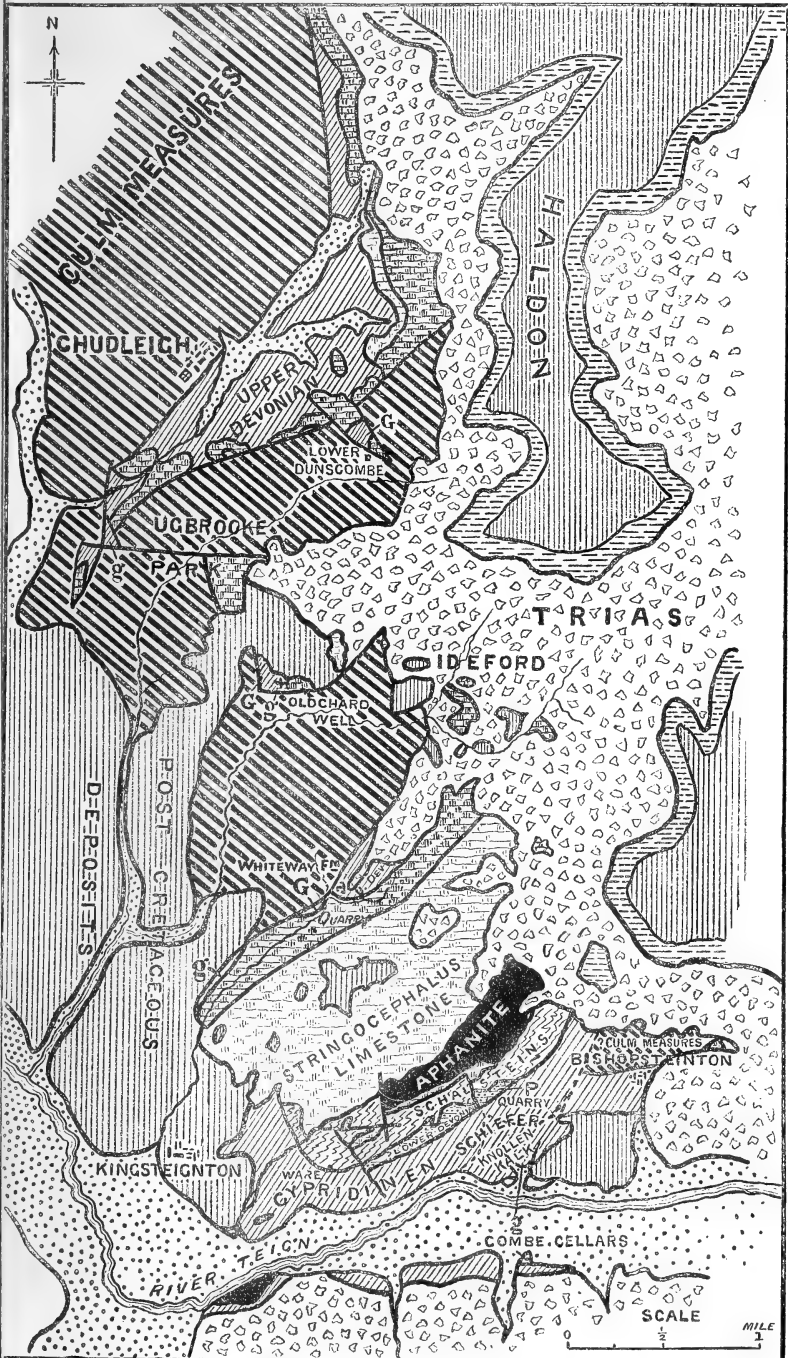
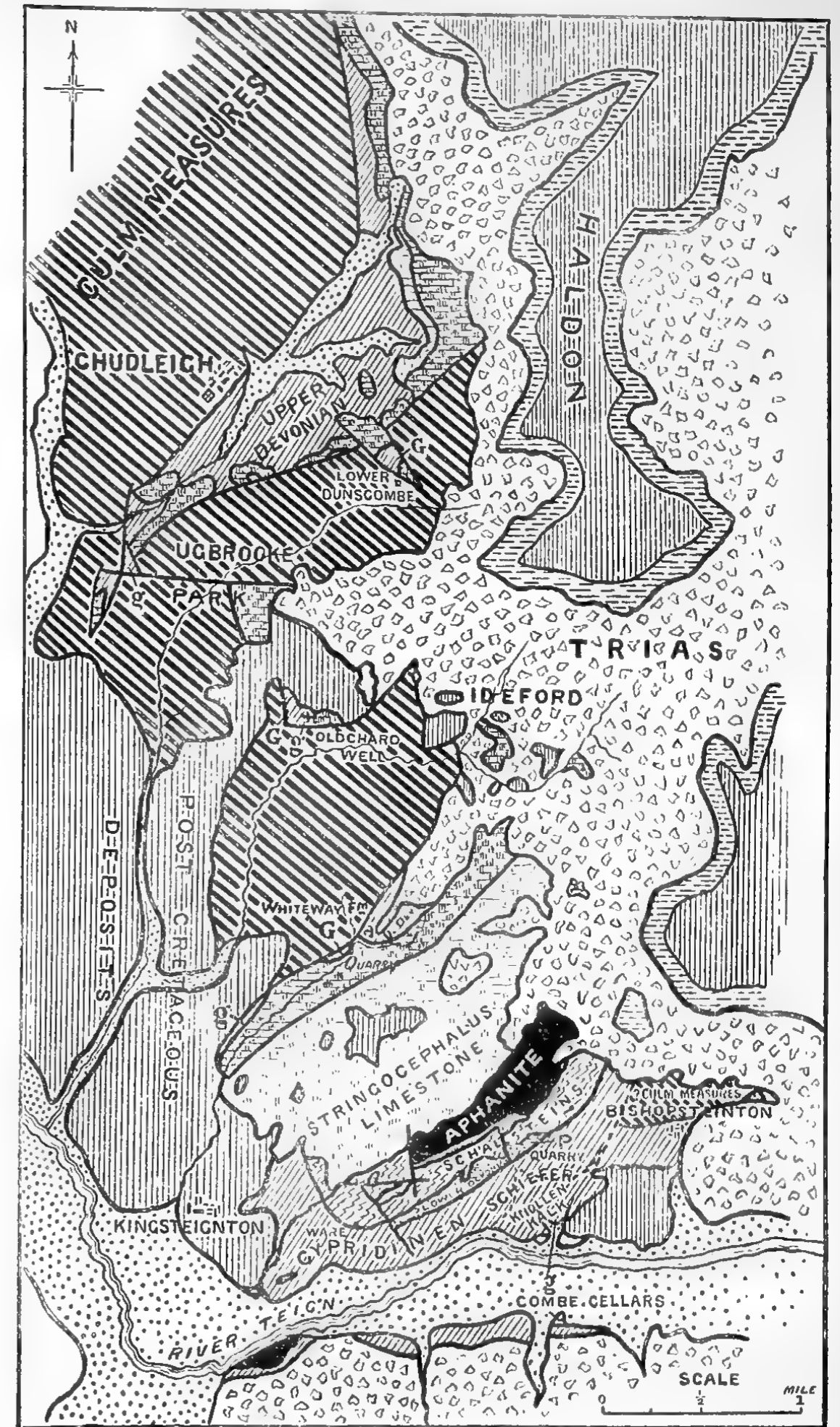
















Fig. 1.—Map of the Distribution of the Devonian Rocks in the District West of Torquay; showing the Relation of the Volcanic Series and the Fossil Finds, proving Upper and Lower Devonian.



Fig. 2.—Map of the Distribution of the Devonian Rocks in the District between the River Teign and the Haldon Hills; showing the Kingsteignton Succession and the new Fossil Finds.



EXPLANATION OF FIGS. 1 & 2.

- | | | |
|---|---|---|
|  Alluvium. |  Culm-measures. |  Aphanite, hard Diabase. |
|  Post-Cretaceous. |  U.D. Upper-Devonian Slates. |  M.D.L. Middle Devonian Limestone. |
|  Cretaceous. |  U.D.L. Upper-Devonian Limestone. |  E. Eifelian Slates. |
|  T. Lower-Trias Breccia and Sandstone. |  V. Volcanic Tuffs, Schalsteins, and Diabases. (Harder Diabase masses, black.) |  L.D. Lower Devonian. |

g. Goniatite-beds.

G. Goniatite-beds: *Goniatites* found.

P. Pleurodictyum-beds.



local successions are not capable of general application. Thrust-faults on the axes of inversions are frequently present on a small scale; but to ascertain their existence on a large scale demands palæontological data of a most definite character, which from the comparative rarity of characteristic fossils does not appear to be obtainable. We have therefore to fall back upon such information as can be procured of the general types of Upper-, Middle-, and Lower-Devonian faunas; for without these an appeal to stratigraphy can only lead the enquirer to a mass of apparently contradictory details.

From this it must not be inferred that the occurrence of individual characteristic forms is anywhere of weight unless supported by sufficient positive, negative, or comparative evidence, or that its admission in any way violates definite stratigraphical position.

Although the lithological constituents of the Upper-, Middle-, and Lower-Devonian beds are broadly distinguishable, yet there is no definite lithological boundary between the groups. The Lower Devonian is mainly distinguished by the occurrence of sandstone and grit; but the upper beds are slates or shales passing, where unfaulted, indistinguishably upward into the Middle Devonian slates. In no part of the Lower-Devonian area have igneous rocks been found.

The Middle Devonian consists of limestones upon shaly limestones upon slates.

The slaty and shaly basement-limestone and underlying slates represent the Calceolen-Kalk and Calceolen-Schiefer. The Calceolen-Schiefer is somewhat variable in character, the irregular grey slates with fossiliferous lenticles, developed in Berry Park, and the even grey and bluish-grey slates of Mudstone Bay, being different types. These slates and the overlying thin limestones are characterized by the occurrence of *Spirifer speciosus*.

The Middle-Devonian limestones are well bedded in the lower part of the mass, where they are usually dark-grey, and contain *Heliolites porosus*, *Cystiphyllum vesiculosum*, *Cyathophyllum helianthoides*, and *C. dammoniense*. *Stringocephalus* is found here and there throughout the district in the bedded limestones. The upper part of the Middle Devonian generally consists of pale bluish-grey and grey limestone, often massive, as in the Lummaton and Barton quarries, where it is composed of corals, amongst which *Smithia Hennahi* and *S. Pengellyi* are noticeable. These massive limestones denote the passage from the Middle Devonian, in which the Lummaton fauna occurs, to the *Cuboides*-beds of the Upper Devonian; and, as it is not possible to draw any definite boundary in them, they must also be regarded as partly of Upper-Devonian age.

The Upper Devonian first becomes distinctly recognizable by thin-bedded limestones and limestone lenticles intercalated with chocolate-red, lilac-weathered slates and mudstones. These limestones are, as a rule, red or liver-coloured and of very compact texture; they are often knubbly or concretionary, as at Lower Dunscombe, at Oldchard, near Whiteway Farm (where they contain *Goniatites*), and

by the River Teign opposite Combe Cellars. This concretionary character, distinguishing the Knollen-Kalk, is locally developed in the form of calcareous nodules in irregular dark-grey slates, as near Lewell (Chudleigh), near Bishopsteignton, by the Teign west of Combe Cellars, and west of Abbotskerswell.

Above the Knollen-Kalk we encounter chocolate-red slates and mudstones, containing *Posidonomya venusta* and *Entomis*, locally greenish and grey. In addition to the localities mentioned by Kayser, these beds, correlated by him with the Cypridinen-Schiefer, occur in Kingsteignton Railway-cutting at Newton-Abbot, Anstey's Small Cove, and Goodrington. In the district west of Newton-Abbot the Upper-Devonian beds consist mainly of red and greenish slates, the latter furnishing badly preserved *Goniatites* at Wrigwell House.

Sporadic evidences of vulcanicity frequently render the relations of the Upper and Middle Devonian extremely obscure, and outside the limestone areas, where the normal slate type everywhere prevails, the localization of these groups (as may be seen from a recent communication to the Devon Association on the geology of Tavistock) is extremely indefinite.

The main distinctions between the lithological characters of the three Devonian groups in the area under description are as follows:—Lower Devonian: presence of grits and sandstones, often in mass.

Middle Devonian: slates, of grey and bluish tints; fossils in lenticles and much distorted, but not infrequent.

Upper Devonian: slates, very unfossiliferous, red and pale green tints prevalent.

The common characteristics of the groups are:—

Middle and Lower Devonian: slates in which the boundary can only be ascertained by palæontological evidence.

Upper and Middle Devonian: massive limestones, in which no hard-and-fast boundary-line can at present be traced by the discovery of fossils; local prevalence of volcanic schalsteins and tuffs, breaking up the limestones and obscuring general indications of boundary.

§ III. RELATIONS OF THE CULM AND DEVONIAN.

No paper on the Devonian rocks of South Devon would be complete without a reference to the relations of that formation to the Culm-measures. Here it must be confessed that the details supplied by this district are wholly inadequate to furnish even general conclusions of a trustworthy nature, the boundaries being in most cases fault-lines. There are, however, certain known facts outside the district available to supplement the meagre evidence within it. Holl* advocated the existence of a considerable unconformity between the Culm and the Devonian rocks of South Devon, on the

* Quart. Journ. Geol. Soc. vol. xxiv.

ground that, whilst the lower beds of the Culm-measures were equally well developed in North and South Devon, the upper beds of the Devonian did not correspond; and even in South Devon and East Cornwall the Culm-rocks appeared to rest upon Devonian strata of different ages.

I have elsewhere given reasons* for regarding the Petherwin beds and those of Druid, near Ashburton, as probably contemporaneous with the *Rhynchonella-letiensis*-zone of the "Fammenien" of the Ardennes, but beyond this I have been unable to extend the comparison to that region; the Cypridinen-Schiefer mainly constituting the upper part of the Devonian in the district under description proves, as Dr. Kayser has shown, a correlation rather with the German than the Franco-Belgian Upper-Devonian type.

In 1887 I discovered Upper-Devonian slates in the Culm-measure area between Bickington and Bovey Tracey; these consist of grey slates and grey and brown mudstones, somewhat recalling the Druid beds, and of red and greenish slates of the normal type of the Cypridinen-Schiefer. In the only places where unfaulted junction-relations with the Culm-measures are visible, no unconformity is apparent. Coddon-hill beds (identified as phthanites by Professor Gosselet) seem to overlie the Knollen-Kalk and Cypridinen-Schiefer by the path-road to Lewell, near Chudleigh. This junction appeared to Prof. Kayser to be a natural one; whilst M. Gosselet regarded it as a proof of unconformity. The subsequent experience I have acquired does not enable me to decide authoritatively between these views; but the acceptance of a natural junction in this spot is not in accordance with the development of the Upper-Devonian slates in the South-Devon area.

We may conclude generally that the Upper-Devonian slate and psammite type of North Devon gave place southward to a purely slate type; and that the latter, probably from unequal rate of deposition in deeper water, attenuated as the distance from the shoal-areas increased; but, as the conditions which produced similar sedimentation in the earliest Culm-rocks of North and South Devon would probably be the same, it is not unlikely that their production in South Devon precluded the equivalent representation of the upper part of the Devonian series, and even occasioned an overlap of the Culm-measures.

I purpose to lay before the Society the evidence for the grouping of the Devonian rocks of South Devon under the following heads:—

Upper Devonian	.....	{	Cypridinen-Schiefer (Entomis-slates).
			Goniatite-limestones and slates.
			Massive limestones.
Middle Devonian	.....	{	Middle Devonian Limestones.
			Ashprington volcanic series.
			Eifelian slates and shaly limestones.
Lower Devonian	.....		Torquay area, Paignton area.

* Trans. Devon. Assoc. for 1889.

§ IV. LOWER DEVONIAN.

1. *Torquay Area*.—Up to the year 1889 the record of the occurrence of Lower Devonian in South Devon is confined to the Torquay promontory. (See Map, Fig. 1, opposite p. 490.)

In that promontory two divisions of the Lower Devonian had been recognized, the Upper (Lincombe and Warberry beds) consisting of red sandstones and grits with shales, the Lower (Meadfoot beds) of irregular bluish-grey slates with hard grits.

Mr. Champernowne discovered *Homalonotus* on the east side of Lincombe Hill by the New Cut, “in some red finely-sandy or silty beds, interstratified with grits. The beds are traversed by a coarse cleavage dipping south, which usually ignores the hard grit-bands.

“We may call them . . . the Lincombe, Warberry, and Smuggler’s-Cove grits . . . Within a hundred yards west of the spot where the specimen occurred, this subgroup becomes mottled with light colours, brown grits appearing, and passes down into the Meadfoot series. . . . The grits of the Meadfoot series are less distinctly quartzose, and are more tenacious, requiring heavier hammers. If we imagine this lower group coloured red, it is difficult to say whether, on purely palæontological grounds, they would be separated from the upper; but it is probable they might be. The buff and brown weathering of the Meadfoot beds disappears with depth, as the heaps shot out from the Torquay drainage-works show, grits and shales alike being of a blue-black tint; whereas red or purple beds, as a rule, are so both at the surface and in depth. In the passage-beds described above, I hold that we have a horizon corresponding in general terms with that between the Hangman and Lynton groups of North Devon If now we look abroad, we seem to gain some insight into the occurrence of red sandstones of marine origin on the same horizon in the Devonian rocks. In the Eifel district the ‘*Homalonotus* Red Flagstones,’ so named by Murchison, “occupy a horizon high in the Lower-Devonian beds, scarcely removed from the base of the Calceolen-Schiefer, and the bulk of the Coblentzian or Ahrian, the chief home of *Pleurodictyum problematicum* (though this mud-loving Favositid ranges higher in the series) lies below them”*.

The Lincombe and Warberry beds occupy the highest land in the Torquay promontory; in their extension to the coast at Smuggler’s Cove they are faulted on the north and south, but on the hill above Kilmorey they occur in an isolated patch.

These grits do not appear on the coast in unfaulted relation; and, as red Eifelian shales and shaly limestones with *Calceola* directly underlie the limestone of Daddy-Hole-Knoll, their absence between this and the Eifelian shales and limestones of Hope’s Nose is only to be accounted for by an extensive fault cutting them out, unless we are prepared to admit that they underlie the Meadfoot beds, or occur impermissibly in the upper part of that series.

* Geol. Mag. 1881, pp. 487, 488.

The following is a list of Fossils obtained in the Lincombe and Warberry beds:—

At Warberry Hill fossils are very rare. Tentaculites have been identified; also *Beyrichia Wilckensiana* *.

From the Lincombe-Hill grits fossils have been obtained in the following places:—

Oxlea hill:

Homalonotus.	|	Pentamerus.
Spirifer.	|	Orthis.

New Cut:

Orthoceras.	|	c. <i>Chonetes sordida</i> , often crowded in certain layers.
c. <i>Myalina</i> (small).	|	c. <i>Homalonotus Champernownei</i> .
Tentaculites.	|	<i>Pleurodictyum problematicum</i> .
c. <i>Cypricardites</i>.	|	
<i>Avicula anisota</i>.	|	

[c.c.c.c. from Mr. Champernowne's list.]

On the hill behind Kilmorey:

<i>Atrypa</i>.	|	<i>Spirifer cultrijugatus</i> .
<i>Chonetes</i>.	|	<i>Homalonotus Champernownei</i> .

From Smuggler's Cove:

<i>Edmondia</i>.	|	c. <i>Leptana laticosta</i> .
<i>Macrocheilus</i>.	|	<i>Pleurodictyum</i> .
c. <i>Orthis</i> .	} Numerous casts.	
c. <i>Spirifer</i> .		

From the Meadfoot beds the following fossils were obtained:—

In beach-reefs near Kilmorey, described by Kayser as dark slates and grauwacké, here and there enclosing masses of fossils:

<i>K. Chonetes sarcinulata</i>.	|	<i>K. Strophomena</i> , allied to <i>Murchisoni</i> .
<i>K. Pterinæa costata</i>.	|	<i>U. Cucullæa</i> .
<i>U. P. spinosa</i>.	|	<i>U. Trimerocerphalus</i> .
<i>K. Rhynchonella daleidensis</i>.	|	<i>U. Pleurodictyum problematicum</i>
<i>K. Spirifer hystericus</i>.	|	(two specimens).
<i>K. Sp. paradoxus</i>.	|	<i>U. Fenestella</i> .
<i>F. Sp. macropterus</i>.	|	<i>F. Zaphrentis oolithica</i> .

[*K.* denotes Kayser's list; *F.* identification by Frech on the spot; *U.* found by Ussher.]

The following were obtained by me in the Meadfoot Beds:—

Near St. Raphael's Home:

<i>Spirifer</i> .		<i>Streptorhynchus</i> .
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In quarry east of Kilmorey:

<i>Chonetes</i> .		<i>Homalonotus</i> .
<i>Spirifer</i> .		<i>Pleurodictyum</i> .

* [The *Beyrichia* (or rather *Kladenia*) *Wilckensiana* from Warberry Hill is matched by what Richter has figured and described as *Beyrichia aurita* in the *Zeitschrift deutsch. geol. Gesell.* vol. xx. (1869), p. 775, pl. xxi. fig. 15 (not fig. 16), from the Upper or Middle Devonian, which is, indeed, the same as *Kladenia Wilckensiana*.—April 29, 1890, T. R. JONES.]

Grit-bed on beach in cove west of the raised beach at Hope's Nose :
 Loxonema. | Pleurodictyum problematicum.

On surface above Hope's Cove :

Orthis. | Homalonotus (? Champernownei).
 Spirifer (? undiferus). |

At small cove, 30 chains from Kilmorey :

Natica. | Petraia.
 Spirifer. | Fucoids.

At 50 chains from Hope's Nose Quarry-well :

Spirifer (? speciosus).

In slates faulted against the limestone of Hope's Nose* Quarry :

Strophomena rhomboidalis. | Pleurodictyum problematicum.

By wood north-east of Kilmorey :

Pleurodictyum.

Before proceeding to the consideration of the Lower-Devonian area of Paignton, it must be remarked that slates identical in character with those of the Eifelian of Torquay occur in the area occupied by the Meadfoot beds.

Furthermore, between Kingsteignton and Bishopsteignton a strip of dark-grey fossiliferous clay-slates, faulted on the south against the Entomis-slates, but overlying, with inverted dip, volcanic beds, which separate them from the Middle-Devonian limestones, show Middle- and Lower-Devonian affinities, containing :—

Pleurotomaria. | Aulopora.
 Phacops. | Pleurodictyum (numerous).

[It seems possible that the traces of "*Pleurodictya*," so numerous in the quarry near Bishopsteignton, might be casts of portions of *Sphaeronites tessellatus*. I do not in any case think that they belong to the species *Pl. problematicum*.—June 1890.]

2. *Paignton Area*.—The Triassic area of Paignton is bounded by red and brown sandstones and grits and red slates. The grits, constituting the heights of Beacon Hill and Windmill Hill on the north of Stoke-Gabriel, are faulted against Middle-Devonian limestones and volcanic materials on the south, and against Berry-Park (Eifelian) slates on the west. These sandstones give place on their borders to red slates, partly intercalated with hard grit bands, as near Westerland and at the south end of Goodrington beach. They are very irregularly associated with red slates, which appear to underlie the sandstones, with a low dip, south of Cockington, but to pass up into the Eifelian near Marldon. (See Map, Fig. 1.)

The red slates with hard grit beds south of Goodrington beach

* *Petraia bina* and *P. celtica*, doubtfully identified by Messrs. Sharman and Newton, were found both here and in the quarry west of Bishopsteignton. *Goniatites spiralis* was also found in the latter, and furnishes an inexplicable anomaly.

support a Triassic outlier, and are faulted against the red slates and mudstones in which Mr. Lee discovered the Upper-Devonian Goniatite-fauna of Budesheim. The fault is entirely concealed by slips and undergrowth, and at the bridge spanning the adjacent railway-cutting it is by no means clear.

As before mentioned, Mr. Champernowne placed the Cockington grits in their true position at the base of the series in 1878* ; but the stratigraphy of the districts he subsequently investigated was so contrary to this view that he abandoned it, placing them at the top of the series, a conclusion I also came to from the independent observation of the Plymouth section †.

Mr. Champernowne's later views appeared in the succession given in the Ashprington paper lately communicated to this Society ‡, in which the Lower-Devonian slates or shales, correlated by him with the Cockington beds, were placed above the Goniatite-beds. This opinion was evidently entertained in ignorance of the discovery of Lower-Devonian fossils by the Rev. G. F. Whidborne in these beds in the adjacent railway-cutting. Incidental reference to this discovery is given by Davidson in the 'Supplement to the British Devonian Brachiopoda,' p. 4, in the following passage:—
 "At Saltern railway-cutting (behind Saltern Cove, within four or five miles of Torquay), Mr. J. G. Greenfall and Mr. G. F. Whidborne came upon a light brownish-red shale, in which several species of Brachiopoda occurred in considerable numbers, accompanied by *Pleurodictyum problematicum* and *Petraia*, sp. The fossils occur in the condition of impressions and casts, much distorted and compressed, so that it is not possible in most cases to arrive at a satisfactory identification. I thought I could, however, recognize among them *Spirifera levicosta*, *Rhynchonella Pengellyana*, *Leptena Looiensis*, *Orthis hipparionyx*, a small circular species of the same genus somewhat similar in shape to *O. arcuata*, and *Chonetes Hardrensis*."

At p. 8, further on, "Goodrington Sands (south of Paignton)" is bracketed with "*Pleurodictyum-problematicum* beds," under the heading of Lower-Devonian localities.

On accidentally hearing of this discovery from Mr. Hunt, early in 1888, I visited the cutting with him and Mr. Whidborne, when we obtained *Pleurodictyum problematicum*, *Chonetes sordida*, &c.

As I considered a single find of Lower-Devonian fossils insufficient to disprove my friend's stratigraphical conclusions, I proceeded to ascertain whether the fossiliferous beds were really a part of the Cockington series, and whether that series was wholly unfossiliferous.

The success I met with in these quests is more than neutralized by regret that my friend cannot share in it.

Fossils are exceedingly scarce in the Lower-Devonian slates, shales, and sandstones of the Paignton area ; but a diligent search, in spite of repeated disappointments, has enabled me to place the

* Geol. Mag. 1878, p. 193.

† Proc. Geologists' Assoc. vol. viii. pp. 442, &c.

‡ Quart. Journ. Geol. Soc. vol. xlv. p. 369, &c.

Cockington Beds in the Lower Devonian on palæontological evidence quite as strong as any furnished by the Torquay promontory, as may be seen from the following discoveries:—

In the red slates with grit-bands at the south end of Goodrington Sands:

Orthoceras.	|	Spirifer.
Tentaculites.	|	Pleurodictyum.

In the adjacent railway-cuttings (the site of Mr. Whidborne's find):

Orthis.	|	Pleurodictyum problematicum.
Spirifer speciosus.	|	

Near Westerland House, south of Marldon, in red slates passing into the Middle Devonian (Eifelian):

Orthis.	|	Pleurodictyum problematicum.
Petraia.	|	

In red slates (resembling those at the south of Goodrington Beach) south of the Ship Inn, Churscombe, by the highroad east of Lower Westerland:

Orthis.	|	Streptorhynchus.
Spirifer speciosus.	|	Pleurodictyum problematicum.

The above finds prove the position of the red slates of the Saltern-Cove cutting to be at the top of the Lower Devonian.

The following lists further prove their connection with the Cockington grits. For the identifications I am indebted to Messrs. Gosselet and Barrois, whose remarks accompanying the identifications are quoted:—

In sandstones on the margin of Staddon plantation, near Cockington:

Pterinaea.		Spirifer hystericus.
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In shaly sandstones near Shortdown, north of Paignton:

Spirophyton.

In red shales and sandstones between Churscombe and Ramshill Cross:

Pleurodictyum.

On Beacon Hill, south of Westerland House, in red and brownish sandstones:

Nucula, "voisine de *N. kahlebergensis*, Bausch, peut-être Palæoneilo du Coblenzien" (M. Gosselet's label).

Homalonotus.

In a little quarry on Windmill Hill, north of Stoke-Gabriel, in slaty grits resembling those of the New Cut:

Chonetes sarcinulata.

— semiradiata.

Rhynchonella hexatoma, "voisine de daleidensis."

— daleidensis (identified by Prof. Kayser).

Homalonotus gigas ("Coblenzien inférieure").

Pleurodictyum problematicum.

In a surface stone in the same district:

Leptæna, "probablement l'espèce que j'appelle *Leptæna spathulata*" (M. Gosselet's label).

My first discovery in the Cockington Beds was a fragment of *Homalonotus* in red slaty beds in Seaway Lane, Cockington.

The subdivision of the Lower-Devonian Beds of the Torquay and Paignton area into Upper and Lower Coblenzian is not justifiable, the districts being too much disturbed to furnish a certain succession; very detailed investigation in the Torquay district would, however, probably settle this question; all that can be said so far is that the Middle-Devonian slates pass downwards into Lower-Devonian slates, and these, through intercalation with grit, into the Lincombe, Warberry, and Cockington Sandstones; but whether the main mass of the Meadfoot beds are below these grits or not, depends on the existence of a dislocation of sufficient magnitude to cut out the latter on the coast near Hesketh Crescent, and this I consider to be probable.

V. MIDDLE DEVONIAN.

1. *Eifelian*.—The Warberry beds near Ellacombe, and the Cockington beds near Westerland and in Berry Park, are bounded by grey slates, generally irregular, which contain distorted fossils in lenticles. *Streptorhynchus* is common in these beds, and *Spirifer speciosus* is by no means rare; the *Zaphrentida* in a crushed condition are also frequent, as well as *Phacops latifrons*. The more usual type of these slates is exhibited in the cliffs of Mudstone Bay, near Hope's Nose, and in Daddyhole Cove. In their upper part they contain limestone lenticles, and frequently pass up into the limestone through thin-bedded limestones, calcareous slates, and slaty limestone, representing the Calceolen-Kalk.

Speaking of the relation of the Cockington beds to these slates, we find amongst the unpublished notes of Mr. Champernowne the following passages:—

“The same beds form Staddon Heights and Mount Edgecombe in Plymouth Sound, and, as Dr. Holl has shown, they also support the Paignton Trias, rising on opposite sides into the high ground of Windmill Hill and Westerland Beacon; and they must be many hundred feet thick around Cockington, but are too disturbed to form any estimate from.”—“Wherever the sequence is anything like complete the last beds appear to pass down by an easy transition into bluish slaty shales, which are well exposed in road-cuttings and small quarries in Berry Park. Nevertheless good sections at the junction are exceedingly rare, and certain local appearances would lead to a belief in more or less unconformity between the two, or even a complete covering-up of the bluish slates . . . Fossils, almost entirely in the state of casts, are fairly common. *Streptorhynchus umbraculum*, much distorted, is common near Berry Castle; and in the same beds at Dartington, at the former locality, I found a cast of *Rhynchonella cuboides*.”

The above passages represent the evidence of stratigraphy. At Lower Westerland Berry-Park slates occur, apparently underneath red Lower-Devonian slates, the anomaly being probably due to

thrusts; and east of Wildwood the bluish slates seem to dip under the Cockington beds. The *Rhynchonella cuboides* above mentioned is probably *procuboides*, noticed by Kayser as occurring in the Eifelian limestone of Hope's Nose.

The Eifelian slates occur on Meadfoot Road, Torquay, south of Marychurch, from Broadhempston southward to Totnes, and thence to Marldon, bounding the limestones of Dartington, Berry-Pomeroy, Little Hempston, and Marldon, which, with natural, inverted, or fault dips, overlie them; and they also bound the Ashprington volcanic series, under which they pass, generally with inverted dips. The shaly Calceolen-Kalk, or Eifelian limestone, is frequently brought up in the limestone masses of Torquay and elsewhere by contortion. At Hope's Nose slaty Calceolen-Kalk is apparently completely inverted upon massive bedded limestone, containing *Heliolites porosus*, and is also affected by thrust-faults. Patches of limestone occur at the base of the Ashprington series at and near Totnes, which belong to this group; the lower parts of the Berry-Park, Dartington, Little-Hempston, and Marldon limestones belong to the same horizon, also apparently the base of the Torbryan limestones, the Broadhempston limestone, and part of the limestones in Ellacombe, and perhaps Babbacombe and Torre, and the thin beds in Torquay cemetery. The Calceola-beds and their relations to the limestones of Daddyhole were described by Mr. Champernowne in a paper published in the 'Transactions' of the Devon Assoc. for 1874.

The following fossils are common in the Eifelian slates:—*Atrypa reticularis*, *Streptorhynchus crenistria*, *Spirifer speciosus*, *Phacops latifrons*, *Fenestella*, *Aulopora*, and less frequently *Leptaena interstitialis* and *Strophomena rhomboidalis*, found in a quarry in Berry-Park slates west of Westerland House; *Phacops batrachius* east of Little Hempston wood; *Retepora repisteria* near Bulleigh Cross; and *Orthis striatula* north of Follaton House, west of Totnes, identified by Professor Gosselet, as also *Orthis*, near to *O. eifelensis*, near Port Bridge, north-east of Stoke Gabriel.

Helianthaster filiciformis, Woodw., was found by Mr. Champernowne* in the upper part of the Eifelian slates near Harbertonford.

The following lists of fossils from the thin limestones of Hope's Nose and their representatives elsewhere will show the connection of the beds, in a palæontological aspect, with the slates they overlie and the limestones above:—

From Hope's Nose thin limestones.	Dr. Kayser's list:—
<i>Atrypa reticularis</i> .	<i>Spirifer curvatus</i> (in typical shapes).
<i>Kayseria lens</i> .	— <i>speciosus</i> .
<i>Leptaena interstitialis</i> .	<i>Streptorhynchus umbraculum</i> .
<i>Pentamerus galeatus</i> .	<i>Cyathophyllum heterophyllum</i> .
<i>Rhynchonella procuboides</i> .	

Identified by M. Frech on the spot:

<i>Cystiphyllum vesiculosum</i> .	<i>Phacops latifrons</i> .
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* Geol. Mag. 1874, p. 1.

Identified by Messrs. Sharman and Newton:

<i>Atrypa aspera.</i>		<i>Scoliotoma (Turbo) texatum.</i>
— desquamata.	|	<i>Heliolites porosus.</i>
<i>Productus subaculeatus.</i>	|	

From Daddyhole Cove. Identified by M. Freeh on the spot:

<i>Cyrtina Whidbornei.</i>	|	<i>Calceola sandalina.</i>
<i>Pentamerus galeatus.</i>	|	<i>Monticulipora</i> , allied to <i>M. fibrosa.</i>

In red shaly limestones and shale under Daddyhole Knoll*, at south end of Meadfoot sands, I obtained *Atrypa*, *Leptaena* resembling *laticosta*, *Spirifer* like *speciosus*, *Phacops*, *Calceola sandalina*, and *Fenestella*.

In Torquay Cemetery irregular limestone beds, associated with slate, furnished *Atrypa reticularis* and *Spirifer speciosus*, identified by Prof. Gosselet.

In shaly limestones turned out of wells at Higher and Lower Weston Farms, identified by Dr. Kayser: *Atrypa reticularis*, *Spirifer* allied to *speciosus*, not apparently the *speciosus* with broader folds.

Weston Wells. Identified by Messrs. Sharman and Newton:

Arca.	|	Alveolites.
Chonetes.	|	Favosites Goldfussi.
Orthis.	|	Cyathophyllum damnoniense.

Limestone north of Bridgetown, Totnes:

Cystiphyllum vesiculosum.

Limestone at Highlands, Totnes:

Alveolites.	|	<i>Cyathophyllum helianthoides.</i>
<i>Stromatopora concentrica.</i>	|	

Reddish-weathered shaly limestones, at base of Brixham limestones, at Churston Station:

Favosites Goldfussi.		<i>Heliolites porosus.</i>
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As there is absolutely no line of demarcation between the upper horizon of the Eifelian (the Calceolen-Kalk) and the bedded limestones above, this separate treatment of Eifelian limestones and limestones of the Stringocephalus horizon is purely arbitrary.

2. *Middle-Devonian Limestone* (Stringocephalus-horizon).—The Middle-Devonian Limestones of Dartington, Littlehempston, Berry-Pomeroy, Gatcombe Park, Marldon, Daddyhole, London Bridge (Torquay), of Anstey's Cove in part, and of Babbacombe-Down cliffs belong to the same series; they are usually bluish grey or dark grey and distinctly bedded. The lower part, at least, of the Torbryan, Denbury, and West-Ogwell limestone, and probably the limestones of Whilborough and Abbots-Kerswell, and those between Bulley-Barton and Wrigwell, south of Dainton, may be bracketed with the above. But the limestones of Barton, Lummaton, and Yeardown, and those

* *Kyamodes*, a new genus of Ostracod, was obtained by the Rev. G. F. Whidborne in the lower part of the Daddyhole limestone (Eifelian).

between Carey Arms, Babbacombe, and Ilsham, for the most part, the Kingskerswell and Kerswell-Down limestone mass, the limestones of Woolborough, Langs Copse, Bradley Manor, East Oghwell, Conniter, and Dornafeld, north of Ipplepen, belong to a higher horizon, in which we may also include the Clennon-hill limestones and most of the limestones south of Goodrington. Parts of the East-Oghwell, Woolborough, Kingskerwell, Barton, and Ilsham limestones may be included in the Upper Devonian. The commonest corals are *Alveolites*, *Favosites polymorpha*, and *Stromatopora*, whilst in the lower beds *Cystiphyllum vesiculosum*, *Cyathophyllum helianthoides*, and *C. damnoniense* are locally common, as also *Heliolites porosus*, and *Favosites Goldfussi*.

The Marlton limestones contain in the lower beds *Amplexus tortuosus*, *Cyathophyllum helianthoides*, and *Cystiphyllum vesiculosum*.

The age of the West-Oghwell limestone is sufficiently proved by the occurrence in it, near Chircombe Bridge, of *Stringocephalus*. *Receptaculites Neptuni* was found in the same locality by Professor Gosselet; yet three species of *Phillipsia*, identified by Salter, viz. *P. anticipator*, *P. Brongniarti*, and *P. Pengellyi*, are recorded by Mr. Pengelly (in "Notes on Recent Notices," &c., pt. i. Trans. Dev. Assoc. for 1874) as having been obtained at Chircombe Bridge*. Crinoidal limestones occur at Denbury and Torbryan; but crinoidal limestones are not restricted to particular horizons.

Stringocephalus has been obtained at Clennons-Linhay, near Ipplepen, and in the Kingsteignton limestone mass, which also contains *Heliolites porosus*. I can trace no persistent Gasteropod-horizon in the Middle-Devonian limestone; numerous small Gasteropods occur locally in it, as near Stantor, north-east of Marlton.

The limestones betray a tendency to pass into slate near Little Hempston; and, as the Marlton, Berry-Park, and Dartington limestones form only the lower part of the larger masses of Ipplepen, Kingsteignton, Kingskerswell, and Torquay, it seems as if the centre of the Dartington trough was occupied by slates representing the middle or upper parts of the Middle-Devonian limestone. As the Ashburton limestones also die out southward, there is an apparent replacement of limestone by slate to the south of Torbryan, the upper part of the limestones being the least persistent.

At Dartington, north of Little Hempston, and at Dainton, blue-black slates, similar to those at the base of the Babbacombe cliff, occur; but the suggestion that these are a type of slates replacing the medial portions of the Middle-Devonian limestone is not at present susceptible of proof. Those in the Babbacombe cliff were compared by Dr. Kayser to "the upper part of the Wissenbach and Goslar slates of the Upper Harz, which belong to the *Stringocephalus*-horizon." Mr. Champernowne's version of the Dartington structure would entirely confirm Dr. Kayser's comparison, which is also in general accord with the facts; but these are of so complex

* These would now be doubtless referred to the Devonian genus *Dechenella*.

a nature, and involve so close a study of local relations, that I must here merely confine my remarks to general conclusions as to the formation and occurrence of the limestones of South Devon, without presenting the innumerable local observations on which those conclusions are based.

3. *Middle- and Upper-Devonian Limestones.*—The massive limestones of Woolborough and Lummaton are so well known through Mr. Whidborne's researches that it will be unnecessary to give fossil-lists; Dr. Kayser correlates the Lummaton shelly limestone with the upper part of the Middle Devonian. From its massive nature the structure of the Lummaton limestone, as also that of Barton, which I correlate with it, is not apparent. The Brachiopod fauna occurs in a very restricted space, and the rock is there very similar to parts of the Ugbrooke-Park and other limestone masses on the border-land between the Middle and Upper Devonian.

The upper part of the Kingsteignton mass, &c., the massive limestones of Chudleigh, Ugbrooke Park, Oldehard, and Ideford belong to the same general group, as also a considerable part of the Kingskerswell mass.

The limestones of Barton and Lummaton are coralline masses, *Alveolites*, *Stromatopora*, and other common forms being associated with *Smithia*. In the Barton quarries, *Chonophyllum perfoliatum* is common, and this form occurs in the Ramsleigh limestone*, associated with *Acervularia pentagona*.

A part of the Barton limestone is a coral-breccia recemented; and in one nearly vertical fissure or fault the fragments also appear rolled. Whether this phenomenon is due to surf-talus banked on a mass of coral-growth or not, I leave to the judgment of those better qualified to form an opinion.

North of the Woolborough quarry, in Langs Copse, I obtained the following:—

Athyris.	|	Rhynchonella pugnus.
Atrypa desquamata.		Strophomena rhomboidalis.
— Duboisi.		Alveolites.
Rhynchonella cuboides.		Heliolites porosus.

Mr. Champernowne, in unpublished notes, mentioned his discovery of "a fine example of *Rhynchonella cuboides* at Ramsleigh"; and further, "*Rhynchonella cuboides*, in Devonshire, is most abundant at Woolborough quarry and Lummaton hill, near Torquay, both of which contain occasional *Stringocephali*" "Either the first shell lived earlier in Britain than on the Continent, or the *Stringo-*

* With reference to this we find the following query in Mr. Champernowne's unpublished notes:—"Is not the so-called *Chonophyllum perfoliatum*, E. & H., of Ramsleigh, more allied to the genus *Ptychophyllum*? Milne Edwards and J. Haime state that it has neither columella nor walls. The latter I admit; but the central area, either in horizontal or vertical sections, consists of densely twisted plates (very like what occurs in *Ptychophyllum*). The outer part of the expansions of which the coral is made up is rounded, plicated, and slightly granulated on the surface, which expansions, as they near the true central depression (calice), are crested by a septal ridge."

cephali survived later." In the same manuscript we find:—"In cutting the Torquay line at Kingskerswell Station many specimens of *Acervularia*, corresponding to those of Ramsleigh, were found." In a quarry near Kingskerswell Station I obtained *Leptaena interstitialis*, *Orthonota (Cypricardia) semisulcata*, and fragments of *Trilobites*.

In the same limestone mass, east of Bulleigh Copse, the limestone is pale grey and pink, and contains *Orthoceras* plentifully; with this I would compare the limestone on the north of Oddicombe beach, which is in part red and rich in *Orthoceras* and lithologically similar to the rock just mentioned; both probably belong to the *Cuboides*-beds.

From what has been said it will be seen that the bedded limestones which succeeded the shelly and coralline bands representing the Eifelian limestone became in places the bases for more uninterrupted coralline growth, and that that growth was locally continuous to the earlier stages of the Upper-Devonian period; but that from plication and fracture it is impossible to trace the marks of change in fauna, which during the prevalence of uniform conditions might be very gradual and local.

§ VI. THE ASHPRINGTON VOLCANIC SERIES.

It is unnecessary to describe the tuffs, schalsteins, and harder diabase masses which constitute this series; that has already been ably performed. We are here concerned simply with the chronology of this long period of volcanic activity. In the first place, we find that the volcanic beds are bounded on the north and south by slates, which are the upper part of the Eifelian slates, as in the vicinity of Totnes and elsewhere. Eifelian limestones occur here and there at the base of the volcanic series, as at Highlands, Weston Farms, &c.

Slates are occasionally visible in the volcanic area, as at Parker's Barn, where they contain calcareous lenticles, and near Gerston Cross, where they are dark grey and either partly calcareous or accompanied by small masses of limestone.

In unpublished notes by Mr. Champernowne we find the following:—"Tuckenhay Creek, on the west side of the Dart, is along the line of an anticlinal, with inversion on the north. A strip of limestones and shale extends about half a mile on the south side, where one quarry is still worked, very rich in corals." These beds are on the same horizon with those near Galmpton Mill mentioned in the Ashprington paper as rich in *Cyathophyllum damnoniense*, *Cystiphyllum vesiculosum*, &c.*

At Endsleigh, Totnes, limestone is visible in almost undistinguishable association with the volcanic rocks. With this may be compared the following note by Mr. Champernowne:—"At Hazard quarry, near Sandwell (on south border of the volcanic beds), where the trap overlies limestone dipping N. at about 10°, the top beds of

* Quart. Journ. Geol. Soc. vol. xlv. p. 337.

the limestone, which abounds in *Alveolites vermicularis*, E. & H., appear to be intimately mixed with volcanic matter, so as to be, in Sandberger's words, either a 'Kalk-Schalstein' or Schalstein-Kalk. A similar intimate blending of material appears to take place at Factory-hill quarry, near Harbertonford."

In a note on the site of a Starfish (named by Dr. H. Woodward, *Helianthaster filiciformis*), Mr. Champernowne mentioned the low northerly dip of the Harbertonford limestone, the occurrence, at Roster Bridge, of numerous "large Spirifers and other fossils," and the predominant cleavage of the limestone*.

At the Lion Brewery, Totnes, a boring was made to a depth of 139 feet in blue slate rock, under blue limestone only 2 ft. 6 in. thick.

From the above observations it is evident that an extraordinary uniformity in conditions is manifested by the deposits immediately preceding the volcanic outbursts, and that the volcanic materials were poured out upon a muddy bottom whereon masses of shells and corals were here and there accumulating.

But, as by fossil and stratigraphical evidence, the position of the limestone patches is proved to coincide with the Eifelian limestone, we are at once supplied with a reliable date for the commencement of this phase of volcanic activity, namely the later stages of the Eifelian deposition. This is borne out by the absence of volcanic materials in the Lower-Devonian and Eifelian-slate areas.

The Ashprington series may represent continuous or intermittent vulcanicity up to the middle of the Frasnian; but, as there are no newer sedimentary beds above it, no measure of its duration is furnished in the Ashprington area.

The numerous evidences of volcanic activity outside the Ashprington area are so distributed as to suggest local centres of eruption; thus the aphanites and tuffs of Saltern Cove and Goodrington obscure the relations of the Middle and Upper Devonian, vulcanicity having there begun during a late stage in the accumulation of the Middle-Devonian Limestone. Again a volcanic area north of Waddeton complicates the relations of the Middle-Devonian limestones of Yalberton and Crabb's Park and Upper-Devonian slates, even suggesting partial volcanic activity near Waddeton as early as the commencement of the Ashprington series.

It is instructive to find a great development of Middle-Devonian limestone on the immediate borders of the volcanic materials, north of Stoke-Gabriel, as it is thereby demonstratively proved that the accumulation of the limestone took place contemporaneously with the Ashprington volcanic outbursts. This is further proved by the occurrence of detached masses of the Berry-Pomeroy limestones in direct contact with the volcanic series near True Street, east of Totnes.

Near Yalberton volcanic materials appear to rest on the limestone; but when we consider that these impermissibly associated

* Geol. Mag. 1874, p. 5.

materials have since been inverted, plicated, faulted, and chemically altered to a very great extent, it is not extraordinary that we are unable to trace the different incursions of the tuffs and ashes of the successive eruptions of this ancient Krakatoa, or to distinguish the necks from which they emanated.

The Middle-Devonian limestones are frequently dolomitic, and where this is the case their surface is susceptible of irregular dissolution into hollows, wherein overlying tuffs would gradually subside. This state of things no doubt to some extent accounts for the irregular indentations of the volcanic and limestone boundaries near Aish and Yalberton; but near Goodrington and East-Ogwell the accumulation of limestone has been distinctly interrupted by local influxes of volcanic materials. Felspathic tuffs occur in the Upper-Devonian slates south of Goodrington. North of Little Hempston the Middle-Devonian slates (replacing limestones above the Eifelian) contain tuffs and occasionally schalsteins. The limestone of Dartington is partially replaced by diabase; this is also the case with the Bickington limestone. At both Bickington and Ashburton the limestone is overlain by tuffs and schalsteins. The Kingsteignton limestones are bounded by tuffs, schalsteins, and aphanites, which appear to be inverted upon them.

North of Broadhempston numerous patches of diabase occur in Middle-Devonian slates. Between Newton-Abbot and Woodland there are also an infinite number of diabase and melaphyr patches in the Upper-Devonian slates. The Babbacombe limestone, which is of the same age as that of Dartington and Marlton, is plicated with a mass of diabase, occasionally associated with purple igneous rocks identical with peroxidated materials in the Ashprington series; in the Babbacombe cliff and beach-reefs masses of diabase, in some places coarsely porphyritic, occur.

Spilosite is frequently noticeable in the Upper-Devonian slates at contact with the diabase, particularly north-west of Chircombe Bridge. This type of contact-metamorphism has been recognized in the Middle-Devonian slates of Babbacombe by Dr. Kayser.

§ VII. UPPER DEVONIAN.

Prior to 1887, Mr. Lee's find of the Budesheim fauna at Saltern Cove, and of the Goniatite-limestones at Lower Dunscombe, and the Acervularia-limestone of Ramsleigh, were the only proved occurrences of Upper-Devonian rocks in this district. In 1887 I discovered inliers of Upper-Devonian slate at and near Livaton in the Culm-measure area south of Bovey-Tracey, and also near Lewell in the Chudleigh area. The discovery of *Clymenia levigata*, in irregular grey and greenish slates, near Lewell by M. Tschernyschew, and the identification by Kayser of the red slates beneath them, with *Posidonomya venusta* and *Entomis serratostrata*, as the Cypridinen-Schiefer of Nassau and the Harz, supplied a clue to past and future work, as I had identified exactly similar slates in Kingsteignton Railway-cutting and in Anstey's Small Cove, Torquay, and had discovered both these

forms in them. Several new fossil finds in 1889 have enabled me to extend the Upper-Devonian districts very much further.

1. *Massive Limestones* *.

The limestones of Petitor, part of the Kingsteignton mass, the Chudleigh limestone, the Ugbrooke-Park limestone in part, the Oldchard limestone in part, the Ideford limestones, and the uppermost part of the Kingsteignton mass, may be regarded as Upper Devonian; as also certain rather thin-bedded limestones on Elbury Warren and perhaps portions of the limestones south of Goodrington.

The *Cuboides*-beds form a lower Frasnian horizon than the Goniatile-beds; and the massive limestones of Chudleigh, Oldchard, and Kingsteignton are directly overlain by the red, compact, concretionary Goniatile-limestones; whilst the red slates of Petitor combe, at their junction with the Petitor limestones, contain red shaly limestone with *Goniatites*, and also furnished imperfect *Goniatites*. Again the Ramsleigh limestone is irregularly bounded near East-Ogwell Mill by slates resembling those of Saltern Cove, and in East Ogwell by dark slates containing *Entomis*. The Woolborough limestone is partly bounded by slates of Upper-Devonian types.

The Bradley-Manor limestone, near Newton-Abbot, is also bounded on the north by Upper-Devonian slates. The Barton limestone, near Marychurch, is nearly surrounded by slates of the Saltern-Cove type. The junctions of these limestones with the Upper-Devonian slates are so often abrupt and irregular that they suggest coralline growths at a much more rapid rate than muddy sedimentation on their immediate borders, so that Upper-Devonian slates might be banked against Middle-Devonian limestone in places.

Dr. Kayser's list from Lower-Dunscombe quarry below the Goniatile-beds, in light crystalline limestone, is:—

Rhynchonella cuboides.	|	Spirifer bifidus.
— acuminata.	|	Productus subaculeatus.
Atrypa reticularis.	|	Conocardium.
Athyris concentrica.	|	Harpes.

In a small quarry in the Ideford limestone, near Coalmansford, I obtained *Rhynchonella*; comp. *Camarophoria formosa*, Schnur, and *Rh.* near to *parallelepipeda*, identified by Dr. Kayser, who remarks "Wohl Oberdevon=Cuboides-Kalk."

The Goniatile-beds near Whiteway Farm rest upon a limestone exactly similar to that of Chudleigh, in which I found a small *Spirifer (bifidus?)*, *Goldius granulatus*, *Cyathophyllum hexagonum*, and *Fenestella*.

* Partly Middle Devonian, under which head the same limestones have also been alluded to. I do not think it is possible to draw an arbitrary boundary between Middle and Upper Devonian, below the shaly Goniatile-limestones, in South Devon; nor is it possible in dealing with the massive limestones to confine the description of such limestones to particular headings. Any apparent confusion in arrangement is strictly in accordance with the state of the case.

Buckley-Wood quarry, on the opposite side of the valley, yielded *Stromatopora Hüpschii*, Barg., and *Actinostroma clathratum* (?), Nich., kindly identified by Professor Nicholson.

The Ramsleigh limestone contains small Brachiopods at a short distance north of the quarries, amongst them the Rev. G. F. Whidborne identified *Spirifer lineatus*, Martin, and *Waldhemia Whidbornei*, Dav.

A similar Brachiopod-horizon occurs in a patch of limestone at Dagers-Mellons Copse between the Broadridge-Wood and Bradley-Manor limestone masses. Amongst these small Brachiopods may be, as Dr. Kayser kindly informs me, *Nucleospira lens*, Schnur, perhaps *Spirifer Urei*, Fleming. Mr. Whidborne identified *Merista plebeia*.

The fibro-crystalline calcite veins termed "Stromatactis" by Dupont abound in the limestones of Petitor and Ramsleigh (or Ransley), and have also been detected by Prof. H. A. Nicholson in specimens from Bickley Wood, near Whiteway Farm, and from Upper Bradley, near Newton-Abbot.

2. The Goniatile-beds.

Some months ago I visited Elbury Cove to test the boundary of the Brixham limestones and the slates which there apparently underlie them.

These slates exhibit Upper-Devonian characteristics. After a fruitless search for fossils in them, I proceeded along the coast to Silver Cove, where more or less massive limestones are apparently underlain by tolerably thin, plicated limestone, passing down into red slates and mudstones, through red slates intercalated with thin bands and plaques of limestones. The whole was so suggestive of the Saltern-Cove Goniatile-mudstones that I searched diligently, and was rewarded by the discovery of the Saltern-Cove fauna. The Goniatites are much crushed; but well-preserved examples of *Cardiola retrostriata* and numerous *Bactrites* were obtained. Further investigation proved the junction to be inverted, the thin beds of limestone occurring in their natural position in the low cliffs of Galmpton Point.

The Galmpton-Point limestones are full of *Alveolites*, and they resemble the Ramsleigh limestone in colour and texture. The Silver-Cove and Elbury slates extend as far west as the borders of the Yalberton volcanic series; and they also occur in Fishcombe Cove, near Brixham.

The Upper-Devonian slates of Saltern and Silver Coves are chocolate-red, weathering to a lilac-red hue, which is distinct from the colour of the red Lower-Devonian slates, against which they are faulted at Saltern Cove.

The Silver-Cove and Galmpton-Point limestones seem to be represented by the limestone bands and coralline masses which occur in Saltern-Cove railway-cutting, on the beach, and at the point on the south of the large Cove, in which places, as Mr. Champernowne

pointed out, they irregularly overlie aphanites and tuffs. Beds of concretionary limestone-nodules occur in the Saltern-Cove slates and mudstones; these are the indications of the knubbly Goniatite-limestones or Kramenzel-Stein and of the Knollen-Kalk.

Wherever we find the Cypridinen-Schiefer in the vicinity of fine, crystalline, grey limestone, we should expect to meet with a representation of the Goniatite-beds; accordingly we find the Ilsham limestone most irregularly bounded by red limestone, much crushed, with calc-spar veins and filaments, distributed so as to suggest Goniatites or *Orthoceras* distorted beyond recognition; and further from the grey limestone concretionary limestone beds occur.

The Upper-Devonian slates of Anstey's Small Cove and Ilsham are probably faulted against the massive limestone of Anstey's Large Cove.

The red slates of Petitor combe contain thin bands and lenticles of limestone at their junction with the limestone on the south and north. In one spot on the north side I have obtained *Goniatites sagittarius* and several specimens of Goniatites on the south side*.

The red slates of Barton have as yet yielded no fossils; in one or two places, where their junction with the massive limestone of Barton can be seen, they are associated with red limestone beds.

Due north of Combe-Cellars, on the north side of the River Teign, greenish-grey argillaceous slates, with buff, powdery nodules and lenticles of decomposed limestone, pass down into similar slates with lenticles and nodules of limestones, very compact and distributed in beds, as in the Saltern-Cove Upper-Devonian slates. Near a small patch of Trias, by the river, red slates crop out containing similar nodules of brown powder; in their vicinity I discovered two Cephalopods on the beach, which had been evidently washed out of rock, they were sent to Dr. Kayser, who says:—"The smaller Goniatite (or *Clymenia*) is unidentifiable. The larger specimen is probably a Goniatite, but of a species unknown to me." In some of the powdery nodules in the slates I detected bivalve impressions, resembling *Cardiola retrostriata*. I sent these to Prof. Gosselet, who returned them with the following identifications, at the same time recommending me to submit them to Dr. Kayser:—

Gasteropod fragment. Encrinite fragment.

Sanguinolaria elliptica?

Cardiola (very near to *retrostriata*; ornaments effaced).

Chonetes.

Goniatite or *Clymenia*.

In these fragments Dr. Kayser identified:—

Cardiola retrostriata.

A small *Orthis* or *Chonetes*.

These beds are the Knollen-Kalk. The concretionary limestone-beds are similar to those on the margin of the Ilsham limestone

* The Goniatites were discovered after this paper had been sent in.

near Anstey's Small Cove, and also to the Goniatite-limestones of the Chudleigh district and of Oldchard.

The Knollen-Kalk passes under the red slates of the Cypridinen-Schiefer, so well exposed in the Kingsteignton railway-cutting, and in lane-cuttings west of Bishopsteignton. On the south bank of the Teign west of Combe-Cellars the Knollen-Kalk, consisting of dark slates with hard concretionary nodules in which no fossils were found, passes under the Entomis-slates.

In the autumn of 1889, I reinvestigated the boundaries of the Kingsteignton limestone on the 6-inch scale map; and, in following its faulted junction with the Culm-rocks from Lindridge Hill toward Whiteway Farm, discovered a strip of red, compact, concretionary limestone, associated with red and grey slates resting directly on the massive limestone. Although these beds are cut out by the fault at Torhill Cottages, they reappear in the form of the Chudleigh Goniatite-limestone above an abandoned quarry in grey finely crystalline limestone at 15 chains from Whiteway Farm. Here we have a replica of the junction in Lower-Dunscombe quarry, and I found many very imperfect traces of Goniatites, which on slicing revealed the septa. Just after this discovery I noticed a large red limestone block used to cover a drain in Whiteway Farm-yard, containing a large example of *Goniatites intumescens*, and traces of other *Goniatites*, including *G. sagittarius*. Thinking the block might have been brought from Lower Dunscombe, which is two and a quarter miles due north of Whiteway Farm, I questioned Mr. Soper, the farmer, who assured me that the block had been quarried on his farm, and had, to the best of his recollection, been obtained from the neighbouring quarry, viz. that in which I had shortly before proved the presence of the Goniatite-beds. This discovery, in enabling us to trace the connection of the Goniatite-limestones with a continuous limestone formation extending from the Eifelian upward, is of the utmost importance.

Another link in the chain of evidence was obtained at Oldchard, about halfway between Whiteway and Lower-Dunscombe Farms. Here the Devonian rocks are faulted against Culm-measures on the south and west, and concealed on the north by debris from the Trias and Cretaceous formations.

In Oldchard-Well Farmyard pale grey, finely crystalline, massive limestones are exposed in a quarry behind the house, where they are faulted against red shales with plaques of limestone, exactly similar to those of Silver Cove. Beneath these are thin-bedded, compact, nodular limestones, which in the adjacent orchard are seen to rest upon the massive grey limestone. No fossils were obtained in the farmyard, but between 10 and 15 chains west of it grey and greenish clay-slates, with nodular pieces of compact limestone, but more often of pale buff powdery matter resulting from its dissolution, recall the Knollen-Kalk by the River Teign. These beds rest on red shales or slates containing red nodular limestone, which is ploughed up in an adjacent field, and proved to be rich in *Clymenia*, associated with very imperfect *Goniatites*.

Dr. Kayser identified the *Clymenia* as *C. levigata* and *C. annulata*.

The Goniatite-limestone of Lower Dunscombe, with overlying red slates or shales, forms a very small patch, faulted against Culm-measures on the east and west and overlying the massive limestones on the north and south, in the form of similar compact, concretionary, red limestones; it also occurs in a triangular patch bounded by faults at the westernmost termination of Ugbrooke Park, near the pathroad to Lewell. The Chudleigh limestone is probably folded or thrust over the greenish slates, which bound it on the west, the latter being of Upper-Devonian aspect. In the middle or lower part of the limestone Mr. Clement Reid * found *Heliolites porosus*; the same coral in association with *Rhynchonella cuboides* was found by me in the Woolborough limestone in Lang's Copse; hence it becomes a question as to the relative importance of the Coral or the Brachiopod in determining the Middle- or Upper-Devonian age of the rocks. There is, however, no reason to object to the Middle-Devonian age of the lower part of the Chudleigh limestone.

Dr. Kayser's list of fossils from the Goniatite-limestones in Lower-Dunscombe Quarry consists of:—

Goniatites intumescens.	|	Cardiola retrostriata.
— acutus.	|	Myalina.
— simplex.	|	

Herr Frech identified in these beds, in addition to the above:—

Goniatites complanatus (a variety of intumescens).
Cyrtoceras and Harpes.

Add to these *Goniatites multilobatus* (*G. sagittarius*) found by Mr. Lee †.

In the disturbed districts between Ipplepen and Newton-Abbot, Upper-Devonian beds have not been detected by their fossils, except in the case of the Ramsleigh ‡ limestone, and the presence of volcanic materials appears to have irregularly interfered with the accumulation of the limestones; but it is probable that the red slates between Woolborough and Abbotskerswell, and those bounding the Lang's-Copse limestone, may be Upper Devonian, as also the slates and tuffs south of East Oggwell. Even in this excessively faulted and complicated district, however, a patch of Upper Devonian is proved to occur on the south of the faulted termination of a mass of Culm-measures near Rydonball Cross, between Rydon Farm and Abbotskerswell Cross. Here a band of grey and red, compact, nodular, concretionary limestone, with irregular yellowish-brown kernels of decomposed limestone, occurs in red, greenish, and grey slates resembling those of Livaton, Lewell pathroad, and the Teign Bank opposite Combe-Cellars. These

* Geol. Mag. 1877, p. 454.

† *Ibid.* 1880, p. 145.

‡ Ransley on the 6-inch Map.

slates are blackish by the highroad west of Abbotskerswell, and they contain lenticular limestone (resembling that in the little quarry at Livaton) at 25 chains south of Rydonball Cross. I have no hesitation in regarding these beds as Upper Devonian, probably representing the Knollen-Kalk and Entomis-slates.

As the Cypridinen-Schiefer has been traced by its characteristic lithological character and by the presence of *Entomis* and *Posidonomya* at Newton-Abbot, Highweek, and Houghton, the representation of the Goniatite-beds between it and the limestones and diabases of Bickington on the one side, and the limestones of Bradley Woods and West Oghwell on the other, is almost demonstrated.

As the occurrence of Upper-Devonian beds between these limestones is established by the discovery of the Cypridinen-Schiefer (Entomis-slates), Mr. Champernowne's correlation of the Ashburton and Oghwell limestones is demonstratively proved, by synclinal, not anticlinal structure, as was supposed. This synclinal is occupied by red, pale greenish, and grey slates, in which fossils are extremely rare. By lithological character no line can be drawn in this slate-area.

Red slates resembling those of Saltern Cove bound the Bradley-Manor limestone on the north, and can be traced, with varying characters, to the Lemon Valley opposite East-Oghwell Mill. Near East-Oghwell Mill they contain limestone plaques and are very similar to the slates of Silver Cove; from the Mill these slates, varying to greenish and dark-grey tints, may be traced southward through East Oghwell, where they contain *Entomis*, and round the southern termination of the Ramsleigh limestone.

Following round the limestone border from Bradley Farm to Denbury, we find a gradually broadening area of grey slates separating the red and green Upper Devonian, which are continuous through Woodland, from the limestone. These slates, traced southward, are found to represent the Middle-Devonian limestones of the Ipplepen and Plymouth districts; they contain shaly limestones here and there near Staverton.

Here, then, we have the Middle- and Upper-Devonian types described in my paper* on the Tavistock district, and an analogy is presented to the Morthoe and Ilfracombe slates of North Devon, and the red slates of the Pickwell-Down series.

In the area between Newton-Abbot and Bickington, at Wrigwell House, 2 $\frac{3}{4}$ miles west of Newton, in pale greenish slates I discovered traces of *Goniatites*, one though indistinct being perfect, although, alas, quite unidentifiable. In the same slates I obtained small *Orthocerata* or *Bactrites*. All Dr. Kayser says about these fossils is "scarcely recognizable, but by the matrix probably Goniatite-slates (= Budesheim)."

Near Metley, at about half a mile south of Wrigwell House, and near Killinch, about half a mile west of Metley, I detected traces of

* Trans. Devon. Assoc. 1889.

small fossils in similar slates, which appeared to me to resemble the Saltern-Cove fauna very badly preserved.

These green and lilac slates are not similar to the types of the Goniatite-beds we have been considering; but they occur where we should expect to find Frasnian beds represented; and therefore, if the fossils in them in any way resemble the Goniatite-fauna, they are more likely to belong to it than to other horizons, as we do not find the *Posidonomya venusta* and *Entomis* in their vicinity.

To the north of the *Entomis*-slates, which are continuous by fossils from Newton to Houghton, and by lithological character from thence to Woodland, I feel convinced that these practically unfossiliferous slates would reveal to a patient searcher traces of the Goniatite-fauna, my find at Wrigwell House being quite accidental, and the time at my disposal much too limited for protracted search for fossils.

The relations of the Upper-Devonian slates to the Middle-Devonian slates and limestones of Chircombe Bridge and Bradley Manor, as also to the limestone of East Ogwell, are such as I can in no way account for by ordinary faults or plications, but such as would be explained by thrust-faults, or by the abrupt termination of the limestones, and the slower rate of accumulation of muddy sediments on their borders; for the limestones which these slates bound at East Ogwell and Ramsleigh seem to be higher in the series than those which they bound at Bradley Manor; and this difficulty is not to be explained by assuming that the slates in the former case represent higher Upper-Devonian beds than those in the latter.

3. *Cypridinen-Schiefer* (*Entomis*-slates).

The description of these beds has been almost completed by the references to them in the previous notes.

They occur in the area between Kingsteignton and Bishopsteignton, on each bank of the Teign, where the characteristic *Posidonomya* and *Entomis*, with an occasional imperfect Trilobite (perhaps *Phacops*), have been found in them. On the other side of the Teign alluvium from Knowles Hill, Newton-Abbot (where contact alteration with diabase has converted them into spilosite in places), to Highweek and Houghton their occurrence is similarly proved by fossil evidence. They are recognizable by similar characteristics near Ilsham and Anstey's Small Cove.

In Whiteway farmyard greenish-grey clay-slates were identified as *Cypridinen-Schiefer* by Kayser, who mentions the occurrence of numerous examples of *Posidonomya venusta* as well as *Trimeroccephalus* cf. *cryptophthalmus* in them. At Goodrington red clay-slates contain *Posidonomya venusta* and *Entomis serratostrata*.

The faulted inliers of Upper-Devonian slate in the Culm-measure area between Bickington and Bovey-Tracey contain beds of different lithological type, all of which have their analogues in the Chudleigh district and in the Upper-Devonian tract between Rydon

Farm and Abbotskerswell, south of Newton-Abbot. Though they probably represent the Cypridinen-Schiefer for the most part, there are beds at and near Livaton and Woodhouse which may belong to a higher horizon. As these beds were mapped on the old 1-inch sheet in the commencement of 1888, and the fossils obtained, including numerous *Clymenia*, *Spirifer*, and *Orthis*, have yet to be specifically determined, I shall not refer more particularly to them.

The discoveries of the extension of the Waddon-Barton horizon, of the representation of the West-Leigh limestone horizon, and of the occurrence of Culm conglomerates and of interbedded tuffs or schalsteins, and other points in connection with the Culm-measures of this area, are of sufficient interest to constitute a separate communication.

Addendum.—Since this paper was written, Professor Rupert Jones has had the opportunity of examining many specimens collected in the *Entomis*-slates (Cypridinen-Schiefer), and his kind offices enable me to append the following identifications with localities:—

Whiteway Farm, some small oblong Ostracoda (? *Primitiæ*).

About a quarter of a mile north-north-west of Whiteway

Farm: *Entomis serratostrata* (Sandberger), good and abundant; and *Entomis Sandbergi* (Richter), rare.

South bank of the Teign, west of Combe-Cellars: *Entomis*, very obscure.

Kingsteignton Railway-cutting, near Hackney: *Entomis serratostrata*, numerous.

Knowles Quarry, Newton-Abbot: *Entomis serratostrata* and *E. gyrata* (Richter).

East side of Knowles hill, Newton-Abbot: *Entomis serratostrata* and *E. gyrata*.

North of Greenaway Place, near Newton-Abbot: *Entomis serratostrata*?

Castle-Dyke Quarry, near Highweek: *Entomis gyrata*, abundant; *E. serratostrata*, rare.

West of Western House, near Highweek: *Entomis serratostrata*.

By road west of Western House: *Entomis gyrata*.

East Ogwell: *Entomis serratostrata*.

West of Livaton: *Entomis serratostrata*, rare.

Lane near Lenda Mill, near Livaton: *Entomis serratostrata*, obscure.

Anstey's Small Cove Cliff: *Entomis serratostrata*, numerous.

West end of Goodrington village: *Entomis serratostrata*, squeezed and obscure.

I also gladly embrace the opportunity of here expressing my thanks to Professor Dr. H. A. Nicholson for his kindness in identifying a series of specimens of Devonshire limestones containing Stromatoporoids.

The following may be mentioned :—

Stromatopora Hipschii, Barg., from Laugs Copse, Compton near Marlton, Buckley Wood.

Dania, sp., South of Colway Cross, west of Bishopsteignton.

Actinostroma hebbornense, Nich., Coombes End Quarry, south of Whiteway Farm, Daddyhole Knoll, Yarneford Copse Quarry.

Actinostroma clathratum, Nich., Broadridge Wood.

Actinostroma verrucosum, Goldf., Old Quarry, Coombes End.

Stromatopora buchaliensis, Barg., Stantor.

Clathrodictyum, Highlands, Totnes.

§ VIII. CONCLUSIONS.

From the above observations it will be seen that by detailed investigations, aided by the discovery of characteristic fossils, the Devonian rocks of this part of South Devon fall naturally into Upper, Middle, and Lower groups, each possessing distinctive lithological and palæontological characteristics, yet also exhibiting in both respects points of similarity which prevent the definition of sharp boundary-lines.

The structure of the country, owing to faulting and plication, and to a still greater degree owing to the impersistence of the limestones, either from the abrupt termination of organic growth, from gradual or irregular replacement by slate, or from episodes of vulcanicity during their accumulation, is only to be interpreted by piecing the evidence and amalgamating disconnected data to form a connected sequence.

Although there is no evidence of atolls, and barrier and fringing reefs are out of the question, in a district where volcanic materials were being spread beneath the sea during a period in which coralline growth was taking place, and the débris of organic existence actually strewn the sea-bottom upon which the earliest volcanic ejectamenta were outpoured, it cannot be denied that we have conditions manifested somewhat similar to those which are known to be favourable to coralline growth in the present day in the Java seas.

The discovery of *Goniatites* near Whiteway Farm in beds which directly overlie massive limestones of the Chudleigh type, themselves succeeded by bedded limestones containing *Stringocephalus* and *Heliolites porosus*, which are separated by inverted aphanites and schalsteins from slates with both Middle- and Lower-Devonian affinities, affords, notwithstanding inverted dips, at once the most important and the most connected succession to be met with in the district.

It will be seen that the irregular unfaulted junctions between the Upper-Devonian slates and the limestones in some places give colour to the supposition that the limestones were partly accumulated as coral-banks, and that the muddy sedimentation on their margin may have taken place at a much slower rate.

From what Professor Gosselet has shown me in the Ardennes, and on a brief visit to the Eifel, I was greatly struck with the comparatively recent appearance of the Upper-Devonian shales, which reminded me more of weathered Lias- and Oolite-shale, and of Rhætic shales, in places, than of any Upper-Devonian slates in Devonshire, where the rocks are much more indurated, compressed, and cleaved. The same phenomenon is exhibited by the Eifelian slates of Couvin and of Gerolstein on comparison with the slates of Berry Park and Mudstone Bay.

In the Lower-Devonian of the Gerolsteiner-Wald, I recognized similarities to Lower-Devonian rocks in North and South Devon: and in the Lower-Devonian slate types of St.-Hubert, Oignies, and Mondrepuits, in the Ardennes, near Fumai, I detected a great resemblance to the Dartmouth slates. In fact, in the districts where the rocks had undergone the greatest disturbance the similarity to those of Devon seemed to be the most pronounced.

As regards South Devon, the facts established in this paper have a much wider application than to the district described; for De la Beche's Map and the Report (pp. 76-79), referring to the geology of the district from the Dart southward to Plymouth, will show the existence of extensive areas of Lower Devonian (Cockington beds) from Morleigh Down and Black Down to the coast at Erme Mouth, and at Staddon heights and Modbury.

I conclude with the following quotations from Mr. Champernowne's Notes on the Ashprington series, when referring to the relations of the volcanic materials to the limestones:—"all these anomalous appearances are at the same time quite capable of being accounted for, if we consider what might take place in a reef district which was at the same time the arena of volcanic disturbance."

Referring to the difficulty in distinguishing the slates below from those above the limestone, he says:—"But why should there not also be slates neither exactly above nor below the limestone, but replacing it? So that De la Beche's words would also be true, viz. that 'the geological continuation of certain limestones appears to consist of slate'"*.

DISCUSSION.

The PRESIDENT referred to the late Mr. Champernowne's paper on the Ashprington Series, and to the maps presented by that geologist to the Geological Survey. The task of dovetailing the Survey-maps with those of Mr. Champernowne was entrusted to Mr. Ussher, who had now for the first time made a careful comparison between the rocks of South Devon and those of the Continent. Dip and strike went for little in such plicated and dislocated countries as that which the Author had surveyed, but he had with great patience and success pieced together the fossil evidence, and had thus brought

* Quart. Journ. Geol. Soc. vol. xlv. p. 377.

the different members of the Devonian series in relation to one another and to those of other countries.

Prof. T. RUPERT JONES called attention to the distortion of the Ostracods. He adopted the term *Entomis*-shales, or Entomiden-Schiefer, for the old and incorrect Cypridinen-Schiefer. Having had some of the Author's specimens figured, he exhibited the figures. The genus passed up into the Carboniferous. *Klaedenia Wilckensiana*, found in the Warberry Grits, also occurs in the Devonian near Saalfeld.

Prof. HUGHES maintained that two horizons occurred at Lummaton, the *Stringocephalus* occurring at the base of the quarry. The limestones often thickened, owing to folding, but he believed the Lummaton succession was a true one. He was quite prepared to follow the Author's explanation of the Saltern-Cove district.

The AUTHOR, in reply, defended the term slate for the *E. serratostriata* beds. If it were definitely proved that *Stringocephalus* came below the very fossiliferous horizon in the Lummaton quarry, he would be very glad; but fossils were frequently brought from a distance by the quarrymen.

30. *On the so-called "UPPER-LIAS CLAY" of DOWN CLIFFS* *.
By S. S. BUCKMAN, F.G.S. (Read May 14, 1890.)

IN a former paper † I gave a section of part of Down Cliffs, near Seatown, Dorset; but I had obtained no evidence of the palæontological contents of the Bed 19.

Partly, no doubt, on account of its position (only a little above the Marlstone), and partly on account of its blue colour, this bed has been called by Day ‡ and by H. B. Woodward § "Upper-Lias Clay;" and I think that I am correct in saying that this term has, in this country, usually signified those argillaceous deposits which, occupying a very similar position above the Marlstone, contain the fauna of the *Falciferum*- and *Commune*-zones.

Last summer I had an opportunity of further examining Down Cliffs, and, after some search, was enabled to procure sufficient evidence to show what is really the correct horizon of the clay- or marl-bed in question. The evidence consisted of Ammonites of the genus *Dumortieria*; but their condition was unsatisfactory for preservation, since they were little else than impressions or casts in the marl, and were often crushed. I was, however, able to preserve a few specimens; and, having frequently met with similar Ammonites in the Cotteswolds, I was able to determine even those specimens which I could not preserve. One species I could make out with certainty, namely *Dumortieria radians* ||. Accompanying this, was a wider-ribbed form of the same genus—a genus so easily recognized by the peculiar straightness of the ribbing. The wider-ribbed species was most probably *Dumortieria Levesquei*.

Now, species of the genus *Dumortieria* are practically confined to a limited horizon, namely, to strata to which I applied the terms *Moorei*- and *Dumortieria*-beds ¶, in other words, the base of the *Opalinum*- and the top of the *Jurense*-zone; and *D. radians* may be regarded as a species distinctive of the top of the latter zone. In that case, this blue marl is really only a part of the Yeovil Sands, seeing that this species occurs also in them; and this blue marl is of distinctly later date than the blue clay of the White-Lackington Section **. Here, then, is a further instance of the later prevalence of clayey conditions the further we go South.

* This paper consists of notes supplementary to a paper on the Cotteswold, Midford, and Yeovil Sands, &c., Quart. Journ. Geol. Soc. xlv. 1889, pp. 440-473.
† *Ibid.* p. 452.

‡ Day, "On the Middle and Upper Lias of the Dorsetshire Coast," *op. cit.* vol. xix. 1863, p. 285.

§ Geology of England and Wales, 2nd ed. p. 276. "The Upper Lias in Dorsetshire is represented by a clay-deposit, which rests upon the remarkable junction-bed"

|| In my former paper (p. 443) this species was alluded to as *D. rhodanica*. I must refer the reader to the forthcoming Part V. of my Monograph on Ammonites (Pal. Soc. vol. for 1890) for the explanation of this matter.

¶ Q. J. G. S. vol. xlv. p. 443.

** *Ibid.* p. 450, bed "2," &c.

This blue clay or marl lying *below* the Yeovil Sands contains *Dumortieria radians*; but the position of the same species in the Cotteswolds is in the limestone *above* the Cotteswold Sands*. In other words, the blue clay of Down Cliffs is contemporaneous with the limestone above the Cotteswold Sands of Gloucestershire; yet the former is called “Upper Lias,” while the latter has been placed in the “Inferior-Oolite Series.”

The names themselves are of no importance. The cause of complaint is that the same palæontological horizon should receive two names, causing it to appear of earlier date in one place than in the other.

It is possible to obtain a fairly complete section, from the Middle Lias to the top beds of the Inferior Oolite, by superposing upon Down Cliffs the Chideock Hill, which lies just inland to the north; and the following is the result:—

Section at Chideock Hill and Down Cliffs.

<i>Parkinsoni</i> - zone.	1. Pale and somewhat shelly limestone, with <i>Parkinsonia Parkinsoni</i> , <i>Terebratula spheroidalis</i> , <i>Waldheimia Meriani</i> about	ft. in. 9 0
	2. Brown limestone, with small grains	1 9
<i>Concavum</i> - zone.	3. Yellow limestone, with very coarse, almost pisolitic, brown grains; in places much disintegrated ...	1 3
<i>Murchisonæ</i> - zone.	4. Yellowish limestone, with small dark grains; <i>Ludwigia Murchisonæ</i> , <i>Lioceras bradfordense</i> , <i>Lytoceras Wrighti</i> visible for	3 6
<i>Opalinum</i> - zone.	5. Small part unseen.	
	6. Yellow sands and calcareous sandstone, with <i>Lioceras opalinum</i> , capping the	
Down Cliffs.	7. Yellow sands.	}(say) 150 0
<i>Jurensis</i> -zone.	8. Yellow sands with <i>Dumortieria radians</i> .	
	9. Blue micaceous (?) shale, altogether more compact. <i>D. radians</i> , and a coarser-ribbed species of the genus, possibly <i>D. Levesquei</i>.....about	70 0
<i>Commune</i> - and <i>Falci-</i> <i>ferum</i> -zones.	10. Mottled, pink and cream-coloured limestone in two layers; as may be seen from fallen blocks, <i>Hildoceras bifrons</i> is dominant in the upper layer, and <i>Harpoceras falciferum</i> in the lower	10
<i>Spinatum</i> - zone.	?11. Ironshot limestone, much stained in places; <i>Rhynchonella furcillata</i>	7

Note.—Bed 9 is more clayey below; and, as it passes upwards, becomes more of a marl. The Ammonites were found some distance down (12 feet and more). Nothing was discovered in the lower part of the bed; but, of course, it is possible that the lower part may contain different species of Ammonites. When compared with the Cotteswolds, it is seen that the horizons called *Dispansum*-, *Striatulum*-, and *Variabilis*-beds—the latter being equal to the Cotteswold Sands—should come between the *Commune*-zone and the *Dumortieria*-beds, that is to say, somewhere in the lower part of Bed 9, or, it may be, partly in Bed 10.

The section of Chideock Hill differs in one noticeable particular

* The limestone-capping of the Cotteswold Sands, usually called the Cotteswold Cephalopoda-bed, contains four Ammonitiferous horizons, namely (in descending order) *Moorei*-, *Dumortieria*-, *Dispansum*-, *Striatulum*-beds. It is in the second of these that *D. radians* occurs.

from the section at Burton-Bradstock* ; and, although somewhat outside the scope of this paper, it may be interesting to call attention to it. This is in regard to the bed with *Ludwigia Murchisonae*, from which I collected several fine specimens ; but at Burton-Bradstock I neither detected this species, nor a bed of similar matrix.

At the neighbouring Symondsburly Hill I found *Ludwigia Murchisonae* and *Lioceras opalinum* in the same bed ; and this bed was probably on the horizon of "5," "part unseen," at Chideock Hill. The occurrence of these two species together is a most interesting fact, rendering it rather difficult to draw any line of demarcation between the Lias and the Oolite at the top of the *Opalinum*-zone.

Not only do the lowest beds of the so-called "Inferior-Oolite Limestone" belong to the *Opalinum*-zone, but the upper portion of the Yeovil Sands as well, a fact which the Burton-Bradstock section showed very noticeably. (In this case also we have parts of the same horizon receiving two distinct names.) Further down in the Sands there is good evidence, at Burton-Bradstock, of the *Moorei*-beds (lower part of the *Opalinum*-zone) with *Grammoceras aalense*, &c. Where the *Moorei*-beds begin and the *Dumortieria*-beds (upper part of *Jurense*-zone) end cannot, as in the Cotteswolds, be stated with certainty ; but at the base of the Sands of Down Cliffs, and also in the yellow Sands of Ham Hill, we have species of *Dumortieria*, showing clearly that the lower part of the Yeovil Sands belongs to that horizon. This, again, is borne out by the section at White Lackington, where the argillaceous deposits immediately below the Sands show the fauna of the *Dispansum*-beds, that is, of the beds next in descending order in the Cotteswolds.

The Blue Clay of Down Cliffs, however, does not contain, so far as I could discover, any trace of the *Dispansum*-beds. It yielded only Ammonites of the *Dumortieria*-horizon. It is, therefore, of rather later date than the Clay of the White-Lackington section ; and still more, therefore, is it of much later date than what is generally known as Upper-Lias Clay,—namely, the *Commune*- and *Falciferum*-zones. At Down Cliffs the only representative of the *Commune*- and *Falciferum*-zones is to be found in the Pink Limestone, which lies at the base of the blue shale †. It is 10 inches thick, and really contains two layers. Extended search, judging from other localities which have been carefully and minutely worked, would reveal a distinct fauna for each of the beds.

The foregoing remarks furnish additional evidence of the unreliability of a grouping which depends on lithological appearances. This was one of the points of my former paper ; and it was because no satisfactory line could be drawn between the Lias and the Oolite, as is usually proposed, that I supported the Continental plan of a grouping upon palaeontological grounds, which would combine the Upper Lias and the lower part of the Inferior Oolite under the term "Toarcian." The following statements in support of this view may

* *Op. cit.* p. 451.

† *Op. cit.* p. 458.

be here noticed. In 1865* and subsequently† Brauns ends the Lias with the *Amaltheus*-zone‡; he unites as “Toarcian” “Der obere Lias und unterste braune Jura”§; he also speaks of this as the “Falciferenschicht”||; and he commences the “Unteroolith” with the “Coronatenschicht”¶. Branco** states that in Alsace-Lorraine the Lias ends most naturally with the zone of *Amaltheus costatus*††, and he finds no sharp line of division from the *Posidonomya*-beds until the zone of *Harpoceras Sowerbyi*‡‡.

Haug §§ says that the zones of *Opalinum* and *Jurense* are so closely united by what are practically the same species that one cannot draw the line separating Lias and Oolite as the Germans wish; further, that the zones of *Murchisonæ* and *Opalinum* are quite as closely connected |||, and he is of opinion that, from a palæontological point of view, the division at the base of the *Sowerbyi*-zone is the most practicable ¶¶.

These opinions are worthy of attentive consideration. When the views of d’Orbigny, Deslongschamps, Vacek***, and Lepsius††† are added to the above, and also the facts which Hudleston‡‡‡ so constantly impresses upon us concerning the difference between the Upper and Lower divisions of the Inferior Oolite, it will be seen that there is a very strong case in favour of a division like the Toarcian.

DISCUSSION.

Mr. H. B. WOODWARD observed that Mr. Day had, in 1863, first described in the Down Cliffs a band of limestone forming the junction of Middle and Upper Lias. The lower portion, an ironshot-limestone (Marlstone), yielded *Ammonites spinatus* and *A. crassus*, and the upper portion, a pale limestone, *A. bifrons*; while, common to both portions, Mr. Day found *A. communis*, *A. Holandrei*, *A. serpentinus*, and *A. radians*. He had himself found *A. striatulus* in the base of the Upper Lias at Down Cliffs and at Allington near Bridport. The same lithological characters and stratigraphical succession, and the same assemblages of fossils, characterize the Marlstone and the basement-beds of the Upper Lias from Dorsetshire to Lincolnshire. He

* “Die Stratigraphie und Paläontologie des südöstlichen Theiles der Hilsmulde,” Paläontographica, xiii.

† Untere Jura in Nordwestlichen Deutschland, 1871.

‡ Die Stratigraphie, p. 85. § p. 87. || p. 89. ¶ p. 90.

** “Untere Dogger,” Abhand. zur geol. Spez.-Karte Elsass-Lothringen, Bd. ii. Heft i. 1879.

†† p. 141.

‡‡ p. 140.

§§ “Polymorphidæ,” Neues Jahrbuch für Mineralogie, &c., Bd. ii. 1887, p. 161.

||| Compare my remarks, p. 520.

¶¶ Haug would extend the Lias to this point, as Vacek wishes; but I prefer the division Toarcian for the period dominated by the *Hildoceratidæ* or the *Falciferi*.

*** Quart. Journ. Geol. Soc. vol. xlv. p. 466.

††† Beiträge Jurass. Unter-Elsass, 1875.

‡‡‡ Inf.-Oolite Gasteropoda, Pal. Soc. vol. xl. p. 26 *et seq.*

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read lists in support of this view, showing that forms identified as *A. radians* and *A. striatulus* occur with the ordinary characteristic species in the basement-beds of the Upper Lias, as far as Lincolnshire. Hence, while accepting the Author's facts, he could not accept his conclusions, as by so doing we should abolish the Upper Lias throughout the country.

The occurrence of *A. opalinus* with *A. Murchisonæ* was interesting. Such an association of two zonal forms was common in the Lias, in the case of *A. margaritatus* and *A. spinatus*, &c. He pointed out that the Author appeared to settle his zone in defiance of stratigraphical evidence, by range of species rather than by the assemblages of forms, upon which he (the speaker) would himself prefer to lay stress.

Mr. HUDLESTON pointed out that we had here a test case as to the relative value of lithological and palæontological characters in determining horizons. At Down Cliffs he thought the Author was practically correct in his contention that the clays were a continuation of the Yeovil Sands with Ammonites of the upper part of the *Jurensis*-zone. He had very little doubt that, in the main, the Author's Ammonite-horizons were accurate; and that, when a predominance of any particular Ammonite occurred, it indicated a definite horizon, whatsoever might be the lithological characters of the horizon. He was surprised at Mr. Woodward's remarks concerning the commingling of forms in the Marlstone, including species usually characteristic of the *Jurensis*-zone. He could not understand this, and laid great stress on the desirability of collecting fossils inch by inch, as otherwise zones might easily be missed. He felt that the statement that such forms as *Amm. margaritatus*, *spinatus*, *bifrons*, *communis*, and *radians* occurred together should be challenged; for if they did, the whole question of the identification of strata by organic remains was attended with extreme difficulty. He, however, objected to the introduction of the term "Toarcian" in the sense used by the Author; for English geologists were the best judges of what were the proper divisions of their own Jurassic rocks, and M. de Lapparent was on the side of the British geologists so far as to include the "Malière" of Normandy (zone of *Amm. Murchisonæ* and *opalinus*) in the Bajocian. On purely palæontological grounds he thought the best line between Upper Lias and Inferior Oolite was the base of the *Opalinus*-zone.

Mr. H. B. WOODWARD did not wish to assert that the forms identified as *Amm. radians* and *A. striatulus* were common in the Marlstone or Upper Lias.

The PRESIDENT thought that there was a tendency to aim at a too artificial precision of palæontological zones, and to regard these as everywhere applicable. He believed that in Nature there were no hard-and-fast lines, either lithological or palæontological. As regards tracing lines for cartographical purposes, he did not know how this could be done without some lithological characters upon which to depend, and he would be very sorry to see the line which Mr. Woodward had drawn done away with.

Published Nov. 17890

31. ORIGIN of the BASINS of the GREAT LAKES of AMERICA. By J. W. SPENCER, M.A., Ph.D., F.G.S. (Read April 16, 1890.)

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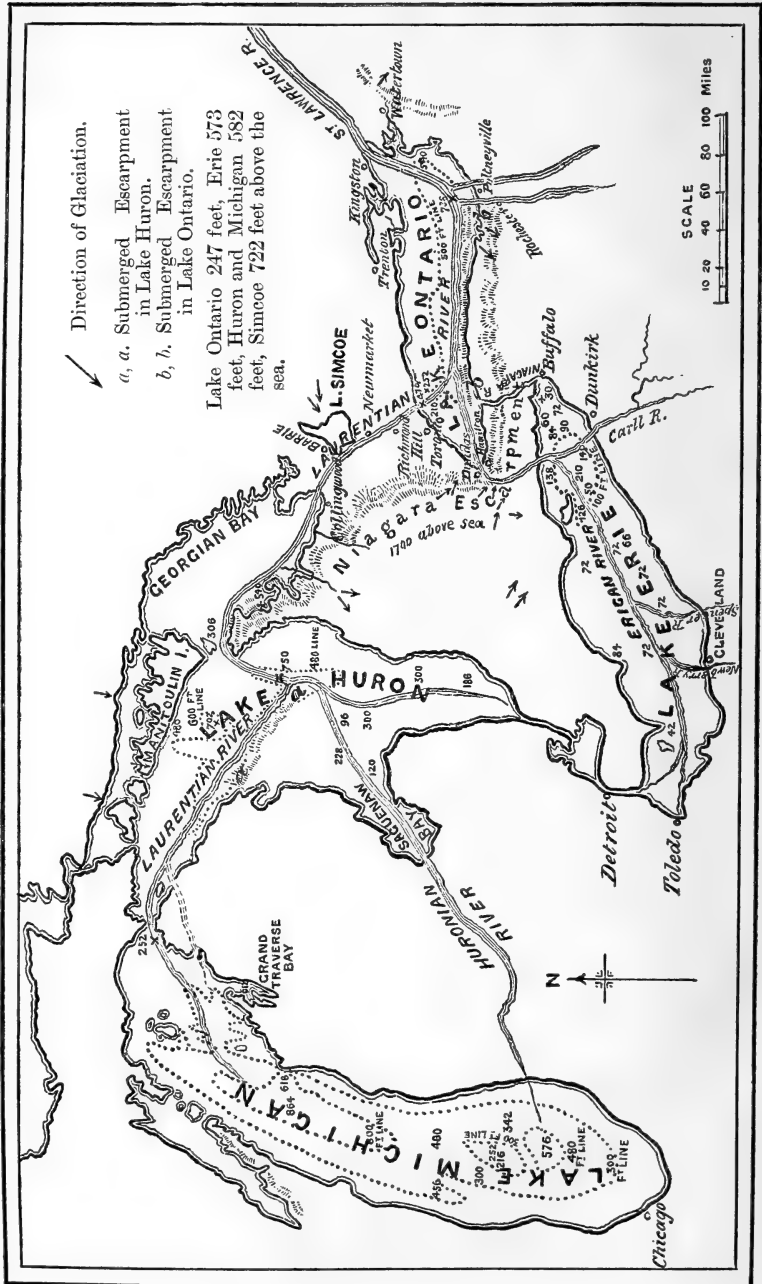
1. *Introduction.*

EVEN as recent as a decade ago very little was known as to the origin of the Great Lakes of North America. Whilst we find such generalized statements as "most lakes are due to terrestrial crust-movements," yet such crust-movements had not been tested in the American lake-region. Again, from the time of early geological investigations in America, statements are found that the basins were the result of erosion; but the methods of erosion were not explained, and this was the more necessary as most of the basins have rock-bound outlets. Later, in some geological literature, the method of excavation was hypothetically attributed to glaciers. Such was the unsatisfactory condition of our knowledge of the problem when the writer first commenced the study, in attempting to solve the origin of the Dundas Valley, at the western end of Lake Ontario, more than a dozen years ago. This investigation has developed results bearing not only upon the origin of the lake-basins, but also upon the physical history of the lakes, and broader questions of the building and sculpturing of the continent.

The methods of investigation have been the studying—(1) of the hydrography of the modern lake-basins and submerged channels upon the coast of America; (2) of the deep wells bored into, or through, the Drift deposits, by which buried channels, and their relation to or contrast with the modern valleys, have been discovered; (3) of the elevation of the continent; (4) of the direction of the glaciation in the lake-region; and (5) of the now high-level beaches, in which are recorded continental uplifts, together with the deformation of the old surfaces, owing to unequal terrestrial movements or warpings of the earth's crust*. The lakes which have been the basis of the more careful investigation are Ontario, Erie, Huron, and Michigan, with the respective altitudes of 247, 573, and, of the last two, 582 feet above the sea (see the Map, p. 524).

* In the field-work I here acknowledge the assistance of Professors D. F. H. Wilkins, W. W. Clendenin, and W. J. Spillman.

Map of the Drainage of the Ancient Laurentian Valley, now obstructed and forming the Great Lakes.



2. Features of the Ontario Basin.

Lake Ontario, as was shown in an earlier publication*, is a basin bounded on its southern side by escarpments, often precipitous, of which some of the steps are now submerged. At the foot of the submerged escarpments a valley like that of an ancient river may be recognized from the western part of the lake to near the eastern end, but there it disappears, for reasons to be noted later. The deepest part of this valley is 738 feet beneath the surface of the lake. From this trough the floor of the lake rises gradually, or with occasional low steps, to the northern shore. In short, the basin was once an old land-valley traversed by a river. At the western end of the lake borings have revealed an old channel, having a lateral depth of 292 feet. This is the continuation of the *cañon* of the Dundas Valley, which is about two and a half miles wide, bounded by rocky walls nearly 500 feet high, capped with Niagara Limestone. Down this valley the waters of the ancient Erie basin once flowed †.

If the waters of Lake Ontario were withdrawn, its present basin would be a broad valley, continuous with that of the St.-Lawrence valley, having a breadth of thirty or forty miles. Into this plain, at a point about twenty miles east of Toronto, there is a channel, approaching the shore, whose bed is 474 feet below the surface of the lake ‡, but with boundaries submerged to only 200 feet. This depression trends southward and joins that at the foot of the submerged escarpment before mentioned §.

3. Features of the Erie Basin.

The floor of Lake Erie is a broad flat plain, now rarely submerged to a depth of more than 84 feet, and usually less. Only a small area, situated directly south of the western end of Lake Ontario, is of greater depth, and there the greatest sounding is 210 feet ||. But from this region the Erie Valley was drained by the Grand River and Dundas Valleys into the western end of Lake Ontario, as was shown in 1881; for the Niagara river did not then exist. Numerous tributaries of the modern shallow lake flow over deeply buried channels, the deepest of those discovered being 228 feet below the lake-surface, as described by Dr. Newberry ¶, although the floor of that portion of the lake is nowhere over 84 feet below the surface of the water.

Similar channels, buried to depths below the floor of the eastern end of Lake Erie, near Buffalo, have been described by Dr. Julius Pohlmann **. The borings into many others in the region of the

* "Discovery of the Preglacial Outlet of the Basin of Lake Erie into that of Lake Ontario," by J. W. Spencer; Proc. Am. Phil. Soc., Philad. 1881.

† See "Discovery of the Preglacial Outlet of Lake Erie," &c.

‡ See British Admiralty Chart of Lake Ontario.

§ See U. S. Lake-Survey Charts of Lake Ontario.

|| See U. S. Lake-Survey Chart of Lake Erie.

¶ Geology of Ohio.

** Paper read before the Amer. Assoc. Advanc. Science, 1883.

western end of the lake have been recorded by Prof. T. Sterry Hunt*, and prove the existence of similar buried channels.

The original recognition † of the valley-like character of the basins of Ontario and Erie was based upon the above-mentioned characters, and upon others now supplemented by a more perfect collection of facts; but the greatest difficulty was in the occurrence of the rock-bound outlet of Lake Ontario, a difficulty which observations have at last dispelled, as will be seen later on.

4. *Features of the Huron Basin.*

The southern half of Lake Huron is a plain traversed by valleys and submerged to form only a shallow lake. Northward of this shallow basin, and extending obliquely across the lake for ninety miles, there is a submerged escarpment rising to a height of from 300 to 450 feet, facing north-eastward. The deeper part of the lake then trends northward in the direction of Georgian Bay. At one point the extreme depth of the submerged valley reaches 750 feet. The absolute depth of the rock in the deepest channel between Lake Huron proper and Georgian Bay is not known, but soundings show 306 feet; and as there is a deep channel upon the western side of Georgian Bay it becomes highly probable that a deeper and connecting channel is filled with Drift, like those known to occur elsewhere, beneath the lakes. From the straits, between the islands, the narrow channel in Georgian Bay, just referred to, extends south-eastward and is submerged to a depth of 510 feet. This is at the foot of the Niagara escarpment, which extends, as a strong topographic feature, from the head of Lake Ontario, and, rising in places to 1700 feet above the sea, into the peninsula between Georgian Bay and Lake Huron proper. The channels at the foot of escarpments, submerged or otherwise, in Lake Huron and Georgian Bay are fragmentary records of the history of the lake-valleys ‡.

5. *Features of Lake Michigan.*

This lake is divided into two basins. The more northern and larger basin has a maximum depth of 864 feet. It is, in part, bounded by vertical submerged escarpments, one of which, upon the eastern side, has a height of 500 feet. Whilst the deepest sounding at the modern outlet of the lake is only 252 feet, there are adjacent channels buried to unknown depths. But these have been imperfectly explored. Into this shallower portion of the lake, however, the fjord of Grand Traverse Bay has a northerly trend; it is 612 feet deep. This and the lesser fjords indicate the existence somewhere of a deep channel connecting with the Huron basin, as much as the river-valleys buried beneath the Drift materials of the modern floor of Lake Erie prove deep channels throughout that

* See Reports Geol. Canada, 1863-66.

† See "Discovery of the Preglacial Outlet of Lake Erie," &c.

‡ See U. S. Lake-Survey Chart of Lake Huron, and the Canadian Chart of Georgian Bay.

basin, although not shown by the soundings ; for the Lake-Michigan valley is carved out of undisturbed and almost horizontal Palæozoic rocks, the newest of which are Coal-Measures.

The southern basin of Lake Michigan is separated from the northern by a plateau submerged to a depth of from 300 to 342 feet ; whilst the southern basin itself is now 576 feet deep. The area of this portion of the basin is now much smaller than that of the Prepleistocene valley, as its margins have been filled with Drift, and now form broad plains bounding the lake. Beneath these deposits is a deeply buried channel, leading to the valley of Lake Huron, and to be noted further on.

6. *Buried Valleys revealed by Borings.*

The deep wells revealed the existence of the buried channel down which the waters of the Erie Valley originally drained, and thus established the relationship of the Erie with the Ontario Basin. But the most important series of borings were those between Georgian Bay and Lake Ontario, for here we have the connecting-link between the valleys of the upper lakes and that of Lake Ontario, and indeed the key to the origin of the valleys of the lakes.

Between Georgian Bay and Lake Ontario, a distance of about 95 miles, a portion of the country is comparatively flat or composed of a series of rising plains ; but there are also high transverse ridges of Drift, having a general trend of east and west. It is upon the northern side of the Drift ridges that Lake Simcoe, with a diameter of about twenty miles, is situated. But upon the northern side of Lake Simcoe there is another series of Drift ridges trending towards the north-east. Both of these series of ridges rise to between 200 and 550 feet above Lake Huron, these measurements being the extreme variation in their height.

From Georgian Bay to near Lake Simcoe, for a distance of thirty miles, the country is low and flat, with a known absence of rock to far below the level of the bay. Lake Simcoe is 140 feet above Georgian Bay, but upon its northern side, at Barrie, a well has been sunk in the Drift, without penetrating it, to a depth of 280 feet below its surface. Thirty miles further inland, south of Lake Simcoe, at Newmarket, a well was in the process of being bored. It had reached a level below Georgian Bay and was yet in Drift deposits when visited. In another well, several miles to the westward, near the side of the ancient buried valley at Beeton, rock was reached at 50 feet below the surface of Georgian Bay.

Between Newmarket and Richmond Hill there are several deep wells on the heavy Drift ridges which cross the country. But at Richmond Hill, at a height of 217 feet above Georgian Bay, there is a well 400 feet deep without penetrating the Drift. This proves the thickness of the Drift of the higher ridges crossing the old Valley north of the well to be not less than 700 feet in the old channel. Southward of Richmond Hill the country falls away in a series of more or less rolling steppes to Lake Ontario, but these

plains show the absence of rock along deeply-cut valleys to far below the level of the upper lakes. Upon the western side of this chain of borings, but a few miles distant, there is the Niagara escarpment. Upon the eastern side of Lake Simcoe the country is covered with flat limestones, rising to 150 feet above that lake. From the known absence of rocks along the line of borings and stream excavations, between a high mountainous escarpment upon one side and a rocky floor upon the other, and from these borings reaching to 200 feet or more below the upper lakes, without penetrating the Drift but stopping in quicksand, there has been discovered the existence of the only channel of antiquity which could now draw off the waters of the upper lakes, if the Drift were removed. Although none of the borings have reached the original rocky floor, yet the depth of the buried valley is suggested by the channel close upon the northern side of Lake Ontario, now submerged to 474 feet, which is deep enough to drain the last drop of water out of Lake Huron.

We have now found one continuous channel from Lake Michigan through Lake Huron and Georgian Bay, and thence buried beneath Drift deposits until it is again recognizable throughout nearly the whole length of Lake Ontario, being joined at the western portion by an ancient outlet of the Erie Valley (the ancient *Erigan* River). But the relative maximum depression of the channels, as far as explored, is disturbed by terrestrial warpings to be described hereafter.

Across the southern part of the peninsula of Michigan, between hills rising upon either side to heights of sometimes 800 or 1000 feet above Lake Huron or Lake Michigan, there is a valley whose western portion is occupied by the Grand River, and the eastern by a small river emptying into Saginaw Bay. At the divide between these rivers the land does not exceed 100 feet above the lakes. The topographic features of the valley show its original opening as having been into the Huron Valley by Saginaw Bay; but a considerable proportion of the modern drainage is in a direction opposite to that of the valley, or flowing towards Lake Michigan—that is, the drainage has been reversed. The maximum depth of the western portion of this buried valley is not known, but there is an absence of rock, as shown in several borings, to between 100 and 200 feet below the lake-level. But farther east in this trough there are several deep wells, in one of which the Drift is 500 feet below the floor of the side of the valley, or 350 feet below the surface of Lake Huron*. Hence we have established the great depth of the buried valley between the southern part of Lake Michigan and Lake Huron, whose ancient river I name the *Huronian*.

Other buried valleys and channels submerged could be given, but they all indicate the origin of the basins of the lakes as the valleys of a great river and its tributaries—a river of such high antiquity that the rains and rills had already ground off the surrounding hills to broaden the valleys. But for all this evidence, there are now rocky barriers forming an apparent obstacle in the way of a complete solution of the problem.

* This is at the Sanitarian Well at Alma, Mich., the record being furnished by Prof. Charles A. Davis.

7. *The Glaciation of the Region.*

At the present stage in the investigation this subject can be quickly dismissed. The question whether glaciers can erode great lake-basins is hardly pertinent, for nowhere about the lakes is the glaciation parallel to the shores or vertical escarpments which are associated with the lakes. Indeed, the direction of the striæ is often at high angles, even to 90° , to the trend of the vertical walls of rock bounding or crossing the lakes. Nor are the faces of these great walls of limestone polished by an agent moving along their faces. That there are no striæ parallel to some local inlet or valley would be perhaps rash to assert; but, if so, it is a mere coincidence, with no bearing upon the origin or moulding of the Great Lake-valleys. Hence we are forced back upon a conclusion that the lakes were subaërial valleys in spite of the barriers, and the fact that the floors of most of the basins are below sea-level—that of Ontario being nearly 500 feet.

8. *The former High Continental Elevation of North America.*

If the lakes and valleys originated from atmospheric and river erosion, then the continent stood at much greater elevation than at present, as shown by the depths of the lakes themselves. But there is much collateral evidence that in the later Tertiary days, probably during the Pliocene, the continent was very high. This is shown by the submerged valleys of the St.-Lawrence Gulf, of the Gulf of Maine, off New York, at the Mouth of the Mississippi River, upon the Pacific coast, and in Hudson Strait. These indicate that eastern America stood for long ages at between 1200 and 1800 feet above its present altitude; and the whole continent in more recent times, but for a briefer period, at upwards of 3000 feet*. Hence the former continental elevation was sufficient to satisfy all demands for the erosions of the lake-valleys; but the rocky barriers still demand explanation, both on account of the present obstructions not having impeded the erosion of the valleys, and on account of their subsequent closing the valleys, in part, into lake-basins—the necessary observations for the explanation having long eluded investigation.

9. *Deformation of Raised Shores and Beaches.*

At the close of the episode of the newest Till, the region of the Great Lakes was submerged to a depth of at least 1700 feet, as is recorded in the beaches which overlie the Till. These high beaches only remain as fragments about ancient islands; but if we descend to beaches of lower levels we find them well developed and containing all the necessary evidence for explaining the rock-barriers at the outlets of the lakes. Gen. G. K. Warren, Corps of Engineers, U. S. A., was the first to suggest the closing of the lakes by warpings of the Earth's crust†. Portions of the high-level beaches

* "High Continental Elevation preceding the Pleistocene Period," by J. W. Spencer, Bull. Geol. Soc. Am., vol. i. 1889; and Geol. Mag., May 1890.

† Appendix 13, Report of Chief of Engineers, U. S. A., 1875.

about the lakes have long been noted. But it was Mr. G. K. Gilbert who first connected the beaches upon the southern and eastern sides of Lake Ontario, and measured their great rise towards the north-east; but, as he did not apply his discovery to the explanations of the lake-basins, it was first applied by the present writer*. The results of Mr. Gilbert's investigations of beaches in New York and Ohio, and of the writer's researches in Canada, Michigan, New York, and elsewhere, are sufficient to form a chapter by themselves, and are still mostly unpublished, but I will draw upon them only to the extent of explaining the barriers across the outlets of the old valleys.

The most important raised beach of the Ontario basin is the *Iroquois* †. At the western end of the lake it now rests at 363 feet above the sea, but rises slightly to the east and still more towards the north, until at four miles east of Watertown it is 730 feet above the sea. Still further north-eastward, near Fine, on the borders of the Adirondack Wilderness, it reaches an elevation of 972 feet above the sea, beyond which I have made no instrumental measurements. At the western end of the lake the uplift is scarcely two feet in a mile in the direction of N. 28° E. At and beyond the north-eastern end of the lake the uplift is found to have increased to five feet in a mile, and in the region of farthest observation to somewhat more, in a north-eastward direction. Thus in the deformed water-level I have already measured a barrier of about 609 feet raised up at the outlet of the lake. Of this, about 530 feet is confined to the region of and beyond the eastern end of the lake, where the later Pleistocene barrier across the ancient Laurentian Valley has appeared. Whilst we know what are the maximum soundings in the river, yet the old channels are so filled with Drift that their depths are not revealed. Still, we know that in one portion of the channel cut out of limestone and more or less filled with Drift, the sounding is 120 feet. A short distance beyond, the channel across the Laurentian gneisses shows soundings of 240 feet. The maximum depth of the lake-basin is 738 feet. The deformation recorded in the beaches is more recent than the episode of the Upper Till. Consequently, if the continent were at a high level, with the warping, known to have occurred since the Drift was deposited, removed, as shown by the above figures, there would be not only no barrier, but a sufficient slope in the Laurentian Valley for the drainage of what is now the Ontario Basin.

Furthermore, the presence of the rocky barriers of the Rapids of the St. Lawrence, further east, are wholly accounted for by the terrestrial warpings of the region. Hence I have demonstrated, after a decade of study, that no barrier existed across the Ontario Valley when it was being carved out by the ancient St. Lawrence, and that this barrier is of quite modern origin.

South-east of Georgian Bay the average measured warping is four

* See "Notes on the Warping of the Earth's Crust in its Relations to the Origin of the Basins of the Great Lakes," *Amer. Nat.*, Feb. 1887, pp. 168-71.

† "Iroquois Beach; a Chapter in the Geological History of Lake Ontario," *Proc. Roy. Soc. Canada*, 1889.

feet per mile, in mean direction of N. 20° E. This will account for a portion of the barrier closing the Georgian outlet of Lake Huron. The more elevated beaches in the region of Lake Huron record a still greater change of level.

At the outlet of Lake Erie, Mr. Gilbert and myself find a differential uplift of about two feet per mile, and this is sufficient to account for the recently formed basin of Lake Erie.

The warping affecting the Michigan Basin has been that towards the north and east; and even in the buried channels south of Lake Michigan there is no evidence of an ancient drainage to the south, as their beds were too high compared with those of the northern, although the latter have been elevated recently by warping.

10. *Conclusions from the Observations.*

The valleys of the great lakes here studied are the result of the erosion of the land-surfaces by the ancient St. Lawrence (named *Laurentian*) River and its tributaries, during a long period of continental elevation, until the streams had reached their base-lines of erosion, and the meteoric agents had broadened the valleys. This condition was at the maximum just before the Pleistocene period.

The closing of portions of the old Laurentian Valley into water-basins occurred during and particularly at the close of the Pleistocene period, owing, in part, to Drift filling some portions of the original valley, but more especially to terrestrial warpings of the Earth's crust, which, to a sufficient degree, is measurable.

DISCUSSION.

The CHAIRMAN noted that there were one or two Fellows who had a local knowledge of the area, but the question of the origin of lake-basins in general was raised in the paper.

Dr. HINDE did not think that Dr. Spencer's explanation of the origin of the American lake-basins was the true one. The submerged deep channels of the alleged ancient rivers, to which the lake-erosion was said to be due, were traced towards the east end of Lake Ontario, where they ceased; and their discontinuity through the barrier formed by the hard gneissoid region of the Thousand Isles was attributed to differential elevation, or so-called earth-warping. This assumed warping where barriers existed could always be brought in to account for them. He (the speaker) asked where the beaches existed near Kingston, at the east end of Lake Ontario, on the difference of level of which the supposed warping was based. From his own observations on the region, he doubted the existence of the alleged buried channel between Lakes Huron and Ontario, and he did not think that the acknowledged great thickness of Drift now covering the elevated area between these lakes should be regarded as proof of the presence of a former channel directly connecting them. With reference to the supposed old channel between Lake Erie and Lake Ontario, by way of the Grand River and the Dundas valley, the water of Lake Erie was supposed to

have run *up* the valley by which the Grand River now came *down* to the lake. All these lakes and the elevated regions between them had been covered by glaciers, and their movement had been in a contrary direction to that of the present water-drainage; and judging by the amount of drift-material transported by the ice from the lake-basins over the adjoining land-surface, he believed that the glaciers had been important factors in their excavation. If, on the Author's views, there had been a recent submergence to the extent of 1700 feet, where were there traces of marine remains over the lake-region west of the meridian of Kingston, though such were not uncommon in the clays of the St. Lawrence and Ottawa rivers? Also, on the Author's hypothesis of a former great lake whose surface would be at a considerable elevation above the sea, what barrier was there at the south end of Lake Michigan, near Chicago, to keep such a lake from draining into the Mississippi valley?

Prof. BONNEY thought that Dr. Hinde's criticism was not a valid one, as he had not understood that the Author denied the occupation of the lakes by ice, though he did not uphold their glacial origin. He could not understand the formation of Georgian Bay by ice and the preservation of Manitoulin Island. He was struck with the similarity of the Author's sections and those of the Lake of Como, published by the late Mr. J. Ball, which he had previously shown to be adverse to the glacial theory of the origin of lake-basins. It was not safe to argue from the absence of remains of marine organisms; for elsewhere they were commonly wanting in deposits formed under circumstances similar to these, yet undoubtedly marine. He, again, could not follow Dr. Hinde in his objections to differential movements of the earth's surface, and insisted on the great movements of recent times, as evidenced along the Frazer River and in Norway. Only last autumn he had seen distinct evidence of comparatively modern depression along the Dalmatian coast. He suspected some changes even in historic times. The buried river-channels described by the Author were paralleled in Switzerland. He did not deny the efficiency of ice to produce some effect, but it did not bring about what had been attributed to it by some geologists.

Dr. IRVING congratulated the Author on the results he had placed before the Society. He thought Dr. Hinde had not followed Dr. Spencer's arguments throughout, as, for instance, in the case of the connexion between Huron and Ontario. He was glad to find the main points of his own theoretical conclusions as to the inability of ice to excavate confirmed by the Author's observations in Norway and America. He saw nothing startling in the "warping" hypothesis.

Mr. CLEMENT REID had no objection to Dr. Spencer's views on "warping." He thought all turned on accuracy of observation in tracing the terraces, and he wished to know whether it was absolutely certain that the same terrace was traceable throughout the whole distance.

Rev. E. HILL called attention to the fact that tracts of Lake Superior were now below sea-level, and yet no marine deposits are forming there. He called attention to the advantage of the

Hydrographic Survey, which the Author had utilized, and which we had in vain asked for in England. The depth of the Saguenay valley would be also accounted for by the Author's explanations.

Prof. SEELEY was prepared to accept the ancient drainage of the Laurentian river as now set forth. But he did not think it followed that the ancient valleys had been excavated by the river any more than that they were the work of ice. The general course of the Laurentian lakes followed the outcrop of the strata sufficiently to suggest that the lakes were originated by earth-movements. The main work of excavation seemed to him attributable to marine denudation in times when the level of the land was lower. And as tidal waters retired from the valley which they had cut out, the river-drainage necessarily occupied these inlets after the land was elevated.

Mr. WHITAKER asked why objection was raised by Dr. Hinde to deductions from borings in America when in England they were accepted. No other evidence of buried channels was to be had, sometimes. He would like to have some idea of the number of borings on which the Author relied.

The AUTHOR, in reply, answered Dr. Hinde and Mr. Whitaker that he had only written a condensed account of the origin of the basins, not of the lakes themselves. There were no escarpments in the place where Dr. Hinde had asserted their existence. There were scores of deep wells sunk in the Drift between Lake Simcoe and Georgian Bay, where deep Drift was shown. Similar sections were shown at the south-east end of the lake. He gave fuller details of the extension of these borings to the S.E. He cited instances of modern buried channels of a similar nature to those which he had described, and which evidenced a high continental elevation. To Prof. Seeley he replied that he had no objection to the assistance of sea-waves, in part, enlarging the valleys in some Pre-Pleistocene times. The old Erie-Ontario channel has been warped two feet per mile, which would account for the obstruction of the ancient valleys. Mr. Gilbert and he had traced one particular beach continuously round Lake Ontario. The elevations he had deduced from observations were founded on accurate instrumental measurements along this line, and similar observations had been made by him in other areas. There was no other evidence of barriers in the Erie-Ontario valley other than such as were due to differential elevation or partial filling with Drift. The Pre-Pleistocene drainage of the Lake-Michigan Basin was not to the south; hence no barrier greater than at present was needed, as explained in the paper.

There were no beaches about Kingston on account of the low altitude, but he had traced beaches in other parts of the region.

If we were to follow the differential elevation we should find that there were no Canadian Highlands at the close of the episode of the Upper Till, but he could not now enter into the ice-hypothesis. He gave instances of the absence of marine organisms in undoubted marine beaches, and instanced the discovery of a whale in beach-deposits upon which the evidence of warping was partly founded.

32. *On some DEVONIAN and SILURIAN OSTRACODA from NORTH AMERICA, FRANCE, and the BOSPHORUS.* By Prof. T. RUPERT JONES, F.R.S., F.G.S. (Read May 21, 1890.)

[PLATES* XX. & XXI.]

CONTENTS.

- § I. Devonian Species, from North America and the Bosphorus.
- § I. From Clarke Co., Indiana.
 - § II. From Thedford, Ontario, Canada; and Eighteen-mile Creek, Lake Erie, New-York State.
 - § III. From the Bosphorus.
- § II. Silurian Species.
- § I. From Anticosti, Canada.
 - § II. Silurian Species from Dundas, Ontario, Canada.
 - § III. Silurian Species from Canada, Coll. Geological Survey of Canada.
 - § IV. A Lower-Silurian *Beyrichia* (from Brittany), named and discussed by M. G. de Tromelin some years ago, but not hitherto figured.

§ I. DEVONIAN SPECIES.

§ I. As stated at page 14 of the Quart. Journ. Geol. Soc. for February last, Mr. J. M. Clarke, of Albany, N. Y., sent me some Devonian *Ostracoda*, collected by him in Ontario Co., N. Y., and some from Clarke Co., Indiana. These are now illustrated and described herewith.

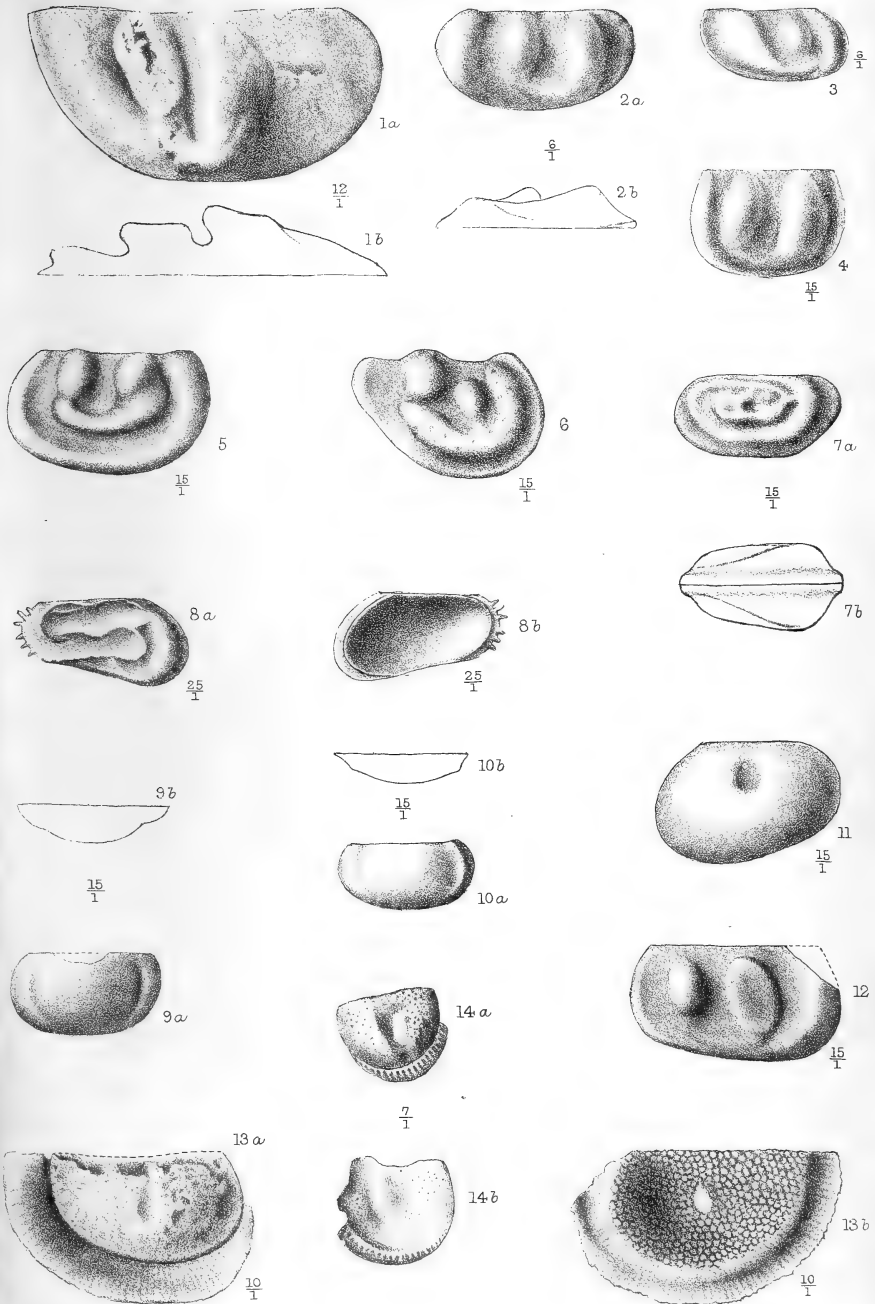
1. The first-mentioned occur in the buff-coloured, earthy portion of a decomposing siliceous rock, known as "the Chert of the Corniferous Limestone," and cavernous with casts (internal and external) of Polyzoa, *Ostracoda*, remains of Trilobites, and other organisms, comprising some interesting specimens of *Beyrichia* and allied genera. There are six species, and these are illustrated in Pl. XX. figs. 4, 9-13, and Pl. XXI. fig. 1.

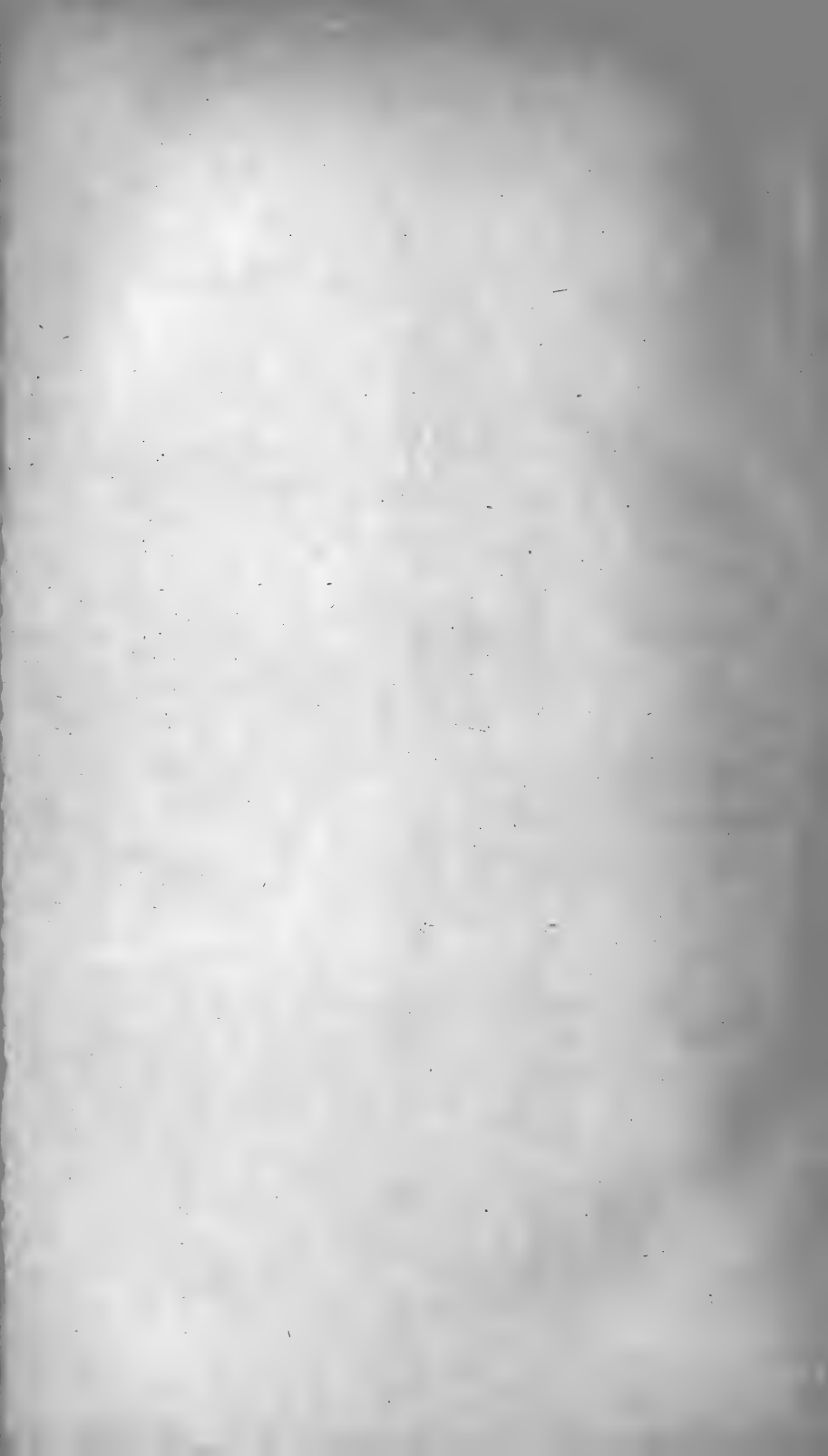
2. Two species, collected also by Mr. J. M. Clarke, from the Hamilton Group, Clarke Co., Indiana, U. S., Pl. XX. figs. 6 & 7.

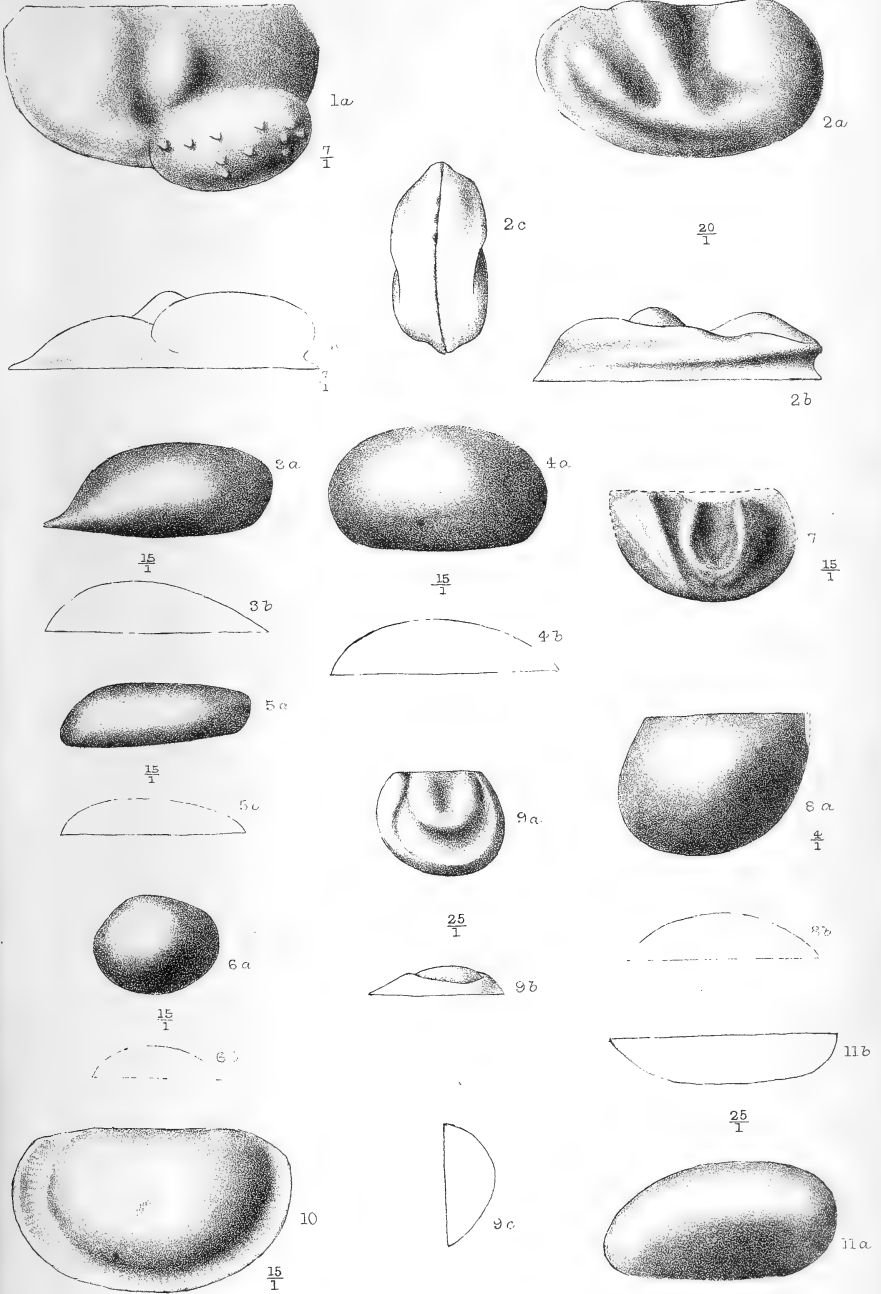
§ II. Among the additional *Ostracoda*, collected by Dr. Hinde, F.G.S., as mentioned at page 28, Feb. No., Q. J. G. S., are some Devonian *Ostracoda* from the Hamilton Group at Thedford, Ontario, Canada, and from the same formation at Eighteen-mile Creek, Lake Erie, N.Y. Four of these, being new species, are here described and figured (Pl. XX. figs. 5 & 8; and woodcuts, figs. 1 & 2).

Note.—The genera *Bollia*, *Moorea*, *Octonaria*, *Eurychilina*, and *Utrichia* are hereby added to the list of "Hamilton" fossils.

* These Plates have been drawn with the aid of a Grant from the Royal Society.









§ III. The Devonian *Beyrichia* collected some years ago by M. Dumont at the Bosphorus, and noticed by Dr. Ferd. Römer in the 'Neues Jahrbuch,' &c. for 1863, having been kindly lent by M. Dewalque for examination, is here figured and described in detail (Pl. XX. fig. 1).

Devonian Species.

I. PRIMITIA, Jones & Hall.

1. *Primitia Clarkei*, sp. nov. Pl. XX. fig. 11. Ontario Co., New York.

II. BEYRICHIA, M^cCoy.

2. *Beyrichia devonica*, Jones. Pl. XX. figs. 1 *a*, *b*, 2 *a*, *b*, 3. Bosphorus and Devon. 2 *a*, *b*, and 3 are from Devon.
 3. — *subquadrata*, sp. nov. Pl. XX. fig. 4. Ontario Co., N.Y.
 4. — *Kladeni*, M^cCoy, variety. Pl. XXI. figs. 1 *a*, *b*. Ontario Co., N.Y.
 5. — *Kolmodini*, sp. nov. Pl. XX. fig. 6. Clarke Co., Indiana.

III. EURYCHILINA, Ulrich.

6. *Eurychilina reticulata*, Ulrich. Pl. XX. figs. 13 *a*, *b*. Ontario Co., N.Y.

IV. BOLLIA, Jones & Holl.

7. *Bollia bilobata*, sp. nov. Pl. XX. fig. 12. Ontario Co., N.Y.
 8. — *Hindei*, sp. nov. Pl. XX. fig. 5. Eighteen-mile Creek, N.Y.
 8*. *Bollia*? An undetermined form, not figured. Eighteen-mile Creek, Lake Erie, N.Y.

V. STREPULA, Jones & Holl.

9. *Strepula plantaris*, sp. nov. Pl. XX. figs. 8 *a*, *b*. Eighteen-mile Creek, Lake Erie, N.Y.

VI. OCTONARIA, Jones.

10. *Octonaria Linnarssoni*, sp. nov. Pl. XX. figs. 7 *a*, *b*. Clarke Co., Indiana.

VII. MOOREA, Jones & Kirkby.

11. *Moorea Kirkbyi*, sp. nov. Pl. XX. figs. 9 *a*, *b*, 10 *a*, *b*. Ontario Co., N.Y.

Also, figured in woodcuts :

12. *Primitia* (?) *Walcotti*, sp. nov. Thedford, Ontario, Canada. Woodcut, fig. 1.
 13. *Ulrichia Conradi*, gen. et sp. nov. Thedford, Ontario, Canada. Woodcut, fig. 2.

I. PRIMITIA, Jones and Holl.

1. PRIMITIA CLARKEI, sp. nov. (Pl. XX. fig. 11.)

Length 1.66 mm.

Obliquely-subovate, narrow (low) and semicircular in front, boldly and obliquely rounded behind, where the height is to that in front as 16 to 13, measured at the ends of the hinge-line, which is about half of the greatest length of the valve. Surface almost uniformly convex, but fullest along the ventral and posterior regions; and marked with a relatively large oval pit between the centre and the back.

The nearest to this is *Primitia humilis*, J. & H., referred to in the February No. of the Q. J. G. S., p. 5; but it is much less oblong,

having a diagonal obliquity; it is more convex than *P. humilis*; and its normal pit or umbilicus is large and without a furrow.

From the decomposed Chert of the Corniferous Limestone (Devonian), Ontario Co., New-York State. Collected by Mr. J. M. Clarke, of Albany, N. Y.

There are also in this rock some other more or less oblong, very small casts of *Primitia* (?); and a few minute, almost oval casts, indeterminate.

Dr. Hinde, F.G.S., has favoured me with the following note (March 27, 1890):—"The siliceous rock seems to have been composed of calcareous organisms and then infiltrated with silica. Subsequently the shells, &c., composed of carbonate of lime, have been dissolved out, whilst the silica has been changed into 'rottenstone.'

"I do not see any traces of *siliceous* organisms in the decayed rock; and, if these had been originally present, they have been dissolved. I am very familiar with this kind of rock, which prevails in the Corniferous Formation of Canada. Wherever it occurs, the corals and other organisms are replaced by silica. I have often searched for spicules in this chert before it has been decayed, but not with much success, but I have some Indian arrow-heads made from it in which spicules are plainly seen.

"Dana, in 'Manual of Geol.' edit. 1875, p. 257, figures a variety of microscopic forms* from this Corniferous chert or hornstone of Central and Western New York, some *Xanthidia*, some perhaps spicules, but the forms are not very characteristic."

II. BEYRICHTIA, M'Coy.

2. BEYRICHTIA DEVONICA †, Jones. (Pl. XX. figs. 1 a, 1 b, 2 a, 2 b, 3.)

Beyrichia, sp., Ferd. Römer, N. Jahrb. f. Min. &c. 1863, p. 521, pl. 5. figs. 9 a, 9 b.

Beyrichia devonica, Jones, Geol. Mag. 1889, pp. 386-388, pl. 11. figs. 3, 4, 5.

Beyrichia (Bollia) obliqua, Fr. von Sandberger, Jahrb. Nassauisch. Ver. Heft 42, 1889, p. 33.

Length 3·8 mm., probably longer than at first; height 1·9 mm., probably rather less than at first; thickness about ·9 mm., probably less than at first.

In the 'Neues Jahrbuch für Mineralogie, &c.' Jahrgang 1863, Heft 5, pp. 513-524, Prof. Dr. Ferdinand Römer gave a geological account of a journey to Constantinople, &c., and included a notice

* See also Dr. M. C. White, 'American Journ. Sci. & Arts,' ser. 2, vol. xxxiii. 1862, p. 386; and 'Geologist,' 1862, vol. v. pp. 239-240.

† In the 'Neues Jahrb. f. Min.' &c. Jahrg. 1890, vol. i. p. 184, Dr. Frid. von Sandberger mentions that *B. devonica* is identical with his MS. species *Beyrichia obliqua*, given in the list of fossils from the Lower-Devonian strata near Offdillen, between Dill and Sieg. in the northern part of the Dillenburg district, Nassau, as *B. (Bollia) obliqua*, Jahrb. Nassauisch. Vereins f. Naturk., Heft 42 (August 1889), p. 33; and he withdraws this latter name.

of some fossils previously collected by M. Dumont from the fossiliferous, Devonian, schistose rocks at Arnaut Kjöi, on the Bosphorus, and preserved in the Museum of the University of Liége. M. Dewalque, the Director of that Museum, has very kindly allowed me to examine and describe the *Beyrichia* noticed by Dr. Ferd. Römer in the memoir referred to above, the two little figures given in 1863 not being sufficient for the determination of the species.

It is a somewhat worn, ferruginous cast of a left valve in a schistose sandy mudstone, containing also casts of the remains of Brachiopods and Encrinites. The valve has been squeezed, lengthened, and considerably distorted, as is especially shown by its profile, fig. 1 *b*. Apparently it possessed three lobes; two of them joined together ventrally, thus making one curved lobe; the other being separate and close to one end of the valve. In the cast, however, the horseshoe lobe (consisting of the large pyriform posterior or gigot lobe, and the middle lobe, united) has been pushed far on over the middle of the valve, closely approaching the separate (anterior) lobe, and leaving a wide, sloping, blank area behind.

For comparison, fig. 2, *B. devonica*, from Devonshire (left valve; Geol. Mag. *loc. cit.* fig. 3, of the same natural size, but $\times 6$ diam. instead of $\times 12$), is here introduced; also fig. 3, which is a squeezed modification of the same species (right valve; *ibid.* fig. 5, nat. size 3 mm. and $\times 6$ diam.), in which the curved junction of the big and middle lobes is broken, and the anterior lobe somewhat lessened in size. Taking fig. 2 *a*, which was chosen from among numerous more or less modified individuals in the same rock, to represent a valve (from Devonshire) in its natural condition, we may readily take fig. 1 (from the Bosphorus) as a distorted example of a similar form; and I venture to suggest that it may belong to the same species.

At page 517 of his Memoir mentioned above, Dr. Ferd. Römer refers these fossiliferous rocks of the Bosphorus to the Middle and Upper Devonian; but M. de Verneuil (Bullet. Soc. Géol. France, sér. 2, vol. xxi. (1864), pp. 147-155) regarded them as of Lower-Devonian age. In his memoir on the Geological Conditions of the Eastern part of European Turkey (Jahrb. der k.-k. geol. Reichsanstalt, vol. xx. 1870), Dr. Ferd. von Hochstetter referred them on palæontological grounds to the horizon of the Lower-Devonian beds of Western Europe, noting also that they contain some few Upper-Silurian fossils. Mr. W. R. Swan, also, in the Quart. Journ. Geol. Soc. vol. xx. 1864, p. 115, treats of them as being on a level with the Lower Devonian of the Rhine and probably of Plymouth and Ogdell in Devonshire.

3. BEYRICHIA SUBQUADRATA, sp. nov. (Pl. XX. fig. 4.)

Length 1.3 mm.; height .93 mm.

A hollow cast of the outside of a Beyrichian valve gives, in reverse, the shape and contour shown in fig. 4. This approximates in some degree to *B. devonica* (figs. 1, 2, 3), having an isolated anterior lobe and two thick lobes united by a ventral curve. Its relative

squareness of form, however, being only one third longer than high, whereas *B. devonica* is twice as long as it is high, is a characteristic distinction. Therefore I propose to give it a separate name—*B. SUBQUADRATA*.

In the decomposed Chert of the Corniferous Limestone, Ontario Co., N. Y. Coll. Mr. J. M. Clarke.

4. *BEYRICHIA KLÆDENI*, M'Coy, variety. (Pl. XXI. figs. 1 a, 1 b.)

Length 5·7 mm. ; height 3 mm. ; breadth (through the middle lobe) 3 mm.

This is evidently a smooth *B. Klædeni*, of the var. *clausa* type, with a pimpled hypertrophied anterior lobe. The correctness of this determination may be seen by reference to the April No. of the 'Ann. & Mag. Nat. Hist.' 1886, pp. 354–356, pl. xii. figs. 9 & 13, where specimens having one or the other of the characters here present are treated of; and the perfectly smooth variety is mentioned, *op. cit.* p. 351, as var. *nuda*.

So true a varietal form of *B. Klædeni* in the Devonian Formation is of great interest, as an instance of persistency of species.

The specimen figured is from the Corniferous Chert of Ontario Co., New York. Coll. Mr. J. M. Clarke.

5. *BEYRICHIA KOLMODINI*, sp. nov. (Pl. XX. fig. 6.)

Length 1·7 mm. ; height 1 mm.

This has evidently a structure analogous to that of the Scandinavian *Beyrichia clavata*, Kolmodin, especially of that variety figured in the 'Ann. & Mag. Nat. Hist.' ser. 6, vol. i. p. 399, pl. xxi. fig. 8, in which the upper part of the anterior lobe is crossed by a sulcus. In the specimen before us the front of the valve is more acute (narrower) than in *B. clavata*, and the hinder portion rounder and fuller, with a bold curvature. The three lobes run together at their base, but more equally than in the fig. 8 referred to, the front and hind lobes making one nearly uniform, curved, sausage-like, pimpled swelling, from the inner curve of which the small, smooth, pyriform, middle lobe divides off with a narrow neck. The separated portion of the anterior lobe is bold and round, and much larger than in the variety of *B. clavata* above-mentioned. The free margin, though very distinct, is not radiated.

It is from the Hamilton Group, of Clarke Co., Indiana, U.S.A. Collected by Mr. J. M. Clarke, of Albany, N. Y.

The species is worth naming after the Swedish palæontologist Dr. Lars Kolmodin, of Wisby, who has given good drawings and descriptions of Scandinavian Ostracoda.

III. EURYCHILINA, Ulrich, 1889.

Geol. and Nat.-Hist. Survey of Canada : Contributions to the Micro-palæontology of the Cambro-Silurian Rocks of Canada, Part II., by E. O. Ulrich, 8vo, 1889, p. 52.

This is a proposed genus, characterized by a thickened marginal

lip along the free border of the valve, bearing a thin, flange-like, projecting border, either narrow or broad, and either plain or marked with radiate striæ. In other respects the valves are Primitian in shape and ornament*.

6. *EURYCHILINA RETICULATA*, Ulrich. (Pl. XX. figs. 13 *a*, 13 *b*.)

Eurychilina reticulata, Ulrich, Contributions, &c., Part II., 1889, p. 52, pl. 9, figs. 9 & 9 *a*.

Length, including the fringe	mm. 3·5
———, without the fringe	2·5
Height, with the fringe	2
———, without the fringe	1½

An inner (fig. 13 *a*) and an outer cast (fig. 13 *b*) of one fine individual belonging to this handsome species, in the decomposed Chert of the Corniferous (Devonian) Limestone of Ontario Co., New-York State, supply material for the recognition of the same form as is figured and described by Mr. E. O. Ulrich, as quoted above, from "the Trenton Shales at Minneapolis, St. Paul, Fountain, and other localities in Minnesota." The recurrence of this beautiful species in the Devonian Formation is of great interest.

Another fringed Ostracode, having the Primitian features of umbilical pit and furrow, and a reticulate sculpture, is the Sardinian "*Beyrichia reticulata*," of J. G. Bornemann†. Though imperfect, the specimen has evidently been carefully figured; and it is reproduced here for comparison (Pl. XX. figs. 14 *a*, 14 *b*), because the work is rare. There is not, however, sufficient evidence in the drawings that the ventral border had the inner thickened marginal lip or rim that *Eurychilina* requires. Should, however, Dr. Bornemann's prove ultimately to belong to this genus, the specific name of Mr. Ulrich's species will have to be changed.

* For some *Beyrichian* forms, with thickened and frilled edge, and regarded as *Beyrichiopsis* by Jones & Kirkby, see 'Geol. Mag.' 1886, p. 433, &c. pls. 11 & 12; and others still retained in *Beyrichia* are noticed in 'Ann. & Mag. Nat. Hist.' ser. 5, vol. xiii. 1886, p. 257, pl. viii. figs. 1 & 2. Dr. Aurel Krause has described some flanged and fringed *Primitiæ*, and a fringed *Entomis*, in his Memoir on the *Beyrichiæ* and related *Ostracoda* from the Lower-Silurian Drift-gravel of North Germany, 'Zeitsch. d. D. geol. Ges.' 1889, pp. 1-26, pls. 1 & 2. Without sections of the ventral border, to show the proportions of the thickened marginal rim and flange, it is impossible to determine how far any of these may agree with Mr. Ulrich's diagnosis of *Eurychilina*. Fig. 3 *b* in Dr. Krause's plate, referred to, does not exhibit the required thickness of lip, being only the surface-outline of one valve of *Primitia distans*, Kr., which is curiously like Bornemann's "*Beyrichia reticulata*," allowing for the effect of pressure on the latter (Pl. XX. figs. 14 *a*, 14 *b*).

† 'Paléontologie de l'île de Sardaigne,' par le Prof. Chev. Joseph. Menechini, Turin, 1860; Supplément (p. 8). 'Voyage en Sardaigne,' &c. par Lieut.-Général Conte Albert De la Marmora, 3^{ème} Partie, Géologie, vol. ii. Lettre de M. le Docteur J. G. Bornemann (p. 7), relating to fossils found in schistose Silurian rocks at a spot called Perdas de Fogu, near the village of Fluminimaggiore, Province of Cagliari, in the Island of Sardinia; collected and described by Dr. J. G. Bornemann.

IV. *BOLLIA*, Jones and Holl, 1886.

Bollia, J. & H. 'Ann. & Mag. Nat. Hist.' ser. 5, vol. xvii. p. 360.

7. *BOLLIA BILOBATA*, sp. nov. (Pl. XX. fig. 12.)

Length 1·8 mm. ; height 1 mm.

This is a broken and worn cast from the decomposed Corniferous Chert of Ontario Co., N. Y. It is probably an oblong *Bollia*, the two lobes of which have been very prominent, but have been modified by accidental rubbing, and their curved connecting ventral ridge almost worn away. It is much like *B. bicollina*, J. & H. ('Ann. & Mag. Nat. Hist.,' April 1886, p. 361, pl. xii. figs. 14-16), but the valve is longer, being more oblong, and the lobes are much lower down, away from the dorsal margin. There is also an appearance of similarity to such a form as fig. 2 *a*, Pl. XXI., but the two restricted lobes are too far away from the dorsal margin; and the marginal lobe is at the contrary end of the valve, and herein agrees with the thick posterior marginal ridge in fig. 5 (*Bollia Hindei*).

Coll. Mr. J. M. Clarke, of Albany, N.Y.

8. *BOLLIA HINDEI*, sp. nov. (Pl. XX. fig. 5.)

Length 1·7 mm. ; height 1 mm.

This differs from the typical Upper-Silurian *Bollia bicollina*, J. & H., *op. cit.*, in being relatively longer, in having a much thicker marginal rim, a shorter and less open curve of its thick horse-shoe lobe, and in having not only the anterior part of that lobe pinched at its neck, but the hinder portion impressed with a strong oblique furrow. *B. interrupta*, Jones, *op. cit.* vol. xix. p. 408, pl. xii. fig. 14, presents an analogy in having its hinder lobe divided into two unequal parts, but the rest of the valve differs from our specimen. The latter is from the Hamilton Group (Devonian), at Eighteen-mile Creek, Lake Erie, New-York State (attached to a small Coral), where also some of the Devonian Ostracoda described in the February No. of the 'Quart. Journ. Geol. Soc.' vol. xlvi., were obtained. Coll. Dr. G. J. Hinde, F.G.S., after whom it is named.

8*. *BOLLIA* ?, sp. (Not figured.)

Length ·64 mm. ; height ·48 mm.

A very small semicircular valve, rather rounder at one end than at the other, somewhat undulate on the surface, with a faint curve visible at the middle, as if it had been worn down from the curved lobe of a *Bollia*.

From the Devonian strata at Eighteen-mile Creek, Lake Erie, N.Y. Coll. Dr. G. J. Hinde, F.G.S.

V. *STREPULA*, Jones and Holl, 1886.9. *STREPULA PLANTARIS*, sp. nov. (Pl. XX. figs. 8 *a*, 8 *b*.)

Length ·88 mm. ; height ·44 mm.

This is one of the *Strepulæ* with tortuous, and not merely loop-

like, ridges; and therefore it comes nearer to *S. sigmoidalis*, J. ('Quart. Journ. Geol. Soc.' February 1890, p. 11, pl. ii. fig. 4) than to those figured in the 'Ann. & Mag. Nat. Hist.' May 1886, pp. 403-406, pl. xiii. figs. 1-9 & 15. Indeed it came from the same locality as *S. sigmoidalis*, namely from the Hamilton Group at Eighteen-mile Creek, Lake Erie, N.Y. Coll. Dr. G. J. Hinde, F.G.S.

The valve has unequal ends, being semicircular in front and obliquely rounded behind. In outline it is somewhat like the sole of the human foot. Hence it may be called *PLANTARIS*. The broad or hinder end has a thin, flat, lip-like margin, obscurely marked with about ten shallow pits. The narrow or front end has six strong, outstanding, marginal denticles. There is a thick curved ridge within the posterior margin. The surface bears a thin, sigmoidal, tortuous ridge, passing along the dorsal and along the middle and ventral regions, curving in front and behind. It is double for a short distance in the antero-dorsal region, and is slightly interrupted at the anterior third of the valve. It gives off two short branches in the posterior third of the valve; the higher one touches the inside curve of the thick ridge, and the lower branch falls into the ventral end of that ridge.

VI. OCTONARIA, Jones, 1887.

Octonaria, Jones, 'Ann. & Mag. Nat. Hist.' June 1887, p. 404.

10. OCTONARIA LINNARSSONI, sp. nov. (Pl. XX. figs. 7 a, 7 b.)

Length 1.4 mm.; height .7 mm.

In this specimen we have the two very convex and thick-ridged carapace-valves of *Octonaria*, but with a surface-pattern different from any of those described and figured in the 'Annals & Mag. N. Hist.' ser. 5, vol. xix. pp. 404-407, pl. xii. figs. 1-8. In shape it approaches *O. flexuosa*, *loc. cit.* fig. 1 (if its position on the plate be reversed), but not at all in the ornament. This is a compressed spiral ridge, beginning with a thick portion at one end, becoming thinner as it passes along the ventral region, and much thinner after curving up into the dorsal region, then throwing off a short connection with the first portion, and turning down into the middle of the valve with a confused loop, little lumps, and central pit. The last feature can be traced obscurely in figs. 2, 5, & 7 of the illustrations referred to. Although, perhaps, some doubt attaches to the determination, I think that both naturally and conveniently it may be referred to *Octonaria* as *O. LINNARSSONI*—after the lamented Swedish palæontologist who has done good work among these and other fossil Crustacea.

From the Hamilton Group, Clarke Co., Indiana. Coll. Mr. J. M. Clarke, of Albany, N.Y.

VII. MOOREA, JONES and Kirkby, 1867 & 1869.

Moorea, Jones & Kirkby, 'Ann. & Mag. Nat. Hist.' ser. 4, vol. iii. p. 225, and ser. 5, vol. xviii. p. 261.

11. MOOREA KIRKBYI, sp. nov. (Pl. XX. figs. 9 a, b, & 10 a, b.)

	Length.	Height.	Thickness.
	mm.	mm.	mm.
Fig. 9	1.33	.73	.66
10	1.2	.6	.48

The species of *Moorea* that have been described in the papers referred to above have more or less of marginal ridges, as well on the dorsal and ventral, as at or near the ends. The specimens which we have from the Corniferous Chert of Ontario Co., New-York State (Coll. Mr. J. M. Clarke), have ridges only at the ends of the valve. Another form (Silurian), *M. Smithii*, Jones, *op. cit.* vol. xix. p. 499, pl. xiii. fig. 11, has a median ridge forking at the posterior region.

Neatly suboblong with rounded ends, straight back, and nearly straight ventral margin, these specimens, both an inner and an outer cast, show that two nearly equal curved ridges, each parallel with its neighbouring margin, starting abruptly on the dorsal, and dying away on the ventral edge, existed on each valve.

This distinct, though simple, form deserves a specific name, and I associate it with that of my valued friend and fellow-worker, Mr. J. W. Kirkby.

*Devonian Species from the Hamilton Formation at Thedford,
Ontario, Canada.*

The occurrence of numerous specimens of *Primitiopsis punctulifera* (Hall) in various stages of development as to size, reticulation, tubercles, and smoothness of ends (nothing of the last in the very young state; length .9, height .5 mm.), is mentioned at page 28 of the February No. of the 'Quart. Journ. Geol. Soc.' 1890.

Some interiors of small valves of *Primitiopsis punctulifera* are shown on one of the pieces of grey limestone (composed of small Brachiopods, &c.) from the Hamilton Group at Thedford, Ontario, Canada. They are 1.25 mm. long, and .75 mm. high, and not full-grown, but rather larger than fig. 7. pl. ii., Q. J. G. S., February 1890. They show distinctly that the front border is bevelled inwards, the ventral edge of the right valve somewhat inturned at its hinder moiety, the posterior edge thin, and the dorsal edge straight, with a simple groove along its length, slightly overlapped by the outside edge of the valve brought over at the middle.

Also collected by Dr. Hinde, in the same locality, are two other interesting small Ostracoda associated with them. These occur with

P. punctulifera in a thin limestone composed of the usual fragments and small organisms, and are—

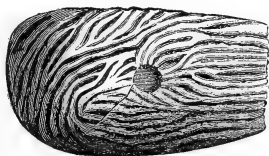
(1) *Primitia Walcotti*, sp. nov.; and (2) *Ulrichia Conradi*, gen. et sp. nov.

12. *PRIMITIA* (?) *WALCOTTI*, sp. nov.

Length .95 mm.; height .47 mm.

An oblong *Primitia*? (woodcut, fig. 1), imperfect at one end, with a central pit, and elegantly ornamented with narrow curved ridges and furrows (of about equal width). These are nearly straight, and somewhat inosculating on the dorsal, tortuous and

Fig. 1.—*Primitia Walcotti*, sp. nov. (Magn. 40 diam.)
From Theford, Canada. Coll. Dr. Hinde, F.G.S.



interrupted on the ventral region. Small pits occur here and there along the furrows, as if marking obsolete meshes.

This I name *P. WALCOTTI*, in honour of C. D. Walcott, F.G.S., of Washington, U.S., who has discovered and described several very interesting forms of North-American Ostracoda.

VIII. Genus *ULRICHIA*, nov.

Among the *Primitie* which have the normal medio-dorsal sulcus, there are many having the edges of the sulcus more or less swollen, sometimes on one, and sometimes on both sides. The varieties of *Primitia mundula* often show this modification in some degree. This varietal feature, however, becomes so much exaggerated as to obliterate the sulcus by the presence of two large tubercles, mostly without a definite pit or furrow between them. This is seen in *P. bicornis*, J., 'Ann. & Mag. Nat. Hist.' ser. 2, vol. xvi. (1855), p. 173, pl. vi. fig. 23, and *op. cit.* ser. 3, vol. xvi. (1865), p. 420; in *P. æqualis**, J. & H., *op. cit.* ser. 5, vol. xvii. (1886), p. 412, pl. xiv. fig. 11; in *P. Morgani*, J., Q. J. G. S. February 1890, p. 5, pl. iv. fig. 6; and in a species now described, and dedicated to T. A. Conrad. Mr. E. O. Ulrich, of the Illinois Geological Survey, has shown me sketches of somewhat similar forms from the Lower Silurian at Corryville and Fairmount, near Cincinnati. As all

* *P. diversa* and *P. cornuta*, J. & H. (*op. cit.* figs. 10 & 12), are also regarded as having tubercles which, although far apart, represent "essentially the elevated sides of the modified dorsal furrow" (*op. cit.* p. 412).

these forms, in their two medio-dorsal knobs, usurping the place of the sulcus on each valve, show a departure from the simple *Primitia*, and bear evidence of the persistency of their peculiar bitubercular feature, it is allowable to give them a generic standing; and I name the genus *ULRICHIA*, after Mr. E. O. Ulrich, who has largely collected the Palæozoic Ostracoda of North America, and has figured and described several important species.

[In his Memoir on the Fauna of the Graptolite-rock &c., 'Neue Lausitzische Magazin,' Görlitz, vol. liv. 1878, pp. 85 & 109, pl. v. fig. 11, K. Haupt gives a small figure of a valve (about 1.5 mm. long), apparently belonging to this genus. He refers to it as "*Beyrichia*, sp."

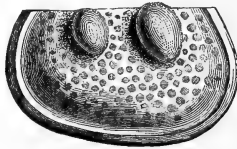
A somewhat similar form of bituberculate valve occurs in the Lower-Coalmeasure shales of Nova Scotia ('Geol. Mag.' 1884, p. 358, pl. xii. fig. 7); but this is the young form of *Beyrichia nova-scotica*, J. & K., as intimated at p. 358, and proved by its free association with mature forms in a series collected by Dr. Hinde.]

13. *ULRICHIA CONRADI*, gen. et sp. nov. (Woodcut, fig. 2.)

Length .8 mm.; height .46 mm.

A small, left valve, suboblong, straight on the back, obliquely curved below, rounded at the ends, the posterior higher and fuller than the anterior. Two largish prominent knobs, oval in section and obliquely peaked (much too neatly oval in the figure), divide the dorsal region in three nearly equal portions; the front tubercle is smaller than the other. The surface of the valve is faintly reticulated, and has along the free borders a neat marginal ridge.

Fig. 2.—*Ulrichia Conradi*, gen. et sp. nov. (Magn. 40 diam.)
From Thedford, Canada. Coll. Dr. Hinde, F.G.S.



This small bituberculate and punctate valve is near *P. Morgani*, J. (Quart. Journ. Geol. Soc., February), p. 5, pl. iv. fig. 6; but it is more oblong, margined with a distinct raised rim, and has the two tubercles (which take the place of the sulcus of *Primitia*) obliquely peaked, and nearly equal in size. This species I propose to name *CONRADI*, in memory of T. A. Conrad, who was one of the first to describe the fossil Ostracoda of North America.

§ II. SILURIAN OSTRACODA.

§ I. *From Anticosti. Arranged geologically.*

Nos. continued from p. 544.	Nos. of the Silurian Species.		Anticosti Group.	
14.	1.	<i>Beyrichia diffissa</i> , sp. nov. ...	Pl. XXI. fig. 7.	Division 3.
15.	2.	<i>Leperditia frontalis</i> , sp. nov.	" 8.	" 3.
16.	3.	<i>Primitia Billingsii</i> , sp. nov.	" 10.	" 2.
17.	4.	<i>Bollia semilunata</i> , sp. nov. .	" 9.	" 1.
18.	5.	<i>Bythocypris</i> (?) <i>Lindstrœmii</i> , sp. nov.	" 11.	" 1.
19.	6.	<i>Bairdia anticostiensis</i> , sp. n.	" 3.	Lowest.
20.	7.	<i>Macrocypris</i> (?) <i>subcylindrica</i> , sp. nov.	" 5.	"
21.	8.	<i>Bythocypris</i> (?) <i>obtusa</i> , sp. n.	" 4.	"
22.	9.	<i>Polycope sublenticularis</i> , sp. nov.	" 6.	"

Generic Nos.
(See pp. 535-543
for I.-VIII.)

Genera from Anticosti.

I. PRIMITIA	in Division 1.
II. BEYRICHIA	" " 3.
IV. BOLLIA	" " 1.
IX. LEPERDITIA.....	" " 3.
X. BYTHOCYPRIS ?	" " 1 and Lowest Div.
XI. BAIRDIA	} Lowest Division.
XII. MACROCYPRIS ?	
XIII. POLYCOPE	

§ II. *From Dundas, Ontario, Canada.*

Nos. continued from p. 550.	Nos. of the Silurian Species.	
23.	10.	<i>Primitia mundula</i> , J.
24.	11.	<i>Beyrichia Klædeni</i> , M'Coy.

§ III. *From the Dominion of Canada, Coll. Geological Survey of Canada.*

25.	12.	<i>Primitia mundula</i> , J.	} Upper Silurian.
26.	13.	— <i>ovata</i> (?), J. & H.	
27.	14.	<i>Beyrichia tuberculata</i> , Boll. — —, var. <i>pustulosa</i> (Hall). — —, var. <i>Bronni</i> (Reuter).	
28.	15.	— <i>equilatera</i> , Hall.	
29.	16.	<i>Primitia mundula</i> , J., and varieties.	} Lower Silurian.
30.	17.	— <i>Ulrichi</i> , J.	
31.	18.	—, spp.	
32.	19.	<i>Ischilina ottawa</i> , J., var.	
33.	20.	<i>Leperditia</i> , spp.	
34.	21.	<i>Beyrichia</i> , spp.	
35.	22.	<i>Polycope</i> , sp.	

NOTE.—The foregoing list supplies us with one genus (*Polycope*) as an addition to the Lower-Silurian forms (already known in the Devonian and Carboniferous strata); and enables us to place *Macrocypris*, *Bairdia*, and *Bythocypris* more certainly than heretofore in the Lower-Silurian column of the Table at page 2 of the February No. of the Quart. Journ. Geol. Soc.

§ IV. *From France (Brittany).*

Nos. contd.	Sil. sp.	
36.	23.	<i>Beyrichia Guillieri</i> , Tromelin, Pl. XXI. fig. 2. Lower Silurian.

§ I. Of the Silurian Ostracoda, from North America, additional to those described and figured in the February Number of the 'Quart. Journ. Geol. Soc.,' we have nine species collected by Dr. G. J. Hinde in Anticosti. Of these, five belong to the Divisions 3, 2, & 1 of Billings's four Divisions of his "Anticosti Group,"* and four to the lowest Division there, which he termed the "Hudson-river Group." This last Division is equivalent to Groups A and B of the Geological Survey of Canada (Reports 1853-56, and 1863), and is now regarded, Dr. Hinde informs me, as equivalent to the "Cincinnati Group" †.

Group C is equal to Billings's Division 1 of the "Anticosti Group," and was placed by him doubtfully at the base of the Middle Silurian there, but is now regarded by Dr. Hinde as being more probably Lower Silurian. Group D = Div. 2, Group E = Div. 3, and Group F = Div. 4 of the Anticosti Group, were characterized by what Mr. Billings regarded as Middle-Silurian fossils, but the term "Middle Silurian" appears to be almost obsolete with American geologists. Mr. Billings included the "Medina, Clinton, Niagara, and Guelph" Formations of New-York State and Western Canada in the "Middle-Silurian" series.

The genera to which these nine species belong are already included in the Table at p. 2 of the previous memoir (February 1890): but all the species are new.

§ I. *From Anticosti, Canada.*

II. BEYRICHIA, M'Coy. (See also pages 236-238.)

14. BEYRICHIA DIFFISSA, sp. nov. (Pl. XXI. fig. 7.)

Length 1.5 mm.; height 1 mm.

A rather narrow-lobed *Beyrichia*, not far removed from some varieties of *B. Klødeni*, but having its anterior lobe long, narrow, oblique, furrowed, and, as it were, split longitudinally for the greater part of its length. Hence the proposed name DIFFISSA. The middle and hinder lobes unite below; and the latter is broad and faintly punctate. The upper ends of the split lobe are broken in the specimen.

From the Division 3 of the Anticosti Group, Jupiter River, Anticosti. Attached to an *Atrypa*. Coll. Dr. G. J. Hinde, F.G.S.

* 'Geol. Surv. Canada: Catalogues of the Silurian Fossils of the Island of Anticosti,' 1866.

† In the February No. of the Q. J. G. S., at p. 28, 8th line from the bottom, Div. G should be Div. A. At p. 27, 3rd line from the bottom, for fig. 17 read fig. 12.

IX. LEPERDITIA, Rouault, 1851.

'Ann. Mag. Nat. Hist.' November 1881, p. 334.

15. LEPERDITIA FRONTALIS, sp. nov. (Pl. XXI. figs. 8 a, 8 b.)

Length 6.2 mm.; height 4.7 mm.; thickness 3 mm.

This is a small, subquadrate, or rather subrhomboidal, valve, with the general aspect and the ocular tubercle of *Leperditia*; its muscle-spot is not visible; but its ventral margin is thickened, hence probably it is a *Leperditia* and not an *Isochilina*.

In outline and contour it would be like figs. 5 & 11, pl. i. 'Quart. Journ. Geol. Soc.' February 1890, were it not so oblique from above downwards and backwards, and less convex. Our specimen has the antero-dorsal angle well forward, the antero-ventral margin sloping inwards, and the postero-ventral margin boldly curved outwards. It is somewhat like fig. 12 a (*loc. cit.*), but the front dorsal angle is more pronounced, and there is no fold or sinus on the ventral margin. So also it approaches F. Schmidt's figure of a variety of *L. Hisingeri*, 'Mém. Acad. Imp. Sci. St.-Pétersb.' ser. vii. vol. xxi. No. 2, 1873, pp. 9, 16, & 25, figs. 22, 23; but its front dorsal angle is too prominent. An unnamed Lower-Silurian *Leperditia* from the East of the Cordillera of San Juan, in the Argentine Republic (E. Kayser, 'Palæontographica,' Suppl. III. 1876, p. 10, pl. i. fig. 19), matches F. Schmidt's variety of *L. Hisingeri*. *L. canadensis*, var. *anticostiana** (*L. anticostiensis*), Jones, 'Ann. Mag. Nat. Hist.' Nov. 1881, p. 344, pl. xix. fig. 8, is also near our specimen, but differs in the outline of its anterior moiety. On account of the antero-dorsal angle being so strongly pronounced, the *Leperditia* under notice may, I think, be called FRONTALIS. It occurs in a grey limestone made up of fragments of Encrinites, Polyzoans, Trilobites, Brachiopods, &c., in the Division 3 of the Anticosti Group, near the Jumpers, Anticosti. Coll. Dr. G. J. Hinde, F.G.S.

I. PRIMITIA, J. & H. (See also page 235.)

16. PRIMITIA BILLINGSII, sp. nov. (Pl. XXI. fig. 10.)

Length, with fringe, 2.4 mm.; without fringe 1.9 mm.

Height, " " 1.4 " " " 1.2 "

This is a fine oval-oblong, or semioval (longwise), convex, smooth, Primitian valve, with the umbilical pit large, round, shallow, and low down (below the middle line). A nearly uniform, wide, flat, thin, and delicately radiate lip is attached to the free margin, and is rather narrower in front than behind.

There is no evidence of a definitely thickened condition of the margin behind the flange; if there were, it might be grouped as *Eurychilina* (see p. 239).

This form is closely allied to both *Primitia plana*, Krause, and *P. cincta*, Kr., 'Zeitschr. d. D. g. Ges.' 1889, pl. i. fig. 1 & fig. 4; but

* This should be *anticostiensis* according to rule.

it differs from both; and, well deserving a specific name, I dedicate it to the memory of the ardent and industrious palæontologist of the Geological Survey of Canada, who devoted much time to the fossils of Anticosti.

It is from the Clinton or Niagara Formation, Division 2 of the Anticosti Group, west of Jupiter River, Anticosti. Coll. Dr. G. J. Hinde, F.G.S. In a compact, thin, grey limestone, composed of small organisms, and showing *P. Billingsii* and some obscure forms on one of the bed-planes.

IV. BOLLIA, J. and H. (See also page 540.)

17. BOLLIA SEMILUNATA, sp. nov. (Pl. XXI. figs. 9 a, 9 b.)

Length .68 mm.; height .54 mm.; thickness .32 mm.

In this little species the horse-shoe lobe is neat, nearly symmetrical, and relatively strong, being thick and high, not reaching below the middle of the valve, but touching each end of the hinge-line. The outline of the valve is more than half a circle,—that is, it is nearly two-thirds of an irregular disc, the hinge-line being its cut edge. The marginal ridge along the free border is strong, but thicker at one end than at the other; and the clear crescent-shaped space between it and the curved lobe is very distinct.

From the Cincinnati Formation; Division 1 of the Anticosti Group (Billings), South of Junction Cliff, Anticosti, attached to a small Brachiopod. Coll. Dr. G. J. Hinde, F.G.S.

X. BYTHOCYPRIS, G. S. Brady, 1880.

(See 'Ann. & Mag. Nat. Hist.' March 1887, p. 184.)

18. BYTHOCYPRIS? LINDSTRÖMII, sp. nov. (Pl. XXI. figs. 11 a, 11 b, 11 c.)

Length 1.2 mm.; height .6 mm.; thickness .48 mm.

In outline and contour this Cypridoid Ostracode (from Billings's Division 1 of the Anticosti Group; south of Junction Cliff, Anticosti. Coll. Dr. G. J. Hinde, F.G.S.) nearly resembles the smooth oblong-ovate *Bythocypris symmetrica*, Jones, 'Ann. & Mag. Nat. Hist.' ser. 5, vol. xix. p. 186, pl. vii. figs. 3, 4, & 7; but it is larger, and tapers more suddenly at the anterior third. Being so far different, it may have a distinct name—LINDSTRÖMII, after my friend the eminent Swedish Palæontologist, Professor Gustav Lindström, F.C.G.S., of the State Museum, Stockholm, who has taken great interest in this branch of Carcinology.

Several specimens, somewhat variable in outline, occur attached to small Corals and Brachiopods.

XI. BAIRDIA, M'Coy, 1844.

19. BAIRDIA ANTICOSTIENSIS, sp. nov. (Pl. XXI. figs. 3 a, 3 b.)

Length 2.0 mm.; height .8 mm.; thickness .9 mm.

An elongate, subrhomboidal, very convex, smooth form; slightly arched on both ventral and dorsal border, but the latter suddenly

slopes, with a hollow curve, down to the postero-ventral angle; rounded in front and terminating in a sharp triangular process of the ventral border behind. Thus it approaches *Bairdia*, especially such forms as were ascribed to that genus in 1879 ('Quart. Journ. Geol. Soc.' vol. xxxv. pp. 572 *et seq.* pl. xxix. figs. 11-16, and pl. xxxi. figs. 1-7). None of these Carboniferous valves, however, quite match our figured specimen. *Bairdia Griffithiana*, Jones & Holl, 'Ann. & Mag. Nat. Hist.' July 1868, p. 58, pl. vii. fig. 10, from the Lower Silurian of Ireland, is not far removed, but is much shorter, higher, and blunter.

From the lowest Division of the Anticosti Group (Cincinnati Formation, Dr. Hinde), at English Head, Anticosti. Several specimens of single valves, together with numerous other Ostracoda, lie on the bed-plane of a compact grey limestone, probably composed of similar organisms. Coll. Dr. G. J. Hinde, F.G.S.

The edges of the valves are in general so much concealed by the matrix that it is difficult to define many of the individuals. There is an undetermined *Leperditia* among them.

XII. MACROCYPRIS, G. S. Brady, 1867.

20. *MACROCYPRIS*? *SUBCYLINDRICA*, sp. nov. (Pl. XXI. figs. 5 *a*, 5 *b*.)

Length 1.6 mm.; height .5 mm.; thickness .6 mm.

Fig. 5 is a long, convex, smooth, right valve of a subcylindrical carapace, nearly straight above and below, but higher behind, and with oblique ends, one more so than the other. Nearly straight above for four-fifths of the dorsal edge, and then sloping down with a very gentle curve to the obtuse postero-ventral angle. Straight below. Ends oblique; subangular behind; the front end narrow, with a short oblique curve bending downwards and backwards.

It is somewhat like *Macrocypris siliquoides*, Jones, 'Ann. & Mag. Nat. Hist.' 1887, ser. 5, vol. xix. p. 194, pl. v. fig. 9, which is arched on the back and rather sharper at one end than the other; and also somewhat near *M. symmetrica*, *op. cit.* p. 181, pl. vii. fig. 8, which is blunt at the ends and with nearly equal edges: the specimens under notice are very much narrower than either. As the two *Macrocyprides* referred to above offer the nearest analogies, I place this species also in *Macrocypris*.

This species occurs in some numbers with *Bairdia anticostiensis*, &c., at English Head, Anticosti.

X. BYTHOCYPRIS. (See page 548.)

21. *BYTHOCYPRIS*? *OBTUSA*, sp. nov. (Pl. XXI. figs. 4 *a*, 4 *b*.)

Length 1.8 mm.; height 1.0 mm.; thickness .9 mm.

This suboblong form is very near to *Bythocypris symmetrica*, Jones, *op. cit.* 1887, p. 181; but, being much blunter in front, has almost equal ends.

With *Bairdia anticostiensis*, &c., in limestone of the Cincinnati Group, at English Head, Anticosti. Coll. Dr. G. J. Hinde, F.G.S.

XIII. POLYCOPE, Sars, 1865.

22. POLYCOPE SUBLENTICULARIS, sp. nov. (Pl. XXI. figs. 6 a, 6 b.)

Length 1.1 mm.; height .86 mm.; thickness .53 mm.

This suborbicular form reminds us of *Polycope*, being round and only slightly angular on its dorsal border. Whether one side or the other of the low dorsal angle corresponds to a hinge-line, or if the hinge were limited to the umbo-like angle itself, is uncertain. Among the Devonian forms, however, of this genus, *Polycope Hughsiæ*, Whidborne, and *P. devonica*, Jones, var. *concinna*, Whidborne, show a decided tendency to have a subangular dorsal border. See 'Monogr. Devonian Fauna,' Pal. Soc. 1889, pp. 49, 50, pl. iv. figs. 11 a & 17 a.

Among Silurian *Ostracoda*, *Macrocypris?* *crassula*, Jones, 'Ann. & Mag. Nat. Hist.' March 1887, p. 181, pl. vii. fig. 10, is one of the nearest, but it is too nearly reniform, and has not such a uniform convexity. *Primitia* (*Aparchites*) *Maccoyii*, junior, Salter, sp. (J. & H., 'Ann. & Mag. Nat. Hist.' ser. 4, vol. ii. p. 55, pl. vii. fig. 3), is still nearer in shape, but is too uniformly oval in outline.

Several of these round valves, usually black in colour, accompany *Bairdia anticostiensis*, *Bythocypris obtusa*, &c., on the bed-planes of the thin grey limestone at English Head, Anticosti. Coll. Dr. G. J. Hinde, F.G.S.

§ II. From Dundas, Ontario, Canada. (Species, nos. 23, 24; p. 545.)

Among the Upper-Silurian *Ostracoda* collected by Dr. Hinde in North America, and noted in the February No. of the 'Quart. Journ. Geol. Soc.' p. 28, are numerous small and rather obscure forms in a thin, brownish, earthy shale (with impressions of *Orthis*, &c.) from the Niagara Formation at Dundas, Ontario, Canada. Most of these little Entomostraca are *Primitia* (1 mm. long, and less), neatly suboblong in outline, with a mid-dorsal sulcus and a marginal rim. The sulcus has its edges partially thickened in some specimens. These features belong to *P. mundula*. In a few individuals a very small, but distinct, tubercle appears in the sulcus or on one of its edges, giving the appearance of a minute (or young) *Beyrichia notata*, or a *B. Klædeni*, var. *acadica* (compare some of the figs. in pls. xvi. & xvii., 'Ann. & Mag. Nat. Hist.' May 1889). There is also at least one small *B. Klædeni* (more than 1 mm. long), with its three well-developed lobes. These are not figured here.

§ III. Silurian *Ostracoda* from the Dominion of Canada, Coll. Geol. Survey of Canada. (Species, nos. 25-35; p. 545.)

A. From Mr. H. M. Ami, F.G.S. Lower Silurian; Canada.

§ I. Utica Shales.

1. *Primitia mundula*, Jones.
2. — *Ulrichi*, Jones.

§ II. Chazy Limestone.

1. *Isophilina ottawa*, Jones, variety.

B. From Mr. J. F. Whiteaves, F.G.S.

B. a. § I. Upper Silurian; Arisaig, Nova Scotia.

1. *Primitia mundula*, J., variety.
2. ——— *ovata* (?), J. & H.
3. *Beyrichia tuberculata*, Boll. Young.
———, var. *pustulosa* (Hall).
———, var. *Bronni* (Reuter).
4. *Beyrichia æquilatera*, Hall.

B. b. § II. Lower Silurian.

§ 1. Trenton Limestone.

1. *Primitia*, sp.
2. *Primitia mundula*, J.
3. ———, variety.
4. *Leperditia*, sp. nov. ?
5. *Beyrichia*, sp. nov.
6. *Polycope*, sp.

§ 2. Trenton Limestone.

1. *Leperditia*, sp. nov. ?

§ 3. Birdseye Limestone.

1. *Leperditia*, sp. nov. ?

§ 4. Chazy Limestone.

- § II. 1. *Primitia*, sp.
———, sp.

§ I. 1. *Isochilina ottawa*, J., variety.

§ III. 1. *Leperditia*, sp. nov. ?

§ II. 3. *Polycope*, sp.

§ 5. Chazy Shales.

1. *Primitia mundula* (?), J.
2. *Leperditia* ?
3. *Beyrichia*, sp. nov.

A. Some Palæozoic specimens from Canada, sent by Mr. Henry M. Ami, F.G.S., Assistant-Palæontologist of the Geological Survey of Canada, to me for examination, consist of:—

§ I. Some pieces of hard, black, somewhat bituminous shale from the Utica Formation at Rideau Street, New Edinburgh, Ottawa, containing small obscure casts, very numerous on the bed-planes and much squeezed. *Primitia mundula*, J., 1855, and *P. Ulrichi*, J., 1890, are barely distinguishable, and perhaps *Leperditia* (?) *cylindrica*, Hall. The following fossils are also present, as named by Mr. Ami:—*Trocholites ammonius*, Emmons, *Lingula Progne*, Billings, *Leptobolus insignis*, Hall, *Zygospira modesta*, Say. Also remains of Trilobites and Encrinites.

§ II. *Isochilina ottawa*, Jones ('Ann. & Mag. Nat. Hist.' April 1858, p. 248, pl. x. fig. 1), Variety: occurring—(1) abundantly on the bed-planes of a piece of thin-bedded limestone, from a loose block in Sussex Street, Ottawa, and probably belonging to the Chazy Formation (upper portion). (2) Constituting, with a few bivalve Molluscs, the greater part of an easily-broken grey limestone from Nepean, Ontario, Canada, belonging to the Chazy Formation.

B. A larger collection, submitted by Mr. J. F. Whiteaves, F.G.S., Palæontologist to the Geological Survey of Canada, of Canadian Palæozoic Ostracoda, comprises:—

B. a. § I. Upper Silurian (Upper Ludlow) Formation. Dr. Honeyman's "Arisaig Group", Division D. Nova Scotia.

§ 1. In dark-grey limestone, with hæmatitic stains, and made up of small organisms, such as the Ostracoda, together with 14 species † of Mollusca, Brachiopoda, and Trilobites, and some Encrinital remains. Stonehouse Brook, Arisaig, Nova Scotia. Division D.

1. *Primitia mundula*, J., a small variety.—This is probably the *Primitia* mentioned at p. 492, lines 38–41, 'Quart. Journ. Geol. Soc.' vol. xxvi., but not the species referred to in lines 36–37.

2. *Primitia ovata* (?), J. & H.—An obscure oval cast, probably the same form as referred to in 'Geol. Mag.' 1881, p. 344.

3. *Beyrichia tuberculata*, Boll, young; *B. tuberculata*, var. *pustulosa* ‡ (Hall), and var. *Bronni* (Reuter).—Of six more or less perfect casts of this Ostracode, five are very near to Reuter's variety *tuberculata-gibbosa*; but the middle lobe is sometimes constricted, and the marginal rim is smooth in some, and tubercled in others. One is equivalent to *B. Bronni*, Reuter ('Zeitsch. d. D. g. Ges.' 1885, p. 638, pl. xxv. fig. 6. Another is a variety of *B. tuberculata*, with its hinder lobe almost entire, and its anterior lobe hypertrophied.

4. *Beyrichia æquilatera*, Hall. February No. Q. J. G. S. page 18.—Two specimens, like that figured in pl. ii. fig. 6, *op. cit.*, differing slightly from it in the proportions of the lobes. I have not yet met with a specimen having* a lobe quite divided into two parts, as in the woodcut, fig. 20, published in 1860.

§ 2. In a brown ferruginous cavernous band or bed-plane in a dark-grey micaceous sandstone, with casts of Polyzoa, Encrinital joints, Brachiopods, Trilobites, &c. McAdams Brook §, below the falls and fort, Arisaig, Nova Scotia. Division D.

1. *Beyrichia tuberculata*, var. *pustulosa* (Hall), equivalent to *tuberculata-gibbosa*, Reuter.—Three or four casts, badly preserved.

B. b. § II. Lower Silurian; Canada.

§ 1. Trenton Limestone.—Dark-grey hard limestone, with Ostracoda, Encrinital joints, and small Brachiopods. Lorette, Falls of the River St. Charles, Province of Quebec.

1. *Primitia*, sp.—Large, black, subconvex, boldly curved below, obliquely and nearly equally rounded at the ends; faint mid-dorsal sulcus.

* See Quart. Journ. Geol. Soc. vol. xx. 1864, pp. 333–345, and vol. xxvi. 1870, pp. 490–492; also 'Acadian Geology,' 3rd. edit. 1878, pp. 565–570.

† Determined by Mr. H. M. Ami, namely:—*Murchisonia arisaigensis*, Hall, *M. nova-scotica*, H., *Nuculites erectus*, H., *N. cuneatus*, H., *N. subovatus*, H., *Megambonia cancellata*, H., *Pterinea*, sp., *Pholidops squamiformis*, H., *Lingula*, sp., *Rhynchonella*, sp., *Chonetes tenuistriata*, H., *Spirifera subuculata*, var. *perlata*, H., *Crania acadensis*, H., *Calymene*, sp., *Dalmania Loganii*, H., *Beyrichia pustulosa*, H., *Cornulites flexuosus*, H., var. *gracilis*, H.

‡ February No., page 18.

§ See 'Quart. Journ. Geol. Soc.' vol. xx. p. 342.

2. *Primitia mundula*, J., with a little tubercle on each side of the sulcus.

3. *Primitia mundula*, var.—Longer and narrower than the type; in some cases the sulcus is mid-dorsal; in others it is much nearer one end.

4. *Leperditia*, sp. nov.?—Small, subconvex, oblong, with equally rounded ends. Also another, similar, but not showing the overlap so clearly; small and black.

5. *Beyrichia*, sp. nov.—Narrow-lobed; the two lobes in front are nearly equal in length, parallel, slightly curved upwards and forwards, joined below, and passing into the base of the hinder lobe, which is variably compound. Rather frequent.

6. *Polycope*, sp.—Sublenticular, with a short, straight hinge-line.

§ 2. Trenton Limestone.—Dark-grey limestone, which contains *Lituites undatus*. Falls of Lorette, Province of Quebec.

1. *Leperditia*, sp. nov.?—Like § II. § 1, 4.

§ 3. Birdseye Formation.—Free specimens from the Birdseye Limestone. Associated with *Tetradium fibratum*, *Orthoceras multicameratum*, *Bathyrurus extans*, &c. Lot 3, Concession 3, River Front 1, Gloucester Township, Co. Carleton, Ontario, Canada.

1. *Leperditia*, sp. nov.?—Subglobose, being relatively high and thick; ends not quite equal, the posterior curve being fuller and bolder; greatest height and greatest thickness a little behind the middle. The overlap seems to extend all round the free margin.

§ 4. Chazy Formation. Chazy Limestone.

§ 1. Pointe-aux-Pins, Aylmer, Province of Quebec, Canada.

1. *Isochitina ottawa*, Jones. Variety. Abundant in a dark-grey limestone.

§ II. South of St. John's Market, Quebec City.—Dark fine-grained limestone.

1. *Primitia*, sp.—Suboblong, neatly curved on the free margin, which bears a nearly uniform flattened rim; sulcus represented by a distinct relatively large round pit. This may be related to *P. renulina*, J. & H.

2. *Primitia*, sp.—Suboblong, ends rounded, but narrower (lower) in front than behind; sulcus mid-dorsal, distinct, but not deep.

§ III. Chazy Limestone. Broad-street Asylum, Quebec City.

1. *Leperditia*, sp. nov.? Small, dark-coloured, with the greatest ventral curve in the middle; front end subangular. Abundant in a black limestone, especially on the bed-planes.

§ IV. Chazy Shales. Broad-street Asylum, Quebec City.—Dark-coloured, micaceous, shaly mudstone, somewhat ferruginous.

1. *Primitia mundula* (?), J.—Rather large, with a deep sulcus, which has one of its edges strongly tuberculate.

2. *Leperditia*?—Very neat cast of the interior of a left valve, but the eye-spot, muscle-mark, and ventral flange are not shown. The greatest ventral curve is in the postero-ventral region.

3. *Beyrichia*, sp. nov.—Ovate-oblong, broad-lobed; the two main

lobes are of nearly equal bulk, and unite with a broad curved junction below; the middle lobe is of an irregular and reversed club-shape, constricted at its upper third; there is also a curved, low, subsidiary ridge at one end, just within the margin. Abundant.

§ IV. *From Brittany, France.*

BEYRICHTIA, M'Coy. (See also pages 236–238, 246.)

36. BEYRICHTIA GUILLIERI, Tromelin. (Pl. XXI. figs. 2a, 2b, 2c.)

Beyrichia Guillieri, Tromelin, Association Française pour l'avancement des Sciences; Compte rendu de la 4^{me} Session, Nantes, 1875 (8vo, Paris 1876), p. 623, *footnote* (not figured).

Length 2 mm.; height 1 mm.; thickness .5 mm.

This is a three-lobed *Beyrichia*, as shown by the cast of left valve in light-coloured mudstone, apparently not distorted by pressure. In outline it is subovate, but straight on one edge (dorsal). The two smaller lobes are club-shaped, high and rather narrow, forming a fork, which opens upwards and forwards; the front lobe is low down, near the antero-ventral margin, and gently curved; the middle lobe is straight, oblique, and prominent, reaching the dorsal margin. The junction of these two lobes below is continued to the curved base of the large and rounded posterior or gigot lobe.

In some respects, as for instance in the proportions of the lobes, one variety of Kiesow's *Beyrichia Lindstræmi*, from the Upper Silurian of Gothland, namely fig. 4. pl. i. p. 5, 'Zeitsch. d. D. geol. Ges.' 1888, bears a resemblance to *B. Guillieri*, but in other respects it differs.

The figured specimen is from the Lower Silurian (Ordovician) strata at Domfront (Dep. Orne), and was kindly given by M. P. Lebesconte, of Rennes. There were several individuals together.

In the same collection (M. Lebesconte's) are numerous specimens of the same species, but variously squeezed, and in some instances much distorted, in the "Schiste ardoisier inférieur" (Ordovician), below the "Grès de May," at Lailé (Dep. Ille-et-Vilaine). One specimen, somewhat shortened diagonally, from the postero-ventral to the antero-dorsal region, has the two smaller lobes more vertical, and all the lobes more equally separated, than in the figured (normal) form; but its thick, rounded posterior lobe is still characteristic. In another case, pressure, transverse and nearly perpendicular to the long diameter of the valve, has elongated the valve, making its height scarcely a fourth of its length, and disturbing the positions and proportions of the lobes.

This was compared with some Bohemian and other species by M. Gaston le Goarant de Tromelin in a footnote to a memoir by himself and M. Paul Lebesconte on the Silurian Fossils of the Departments of Maine-et-Loire, Loire-Inférieure, and Morbihan (Anjou and South Brittany), in the Report of the French Association for 1875, referred to above. It is mentioned also in that paper at p. 620, as having been first found at Domfront (Orne), and as one

of the characteristic fossils (with *B. bussacensis*, J., and *Primitia simplex*, J. [*P. mundula* ?]) of the Upper Zone of the "Schistes ardoisiers," belonging to Barrande's "Faune Seconde Silurienne"; also in Table B, opposite p. 636, as from Le Creux and Andouillé*. In the 'Bulletin Soc. Géol. France,' sér. 3, vol. iv. 1876, in the memoir by MM. Gaston de Tromelin and P. Lebesconte on the Primary Strata of the Department of Ille-et-Vilaine and other parts of Brittany, *B. Guillieri* is referred to at p. 601.

It may be a cast of a variety of *Beyrichia ciliata*, Emmons (Q. J. G. S. February No., p. 19), with a sketch of which Mr. E. O. Ulrich has kindly favoured me, and for which in a letter he has proposed the new generic name of *Ctenobolbina*.

It may be here noticed that in M. Lebesconte's collection there are casts of another species of *Beyrichia* from the "Schiste ardoisier inférieur" of Andouillé (Dep. Mayenne), which approaches more nearly to *B. Klædeni*, M'Coy; the lobes, however, are thin, the anterior and middle lobes nearly symmetrically curved, with an oval sulcus between them, and the posterior lobe much smaller than that of *B. Guillieri*. One of these specimens was referred by M. de Tromelin, in the 'Bullet. Soc. Géol. France,' sér. 3, vol. iv. 1876, p. 588, to *B. reticulata*, Bornemann, but they have no direct relationship at all (see Pl. XX. fig. 14, and page 539).

From the same strata at Andouillé there occur (in M. Lebesconte's collection) *Beyrichia bussacensis*, J., 'Quart. Journ. Geol. Soc.' vol. ix. p. 160, pl. vii. figs. 5 & 6, and 'Ann. & Mag. Nat. Hist.' ser. 2, vol. xvi. p. 169, pl. vi. fig. 14; also *Primitia mundula*, J., *op. cit.* p. 174, pl. vi. figs. 28-31; a non-sulcate *Primitia* or *Aparchites*; a small *Leperditia*, related perhaps to *L. nana*, J., *op. cit.* ser. 3, vol. i. p. 244 ("L. canadensis, var."), pl. ix. fig. 12; and a Cytheroid form, possibly a *Bythocypris*, near *B. symmetrica*, J., *op. cit.* ser. 5, vol. xix. p. 186, pl. vii. figs. 3, 4, 7.

EXPLANATION OF PLATE XX.

Devonian Ostracoda, with one (fig. 14) Silurian.

- Fig. 1. *Beyrichia devonica*, Jones. A cast of the inside of a crushed valve; one lobe partly worn away. *a*, left valve; *b*, edge profile. Bosphorus. $\times 12$ diam.
2. ———. *a*, left valve; *b*, edge profile. Devonshire. $\times 6$ diam.
3. ———. Right valve, obliquely squeezed. Devonshire. $\times 6$ diam.
4. *Beyrichia subquadrata*, sp. nov. Left valve (reversed drawing of a hollow cast). Ontario Co., New York. $\times 15$ diam.
5. *Bollia Hindei*, sp. nov. Left valve. Eighteen-mile Creek, Lake Erie, N.Y. $\times 15$ diam.
6. *Beyrichia Kolmodini*, sp. nov. Left valve. Clarke Co., Indiana. $\times 15$ diam.
7. *Octonaria Linnarssoni*, sp. nov. Carapace. *a*, left valve seen; *b*, ventral view. Clarke Co., Indiana. $\times 15$ diam.

* The Entomostraca mentioned as occurring in the same strata with *B. Guillieri* I have not been able to recognize in the collection kindly submitted by M. Lebesconte last year, excepting *Bolbozoe anomala*, B., and *Beyrichia bussacensis*, J.

- Fig. 8. *Streptula plantaris*, sp. nov. *a*, left valve, outside; *b*, inside. Eighteen-mile Creek, Lake Erie, N.Y.
9. *Moorea Kirkbyi*, sp. nov. *a*, left valve; cast (here the furrow is stronger than the ridge); *b*, edge profile. Ontario Co., N.Y. $\times 15$ diam.
10. ———. *a*, left valve; cast (here the ridge is stronger than the furrow inside it); *b*, edge profile. Ontario Co., N.Y. $\times 15$ diam.
11. *Primitia Clarkei*, sp. nov. Right valve, cast. Ontario Co., N.Y. $\times 15$ diam.
12. *Bollia bilobata*, sp. nov. Left valve; cast, with one lobe and the junction much worn. Ontario Co., N.Y. $\times 15$ diam.
13. *Eurychilina reticulata*, Ulrich. *a*, convex cast of the inside of a left valve; *b*, hollow cast of the outside of the same individual valve. Ontario Co., N.Y. $\times 10$ diam.
14. *Beyrichia reticulata*, Bornemann. *a*, convex cast of the inside of a right valve (taken with gutta-percha); *b*, hollow cast of the outside of another valve. Sardinia. $\times 7$ diam. Reproduced from careful tracings of the four original figures; for these I am indebted to the kindness of Chev. W. P. Jervis, F.G.S., of Turin. (Fig. 14 *a* is "fig. 3," and fig. 14 *b* is "fig. 2 *b*" of the originals.)

EXPLANATION OF PLATE XXI.

Silurian Ostracoda, with one (fig. 1) Devonian.

- Fig. 1. *Beyrichia Klædeni*, M'Coy. Variety. *a*, right valve, with hypertrophy of the antero-ventral lobe; *b*, ventral view. Ontario Co., New-York State. $\times 7$ diam.
2. *Beyrichia Guilleri*, Tromelin. *a*, left valve, cast; *b*, ventral view; *c*, front view. Domfront, Brittany. $\times 20$ diam.
3. *Bairdia anticostiensis*, sp. nov. *a*, right valve; *b*, ventral profile. English Head, Anticosti. $\times 15$ diam.
4. *Bythocypris? obtusa*, sp. nov. *a*, right valve; *b*, ventral profile. English Head, Anticosti. $\times 15$ diam.
5. *Macrocypris? subcylindrica*, sp. nov. *a*, right valve; *b*, ventral profile. English Head, Anticosti. $\times 15$ diam.
6. *Polycope sublenticularis*, sp. nov. *a*, right valve; *b*, ventral profile. English Head, Anticosti. $\times 15$ diam.
7. *Beyrichia diffissa*, sp. nov. Left valve. Jupiter River, Anticosti. $\times 15$ diam.
8. *Leperditia frontalis*, sp. nov. *a*, right valve; *b*, ventral profile. Near the Jumpers, Anticosti. $\times 4$ diam.
9. *Bollia semilunata*, sp. nov. *a*, left valve; *b*, ventral view. South of Junction Cliff, Anticosti. $\times 25$ diam.
10. *Primitia Billingsii*, sp. nov. Right valve. West of Jupiter Road, Anticosti. $\times 15$ diam.
11. *Bythocypris? Lindstromii*, sp. nov. *a*, right valve; *b*, edge view; *c* (*G c* on the Plate), end view. S. of Junction Cliff, Anticosti. $\times 25$ diam.

DISCUSSION.

Dr. HINDE wished to express the obligations of geologists to Prof. Jones for the excellent work which he had done amongst the Entomostraca; and particularly on the present occasion, for the clear manner in which he had explained the wide distribution of some of the species.

The PRESIDENT alluded to the long years of arduous labour which Prof. Jones had bestowed on these minute fossils, and to the interesting results he had obtained from them.

33. NOTE on the PLATEAU-GRAVELS of EAST BERKS and WEST SURREY ;
 their AGE, COMPOSITION, and STRUCTURE. By the Rev. A. IRVING,
 D.Sc. (Lond.), B.A., F.G.S. (Read May 21, 1890.)

(Abridged.)

IN the year 1883 my first paper on Tertiary geology * was published by the Geologists' Association. In dealing with the gravels of the Bagshot district I pointed out that my observations up to that date had led me to regard the Plateau-gravels as Pre-glacial and contemporaneous with the Crag. This view has been worked out in fuller detail by Prof. Prestwich in Part III. of his recent paper "On the Mundesley and Westleton Beds and their extension inland." † It was a gratification to find myself in accord with him as to their pre-glacial age. For several years past it has been in my mind to give the results of further studies in this subject to the Society; he has happily forestalled me, and brought to the consideration of the subject a much wider range of data than I could command. Still it seems that the argument by which he arrives at the conclusion that these Plateau-gravels are of *later* Pliocene age is not a very strong one; for, when the Diestian age of the Lenham deposits is admitted (and Mr. Clement Reid's conclusion ‡ that they both are of older Pliocene age is also admitted), the assumption (which forms the cardinal point of the whole argument) that certain outlying sands high up on the slope of the North Downs are contemporaneous with the Lenham deposits has no other support than their being at approximately the same height; while the lithological evidence points to their Eocene age §. This might very well be, if—as seems probable from various considerations—the north-western portions of the Weald partook in later Eocene time of the movement which is recorded in the upheaval of the axis of Kingsclere and Inkpen ||. Again, there is the absence of all marine deposits of Miocene age in the South of England, indicating (in addition to many other collateral considerations) a high degree of probability that the Miocene was the period of maximum elevation of this part of Europe, rather than one of depression beneath the sea. To this long period of Miocene (and Pliocene) elevation of the Weald we must look, I think, mainly for the supply of the vast amount of flinty subangular detritus under notice. From long exposure on the surface of the Chalk, as chemical erosion proceeded,

* See Proc. Geol. Assoc. vol. viii., "On the Bagshot Beds of the London Basin, and their associated Gravels."

† Quart. Journ. Geol. Soc. vol. xlvi. pp. 155 *et seq.*

‡ See *Nature* (1886), vol. xxxiv. pp. 341, 342. I have discussed this matter with Mr. Reid, and have examined the Lenham fossils in the Museum of Practical Geology.

§ See some remarks by the author in the Geol. Mag. 1888, pp. 123, 124; and 1890, p. 406.

|| In Topley's memoir "On the Geology of the Weald" there are many facts which point to this conclusion.

it suffered that amount and kind of lithological change* which, with subsequent fluvial transport for distances of 10 to 15 miles, would give such materials the character and the subangular form which they for the most part are found to present in the Plateau-gravels. The flint pebbles, with which they are now intermingled, were probably preserved from the action of those atmospheric agencies which induced the lithological changes in the subangular flints, by having been sealed up in the Eocene strata, after having been formed by shore-action †. These two chief constituents of the Plateau-gravels, together with the subangular fragments of Neocomian chert, were intermingled, no doubt, in the rivers which flowed from the Wealden Hill-range, as the denudation of the Eocene beds in their formerly southerly extension proceeded, with the increased accentuation of the anticline, *pari passu* with the transport of the angular-flint material by rivers from the Weald across the northward-sloping plateau of Eocene land.

These Plateau-gravels seem to have no necessary connexion in time or otherwise with the "Mundesley and Westleton shingle" of Prestwich, since the flinty materials found in that might very well have been derived from an elevated Chalk region of Mercia and East Anglia.

Even the high-level gravels of the country north of the Thames may have had to a large extent a subaërial origin; for the fact that so many of them are covered up by boulder-clay (and so protected from the solvent action of carbonated atmospheric waters) renders it extremely difficult to account for their non-fossiliferous character by the hypothesis of "decalcification" ‡. The above explanation of the intermingling of such different forms of the flinty material was put forward in 1883; and was, as then pointed out, suggested to me by my previous observations of the vast accumulations of angular flint material (mere insoluble residue) found to-day on the top of Saint-Boniface Downs in the Isle of Wight §. The quartz-pebbles mentioned by Prof. Prestwich in his recent paper, and by Prof. Rupert Jones ||, are in my experience rare in the Plateau-gravels; nor do I believe, after sifting the evidence, that Mr. Monckton's large rolled block of vein-quartz came out of them ¶.

Observation in the field tells us that as we work south the presumably older gravels become, as we should expect, more angular, and acquire a more massive development, most fully seen in the vast

* See Appendix i. Note e, in my "Chemical and Physical Studies in the Metamorphism of Rocks," p. 103 (1889).

† See Proc. Geol. Assoc. vol. viii. 1883, pp. 167, 168; also the Quart. Journ. Geol. Soc. vol. xlv. p. 184.

‡ Prestwich, *op. cit.* p. 146. The predominance of land and freshwater remains in the list of organic remains given in Quart. Journ. Geol. Soc. vol. xlv. pp. 115, 116, seems to point to an estuarine origin for the beds at Westleton and Mundesley, suggesting a terrestrial origin for the higher beds inland.

§ See also the new edition of the Geol. Survey's 'Memoir on the Geology of the Isle of Wight,' 1890, p. 210.

|| See Proc. Geol. Assoc. vol. vi. p. 439.

¶ See Quart. Journ. Geol. Soc. vol. xlv. p. 154.

accumulations of coarse flint detritus which cap the highest ground remaining of the Bagshot *terrain*, on Cæsar's Camp (600', ordn. datum) and Hungry Hills (550', o. d.) above Aldershot*. These vast accumulations (in places cemented into a conglomerate) of almost unworn flints, with scarcely a trace of even the rudest stratification, impress the mind more than anything I have seen in this part of England with a vivid idea of the enormous extent of the destroyed Upper-Chalk strata, which once arched over the region lying directly to the south. They may be the remains of the insoluble *débris* which accumulated under subaërial conditions along the base of the northern slope of the old Miocene Wealden mountain-range; materials, which, by their assortment and transport in part across the sloping plateau of the old Tertiary district immediately to the north, furnished the chief constituent, in a more rolled and worn condition, of the Plateau-gravels of the "Southern Drift." I know of nothing with which they compare so well as the old (pre-glacial) "Schotter" (unstratified *débris* often conglomeratic) of the lower Alpine valleys, which Von Hauer† and other authors have described under the name "Terrassen-Diluvium."

Such materials, however, as were carried away northwards and deposited in the lines of river-drainage or spread out on flats, where the declivity of the plateau diminished‡, assumed a more or less *stratified arrangement*. This structural character is of great importance in recognizing the ancient Plateau-gravels in the sections furnished by the numerous gravel-pits opened of late years on the hill-tops, as the demand for road-material has increased with the opening-up of this ancient forest-country. The structural facies they most commonly present is that of interstratified masses of sand§ (often loamy) and shingle, the sand-layers being generally coarse and ferruginous, with pronounced oblique lamination or current-bedding. Even where there are not distinct layers of sand in the sections, the stratification is generally manifest from the horizontal position of the longer axis of the pebbles and of the flint and chert fragments, allowance being made for the occasional local disturbance of these by the roots of pine-trees, by "soil-cap" movements on a small scale, and by the formation of talus at the expense of the plateau-gravels, owing to the removal of the sandy materials of the subjacent hill-flanks by ordinary agencies of erosion||.

Further field-work since 1883 has shown me that the plateau-gravels must be recognized down to levels (as we work northwards) as low as 300 ft. (o.d.) and even lower. These are, of course, the

* I cannot recollect ever meeting with rolled flint pebbles in these gravels.

† See 'Die Geologie,' 1878, p. 704.

‡ Somewhat, as I conceive, after the fashion in which the broad expanses of gravelly detritus are formed by the Alpine rivers as they debouch upon the Plain of Bavaria.

§ These are sometimes cemented by ferric oxide into the hard "pan" occasionally used for building, and which defies the action of the atmosphere, as in the Roman Wall of Silchester.

|| Often resulting from the high-level springs which frequently issue from the base of the gravels; Rupert Jones, Proc. Geol. Assoc. vol. vi. p. 434.

youngest deposits of the series; for I conceive that the series as a whole covers a very large interval of geologic time, perhaps the whole of the Pliocene Period, the oldest of them (on Cæsar's Camp and Hungry Hill, Aldershot) being possibly of very early Pliocene age. On the other hand, the patches of unstratified and angular gravel found on the higher slopes and minor bluffs of the present valleys are probably mere "run-of-the-hill" of the later denudation of the country, and do not necessitate the idea of glacial action.

Localities furnishing Sections of the Plateau-gravels.

Locality.	County.	Above o.d. feet.
Cæsar's Camp and Hungry Hill (Aldershot)	Hants.	500 to 600
Hook Wood (north of Netley Heath) *	Surrey.	500 to 600
Fox Hills.....	"	350 to 400
Frimley Ridges	"	400
Bagshot Orphan-Asylum †	"	400
Obelisk Hill (Camberley)	"	370
Crawley Hill (Camberley)	"	350
Long Down (Sandhurst)	Berks.	350
Edgeburrow (Sandhurst)	"	370
Broadmoor	"	400
Cæsar's Camp ‡ (Easthampstead).....	"	400
Wagbullock Hill (Easthampstead) ‡	"	400
Gravel Hill (Swinley) ‡	"	400
Finchampstead Ridges §.....	"	330
Tower Hill (Swinley).....	"	350
Race-Course Hill (Ascot)	"	300+
Long Hill (Ascot)	"	300+
Chevy Down (Ascot)	"	300+
Goathurst Hill (Ascot)	"	320
Buckhurst Hill ¶.....	"	300+
Farley Hill (S. of Reading)	"	280
Bearwood ¶.....	"	280

The whole of Easthampstead Plain and Chobham Ridges is probably capped with the same sort of gravels as are exposed at the localities mentioned.

In nearly all the sections the stratification is clear, and in most cases as pronounced as it is in the Low-level Gravels of the present Valley of the Thames, at Reading, at Ealing, and at Kensington; a fact which seems to point clearly to their river-origin. They are totally destitute of organic remains, except such as have been brought in the flints from the Chalk (impressions of fragments, spines, and occasionally complete casts, of *Micraster*, *Galerites*, *Ananchytes*, *Pecten*, *Inoceramus*, &c.), or as Sponge-spicules from the

* Flint pebbles and coarse unworn flint débris, interstratified with a stiff loam.

† Nine feet of gravel proved in the well-section (see 'Mem. of the Geol. Survey,' vol. iv. p. 537).

‡ Three great spurs at the north end of Easthampstead Plain. Open gravel-pits may be seen on each of these hills.

§ Three extensive pits worked for gravel.

¶ This gravel extends some distance to the north in the direction of Binfield.

¶ See Geol. Mag. dec. iii. vol. iv. pp. 112, 115.

Neocomian. On comparing their altitudes some allowance has to be made for slight Post-Pliocene movements producing some changes of the relative levels. They remain as indexes of the ancient Pliocene lines of drainage northwards, having preserved the present hills from degradation; while the originally higher ground has been scored with the present valley-system.

Evidence of Glaciation.

With one apparent exception * I know of no distinct evidence of glaciation in the part of England referred to in this paper, nor in the Thames Valley above 240 ft. (o.d.), though many examples of it have been described at lower altitudes. If we assume, therefore, that these mark the period of the maximum glaciation of the old Thames Straits, we have to allow for a very considerable amount of excavation of the present valley-system of this part of England prior to the Glacial Period.

§ 1. In a new pit † at the Brickyards of Messrs. T. Lawrence and Sons, close to the Nine-mile Ride, between the Wokingham and Binfield roads, a fine section has been recently opened, exposing the laminated basal clays of the Middle Bagshot, with the underlying Lower Sands. The clays here are splendidly contorted, and overfolded by great masses of gravel, in some cases weighing several tons apiece, having been driven, probably in a solid (frozen) condition, into them. The lamination of the clays is distinctly traceable in the contortions, and leaves no doubt as to the nature of the agency which has here been at work. Altitude, 230 to 240 ft. (o.d.).

The gravel is one of the secondary or terrace-gravels of the country, derived from the older Plateau-gravels, with an increased proportion of flint pebbles, furnished by the destruction (prior to the glacial action) of the pebble-beds of the Bagshot terrain to the south.

§ 2. In the Tangley cutting of the South-Western Railway near Wokingham, on the other side of the valley, very distinct glaciation of the same laminated clays is seen at the top of the cutting above the Lower Sands at about 220 ft. (o.d.).

§ 3. At Sunninghill the same succession is seen in the railway-cutting, with similar folding, puckering, and included pockets of gravel, at about 220 ft. (o.d.).

* The case here referred to is that of a completely unstratified gravel, with scarcely any pebbles in it, which occurs on Lodge Hill, Broadmoor, at 400 ft. (o.d.). The angular fragments stand in all positions in it. May it not, from its exceptional character and altitude, be a glacial deposit of the cold Pliocene age (Etheridge, 'Manual of Geology,' p. 652; and Lyell's 'Student's Elements,' p. 181). The pit has been recently re-opened. It reminds me of nothing so exactly as of the moist masses of loose, incoherent, subangular stuff, which every observer of higher Alpine phenomena is familiar with in the trail of the minor snowfields as they retreat up the smaller valleys during the summer. A repetition of such deposits of trail for a number of seasons would give just what we see in the pit on Lodge Hill.

† This pit has been considerably extended since the note referring to it at the foot of p. 164 of vol. xlv. of the Society's 'Journal' was written.

§ 4. Other evidences of glaciation may be seen (*a*) in an unstratified clay with pebbles standing erect in it, upon an older angular and sandy gravel, which lies upon an eroded surface of London Clay in the Brick-and-Tile Company's Brickyard north of Bracknell; (*b*) in what appears to be a lacustrine deposit, as if in an extramorainic lake, above the Bagshot beds in the brick-pits at Warfield*, wrongly described (as I venture to think) as a part of the Bagshot formation; (*c*) in the California clay-pits at Finchampstead †, where a similar lacustrine deposit probably occurs above the Middle Bagshot Clay, at about 230 ft. (o.d.).

The phenomena described in §§ 1, 2, 3, I take to be due to the mechanical work of floating ice, as pack-ice was formed from time to time in the old Thames Straits under the influence of high winds ‡.

Conclusions.

(1) Looking at the distribution of the Plateau-gravels of the district under consideration, their roughly-stratified structure, their constituent materials, the entire absence in them of contemporaneous organic remains, the frequent occurrence in them (especially near their base) of blocks of concretionary sandstone § (in many cases unworn, in others smoothed on the upper surface by the scouring action of sand and water), the frequent reconstruction and rough stratification of the immediately subjacent Upper Bagshot Sands (on which for the most part these gravels rest), and the marked erosion of these sands in many places beneath the gravels,—it is difficult to resist the conclusion that they had a fluviatile origin, the materials having been derived from the south.

(2) The only conception I can form which harmonizes with all the evidence available, is that of an elevated district of the older Tertiaries, subjected to subaërial waste, and having a general slope to the north towards what may have been an estuarine arm of the ancient Anglo-Germanic Sea, on the western margin of which the Crag was being deposited at levels not very different from those at which it is found to-day; the present gravels marking the drainage-courses of the later Tertiary valleys, while the present valley-system of the district occupies those portions which then formed higher ground, and has been initiated owing to the absence of the gravel-capping to which the present hills owe their preservation.

* Compare Section F, p. 386, vol. xliii. Quart. Journ. Geol. Soc. 1887.

† *Ibid.* vol. xlv. p. 172, Section Q.

‡ In all such cases the piling up of the ice takes place too quickly for deformation of the ice-masses to proceed *pari passu* with the increase of pressure. We thus get a mechanical agency brought into play quite different from anything which we can rationally postulate from the slow movement of a glacier. See my paper on the "Mechanics of Glaciers," Quart. Journ. Geol. Soc. vol. xxxix.; also the published work of Prof. Spencer, Geol. Mag. April 1887, and 'American Naturalist,' vol. xxii. 1888.

§ In the Proc. Geol. Assoc. 1883, I gave reasons for rejecting the Sarsens as evidence of a glacial origin of the gravels, in and near the base of which they usually occur.

(3) The more ancient arterial line of drainage of southern Eocene England* having been obliterated by the silting up of the Eocene estuary † by the Bagshot Beds, and subsequent regional movements of the Mesozoic strata to the south, the modern Thames Basin began to be outlined, although probably its main line of drainage did not coincide exactly with the modern valley of the Thames.

(4) Distinct evidence of glaciation at much lower levels than the plateau-gravels (210 to 240 ft., o.d.) being now to hand in the district, and this being presumably the work of floating ice in the old Thames Straits, we may (in the absence of distinct traces of glaciation at higher levels) assign something like 200 feet (vertical ‡) of the excavation of the present valley-system of this part of England to a period intervening between the deposition of the plateau-gravels of the Southern Drift and the Glacial Epoch at its maximum.

(5) The deposition of these Plateau-gravels appears to have occupied a considerable portion (perhaps the whole) of the Pliocene Period; the only data available for fixing the time of the initiatory stage of their deposition being the inconclusive evidence furnished by the well-known Lenham deposits. The results of my own work and of the independent researches of Prof. Prestwich are thus seen to confirm the suggestions of Sir A. C. Ramsay §, made years ago, as to the pre-glacial age of these Plateau-gravels, and of the present valley-system of Southern England.

DISCUSSION.

Mr. MONCKTON had no doubt that the block of quartz referred to in the paper came from the Plateau-gravel. Everybody was agreed as to the materials of the Plateau-gravels having come from the south-east. Such contortions as described were generally accepted as evidence of snow or ice. The age of the Plateau-gravels was admittedly doubtful; and, if possible, the Author had rendered their age more unsettled than ever. He (the speaker) inquired as to whether the Author used the term Boulder-clay with chronological significance, and what evidence was brought forward as proof of the marine or fluviatile origin of the Plateau-gravels.

Prof. RUPERT JONES said that Mr. Godwin-Austen referred the Plateau-gravel to an early Tertiary age. He had lately seen, at Cuckmere, conditions of the shingle analogous to those which Dr. Irving had suggested for the Plateau-gravel. He believed that this, as well as the lower gravel, exhibited the effects of ice-action.

* See "The Stratigraphy of the Bagshot Beds, &c." *Quart. Journ. Geol. Soc.* vol. xlv. pp. 181, 182.

† This question has been discussed in my papers on the Bagshot Beds in the *Quart. Journ. Geol. Soc.* vols. xliii. & xlv.

‡ To this it would be easy to attach an exaggerated importance, if we overlooked the easily-destructible nature of the Bagshot strata.

§ 'Physical Geography and Geology of Great Britain' (5th ed.), p. 533.

The AUTHOR, in reply, stated, with reference to the contortions, that the cases cited by Mr. Monckton hardly bore on the question, as they occurred much lower down the Thames valley, and at lower altitudes. The main point on which he differed from Prof. Prestwich was that he could not accept his later Pliocene date as fixing the minimum time. The term "Boulder-clay" was used only in a descriptive sense. He thought that one of the speakers had not given attention to all the facts brought forward.

Fig. 2. Magn. 2 diam.



Fig. 1. Nat. size



COCCODUS LINDSTREMI, Davis.



34. *On a New Species of COCCODUS (C. LINDSTRÖMI, Davis).* By
 JAMES W. DAVIS, Esq., F.L.S., F.G.S. (Read May 21, 1890.)

[PLATE XXII.]

WHILST on a visit to Stockholm last year my attention was drawn by Professor G. Lindström to a small fossil fish from the Hard Chalk of Hakel in Mount Lebanon, which had been presented to the Museum of the Academy by the Duke of Leuchtenberg. It is nearly related to *Coccodus armatus*, Pictet*, and exhibits for the first time an almost complete outline of the body of a member of this genus. It is smaller than the species described by Prof. Pictet, and presents several features which dissociate it specifically from *Coccodus armatus*.

The fish is 0·065 m. in length from the tip of the snout to the base of the tail; its height in front of the dorsal spine is 0·022 m., and rapidly diminishes to the peduncle of the tail; anteriorly the head, triangular in outline, terminates in a pointed snout. Nearly two-thirds of the anterior part of the body is covered with strong osseous plates, the remaining portion being devoid of protection. The impressions of about twenty vertebræ remain; they were probably cartilaginous, for neither in this specimen, nor in those found previously, is there evidence of bony centra. Strong osseous neural spines with *branching* neurapophyses extend from the vertebral column, and midway along the dorsal surface support nine interneural spines; the latter are thick towards the distal extremity and afford a broad base of attachment for the rays of the dorsal fin. The dorsal fin extends 0·006 m.; its anterior ray is 0·006 m. behind the spine, and its posterior ray is separated by a distance of 0·010 m. from the base of the caudal. The hæmal spines are similar in structure to the neural, and have attached to them strong inter-hæmals, apparently broader † than the interneurals, and which support the rays of the anal fin. The latter has its origin immediately behind the bony armature of the head and abdomen, and extends thence half the distance to the tail. The caudal fin is supported by articulated rays, of which ten can be counted supporting the lower half, and probably an equal number constituted the upper half. The rays are 0·01 m. in length. The termination of the vertebral column is dilated to a radiating flattened piece, with which the caudal fin-rays are connected. The median rays of the tail are longer than those above and below, presenting a uniformly convex posterior margin. The pectoral and ventral fins, if such existed, are not preserved.

* F. J. Pictet.—“Description de quelques Poissons fossiles du Mont Liban,” 1850, p. 51, pl. ix. fig. 9.

James W. Davis.—“The Fossil Fishes of the Chalk of Mount Lebanon, in Syria,” Trans. Roy. Dublin Soc. ser. 2, vol. iii. 1887, p. 546, pl. xxx. fig. 1.

† Rather too weak in the illustration.

The head and anterior part of the body are protected by osseous plates of considerable thickness and strength, surmounted at the occiput by a large and massive spine. The spine is situated near the middle of the back at a distance of 0.04 m. from the tip of the snout. It rises to a height of 0.015 m. from the dorsal surface, and is inclined at a very slight angle backwards. The anterior part of the base of the spine is connected with the osseous plates of the cranium by a broad expansion of its surface, which is overlapped by the cranial bones. The surface of the spine is ornamented by longitudinal striations, parallel with its anterior margin; the striæ on the posterior portion disappearing along that surface. The posterior margin of the spine is armed with a series of nine or ten denticles—long, pointed, and robust, equal in length to the diameter of the spine in its upper part. The denticles are all inclined upwards, at an angle with the spine of about 45 degrees.

The orbit (*Or.*) is medium-sized, situated very high, and at a distance of 0.023 m. from the extremity of the snout. The inter-orbital space is occupied by one or more osseous plates, extending from the base of the spine to a distance in advance of the orbit. Connected with this is a long plate terminating in a sharp-pointed snout, and probably overlapping the maxillary bone (*Mx.*). The surface of this bone, and also of those occupying the interorbital area, is covered with minute tubercles, arranged more or less in lines parallel with the longer axis of the plates. The under surface of the head is covered with a series of plates: the most anterior is probably the mandible (*Mn.*). It does not extend so far forward as the maxillary bone, and its posterior portion assumes a V-shaped form: the upper branch, extending parallel with the maxillæ, may be the dentary, whilst the lower and longer branch probably constitutes the articular bone. Between the orbit (*Or.*) and the operculum (*Op.*) is a series of bones, which in this specimen are somewhat indeterminate. The space between these and the lower jaw is not very well-preserved; but there are indications of a large, more or less triangular plate, whose under surface was covered by a series of lines radiating from above downwards, and covering the region occupied by the mandibular suspensorium. The gill-cover is large, and consists of preoperculum (*Pop.*), operculum (*Op.*), and probably suboperculum (*Sop.*). The anterior margin of the preoperculum (*Pop.*) is almost straight, and extends in an oblique line from the anterior base of the spine to the posterior extremity of the mandible. It is a long and narrow bone; attached to its posterior margin is the operculum (*Op.*), larger in size, and with a circular posterior margin extending forwards beneath the preoperculum. The surface of both is covered with minute tubercles arranged in lines. The space beneath the operculum may have been occupied by the suboperculum. Behind the operculum and extending to the abdominal aspect of the body is a large bony plate representing the clavicular portion of the scapular arch (*Sc.*). The posterior extremity of the bone forms a process extending considerably backwards; its upper portion is enveloped by the operculum; its surface is orna-

mented in a manner similar to that of the external bones already described.

Coccodus armatus, Pictet.—The specimen described by Prof. Pictet (*op. cit.* pl. ix. fig. 9) exhibited the under surface of the upper jaw, with the arrangement of the teeth; and the under surface of the shoulder-girdle, to which is attached a pectoral spine. The skeleton is regarded as being of a more fibrous than osseous structure; the vertebral column is deformed by fossilization; the osseous spines are large and solid, and probably held the fins. The pectoral arch recalled to the mind of the learned author the organization of the Rays. The upper jaw is armed with four ranges of flat teeth, which cover the entire surface of the palate; they are preceded by a number of small teeth at the extremity of the jaw. The teeth of the lower jaw are represented by a single row; they are smaller than those of the upper, and Pictet found on examination that they were attached to the jaw without roots, in a similar manner to those of Pycnodont fishes. The spines attached to the pectoral arch recall those of the *Pimelodus Clarias*, Geoff., a Siluroid fish found in the Nile, as does also the bone to which it is attached, extending along the side of the body. It also approaches the Sclerodermic *Ostracion* in the bony covering of the anterior portion of the body. In conclusion, Pictet considers that the fish most nearly approaches the Siluroids, with some Sclerodermic resemblances, but differs from both in the character of the teeth.

The second example of *C. armatus*, described in the Transactions of the Royal Dublin Society, is also imperfect, but exhibits a lateral presentment of the bones of the head, a part of the vertebral column, and the position of the dorsal fin. The fin referred to as the "ventral," which should be "anal," is shown by the specimen now described to be the base of the caudal. The anal fin is opposite to the dorsal, but is absent in that specimen. The arrangement of the teeth is exhibited, and is similar to that in the specimen figured by Pictet. The arrangement and character of the bones covering the posterior part of the head are shown. There is an expansion of the pectoral arch into three prominent, pointed, spinous processes. The first has its origin behind the median portion of the operculum, and from a broad base extends downwards, with a curvature ending in a more or less pointed apex. A second and smaller process extends in an outwardly diagonal direction from the body. The third extends backwards parallel with the abdominal surface of the body, becomes attenuated, and ends in a point. The surface of each is striated and their margins are denticulated.

Coccodus Lindstroemi, sp. nov.—The example now described, whilst possessing a sufficiently clear generic resemblance to *Coccodus*, as defined and described by Pictet, presents several peculiar features, which differ from the detailed characters of *C. armatus*, and renders necessary the institution of a separate species. The size of the body and the character and arrangement of the teeth are similar in all the specimens previously described; and the pectoral spine exhibited in Pictet's figure is probably represented by the lower one

figured in the Transactions of the Royal Dublin Society (1887, pl. xxx. fig. 1). In the species now described an equivalent of this spinous process does not appear, unless the posterior extension of the scapular arch could be so construed. The posterior basal extension of the dorsal spine is also very different in the two forms. The dentition of this specimen is not exposed, and the size of the body is only about one-third that of *Coccodus armatus*, Pictet. The dorsal fin in *C. armatus* is separated from the occipital region by a distance equal to the length of the head; but in this smaller specimen it is comparatively near, and was, compared with the size of the fish, a larger fin.

The imperfection of the specimen at the disposal of Professor Pictet led him to the conclusion that the fish presented the most marked analogy with some of the Siluroids, indicating more particularly *Synodontis*, locally termed "Schal," which is found in the Nile, and *Pimelodus*, also found in the Nile, but more abundantly in the rivers of South America. These fishes are protected by dermal coverings on the head, and possess pectoral and dorsal spines; but in *Synodontis* the mouth is small, and is armed only with weak, though long, pointed teeth; and the jaws of *Pimelodus* are edentulous. The arrangement of the fins, as shown in the specimen now described, is quite different from that of the Siluroids named above; in the latter the dorsal fin is attached to the spine; in *Coccodus* it is widely separated from it; and the anal is shorter and not of the form of that in *Coccodus*. The great resemblance of the teeth of *Coccodus* to those of the Pycnodonts, and the cartilaginous character of the vertebræ, indicate a relationship with the Ganoids; but its exact location in that group must still remain problematical.

I have pleasure in appending the name of my friend Professor G. Lindström, to whom I have been in many ways indebted, to designate specifically the fish now described.

EXPLANATION OF PLATE XXII.

Fig. 1. *Coccodus Lindstrœmi*, Davis. Outline; natural size.

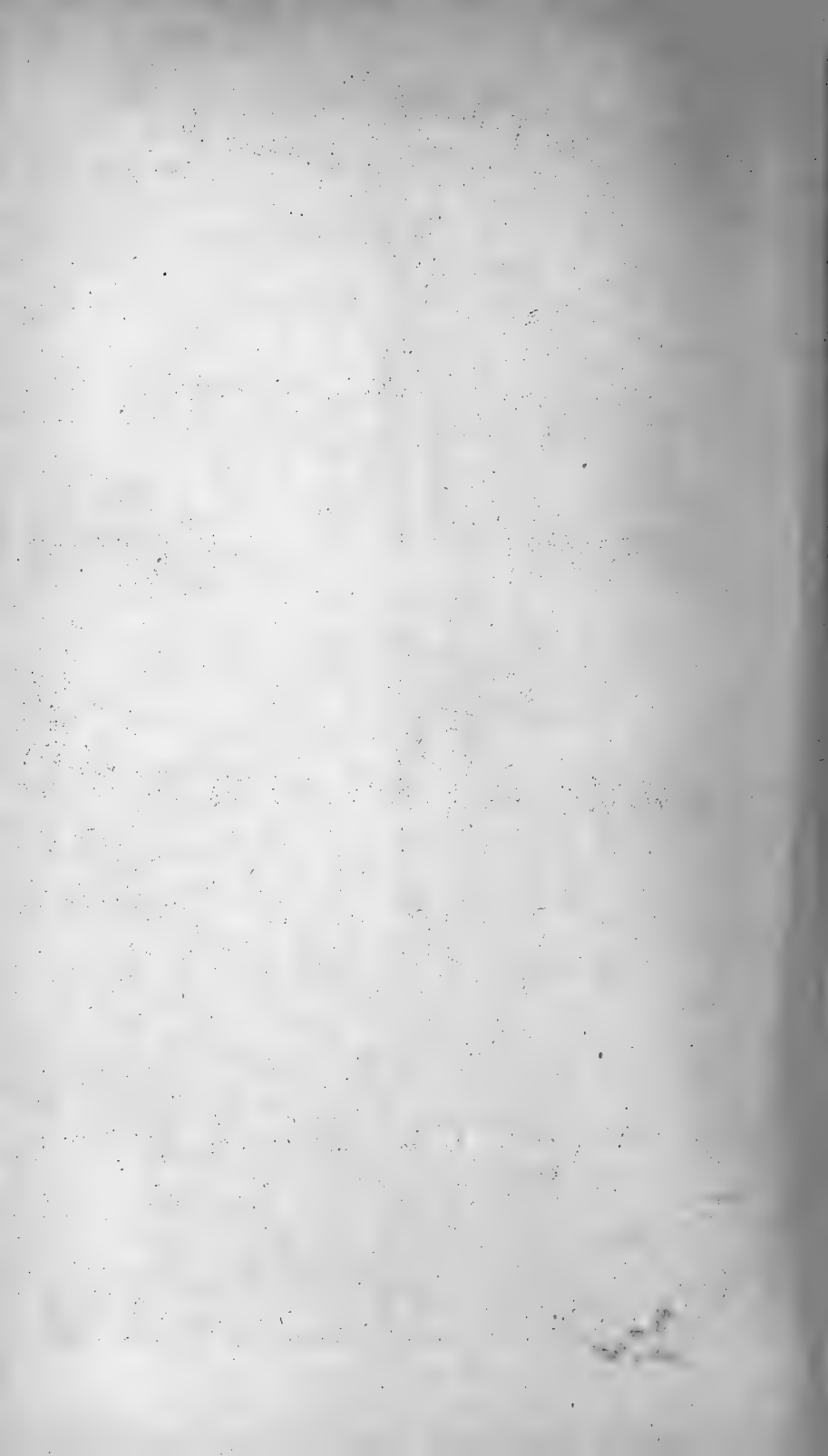
2. The same; enlarged two diameters.

Or., orbit; *Mx.*, maxilla; *Pmx.*, premaxilla; *Mn.*, mandible; *Pop.*, preoperculum; *Op.*, operculum; *Sop.*, suboperculum; *Sc.*, scapular arch; *Fr.*, frontal.





ROCKS NEAR NEW GALLOWAY.



35. CONTACT-ALTERATION *near* NEW GALLOWAY. By Miss M. I. GARDINER, Science-Mistress, St. Leonard's School, St. Andrews. (Read May 14th, 1890.)

(Communicated by J. J. H. TEALL, Esq., M.A., F.G.S.)

[PLATE XXIII.]

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1. Introduction.
 2. The Knocknairling-Burn Section.
 3. Shales traced along their Strike to their Junction with the Granite.
 4. Flags and Grits traced along their Strike to the Junction.
 5. Chialstolite-mica Schists.
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 7. Age of the Metamorphosed Rocks.
 8. Remarks.
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§ 1. INTRODUCTION.

THE eastern end of the northern edge of the Cairnsmore-of-Fleet granite-mass follows the crest of the Knocknairling Hill to the west of New Galloway for about half a mile. The metamorphism of the rocks of this hill has been briefly alluded to in the "Memoir Explanatory of Sheet 9 of the Geological Survey of Scotland," p. 22, but is so extreme as to deserve a fuller description.

There are many exposures on the hill-side; and the Knocknairling Burn gives a good section across the series at a distance of about half a mile from the granite. It is a pity that the beds cannot be traced farther from the granite, especially as there is some doubt as to the series to which they belong. The Cairnsmore-of-Fleet granite is some twelve miles by six in extent, with its greatest elongation in the direction of the prevalent strike of the Silurians. The Survey has given the name of "Queensberry Grits" to the series into which it has been intruded, but suggests that the altered rocks of Knocknairling Hill consist of the underlying Moffat shales and Upper Ard wells, brought up here during the folding of the district. The Upper Ard wells, where unaltered, to the east of the granite, consist of rapidly alternating flags, shales, and greywackés. The flags and shales are often sandy and micaceous. The greywackés do not seem to differ from those of the overlying Queensberry Grits.

§ 2. THE KNOCKNAIRLING-BURN SECTION.

In working up the Knocknairling Burn from Wauk Mill (see Map, fig. 1) one crosses first beds of grits altered to a varying extent. Parts are grey and very like unaltered grits farther east; but the greater part has the tint described as "purplish brown" by

Prof. Bonney and Mr. Alport in describing the similar altered grits from the Bennan Hill to the south of New Galloway*. This tint is due to the presence of brown mica in continuous planes or in thick-set, rounded patches. Amongst the grits are bands of pyritous shale, and one band, 6 or 8 feet thick, of spotted shale. Above the rickety little wooden bridge is a thicker band of shale, which I take to be that seen farther up the hill, and which, at its contact with the granite, is entirely recrystallized. Above the shale lie grits, like those below, and then follow more shales with highly altered schistose bands, very silvery, and containing minute garnets. To these succeed beds like these highly altered bands, but rather more quartzose. These I suppose to be altered flags. They are not well exposed in the stream, but there is a good exposure a few yards from the right bank.

A microscopical section of the purple-brown grit (Pl. XXIII. fig. 6.) shows large quartz-grains with here and there a felspar, and highly dichroic brown mica, in flakes about $\cdot 01$ inch long. Amongst the purple-brown grits are bands and patches, from an inch to a foot or two broad, containing no mica and much more clayey matter.

The knotted schist is different from that of Skiddaw. It is not so compact, and the knots are larger, being from $\frac{1}{8}$ to $\frac{1}{4}$ inch in diameter. The microscope shows the Skiddaw knots to consist of one or two crystals of a mineral containing many small inclusions. A few of the knots in the Knocknairling-Hill rock have the same structure, but the inclusions are more numerous. As a rule the knots are only formed of material much finer in grain than the bulk of the rock. They are sometimes sigmoidal in form, and their outlines are continuous with the wavy folds into which the rock has been thrown.

The flaggy beds mentioned as containing garnets show in a microscopical section more brown mica than the grit, though they are grey in colour. From side to side of the slide sweep wavy bands of minute flakes, polarizing in bright pink and green, probably sericite. The small garnets, about $\cdot 015$ inch across, are colourless in the section, and fairly well formed. A high power shows them to contain inclusions, probably of quartz, whose rounded outlines with bays and gulfs remind one of the outlines of gas- and fluid-inclusions in quartz.

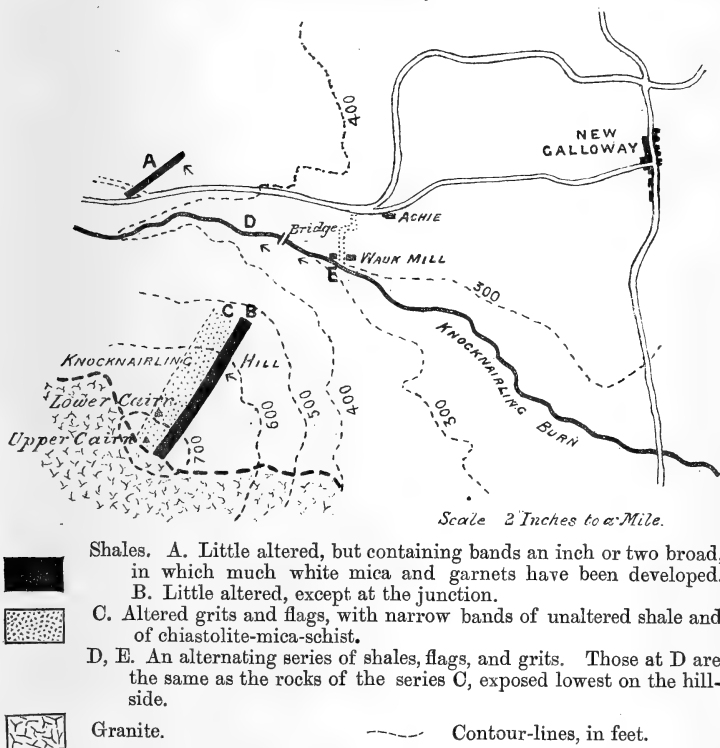
§ 3. SHALES TRACED ALONG THEIR STRIKE TO THEIR JUNCTION WITH THE GRANITE.

The Shales B of the map (fig. 1) are frequently exposed for about $\frac{1}{3}$ of a mile from the granite margin. They are dark shattery shales, a good deal iron-stained and often crumpled into frills and zigzags (Pl. XXIII. fig. 4). The plications have frequently parted, and the interspaces been filled with wavy bands and lenticles of quartz, from an inch or two broad down to microscopic dimensions.

* "Report on the effects of Contact-metamorphism exhibited by the Silurian Rocks near the town of New Galloway," Proc. Royal Soc. vol. xlvii., 1889, p. 200.

The great variation in the amount of effect produced by an intrusive mass at a given distance has often been noticed. It is noticeable even in different bands of these shales. Within 100 yards of the granite some bands show no alteration, whilst others become hardened into a compact, but generally fissile, rock with a good deal of muscovite in flakes so small as only to show by their sparkle. For about the last three yards the rock, where the

Fig. 1.—Map of the Knocknairling Hill and Burn, near New Galloway.



junction is exposed, rapidly lightens in colour and changes in character. It finally becomes a light grey, almost white, granular rock with black patches, of about the size of a sixpenny-piece. It shows on a cross fracture no signs of foliation, though it has a tendency to break along planes covered with small flakes of muscovite. This rock weathers with the granite so that it is difficult to tell on a weathered surface where the margin is at the junction. The microscope, however, shows that that there is no shading off, and that the altered shale has a marked character of its own.

A similar rock occurs on a hill to the west of Knocknairling, where another bed of shale, probably that marked A on the map, is cut across by the granite.

A microscopical section of the shale B of the map, taken from about $\frac{1}{4}$ mile from the junction (Pl. XXIII. fig. 4), shows the spaces mentioned above filled in with quartz. The black colouring matter, although it is still thickly scattered through the rock, has collected more thickly down one slope of each wave, so that the section is crossed by transverse black lines. The rock consists of very minute grains, probably, from their colours of polarization, quartz and white mica. It contains also larger flakes of mica, almost colourless with vibrations parallel to their length, and a light brown with transverse vibrations. These micas occur in the greatest quantity on the edges of the quartz bands, and in independent eyes and bands.

Sections from the more altered bands, nearer the granite, show that the colouring matter has become still more collected in lines and granules. One slide shows clear vein-quartz alternating with thick bands of black colouring matter and a little mica. Another looks as though the minute quartz-grains and mica-flakes of the little-altered shale had segregated into separate patches, and here and there the small mica-flakes had built up an almost perfect larger flake. A third section from a dark grey rock, with a good deal of white mica, is figured in fig. 5, Pl. XXIII. Mr. Teall has kindly looked at this for me; and finds that the lighter oval patches, of which the rock principally consists, are biaxial. He is of opinion that the mineral is probably a feldspar allied to albite. The grains are too small and too full of inclusions to yield cleavage-flakes, by which their nature could be determined with greater certainty. Occasionally one of these rounded patches contains two or three white mica-flakes. These flakes have a dappled look, as indeed much of the white mica has throughout, as though each large flake consisted of many very small ones turned in slightly different directions.

In a slide of the light-coloured granular rock, which is the final stage of alteration (fig. 1, Pl. XXIII.), what first strikes the eye is the great quantity of white mica, in well-formed flakes, about $\cdot 015$ inch long. A highly dichroic light-brown mica is also present, often intercrystallized with the white in such a way that the two extinguish together. Such intergrowths may be seen at the top and on the left of the figure. The dark mica is indicated by shading. The brown mica commonly contains spots, not visible with vibrations at right angles to the cleavage, which appear much darker than the rest, and of a greenish tinge with vibrations in the opposite direction. There are often two or three small black grains, probably the colouring matter of the rock, in these spots.

The principal part of the rock consists of granules which polarize in grey tints. Though most of them seem to be quartz, biaxial grains, probably of feldspar, are by no means rare. The smaller grains are rounded or sub-hexagonal, but the larger, as seen in the

figure, round the large brown mica on the right, are often of very irregular outline. Here and there is a thick network of black colouring matter; other parts are free from it. In parts the quartz is quite free from inclusions, but usually contains many highly refracting grains, too small for their nature to be determined with any certainty.

In working over this microscopical slide, which is rather less than 1 inch in diameter, one notices that in about half a dozen places the rock becomes coarser. Two such coarse parts are shown in the figure: round the largest mica-flake, and on the margin of the slide diagonally opposite it. They have a very granitic look; but the brown mica is the same as that in the rest of the rock, and different from that in the granite, and black colouring matter occurs in them as well as in the finer parts; so I do not see any reason to suppose them to be injections of granite, although felspar is more plentiful than elsewhere.

§ 4. FLAGS AND GRITS TRACED ALONG THE STRIKE TO THE JUNCTION.

Less than halfway up the hill a rocky ridge is seen; this, continued by a series of bosses to the margin of the granite, runs parallel to the line of shale exposures just described. The ridge consists mainly of schistose rocks, exactly like those described as altered flags in the stream. In places this rock is interbedded with more shaly-looking bands, with chialstolite, and in others with more quartzose gritty-looking rocks. There are also unaltered shales amongst these rocks. The bosses, which continue the line up to the granite, lie a little nearer the shales, and are of a more compact quartzose variety. I suppose them to be the same as the grits which lie in the stream between the schistose rocks and the shales.

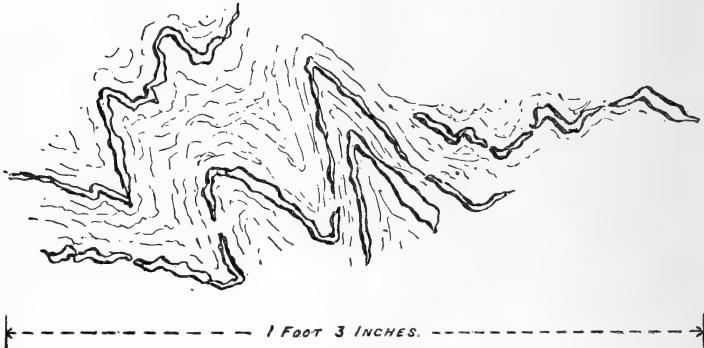
The main differences between different layers of these altered grits and flags, from a part of the hill lower than the first cairn, consist in the character of the garnets and in the nature, size, and quantity of the mica-flakes. The garnets are sometimes well-, sometimes ill-formed; sometimes they contain inclusions in the centre, sometimes in a ring round the centre, rarely none. The mica is usually the purple-brown variety, but is sometimes greenish. Larger flakes of white mica occur occasionally. In the more compact rocks the mica is scattered through the rock; in the more schistose varieties there are bands of minute flakes, as in the rock described from the stream. The base is essentially a fine-grained quartzite.

Fig. 7, Pl. XXIII. gives an idea of the principal varieties. Near the top is a lenticle of clear, large-grained vein-quartz and garnet; below this is a band with well-formed garnets and small flakes of a greenish mica; then follows one of the bands of minute flakes, and at the bottom is a variety with larger brown mica-flakes in more continuous lines than those above.

Both macroscopically and microscopically the rocks show great

signs of contortion. Fig. 2 represents a piece of weathered rock in cross section. Quartzose layers, of one of which the little lenticle at the top of fig. 7, Pl. XXIII., is a section, form the prominent bands; and lines of brown mica weather out, leaving fine ridges, conforming to the twists and turns of these bands.

Fig. 2.—*Altered Grits contorted.*



Weathered surfaces of this kind are common and striking; but perhaps, considering how quartzose it is, the character of the rock, which is exposed just below the one E. and W. wall along the hill-side, is more so. A vertical section shows Vs, of about $\frac{1}{8}$ inch in length, through whose points the rock cleaves horizontally or nearly so. This rock (fig. 8, Pl. XXIII.) consists of the same minerals as the other altered grits, together with a little chialstolite. The Vs are formed with thick bands of light brown mica-flakes, always well-formed and never bent. The cleavage takes place along bands of quartz-grains, which run through the points of the Vs. This quartz consists of small granules, such as form the quartzite-like base of the other altered grits. Chialstolite is seen in the two rectangular sections on the left of the slide (fig. 8, Pl. XXIII.). The light patch at the top, where it is clearly marked by black lines, consists of large flakes of white mica, probably replacing chialstolite. It will be noticed that the chialstolite affects the folds, and that the garnets often lie in small lenticles of quartz.

Following the grit bosses up the hill, at about 200 yards from the granite junction, the lower cairn (see Map, fig. 1) is reached. The rock attracts attention by the brilliant sparkle of the small white mica-flakes. A cross fracture shows the rock to resemble the more quartzose varieties of the altered rocks just described, but to be rather coarser in structure, and to contain more white mica. The mica-flakes are about $\frac{1}{20}$ inch in diameter. Though, roughly speaking, their cleavage-faces are parallel, they are not in sufficiently continuous planes to make the rock cleave easily. The rock still has the purplish tint of the grits in the stream.

The microscope shows that the rock varies in texture in different

parts, in the same way as the most altered shale. There are parts of microscopical slides which could be matched in slides from rocks farther down the hill, such as fig. 7, Pl. XXIII. Fitted in with these are bands and patches of a much coarser texture, in which the quartz is in large pieces. These must be secondary, because they often embrace large flakes of mica. Especially near the borders of the less altered parts the large quartz grains form a sort of ground-mass to quartz (?) granules of such regular oval or circular outline as to look as if they had been acted on by a solvent. Both quartz and white mica look thick and cloudy, particularly towards the centre. A high power shows this to be due to the presence of a multitude of fine highly-refracting needles, in bands or radiating bundles, which I take to be sillimanite. All the clear grains containing sillimanite which I have found to give a figure are uniaxial, so I presume that cordierite is not present. The black mica is very highly dichroic. Between crossed nicols lath-shaped sections are of a light yellow in the one direction, and in the other extinguish, almost as completely as tourmaline does, vibrations in the opposite direction. It is noticeable that in rotating the colour changes from the yellow tint to a rich brown, and that just before the maximum extinction it loses all trace of brown and becomes a dull grey. This mica often contains black spots; and sometimes a high power shows highly-refracting grains in the centre of these. Associated with the quartz of both finer and coarser parts are occasional striated feldspars. These are rare; and tourmaline, of which a little has been noticed, is still rarer.

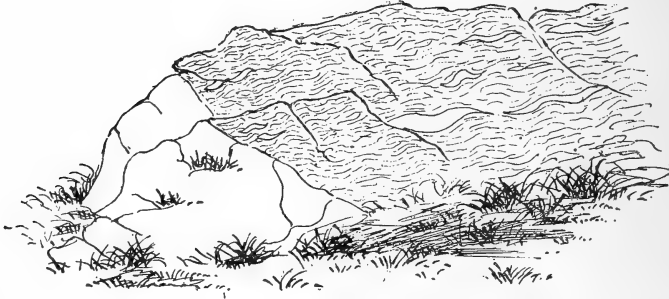
The upper cairn (see Map, fig. 1) stands on another bold crag, about halfway between the first and the granite. The rock is now coarser throughout, and, if from an unknown locality, would probably be described as a fine-grained gneiss. The white mica is even more conspicuous than before, being present in greater quantity and in larger flakes. A cleaved surface shows, besides the white mica, nests of small black micas, just distinguishable as such without a lens; and between these are patches of quartz and garnets. These different patches branch, and fork, and jut into each other, like the counties on a map, the average greatest dimensions being perhaps $\frac{1}{2}$ inch. A cross-section is marked by the black dashes which give the rock its gneissic look, and which are the sections of the black mica nests.

Microscopical slides show that more than half the bulk of the rock now has the character of the coarser parts of that on which the lower cairn stands. The quantity of sillimanite has consequently increased. Except for this mineral the quartz is remarkably free from inclusions, and thus differs from that of the most altered shale.

The granite-junction occurs on the south side of a third boss. As is shown in fig. 3, light-coloured lenticles are conspicuous in the weathered cross-section. These are a foot or two long, by about 3 in. broad. The main part of the rock differs from that of the upper cairn in being even coarser and more distinctly banded. The white micas are often as much as $\frac{1}{4}$ inch in diameter, and form thick piles

round the edges of the light lenticles. They are often thickly studded with small garnets. Branching masses of a somewhat ivory-like material occur. A lens shows this to contain many very small flakes of white mica. These are packed in a substance which, when crushed, breaks into numberless small needles, negative in

Fig. 3.—*Junction of the Granite and Altered Grits, on the southern side of the Third Boss, showing quartz-garnet lenticles.*



sign and extinguishing parallel to their length, hence probably sillimanite. The microscope shows (fig. 2, Pl. XXIII.) that the rock has lost all signs of its elastic origin. As seen in the upper part of the slide, it consists of quartz and white mica, both containing sillimanite, with brown mica and garnets. To the right is indicated the cloudy look of one of the mica-sillimanite aggregates.

The main part of the lenticles, as seen at the bottom of fig. 2, Pl. XXIII., consists of garnets. These give to a freshly-broken surface a delicate pink tint. They are set in clear vein-quartz, often in large pieces, having an angular outline, and traversed by lines of liquid- or gas-inclusions. The sillimanite-mica aggregate just described occurs in large branching masses, often an inch or two long.

I have had no opportunity of comparing the less altered grits with the "quartzite micacé" of Guéméné, which, from the descriptions, they seem to resemble; but I have seen a specimen and slide of the "leptynolithe granatifère" of Rostrenen. The "leptynolithe" is a compact dark purple rock, looking microscopically less altered than the New Galloway rocks; but the microscope shows it to be as entirely recrystallized, with these differences,—that it is much finer in grain, and that the minerals are not so well formed. I sent a specimen of the most highly altered grit to M. Barrois, and asked if he would kindly tell me whether it resembled the "quartzite sillimanitisé" of Guéméné; he answered that there was no such rock amongst the Silurians or Devonians in France, but only amongst rocks of doubtful origin. He further says that the specimen is identical with the "Archeans" of Nantes metamorphosed by granulite.

§ 5. CHIASTOLITE-MICA-SCHISTS.

Amongst the grits and flags marked C on the map are some unaltered shales, and others which may be called chialstolite-mica-schists. These are very black (fig. 9, Pl. XXIII.), and cleave along surfaces with the lustre of highly polished black lead. The cleaved surface is often rough with garnets of very varying sizes, or shows clusters of chialstolite needles, from $\frac{1}{8}$ to $\frac{1}{2}$ inch in diameter and 1 or 2 inches long. A cross-fracture has a more brilliant lustre, as the black mica, which forms a great part of the rock, is more conspicuous. The chialstolite is water-clear, and often shows the pink and green dichroism as well as the characteristic black figure. Parts of the crystals are sometimes replaced by white mica, and sometimes by quartz. The chialstolite usually includes garnets, and often, with them, little masses of fine-grained quartz. Very rarely it includes mica, and this is in small flakes.

The garnets are sometimes $\frac{1}{4}$ inch in diameter, but usually smaller. In sections a dark ring is often seen round the centre, sometimes due simply to difference of colour, sometimes to inclusions of black grains. Often on each side of the garnet is a small triangle of quartz, making with it a clear eye.

The main mass of the rock consists of quartz and black mica, with much colouring matter, which renders much of a slide opaque.

There are quartz-garnet lenticles, like those described in the gneissic rocks; and round their margins are large masses of chialstolite with few or no crystal faces.

§ 6. APLITE VEINS.

On Knocknairling Hill and at other parts of the margin both granite and sedimentaries are veined by a granite, which would answer to the description of aplite given by Prof. Rosenbusch, if it were not that he says that muscovite is present only in small quantities. The rock is usually very coarse, but here and there becomes fine-grained. It consists of felspar (often in large masses), quartz, and a considerable quantity of white mica. Tourmaline and garnets are accessory minerals.

The felspar is mostly microcline. In some veins it forms a micropegmatite with the quartz; in others it forms the bulk of the rock. In one vein, to the west of the granite, there are masses of it 2 or 3 feet across, with continuous cleavage-planes some inches long. The felspars often include garnets.

The quartz is traversed by many lines of small inclusions. That associated with the large felspar masses just mentioned can be seen, with a hand lens, to consist of small, flattened, hexagonal prisms, with pyramids at one end, built up in parallel rows.

The white mica is often in hexagonal plates, as much as $\frac{1}{2}$ inch in diameter. Along the edge of one of the veins on Knocknairling Hill there are triangular flakes arranged in a plumose manner. The mica feathers point inwards from the edge of the dyke, and are 3 or 4 four inches long.

The small garnets are sometimes of a brownish red, as in the altered grits, and sometimes a bright wine-red colour. Large yellow garnets occur occasionally.

Tourmaline occurs in the Knocknairling-Hill vein in patches curiously intergrown with quartz, so as to form what looks like a graphic granite, with the little hooked letters in dark tourmaline instead of in quartz (Pl. XXIII. fig. 3). The tourmaline needles are parallel with each other, instead of radiating as in luxullianite. Some of it is of an indigo, and some a bottle-glass brownish-green colour. These tourmaline-quartz patches have an area of 1 or 2 square inches. Groups of tourmaline sections extinguish together, but the quartz-grains have their axes at all angles.

The fine-grained variety of the aplite has a sparkling saccharoidal look, and the little pink garnets show conspicuously on the white surface of a freshly-broken specimen. It consists of about equal quantities of felspar and quartz in grains. There is a good deal of white mica, garnets are common, and small needles of tourmaline occur occasionally. In some places coarser veins shade off in parts into this fine-grained material; and in others it occurs in veins by itself.

§ 7. AGE OF THE METAMORPHOSED ROCKS.

The evidence that the metamorphosed rocks of Knocknairling Hill are of Silurian age is, I think, fairly conclusive.

There can be no question as to the age of the grits and shales of the stream. They are just like grits and shales which occur at various parts of the margin. The amount of mica in the grit varies, and in some parts the rock differs but little from the unaltered grits of the district. It is certainly a pity that the schistose beds of the stream, which I have called altered flags, cannot be traced farther from the granite; but the way in which they begin by alternating with unaltered shales renders it unlikely that they have been faulted in. This alternation is just like that of the flags and shales of the Ard wells. A similar case of the alternation of thin, highly altered bands with unaltered shales occurs at a greater distance from the granite in the shales marked A on the map (fig. 1). In these there are quartzose bands, an inch or two thick, with much white mica and garnets.

The grits and shales are Silurian. The mode of occurrence of the schistose beds in the stream renders it probable that they are of the same age.

The more altered rocks of the hill-side seem clearly to be the same series. There are unaltered shales on one side, and altered flags, like those in the stream, on the other. The strike of the whole, as given not only by the foliation, but by the shales interbedded with the altered flags, is the normal strike of the Silurians of the district.

There is also evidence of a different nature. Nowhere else is the metamorphism of the rocks in contact with this granite-mass so striking; but to the south, at the Clints-of-Dromore, the grits, at the

contact, have been altered to a rock very like that of the lower cairn of Knocknairling Hill without the garnets; and on the Bennan Hill to the east, and Laughenghie Hill to the south, there are in purple-brown grits spots, an inch or so long, closely resembling the most altered grits of Knocknairling Hill.

§ 8. REMARKS.

In connexion with metamorphism the following points seem noteworthy:—

1. The extreme variation in the amount of alteration undergone at different places at the same distance from the granite.

a. At the actual contact in different parts of the margin.

b. In the case of beds close together, as on Knocknairling Hill, where, at a distance of 200 yards, grits are highly altered and shales little affected.

c. In the case of different layers of the same rock, as on Knocknairling Hill, where bands of shale, a few inches thick, are much more altered than those with which they alternate; and even more noticeably in the shales marked A on the map, where, in an exposure of hardened shale about 8 feet high, are bands, an inch or two thick, much altered, with white mica and garnets.

2. The way in which the extreme alteration of the grits has spread from the margin on Knocknairling Hill, the whole being recrystallized near the margin, parts of irregular outline similarly affected at a distance of 100 yards, and smaller portions farther off.

3. That material seems to have travelled through the rock.

a. The larger lenticles of fig. 3, and the smaller of fig. 2, containing quartz, garnet, and sillimanite, as well as the numerous eyes and lenticles of quartz alone, have the appearance of having been filled by material which has been brought from the surrounding rock.

b. The more altered grits consist largely of clusters of crystals, here of one mineral, and there of another. It would seem as if material must have been conveyed from one part of the rock to another to form such nests of only one mineral.

4. The apparent order of succession of the minerals. Garnets extremely rarely contain anything but colouring matter and quartz; chiastolite contains garnets; bands of mica bend round both.

5. The microscopical slides give the impression that the minute folding could not all have been prior to the mineral alteration. One would suppose that the black colouring matter of fig. 4, Pl. XXIII., must have been heaped up on one side of the waves during the folding, and the form of the knots in the knotted schist connect them with the folding. No inconsiderable part of the rocks consists of twisted bands and eyes of segregated material. The spaces thus filled might have been caused by shrinkage in consequence of crystallization in the more altered rocks, but could not have been so caused in the slightly altered shales. They suggest easing during folding. The little garnet quartz-eyes suggest the same idea.

Some of the mineral alteration may be due to the energy of the resisted force which caused the folding; but the main effect must, I think, be acknowledged to be due to the granite. The mica of the purple-brown grit is evidently a product of contact-metamorphism, for there is a zone of this rock almost all round the granite. The increased metamorphism of the Knocknairling-Hill rocks as the granite is approached indicates the same cause.

The variation in the amount of alteration at the same distance from the margin,—the way in which the extreme alteration of the grits begins in patches which increase in size until the whole is re-crystallized at the margin,—the way in which the large quartz-grains of the altered rocks contain little grains which look partly dissolved,—and the signs of the transference of material, suggest to my mind the action of highly-heated water.

Folding on the large scale was certainly over when the granite was intruded, for both on the east and west the granite is constantly seen cutting across the folds; but, supposing the contact-effect due principally to highly-heated water, which would very likely have been emitted during a long period of time following the injection of the granite, might not the minute folding have taken place during the same time, so that dynamic- and contact-metamorphism have taken place simultaneously?

EXPLANATION OF PLATE XXIII.

- Fig. 1. Most highly altered shale: \times about 50. Showing white mica, brown mica (shaded), colouring matter (marked black), and quartz. The quartz is shaded, and is dotted where it is full of small inclusions.
2. Most highly altered grit: \times about 50. The upper part of the slide represents the main mass of the rock; the lower, part of a quartz-garnet lenticle. The minerals are white mica and quartz containing sillimanite needles, brown mica (shaded), and garnets. The cloudy-looking portions on the right, both in the rock itself and in the lenticle, represent the mica-sillimanite aggregates described in the text (p. 576).
3. "Graphic" arrangement of tourmaline: \times about 6.
4. Altered shale; drawn with a hand-lens: \times about 2. Showing quartz-veining and arrangement of colouring matter along folds.
5. Altered shale: \times about 10. Showing elongated irregular patches of a biaxial mineral, probably a feldspar, and bands of large-granular quartz.
6. Purple-brown grit: \times about 50. Showing quartz-grains, brown mica, and a few feldspar-grains; one lies S.E. of the centre.
7. Altered grit; drawn with a hand-lens: \times about 4. Showing garnet, mica, and quartz.
8. Altered grit, with secondary cleavage; drawn with a hand-lens: \times about 2. The shaded bands forming the Vs are masses of small light-brown micas, and the interspaces fine-granular quartz. Chialstolite to the left.
9. Chialstolite-mica-schist; drawn with a hand-lens: \times about 2. Chialstolite, dark-brown mica, colouring matter, and garnets. A good deal of quartz in the light bent band in the middle.

DISCUSSION.

The CHAIRMAN (Mr. HUDLESTON) remarked on the satisfaction he felt in seeing microscopic examination of rocks taken up by ladies. He noticed that there were no chemical analyses given in the paper.

Mr. HARKER had never seen gritty rocks so highly metamorphosed as those laid upon the table. The mode of occurrence of nodular masses of garnet and quartz struck him as interesting, and he would ask whether it was concretionary or connected with folding. Highly granatiferous rocks were found elsewhere, as in the Ardennes, coming in in a lenticular fashion. The large quantity of mica would seem to indicate an arkose rather than a grit, but he would await the publication of the paper.

Prof. HUGHES thought that whatever may have been the origin of the gneissic rocks exhibited they had certainly been much affected by dynamical metamorphism, and that the Author had made out a good case for contact-metamorphism also, though he believed she did not profess to have traced the ordinary sedimentary grits continuously into the highly altered rocks.

Mr. TEALL explained that though he had communicated the paper, he had no special knowledge of the locality. He felt that the Author was perfectly well able to examine rocks microscopically, and she had also done a considerable amount of field-work. He very much regretted the absence of the Author.

36. *On the VALLEY-GRAVELS about READING, with especial reference to the PALÆOLITHIC IMPLEMENTS found in them.* By O. A. SHRUBSOLE, Esq., F.G.S. (Read June 18, 1890.)

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§ 1. INTRODUCTION.

HAVING had the Pleistocene deposits of this part of the Thames Valley under observation for some years past, and more particularly (since first finding worked flints here fifteen years ago) in reference to the evidence which they afford of the former presence of Man in the district, I desire to offer to the Society a few notes on some of the sections which have proved of especial interest. It is not pretended that this communication aims at presenting a complete view of the subject; but, as sections are liable to be covered up or to change their character in the course of time, I have thought it well to put on record what has come under my own observation, as it may serve to present a general view of the manner of the occurrence of the relics of Man within a definite area.

The Valley of the Thames in this vicinity forms in the deepest part a trough, cut in the Chalk, about a mile and a half wide, beyond which the levels ascend more gradually. Gravel is found here as elsewhere at various elevations, creeping up the valley-slopes, often for a considerable distance where the form of the ground has been such as to retain it.

Of the plateau- and hill-gravels which succeed the valley-terraces I do not here speak; but there is often some difficulty in making out a clear line of demarcation. At about the 300-foot contour-line or less, however, we find that we have to deal with what are generally known as the plateau-gravels.

§ 2. GRAVELS NORTH OF THE THAMES.

1. *Toots Farm, Caversham.*

There is a considerable spread of valley-gravel around the village of Caversham. On the hill about a mile north of the river, at an

elevation of about 269 feet above sea-level, a section shows about 8 feet of irregularly-bedded, ochreous, subangular flint-gravel, with pebbles of flint, a few quartzites, &c. There are various other sections at about this elevation within a mile or two; but the only one of special interest is at a somewhat lower level, near Caversham church, in a pit on Toots Farm at a height of 235 feet above sea-level, and 114 feet above the adjacent river-surface.

The section shows about 8 feet of slightly-bedded, subangular, flint-gravel, containing many large flints in a light-coloured sandy matrix, together with occasional fragments of felsitic and other rocks, and a considerable number of the usual pebbles of quartz, quartzite, sandstone, &c., which are found in our valley-gravels at all levels, and which are generally admitted to have been derived from the waste of a Triassic coast-line further north. The gravel has many pot-holes, filled with a compacted clayey and gravelly loam.

It rests on the Chalk, and, beyond the occasional bending of its bedding-planes, which may have been subsequent to its deposition, it does not present evidence of any unusual or violent action.

In this pit a large number of flint implements have been found. They occur mostly in a definite zone, which follows the bedding of the gravel, and is usually only 1-3 feet from the surface. I have caused excavations to be made down to the Chalk, and the result has confirmed the statements made by the men. The implements occur in considerable numbers, so that it is not difficult to obtain specimens *in situ*; and I have repeatedly taken them from the gravel face.

Some years ago I visited the pit when it was not being worked, and no good section was visible; but subsequently Dr. Joseph Stevens was more fortunate, and obtained implements from this pit and from the gravel thrown out in digging the foundations for a house nearer the river, in the same deposit; and a considerable number have been secured for the local Museum by carefully turning over the upper portion of the gravel.

The condition in which the implements are found is such as to suggest that the greater portion of them have not travelled far. They are but slightly abraded or worn, as a rule, and there is more or less unity of character in the forms, and similarity of surface-condition. The sharp-pointed type is of general occurrence. They are of various degrees of finish, some being worked but very slightly indeed, or perhaps spoiled in the working; others are carefully executed. It seems likely, having in view also their numbers, that they were made not far from the spot.

These traces of Man do not occur all over the gravel-deposit, but they do extend over a considerable area, as is proved by casual openings. At the Toots-farm pit, the gravel occupies a sort of promontory, bounded on one side by the river, on another by a dry chalk valley, and on the third side it faces gently rising ground,—a position in which gravel would readily accumulate.

Selected nodules appear to have been largely used as the material of the implements. The mineral condition of the surface, where

cut, is generally similar to that of the broken surface of the other flint fragments with which they are associated, and presents a light-buff or cream-coloured patination, sometimes bluish, or with the natural colour of the flint little altered. Frequently one side of an implement will have a different patination from the other.

The general conclusion seems to be that most, if not all, of the implements belong to the same palæolithic date. It is worthy of note that fragments of quartzite are occasionally found which appear to have been hollowed at the edge and used for scraping or rubbing. This is of interest as indicating that the fragments in question, if the hollowing be artificial, were used by Man after such glacial conditions had set in as produced their transport to this district.

In order to form an idea of the original thickness of the gravel at this point, allowance must be made for the removal of a considerable quantity by denudation, which, owing to the contour of the ground, would necessarily be rather severe. That the gravel which has been removed contained some implements seems probable, from the occasional occurrence of a specimen at a lower level.

This is, I believe, the highest point at which so far the valley-gravels of this district have yielded traces of Man. Animal remains are rare. I have not met with any, but Mr. L. Treacher informs me that he has found at this pit a much decayed tooth of horse, and a few small fragments of bone also in a decayed state. Prof. Prestwich and others have suggested that the rarity of the occurrence of mammalian remains in the older high-level gravels is due to their gradual destruction by percolating water.

I have obtained an implement from a casual opening in gravel about half a mile west of the Toots-farm section and at about the same level.

2. *Henley Road, Caversham.*

There is a pit from which gravel and Chalk have been extracted on the east side of the village, about a mile distant from the Thames and about 168 feet above sea-level. The section shows a very uneven surface of Chalk, which is ravined, and overlaid by a clayey gravel, showing strongly-marked bedding in places, and in other places looking like a "wash." In one place there is a thin patch of sandy gravel resting on the chalk-rubble, which I take to be a relic of a once larger deposit and to be older than the mass of the gravel. From this part I have obtained a flat ovoid flint implement, much abraded, and a few other worked flints. The type is unlike that of the implements from the Toots-farm gravel, and resembles those obtained from the opposite side of the valley. A molar of *Elephas primigenius*, in a decayed state, was found here.

3. *Shiplake.*

About three miles from the last-mentioned locality there is a terrace of gravel occupying a level of about 200 feet above sea-level, a section of which, in a pit by the side of the road to Henley, shows

about 8 feet of rather small subangular gravel, mostly of flint, sandy in the lower portion, and resting on Chalk. The river flows very near this spot. Implements resembling those from Toots Farm occur here. Another opening in the ground made during the construction of farm-buildings showed a greater depth of gravel, 15 or 16 feet; and from gravel thrown up from near the bottom I obtained two implements approximating to the Toots-farm type.

About a mile from this point, near Shiplake Station, and at about the same level, gravel has recently been dug for the construction of a road. It is a small, bedded gravel, containing many small pebbles, and, in addition to the flint and quartzites, a few pieces of chert, which may have been derived from the plateau-gravel. I observed flint flakes in this pit, from which I infer that implements would be found also.

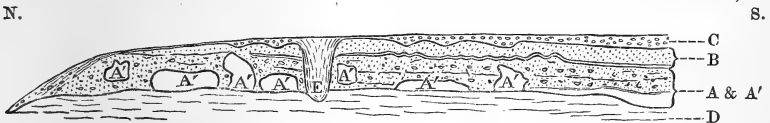
§ 3. GRAVELS SOUTH OF THE THAMES.

1. Tilehurst Road, Reading.

On the southern or Berkshire side of the Thames two tributaries join the main stream in this district, namely the Kennet, which flows through the town of Reading, and the Loddon, which enters the Thames at Wargrave, about four miles lower down. There is, of course, a considerable accumulation of gravel about these rivers. The town of Reading is built on the gravel sheets of the Thames and Kennet, which unite and spread over the watershed of the two rivers. There is a good section (see fig.) about a mile

Section of Gravel-pit, Tilehurst Road, Reading.

(Length of section, 63 yards. Maximum thickness of gravel, 22 feet.)



- A. Lower part of the ochreous gravel. A'. Chalky portions of the same gravel.
- B. Ochreous gravel, with a loamy seam, occasionally showing contorted bedding ("Trail").
- C. Whitish clayey gravel, at the top.
- D. Woolwich-and-Reading Sand.
- E. Sand-pipe.

from the centre of the town, westward, on the Tilehurst Road, at an elevation of 197 feet above sea-level, and about 75 feet above the surface of the Thames at the nearest point, about a mile and a quarter distant.

The maximum thickness of the sheet here is 14 to 19 feet, and it thins out in the direction of the Thames and Kennet respectively by denudation.

The section to which I have referred occurs in a large pit on the

Elm-Lodge estate* which has been largely worked for road-material; and the sections exposed from time to time have presented some features of interest. The gravel here rests upon an uneven surface of the buff-sand of the lower part of the Woolwich-and-Reading series. It consists of subangular ochreous flints, whiter near the surface, in a more or less sandy matrix, particularly in the lower portion of the deposit, with pebbles and boulders of brown and purple quartzites, white quartz, sandstone, &c., and occasionally fragments of igneous and metamorphic rocks.

In certain parts of this gravel, however, there are included masses of a gravel distinct in character, except that quartzites are found in both. This is a clean whitish gravel containing many small water-worn flints weathered white by change in the iron-oxide, larger fragments of black flint, irregular lumps and pebbles of chalk, and fine chalk material. Incrustations of calcite appear on some of the flints. Chalk also occurs in the hollows of others. It is evidently, as regards the greater portion of it, the result of the wasting of a Chalk district. These included masses of gravel vary in size and shape: some are lenticular or flat; others are roughly circular in section, and the materials composing them lie at such an angle as seems to require the support of the ochreous gravel by which they are surrounded. They have the appearance usually of being contemporaneous with the other gravel, as the lines of bedding seem frequently to pass through both. Black stains, due to manganese, also affect both gravels equally.

As the gravel has been worked away eastward the masses of the chalky gravel exposed have been larger in number and size. The sketch (fig. at page 585) will give some idea of the manner in which they occur. Some of these are 10 or 12 feet in diameter in their shorter axis, and extend some distance horizontally. Many rest on the floor of Reading Sand; others, as seen in the section, are entirely inclosed by ochreous gravel. The workmen think that they all ultimately touch the bottom.

Whether the two different gravels were here laid down contemporaneously or not is difficult to decide. Possibly stranded and piled-up ice inclosed portions of the frozen bottom of another part of the old river, and melted among the accumulating deposit. But more probably the chalky gravel may have been an earlier deposit, partly worn away, and covered unequally by the ochreous gravel. At all events the chalky gravel was accumulated rapidly, for some of the fragments of Chalk are angular, and chalky mud still fills cavities in the flints.

The patches are most numerous near the base of the gravel and

* Sometimes called the "Grovelands Pit." See Dr. Stevens' notes in the *Transact. Brit. Archæol. Assoc.*, March 1881; *Proceed. Geol. Assoc.* vol. viii, 1884-5, p. 347; and *Ibid.* vol. ix. 1886-7, p. 211; and *Journ. Anthropol. Instit.* for 1884, pp. 192-200.

Grovelands is the next farm westwards, where there are other gravel sections of less interest, although I have found a few worked flints there. The prominent gravel ridge commences with the Elm-Lodge Estate, occupies its southern boundary, and extends also further east.

in a line parallel with the direction of the present river, near where the upper gravel thins out on the valley-slope and leaves them near the surface. Further back in the gravel-working they lie under many feet of gravel, but finally disappear.

It will be seen by reference to the figure, p. 585, that relatively tranquil conditions of deposit supervened, as shown by a sandy seam (between A and B) near the top. Some years ago this was exposed as a very distinct bed of greenish sandy clay with small pebbles. As it passed over one of the masses of chalky gravel its level was considerably raised, as if on account of the latter. A non-ochreous gravel, apparently of more recent date, comes in above (c in the fig.).

Resting on the Tertiary Sand (D) at the base of the gravel are many massive flints and some sarsen-stones.

Flint implements are sparsely scattered in the gravel, and it is not easy to obtain a specimen *in situ*; but, owing to the quantity of gravel removed, a considerable number have been secured. Some of the forms have been described by Dr. Stevens*. Though chiefly found in that part of the gravel which is associated with the included masses of a chalky gravel, yet they occur in both kinds of gravel (A and B), and some few have been found in the uppermost gravel (c) which covers the greater portion of the sheet.

As a rule the implements are much worn by attrition, and the appearance of many of them further suggests that they have had continued use. Flakes and fragments with sharp edges are, however, by no means uncommon. The surface-colouring varies. Some of the tools are of black flint, little altered, and these seem to be confined to the chalky gravel (A'). A common tint is a deep ochreous brown. Others are lighter, and some are of a uniform dirty white. In some cases the mineral condition of the surface is sufficiently accounted for by the position of the implements in the present gravel, the matrix in which they are embedded, and their nearness or otherwise to the surface of the ground. There are cases, however, which are not fully explained in this way. It is not unusual in gravels of this kind to find unworked stones, which have apparently come from an older gravel, as they exhibit fractures of two distinct ages. In the chalky gravel some of the implements are of black flint, slightly altered on the surface, while others are more or less ochreous. Cases of this kind are by no means clear or conclusive. One implement, however, had evidently been abraded and had acquired its present coloration before it was swept into this gravel deposit. It has been much worn, so that the marks of chipping are almost obliterated. Its surface is an opaque whitish colour, slightly mottled with light brown. It has escaped any serious fracture; but small pieces have been knocked off its edges, and where that has occurred quite a different patination is apparent which shows the extent to which the surface has been modified in the present gravel. It appears, therefore, that this tool has been

* Journ. British Archæol. Assoc. 1881.

derived from some older gravel where it had suffered abrasion and had acquired, in the main, its present alteration of surface. The adherent matrix shows it to have come from the ochreous part of the gravel. It does not differ in type from other implements found in the same deposit.

Indications of this kind suggest caution in our attempts to synchronize a deposit, particularly a deposit of so shifting a character as gravel, with its inclusions organic or otherwise, or the inclusions with each other. Evidence of the same kind is afforded by the fragments of Lower Cretaceous and Oolitic fossils which are found in this gravel.

There is, however, an indication that some of the tools were fabricated since the dispersal of the Triassic conglomerates, and the partial submergence which aided that dispersal. It is not unusual to find fragments of quartzite that have been hollowed out artificially, to all appearance, so as to form a scraping or polishing tool. I have found several specimens of this sort, and a hatchet of brown quartzite, found in this deposit by Dr. Stevens, is now in the Reading Museum.

With regard to the type of the implements found here, the most characteristic form is the ovoid; but more pointed forms, generally in a damaged state, occasionally occur.

Flakes, sometimes of large size, which have been used as scrapers are common, and massive rudely shaped implements are not unusually found associated with the large flint fragments at the base of the gravel. The implements, as a whole, have an entirely different facies from those of the Toots-farm deposit. In the latter the flat obtusely pointed tool is practically unknown; and the Caversham workers appear to have operated, as a rule, on smaller nodules, and to have been more sparing in their use of the material. The non-descript tools and large scraping and chopping flakes are also relatively more abundant here (Tilehurst Road).

The organic remains found here include so far as my own observation has extended:—

Elephas primigenius. Teeth and fragments of bone not uncommon.

Rhinoceros. A worn molar.

Bos primigenius. Bone fragments and teeth.

Equus caballus. Teeth rather common.

Cervus elaphus. Portions of antlers.

I have two fragments of bone, which have been cut as if by a flint implement; and, when put together, they are seen to have formed part of the same bone—a radius of *Bos*, which had evidently been split before it became embedded in this gravel*. The separate pieces, perhaps, have not been subjected to much rolling, or they would probably not have been found near together. Mammalian remains occur both in the ochreous and the non-ochreous parts of the gravel.

* Journ. Anthropol. Instit. 1884, p. 199, pl. xi. figs 8 a, 8 b.

In the same field as that in which the gravel occurs, but at a lower level, about 144 feet above the sea-level, a very good section was exposed in digging a foundation. It appeared to indicate that, at the later period of the deposition of this lower-level gravel, somewhat similar energetic denuding agencies were at work in the valley. The section has since been covered up. The buff sand occurred very irregularly. The pebbles of Chalk in the chalky gravel below were flat and covered with cracks, somewhat suggestive of the action of frost. Some fragments of mammalian bone were obtained from this opening; one of them is referable to the Mammoth.

2. *Norcot Brickyard.*

At this place, about three-quarters of a mile westward of the above-mentioned locality, there is a section of a gravel at a higher level than that in the Tilehurst Road, namely about 288 to 294 feet above sea-level. At present there is a thickness of about 6 feet of it overlying the lower part of the London Clay and the Woolwich-and-Reading beds at this place. It is evenly bedded, but the flints are in much smaller proportion than in any other gravel in the district. The pebbles and boulders of quartz, quartzite, &c., are numerous, and there are boulders of various igneous rocks, a kind resembling diorite deeply weathered being common, and occurring in rounded masses of considerable size.

No trace of Man or any other mammal has been found here.

Such a deposit as this would approach more nearly in point of date, probably, to the era of the wearing away of the Triassic coast-line of Warwickshire &c.

The gravel at the Tilehurst Road section (page 585) may have been derived to a small extent from such a gravel as this.

As this gravel comes into the valley as far as to about 288 feet above the sea-level, I have taken it as a sort of datum-line for the purpose of comparison. As it ranges over the higher ground of the Tilehurst Tertiary outlier to 340 feet above the sea-level it has the character of a plateau-gravel, and becomes very variable in its composition, consisting in places of finely comminuted material and layers of clayey or sandy loam of considerable thickness.

3. *Redlands, Reading.*

Crossing over the Kennet we come to a sheet of gravel south of the Thames and Kennet, near the point of junction of the latter. The ground is now mostly built over, but the section seen in a large pit has been fully described by Mr. E. B. Poulton*. It showed a considerable amount of local disturbance of the beds beneath the gravel. The level is low, being 156 feet above sea-level, and 40 feet above the surface of the Kennet. In gravel taken from this pit I found the first flint implement discovered in this district. By further search I obtained a miscellaneous collection of about a dozen implements and only two flakes. These varied in their types, and

* Quart. Journ. Geol. Soc. vol. xxxvi. 1880, pp. 296-306.

in the amount of abrasion they had suffered. In all cases but two I found them in the heaps of gravel, but the workmen who discovered these two informed me that they came from the deepest part of the gravel. One of these two specimens is a large pointed implement.

This terrace of gravel is continuous to the point where the Kennet enters the Thames.

From another pit a short distance off, near the cemetery, a tooth of Mammoth was found some years ago.

4. Kennet Mouth.

Close to the mouth of the Kennet, gravel has been extracted for many years, as shown by the old workings. The present pit shows the gravel to be here about 16 feet thick, resting on Chalk, at a height of 30 feet above the river-surface. It is a water-worn, non-ochreous gravel, containing, in addition to the flints, the usual quartzites. At the upper part are numerous furrows filled in by washes of surface-soil. Fragments of shells and of mammalian bones have been met with. The only species of mammal determinable is the Mammoth. No traces of Man have been found. *Elephas primigenius* has occurred at three different points in this terrace of gravel.

5. Southern Hill and Earley.

As we pass to the higher ground between the Kennet and the Loddon, this gravel ends against the valley-brow, and is succeeded by the gravel of the watershed. A section through the lower part of this is afforded by the cutting on the South-Western Railway at Earley, where it is seen to be 7 or 8 feet thick, and to consist of worn and comminuted material, principally flint, at 212 feet above sea-level.

At the edge of the terrace overlooking the Thames, an opening for sewerage purposes showed gravel, 9 or 10 feet thick, of the ordinary mixed kind; and from this I have obtained a few flint chips and a rude implement. The level is about 223 feet above sea-level.

6. Sonning Hill.

A section is here afforded of the gravel of the Thames-and-Loddon watershed at a level of about 185 feet above sea-level. A pit by the road-side, close to the railway, shows about 10 feet of clayey ochreous flint gravel, with quartzites. The line of the Great-Western Railway passes this spot in a deep cutting, and a spoil-bank formed of the surplus material has for many years been worked for brick-making. From the gravelly part of this soil-heap a few flint implements have been obtained, and are in the Reading Museum. One of them is a large ovoid implement, ochreous in colour.

7. Charvil Hill, Sonning.

From Sonning Hill the ground gradually descends towards the point of confluence of the Loddon with the Thames. A terrace of gravel occurs at Charvil Hill, near Sonning, at 171 feet above the sea-level. A pit by the side of the road from Reading to Twyford

exhibits a bedded gravel, with a few thin layers of clay. Mr. L. Treacher, of Twyford, informs me that he has here obtained two flint implements somewhat abraded. He observed on one occasion a lump of mottled clay, about 4 feet in its longest diameter, embedded in the gravel.

8. *Ruscombe, Twyford.*

Continuing in a north-easterly direction by the road from Reading, and crossing the Loddon at Twyford, a higher and lower terrace of gravel are met with. The former is seen at the Ruscombe brick-works, where it overlies the Woolwich-and-Reading beds at an elevation of 167 feet above sea-level, and 60 feet above the surfaces of the Loddon and Thames. Owing doubtless to denudation, it is a thin deposit, being in places only 2 or 3 feet thick; but it fills up hollows of considerable size in the underlying sands or clay.

The brickyard itself affords a fine section of the variable Woolwich-and-Reading series, apparently with a N.E.-S.W. fault.

I was led to examine the gravel here by finding a flint implement in the village, where some road-material had been laid down; and from time to time I have obtained a few specimens from the gravel thrown out. Others have been obtained by Mr. Treacher, who resides close by. Some of these are stated by the workmen to have been obtained from the clay itself, at some slight distance from the gravel. There is no real improbability in this, for the gravel enters the clay, as stated above, and its heavier materials would have a tendency to sink the farthest in the clay. Some of the implements found thus are quite sharp and unworn.

The implements found here are various in character and do not belong to any one type; but pointed tools are well represented. Some of the implements are buff in colour, others nearly black.

Although this would seem at first sight to be a gravel of the Loddon, which flows past the village, it may perhaps be related rather to the Thames, which is at no great distance, and towards which the ground slopes. At Hurst, further up the Loddon-valley, the gravel is at a lower level and is of a different character, as it contains many fragments of chert, and quartzites appear to be absent.

§ 4. GENERAL CONSIDERATIONS.

With so few data within a limited area, it would be rash to make large generalizations. It may be well, however, to consider whether any, and what, significance attaches to the different levels at which gravel containing palæolithic implements occurs. The highest gravels of the valley, those, namely, which lie between 235 feet and 269 feet above sea-level, do not contain, as far as my observation has extended, any traces of Man, or indeed any contemporaneous organic remains. In the neighbourhood of Caversham, gravels, only 20 feet higher than that at Toots Farm, appear to have been accumulated under similar conditions, yet they have not yielded any implements.

Assuming the highest gravels of the valley to be the oldest, the

indications are that a considerable amount of valley-erosion must have taken place before the implements now found at 235 feet above sea-level were placed there. A still greater amount of erosion had taken place before the implements and mammalian remains now found at 197 feet above sea-level reached their present position.

With regard to any indications that are afforded as to former climatic conditions, it is not until we reach the level last mentioned, in descending order, that any very marked irregularities in the deposit of gravels occur; the higher-level valley-deposits, like the plateau-gravels and the hill-gravels, presenting no marked difference from the results of ordinary water-action. Irregular bedding is again observable as belonging to the considerably later epoch when the valley had been lowered to about 150 feet above sea-level.

The very large percentage of quartzites and other rocks not occurring *in situ* in the Thames-valley in the composition of the gravel at Norcot (page 589), 294 feet above sea-level, may be taken as an indication that glacial action and submergence had taken place at no distant interval from the time when it was laid down.

So far, then, as the gravels of the valley can be considered representative of important stages in its history, the indications are of a severe climate occurring at an early stage and recurring later on. Traces of Man occur in many of the stages intermediate between the Norcot gravel and that of the comparatively low-level at Elm Park and Kennet Mouth. Traces of other mammalia are found at those last-mentioned localities, but not of Man.

A comparison of the types of the implements found at the different levels shows that, assuming the highest level to be the oldest, the pointed type, with a thickened butt, might be adjudged to be the most ancient in the district. On the other hand, the Ightham implements, found at heights of from 380 to 500 feet above sea-level, described by Prof. Prestwich*, and considered by him to be "possibly pre-glacial†", do not differ in any special manner from those found in this district at levels lower than that of Caversham.

This similarity was alluded to by Dr. Evans‡; and, as there is reason for supposing the Ightham implements to have formed part of gravels which have been in a great measure removed by denudation, it is probable also that many of the implements found in the lower levels at Reading have been derived from gravels which have been swept away. This is the more likely when we have regard to the mixed character of the types generally found in the lower levels, and to the fact that a river can accumulate a considerable thickness of gravel in a short time. It is not likely, therefore, that the implements of various types found at any particular place represent the gradual entombment of the specimens in a slowly accumulating deposit spread over a considerable interval, but rather the result of a mixing-up of materials derived from gravels of various dates and from various levels.

The position in which the implements occur in these lower-level gravels is also worthy of notice. Wherever the gravel attains any

* Quart. Journ. Geol. Soc. vol. xlv. 1889, pp. 270-296.

† *Ibid.* p. 292.

‡ *Ibid.* p. 295.

considerable thickness, they occur near the bottom of the deposit, as a rule, but occasionally dispersed in the mass. At Ruscombe they are found, as stated (page 591), in the underlying clay. In consequence of the discontinuity of the several gravels, there is great difficulty in obtaining from them detailed and consecutive data. Juxtaposition in a gravel does not necessarily imply contemporaneous origin; and, as we might expect, there has been a dovetailing of deposits, and a destruction and mixing together of gravels formed at various dates.

A list of localities exhibiting the typical gravels of the valley, excluding those of the lowest levels, is appended herewith in order to show at one view their approximate height above the ordinary river-level at the nearest point, and their relation to the occupation of the valley by Man and the other mammalia, so far as I have been able to ascertain.

It should be mentioned that the levels have been taken from usually the highest point of each section at the surface; but allowance must be made for the varying contours of valley-deposits, and for the fact that it has not been practicable in all cases to get the exact level surveyed.

I have, through the kindness of Mr. Thomas Reed, of the Ordnance Survey at Reading, obtained the exact height above the sea-level of the river-surface at two points, namely, at the junction of the Thames and Kennet (116 feet), and at Caversham (120·77 feet). Below those points the level of the river has been estimated.

I take this opportunity of acknowledging my indebtedness to Messrs. William Davies, F.G.S., A. S. Woodward, F.G.S., and E. T. Newton, F.G.S. for the identification of mammalian remains at various times.

	Above sea-level.	Above river Thames.	Traces of Man, *; other mam- malia, †.
	feet.	feet.	
<i>North of Thames.</i>			
Caversham Hill	269	148	
Wallingford Road	255	133	
Toots Farm, Caversham.....	235	114	* †
Shiplake	200	92	*
Shiplake	194	87	*
Shiplake	184	77	*
Henley Road, Caversham	168	52	* †
<i>South of Thames.</i>			
Norcot (glacial)	294	172	
Southern Hill, Reading	223	107	*
Tilehurst Road, Reading	197	75	* †
Sonning Hill	185	70	*
Charvill Hill	171	64	*
Ruscombe	167	60	*
Redlands, Reading	156	40	* †
Kennet Mouth, Reading	146	30	†
Elm Park, Reading (lower level)	144	22	†

It will be seen from this Table that there is a somewhat wide range of height above the nearest river-level in the case of the gravels containing relics of Man, namely from 40 feet to 114 feet. While it is evident that Man was in the valley certainly as far back as when its level stood 114 feet higher than at present, we cannot, owing to the shifting nature of valley-deposits, positively say that the occupation continued down to the date represented by the lower level of 40 feet, although it may have been so.

With regard to the larger mammalia, the evidence here seems to accord with that from other districts, their remains having been found at lower levels than the implements fabricated by Man. It may therefore be inferred with some degree of probability that those animals remained in the valley for some time after Man had left, if the chronological indications of valley-deposits could in all cases be relied on.

DISCUSSION.

Mr. MONCKTON had noticed great variability of the gravels around Reading, and would like to learn whether it was possible to trace the gravels shown in the section at Grovelands for any distance laterally.

Mr. ABBOTT could not understand from the section displayed that the Groveland gravel belonged to the Thames system, dipping, as it did, to the valley of the Kennet; a continuation of the line of dip appeared to take it over to the higher-lying gravel on the north, making it appear as if the two gravels were the same, and had been cut through by the Thames valley.

The AUTHOR said that the variations had, to some extent, been traced laterally. The appearance of dip towards the Kennet in the section referred to by Mr. Abbott was misleading, as the section was diagrammatic. He did not expect contemporaneous gravels to be discovered on both the Oxford and the Berks side of the river. The gravel referred to was distinct from that at Caversham, and both were essentially valley-gravels.

37. *On BURROWS and TRACKS of INVERTEBRATE ANIMALS in PALÆOZOIC ROCKS, and other MARKINGS.* By Sir J. WILLIAM DAWSON, LL.D., F.R.S., F.G.S. (Read May 14, 1890.) *Pub. Nov. 17890*

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§ I. INTRODUCTION.

THE present paper is intended to contribute some recently acquired facts to the solution of questions connected with these often problematical markings; and it will consist rather of short notes, illustrated by photographs, than of a connected discussion of the subject. I propose to notice the nature of certain markings sometimes referred to plants, under the name of *Bilobites*,—to the true nature of the *Scolithus canadensis* of the Potsdam Sandstone,—to certain tubes similar to those of modern *Sabellæ*,—to cylindrical concretions resembling trunks of trees,—and to imitative markings, and peculiar trails of doubtful origin.

§ II. BILOBITES, RUSICHNITES, PROTICHNITES, and CLIMACTICHNITES.
(Figs. 1 to 6.)

The name *Bilobites*, proposed by DeKay in 1823, was, as Newberry has shown,* originally applied not to objects of this kind, but to casts of certain bivalve shells. It was therefore dropped in America; but it has been revived and has gained currency in Europe †, as a term including various forms of markings referred to different genera. The dominant characters are a band, or an oval mass, with a median longitudinal furrow or ridge, and marked with transverse or oblique furrows or striæ, and with or without a marginal ridge.

The writer was enabled to show in 1864 ‡ that one of the most remarkable of these impressions, *Rusophycus grenvillensis* of Billings, and *Cruziana*-like markings associated with it, were really

* 'Science,' vol. v. no. 124, 1885, p. 508.

† In Senhor J. F. N. Delgado's 'Étude sur les Bilobites et autres Fossiles des Quartzites de la Base du Système Silurique du Portugal,' 4to, Lisbon, 1886, and the 'Supplément,' 1888, numerous bibliographic references to other authors treating of these and some allied fossils are given in full.

‡ 'Canadian Naturalist,' n. s. vol. i. pp. 363, 458.

burrows and tracks of marine animals, probably Crustaceans. He arrived at this conclusion by a careful study of the impressions made by the recent *Limulus polyphemus* on muddy and sandy bottoms, and by the application of these results to the explanation of a very fine exposure of the impressions above-named in the works undertaken for the enlargement of the Grenville Canal, on the Ottawa River. In this paper, descriptive of the facts observed at Grenville, it was proposed to substitute the generic name *Rusichnites* for *Rusophycus* or *Rysophycus*, and it was pointed out that the so-called fucoids of the genus *Arthrophyucus* were probably of like nature, and might be placed in the same category with the impressions described by Logan as *Climactichnites* from the Potsdam-Sandstone*. These observations were supposed to have conclusively settled the question as to the nature of all the *Bilobites*; but little attention seems to have been given to them by European Palæontologists. Nathorst has, however, arrived at similar results, in a somewhat similar manner, by comparison with modern impressions †; and Williamson has described as casts of animal-tracks markings of this nature from the Yoredale rocks ‡. Bureau has also adduced some striking evidences in favour of the theory that some at least of the *Bilobites* are the work of Phyllopod Crustaceans §. Saporta, Delgado, and others still regard the *Bilobites* as true Algæ, and Schimper describes one form as a plant, under the name *Crossochorda*. In so far as American examples are concerned, it may be considered as settled that they may best be explained in the way above indicated. The following genera may be included in this general statement:—

Rusichnites = *Rusophycus*, *Hall*.
Arthrichnites = *Arthrophyucus*, *Harlan*.
Cruziana, *D'Orbigny*.
Climactichnites, *Logan*.
Fræna, *Rouault*.
Crossochorda, *Schimper* (in part).

These impressions pass into *Protichnites* of Owen through such forms as *P. Davisi* of Williamson ||, and the *Særichnites* of Billings ¶ and *Diplichnites* of the author**. They are connected with the undoubted worm-tracks of the genus *Nereites* by specimens of *Arthrichnites*, of which I have several in my collection, and in

* *Canad. Nat. Geol.* vol. v. p. 279.

† *Kongl. Svenska Vetenskaps-Akad. Handlingar*, vol. xviii. No. 7, 1881; eleven plates, 104 pages, including an Abridgment in French. The List of Books and Memoirs treating of Trails and Tracks, from 1823 to 1881, occupies six of the quarto pages in this work. Also 'Nouvelles Observations sur les Traces des Animaux;' Stockholm, 1886.

‡ *Mem. Manchester Lit. & Phil. Soc.* 3rd series, vol. x. 1885, pp. 19–29, 3 plates.

§ *Comptes-rendus*, vol. 104, 14 Février et 4 Juillet, 1887, page 7 of the author's reprint.

|| *Op. cit.* pl. i. fig. 4.

¶ *Catal. Sil. Foss. Anticosti*, 1866, p. 73.

** *Amer. Journ. Sci.* ser. 3, vol. v. 1873, p. 19, and p. 23, fig. 3.

which the central furrow becomes obsolete, and by the genus *Gyrichnites* of Whiteaves, and other forms destitute of a median groove*.

They cannot be sharply divided into genera or species, because of their variability in passing over different kinds of bottom, and of the changes which occur in consequence of the various modes of progression employed by the animals.

Fig. 1 represents a typical specimen of *Rusichnites*, from my paper

Fig. 1.—*Rusichnites grenvillensis*. The cast of a Crustacean Burrow, with part of a trail leading to it, or from it, at *a*. Cambro-Silurian; Grenville, Canada.



of 1864, and shows traces of the trail leading to or from the cast of the deep burrow or excavation. Fig. 2, *Rusichnites acadicus*, from the Carboniferous, I now regard as a result of successive strokes of a crustacean tail, with marks of the carapace and limbs. The specimen represented in fig. 3, which is from the Clinton Formation of Canada (and from the collection of Lieut.-Col. Grant, of Hamilton, Ontario), illustrates the probable origin of these markings, but also suggests the idea of some of them having been the trails or castings of worms rather than marks of crustaceans. It is evident indeed that these markings are closely connected with those named *Nereites* by Hall, and of which he has figured several kinds from the Clinton formation, ascribing them to Molluscs. Similar objects have been named *Psammichnites* by Torell, and are supposed by him to resemble

* Trans. Roy. Soc. Canada, vol. i. 1883; Section iv. 1882, pp. 109-111.

Fig. 2.—*Rusichnites acadicus*. A Crustacean Track, showing the marks of the edge of the carapace. Carboniferous; Cape Breton.

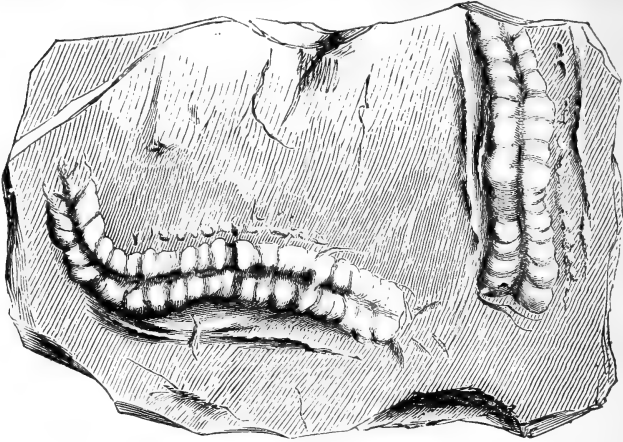


Fig. 3.—*Rusichnites* (*Psammichnites*) *clintonensis*, sp. nov. Silurian of Ontario, Canada. (From a Photograph.)



castings of the Lobworm*. I am indebted to Lieut.-Col. Grant for an extensive series of these markings, on which it can be seen that the same trail often assumes very different characters, sometimes resembling *Crossochorda* or *Cruziana*, and at others passing into the ordinary *Nereites* or even into a simple trail.

The *Protichnites* † of the Potsdam Sandstone are indubitable tracks of Crustaceans; yet it is possible, as I have shown in the case of *Limulus*, that the same animals which produced *Protichnites* may also have been the authors of the transversely ridged *Climactichnites* so often associated with them (figs. 4 and 5). It is also to be observed that such forms as my *Protichnites acadicus* ‡ or the *Pr. scoticus* of Salter § form connecting links between this kind of track and *Cruziana*.

To the same category may be referred the trails with wave-like transverse markings and no central line, found both in the Upper Cambrian and Devonian, and which Whiteaves has named *Gyrichnites*||.

I copy here the remarks on *Rusophycus* (*Bilobites*) in my paper of 1873, merely adding that I now believe some markings of this kind may have been produced by Chætopod Worms, as well as by Phyllo-pods:—

“In a paper published in the ‘Canadian Naturalist,’ 1864, I showed that the singular bilobate markings with transverse striæ, named *Rusophycus* by Hall, and found in the Chazy of Canada and the Clinton group of New York, are really casts of burrows connected with footprints, consisting of a double series of transverse markings, and that a comparison of them with the trails and burrows of *Limulus* justified the conclusion that they were produced by Trilobites. I proposed for these, and for similar impressions of small size found in the Carboniferous, the name given above. The Carboniferous examples, I supposed, might have been produced by the species of *Phillipsia* found in these beds. A specimen recently obtained from Horton shows this kind of impression passing in places into a kind of *Protichnites*, as if the creature possessed walking feet as well as the lamellate swimming feet which it ordinarily used.”

I can scarcely doubt that the *Cruziana semiplicata* of Salter, and *C. similis* of Billings from the Primordial of Newfoundland, must have been produced by Crustaceans not dissimilar from those to which *Rusichnites* belongs.

To *Rusichnites*, rather than to *Protichnites*, ought perhaps to be

* Lunds Univ. Årsskrift, vol. vi. p. 34, 1869.

† Logan and Owen, Quart. Journ. Geol. Soc. vol. viii. 1852, pp. 199–225. In the ‘Geologist,’ vol. v. 1862, pp. 128–139, and pp. 454–456, the probability of *Climactichnites* having been the infallen gallery-tracks made by *Paradoxides* burrowing in the sand of the old sea, like *Sulcator* and *Kroyera* (as shown by Albany Hancock) burrow in the present sea-sands, has been suggested. A similar explanation was given in Prof. Dana’s ‘Manual of Geology,’ 1863, p. 189. This does not, however, seem applicable to the Canadian specimens. See figs. 4 & 5, and further on.

‡ Amer. Journ. Sci. ser. 3, vol. v. 1873, pp. 17, 18, 23, fig. 2.

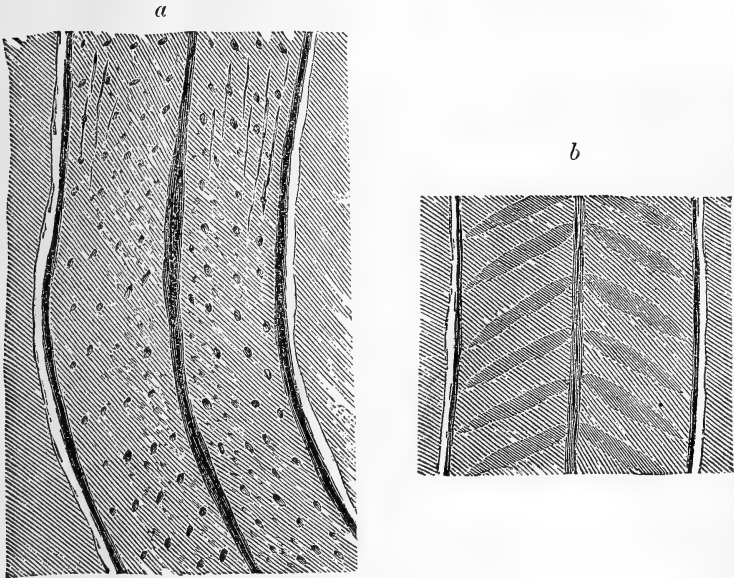
§ Quart. Journ. Geol. Soc. vol. xii. p. 243, fig. 2.

|| ‘Trans. Roy. Soc. Canada,’ *loc. cit.*

Fig. 4.—*Climactichnites* and *Protichnites*, associated on the same slab. From the Potsdam Sandstone of Ontario (in the Peter-Redpath Museum). About $\frac{1}{2}$ of natural size. The large slab is the *overlying* impression; the small one, placed below, is the *underlying* surface. (From a Photograph.)



Fig. 5.—*a*, Protichnite-like ; *b*, Climactichnite-like Trails of *Limulus polyphemus*. Modern. Coast of Maine.



referred certain transverse linear impressions with a broad central groove from the Lower Carboniferous of Horton, which occur at that place under different modifications, and sometimes seem to change into light scratches, or touches of feet employed in swimming, or end abruptly, as if the animal had suddenly risen from the bottom.

Nathorst* and Bureau have further shown that impressions similar to *Bilobites* may be produced by the successive strokes of the tail of certain Crustaceans (*Crangon* and *Palæmon*). From all the phenomena attending the Potsdam *Climactichnites*, I am now inclined to regard them as of this nature, and as implying the existence of a large Crustacean with a truncated tail divided into two movable lobes. This would account for the ridge sometimes dividing the furrows and transverse ridges, and for its change of position from side to side of the mesial line,—also for the interrupted ridges on each side of the trail, which would be the natural result of the successive strokes of a flat organ,—and for the appearances presented when the tracks turn abruptly † (see fig. 4).

There is confessedly some difficulty in separating the marks known as *Phymatoderma* from Fucoids allied to *Caulerpa*, and even from

* Trans. Roy. Acad. Sweden, vol. xviii. no. 7, 1881.

† "Impressions of Aquatic Animals," 'Amer. Journ. Sci.' ser. 3, vol. v. 1873, p. 16.

stems of the coniferous genus *Brachyphyllum*; but Zeiller has recently described a roofed tunnel or burrow made by the mole-cricket, which completely reproduces some of the forms known under the name *Phymatoderma*.* I have in my collection (fig. 6) a

Fig. 6.—Roofed Burrow: *Phymatoderma*. Silurian; Ontario, Canada. (From a Photograph.)



specimen, collected by Col. Grant in the Clinton formation, which shows that some Silurian animal, possibly a Crustacean, made covered burrows of this kind.

§ III. SCOLITHUS, &c. (Figs. 7 to 10.)

This genus, proposed by Haldimand as early as 1840, though the name would indicate that it refers to a worm, was originally placed with Fucoids; and both Hall and Billings regarded the cylindrical cavities, designated by the title, as representing "stems." No evidence, however, has been found of any organic matter in connection with *Scolithus*; the tubes being usually filled with a sandy argillaceous or calcareous material, which weathers out of the hard matrix, leaving cylindrical holes.

* Bull. Soc. géol. France, sér. 3, vol. xii. 1884, pp. 676-680.

Two species have been recognized in the Potsdam Sandstone of Canada and the United States, *Scolithus linearis* of Hall and *Sc. canadensis* of Billings. The former is usually straight, at right angles to the bedding, and smooth, or with obscure striation. The latter is rather smaller, tortuous, and unequal in diameter, sometimes branching and curving, and occasionally showing slight transverse ridges on the sides of the cylinders.

The latter species is very abundant in the Potsdam of St. Anne's on the Island of Montreal, where many varieties can be collected; but none of them shows any distinct structure. So far as indicated by the ordinary specimens, they may be moulds left by the decay of plants, sponges, or corals, or by the stems of *Lingulæ*, or the burrows of worms.

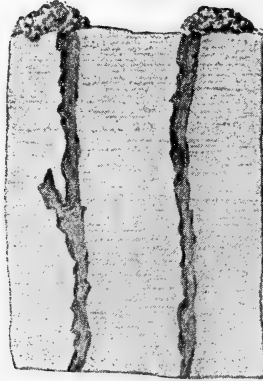
Fig. 7.—Slab with castings of *Scolithus*. Perth, Ontario.
(From a Photograph.)



Their true nature is made evident by a fine slab kindly presented to the Peter-Redpath Museum by Mr. W. J. Morris, of Perth, Ontario. A portion of the upper surface of this slab is represented in fig. 7, which shows rounded pellets and ridges of hardened sand, very

similar to those ejected by many modern worms from their burrows. From these the tubes of *Scolithus* descend into the sandstone in the manner represented in fig. 8. It is, I think, quite evident that this variety of *Scolithus* represents burrows with castings at their entrances; and, since it is referable to *Sc. canadensis*, I have no hesitation in affirming that this interesting specimen indicates that

Fig. 8.—Sectional view of *Scolithus*, showing castings at the orifices. Perth, Ontario.



that species at least must be regarded as a worm-burrow. From the forms of these burrows it is not improbable that they may have been lined with a fine membrane sufficient to protect the body of the animal from the roughness of the sand, and that this lining may have aided in preserving their forms.

It is to be observed with reference to burrows of this kind, that under different circumstances their orifices may present very different appearances. Where the castings from them have been removed by a rapid current, they may have merely a simple opening at the summit. Where the animal has moved inward and outward, enlarging the opening, they may be funnel-shaped at top, like the burrows to which the term *Monocraterion* (Torell) has been applied; and, where the worm has made grooves radiating from the orifice, forms similar to *Scotolithus mirabilis* of Linnarsson*, or the forms which have been named *Pyrophyllites* and *Asterophycus*, may have been produced. I do not maintain that the forms indicated by the above names are identical with *Scolithus canadensis*, but I have seen in connection with that species appearances resembling these forms. Fig. 9 shows a form of this kind; but it is from a higher horizon, the Clinton, from which formation I have also funnel-topped burrows, like those of the Cambrian *Monocraterion*.

The singular radiating markings, from the Cambrian of Nova Scotia, which I have described as *Astropolithon Hindii*, and which

* Trans. R. Swed. Acad. Sci. vol. ix. 1871, p. 18, pl. v. figs. 21, 22.

Fig. 9.—*Radiating Burrow*. Silurian; Ontario, Canada.
(From a Photograph.)



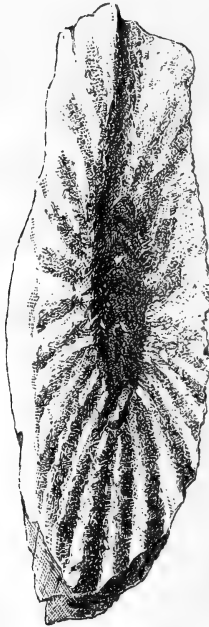
also occur in the Quebec Group at Metis, Canada, may possibly have the character of mouths of large burrows with radiating trails, though the radiating marks in this case seem to be of the nature of vertical plates, rather than of grooves (see fig. 10).

§ IV. *SABELLARITES*, gen. nov. (Figs. 11 & 12.)

The modern genus *Terebella*, which constructs tubes of grains of sand and fragments of shells attached to a membranous lining, has been recognized by its tubes as low as the Lias (*T. capilloides*, Goldf.), and I have ascertained the existence of similar tubes as low as the Siluro-Cambrian; though, as the tubes do not necessarily indicate the precise affinities of the animal, I prefer to designate them by the name above given, and to define this as indicating elongated tubes composed of grains of sand and calcareous organic fragments,

associated with carbonaceous flocculent matter, indicating a horny or membranous sheath. I have long suspected the existence of such tubes, and their connection with many of the cylindrical bodies often confounded with fucoids of the genera *Palæophycus* and *Buthotrephis*, but have only recently been able actually to demonstrate the fact.

Fig. 10.—*Astropolithon Hindii*, a burrow or organism from the Lower Cambrian of Nova Scotia. ('Acad. Geol.' 3rd ed. Suppl. 1878, p. 83.)



In the Black-River Limestone (Trenton group of the Siluro-Cambrian) at Pointe Claire, on the St. Lawrence, near Montreal, certain layers of grey limestone contain numerous dark-coloured, cylindrical, tortuous bodies, from $\frac{1}{10}$ th to $\frac{1}{8}$ th of an inch in diameter. When broken across, they are seen to be filled with crystalline calcite, as if they had been tubes; and, when thin slices are prepared for the microscope, the character of their walls, as composed of fragments of stone and broken shells &c., cemented by an organic material, now carbonised, becomes apparent. Figs. 11 and 12 show the appearance of the tubes on the weathered surfaces, and in section. The species may be thus described:—

The tubes are 1 to 3 millimètres in external diameter, and 3 centimètres or more in length, tortuous, irregular as if sometimes compressed, and sometimes in groups of two or more attached together. This would show a fixed or sessile condition as in *Sabellaria* or *Sabella*, rather than freedom, as in the *Terebellidae*.

Fig. 11.—*a, b, c, Sabellarites trentonensis*. *a*. On a weathered surface; nat. size. *b* and *c*, enlarged. Black-river Limestone; Pointe Claire, near Montreal.

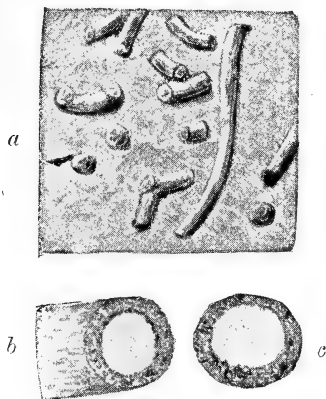
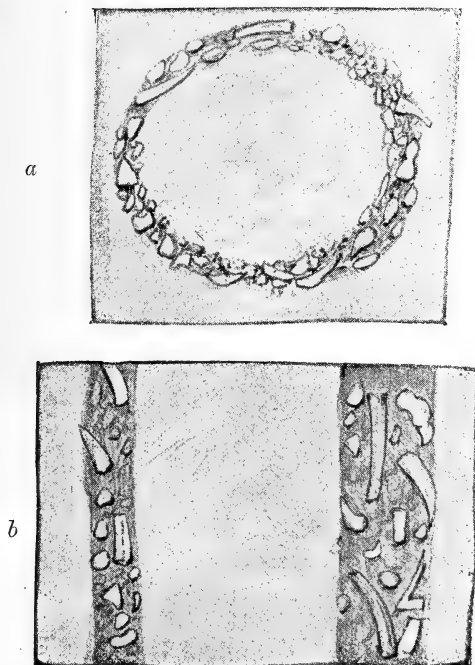


Fig. 12.—*a, b*, Transverse and Longitudinal Sections of *Sabellarites*. (Enlarged.)



The wall of the tube is somewhat thick and composed of fragmental matter, cemented by a dark-coloured organic substance. It is to be observed that in the case of tubes, as distinguished from mere burrows, like *Scolithus*, when two or more are attached together an appearance of branching results.

Tubes apparently of similar character, but of considerably larger size, occur in the same formation; and many obscure cylindrical or flattened bodies, not distinguished from branches of Algæ, may be of the same nature. I would also refer to a similar origin, and provisionally to this genus, the curious primordial burrows from the Hastings group described in the Quarterly Journal of this Society * in 1866, and the phosphatic tubes from the limestone of the Quebec group at Kamouraska, described in the Quart. Journ. Geol. Soc. in 1876†. The latter, however, I fancy are composed of excrementitious matter, or débris of the food of worms feeding on Linguoid shell-fish.

While preparing this paper, I have re-examined these tubes, and have had some new slices prepared. These confirm my previous statements. The thick walls of the tubes are destitute of lamination, and have a finely granular texture, resembling that of the paste of coprolites. They contain a few fine grains of sand, and minute fragments of shells and of carbonaceous fibres. The whole seems to indicate that they are formed, as already stated, of the phosphatic dejections of animals subsisting on *Lingula*, *Trilobites*, *Hyolithes*, and other creatures having coverings of calcium-phosphate.

In the same paper I referred to the fact that the shells of *Hyolithes* ‡ [*Hyolithellus*, and *Salterella*] are rich in phosphates, and that some of these shells are thick-walled with concentric lamination and with tubes or pores penetrating their walls, suggesting the idea that they may be shells of Worms rather than of Pteropods. I have since compared them with specimens of the singular phosphatic tubes found not infrequently in the Trenton and Chazy formations, and described by Billings under the name *Serpulites splendens* and *S. dissolutus*. Specimens of these tubes, when sliced, show a structure not fragmental, but composed of very fine concentric laminæ, with indications, in some specimens, of minute sinuous tubuli. They are smooth internally, and without show indications of thickened ridges and of transverse lines of growth. One of my specimens has been coated externally with a thin layer of some Monticuliporid coral. If these are worm-shells, of which there seems little doubt, they suggest affinities with the phosphatic *Hyolithellus* and *Salterella*.

It may, perhaps, be useful to suggest provisional names for the arenaceous and phosphatic worm-tubes resembling those of *Sabellaria* and here described. Those from the Black-River formation may be named *Sabellarites trentonensis*; and the thick-walled phosphatic tubes, from the Quebec group, *S. phosphaticus*.

* Vol. xxii. p. 608. In the paper of 1866 these are referred to as from the Laurentian of Madoc, Ontario. Since then these beds have been recognized as being later than Laurentian, possibly Huronian, and designated the "Hastings group."

† Vol. xxxii. p. 286.

‡ *Op. cit.* p. 288.

§ V. TRUNK-LIKE CONCRETIONS IN THE POTSDAM SANDSTONE.
(Fig. 13.)

Many years ago specimens were obtained from the Potsdam Sandstone of Ontario, by the late Sir William Logan, which presented the aspect of large cylindrical trunks, a foot or more in diameter. They were casts in sandstone, without any external bark or organic matter, though showing obscure concentric lines on the ends. No opinion was, I believe, hazarded at that time respecting their origin; and more recently fine specimens have been collected by Dr. Selwyn on the bank of the Rideau Canal near Kingston; and Mr. A. Young, a student of McGill University, obtained others at Almonte, which he presented to the Peter-Redpath Museum. One of these is represented in fig. 13.

Fig. 13.—*Trunk-like Concretion.* Potsdam Sandstone; Almonte, Canada. $\frac{1}{8}$ nat. size. (From a Photograph.)



An incidental light seems to have been thrown upon their nature by the study of certain recent concretions, now forming in the alluvial clay of the St. Lawrence, by Rev. Prof. Kavanagh, of Montreal. These are small cylindrical bodies with a minute per-

foration in the centre, often containing a little vegetable matter. They were thus described* :—

“These little bodies are evidently clay concretions formed around vegetable fibres, and hardened by a small percentage of calcium carbonate, since when treated with hydrochloric acid they effervesce feebly and become disintegrated. They probably originate in the molecular aggregation of the calcareous matter in the clay around any foreign body included in it. They are about half-an-inch in diameter, and the largest may have been two inches in length; with rounded ends. When broken, they show a small central canal containing a little sand and strips of epidermal tissue, the remains of a root or stem. One shows three branches, apparently proceeding in a verticillate manner from a central stem. In the centre, the light reddish-brown colour of the clay has assumed a greenish hue, owing to deoxidation of the peroxide of iron by decay of the vegetable nucleus.”

On comparison of these recent concretions with the Potsdam cylinders, it becomes apparent that they resemble each other very closely in form and structure, and that the older cylinders may have been formed in a similar manner, though on a gigantic scale. In confirmation of this view, it may be mentioned that in the Pleistocene clays of Green's Creek, on the Ottawa, cylindrical concretions surround twigs of poplar, which have been imbedded in the clay, and that in the Permian Sandstones of Prince-Edward Island ferruginous matter has cemented the sand into cylindrical concretions around stems of Calamites. This view as to the origin of the Potsdam cylinders is further confirmed by the rounded ends of some of them, and by the conformity of the internal concentric structure to this rounding. One of the smaller specimens in the Peter-Redpath Museum shows this peculiarity very well.

In the case of the Potsdam concretions, the nucleus of the concretion must have been an erect stem of some kind, possibly a *Chorda*-like *Alga*. So far as appears, this central stem must have been very slender, but no distinct traces of it have yet been observed. Perhaps the most remarkable fact in the case is that these cylindrical bodies are sometimes several feet in length, and pass through more than one bed of the sandstone. Another peculiarity is the presence in some of them of irregularly rounded cavities, apparently indicating the presence of bodies either concretionary or organic which have been removed by solution or decay. These, however, are very rare.

§ VI. COMBINATIONS OF WORM-TRACKS WITH RIPPLE-MARKS AND SHRINKAGE-CRACKS. (Figs. 14 & 15.)

Fig. 14 shows a rippled surface in Potsdam Sandstone with marks of worms or molluscs, arranged in the hollows of the ripples. The marks are simple trails, of that curious circular or chain-like form sometimes observed, and seem to have been made by animals creeping in the furrows between the ridges of the ripple-marks.

* ‘Canadian Record of Science,’ vol. iii. No. 5, January 1889, pp. 292-294.

Photograph No. XI. (not figured) shows another combination, where numerous trails formed in soft sediment have been affected by shrinkage-cracks, produced by the drying of the mass, in such a manner as to present a very complicated appearance.

Fig. 14.—*Combination of Worm-trails and Ripple-marks.*
Potsdam Sandstone ; Canada. $\frac{1}{3}$ nat. size. (From a Photograph.)



Still another appearance which may be placed under this head is that in fig. 15, which represents part of the surface of a large slab of Calciferous Sandstone from St. Anne's. At first sight it seems to be covered with a network of shrinkage-cracks, but on closer inspection these are seen to be cylindrical worm-tracks or burrows planed off and flattened on one side, as if a slab covered with casts of worm-tracks had been rubbed or ground down till the originally rounded sides of all the more prominent were flattened. The only way in which it seems possible to account for such an appearance is to suppose that the tracks were partly filled with mud incapable of hardening into stone, and then completely filled and

covered with a bed of sand, hardened afterwards into rock. The effect would be that, on weathering, all the prominent parts filled with mud would disappear, leaving the slab in its present state.

Fig. 15.—*Worm-burrows seen in section, owing to the manner of preservation and weathering. Calciferous Sandstone; St. Anne's. (From a Photograph.)*



All of these tracks or burrows are of the plain cylindrical forms to which the terms *Planolites*, Nicholson *, and *Arenicolites*, Salter †, have been applied, and which differ from *Scolithus* only in their more tortuous character, and in their usually being casts of mere trails on the surfaces of beds, rather than burrows or tubes penetrating them. I cannot doubt the origin of these markings, if for no other reason, on account of their covering such great surfaces of strata in a uniform manner.

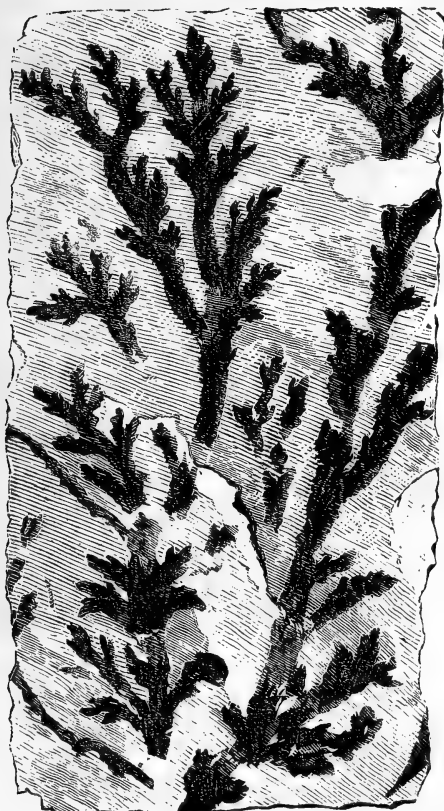
* 'Proceed. Roy. Soc.' vol. xxi. 1873, p. 289; 'Manual Palæont.' edit. 2 vol. i. p. 320.

† 'Quart. Journ. Geol. Soc.' vol. xiii. 1857, p. 204.

§ VII. BRANCHING TRACKS. (Fig. 9, page 605.)

It is very puzzling to the Ichnologist to find so many impressions which he would regard as of animal origin branching in a manner to simulate plants. The distinction, however, between branching plants and branching tracks is usually sufficiently obvious to an experienced eye. The latter are generally of the nature of more or less cylindrical bodies, diverging or radiating from a common centre; while the former display either alternate ramification or bifurcation. As examples I may refer to Photograph No. XIII. (not figured) of *Buthotrephis gracilis*, and *B. Grantii*, figs. 16 and 17, true Fucoids, in

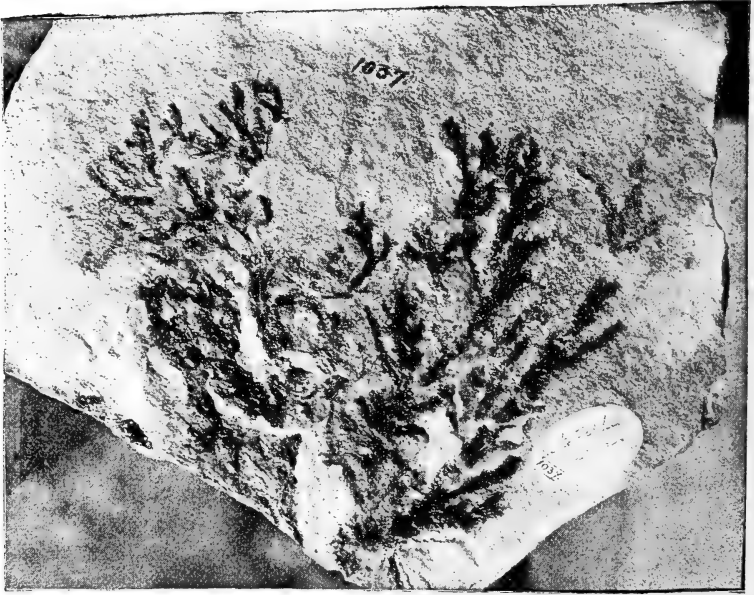
Fig. 16.—*Buthotrephis Grantii*. A true Fucoid, from the Silurian of Canada.



comparison with fig. 9 (above referred to), of radiating Annelid marks, or Photograph No. xv. (not figured), which represents a *Licrophycus*, probably a burrow with diverging tracks. Simple and branching trails of these kinds cover large surfaces of the Cal-

ciferous formation at St. Anne's, and are similar to markings of this kind which I have described from the Lower Carboniferous of Nova Scotia*.

Fig. 17.—*Buthotrephis Grantii*. A true Fucoid: carbonaceous. Niagara Formation. $\frac{1}{2}$ nat. size. (From a Photograph.)



§ VIII. RILL-MARKS, AS DISTINGUISHED FROM ANIMAL- OR PLANT-IMPRESSIONS. (Figs. 18 & 19.)

In my 'Acadian Geology' I have described the remarkable appearances simulating Algæ, or even gigantic trees, produced in the sloping banks of fine mud in the tidal channels of the Bay of Fundy. These are formed by minute rills, oozing from the wet sand or mud, and trickling in fine streams along the slimy surfaces, and uniting into larger and larger streams so as at length to produce the likeness of impressions of flattened trees, with large trunks and branches, dividing into twigs of extreme tenuity. Similar surfaces are often found in the Coal-formation, and sometimes on quite as large a scale as in modern tidal estuaries. Their forms and arrangement differ according to the slope and character of the sediment, and the amount of water it contains; but all show very delicate and often regular branching impressions. Figs. 18 and 19 represent two types of these in my collection from the Carboniferous of Nova Scotia, and

* 'Acadian Geology,' p. 256.

taken from surfaces unquestionably sculptured by water. A curious complication of such markings sometimes occurs when shrinkage-cracks, overflowed by a succeeding tide, have their edges sculptured by minute rill-marks. *Dictuolites Beckii*, of Hall*, is a remarkable example of this.

Fig. 18.—*Rill-mark*. Carboniferous; Nova Scotia.
 $\frac{1}{2}$ nat. size. (From a Photograph.)



It would be invidious to refer to the numerous species of imaginary fossil plants that have been founded on such markings as those referred to above and shown by figs. 18 and 19. I may merely mention the genera *Dendrophyucus*, *Delesserites*, *Vexillum*, *Aristo-*

* 'Palæontology of New York,' vol. ii. 1852, p. 6, pl. 2. fig. 1.

phycus, *Chloëphycus**, *Tricophycus* of authors as examples of genera which contain, or consist of, examples of Rill-marks.

I may add that I have discussed other forms of such impressions in my papers on Footprints of *Limulus*, and on the genus *Rusichnites*, in the 'Canadian Naturalist,' and in that on "Impressions of Aquatic Animals in the Carboniferous Rocks"†. In my work, 'The Geological History of Plants', I have also endeavoured to state the criteria for

Fig. 19.—*Rill-mark*. Carboniferous; Nova Scotia.
 $\frac{1}{2}$ nat. size. (From a Photograph.)



separating such markings from true *Algæ*, and have referred to instances in which, while, on the one hand, mere markings have been elevated into marine plants, on the other, true land plants, imperfectly preserved, have been degraded into *Algæ*. I may also state that in America the Clinton formation, intervening between the Medina Sandstone and the Niagara Limestone, and containing many thin-bedded arenaceous and argillaceous deposits, is remarkably rich in such impressions. Many of these have been figured by Prof. Hall‡ and referred to worms, crustacea, and gastropods. In the vicinity of Hamilton, Ontario, large collections have been made by Lt.-Col. Grant, who has enriched the Peter-Redpath Museum of

* Miller now admits that this is not an *Alga*.

† Amer. Journ. Sci. ser. 3, vol. v. 1873, pp. 17, &c.

‡ 'Palæontology of New York', vol. ii. 1852.

McGill University with a very large and instructive series of slabs including a vast variety of forms, a few only of which have been noticed in this paper.

[I desire also to remark that the facts above detailed, together with the discoveries of Annelid-jaws by Hinde and others, show that the Marine Worms must have culminated, in regard to size, abundance, and range of organization, at a very early geological period.—September 9th, 1890.]

I need not refer to the well-known and important observations of Nathorst, Williamson, Owen, Miller and James of Cincinnati, Zeiller, Salter, and others on this subject, or of the able defence of the Algoid nature of some of them by Delgado, Saporta, and Crié. My object has been merely to give some clear and instructive examples which may tend to settle some of the points which have been in dispute.

The whole of the specimens referred to in the above paper are, with many others, in the Peter-Redpath Museum of McGill University. A number of them are large slabs, of which only a portion or a reduction could be given in the photographs.

§ IX. NOTES.—I append, as an interesting impression, Photograph xx. (not figured), which shows part of a rain-marked surface from the Devonian of Gaspé, which has subsequently curled up and cracked in drying, in the manner which may often be seen in modern pools, when dried up.

I should perhaps add that, after many unsuccessful attempts, I have been able to find vegetable structure on only one specimen of any of the so-called Algæ of the Lower Palæozoic rocks. This is a flattened cylinder referable to the genus *Palæophycus*, from the Trenton Limestone. Its structure is somewhat imperfect, but shows long sinuous tubes like those in the stems of some Laminariæ. All the other Algæ of these older formations that I have met with are either reduced to carbonaceous films destitute of structure or are mere impressions without organic matter.

[Since the above paper was written Mr. G. F. Matthew has given (Amer. Journ. Science, ser. 3, vol. xxxix. 1890, p. 145) a notice of some worm-burrows, from the Lower Cambrian of New Brunswick, which he regards as similar to those described by Torell from the Eophyton- and Furoid-sandstones of Sweden, and certain remarkable markings from the still older Animikie formation of Lake Superior. These last are of two kinds, curved divergent marks (*Taonichnites*), and straight striæ, crossing at acute angles (*Ctenichnites*). The specimens, from the Cambrian of Canada, referred to *Eophyton* seem, so far as known, to be of the nature of the straight markings which I have elsewhere named *Rhabdichnites*.—J. W. D., September 9th, 1890.]

[NOTE.—Lesley ('Dictionary of Fossils,' p. 1195) refers to a specimen, found by Walcott, showing the shell of a large Mollusk at the end of a track resembling *Rusichnites*. Billings and Nathorst have shown that some transversely-wrinkled tracks may have been produced by the foot of Gastropods.—J. W. D., October 2nd, 1890.]

DISCUSSION.

Prof. HUGHES would like to see a combination of geologists and zoologists discussing each one of the various marks. He had paid most attention to *Cruziana*, and was glad to find that the Author agreed with him that it was impossible to refer it to any surface-track, and difficult to explain it on the hypothesis of its representing the form of any soft-bodied animal such as *Nereis*.

Dr. HINDE observed that for many years the origin of these marks had been discussed. He thought that most of them were the tracks and filled-up burrows of marine organisms. The fact that no carbonaceous matter had been found with these forms in the different countries where they occurred was opposed to the theory of their plant-origin. On the other hand, he had obtained undoubted Annelid remains from some of the very beds containing these markings.

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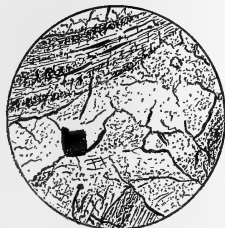
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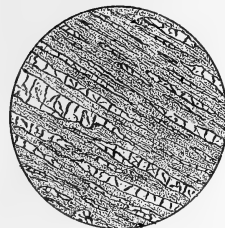
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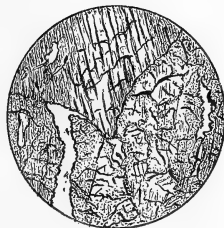
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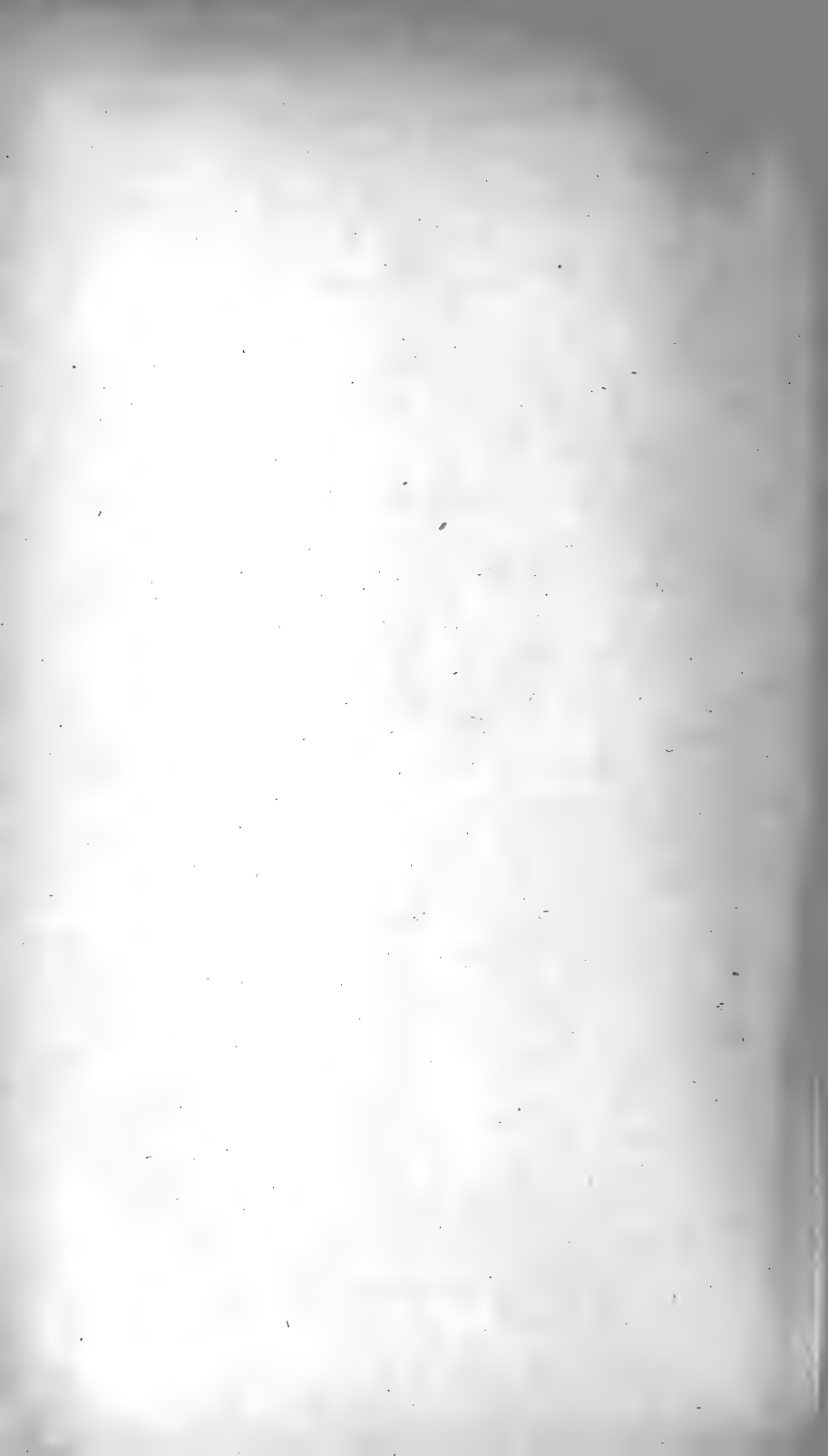
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9



SECTIONS OF PERIDOTITE
from the Red-Hill and Olivine Ranges, South Island, New Zealand.



38. *On the DISCOVERY, MODE OF OCCURRENCE, and DISTRIBUTION of the NICKEL-IRON ALLOY AWARUITE, on the WEST COAST of the SOUTH ISLAND of NEW ZEALAND.* By Professor G. H. F. ULRICH, F.G.S. (Read June 4th, 1890.)

[PLATE XXIV.]

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Introductory.

IN October 1885 Mr. W. Skey, Government Analyst, read a paper before the New Zealand Philosophical Society, Wellington, announcing the discovery of a Nickel-Iron Alloy, which he recognized as a new mineral species and named "Awaruite." The discovery was made in a collection of minerals sent to the Government Laboratory by Mr. Macfarlane, the Warden of the Jackson's Bay District, which includes Big Bay (Maori name, "Awarua"), Barn Bay, and other Bays in that part of the West Coast of the South Island. Mr. Skey found the new mineral as small grains or scales in a sample of heavy black sand, reported as saved by alluvial miners in Barn Bay; and he gave in his paper, besides descriptions of the physical character of the alloy and its mineral associates, interesting particulars concerning its behaviour towards a solution of cuprous sulphate acidulated with hydrochloric acid, and its quantitative chemical composition as:—Ni=67·63, Co=0·70, Fe=31·02, S=0·22, SiO₂=0·43; Formula = 2Ni+Fe; Sp. Gr.=8·1; Hardness about 5. He considered the alloy as the *second* of its kind, of terrestrial origin, so far discovered, under the impression that the known Nickel-Iron "Oktibbehite" (Ni+Fe), which is a meteorite found in Oktibbeha City, North America*, was the *first* alloy of this kind of terrestrial origin; and he also suggested that the mineral would be found in some basic rock in the vicinity of Barn Bay. Mr. Skey's paper appeared in the Transactions of the New Zealand Institute for 1885, and was reprinted with some additions in the Annual Report, for 1885-86, of the Colonial Museum and Laboratory, Wellington. The additions concerned the results of Mr. Skey's examination of other three samples of heavy black sand: namely, no. 1, from Barn Bay, contained no Awaruite; no. 2, from Callery's Creek, contained 4%; and no. 3, from the Gorge River, 45·36%. Amongst other minerals sent with the samples of black sand Mr. Skey mentions a hydrous ferruginous serpentine; and in a footnote he states "this serpentine proves to be the matrix of the nickel-mineral Awaruite, in which

* Wadsworth's 'Lithological Studies,' Table II, p. xiv.

it is dispersed in minute grains, in the same manner as metallic copper occurs in serpentinite in Aniseed Valley near Nelson."

On seeing the notices about Mr. Skey's first paper (October 1885), giving full particulars regarding discovery, composition, &c., of the new mineral, in the daily newspapers, and being cognisant of the fact of Oktibbehite being a meteorite, and therefore Awaruite not being the *second* (as Mr. Skey supposed), but really the *first* nickel-iron alloy of telluric origin, a fact that greatly heightened the scientific interest attaching to it, I at once communicated with some friends at Hokitika and Ross on the West Coast, and was successful in procuring, through their agency, a small parcel of the nickeliferous sand. In order to gain information regarding the special locality of occurrence of the alloy, and, what was of most importance, about the nature of the rocks in the vicinity from which it was likely to be derived, I also wrote to Mr. Gerhard Mueller, Chief Surveyor, Hokitika, and Mr. D. Macfarlane, Warden of Jackson's Bay, two men to whom before all others belongs the credit of having by dangerous explorations procured nearly all the reliable information we have of the topographical and geological features of that wild part of the West Coast in which the new mineral was found.

Mr. Mueller kindly responded by furnishing me with a copy of the topographical plan (p. 624) of the country under notice, which he had prepared from his surveys and explorations, and also with his Report thereon; while Mr. Macfarlane was good enough to inform me that the Red-Hill mountain-complex and the Olivine Range, depicted on Mr. Mueller's plan, largely consisted of olivine-rock, which he was the first to recognize as such, and on account of which Mr. Mueller adopted the name Olivine Range. Regarding my request for specimens of the rocks from the locality where the Awaruite occurs, he intimated his intention of shortly making a journey through the district, when he would specially collect for me the specimens asked for. This journey did not, however, take place, and no further information was received until the beginning of May 1886, when two of my students, Messrs. Henderson and Batement, submitted to me a small collection of rocks and mineral specimens which during the early part of the year they had brought from an exploring-trip extending from the head of Lake Wakatipu across the Dividing Range and through the Red-Hill district down to the west coast of the Island. They had spent several weeks in exploring the wild, inhospitable region of the Red Hill, an enterprise only rendered possible through the fortunate circumstance that just at that time a well-equipped party of gold-prospectors were camping on the Red Hill, at a height of near 3000 ft. To one of them, Capt. Malcolm, I am indebted for several rock-specimens mentioned further on. The collection mentioned, owing to difficulty of carriage, consisted mostly of chips and small pieces, amongst which varieties of peridotite and serpentinite claimed most attention. The several specimens are more specially described in the sequel. They were obtained in various places on the Red-Hill Range, along the red-weathered

outcrop (hence the name "Red-Hill") of the peridotite; but those of the serpentine varieties come principally from the slope of the range, falling towards the Jerry River, a tributary of the Gorge River. One of these latter specimens, of thin lamellar (antigorite-like) structure, was found to be impregnated with fine specks, of silvery-white colour and metallic lustre, which on examination proved to be the new mineral Awaruite. In most of the other serpentine specimens whitish metallic-looking specks were also discovered, but they all turned out to be pyrite, except in one piece of common dark green serpentine, which yielded after crushing and washing, from amongst a small amount of pyrite-powder, a small hackly grain of the alloy.

Up to the time of this discovery of the matrix-rock of the Awaruite nothing was known or had been published about a similar discovery by anyone elsewhere *; but in answer to a letter I wrote to Mr. Macfarlane, pointing out the discovery and asking for any specimens of peridotite and serpentine he might have preserved from his previous explorations, he informed me that he had also noticed the metallic specks and would send a number of specimens containing them. These I received some months later, but found only two specimens (dark-green serpentine) with unmistakable Awaruite in them, the metallic specks in the remainder proving to be pyrite. Considering the great scientific interest attaching to the discovery of the mineral and its matrix combined, because of the apparent close relationship of the occurrence to certain of the stony meteorites, and apprehending the find in danger of being quite overlooked, from the fact that, although made public in New Zealand nearly a year previous, no notice of it had up to that time appeared in 'Nature' and other English and foreign scientific journals of eminence, I wrote letters to a number of distinguished authors, specially interested in the study of the peridotite rocks in England, America, and Germany, giving the main particulars of the occurrence of the mineral and the results of Mr. Skey's work. The President of the Geological Society at that time, Professor Judd, being one amongst the number, considered my communication of sufficient interest to be brought before the Society, and announced at the same time my intention of submitting a paper regarding the discovery, provided I was successful in procuring more detailed information about the geology of the country in which it was made, and more material to work upon †. In

* Mr. Skey's footnote to his second paper in the 'Annual Report of the Colonial Museum and Laboratory,' quoted in the foregoing, appeared several months after my find became known.

† In the 'Abstract of the Proceedings' of the Society at that Meeting, Quart. Journ. Geol. Soc. vol. xliii. 1887, *Proceed.* p. 3, the credit of having discovered the Awaruite is given to me, no doubt through some misunderstanding, whilst Mr. Skey, as the analyst and namer of it, is not mentioned; and it is further stated that I consider Awaruite and the meteorite Oktibbehite as identical in chemical composition. In consequence of these mistakes Sir James Hector, the Director of the Geological Survey of New Zealand, in a letter in the March number of 'Nature' 1887, casts a suspicion of piracy upon me regarding the discovery of the mineral, and accuses me of ignorance as to the second point, although perfectly innocent on both these charges, as my letters to Professors

pursuance of this project I have since written to and interviewed a number of persons who, I thought, could aid me in the matter. The results of these endeavours have not, however, I am sorry to say, come up to my expectations, owing to loss and damage of specimens sent to me, and various other mishaps. Thus my hope that some, from amongst quite a little army of prospectors (about 150 men) who, aided by the Government, landed towards the end of 1886 in Big Bay, would collect and send specimens was quite disappointed, as not one of the party penetrated as far inland as the Red Hill. In fact they soon became so dissatisfied with the hard work of exploring the rough country that they hurriedly left the district in troops, and very soon after not one of them remained. In 1887 I was, however, gratified in receiving from Mr. Macfarlane a larger sample of the Awaruite-bearing sand from the Gorge River, together with portion of a serpentine pebble of nephritic aspect, containing small specks of Awaruite. During the same year, and again in 1888, an intrepid, enterprising prospector, Mr. Robert Paulin, with several hired men, traversed the Red-Hill district in various directions, prospecting the rivers and creeks; and from him I received last year, besides a few more specimens of serpentine and other rocks, some valuable notes, accompanied by a sketch-plan of the district, indicating the distribution of the Awaruite and the extent of the peridotite and serpentine rocks. The several small rock-samples so far enumerated, of which the collection brought by Messrs. Henderson and Batement was the most diversified and important, have thus been all the material available to work upon; whilst regarding the general geological structure of the country, and more especially the mode of occurrence and extent of the peridotite and derived serpentine rocks, I can only give an imperfect outline, gathered from the reports and notes received from Mr. Gerhard Mueller, Messrs. Henderson and Batement, Mr. Macfarlane, Capt. Malcolm, Mr. Paulin, and several other persons I met since who have traversed the district.

2. Geology and Description of the Rocks.

Regarding the general geological structure of the country it is reported that the ranges from near the sea-coast inland to the ice-clad Dividing Range, except where broken through by the peridotite and derived serpentine rocks, consist of metamorphic schists (gneiss, mica-schist, and chlorite-schist) with occasional massive protrusions and probably large dykes of granite and quartz-porphry. Judging from a few small specimens obtained from Mr. Paulin, the granite is medium-grained and rather felspathic (felspar flesh-coloured), with principally dark mica; whilst the gneiss and mica-schist are of ordinary character, showing also mainly dark mica. Where the

Judd, Bonney, and others can prove. I have nevertheless considered it necessary to lay before the Society the foregoing succinct statements of facts relating to the matter, which will afford the explanation which Sir James Hector says the case requires.

spurs from the high ranges do not directly dip steep into the ocean, massive deposits of sandstone and shale and in some cases limestone, of probably older Tertiary age, overlie the old rocks along the coast to pretty high up the easy slopes of the spurs; whilst down the main river-valleys, mostly on both sides, descend extensive high terraces of boulder-drift and hard conglomerates, of morainic character in the higher parts of the valleys. In the embouchures of the rivers there are generally bars or delta-like accumulations of more recent drift. The prospecting of the terrace-drifts for gold and tracing the gold to its original deposits (quartz-reefs) was the main object of the large prospecting party previously referred to.

Coming now to the peridotite and serpentine rocks, the following extracts are of importance. The Chief Surveyor, Mr. Gerhard Mueller, in his report of his explorations*, states on this head as follows:—"The most remarkable feature about the district appears to me to be that of the Olivine Range on the East of Cascade River. It is a red and violet looking mass, and, from about 1000 ft. above the river, devoid of almost every vestige of vegetation. It is of the same formation of which the Cascade Plateau and a great part of the country of the Gorge and Jerry valleys consist. The Red Hill (5000-6000 feet) itself is olivine-rock, whilst the spurs running therefrom are a sort of greyish slate with grey granite belts here and there through them. An extraordinary red granite belt is seen in the Jerry River a little above the proposed road-crossing. The olivine formation is traceable as far as the Humboldt Mountains; the last indication of it I saw on the Cow Saddle, from which the Barrier and Olivine Branches (Creeks) and the Hidden-Falls Creek rise; the extent of it there does not exceed a couple of acres, but it is very marked and distinct." In a letter to me, August 1st, 1889, Mr. R. Paulin, in explanation of his sketch-plan (p. 624), states:—"The Red-Hill formation (olivine and serpentine) occurs all over the parts I have marked with red lines. The Red-Hill and Olivine Ranges are for the most part bare of timber, and the formation is very conspicuous, owing to the burnt-brick colour which the rock assumes where exposed to the atmosphere. Both the Olivine and Hope Ranges are very much broken and shattered, containing no mass of rock that has not cracks in all directions. This is not so much the case in the Red-Hill Ranges."

From these extracts, together with Mr. Paulin's plan, it will be seen that the rocks under notice compose, in the region of the Awaruite discovery, a complex of high massive ranges, the most prominent of which are the Red-Hill and Olivine Ranges, and which comprise, according to Mr. Paulin's plan, an area of about 25 miles in length north and south, and 16 miles in width east and west. The rocks, however, doubtless extend (probably with interruptions and for certain much contracted in width) much further southward, even beyond the point Mr. Mueller mentions near the

* Report on West Coast between Cascade Plateau and Jackson's River on the North, and Lake M'Kerrow and Hollyford Valley on the South; in the 'Report of the Survey Department of N.Z. for the year 1883-84,' p. 73.

Geological Sketch-plan of a Part of the West Coast of the South Island, New Zealand, by R. Paulin; based on Mr. G. Mueller's Topographical Plan of the Country between Jackson's River and the Hollyford Valley.



- Localities where Awaruite has been found.
- Area of the Serpentine and Olivine Rock (Peridotite).
- Ground covered by Mineral-leases for working the Nickel on the Gorge River.
- Cow Saddle. Mr. Mueller's last indication of the Olivine Rock.

Humboldt Mountains (about $6\frac{1}{2}$ miles S. by W. from the junction of the Barrier Creek with the Pyke River). What leads to this conclusion is, that Messrs. Henderson and Batement saw conspicuously bare and red-coloured mountains and ridges (like those of the Red-Hill Range) further southward, near Lake-Harris Saddle, the watershed between the Route Burn (a tributary of the Dart River falling into Lake Wakatipu) and the Hollyford River; and that they found boulders of olivine rock and serpentine in one of the creeks rising near that saddle and falling into the Hollyford River. Still another important proof is that at the head of the Caples River (about 22 miles S. of the junction of Barrier Creek and Pyke River) there occurs in massive outcrops a dark-green serpentine, closely resembling that of the Red Hill and enclosing veins and bunches of compact talc (steatite).

With regard to the geological relations of the peridotite and serpentine rocks to the enclosing crystalline schists, there can be no doubt, according to Messrs. Henderson's and Batement's observations, that the former are intrusive through the latter; several places having been observed by them where the strike of the schists was right against the peridotite and serpentine outcrops.

Judging from examination of the specimens available, the unaltered peridotite, in its petrographic character, is always holocrystalline, and its main constituents (olivine and enstatite) are allotropic. It shows, however, various modifications. On the Red Hill it conforms to Wadsworth's species "saxonite," is of light-greenish colour, and varies from coarse to fine granular in texture. The olivine and enstatite vary much in relative proportions; while in some specimens the former greatly predominates over the latter, in others the reverse is the case. This can be well seen on the red-weathered surface of the rock, which shows the enstatite in outstanding angular particles of irregular size and form; the olivine once connecting them having been decomposed and removed. Chromite, though in some parts abundant, appears on the whole rather sparingly distributed throughout the rock; partly and more frequently in larger and smaller grains of irregular contours; partly in small perfect octohedrons. These grains and crystals are easily identified by their lustre, together with the green colour imparted by the powder to the borax bead. Several specimens with predominating enstatite show on the surface light to dark emerald-green portions which do not seem to occur in the interior of the rock, as I found on cutting two such pieces in various directions. Although they seem at first sight to belong to a different species of pyroxene (diallage), closer examination proves them to be so similar in lustre and structure to the associated, common, yellowish or brownish enstatite, that I suppose they most probably represent only a green-coloured variety of the latter. Owing to the failure of several attempts in preparing thin sections showing the green mineral, through the latter unfortunately breaking away or quite disappearing during the grinding, and not liking to destroy any more of the remaining specimens, reserved for transmission with this paper, I have not

been able to test the correctness of my supposition by microscopic examination. In thin sections both olivine and enstatite become nearly or quite colourless and transparent, the former in parts with a faint greenish, the latter more generally with a feeble brownish-yellow tint; and they are on the whole rather free from inclusions, chromite and picotite excepted. In Pl. XXIV., figs. 1, 3, 5, grains of greenish olivine are indicated by the letter *o*. I suspected these at first to be the green mineral before mentioned, but their rough surfaces and high brilliant polarization-colours unmistakably proved them to be olivine. Between crossed Nicols the enstatite, determined by always extinguishing parallel to the main cleavage-cracks, shows in some grains throughout, in others in parts, a closely and sometimes slightly-curved fibrous structure, which may indicate its alteration into bastite*. On looking straight through a mounted section towards the light with the naked eye, enstatite and olivine are often indistinguishable from each other, if both are clear and colourless; but on looking obliquely down upon the section, whilst turning it in different directions between the fingers, the grains of enstatite are recognizable by a peculiar brightening-up like opalescence, caused by internal reflections. Chromite and picotite, in opaque black and brownish translucent crystals and irregular grains, occur in moderate number in every section. The dark-green translucent serpentine from the Red Hill becomes, in thin sections, perfectly transparent and nearly colourless, with scattered patches of a slightly cloudy aspect; and it encloses numerous black and brown opaque grains of iron-ores, some of which on microscopic examination by reflected light generally prove to be pyrite. Between crossed Nicols the clear substance appears as broken up into a confused intermixture of small granules and narrow, longer and shorter fibrous bodies, most of which (the fibrous bodies invariably) are anisotropic, by polarizing from bright white or yellowish through light and dark shades of greyish-blue to black, the extinction of the latter being in the direction of the fibres. The rest of the granules that are dark remain so on complete rotation of the stage, thus proving to be isotropic. Irregularly outlined portions in the sections, showing more minute granulation, no fibrous bodies, and polarizing in parallel bands in different shades of blue and grey, are doubtless indicative of altered enstatite, and conform to the cloudy patches before adverted to.

It requires now finally to be mentioned concerning the Red-Hill rocks, that, as far as Messrs. Henderson and Batement could observe, there exists no defined boundary between the unaltered peridotite and the serpentine. The two rocks seemed to be quite irregularly intermixed. Rock-masses which at a distance they took to be peridotite proved on examination to be serpentine and *vice versa*, the recognition being always easy on near approach, even without breaking the rock, by the rough surface of the peridotite and the smooth surface of the serpentine. They came in their traverses through the district at several places, pretty far apart, across the boundary of the schist and peridotite rocks (including serpentine); and, judging from

* J. J. H. Teall's 'British Petrography,' p. 88.

the few specimens they collected, it may fairly be concluded that perhaps all along that boundary there occur certain gabbro-rocks, either as irregular intrusions and dykes, or as formed by gradual transition from the peridotite through accession of plagioclasic felspar, disappearance of the olivine, and exchange of the light coloured enstatite for the dark ferri-ferous bronzite, and may be hypersthene and diallage. Which of these suppositions is the correct one is doubtful. Both kinds of relations between peridotites and gabbros have been described by Professors Judd* and Bonney † from Scotland and Cornwall respectively, and are also known from several European districts. From the travellers' descriptions the intrusive mode of occurrence of the gabbro seems the more probable. At uncertain distances away from the peridotite-boundary, within the schist-rocks, they found dykes of augite-porphry and felspar-porphry, and bosses of a peculiar rock consisting of a white felspathic base with long, thin, prismatic crystals of a fine green colour, reminding us of epidote or actinolite. Of this unfortunately they lost the sample ‡.

We now come to the peridotite of the Olivine Range. Of this there are only a few specimens available, and these present two varieties very different in microscopic aspect, and also easily distinguishable from any of the Red-Hill rock. The variety said to be most abundant on the range has a greenish ash-grey colour, looks very close and dense, and consists of olivine and enstatite, the former much predominating. Its special texture is, doubtless, owing to the advanced degree of serpentinization it has undergone, though microscopic examination of a number of thin sections, cut at various angles from a specimen, seems to indicate that the enstatite has, in the aggregate, suffered by this process quite as much as, if not more than, the olivine; this is an occurrence rather at variance with what is usually observed and with the stronger tendency of the latter mineral to decompose by atmospheric action, as shown by its removal from between the grains of enstatite on the surface of these rocks. Every grain of enstatite is more or less attacked along cracks of cleavage and cross-cracks. Some appear broken up, as it were, into a multitude of longer and shorter columnar pieces of varying width, occupying collectively much less space than the serpentine between them (see Pl. XXIV. fig. 7). A small proportion are wholly converted into this mineral, which, in most cases,

* Quart. Journ. Geol. Soc. vol. xli. 1885, p. 583.

† *Ibid.* vol. xxxiii. 1877, p. 904, and vol. xxxiv. 1878, pp. 778, 779.

‡ Among the specimens sent from the Red Hill are examples of varieties of serpentine allied to picrolite, marmolite, and antigorite, with the common dark-green type of the mineral, the latter sometimes containing specks of Awaruite as well as of pyrite and magnetite. In small nests and veins of the serpentine of the Red Hill the following minerals were found:—Garnets (both of light-brown and light-green colour), quartz, a chlorite (probably ripidolite), asbestos or mountain-leather (probably chrysotile), magnetite, and massive talc (steatite or soapstone). From massive outcrops in the same district rock-specimens were collected, which are referred to bronzite-gabbro, common gabbro, augite-porphry or melaphyre, and labradorite-porphry.

is dusky, sometimes nearly opaque. With the olivine the case is different. While in parts of the sections it is traversed by an irregular network of veins of serpentine, in other parts, of about similar extent, such veins are scarce, smaller, or quite absent, and there are only noticeable scattered patches with more pronounced cracks and of slightly impaired transparency, caused by a minute dust or granulation, and which show mostly aggregate polarization between crossed Nicols; the brilliancy of the polarization colours is, however, quite unaffected. Regarding the serpentine of the veins, it is different from that formed from the enstatite, being perfectly transparent and nearly colourless throughout; and its behaviour, as well as the structure of the veins in polarized light (between crossed Nicols with rotation of the stage), accord perfectly with the descriptions given by Prof. Bonney in his paper on the serpentine of the Lizard district, Cornwall*, and therefore need not be detailed here. Only I may mention that in some of the veins the arrangement of a granular dark layer in the centre and a transversely-fibrous layer along each side is very regular, reminding us of the symmetrically banded structure observed in some ore-lodes; also that in parts of some veins the fibrous bodies are more or less regularly radiating (star-like) from dark ferruginous granules. Inclusions of grains of chromite, &c., in the olivine and enstatite are, according to the prepared sections, very scarce indeed; one pretty large section shows not a single grain, and none of the others contain more than three or four. The specific gravity of the rock, as determined on different specimens, ranges from 2.81 to 3.13; and regarding its solubility in HCl, some determinations by Mr. Thomas Batement gave the following results:—

	No. 1.	No. 2.	No. 3.
Soluble	80.08 %	83.73 %	84.11 %
Insoluble	19.92 ,,	16.27 ,,	15.89 ,,
	100.00	100.00	100.00

The soluble portions here evidently represent olivine and serpentine; the insoluble enstatite, with a small percentage of chromite, &c. Judging from what the sections show, the relative proportions of olivine and enstatite in the unaltered original rock may be taken to have been as 2 : 1, or at the outside 3 : 1, say as 70 % : 30 %; therefore the above results would indicate that in the present rock nearly one-half of the enstatite has been converted into serpentine. As already mentioned when describing the thin sections, it is rather questionable whether the olivine has suffered to a like extent.

The second variety of rock from the Olivine Range is of medium-grained, granitoid texture, dark greyish-green colour, and very tough. The amount of outstanding grains of enstatite on the brown-weathered surface of the rock points to this mineral predominating over olivine, and this is confirmed by examination of the several

* Quart. Journ. Geol. Soc. vol. xxxiii. 1877, pp. 907 & 916.

thin sections cut from a specimen at various angles. These sections look under the microscope much like those prepared of Red-Hill rock similarly constituted; the only difference being a more pronounced brownish-yellow colour of the enstatite and a greater quantity of dark ore-grains (chromite &c.). In one section, however, there are seen four small, irregularly-outlined grains of a transparent green mineral, which certainly is monoclinic, though whether it be hornblende or a pyroxene optical examination leaves undecided. Two of the grains, showing a few parallel cleavage-cracks, and parallel to these a slightly fibrous structure, extinguish one at an angle of about 12° , the other at about 17° with these cracks, and are slightly pleochroic, changing from bluish green to yellowish green; the third grain shows only irregular cracks and hardly any pleochroism; but in the fourth grain, rendered rather dusky by fine black dust, there are a few, though very indistinct, cracks, apparently crossing each other at approximately right angles, and the extinction makes nearly equal angles with these cracks; it is feebly pleochroic, the green colour becoming fainter. The employment of convergent polarized light gave no definite results for any of the grains. Accepting the cracks in the fourth grain as really indicating cleavage, the mineral is doubtless a pyroxene, and probably diallage. The specific gravity of the rock is 3.17-3.35, and its chemical composition, according to a bulk analysis by Mr. Thomas Batement, as follows:—

SiO ₂	39.99
Al ₂ O ₃	3.55
Cr ₂ O ₃	Strong traces
FeO.....	8.56
MnO.....	traces
CaO.....	4.19
MgO.....	41.26
H ₂ O.....	2.07
	99.62

Among the specimens from the Cascade River at the foot of the Olivine Range are pieces of a hard nephrite-like serpentine (bowenite?), containing small specks of Awaruite embedded in it. The specimens are evidently portions of rolled pebbles.

3. *Mode of Occurrence and Distribution of the Awaruite.*

The first sample of the Awaruite-bearing black sand examined by Mr. Skey was supposed to have come from Barn Bay (p. 619); but it was subsequently proved to have been washed from the drift of the Gorge River. The valley of this river has since generally been considered to be the only place of occurrence of the mineral, and is, indeed, the one in which it has so far been proved to exist in largest quantity. Mr. G. Mueller, the Chief Surveyor, in answer to my enquiries on this point, states: "The mineral is found in the bed and

the banks of the Gorge River, and the ground covered by the mineral-leases applied for with the view of working the nickel is marked in *red* on the lithograph-plan enclosed [see the indication on the sketch-plan, p. 624]. These deposits have evidently been brought across the saddle into the Gorge River from the Olivine Range at the back of it."

As, in consideration of the large extent of the peridotite or serpentine rocks, it seemed to me very unlikely that the occurrence of the mineral should be confined to the Gorge River only, I specially requested Mr. R. Paulin, before he set out on his exploring and prospecting trip, to look out for the alloy in the olivine and serpentine rocks and the drift of the rivers and creeks he prospected. The results of his examinations in this respect are given on the sketch-plan previously alluded to (p. 624),—the many places where he found Awaruite being marked by black crosses. In his explanatory letter to me he states as follows:—"I have found small specks of nickel in the rocks of various localities, most conspicuous at Silver Creek (a tributary of the Jerry River rising in the Red-Hill Range), and I think that it occurs throughout the whole formation. The free nickel found in different river-beds is much coarser than any I have seen in the stone. On the Red Hill itself I found nickel 2400 feet above sea-level." The area of distribution of the Awaruite is thus by Mr. Paulin's observations proved to be far more extensive than first imagined, and it may be larger still, for I see nothing unreasonable in his belief that the mineral occurs in the impregnated matrix throughout the whole extent of the peridotite and serpentine rocks; and, inferentially, in the liberated state in the drifts derived therefrom. The gradual gathering of practical proof of this, however, will, I fear, take a long time, owing to the great hardships and dangers connected with prospecting in that wild, inhospitable district. The supposed recognition of Awaruite distributed through the rock will also, in many cases, not be free from doubt, unless the specks be detached and specially tested. This is on account of the smallness of the specks, and their frequent association with, and general resemblance in colour to, grains of pyrite, which may therefore be easily mistaken for it. The simplest test in the case of detached specks is by application of the magnet, which energetically attracts the Awaruite specks, but leaves those of pyrite unaffected. The malleability of the specks affords another proof of their identity.

EXPLANATION OF PLATE XXIV.

Figs. 1, 2, 3, are drawn in ordinary light from thin slides cut in different directions from a piece of medium-grained Peridotite from the Red Hill; magnified 20 diams.

Fig. 1. In this both the Olivine and Enstatite are remarkably clear, and the latter is only distinguishable from the former by a faint brownish-yellow tint and parallel cleavage-cracks. The large cross-shaped grain in centre of the figure is Enstatite, showing between crossed Nicols in patches a slightly curved fibrous structure with wavy extinction parallel to the fibres. Polarization-colours yellow, orange to brown. At lower right-

hand corner of centre bar of cross is seen in convergent polarized light a fine optic axis with $\rho < v$. Above the cross-shaped grain, separated from it by a narrow band of Olivine, there is another grain of Enstatite showing a number of well-marked cleavage-cracks. In several parts of the Olivine are seen in convergent polarized light fine optic axes, and two light yellowish-green grains of it, near the centre of the figure, adjoining the Enstatite, are indicated by a line and the letter *o*.

Fig. 2. In this the Olivine is, if anything, clearer and less cracked than in fig. 1. There is only one grain of Enstatite shown in upper part of the figure, recognizable by its numerous parallel cleavage-cracks, in the line of which it extinguishes between crossed Nicols. The large irregularly-contoured black grain and several far smaller black grains near it are feebly brown, translucent, and consist either of Picotite or Chromite, probably the former.

Fig. 3. This shows two grains of Enstatite divided near centre of the figure by fine-granular Olivine, full of minute black opaque and dark brown translucent particles of either Picotite or Chromite. The largest grain of Enstatite is very clear, and shows only a few cleavage-cracks; at the margin of the figure it becomes slightly dusky. The other grain of Enstatite on the left shows both prismatic and brachy-pinacoidal cleavage-cracks, and is therefore a basal section, disclosing in convergent polarized light between crossed Nicols a pretty perfect interference-figure; at the upper end it is broken into by a grain of Olivine. The green-coloured grain (*o*) below the last-noted Enstatite-grain is Olivine, like those in fig. 1, characterized by a rough surface and the same range of brilliant polarization-colours as the neighbouring colourless Olivine. The two black opaque grains at bottom of the figure are probably Chromite.

Figs. 4, 5, & 6 are drawn in ordinary light from sections cut in different directions from a piece of medium-grained, though rather dull and compact-looking Peridotite from the Red Hill. Magnified 20 diams.

Fig. 4. In this are shown two grains of Enstatite, a large one in the upper part, and a small triangular one at the lower margin. Both these grains are more or less fibrous, and show streaks parallel to fibres densely filled with a fine, dark dust, probably the commencement of serpentinization. The Olivine is in parts very clear and not much cracked; but in others it is slightly (on the right-hand edge of the figure very densely) filled with fine, dark dust, as in the case of the Enstatite. The large black grain within the Olivine is quite opaque, and probably consists of Chromite.

Fig. 5. This shows on the left side a large grain of Enstatite, very clear and with well-pronounced cleavage-cracks. On the right-hand edge there is a smaller grain of this mineral, also clear, showing faint cleavage-cracks; and across the middle a row of small, feebly brown, translucent grains of probably Picotite. In the centre of the figure, and in contact with the large grain of Enstatite, there are grains of light yellowish-green Olivine, similarly characterized as the grains in figs. 1 & 3. The Olivine (*o*, *o*) in the lower part of the figure is very clear, but that in upper part is dusky and more fissured. The large irregularly-shaped black grain is in parts faintly brown translucent, the small adjoining one is quite opaque; they probably consist respectively of Picotite and Chromite.

Fig. 6. This shows the grains of Enstatite, one on the lower right-hand edge, the other on the left-hand edge. Both are rather fibrous, and in the lower one a dusty streak (similar to those in fig. 4) runs in the line of the fibres; in the other grain such a streak runs across the fibres, and there are also dusty patches and several strong dark irregular cracks. The Olivine between these Enstatite grains is also in parts more or less dimmed by dark dust. The black grains are opaque and probably Chromite.

Figs. 7, 8, 9 are drawn from sections cut at nearly right angles to each other from a specimen of the Peridotite described as the first variety from the Olivine Range. Magnified 20 diams.

Fig. 7 represents portion of a large Enstatite grain, broken up more or less parallel to the chief cleavage, and converted in this direction for more than half its original bulk into Serpentine. The remaining columnar Enstatite portions polarize in light yellow to orange, and extinguish between crossed Nicols parallel to their longitudinal extent. They are much broken transversely in various directions. The Serpentine between is more or less densely charged with a fine, dark dust, with occasional larger dark particles, probably Magnetite. Under a high power (700) the dust is seen to be arranged streak-like, parallel to the columnar Enstatite portions.

Fig. 8. The large grain of Enstatite in the upper part of the figure is for the greater part closely fibrous (well seen between crossed Nicols) and densely filled with fine, dark dust. Portions polarize like the Serpentine in fig. 7. Small veins and a larger patch of colourless transparent Serpentine are seen in it near the upper left-hand margin. The Olivine below the Enstatite is much fissured, and in parts more or less densely filled with fine, dark dust. Near the left-hand margin it is traversed by a large vein of clear colourless transparent Serpentine; and small patches and interrupted veins of such Serpentine are shown in the centre and close to the right- and left-hand edges of the figure. The large vein shows between crossed Nicols a dark, fine-granular layer in the centre, and transversely fibrous layers on each side.

Fig. 9. In this the Olivine is much fractured, and in parts densely filled with dark dust, and traversed by strong serpentinous cracks, which in ordinary light and between crossed Nicols are nearly opaque. The Enstatite grains—one shown at the upper edge, one in the centre, and a large one in the lower part of the figure—are closely fibrous, and traversed by irregular veins of dusky Serpentine. In the central grain oblong patches of dusky Serpentine appear also in the line of the fibres.

DISCUSSION.

The PRESIDENT noted the interest attaching to the gradual development of our knowledge of native iron of terrestrial origin.

Prof. JUDD was glad to have the present opportunity of removing a misconception that had arisen concerning this mineral. In bringing the matter before the Society on a previous occasion he dwelt upon the facts of special geological interest, and Mr. Skey's name was not mentioned in the few lines placed on record in the 'Proceedings.' No attempt, however, had been made by Prof. Ulrich to claim the discovery of this mineral, though he appeared to have been the first to record its peculiar occurrence in the ultrabasic rocks. In the South Island were the well-known chromite-bearing olivine rocks of the Dun Mountain, but the rock now described was in a distant part of the same island. An interesting series of serpentines derived from peridotites had been sent over by the Author, and these specimens contained the "Awaruite." A number of garnets and chlorites, with chrysotile, talc, and magnetite, had been found in the Red Hill. He was not aware that any "Awaruite" had been discovered in the peridotite; but this was probably due to the softer nature of the serpentine, where it could be more easily detected. He had recently heard that one of the serpentines of Norway had yielded a similar alloy.

GENERAL INDEX

TO

THE QUARTERLY JOURNAL

AND

PROCEEDINGS OF THE GEOLOGICAL SOCIETY.

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PHYSICS DEPARTMENT

PHYSICS 551

LECTURE 1

1.1. Kinematics

1.2. Dynamics

1.3. Energy

1.4. Angular momentum

1.5. Oscillations

1.6. Relativity

1.7. Quantum mechanics

1.8. Statistical mechanics

PROCEEDINGS

OF THE

GEOLOGICAL SOCIETY OF LONDON.

SESSION 1889-90.

November 6, 1889.

W. T. BLANFORD, LL.D., F.R.S., President, in the Chair.

The Rev. D. Charles Evans, Menai Bridge, was elected a Fellow of the Society.

The List of Donations to the Library was read.

The following communications were read:—

1. "Contributions to our Knowledge of the Dinosaurs of the Wealden and the Sauropterygians of the Purbeck and Oxford Clay." By R. Lydekker, Esq., B.A., F.G.S.

2. "Notes on a 'Dumb Fault' or 'Wash-out' found in the Pleasley and Teversall Collieries, Derbyshire." By J. C. B. Hendy, Esq. (Communicated by the President*.)

The "Top Hard" Seam of the district is being worked in these collieries at a depth of 500 yards, where it has an average thickness of 5 feet, with a band of cannel in the middle. In the working it was found that the coal began to thicken, until it became double the usual size, the cannel also increasing in the "Top Seam," but in the Lower Seam running out altogether.

This double thickness of coal continued till the "wash-out" was reached, when both coal and shaly roof disappeared, the space being replaced by sandstone similar to that of the beds overlying the shale. The clay floor of the Lower Seam had not been much interfered with, and this was followed for 60 yards, when the

* This paper has been withdrawn by permission of the Council.

doubly thick seam was again met with, and on being followed gradually assumed its normal thickness.

No fossils have been noted in the "Wash-out" itself, the vertical extension of which is unknown.

DISCUSSION.

The PRESIDENT considered that more particulars would have been useful, and that the section should have been drawn to true scale. He quoted cases in India where there was no thickening of the coal at the edge; the coal had apparently been washed away and replaced by sandstone. It was difficult to understand why the coal washed away should be redeposited at the edges of the stream.

Prof. GREEN, with reference to the want of further particulars, could only endorse what had been said. He spoke of the possible existence of little ponds and lagoons where the channel had been forming.

Prof. HUGHES pointed out that the thicknesses did not give the original measurement of the coal. There was no mention of roots going into the floor, which was described as uninterrupted. The space had been filled up with less compressible material.

Prof. J. F. BLAKE observed that this "dumb fault" was a portion only of a much larger one. In this Mr. Coke had shown that pressure from the sides had been brought to bear, which would account for the thickening observed. Mr. Coke had suggested that the "wash-out" was not due to ordinary denudation, but to an original depression in an area of sinking.

Prof. LAPWORTH considered that such "dumb faults" as had been investigated by himself were due to faulting and to distortion from pressure. The edges of a "dumb fault" were slickensided. The missing coal is to be found in the thickened seam.

Mr. J. G. WOOD alluded to a "dumb fault" described by the late Mr. Buddle about 50 years ago. Subsequently a great contortion had been discovered in near proximity to it, the coal being thrown into an arch with a possible parting asunder.

3. "On some Palæozoic Ostracoda from North America, Wales, and Ireland." By Prof. T. Rupert Jones, F.R.S., F.G.S.

The following specimens were exhibited:—

Remains of a Pliosaur from the Oxford Clay of Peterborough, in the collection of A. N. Leeds, Esq.; the cast of a cervical vertebra of *Iguanodon* from the Wealden of Hastings, in the possession of P. Rufford, Esq.; a cervical vertebra of a Plesiosaurian from the Purbeck; and a dorsal vertebra of *Pelorosaurus (Ornithopsis) Leedsi*, in the collection of A. N. Leeds, Esq.; exhibited in illustration of the paper by R. Lydekker, Esq., F.G.S.

Specimens of Palæozoic Ostracoda, exhibited by Prof. T. Rupert Jones, F.R.S., F.G.S.

November 20, 1889.

W. T. BLANFORD, LL.D., F.R.S., President, in the Chair.

Nagayuke Asano, Esq., Assoc. R.S.M., care of Marquis Asano, Hongo, Tokio; Lieut.-Col. T. Couchman, C.E., Melbourne, Victoria; Frederic H. P. Cresswell, Esq., Assoc. R.S.M., Chile, Venezuela; and Thomas Shilston, Esq., 14 Wentworth Place, Newcastle-on-Tyne, were elected Fellows of the Society.

The List of Donations to the Library was read.

The Secretary announced that a series of specimens from the line and the neighbourhood of the Main Reef, East and West of Johannesburg, Witwatersrand Gold Fields, had been presented to the Museum by Dr. H. Exton, F.G.S., and read the following letter from that gentleman in explanation of them:—

“Johannesburg, Transvaal, South Africa,
7th May, 1889.

“DEAR SIR,—

“Having been engaged in making a collection of specimens of auriferous conglomerate from the principal mines in this immediate neighbourhood, I have packed a series of these, which are now in transit and of which you will be duly advised by the transport-agent. They are designed for the Museum of the Geological Society.

“Commencing eastward of Johannesburg, there are examples from the Black Reef, the Salisbury Mines, Wemmer’s, Robinson’s, Langlaagte Estate, and the Paadl Pretoria—this last-named being now under the new appellation of Langlaagte Consolidated. Excepting the Black Reef, these mines are all upon the Main Reef. The Main Reef has a general direction east and west, with a dip towards the south varying from 45° to 80°. In the Salisbury claims the reef is practically perpendicular.

“On the south side of the Main Reef, and running parallel to it at a distance of from 15 to 20 feet, is a narrow reef called by the miners the south ‘leader.’ This varies from 7 to 15 inches wide, and is generally much richer than the Main Reef.

“At the Wemmer’s Co. this south ‘leader’ consists of several narrow bands in close contiguity, which are so rich that at present this alone is being worked. I am enabled to send specimens of this ‘leader,’ along with the casing both from the north and south faces. From several other mines there are examples from the casing of the Main Reef as well as of the ‘leader.’ Among those from the Salisbury there is a piece of a white friable sandstone, which runs in a narrow band parallel to the south ‘leader,’ and which often runs into the ‘leader,’ still keeping its distinctive feature.

“Accompanying these I enclose for the Geological Society a large plan of the district, with the gold-bearing reef marked upon it, with the farms through which it runs, and the names of the various companies on the site of their workings. This may be relied upon as authentic, though a large number of valuable gold properties have been developed since the publication of this plan.

“Upon the plan I have placed a cross section, almost directly north and south at right angles to the Main Reef. This section covers a little over four miles, crossing the Salisbury claims and passing through the town of Johannesburg. At the south limit of this line I have obtained the specimens A and B, which are at that point in alternate bands of from 7 to 10 feet thick. A is worked for door-jambes, lintels, &c.; but the quartzite B is too hard to be worked. The dip of these rocks is towards the south about 40° . From here to the Main Reef is a coarse sandstone, with here and there a narrow reef of barren conglomerate. From the Main Reef northwards a similar sandstone prevails, having generally the character of C, but (with a redder tinge nearer to the Main Reef) with a dip (southwards) at the northern limit of 75° . Here it is bounded by a fine-grained purplish-red jaspideous slate (specimen D), permeated by narrow lines of quartz. The jagged edges of this dark-red slate protrude above the surface.

“From personal observation I am enabled to state that wherever this formation is maintained the reef of gold-bearing conglomerate is found running more or less parallel to it at a greater or less distance to the south. I am not prepared to state the converse; but the before-named arrangement is true over 20 miles of reef.

“I trust the specimens and plan may be found helpful towards elucidating the geological problem of the origin of the gold-bearing conglomerate, which has hitherto oscillated between the igneous and aqueous theories.

“I am, dear Sir,

“Yours faithfully,

“H. EXTON, F.G.S.”

The PRESIDENT considered the occurrence of the gold in large quantities in such a conglomerate was a remarkable and interesting case. The rock was an ancient-looking one, and the country appeared to have undergone much disturbance.

Dr. HINDE remarked that in Nova Scotia beds of conglomerate of supposed Carboniferous age were formerly worked for gold, but the yield had not been very great.

The following name was read out for the first time in conformity with the Bye-Laws, Section VI. Article 5, in consequence of the non-payment of his arrears of contributions:—DR. R. HÄUSLER.

The following communications were read:—

1. “On the Occurrence of the Striped Hyæna in the Tertiary of the Val d’Arno.” By R. Lydekker, Esq., B.A., F.G.S.

2. "The Catastrophe of Kantzorik, Armenia." By Mons. F. M. Corpi. (Communicated by W. H. Hudleston, Esq., M.A., F.R.S., Secretary.)

3. "On a new Genus of Siliceous Sponges from the Lower Calcareous Grit of Yorkshire." By Dr. G. J. Hinde, F.G.S.

The following specimens were exhibited:—

Specimens and microscopic sections of *Rhaxella perforata*, Hinde, gen. et sp. nov., from the Lower Calcareous Grit of Scarborough (the specimens belonging to the Natural-History Museums of York and Scarborough), exhibited by Dr. G. J. Hinde, F.G.S., in illustration of his paper.

Specimens of *Herpetocrinus Fletcheri*, Salter, from the Wenlock Limestone of Dudley, exhibited by F. A. Bather, Esq., F.G.S.

With regard to these specimens Mr. Bather said that *Herpetocrinus* of Salter (= *Myelodactylus*, Hall) was described in Cat. Foss. Woodwardian Mus. as possessing a coiled cirriferous stem, and a small crown with dichotomous arms. American authorities, however, had maintained Hall's view that the coiled structure was an arm with pinnules. The two specimens belonging to Mr. E. Hollier, of Dudley, which were on the table, conclusively proved the correctness of Salter's position; one of them was very fine, and showed the structure of the dorsal cup. A specimen in the British Museum had quite recently been discovered to possess a crown. The drawings of stem-ossicles and of sections exhibited showed that there were strong muscles on the outer curvature of the stem, which could uncoil it.

December 4, 1889.

W. T. BLANFORD, LL.D., F.R.S., President, in the Chair.

Montagu Browne, Esq., Aylestone Park, Leicester; Joseph Howell Bullock, Esq., The Grove, Pelsall, near Walsall; Arthur Walter Clarke, Esq., Charters Towers, Queensland, Australia; John Errington de la Croix, Esq., F.L.S., 49 Avenue Bosquet, Paris; Henry Nathaniel Davies, Esq., 5 Westbourne Terrace, Weston-super-Mare; Arthur Dudley Dobson, Esq., Warrnambool, Victoria; Charles Henry Dunhill, M.D., Grays Court, York; George Frederick Lee Giles, Esq., Memb.Inst.C.E., The Docks, Southampton; Henry Francis Hermitage, Esq., J.P., Margate; Edward Hodges, Esq., Assoc.M.Inst.C.E., Allahabad, India; Rev. James Hyslop, 4 Stratton Terrace, Truro; Philip Lake, Esq., B.A., Geological Survey of India, Calcutta; Albert Latham, Esq., Memb.Inst.C.E., Margate; J. Bickerton Morgan, Esq., 30 Severn Street, Welshpool; Percival Gerard Pochin, Esq., 13 Ranmoor Park, Sheffield; John Ridyard, Esq., Hilton Bank, Little Hulton, Bolton; Charles Archibald Ross, Esq., Porlock, Somersetshire; Andrew Simons, Esq.,

1 Crescent Place, Plymouth; Evan William Small, Esq., M.A., B.Sc.Lond., High School, Nottingham; John William Teale, Esq., Bishop Auckland, Durham; J. Egerton Wood, Esq., Assoc.R.S.M., 143 Regent Road, Salford, Manchester; and Henry Woods, Esq., St. John's College, Cambridge, were elected Fellows of the Society.

The List of Donations to the Library was read.

The following name was read out for the second time in conformity with the Bye-Laws, Section VI. Article 5, in consequence of the non-payment of arrears of contributions:—DR. R. HÄUSLER.

The President stated that a Circular Letter had been received from the Secretary of the Committee on Geological Photographs, formed at the last meeting of the British Association for the Advancement of Science, to arrange for the Collection, Preservation, and Systematic Registration of Photographs of Geological interest in the United Kingdom, in which the aid and co-operation of geologists' is earnestly requested. Copies of Instructions &c., drawn up in order to secure uniformity, are to be obtained on application to O. W. Jeffs, Esq., Secretary to the Committee, 12 Queen's Road, Rock Ferry, Cheshire.

The following communications were read:—

1. "On Remains of Small Sauropodous Dinosaurs from the Wealden." By R. Lydekker, Esq., B.A., F.G.S.

2. "On a peculiar horn-like Dinosaurian Bone from the Wealden." By R. Lydekker, Esq., B.A., F.G.S.

3. "The Igneous Constituents of the Triassic Breccias and Conglomerates of South Devon." By R. N. Worth, Esq., F.G.S.

4. "Notes on the Glaciation of parts of the Valleys of the Jhelam and Sind Rivers in the Himalaya Mountains of Kashmir." By Capt. A. W. Stiffe, F.G.S.

The following specimens were exhibited:—

Rock-specimens, exhibited by R. N. Worth, Esq., F.G.S., in illustration of his paper.

Specimen and cast, exhibited by R. Lydekker, Esq., F.G.S., in illustration of his papers.

Specimens of Quartz &c., containing Gold, from "Two Brothers" Reef, near Southern Cross and Golden Valley, Yilgarn, Western Australia; and Specimens of "Stream Tin" from the Green Bushes Tin Fields, Blackwood District, Western Australia, obtained by M. F. A. Canning, Esq., exhibited by Dr. H. Woodward, F.R.S., F.G.S.

December 18, 1889.

W. T. BLANFORD, LL.D., F.R.S., President, in the Chair.

Charles Aburrow, Esq., Assoc.M.Inst.C.E., Johannesburg, South Africa; Henry A. Allen, Esq., Assistant Palæontologist to the Geological Survey, Museum, Jermyn Street, S.W.; Thomas Bennett, Esq., Assoc.M.Inst.C.E., Cheshunt Local Board, Cheshunt, Hertfordshire; and R. Lethbridge Tapscott, Esq., Assoc.M.Inst.C.E., 41 Parkfield Road, Liverpool, were elected Fellows of the Society.

The List of Donations to the Library was read.

The following communications were read:—

1. "On the Occurrence of the Genus *Girvanella*, and remarks on Oolitic Structure." By E. Wethered, Esq., F.G.S.

2. "On the Relation of the Westleton Beds or 'Pebbly Sands' of Suffolk to those of Norfolk, and on their extension inland, with some observations on the Period of the final Elevation and Denudation of the Weald and of the Thames Valley."—Part II. By Prof. Joseph Prestwich, M.A., D.C.L., F.R.S., F.G.S.

The following specimens were exhibited:—

Microscopic specimens and photographs, exhibited by E. Wethered, Esq., F.G.S., in illustration of his paper.

Block of Quartz from the Plateau Gravel, $3\frac{1}{2}$ miles W.S.W. of Ascot Station, Berkshire (400 ft. above O.D.), exhibited by H. W. Monckton, Esq., F.G.S.

Book of photographs of Baku and the Caucasus, exhibited by W. F. Hume, Esq., F.G.S.

January 8, 1890.

W. T. BLANFORD, LL.D., F.R.S., President, in the Chair.

William Andrews, Esq., Gosford Lodge, Coventry; the Earl of Berkeley, 21 Drayton Gardens, S.W.; James Wright Croston, Esq., 3 Egerton Street, Prestwich, Manchester; Walcot Gibson, Esq., 34 Radnor Street, Chelsea, S.W.; and Arthur Octavius Watkins, Esq., Assoc.R.S.M., Stow Park, Newport, Monmouthshire, were elected Fellows of the Society.

The following Fellows, nominated by the Council, were elected Auditors of the Society's Accounts for the preceding year:—
H. BAUERMAN, Esq., H. W. MONCKTON, Esq.

The List of Donations to the Library was read.

The following communications were read :—

1. "On some British Jurassic Fish-remains referable to the Genera *Eurycormus* and *Hypsocormus*." By A. Smith Woodward, Esq., F.G.S.

[Abstract.]

Hitherto our knowledge of the Upper Jurassic Fish-fauna has been mainly derived from specimens found in fine lithographic stones, where the various elements are in a state of extreme compression. Within the last few years remains of similar fishes have been discovered in the Oxford and Kimeridge Clays of England, and these are of value for the precise determination of certain skeletal features in the genera to which they belong.

The Author described *Eurycormus grandis* from the Kimeridge Clay of Ely, a large species which makes known for the first time the form and proportions of several of the head-bones in this genus. A technical description of all the bones the characters of which are distinguishable was given, and the Author concluded that there is considerable similarity between the head of *Eurycormus* and the recent Ganoid *Amia*, even to minute points of detail.

He further described *Hypsocormus tenuirostris* and *H. Leedsii* from the Oxford Clay of the neighbourhood of Peterborough, the osteology of this genus not having as yet been elucidated. Portions of the jaws have been discovered, affording valuable information as to the form and dentition of the principal elements.

These jaws are not precisely paralleled by any other Jurassic genus, though they possess a resemblance to *Pachycormus*, as also to the Upper Cretaceous genus, *Protosphyrona*.

DISCUSSION.

The PRESIDENT remarked that *Amia* is a freshwater genus, and inquired whether the fossil fish was freshwater or marine.

Mr. E. T. NEWTON remarked upon the great interest and importance of the paper.

The AUTHOR, in reply to the President's question, said that the old Ganoids were marine, and it was only in more recent times that they had become restricted to fresh water.

2. "On the Pebidian Volcanic Series of St. Davids." By Prof. C. Lloyd Morgan, F.G.S.

The following specimens were exhibited :—

Head of *Eurycormus grandis*, A. S. W., from the Kimeridge Clay of Ely, exhibited by Prof. T. M^cKenny Hughes, F.R.S., F.G.S.

Jaws of *Hypsocormus Leedsi*, A. S. W., from the Oxford Clay of Peterborough, from the collection of A. N. Leeds, Esq., exhibited by A. Smith Woodward, Esq., F.G.S.

Rock-specimens and microscopic sections, exhibited by Prof. C. Lloyd Morgan, F.G.S., in illustration of his paper.

Specimen showing a new method of mounting Gold-leaf so as to exhibit the green and yellow colours and transparency at one view, either by daylight or artificial light, adapted for Museums &c., exhibited by S. H. Needham, Esq., F.G.S.

January 22, 1890.

W. T. BLANFORD, LL.D., F.R.S., President, in the Chair.

Edwin Thomas Beard, Esq., The Colonial College, Hollesley Bay, Suffolk; William Fairley, Esq., Assoc.M.Inst.C.E., 1 Parliament Square, Edinburgh; and Lawrence Morris Lambe, Esq., Geological Survey of Canada, Ottawa, Ontario, Canada, were elected Fellows, and M. Gustave Dollfus, Paris, and Prof. A. von Könen, Göttingen, Foreign Correspondents of the Society.

The List of Donations to the Library was read.

The Secretary, with reference to a Map of Zoutpansberg, presented by C. Maidment, Esq., of Johannesburg, read a letter from that gentleman in explanation of some points in the geology of the district.

The following communication was read:—

“On the Crystalline Schists and their relation to the Mesozoic Rocks in the Lepontine Alps.” By Professor T. G. Bonney, D.Sc., LL.D., F.R.S., F.G.S.

The following specimens were exhibited:—

Rock-specimens and microscopic sections, also four large photographs taken by James Eccles, Esq., F.G.S., exhibited by Prof. T. G. Bonney, D.Sc., F.R.S., F.G.S., in illustration of his paper.

February 5, 1890.

W. T. BLANFORD, LL.D., F.R.S., President, in the Chair.

Wheatley James Atkinson, Esq., 76 Christchurch Road, Streatham Hill, S.W.; A. E. Gooch, Esq., B.A., B.Sc.Lond., 4 Alwyne Villas, Canonbury, N.; Bernard Hobson, Esq., B.Sc.Vict., Tapton Elms,

Taptonville Road, Sheffield; Sir James Maitland, Bart., F.L.S., Stirling; Hugh Frederick Marriott, Esq., the Manor House, Perry Hill, S.E.; S. J. Truscott, Esq., Assoc.R.S.M., care of Messrs. Syme and Co., Singapore; and John Walter Sugg, Esq., Knollbrow, Dorking, were elected Fellows of the Society.

The List of Donations to the Library was read.

The following communications were read:—

1. "The Variolitic Rocks of Mont-Genèvre." By Grenville A. J. Cole, Esq., F.G.S., and J. W. Gregory, Esq., F.G.S., F.Z.S.

2. "The Propylites of the Western Isles of Scotland, and their Relations to the Andesites and Diorites of the District." By Professor John W. Judd, F.R.S., F.G.S., &c.

The following specimens were exhibited:—

Rock-specimens and microscopic sections, exhibited by G. A. J. Cole, Esq., F.G.S., and J. W. Gregory, Esq., in illustration of their paper.

Rock-specimens and microscopic sections, exhibited by Prof. J. W. Judd, F.R.S., F.G.S., in illustration of his paper.

ANNUAL GENERAL MEETING,

February 21, 1890.

W. T. BLANFORD, LL.D., F.R.S., President, in the Chair.

REPORT OF THE COUNCIL FOR 1889.

IN presenting their Report for the year 1889, the Council have much pleasure in congratulating the Fellows upon the continued and apparently increasing prosperity of the Society. The actual Income of the Society was, indeed, rather less than in 1888, but notwithstanding the Investment of a sum of nearly £200, and the considerable expenses incurred in connexion with the Revision of the Bye-Laws, the Balance at the credit of the Society is fully maintained.

The number of Fellows elected during the year was 68, of whom 46 paid their fees before the end of the year, making with 15 previously elected Fellows, who paid their fees in 1889, and 1 Fellow re-admitted without payment of Entrance-fee, a total accession during the year of 62 Fellows. But during the same period there was loss by death of 38 Fellows, and by resignation of 13 Fellows, and 5 Fellows were removed from the List for non-payment of their annual contributions, making a total loss of 56 Fellows. The actual increase in the number of Fellows is thus only 6. Of the 38 Fellows deceased, 7 were Compounders, 14 Contributing Fellows, and 17 Non-contributing Fellows. During the year 13 Contributing Fellows sent in their resignations, and 6 compounded for their Annual Contributions, so that the actual increase in the number of Contributing Fellows is 24, making a total of 856.

The total number of Fellows, Foreign Members and Foreign Correspondents was 1373 at the end of 1888, and 1379 at the close of the year 1889.

At the end of the year 1888 there was 1 vacancy in the List of Foreign Members, and in the course of 1889 intelligence was received of the decease of 2 Foreign Members. During the year 3 Foreign Members were elected. At the close of 1888 there was also 1 vacancy in the List of Foreign Correspondents, and further vacancies were caused by the filling up of those among the Foreign Members, and by the death of 3 Foreign Correspondents in the

course of the year. In this way 7 vacancies were caused in the List of Foreign Correspondents, 5 of which were filled up in 1889, leaving two vacancies in the list at the end of the year.

The total Receipts on account of Income for 1889 were £2775 14s. 3d., being £169 19s. 7d. more than the estimated Income for the year. The current Expenditure of the year, leaving out of account the sum of £198 5s. 6d. expended in the purchase of £200 Consolidated $2\frac{3}{4}$ per cent. Stock, was £2576 17s. 1d., being £6 7s. 1d. more than the Estimate. The actual excess of Receipts over Expenditure during the year amounted to £198 17s. 2d., and the Balance in favour of the Society to £249 4s. 1d.

In accordance with the statement made in the last Annual Report of the Council several Special General Meetings were held during the Spring of the year 1889 for the discussion of suggested amendments of the Bye-Laws. The last of these Meetings was on May 22nd, when the Bye-Laws as amended were formally balloted for and carried. The amended Bye-Laws were then immediately printed and circulated among the Fellows of the Society.

The Council have to announce the completion of Vol. XLV., and the commencement of Vol. XLVI. of the Society's Quarterly Journal.

They have also to mention that Mr. Ormerod has prepared and sent in a Third Supplement to his Index to the Publications of the Society, and that this is now in the Printer's hands.

At the end of last year Prof. Prestwich wrote to the Council on the subject of a series of MS. notes prepared by Dr. James Mitchell, a former Fellow of the Society (who died in 1844), containing the results of his investigations upon the Geology and Botany of the neighbourhood of London, which were especially valuable as referring particularly to the Economic Geology of the District. These notes, having been collected and transcribed, now form five folio volumes, which have been in Prof. Prestwich's possession for many years, and as he now knows of no surviving relatives of the late Dr. Mitchell, he desired to deposit the books in the Society's Library, on the understanding, however, that should any legitimate claimant appear and apply for them they are to be given up. As Prof. Prestwich considered that the notes contained in these volumes might prove useful to Geologists engaged in similar investigations, the Council at once accepted his offer, and the books have now been deposited in the Library.

The Council have awarded the Wollaston Medal to Prof. William Crawford Williamson, LL.D., F.R.S., in recognition of the valuable services rendered by him to the study of Natural History and Geology, especially by his researches on the Foraminifera and on Fossil Botany.

The Murchison Medal, with the sum of Ten Guineas from the Proceeds of the Fund, has been awarded to Prof. Edward Hull, LL.D., F.R.S., F.G.S., in testimony of appreciation of the value of his work as a Geological Surveyor, both in England and in Ireland, through a long series of years, and also of his recent investigations upon the Geology of Palestine.

The Lyell Medal, with a sum of Forty Guineas from the Proceeds of the Fund, has been awarded to Thomas Rupert Jones, Esq., F.R.S., F.G.S., in recognition of the excellent work done by him in many departments of Geological Science, but more especially in connexion with the study of the Foraminifera and Entomostraca.

The balance of the Proceeds of the Wollaston Donation Fund has been awarded to W. A. E. Ussher, Esq., F.G.S., as a token of appreciation of the good work done by him during the progress of the Survey of the South-western Counties of England.

The balance of the Proceeds of the Murchison Geological Fund has been awarded to Edward Wethered, Esq., F.G.S., in recognition of the value of his original investigations into the Microscopic Structure of the Sedimentary Rocks, especially in connexion with their minute organic constituents, and to aid him in the further prosecution of his researches.

The Balance of the Proceeds of the Lyell Geological Fund has been awarded to Charles Davies Sherborn, Esq., F.G.S., as a testimony to the value of his Bibliographical and Microscopical work, especially in connexion with the Foraminifera, and to assist him in carrying on his investigations.

A sum of £20 out of the Proceeds of the Barlow-Jameson Fund has been awarded to William Jerome Harrison, Esq., F.G.S., in recognition of the value of his original researches upon the Geology of the Midland Counties, and of his efforts to popularize and widen the sphere of Geological knowledge, and to aid him in further efforts in the same directions.

REPORT OF THE LIBRARY AND MUSEUM COMMITTEE.

Library.

Since the last Anniversary Meeting many valuable additions have been made to the Library both by donation and by purchase.

As Donations the Library has received about 152 volumes of separately published works and Survey Reports, and about 292 pamphlets and separate impressions of Memoirs, also about 149 volumes and 80 detached parts of the publications of various Societies, and 18 volumes of independent Periodicals presented by their respective Editors or Publishers, besides 17 volumes of Newspapers of various kinds. This will constitute a total addition to the Society's Library of about 352 volumes and 292 pamphlets.

Of Maps, Plans, &c., Geological and otherwise, the number presented during the past year has not been great. They include sheets of the maps of the Geological Surveys of Norway, Saxony, Italy, and Japan; some sheets of the Ordnance Survey Map; and maps of some Mining Districts in Australia and South Africa.

The Books and Maps above referred to have been received from 173 personal Donors, the Editors or Publishers of 20 Periodicals, and 190 Societies, Surveys, and other Public Bodies, making, in all, 383 Donors.

By purchase, on the recommendation of the Standing Library Committee, the Library has received the addition of 41 volumes of books, and of 93 parts (making about 27 volumes) of various Periodicals, besides 16 parts of certain works published serially. Of the Geological Survey Map of France 19 sheets, and of the smaller Geological Map of France, by MM. Vasseur and Carez, 7 sheets have been obtained by purchase, besides a Mineral Map of the district of Bensberg and Runderoth.

The cost of Books, Periodicals, and Maps purchased during the year 1889 was £63 0s. 6d., and of Binding £83 3s. 6d., making a total of £146 4s. 0d.

Several of the Periodicals in the Library are still in an incomplete condition. Inquiry is being made as to the possibility and the cost of filling the existing gaps; and as there can be no doubt of the desirability of the Serial Works in the Library being complete, it is recommended that some provision in excess of former years be made in the Estimates, so as to allow of the purchase of the Volumes necessary to complete the sets.

Museum.

During the past year the following additions have been made to the Society's Museum:—

1. Fourteen specimens of Gold-bearing Rocks from the De Kaap

Gold-fields, South Africa, presented by R. H. Scaddan, Esq., of Johannesburg; and

2. A series of Rock-specimens from the Main Reef, Witwatersrand Gold-fields, South Africa, presented by Dr. H. Exton, F.G.S.

The Collections in the Museum are in good condition, and the glazing and other protections of the drawers appear to answer their purpose very well. As intimated at the close of the last Report of the Committee, the glazing of the drawers in the Lower Museum was continued in 1889, when 220 drawers, large and small, were provided with covers at a cost of £5 4s. 5d. To complete the glazing of the Inner Room of the Lower Museum there still remain 80 large drawers, at least twice the size of any of the others, to be covered; the Committee propose to devote a sum of about £5 to this purpose during the year. The Inner Museum would then be glazed throughout.

COMPARATIVE STATEMENT OF THE NUMBER OF THE SOCIETY AT THE
CLOSE OF THE YEARS 1888 AND 1889.

	Dec. 31, 1888.	Dec. 31, 1889.
Compounders	311	310
Contributing Fellows.....	832	856
Non-contributing Fellows..	152	135
	<hr/>	<hr/>
	1295	1301
Foreign Members	39	40
Foreign Correspondents....	39	38
	<hr/>	<hr/>
	1373	1379

*Comparative Statement explanatory of the Alterations in the Number
of Fellows, Foreign Members, and Foreign Correspondents at the
close of the years 1888 and 1889.*

Number of Compounders, Contributing and Non- contributing Fellows, December 31, 1888	}	1295
<i>Add</i> Fellows elected during former year and paid in 1889		
<i>Add</i> Fellows elected and paid in 1889	}	15
<i>Add</i> Fellow re-elected and who pays no Admis- sion Fee		
		46
		1
		<hr/>
		1357
<i>Deduct</i> Compounders deceased	7	
Contributing Fellows deceased	14	
Non-contributing Fellows deceased	17	
Contributing Fellows resigned	13	
Contributing Fellows removed	5	
	—	56
		<hr/>
		1301
1 Contributing Fellow became Non-Resident, and 1 Non- Resident Fellow was placed on the Contributing List.		
Number of Foreign Members and Foreign Correspondents, December 31, 1888	}	78
<i>Deduct</i> Foreign Members deceased ..			2
Foreign Correspondents deceased ..	3	
Foreign Correspondents elected } Foreign Members	}	3
	—	8
		<hr/>
		70
<i>Add</i> Foreign Members elected	3	
Foreign Correspondents elected	5	
	—	78
		<hr/>
		1379
		<hr/>

DECEASED FELLOWS.

Compounders (7).

Cockburn-Hood, T. H., Esq.	Travers, A., Esq.
Jackson, E. S., Esq.	Turner, H., Esq.
Langdon, Rev. E.	Woods, Rev. J. E. T.
Lendy, Major A. F.	

Resident and other Contributing Fellows (14).

Bateman, J. F. La Trobe, Esq.	Damon, R., Esq.
Blair, M., Esq.	DuSautoy, J. B. A., Esq.
Boyd, E. F., Esq.	Eversley, Viscount.
Bristow, H. W., Esq.	Hamand, A. S., Esq.
Browne, Rev. T. H.	Percy, Dr. J.
Coke, R. G., Esq.	Radcliffe, J., Esq.
Crawford, J. C., Esq.	Readwin, T. A., Esq.

Non-contributing Fellows (17).

Bland, T., Esq.	McConnell, D. C., Esq.
Brand, G., Esq.	Mayo, H., Esq.
Fisher, J. C., Esq.	Mortimer, W. H., Esq.
Floyer, J., Esq.	Murray, W., Esq.
Hawkins, T., Esq.	Nicholson, C., Esq.
Hertzog, W. F., Esq.	Philpot, Ven. Archdeacon B.
Jennings, F. M., Esq.	Turner, Rev. W.
Knowles, Rev. J.	Watson, Dr. J. G. W.
Lingwood, R. M., Esq.	

Foreign Members (2).

Dechen, Herr H. von.	Meneghini, Prof. G.
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Foreign Correspondents (3).

Bellardi, Prof. L.	Seguenza, Prof. G.
Lesquereux, Prof. L.	

FELLOWS RESIGNED (13).

Bourne, A. A., Esq.	Meaden, H. P., Esq.
Colebrooke, Sir T. E.	Morgan, J. A., Esq.
Dresser, C. L., Esq.	Plant, James, Esq.
Eastwood, C., Esq.	Robinson, R., Esq.
Gaskin, D. M. F., Esq.	Sylvester, J. H., Esq.
Longe, F. D., Esq.	Willacy, Rev. T. R., Esq.
Mackintosh, D., Esq.	

FELLOWS REMOVED (5).

Brunt, E., Esq.	Parnell, G. T., Esq.
Häusler, Dr. R.	Wilson, Dr. W. H.
Holme, H. S., Esq.	

The following Personages were elected from the List of Foreign Correspondents to fill the vacancies in the List of Foreign Members during the year 1889.

Professor Ferdinand Fouqué, of Paris.
 Marquis Gaston de Saporta, of Aix-en-Provence.
 Professor Karl Alfred von Zittel, of Munich.

The following Personages were elected Foreign Correspondents during the year 1889.

Professor G. K. Gilbert, of Washington, U.S.A.
 Mons. A. Michel-Lévy, of Paris.
 Doctor Hans Reusch, of Christiania.
 Professor Antonio Stoppani, of Milan.
 Mons. R. D. M. Verbeek, of Padang, Sumatra.

After the Reports had been read, it was resolved :—

That they be received and entered on the Minutes of the Meeting, and that such parts of them as the Council shall think fit be printed and distributed among the Fellows.

It was afterwards resolved :—

That the thanks of the Society be given to Dr. W. T. Blanford, retiring from the office of President.

That the thanks of the Society be given to Dr. J. Evans, Prof. T. M^cKenny Hughes, Prof. J. W. Judd, and Prof. J. Prestwich, retiring from the office of Vice-Presidents.

That the thanks of the Society be given to W. H. Hudleston, Esq., retiring from the office of Secretary.

That the thanks of the Society be given to Prof. T. M^cKenny Hughes, Prof. J. W. Judd, Prof. J. Prestwich, Prof. H. G. Seeley, and the Rev. H. H. Winwood, retiring from the Council.

After the Balloting-glasses had been duly closed, and the Lists examined by the Scrutineers, the following gentlemen were declared to have been duly elected as the Officers and Council for the ensuing year :—

OFFICERS.

PRESIDENT.

A. Geikie, LL.D., F.R.S.

VICE-PRESIDENTS.

Prof. T. G. Bonney, D.Sc., LL.D., F.R.S.

L. Fletcher, Esq., M.A., F.R.S.

W. H. Hudleston, Esq., M.A., F.R.S.

J. W. Hulke, Esq., F.R.S.

SECRETARIES.

H. Hicks, M.D., F.R.S.

J. E. Marr, Esq., M.A.

FOREIGN SECRETARY.

Sir Warrington W. Smyth, M.A., F.R.S.

TREASURER.

Prof. T. Wiltshire, M.A., F.L.S.

COUNCIL.

Prof. J. F. Blake, M.A.	J. W. Hulke, Esq., F.R.S.
W. T. Blanford, LL.D., F.R.S.	Major-Gen. C. A. M ^c Mahon.
Prof. T. G. Bonney, D.Sc., LL.D., F.R.S.	J. E. Marr, Esq., M.A.
James Carter, Esq.	H. W. Monekton, Esq.
John Evans, D.C.L., LL.D., F.R.S.	E. Tulley Newton, Esq.
L. Fletcher, Esq., M.A., F.R.S.	F. W. Rudler, Esq.
A. Geikie, LL.D., F.R.S.	Sir Warrington W. Smyth, M.A., F.R.S.
Prof. A. H. Green, M.A., F.R.S.	W. Topley, Esq., F.R.S.
A. Harker, Esq., M.A.	Rev. G. F. Whidborne, M.A.
H. Hicks, M.D., F.R.S.	Prof. T. Wiltshire, M.A., F.L.S.
Rev. Edwin Hill, M.A.	H. Woodward, LL.D., F.R.S.
W. H. Hudleston, Esq., M.A., F.R.S.	

LIST OF
THE FOREIGN MEMBERS

OF THE GEOLOGICAL SOCIETY OF LONDON, IN 1889.

Date of Election.	
1827.	Dr. H. von Dechen, <i>Bonn. (Deceased.)</i>
1848.	James Hall, Esq., <i>Albany, State of New York, U.S.A.</i>
1851.	Professor James D. Dana, <i>New Haven, Connecticut, U.S.A.</i>
1853.	Count Alexander von Keyserling, <i>Rayküll, Russia.</i>
1856.	Professor Robert Bunsen, For. Mem. R.S., <i>Heidelberg.</i>
1857.	Professor H. B. Geinitz, <i>Dresden.</i>
1859.	Dr. Ferdinand Römer, <i>Breslau.</i>
1866.	Dr. Joseph Leidy, <i>Philadelphia, U.S.A.</i>
1867.	Professor A. Daubrée, For. Mem. R.S., <i>Paris.</i>
1871.	Dr. Franz Ritter von Hauer, <i>Vienna.</i>
1874.	Professor Alphonse Favre, <i>Geneva.</i>
1874.	Professor E. Hébert, <i>Paris.</i>
1874.	Professor Albert Gaudry, <i>Paris.</i>
1875.	Professor Fridolin Sandberger, <i>Würzburg.</i>
1875.	Professor F. August Quenstedt, <i>Tübingen. (Deceased.)</i>
1876.	Professor E. Beyrich, <i>Berlin.</i>
1877.	Dr. Carl Wilhelm Gümbel, <i>Munich.</i>
1877.	Dr. Eduard Suess, <i>Vienna.</i>
1879.	Major-General N. von Kokscharow, <i>St. Petersburg.</i>
1879.	M. Jules Marcou, <i>Cambridge, U.S.A.</i>
1879.	Dr. J. J. S. Steenstrup, For. Mem. R.S., <i>Copenhagen.</i>
1880.	Professor Gustave Dewalque, <i>Liège.</i>
1880.	Baron Adolf Erik Nordenskiöld, <i>Stockholm.</i>
1880.	Professor Ferdinand Zirkel, <i>Leipzig.</i>
1882.	Professor Sven Lovén, <i>Stockholm.</i>
1882.	Professor Ludwig Rüttimeyer, <i>Basle.</i>
1883.	Professor J. S. Newberry, <i>New York, U.S.A.</i>
1883.	Professor Otto Martin Torell, <i>Stockholm.</i>
1884.	Professor G. Capellini, <i>Bologna.</i>
1884.	Professor A. L. O. Des Cloizeaux, For. Mem. R.S., <i>Paris.</i>
1884.	Professor G. Meneghini, <i>Pisa. (Deceased.)</i>
1884.	Professor J. Szabó, <i>Pesth.</i>
1885.	Professor Jules Gosselet, <i>Lille.</i>
1886.	Professor Gustav Tschermak, <i>Vienna.</i>
1887.	Professor J. P. Lesley, <i>Philadelphia, U.S.A.</i>
1887.	Professor J. D. Whitney, <i>Cambridge, U.S.A.</i>
1888.	Professor Pierre J. van Beneden, <i>Louvain.</i>
1888.	Professor Eugène Renevier, <i>Lausanne.</i>
1888.	Baron Ferdinand von Richthofen, <i>Berlin.</i>
1889.	Professor Ferdinand Fouqué, <i>Paris.</i>
1889.	Marquis Gaston de Saporta, <i>Aix-en-Provence.</i>
1889.	Professor Karl Alfred von Zittel, <i>Munich.</i>

LIST OF
THE FOREIGN CORRESPONDENTS

OF THE GEOLOGICAL SOCIETY OF LONDON, IN 1889.

Date of Election.	
1863.	Dr. F. Senft, <i>Eisenach</i> .
1864.	Dr. Charles Martins, <i>Montpellier</i> .
1866.	Professor Victor Raulin, <i>Montfaucon d'Argonne</i> .
1866.	Baron Achille de Zigno, <i>Padua</i> .
1872.	Herr Dionys Stur, <i>Vienna</i> .
1874.	Professor Iginio Cocchi, <i>Florence</i> .
1874.	M. Gustave H. Cotteau, <i>Auxerre</i> .
1874.	Professor G. Seguenza, <i>Messina</i> . (Deceased.)
1874.	Dr. T. C. Winkler, <i>Haarlem</i> .
1877.	Professor George J. Brush, <i>New Haven, U.S.A.</i>
1879.	M. Édouard Dupont, <i>Brussels</i> .
1879.	Dr. Émile Sauvage, <i>Boulogne-sur-Mer</i> .
1880.	Professor Luigi Bellardi, <i>Turin</i> . (Deceased.)
1880.	Professor Leo Lesquereux, <i>Columbus, U.S.A.</i> (Deceased.)
1880.	Dr. Melchior Neumayr, <i>Vienna</i> . (Deceased.)
1880.	M. Alphonse Renard, <i>Ghent</i> .
1881.	Professor E. D. Cope, <i>Philadelphia, U.S.A.</i>
1882.	Professor Louis Lartet, <i>Toulouse</i> .
1882.	Professor Alphonse Milne-Edwards, <i>Paris</i> .
1884.	Dr. Charles Barrois, <i>Lille</i> .
1884.	M. Alphonse Briart, <i>Morlanwelz</i> .
1884.	Professor Hermann Credner, <i>Leipzig</i> .
1884.	Baron C. von Ettingshausen, <i>Gratz</i> .
1884.	Dr. E. Mojsisovics von Mojsvár, <i>Vienna</i> .
1885.	Professor G. Lindström, <i>Stockholm</i> .
1885.	Dr. A. G. Nathorst, <i>Stockholm</i> .
1886.	Professor H. Rosenbusch, <i>Heidelberg</i> .
1886.	Professor J. Vilanova y Piera, <i>Madrid</i> .
1887.	Senhor J. F. N. Delgado, <i>Lisbon</i> .
1887.	Professor A. Heim, <i>Zurich</i> .
1887.	Professor A. de Lapparent, <i>Paris</i> .
1888.	Professor W. C. Brögger, <i>Stockholm</i> .
1888.	M. Charles Brongniart, <i>Paris</i> .
1888.	Professor Edward Salisbury Dana, <i>New Haven, U.S.A.</i>
1888.	Professor Anton Fritsch, <i>Prague</i> .
1888.	M. Ernest Van den Broeck, <i>Brussels</i> .
1889.	Professor G. K. Gilbert, <i>Washington, U.S.A.</i>
1889.	M. A. Michel-Lévy, <i>Paris</i> .
1889.	Dr. Hans Reusch, <i>Christiania</i> .
1889.	Professor Antonio Stoppani, <i>Milan</i> .
1889.	M. R. D. M. Verbeek, <i>Padang, Sumatra</i> .

AWARDS OF THE WOLLASTON MEDAL

UNDER THE CONDITIONS OF THE "DONATION FUND"

ESTABLISHED BY

WILLIAM HYDE WOLLASTON, M.D., F.R.S., F.G.S., &c.

"To promote researches concerning the mineral structure of the earth, and to enable the Council of the Geological Society to reward those individuals of any country by whom such researches may hereafter be made,"—"such individual not being a Member of the Council."

- | | |
|-------------------------------------|--|
| 1831. Mr. William Smith. | 1861. Professor Dr. H. G. Bronn. |
| 1835. Dr. G. A. Mantell. | 1862. Mr. R. A. C. Godwin-Austen. |
| 1836. M. Louis Agassiz. | 1863. Professor Gustav Bischof. |
| 1837. } Capt. T. P. Cautley. | 1864. Sir R. I. Murchison. |
| } Dr. H. Falconer. | 1865. Dr. Thomas Davidson. |
| 1838. Sir Richard Owen. | 1866. Sir Charles Lyell. |
| 1839. Professor C. G. Ehrenberg. | 1867. Mr. G. Poulett Scrope. |
| 1840. Professor A. H. Dumont. | 1868. Professor Carl F. Naumann. |
| 1841. M. Adolphe T. Brongniart. | 1869. Dr. H. C. Sorby. |
| 1842. Baron L. von Buch. | 1870. Professor G. P. Deshayes. |
| 1843. } M. Elie de Beaumont. | 1871. Sir A. C. Ramsay. |
| } M. P. A. Dufrenoy. | 1872. Professor J. D. Dana. |
| 1844. Rev. W. D. Conybeare. | 1873. Sir P. de M. Grey-Egerton. |
| 1845. Professor John Phillips. | 1874. Professor Oswald Heer. |
| 1846. Mr. William Lonsdale. | 1875. Professor L. G. de Koninck. |
| 1847. Dr. Ami Boué. | 1876. Professor T. H. Huxley. |
| 1848. Rev. Dr. W. Buckland. | 1877. Mr. Robert Mallet. |
| 1849. Professor Joseph Prestwich. | 1878. Dr. Thomas Wright. |
| 1850. Mr. William Hopkins. | 1879. Professor Bernhard Studer. |
| 1851. Rev. Prof. A. Sedgwick. | 1880. Professor Auguste Daubrée. |
| 1852. Dr. W. H. Fitton. | 1881. Professor P. Martin Duncan. |
| 1853. } M. le Vicomte A. d'Archiac. | 1882. Dr. Franz Ritter von Hauer. |
| } M. E. de Verneuil. | 1883. Dr. W. T. Blanford. |
| 1854. Sir Richard Griffith. | 1884. Professor Albert Gaudry. |
| 1855. Sir H. T. De la Beche. | 1885. Mr. George Busk. |
| 1856. Sir W. E. Logan. | 1886. Professor A. L. O. Des
Cloizeaux. |
| 1857. M. Joachim Barrande. | 1887. Mr. J. Whitaker Hulke. |
| 1858. } Herr Hermann von Meyer. | 1888. Mr. H. B. Medlicott. |
| } Mr. James Hall. | 1889. Professor T. G. Bonney. |
| 1859. Mr. Charles Darwin. | 1890. Professor W. C. Williamson. |
| 1860. Mr. Searles V. Wood. | |

AWARDS

OF THE

BALANCE OF THE PROCEEDS OF THE WOLLASTON
"DONATION-FUND."

- | | |
|------------------------------------|------------------------------------|
| 1831. Mr. William Smith. | 1862. Professor Oswald Heer. |
| 1833. Mr. William Lonsdale. | 1863. Professor Ferdinand Senft. |
| 1834. M. Louis Agassiz. | 1864. Professor G. P. Deshayes. |
| 1835. Dr. G. A. Mantell. | 1865. Mr. J. W. Salter. |
| 1836. Professor G. P. Deshayes. | 1866. Dr. Henry Woodward. |
| 1838. Sir Richard Owen. | 1867. Mr. W. H. Baily. |
| 1839. Professor C. G. Ehrenberg. | 1868. M. J. Bosquet. |
| 1840. Mr. J. De Carle Sowerby. | 1869. Mr. W. Carruthers. |
| 1841. Professor Edward Forbes. | 1870. M. Marie Rouault. |
| 1842. Professor John Morris. | 1871. Mr. R. Etheridge. |
| 1843. Professor John Morris. | 1872. Dr. James Croll. |
| 1844. Mr. William Lonsdale. | 1873. Professor J. W. Judd. |
| 1845. Mr. Geddes Bain. | 1874. Dr. Henri Nyst. |
| 1846. Mr. William Lonsdale. | 1875. Mr. L. C. Miall. |
| 1847. M. Alcide d'Orbigny. | 1876. Professor Giuseppe Seguenza. |
| 1848. } Cape-of-Good-Hope Fossils. | 1877. Mr. R. Etheridge, Jun. |
| } M. Alcide d'Orbigny. | 1878. Professor W. J. Sollas. |
| 1849. Mr. William Lonsdale. | 1879. Mr. S. Allport. |
| 1850. Professor John Morris. | 1880. Mr. Thomas Davies. |
| 1851. M. Joachim Barrande. | 1881. Dr. R. H. Traquair. |
| 1852. Professor John Morris. | 1882. Dr. G. J. Hinde. |
| 1853. Professor L. G. de Koninck. | 1883. Mr. John Milne. |
| 1854. Dr. S. P. Woodward. | 1884. Mr. E. Tulley Newton. |
| 1855. Drs. G. and F. Sandberger. | 1885. Dr. Charles Callaway. |
| 1856. Professor G. P. Deshayes. | 1886. Mr. J. S. Gardner. |
| 1857. Dr. S. P. Woodward. | 1887. Mr. B. N. Peach. |
| 1858. Mr. James Hall. | 1888. Mr. J. Horne. |
| 1859. Mr. Charles Peach. | 1889. Mr. A. Smith Woodward. |
| 1860. } Professor T. Rupert Jones. | 1890. Mr. W. A. E. Ussher. |
| } Mr. W. K. Parker. | |
| 1861. Professor A. Daubr e. | |

AWARDS OF THE MURCHISON MEDAL

AND OF THE

PROCEEDS OF "THE MURCHISON GEOLOGICAL FUND,"

ESTABLISHED UNDER THE WILL OF THE LATE

SIR RODERICK IMPEY MURCHISON, BART., F.R.S., F.G.S.

"To be applied in every consecutive year in such manner as the Council of the Society may deem most useful in advancing geological science, whether by granting sums of money to travellers in pursuit of knowledge, to authors of memoirs, or to persons actually employed in any inquiries bearing upon the science of geology, or in rewarding any such travellers, authors, or other persons, and the Medal to be given to some person to whom such Council shall grant any sum of money or recompense in respect of geological science."

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|---|--|
| 1873. Mr. William Davies. <i>Medal.</i> | 1883. Professor H. R. Göppert.
<i>Medal.</i> |
| 1873. Professor Oswald Heer. | 1883. Mr. John Young. |
| 1874. Dr. J. J. Bigsby. <i>Medal.</i> | 1884. Dr. H. Woodward. <i>Medal.</i> |
| 1874. Mr. Alfred Bell. | 1884. Mr. Martin Simpson. |
| 1874. Professor Ralph Tate. | 1885. Dr. Ferdinand Römer.
<i>Medal.</i> |
| 1875. Mr. W. J. Henwood. <i>Medal.</i> | 1885. Mr. Horace B. Woodward. |
| 1875. Professor H. G. Seeley. | 1886. Mr. W. Whitaker. <i>Medal.</i> |
| 1876. Mr. A. R. C. Selwyn.
<i>Medal.</i> | 1886. Mr. Clement Reid. |
| 1873. Dr. James Croll. | 1887. Rev. P. B. Brodie. <i>Medal.</i> |
| 1877. Rev. W. B. Clarke. <i>Medal.</i> | 1887. Mr. Robert Kidston. |
| 1877. Professor J. F. Blake. | 1888. Professor J. S. Newberry.
<i>Medal.</i> |
| 1878. Dr. H. B. Geinitz. <i>Medal.</i> | 1888. Mr. E. Wilson. |
| 1878. Professor C. Lapworth. | 1889. Professor James Geikie.
<i>Medal.</i> |
| 1879. Professor F. M'Coy. <i>Medal.</i> | 1889. Mr. Grenville A. J. Cole. |
| 1879. Mr. J. W. Kirkby. | 1890. Professor Edward Hull.
<i>Medal.</i> |
| 1880. Mr. R. Etheridge. <i>Medal.</i> | 1890. Mr. E. Wethered. |
| 1881. Professor A. Geikie. <i>Medal.</i> | |
| 1881. Mr. F. Rutley. | |
| 1882. Professor J. Gosselet. <i>Medal.</i> | |
| 1882. Professor T. Rupert Jones. | |

AWARDS OF THE LYELL MEDAL

AND OF THE

PROCEEDS OF THE "LYELL GEOLOGICAL FUND,"

ESTABLISHED UNDER THE WILL AND CODICIL OF THE LATE
SIR CHARLES LYELL, BART., F.R.S., F.G.S.

The Medal "to be given annually" (or from time to time) "as a mark of honorary distinction as an expression on the part of the governing body of the Society that the Medallist (who may be of any country or either sex) has deserved well of the Science,"—"not less than one third of the annual interest [of the fund] to accompany the Medal, the remaining interest to be given in one or more portions at the discretion of the Council for the encouragement of Geology or of any of the allied sciences by which they shall consider Geology to have been most materially advanced, either for travelling expenses or for a memoir or paper published, or in progress, and without reference to the sex or nationality of the author, or the language in which any such memoir or paper shall be written."

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|---|---|
| 1876. Professor John Morris.
<i>Medal.</i> | 1883. M. E. Rigaux. |
| 1877. Dr. James Hector. <i>Medal.</i> | 1884. Dr. Joseph Leidy. <i>Medal.</i> |
| 1877. Mr. W. Pengelly. | 1884. Professor Charles Lapworth. |
| 1878. Mr. G. Busk. <i>Medal.</i> | 1885. Professor H. G. Seeley.
<i>Medal.</i> |
| 1878. Dr. W. Waagen. | 1885. Mr. A. J. Jukes-Browne. |
| 1879. Professor Edmond Hébert.
<i>Medal.</i> | 1886. Mr. W. Pengelly. <i>Medal.</i> |
| 1879. Professor H. A. Nicholson. | 1886. Mr. D. Mackintosh. |
| 1879. Dr. Henry Woodward. | 1887. Mr. Samuel Allport. <i>Medal.</i> |
| 1880. Mr. John Evans. <i>Medal.</i> | 1887. Rev. Osmond Fisher. |
| 1880. Professor F. Quenstedt. | 1888. Professor H. A. Nicholson.
<i>Medal.</i> |
| 1881. Sir J. W. Dawson. <i>Medal.</i> | 1888. Mr. A. H. Foord. |
| 1881. Dr. Anton Fritsch. | 1888. Mr. T. Roberts. |
| 1881. Mr. G. R. Vine. | 1889. Professor W. Boyd Dawkins.
<i>Medal.</i> |
| 1882. Dr. J. Lycett. <i>Medal.</i> | 1889. M. Louis Dollo. |
| 1882. Rev. Norman Glass. | 1890. Professor T. Rupert Jones.
<i>Medal.</i> |
| 1882. Professor C. Lapworth. | 1890. Mr. C. Davies Sherborn. |
| 1883. Dr. W. B. Carpenter. <i>Medal.</i> | |
| 1883. Mr. P. H. Carpenter. | |

AWARDS OF THE BIGSBY MEDAL,

FOUNDED BY

DR. J. J. BIGSBY, F.R.S., F.G.S.

To be awarded biennially "as an acknowledgment of eminent services in any department of Geology, irrespective of the receiver's country; but he must not be older than 45 years at his last birthday, thus probably not too old for further work, and not too young to have done much."

1877. Professor O. C. Marsh.
1879. Professor E. D. Cope.
1881. Dr. C. Barrois.
1883. Dr. Henry Hicks.

1885. Professor Alphonse Renard.
1887. Professor Charles Lapworth.
1889. Mr. J. J. Harris Teall.

AWARDS OF THE PROCEEDS OF THE BARLOW- JAMESON FUND,

ESTABLISHED UNDER THE WILL OF THE LATE

DR. H. C. BARLOW, F.G.S.

"The perpetual interest to be applied every two or three years, as may be approved by the Council, to or for the advancement of Geological Science."

1880. Purchase of microscope.
1881. Purchase of microscope lamps.
1882. Baron C. von Ettingshausen.
1884. Dr. James Croll.

1884. Professor Leo Lesquereux.
1886. Dr. H. J. Johnston-Lavis.
1888. Museum.
1890. Mr. W. Jerome Harrison.

ESTIMATES *for*

INCOME EXPECTED.

	£	s.	d.	£	s.	d.
Compositions.....	189	0	0			
Due for Arrears of Admission-fees	75	12	0			
Admission-fees, 1890	252	0	0			
	<hr/>			327	12	0
Due for Arrears of Annual Contributions	105	0	0			
Annual Contributions, 1890, from Resident Fellows, and Non-residents, 1859 to 1861	1600	0	0			
Annual Contributions in advance	42	0	0			
Dividends on Consolidated $2\frac{3}{4}$ per Cents.	238	12	8			
Sale of Quarterly Journal, including Longman's account	165	0	0			
Sale of Geological Map, including Stanford's account	10	0	0			
Sale of Transactions, Library-catalogue, Orme- rod's Index, Hochstetter's New Zealand, and List of Fellows	3	0	0			
	<hr/>			178	0	0

£2680 4 8

THOMAS WILTSHIRE, TREAS.

25 January, 1890.

the Year 1890.

EXPENDITURE ESTIMATED.

	£	s.	d.	£	s.	d.
House Expenditure:						
Taxes	23	0	0			
Fire-insurance	15	0	0			
Gas	30	0	0			
Fuel	32	0	0			
Furniture and Repairs.....	20	0	0			
House-repairs and Maintenance.....	15	0	0			
Annual Cleaning	15	0	0			
Washing and Sundries.....	35	0	0			
Tea at Meetings	16	0	0			
				201	0	0
Salaries and Wages:						
Assistant Secretary	350	0	0			
Assistants in Library, Office, and Museum ..	240	0	0			
House Steward.....	105	0	0			
Housemaid	40	0	0			
Errand Boy	48	0	0			
Charwoman and Occasional Assistance	25	0	0			
Attendants at Meetings	8	0	0			
Accountant	10	10	0			
				826	10	0
Official Expenditure:						
Stationery	28	0	0			
Miscellaneous Printing	40	0	0			
Postages and other Expenses	90	0	0			
				158	0	0
Library				160	0	0
Museum.....				5	0	0
Publications:						
Geological Map	20	0	0			
Quarterly Journal	1000	0	0			
" " Commission, Postage, and Addressing	100	0	0			
List of Fellows	33	0	0			
Abstracts, including Postage	110	0	0			
Ormerod's Index	30	0	0			
				1293	0	0
Balance in favour of the Society				36	14	8
				£2680 4 8		

Income and Expenditure during the

RECEIPTS.

	£	s.	d.	£	s.	d.
Balance in Bankers' hands, 1 January 1889.	232	6	0			
Balance in Clerk's hands, 1 January 1889.	16	6	5			
				<u>248</u>	12	5
Compositions	189	0	0			
Arrears of Admission-fees	94	10	0			
Admission-fees, 1889	289	16	0			
				<u>384</u>	6	0
Arrears of Annual Contributions	135	13	6			
Annual Contributions for 1889, viz.:						
Resident Fellows	1575	0	0			
Non-Resident Fellows ...	12	18	0			
				<u>1587</u>	18	0
Annual Contributions in advance	41	9	6			
Dividends on 2½ per cent. Consolidated Stock	245	6	11			
Taylor & Francis: Advertisements in Journal, Vol. 44..	3	10	3			
Publications:						
Sale of Journal, Vols. 1-44	89	14	3			
" Vol. 45*	73	4	0			
Sale of Library Catalogue	1	5	0			
Sale of Geological Map	21	16	1			
Sale of Ormerod's Index	1	4	11			
Sale of Hochstetter's New Zealand	0	2	0			
Sale of Transactions	1	0	10			
Sale of List of Fellows	0	3	0			
				<u>188</u>	10	1
*Due from Messrs. Longmans, in addition to the above, on Journal, Vol. 45, &c.....	61	5	1			

£3024 6 8

We have compared this statement with the Books and Accounts presented to us, and find them to agree.

(Signed) H. BAUERMAN,
HORACE W. MONCKTON, } *Auditors.*

28 January, 1890.

Year ending 31 December, 1889.

EXPENDITURE.

	£	s.	d.	£	s.	d.
House Expenditure:						
Taxes	21	10	0			
Fire-insurance	15	0	0			
Gas	28	11	0			
Fuel	27	9	0			
Furniture and Repairs	37	11	5			
House-repairs.....	11	6	4			
Annual Cleaning	11	7	8			
Washing and Sundries	34	10	3			
Tea at Meetings.....	17	0	0			
				204	5	8
Salaries and Wages:						
Assistant Secretary	350	0	0			
Assistants in Library, Office, and Museum...	240	0	0			
House Steward	105	0	0			
Housemaid	40	0	0			
Errand Boy	48	12	0			
Charwoman	24	11	4			
Attendants at Meetings.....	8	15	0			
Accountant's Fee	11	0	6			
				827	18	10
Official Expenditure:						
Stationery	28	13	6			
Miscellaneous Printing.....	83	13	0			
Postages and other Expenses	106	15	6			
				219	2	0
Legal Charges				16	0	10
Library				146	4	0
Museum.....				5	4	5
Publications:						
Geological Map	19	13	1			
Journal, Vols. 1-44.....	9	8	11			
" Vol. 45.....	880	4	8			
" " Commission, Postage, and Addressing.	105	6	0			
				985	10	8
List of Fellows.....	33	12	7			
Abstracts, including Postage	109	16	1			
				1158	1	4
Investment in £200 Consolidated $2\frac{3}{4}$ per Cent. Stock at 99				198	5	6
Balance in Bankers' hands, 31 Dec. 1889 ..	238	5	0			
Balance in Clerk's hands, 31 Dec. 1889 ..	10	19	1			
				249	4	1
				<u>£3024</u>	<u>6</u>	<u>8</u>

THOMAS WILTSHIRE, *Treasurer.*

"WOLLASTON DONATION FUND." TRUST ACCOUNT.

RECEIPTS.		PAYMENTS.	
£	s. d.	£	s. d.
Balance at Bankers', 1 January, 1889	34 7 2	Cost of striking Gold Medal awarded to Prof. T. G. Bonney	10 10 0
Dividends on the Fund invested in 2 $\frac{3}{4}$ per cent. Consolidated Stock	30 7 10	Award to Mr. A. Smith Woodward	31 15 9
		Balance at Bankers', 31 December, 1889	22 9 3
	<u>£64 15 0</u>		<u>£64 15 0</u>

"MURCHISON GEOLOGICAL FUND." TRUST ACCOUNT.

RECEIPTS.		PAYMENTS.	
£	s. d.	£	s. d.
Balance at Bankers', 1 January, 1889	19 9 2	Award to Prof. J. Geikie, with Medal	10 10 0
Dividends on the Fund invested in London and North-Western Railway 4 per cent. Debenture Stock	39 0 0	" Mr. Grenville A. J. Cole	27 12 2
		Cost of Medal	0 17 0
		Balance at Bankers', 31 December, 1889	19 10 0
	<u>£58 9 2</u>		<u>£58 9 2</u>

"LYELL GEOLOGICAL FUND." TRUST ACCOUNT.

RECEIPTS.		PAYMENTS.	
£	s. d.	£	s. d.
Balance at Bankers', 1 January, 1889	51 7 6	Award to Prof. W. Boyd Dawkins, with Medal	25 0 0
Dividends on the Fund invested in Metropolitan 3 $\frac{1}{2}$ per cent. Stock	68 12 0	" M. Louis Dollo	42 9 6
		Cost of Medal	1 1 0
		Balance at Bankers', 31 December, 1889	51 9 0
	<u>£119 19 6</u>		<u>£119 19 6</u>

"BARLOW-JAMESON FUND." TRUST ACCOUNT.

RECEIPTS.		PAYMENTS.	
£	s. d.	£	s. d.
Balance at Bankers', 1 January, 1889	23 16 9	Balance at Bankers', 31 December, 1889	37 17 2
Dividends on the Fund invested in 2 $\frac{3}{4}$ per cent. Consolidated Stock	14 0 5		
	<u>£37 17 2</u>		<u>£37 17 2</u>

"BIGSBY FUND." TRUST ACCOUNT.

RECEIPTS.	£	s.	d.	PAYMENTS.	£	s.	d.
Balance at Bankers', 1 January, 1889	12	3	10	Cost of striking Gold Medal awarded to Mr. J. J. H. Teall	13	14	5
Dividends on the Fund invested in 2½ per cent. Consoli- dated Stock	5	17	2	Balance at Bankers', 31 December, 1889	4	6	7
	£18	1	0		£18	1	0

VALUATION OF THE SOCIETY'S PROPERTY ; 31 December, 1889.

PROPERTY.	£	s.	d.	PROPERTY.	£	s.	d.
Due from Longman & Co., on account of Journal, vol. xiv. &c.	61	5	1	Balance in favour of the Society	9124	1	2
Balance in Bankers' hands, 31 Dec. 1889	238	5	0				
Balance in Clerk's hands, 31 Dec. 1889	10	19	1				
Funded Property:—							
Consolidated 2½ per Cents. at 97	8900	0	0				
Arrears of Admission-fees (considered good)	75	12	0				
Arrears of Annual Contributions (considered good)	105	0	0				
	£9124	1	2		£9124	1	2

[N.B.—The above does not include the value of the Collections, Library, Furniture, and stock of unsold Publications.]

THOMAS WILTSHIRE, Treas.
25 January, 1890.

AWARD OF THE WOLLASTON MEDAL.

In handing the Wollaston Medal to Prof. J. W. JUDD, F.R.S., for transmission to Prof. W. CRAWFORD WILLIAMSON, F.R.S., the PRESIDENT addressed him as follows :—

Professor JUDD,—

The Council have awarded the Wollaston Medal for the present year to Prof. W. C. Williamson, in recognition of his researches in Palæontology, and especially of the series of important papers in which he has described the structure of the plants that have contributed to the formation of coal. His investigations have added greatly to our knowledge of the Carboniferous flora, and have enabled us to form a much clearer idea of the plant-life in those far distant days of the Palæozoic era than was previously possible. Although Professor Williamson's attention has now for many years been especially devoted to the examination of fossil plants, he had, before his researches on ancient botany commenced, added many valuable details to our knowledge of the fossiliferous rocks of Yorkshire and Lancashire, and he had contributed greatly to the natural history of recent and fossil Foraminifera, whilst in a paper published more than 40 years ago, on some of the microscopical objects found in the mud of the Levant and other deposits, with remarks on the mode of formation of calcareous and infusorial siliceous rocks, he anticipated many recent discoveries, both as to the part played by minute calcareous and siliceous organisms in rock-formation, and also as to the chemical and physical changes to which such organisms are subject during the conversion of soft deposits into hard stone.

In asking you to transmit this Medal to Professor Williamson, may I further beg that you will convey to him an expression of our wishes that he may continue his important studies for many years to come, and of our regret that his engagements have unavoidably prevented our having the pleasure of his presence on this occasion.

Prof. JUDD, in reply, read the following communication received by him from Prof. WILLIAMSON :—

“ I need scarcely say that I feel grateful for the honour done me in awarding me the Wollaston Medal ; and I trust you will not deem me presumptuous when I express a hope that it has been won by conscientious work. Though the rich deposits of fossil plants discovered in the neighbourhood of Scarborough—my native town—

drew my attention to palæobotany at an early age, it was only in 1851 that I commenced the study of their internal organization. I was led to this by a specimen for which I was indebted to our distinguished colleague Professor Prestwich, and which enabled me to interpret the anomalous objects known as *Sternbergia*. The success attending this exploration whetted the appetite; and from that time until now the organization of the Carboniferous plants has received my continuous attention. The difficulties impeding my work, which have been considerable, have chiefly arisen from one cause. Most of the Carboniferous plants belong to the Cryptogamic division of the Vegetable kingdom, the only exceptions being some ancestral forms of the modern Cycads and Conifers. At the present day these Cryptogams are mainly low herbaceous plants. But forests and forest-trees were wanted in that primæval age, which want seems to have been inadequately supplied by the Gymnosperms just referred to. The want was met by uplifting the now lowly Cryptogams into Forest giants, and since the stems of these required some organization additional to that which living Cryptogams possess, to enable them to sustain their superstructures, they were strengthened for their work by the same exogenous growth as effects that end among modern forest-trees. But that any Cryptogams should attain so high an organization was deemed by most botanists so improbable that their almost universal voice rejected my views upon the subject. But the truth has prevailed, and, happily for myself, I have been spared long enough to witness this end of my labours."

In conclusion, Prof. Williamson expressed his great indebtedness to Messrs. Cash, Aitkin, Butterworth, Nield, Earnshaw, Whittaker, Spencer, Binns, Wild, and Lomax, who have collected the valuable materials employed by him in his researches.

AWARD OF THE MURCHISON MEDAL.

In presenting the Murchison Medal to Prof. E. HULL, F.R.S., the PRESIDENT addressed him as follows:—

Professor HULL,—

In handing to you, who were one of Sir R. Murchison's colleagues on the Geological Survey of Great Britain and Ireland, the Medal founded by him, I shall not attempt to enumerate the many additions that you have made to our knowledge of the geology of the British

Islands and to geological literature. Your contributions to the memoirs published by the Survey on various parts of England, and especially on parts of Gloucestershire, Oxfordshire, Cumberland, Cheshire, and Lancashire, are too well known to need recapitulation; and you have done good service to the cause of science by your treatment of one of the principal geological and economical problems presented to the Survey in your 'Coal-fields of Great Britain,' a work that has deservedly passed through several editions. You have aided greatly in the important series of investigations into the underground distribution of the productive Coal-measures when concealed by later unconformable deposits, and you have applied your extensive field-experience of British rocks to solve the difficult question of land-distribution in past epochs, and to the elucidation of the physical geography of the British Islands. For several years past, whilst holding your present post at the head of the Irish Survey, you have contributed in very many different parts of the country, and by the investigation of many distinct rock-formations, to our knowledge of Irish geology, and by your visit to Palestine you have been able to throw much light on the geological structure of the Holy Land.

Prof. HULL, in reply, said:—

Mr. PRESIDENT,—

I appreciate very highly the honour which you and the Council have conferred in awarding to me the Murchison Medal. The gratification I feel is enhanced by the circumstance that this distinction is associated with the name and memory of the founder, who was to me a wise and considerate chief as well as a personal friend.

You have been pleased to refer to my official work on the Geological Survey of the United Kingdom, as well as to that of a more personal nature. It has been my lot to serve under four successive chiefs, namely, De la Beche, Murchison, Ramsay, and Dr. Geikie, whose names will ever be associated with the early history and progress of geological science; and I may truly say that from each and all I received that encouragement and support which is essential to the hearty fulfilment of the duties of a public servant; and I am glad to have this opportunity of saying that in bringing the Geological Survey of Ireland to its completion I have been associated with colleagues in this work who have combined an earnest desire

to fulfil their duties to the public service with no small amount of enthusiasm in carrying on scientific investigation. In view of my pending retirement from this department of the public service, I am somewhat consoled by the hope that, in consequence, I may be enabled, at no distant day, to take a more active part in the work of this great Society than has hitherto been possible. In conclusion, I have only to express my thanks to you, Mr. President, for the kind words in which you have communicated to me the award of the Council; these will be an incentive to further effort in the cause of geological investigation.

AWARD OF THE LYELL MEDAL.

The PRESIDENT then presented the Lyell Medal to Prof. T. RUPERT JONES, F.R.S., and addressed him as follows:—

PROFESSOR RUPERT JONES,—

There is unusual pleasure in presenting one of the chief awards in the gift of the Council to a geologist who has been so long and so honourably associated with the Geological Society as yourself, and the appropriateness of the award is not decreased by the circumstance that your official connexion with the Society commenced when the great geologist who founded this medal was President. Since that time, now forty years ago, you have written much on various fossil organisms, but especially on Entomostraca and Foraminifera, and in many cases, and especially amongst the bivalve crustaceans of the older rocks, it is largely to your researches that we are indebted for our present knowledge of the forms. You have also devoted much time and attention to the geology of South Africa, and to bringing together the scattered information that we possess concerning the geology of that interesting region.

In placing the Lyell Medal in your hands I can only add that I think the Council have carried out the intentions of Sir Charles Lyell, and that they are justified in believing that, in his words, “the Medallist has deserved well of the Science.”

Prof. T. RUPERT JONES, in reply, said:—

MR. PRESIDENT,—

Acknowledging, with respectful thanks, the unexpected honour with which the Council, on the part of the Society, has favoured me, I beg to state that, in following the study of those branches of

geological science to which opportunity and other circumstances have led me to give my best attention, I cannot claim to have been so successful, or so useful, or deserving of such honourable recognition as the Council, in their kindness towards an old worker, seem to have considered me to be.

Thanks to a natural disposition to study both living and fossil organisms, and to look with confidence for signs of the great Divine laws governing the earth and all its belongings, my humble part has been, as far as possible, that of a true "Minister et Interpres Naturæ."

No great discovery, however, nor signal success in elucidating the problems offered for our study, in the organic and the inorganic world, has been attained by me. Persistent and, may be, an industrious search among geological facts for their causes and history, and among fossils, especially microzoa, for evidence of their exact relationships, to the end that our knowledge of these things should be more perfect and more useful, has occupied much of my intellectual life.

How far the Foraminifera, Ostracoda, and Phyllopora have been already, or will in the future be useful palæontological guides to the geologist cannot be noticed here.

In all that I have done my work has been my pleasure, and I can claim no reward for it; and in all that has been good I have to acknowledge warmly the co-operative help given by W. K. Parker, J. W. Kirkby, H. B. and G. S. Brady, Henry Woodward, and C. D. Sherborn; and in just now completing the Supplemental Monograph of the Cretaceous Entomostraca I have had the kind aid of G. J. Hinde.

This Medal, Sir, bequeathed by my old and revered friend Sir Charles Lyell, and the other Awards given so graciously this day by the Council and yourself, on behalf of the Geological Society, bear striking and pleasant testimony to the fact that the good deeds of great and good men live after them.

AWARD OF THE WOLLASTON DONATION FUND.

The PRESIDENT next presented the Balance of the Wollaston Fund to Mr. W. A. E. USSHER, F.G.S., and said:—

Mr. USSHER,—

In connexion with the Geological Survey of the counties of

Somerset, Devonshire, and Cornwall, it has been your province to examine many of the rocks exposed, and in addition to your official work you have contributed several useful accounts of the Palæozoic, Triassic, and Pleistocene deposits to the Journal of this Society and to other geological publications. In recognition of the good work done by you the Council have authorized me to present you with the balance of the Wollaston Donation Fund.

Mr. USSHER, in reply, said:—

Mr. PRESIDENT,—

I thank the Council for the recognition of work this Award implies, and you, Sir, for your allusions to it. Whatever results I may have obtained in the discharge of my ordinary duties on the Geological Survey are not deserving of reward. The construction of maps may be faithfully performed without obtaining results of moment in the furtherance of geological knowledge; official requirements are so engrossing and imperative as to oblige those who, like myself, desire to acquire as competent an acquaintance as possible with the strata on which they are employed, to supplement, by private work, the information acquired in public duty. The results obtained by private investigation, whensoever they contribute to the advancement of our common science, are in themselves rewards.

The result of my twenty years' experience in geological mapping is this:—the acquirement of patience and the entire subordination of theoretical considerations, which should be the outcome of a careful study, collation and comparison of details, and not the working hypothesis to weld them into system during or before the progress of the work.

This principle I have had to keep in view in Pleistocene work, in dealing with a variable and disturbed series of Triassic rocks, and to a still greater extent in dealing with fossiliferous rocks such as the Lias, Oolites, Carboniferous, and Devonian. I have learned the extreme importance of Palæontology in investigating disturbed palæozoic areas, where it appears to me that the evidences of fossils and of stratigraphy should be taken together, and without subordinating the one, as a mere adjunct, to the other.

AWARD OF THE MURCHISON GEOLOGICAL FUND.

In presenting the Balance of the Murchison Geological Fund to Mr. E. WETHERED, F.G.S., the PRESIDENT addressed him as follows:—

MR. WETHERED,—

The remainder of the Murchison Donation Fund has been awarded to you by the Council of this Society on account of the researches you have undertaken into the microscopic structure of sedimentary rocks, and to aid you in prosecuting further inquiries. The results of your examination of the insoluble residues obtained from the Carboniferous Limestone, and of the remarkable minute tubular forms (apparently organic) from various limestones, that you have ascribed to *Girvanella*, are of great interest, and have furnished an important contribution to our knowledge of the manner in which Palæozoic and Mesozoic limestones have been formed.

MR. WETHERED, in reply, said:—

MR. PRESIDENT,—

I desire to express to the Council my thanks for the honour done me in making me the recipient of the Murchison Fund for the year. This kind consideration will greatly encourage me in pursuing that branch of geological research which I have marked out as one of the objects of my life. To have done work which merits the acknowledgment of this Society—the first in the world—is one of the greatest satisfactions a geologist can enjoy.

You have referred to my work on the microscopical examination of limestones, and I should like to say that in this there is a most important field open for investigation. If those who have the opportunity of examining the oldest limestones would do so through the microscope, with due regard in preparing the slides to the optical properties of the rock, my belief is that our knowledge of the life which existed at that early period of the earth's history would be considerably advanced.

I again return my thanks for the honour done me.

AWARD OF THE LYELL GEOLOGICAL FUND.

The PRESIDENT then presented the Balance of the Lyell Geological Fund to Mr. C. DAVIES SHERBORN, F.G.S., and said :—

Mr. DAVIES SHERBORN,—

There is no branch of scientific work at the present day that confers a greater benefit on geologists in general than the recording of geological and palæontological literature. Owing to various causes, the mass of published matter increases yearly ; and as it is impossible for any one to read all that appears, a heavy debt is due to those who undertake the arrangement of a key to the various publications. In Palæontology this is even of greater importance than in Geology. In your recently published ‘Bibliography of the Foraminifera,’ and in the Catalogue of ‘British Fossil Vertebrata,’ published in conjunction with Mr. Smith Woodward, you have contributed to that important object the establishment of a general palæontological list with full references ; whilst in the assistance given to the ‘Geological Record’ you have done good service to the science for the advancement of which this Society exists. As a mark of the value attached by the Council to the completion of a general index to palæontological writings, and as an assistance in the compilation of any portion of the work that you may undertake, I have much pleasure in presenting to you the Balance of the Lyell Donation Fund.

Mr. SHERBORN, in reply, said :—

Mr. PRESIDENT,—

I must ask you, Sir, to express my thanks to the Council for the distinction they have shown me in awarding me the Proceeds of the Lyell Fund. I feel great diffidence in accepting such award, my work having extended over but few years. I have endeavoured to make that work as perfect as possible, and hope to devote my future time to bibliographic research. I wish to thank Prof. Rupert Jones and Mr. Topley for first assistance in my work, and I assure you, Sir, I shall always labour to make my work more perfect.

AWARD FROM THE BARLOW-JAMESON FUND.

In presenting to Mr. W. JEROME HARRISON, F.G.S., a grant from the Proceeds of the Barlow-Jameson Fund, the PRESIDENT addressed him as follows :—

Mr. HARRISON,—

In awarding to you a grant from the Barlow-Jameson Fund, the Council recognize the value of your endeavours to spread a knowledge of Geology by the compilation and publication of hand-books to the Geology of the Counties in England and Wales. They also appreciate your geological researches in the Midland Counties, and trust that the award now made may be of use to you in the prosecution of future efforts to extend geological knowledge.

Mr. HARRISON, in reply, said :—

Mr. PRESIDENT,—

In thanking the Council for the honour they have conferred upon me, I can only say that their award was as unexpected as it was welcome. The daily tasks of a necessarily busy life have left me but little time for original research, and I have done—not what I *would*, but what I *could*. This recognition of my labours, and the kind words with which you have accompanied it, will spur me on to increased endeavours in those studies which the Geological Society was established to promote.

THE ANNIVERSARY ADDRESS OF THE PRESIDENT,

W. T. BLANFORD, LL.D., F.R.S.

GENTLEMEN,

In accordance with the customary practice, I shall commence this Address with brief notices of some of the members of our Society who have died during the past twelve months. Our losses from the list of Ordinary Fellows have not been exceptional, though we miss several valued and familiar names from our roll, but some of our most distinguished Foreign Members and Correspondents have gone from amongst us. Among others, we have to deplore the decease in the same year of the father of the Society, the Venerable Archdeacon B. Philpot, who joined our body in 1821, five years before it was incorporated by charter, and of our senior Foreign Member, Dr. H. v. Dechen, who was elected in 1827. There is no reasonable doubt that Archdeacon Philpot and Dr. H. v. Dechen were the two senior members of the Society; a few names still remaining on the list, with earlier dates of election, are so retained for want of information, there being no reason to suppose that such names represent living Fellows.

The Venerable Archdeacon B. PHILPOT, to whom I have already referred as the "father" of the Society, passed away in May last, at the advanced age of 98. He was born at Laxfield in Suffolk, on January 9th, 1791, and took his degree at Christ's College, Cambridge in 1813. He joined this Society in 1821. By Archdeacon Philpot's death, Mr. John Murray, of Albemarle Street, who was elected in 1828, becomes the senior Fellow of the Society.

ROBERT DAMON, of Weymouth, Dorset, who was born in 1814, and died May 4th, 1889, became a Fellow of this Society in 1864. As a large dealer in fossils, minerals, recent shells, and similar objects, and as an agent for the sale of collections of natural history, Mr. Damon must have been known to most British geologists, by whom he was greatly respected. He was a man of much energy; he travelled extensively; and to his exertions the British Museum is indebted for several valuable specimens, one of those most recently procured from him by that institution being the skeleton of *Rhytina*. Mr. Damon's principal service to geological science, apart from his activity in collecting, was the publi-

cation in 1860 of a work on 'The Geology of Weymouth and the Isle of Portland,' to which Supplements were issued by him in 1864 and 1880, and of which a second edition appeared in 1884.

JOHN FREDERICK LA TROBE BATEMAN, who died on the 10th of June, 1889, was highly distinguished as a civil engineer, and especially known by the large works, the construction of which he had designed or superintended, for the supply of water to towns. He was born in Ockbrook, Derbyshire, May 30th, 1810, apprenticed to a surveyor and mining engineer at Oldham when 15 years of age, and commenced business as an engineer in Manchester in 1833. He first became known by his report on the improvement of the River Bann, in County Down, and by the works constructed by him in the valley of that stream; and having been led by his observations on the relations between the rainfall and the amount of water drained from different districts to some important conclusions as to the best sources for the water-supply of towns, he was engaged for many years upon the reservoirs for the supply of Manchester, first around Longdendale, and later at Thirlmere. It was at his recommendation also that the Corporation of Glasgow were induced to obtain a supply of water from Loch Katrine, and to him is attributed a plan for providing a supply for London from North Wales. Mr. Bateman's observations on rainfall and outflow have been useful for geological inquiries.

In 1869 Mr. Bateman was present as the representative of the Royal Society, of which he was elected a Fellow in 1860, at the opening of the Suez Canal, by invitation of the Viceroy of Egypt. He was President of the Institution of Civil Engineers for two years from 1878.

HENRY WILLIAM BRISTOW, who died on June 14th of last year, was born May 17, 1817. He became a Fellow of this Society in 1843, and of the Royal Society in 1862. He was the only son of Major-General H. Bristow, an officer who devoted himself to Spain; where he died. The son, the subject of the present notice, after receiving an education at King's College, joined the Geological Survey of Great Britain, as Assistant Geologist, under Sir H. De la Beche, in 1842. Of this survey he remained an active member for no less than forty-six years, rising gradually in rank until in 1872 he was made Director for England and Wales.

In the course of his long service, Mr. Bristow was chiefly engaged

in field-surveying in the southern counties of England, and it is on his work as a field-surveyor that his principal title to remembrance by future geologists rests; for he was one amongst the little band who brought the geological surveying of sedimentary rocks to a degree of exactitude and scientific accuracy previously unapproached. Several of the beautiful longitudinal sections published by the survey in former years were prepared by him. One of the best known of the survey memoirs, that giving an account of the geology of the Isle of Wight, was from his pen. He was also the joint author, with Mr. W. Whitaker, of a 'Memoir on the Geology of part of Berkshire and Hampshire.' During the last few years Mr. Bristow was engaged in re-writing his account of the geology of the Isle of Wight, and this at the time of his death was nearly ready for publication.

To the Journal of this Society Mr. Bristow contributed but two papers, one of them a short note "On the supposed Remains of the Crag on the North Downs near Folkestone" (Quart. Journ. Geol. Soc. vol. xxii. p. 553), the other a paper "On the Lower Lias or Lias-conglomerate of a part of Glamorganshire" (Quart. Journ. Geol. Soc. vol. xxiii. p. 199). Amongst the subjects to which his attention was particularly directed, was the question of the Rhætic beds and their British representatives, to which he applied the name of Penarth beds, at the suggestion of Sir R. Murchison, and of which he communicated a description to the British Association at Bath in 1864. Apart from his labours in connexion with the Geological Survey, Mr. Bristow's best known work is probably his 'Glossary of Mineralogy,' published in 1861. He also translated several popular French books by Simonin, Figuier, and others on geology and mining.

Owing to his deafness, Mr. Bristow but rarely took part in the meetings of this Society, and he was probably in consequence less known than he deserved to be. He served on our Council for two years, from 1866 to 1868. Few men have left behind them a better record of geological work, or have more thoroughly earned the respect and esteem of their colleagues.

JOHN PERCY was born at Nottingham on the 23rd of April 1817. He was the son of a solicitor, and after his early education, studied medicine in Paris, where he appears to have derived his peculiar fondness for chemistry from the teaching of Gay-Lussac, Chevreul, and Thenard. Subsequently he entered the University of Edin-

burgh, and took the degree of M.D. in 1839, when only 21 years old. One of his fellow-students at Edinburgh was Edward Forbes, afterwards, like Percy, one of the Professors at the School of Mines.

After leaving Edinburgh, Dr. Percy established himself in medical practice in Birmingham, became physician to the Queen's Hospital, and attained to considerable eminence in his profession. His election to the Royal Society in 1846 was due to original experiments and researches in pathology. But meantime he was much engaged in metallurgical and chemical studies, and especially in investigations upon the properties of nickel and manganese. Some of his discoveries at this period were the foundation of metallurgical processes now in extensive use.

On the establishment of the Royal School of Mines in the Jermyn Street Museum in 1851, Dr. Percy was selected as lecturer on metallurgy, a post which he held for 28 years, until the removal of the School to South Kensington in 1879. He gave up the practice of medicine at the same time as he commenced his metallurgical lectures. His position as by far the first metallurgical authority in the country was now acknowledged on all sides, and the work to which, in addition to his lectures, he devoted the greater part of his time during the years that he held the Professorship in Jermyn Street was the production of a great work on metallurgy in general. At the time when he undertook this, there was no comprehensive work on the subject in the English language. The first volume of his 'Metallurgy' appeared in 1861, and contained general considerations on metallurgical processes, a description of fuel and fire-clay, and the metallurgy of copper, zinc, and brass. The second volume, which appeared in 1864, was devoted to iron and steel, the third in 1870, to lead, and the fourth in 1880, to silver and gold. Part of the first volume was reissued as a second edition in 1875.

It is difficult to over-estimate the importance of this work. A very large portion consisted of descriptions of metallurgical processes from the writer's own observations, many of these processes having never been described or only imperfectly described previously, and all were given with great attention to details, and well illustrated with plans and sections of furnaces, &c. The value of the information may be inferred from the fact that translations of all the volumes, as they appeared, were published both in French and German. That this "magnum opus" has never been completed is a source of deep regret to all interested in the progress of the metallurgical art.

Besides his metallurgical works, Dr. Percy wrote several papers on mineralogy, assaying, &c. His only contribution to the Society's publications consisted in a letter to Sir Charles Lyell, giving an account of the analyses of some American coals, anthracites, &c., published in the 'Quarterly Journal' for 1845. Before his attention was exclusively devoted to metallurgy, Dr. Percy had published several contributions to medical science. He was also a writer of great force and originality on social and political questions.

But above all it is as a teacher that our late Fellow is most warmly remembered by those who, like myself, had the advantage of hearing the admirable course of lectures that he delivered at the School of Mines. Rarely in any country, probably never in England, was a more brilliant and gifted staff brought together for teaching-purposes than those who, under Sir H. de la Beche, established a mining school in London in 1851. Amongst the whole of them, as I can testify from memory, in the unanimous opinion of the students, Dr. Percy's lectures on metallurgy, and Sir W. W. Smyth's on mining, were pre-eminent for clearness, command of the subject, and the power of conveying information from the master to the learner. It is not surprising that Dr. Percy has founded a school of metallurgy in Britain, and that there is, at present, scarcely a scientific metallurgist or assayer who has made himself known in this country by his work who has not passed through Percy's laboratory and learned science from his teaching. And he was a man not easily forgotten. Singularly tall, towering by a head over those around him, spare, yet not weakly built, with strongly-marked features, and a peculiar but very striking delivery, a good command of language, and the most perfect originality of ideas, a more thoroughly impressive and suggestive lecturer could not be found. That there are at this day able teachers of metallurgy in Britain, that metallurgical processes are to some extent directed by an intelligent knowledge of the chemical reactions involved, and not by the kind of guess-work that so long prevailed, is due to the influence of our late Fellow and to the instruction given by him.

Dr. Percy was appointed Superintendent of the Ventilation in the Houses of Parliament in 1865 (February 6), and held the post till his death. In 1876 the Iron and Steel Institute recognized his services to metallurgy by awarding to him the Bessemer Medal; and in 1885 he was elected President of the Institute, and, despite failing health, discharged the duties of the chair with characteristic ability. The Howard Prize was presented to him by the Institution of Civil Engineers in 1887, and, only two days before his death, he received

the award of the Albert Medal from the Society of Arts. It would be difficult to enumerate all the subjects, artistic, literary, and scientific, that he studied at various periods of his life, for he was a man of wide and versatile tastes. Mineralogy, photography, old prints, and various branches of zoology engaged his attention in turn, and he has left behind some extensive collections, the most important of which, consisting of an unrivalled series of metallurgical products, have found a resting-place in the collections attached to the School of Mines, with which so much of the work of his life was connected.

Dr. Percy joined this Society in 1851, and was a member of the Council for three years, from 1853 to 1856. He died June 19th, 1889.

The Reverend J. E. TENISON WOODS, who died at Sydney, N.S.W., on the 9th October, 1889, studied at Oxford, where he was an enthusiastic participant in the Tractarian movement. He joined the Church of Rome, and in 1857 went to Australia for the benefit of his health. He there undertook missionary work, in which he was engaged throughout the remainder of his life, being ultimately appointed Vicar-General of Adelaide. He joined our Society in 1859.

Mr. Woods is the author of numerous papers on Australian geology and palæontology, the greater number relating to Tertiary fossils; he also described organic remains from New Guinea, New Caledonia, the Fiji Islands, and other parts of the Australasian area. He twice contributed to our Journal, in 1860 and in 1865, both his communications relating to the Tertiary rocks of South Australia. He was also the author of several papers on recent mollusca, of a work in two volumes entitled 'A History of the Discovery and Exploration of Australia,' and of some other books. He was in 1880 President of the Linnean Society of New South Wales.

THOMAS HAWKINS, a native of Glastonbury, where he was born in 1810, was chiefly known by writings on Enaliosaurians, on which he published two volumes, the best known being 'The Book of the Great Sea-Dragons' (1840). Mr. Hawkins made several large collections of Ichthyosaurian and Plesiosaurian remains on the Dorsetshire coast, and the finest of these collections was purchased for the British Museum. Other collections were presented by Mr. Hawkins to Cambridge and Oxford. He died at Ventnor, Oct. 15th, having been a Fellow of the Society since 1832.

DANIEL ADAMSON, of The Towers, Didsbury, Manchester, who died 13th January, 1890, was a native of Sheldon in Durham, where he was born in 1818. His early life as an engineer was passed on the Stockton and Darlington Railway, on which he held various posts until 1850. In 1851 he established himself in Manchester as an iron-founder, engineer, and boiler-maker, and from that time brought out a series of improvements in iron and steel-making, and in machinery. Some of his most remarkable inventions were connected with compound engines. He patented and brought out a triple expansion engine as long ago as 1861, and a quadruple engine in 1872. He is, however, perhaps better known for the support he gave to the Manchester Ship Canal, a scheme that, in great measure by his aid, was developed into a practical undertaking.

Mr. Adamson joined the Geological Society in 1875. He was President of the Iron and Steel Institute from 1887 till 1889.

HEINRICH VON DECHEN, the Nestor of German geologists, as he has been aptly termed by Prof. F. v. Römer, passed away from the world he had so long adorned on February 15th, 1889. He was born March 25th, 1800, and had consequently nearly completed his 89th year. As he was elected a Foreign Member of this Society in 1827, he had been one of our body in that capacity for the unprecedented period of sixty-two years. For twenty-one years after his election no Foreign Member was brought into our list who survives him.

H. v. Dechen came of a family ennobled in 1684 and resident in Prussia for more than two centuries. He was born in Berlin, where his father occupied a high official post, and he passed through the usual course of education in the gymnasium and university of that city. At the university he attended the lectures of Prof. Weiss, the well-known mineralogist, and here he made the acquaintance of Leopold v. Buch, who exercised much influence on v. Dechen's subsequent career. On leaving the university in 1819 v. Dechen entered upon the study of mining in Bochum and Essen, and was in 1820 placed on the staff of the Mining Department of the Prussian State. In this department he continued throughout his service, which terminated in 1864. He was appointed "Oberbergamtsassessor" in Bonn in 1828, but transferred to Berlin as "Oberberggrath" in 1831. Shortly afterwards he received the honorary degree of Ph.D. from the University of Bonn, and from 1834 to 1841, in addition to his official duties, he gave lectures in the Berlin Uni-

versity as Extraordinary Professor of Geology. In 1841 he returned to Bonn as Director of the Department of Mines ("Oberbergamtsdirector"), and continued a resident of that city with but trifling exceptions for the remaining forty-eight years of his life.

In his earlier years v. Dechen made many journeys for the purpose of inquiry into the mining systems of other countries, and one of these, made in the company of his friend C. von Oeynhausen to England and Scotland, lasted for more than a year, from September 1826 to November 1827. The object of the two travellers was mainly official, to report to their government on the mining, and especially the coal-mining, of England; but, both being ardent geologists, some of their time was devoted to examining the features of the country. One result of their visit was a paper on Ben Nevis and some other places in Scotland, read to this Society January 19th, 1829. After their return v. Dechen and v. Oeynhausen became connected by marriage, the former marrying a sister of the latter's wife, a lady named Gerhard, in 1828.

A great part of v. Dechen's life was devoted to the official work of mine-inspection, and to him is ascribed a foremost share in the great progress that took place in mining and metallurgical works throughout Rhenish Prussia during the twenty-three years that he was director of the department. But during the whole of that time and for many years afterwards his contributions to geological science were numerous and important. Most of these contributions related to the Rhineland, and his greatest undertaking was the preparation and publication of a geological map of Rhenish Prussia and Westphalia in thirty-five sheets, on a scale of 1 : 80,000 (about $1\frac{1}{5}$ inch = 1 mile). This map, together with two volumes of explanatory text, was issued at intervals between 1855 and 1882, and was the first published geological map on a large scale that represented a considerable part of Germany. A map of the area on a smaller scale, 1 : 500,000, was issued in 1866; a second and improved edition appeared in 1883. Amongst his earlier publications were a translation of De la Beche's 'Geological Manual' into German, published in 1832, and a general geological map of Germany, France, England, and the neighbouring countries, which appeared in 1838. The interest excited by v. Dechen's Rhenish maps contributed greatly to the establishment of a regular geological survey in Prussia and other States of Germany.

Among v. Dechen's services to science must be placed in a high rank the effects of his influence on the two scientific Societies of

Bonn, the "Niederrheinische Gesellschaft," and especially the "Naturhistorische Verein der Preussischen Rheinlande und Westfalens," of which he was an honorary member from its commencement in 1834, and president from 1848 till his death. The fact that the number of members increased from 280 to over 1500 under his presidency sufficiently indicates the spirit imparted to the last-named society by his guidance.

It is unnecessary to attempt to give a list of the honours showered upon so distinguished an official and so worthy a geologist equally by his own and foreign governments and by learned societies in all parts of the world. I have reason to know, however, that he always greatly valued the Foreign Membership of the Geological Society, one of the first recognitions of the kind, and that he was proud of being our senior Foreign Member. He was a corresponding member of the French Academy and a member of the Belgian. In the year 1884, and consequently when upwards of 84 years old, he not only presided over the sittings of the Geological Congress at Berlin as Honorary President, but took a most active part in the proceedings. He preserved his wonderful powers of mind and body to an unusually advanced age, and died regretted and honoured by the geologists of other lands almost as warmly as by those of Germany.

FRIEDRICH AUGUST VON QUENSTEDT was born, the son of poor parents, at Eisleben, in Prussian Saxony, on the 9th July, 1809. He studied at Berlin under Weiss, then Professor of Mineralogy at the University of that city, and became Professor of Mineralogy, Geology, and Palæontology at Tübingen, the University of Württemberg, in 1837. This post he held for more than fifty-two years, until his death on the 21st of last December. He became a Foreign Correspondent of this Society in 1863, was elected a Foreign Member in 1885, and was awarded the balance of the Lyell Donation Fund in 1880.

The principal work of Quenstedt's life was the study of the Württemberg fossiliferous rocks, and especially of the Jurassic system. To this subject several of his best-known publications are devoted, especially his 'Flözgebirge Württembergs' (1843), his 'Jura' (1857), and his last great work 'Die Ammoniten der schwäbischen Jura' (1888). But his most widely-known palæontological publications are his 'Handbuch der Petrefactenkunde,' first issued in 1852, and of which subsequent editions appeared in 1867 and 1882, and his 'Petrefactenkunde Deutschlands,' com-

menced in 1846 and continued at intervals until shortly before his death.

Whilst the great works just mentioned and many papers in transactions of societies and other serials sufficed to place Quenstedt amongst the first palæontologists of the age, he was not less widely known for his mineralogical and crystallographical publications. His earlier papers were on mineralogy, and his 'Handbuch der Mineralogie,' the first edition of which appeared in 1854, has been largely used as a text-book not only in Germany but in many other countries. He also published at least two distinct works on crystallography, 'Methode der Krystallographie' (1840) and 'Grundriss der bestimmenden und rechnenden Krystallographie' (1877).

This by no means exhausts the list of Quenstedt's published contributions to science. He brought out from time to time several popular works on geology, especially 'Sonst and Jetzt' (1854), 'Klar und Wahr' (1872), and 'Die Schöpfung der Erde und ihre Bewohner' (1882).

As a teacher Professor v. Quenstedt enjoyed a high reputation, and his teaching was not confined to his pupils, for it is said that he has actually made geology popular amongst the peasantry of Württemberg. In that Swabian Jurassic region to which Quenstedt devoted so much of his life's work almost every boy is an intelligent collector of fossils, every quarryman acquainted not merely with the different organisms that are found in the rocks, but with the particular horizons at which each occurs. Owing to the impetus given by Quenstedt to the search for fossils, an impetus the force of which was largely due to his personal popularity, not only have magnificent accumulations been amassed at Tübingen and Stuttgart, but the fossils of Württemberg are well represented in the principal museums of the world. It is to Quenstedt amongst others, and perhaps more to Quenstedt than to any other, that we are indebted for the remarkably extensive knowledge of Jurassic life now possessed by palæontologists, a knowledge far exceeding that of any other geological system.

LUIGI BELLARDI was born in Genoa on the 18th May, 1818. He studied for the law, but whilst thus engaged at the University of Turin he devoted his leisure hours to natural history, and especially to collecting fossils from the hills of Superga. His earliest publication, in 1838, when he was only 20 years of age, was on a fossil Gasteropod, and throughout his life the Tertiary Gasteropoda of

Piedmont and Liguria formed the principal subjects of his scientific writings. For thirty years he was a professor of the "Liceo Gioberti" at Turin and at the same time keeper of the palæontological collection in the Royal Geological Museum of that city. The great richness of this collection, especially in Tertiary Mollusca, is chiefly due to Bellardi. Besides his papers on palæontology, the majority of which were published in the 'Memorie della Reale Accademia delle Scienze di Torino,' Bellardi wrote on entomological subjects, and especially on Diptera. He was made a Foreign Correspondent of our Society in 1880, and died 17th September, 1889.

By the death of LEO LESQUEREUX, which took place at Columbus, Ohio, on the 20th of October last, one of the principal palæobotanists of the world is lost to us. He was born at Fleurier, in the canton of Neuchâtel, Switzerland, in 1806, and was of French Huguenot descent. He was educated for the church at the Neuchâtel Academy, but, having become deaf at the age of 26, he worked for twelve years as an engraver of watch-cases and a manufacturer of watch-springs. His taste for natural history, however, gradually made him known, and in consequence of his repute, gained by researches on mosses and peat, he was employed by the government of Prussia in 1845 to examine the peat-bogs of Europe. A translation of one of Lesquereux's later papers on the formation of peat appeared in the Society's Journal for 1848.

Lesquereux went to the United States in 1848, and was at first engaged there, as he had been in Europe, in the study of mosses; but from 1852 he became botanical palæontologist to several geological surveys, and he published in succession a series of reports and monographs relating to fossil plants from Pennsylvania, Arkansas, Illinois, and Mississippi. His best-known works, and perhaps his most important, were a series of monographs issued between 1878 and 1883 on the Cretaceous and Tertiary floras collected by the Geological Survey of the Territories under Dr. Hayden, and a work in three volumes, one of them an atlas of plates, on the Coal-flora of Pennsylvania and the United States, published between 1880 and 1884 by the Second Geological Survey of Pennsylvania. He was a member of the United States National Academy and of many European scientific bodies, also an honorary professor of the Academy of Neuchâtel. He was made a Corresponding Member of our Society in 1880, and received the award of the Barlow-Jameson Fund in 1884.

The last death to which I have to refer is by far the saddest record amongst the year's losses. The distinguished men whose careers have been briefly commemorated in the preceding pages passed away, full of years and honours, at an age when their scientific work might fairly be regarded as finished; but in DR. MELCHIOR NEUMAYR, who died on the 29th January, 1890, at the age of 44 years, we have lost one of the best and most scientific palæontologists who has ever lived, at an age when his talents had but recently arrived at maturity.

Dr. Neumayr was born in Munich October 24th, 1845. He was the son of a Bavarian Minister of State, Max v. Neumayr, and his early life was passed in Stuttgart, where his father was the Bavarian Ambassador. After passing through the course of the gymnasium in Munich, Melchior Neumayr entered the University of that city in the autumn of 1863 with the object of studying law, in accordance with the traditions of his family, who had for generations furnished a series of distinguished lawyers and officials in the service of the Bavarian government. But at the university Neumayr's tastes for science soon asserted themselves, and, abandoning the law, he devoted himself to geology and palæontology, both at Munich and afterwards at Heidelberg, where he completed his studies and took the degree of Ph.D. After some practice of field-geology with Prof. Gümbel, Neumayr entered the Austrian Geological Survey in 1868, at first as a volunteer, subsequently as assistant geologist. In 1872 he left the Survey and returned to Heidelberg as a tutor (*Privatdocent*), but was recalled the next year to Vienna as extraordinary Professor in the newly-created chair of Palæontology. In 1879 he was promoted to the ordinary Professorship, a post which he held till his death. In 1878 he married the daughter of our distinguished Foreign Member Professor Suess.

It would be impossible to attempt within the limits of an ordinary obituary notice to record the various branches of geology and palæontology to which Dr. Neumayr has contributed in the course of the last twenty-five years. In addition to his scientific powers he possessed much literary ability, and his papers are written with a clearness which is unfortunately not always conspicuous in German scientific works. He was consequently a successful popular writer on geology, one of his principal works, his '*Erdgeschichte*,' in two volumes, which appeared in 1887, having had a wide circulation. But although he wrote frequently and well on physical geology, it

is as a palæontologist that he will be remembered, and, moreover, as one of the few who have not only regarded palæontology as a science by itself, dependent on both biology and geology, but nevertheless deserving and demanding separate recognition, but who have aided by their work to prove that the claim of palæontology to be thus recognized was valid.

Amongst the most important writings of Dr. Neumayr were a series of monographs on Jurassic and Cretaceous Ammonites, and another series of papers on the succession and relationships of recent and Tertiary freshwater Mollusca. To the study of the latter he was led by the peculiar facilities afforded by successive faunas in the remarkable series of freshwater Tertiary beds that are so largely developed in south-eastern Europe. The principal attraction to Neumayr in both Ammonites and freshwater shells was the opportunity for tracing their descent. From his student's days he had been an enthusiastic supporter of Darwin's theory of the origin of species, and in his earlier works, as in his last and greatest book, 'Die Stämme des Thierreichs,' of which, unfortunately, only one volume has been completed, he has devoted himself to the task of tracing through the life of former times the same law of evolution as Darwin inferred from that of the existing world. Dr. Neumayr, I learn from Professor Judd, was in constant correspondence with Darwin, who regarded him with the greatest esteem and attached a high value to his observations.

Of Dr. Neumayr's papers two, published in 1883 and 1885, deserve especial notice; one of these treats of the zones of climate during Jurassic and Cretaceous times and the other of the geographical distribution of the Jurassic formation. Both show a wonderful knowledge of palæontological literature, and a remarkable power of distinguishing the important facts amidst a mass of details. The first-named paper, moreover, is one of the most important contributions to the question of climates in Mesozoic times that has ever been written, for in it the author shows by a mass of evidence, derived mainly from Cephalopoda, that in Jurassic and Cretaceous times the equatorial marine fauna differed from that of the two temperate zones, and the latter from that of the arctic zone, much as the faunas of similar zones differ from each other in the present day.

Within a week of his death I received from Dr. Neumayr a packet of papers dealing with a variety of subjects and well illustrating the many-sidedness of his intellect. One was a popular

paper on landslips, another a scientific treatise, of the highest order, on the origin of the Unionidæ, a third related to *Calostylis* and the perforate Hexacorallia, a fourth was a discourse on the climatic relations of past times, a fifth was on Belemnites from Central Asia and South Africa, a sixth on Madagascar fossils, and a seventh on remains of *Hyopotamus* from Eggenburg. All of these are of unusual interest, and some of them, for instance that on the origin of the Unionidæ and that on ancient climates, are clearly the writing of a master, whilst the notes on Madagascar fossils show how very much more can be learned from Mr. Baron's discoveries, described in the 'Quarterly Journal' of this Society, than we, who had the fossils before us, were able to infer. To this subject further reference will be found in a subsequent part of this address.

Personally Dr. Neumayr was singularly quiet, modest, and amiable, greatly beloved and respected by a wide circle of friends. He was elected a Foreign Correspondent of this Society in 1880.

Amongst the other Fellows who have been lost to us during the past year are THOMAS H. COCKBURN-HOOD, F.R.S.E., elected in 1863, who in 1870 contributed to our Journal a paper containing "Geological Observations on the Waipuru River, New Zealand;" and JAMES RADCLIFFE, of Dukinfield, who joined our Society in 1885, and to whom we are indebted for an account of some very curious grooves and quartzite boulders in the Roger Mine at Dukinfield.

As you have learned from the Council's Report, the past year has brought prosperity to our Society. Our Journal has been maintained without difficulty at its usual standard, and its contents will not, I think, be found to show any falling off in interest. The most important event in the history of the Society during the past year has been the revision of the Bye-laws; and although the process was neither pleasant nor quick, I think the Fellows may be congratulated on the circumstance that some necessary improvements have been effected without any serious alteration in those regulations which have now, for so many years, been found to be consistent with the Society's well-being and progress.

It will not, I trust, be necessary to reopen, for many years to come, the questions which were determined by the votes of those Fellows of the Society who were able to attend the series of Special Meetings held for the purpose of considering the various proposals

that were brought forward. Should it, however, be at a future time thought desirable to ascertain the opinions of the Fellows upon any question involving a great change in the constitution or proceedings of the Society, I must express a hope that some means will be used to ascertain the views of the Fellows as a whole, and not merely of those who are able to attend a meeting at the Society's rooms. I find, by going through the lists for 1888, that only about one third of the whole number of Fellows reside in the metropolis or in one of the metropolitan counties, two thirds live beyond those limits. So far, too, as I am able to judge, the proportion of Fellows living at a distance from London tends to increase from year to year.

I shall not, in the present Address, attempt any review of the geological literature of the past twelve months. The various scientific serials that now appear, and contain accounts of all the more important contributions to knowledge, render the task of reviewing the additions to our rather wide-ranging science in the Anniversary Address less necessary than was formerly the case, whilst the majority of the works and papers published can only be fairly judged and analyzed by those who have made a special study of the department of geology treated. There are, however, two palæontological works which I ought not to pass over without mention; for not only are both of them of high importance, but both, I believe and hope, are destined to serve as aids to an advance in the science of Geology.

The first of these works is Nicholson and Lydekker's 'Manual of Palæontology,' in which, for the first time, I believe, in the English language, a fairly comprehensive account of the Animal Kingdom, as represented in past times, has been afforded to students. Excellent as were Professor Nicholson's earlier editions, they could scarcely be said to suffice as works of reference; but the present is a great improvement. It may be hoped, though I fear it can scarcely be inferred, that the appearance of the present work will coincide with the commencement of a period of increased attention to Palæontology in these islands. Hitherto, whilst Geology and Biology have been fairly studied in this country, and whilst trained students in both sciences have appeared in considerable numbers, palæontologists have been of ominous rarity. On four different occasions when a Palæontologist was required for the Geological Survey of India, a German was selected; and I can personally vouch for the fact that, in one instance, and, I believe, in others,

there were no qualified English students, of the proper age, available. I cannot believe that the neglect of Palæontology in this country is due to apathy on the part of teachers, or to incapacity on the part of students; as fairly trained geologists and biologists not rarely come from our educational institutions, I should anticipate that equally efficient palæontologists would be forthcoming if the same opportunities of study were offered. There are, and always have been, a few good palæontologists in the country, but the number might be considerably increased with advantage. It may be hoped that a science, to which none is second in interest, none more prolific in its additions to human knowledge, may gather fresh impetus in the British Islands from the publication of an efficient manual, and that the time may not be distant when British geologists, far from being contented with the two well-filled volumes now offered for their use by Messrs. Nicholson and Lydekker, will demand a still more extensive work, on the scale of the superb Palæontological Compendium now being published by our distinguished Foreign Member, Prof. v. Zittel, a book that, I fear, no English publisher at present would feel justified in undertaking. By the work now brought out Professor Nicholson has worthily repaid this Society for the award to him of the Lyell Medal two years ago.

The other work to which a passing reference is due is that by our (I deeply regret to say) late Foreign Correspondent, Dr. Melchior Neumayr, "Die Stämme des Thierreichs." I have already, in a short obituary notice, endeavoured to express some sense of the loss to geology caused by the death of this distinguished Palæontologist. In this, his last and greatest work, he endeavoured to bring together the results of many years' labours and researches, and to show the lines of descent that can be traced amongst ancient forms of life. In the only volume published, he has treated of the Protozoa, Coelenterata, Echinodermata, Annelida, and Molluscoïda, besides writing several introductory chapters full of suggestive remarks.

My own knowledge of the very intricate questions treated in Neumayr's work does not justify my expressing any view except admiration; but I may, perhaps, quote from one of the first of living palæontologists, Prof. v. Zittel, whose opinion is entitled to attention. He writes thus, "In the first volume of the 'Stämme des Thierreichs,' which appeared a few months ago, Neumayr showed remarkable mastery of the collected data relating to his subject; new observations, surprising applications of known facts,

radical improvements in classification, brilliant hypotheses on the evolution and relationship of fossil organisms, secure for this last work a prominent place in biological literature, and will probably occupy followers and opponents of his views for many years to come."

It is not my intention to attempt any survey of the geological discoveries in the past year, though here, also, passing reference may be made to two events of importance to Geology. Perhaps the most striking, until within the last week, was a discovery that could, however, scarcely be credited to 1889, that of the nature of the Greenland ice-sheet. Though Dr. Nansen's Journey of 1888, the details of which only reached us in the past year, did not do much more than confirm the observations of Nordenskiöld and others, still the results are of the greatest importance, and the facts now clearly ascertained of the enormous dimensions of the ice-sheet bear witness to the accuracy of the inferences drawn by the geologists who investigated the traces of the Glacial epoch, as to the depth of the ice and the erosion exerted by it.

Only yesterday an announcement was made that coal has actually been cut at Dover. Probably geologists, and especially those who have followed the gradual accumulation of evidence as to the occurrence of palæozoic rocks beneath south-eastern England, were much less astonished at the discovery than the public in general. A letter that I received yesterday from Prof. Boyd Dawkins, by whose advice, I believe, the boring was carried out, confirms the information published in the newspapers, that a seam of coal has been reached at a depth of 1180 feet, and that this seam is proved to be of Carboniferous age by the plant-fossils in the associated clays. It must be a source of congratulation to geologists to reflect that the discovery is solely the result of scientific induction, and arrived at by following the line of research first indicated, I believe, by the late Mr. Godwin-Austen and subsequently by Prof. Prestwich.

The question of the permanence of ocean-basins, to which the remainder of this address will be chiefly devoted, is one that has attained great prominence in this country since the 'Challenger' Expedition. The opinion that the deep parts of the ocean have been the same from the earliest period of which we have any record in the Earth's strata, has received the approval of several eminent geologists and biologists. Nevertheless there are many who feel grave doubts on the subject, and I think the arguments on both sides are worthy of reconsideration.

It will perhaps tend to render my treatment of the subject clearer, if I point out at the outset that there are three possible explanations of the phenomena presented to us by the present and past conditions of the land and by the distribution of terrestrial life; these are :—

1. That the present continental areas, including the shallow seas around them, and the present oceanic tracts with a depth exceeding about 1000 fathoms, have been the same since the original consolidation of the earth's crust.

2. That the continental and oceanic areas are not permanent, but that they are from time to time interchangeable.

3. That the continental and oceanic areas are permanent as a rule, but that portions of them have at times passed from one condition to the other.

I propose to take in order the principal physical, geological, and biological arguments in favour of the permanence of ocean-basins, and to inquire how far they are conclusive, and especially whether any exceptions are probable. I wish also to call your attention to a few facts, mainly referring to the distribution of terrestrial organisms, that I think worthy of the attention of geologists.

The permanence of the land- and sea-areas is no new idea. It would be easy to quote from ancient and modern poets and writers a series of extracts to show the prevalent belief in the fixed limits of the ocean-tracts. It is only of late years, since the teaching of Lyell and other modern geologists has become generally received, that the old belief has been replaced by free speculation on the distribution of land and water in past periods. Under these circumstances, scientific men who revert to the ancient faith suffer from the serious disadvantage of leading an enthusiastic school of followers, who have never renounced the creed of their ancestors, and who hail the convert to orthodoxy with the traditional joy over a repentant sinner. There is always a risk of a sound scientific theory being accepted in a much wider sense than was intended by its original advocates, and the risk is extreme when the theory coincides with the popular taste.

The chief arguments brought forward in favour of the permanence of ocean-basins or deep-sea areas are the following :—

I. The higher specific gravity of the earth's crust beneath the ocean, as inferred from pendulum observations, and the further inference that these areas of greater density have been the same since the original consolidation of the earth.

II. The absence, with a few not very important exceptions, in ocean tracts, of islands formed of stratified rocks such as compose the bulk of the continents, and the fact that nearly all oceanic islands are volcanic, and consequently such as may have been built up from oceanic depths by the accumulation of volcanic discharges.

III. The absence of deep-sea deposits in the rocks of continental areas.

IV. The agreement between the distribution of plant- and animal-life and the present arrangement of land-areas.

I propose to consider each of these arguments in order, though the last is that to which it will be necessary to give the most attention.

I. *Greater Density of Infra-oceanic Crusts.*—The first argument is one to which some importance is attached by Prof. Dana *. But it is only founded on a few observations in India and the neighbouring islands, and was suggested by its author, Archdeacon Pratt, as a probable hypothesis to account for some anomalies in the results of pendulum observations. The principal force of the contention appears to lie in the circumstance that if the crust of the earth now below the ocean had been exposed to denudation, and consequently transport, its exceptional density could not have been preserved, because the action of rivers and currents would in the course of ages have mingled its detritus with that of the present continental areas. It has also been urged that, owing to the contact of cold oceanic waters, the crust beneath the ocean has become thicker and more rigid. This view, however, depends on the hypothesis of a fluid layer beneath the solid crust; and although there is much to be said in favour of such a view, it is impossible to accept it as a proved theory and to use it as a basis for argument. Indeed the next point to be noticed, the presence of volcanic islands in many parts of the ocean, is really antagonistic to the idea of a uniformly thicker and more rigid crust beneath the ocean-bed, because the occurrence of volcanoes indicates areas and lines of weakness. If the infra-oceanic crust were much more rigid and thicker than the infra-continental, volcanoes should be confined to the area occupied by the latter; but this is not the case. That volcanoes should be most numerous near the boundaries between continental and oceanic areas is natural.

II. *The Volcanic Origin of Oceanic Islands.*—This, the second

* Manual of Geology, 3rd ed. p. 815.

argument, is, at present, far more important than the first. Darwin was, I think, the first to call attention to the absence of palæozoic and mesozoic strata in oceanic islands, and his words* which have already been quoted by Mr. Wallace in 'Island Life,' will bear repeating. He says:—

“Looking to the existing oceans, which are thrice as extensive as the land, we see them studded with many islands; but hardly one truly oceanic island (with the exception of New Zealand, if this can be called a truly oceanic island) is as yet known to afford even a remnant of any palæozoic or secondary formation. Hence we may perhaps infer that during the palæozoic and secondary periods, neither continents nor continental islands existed where our oceans now extend; for, had they existed, palæozoic and secondary formations would in all probability have been accumulated from sediment derived from their wear and tear; and these would have been at least partially upheaved by the oscillations of level, which must have intervened during these enormously long periods. If, then, we may infer anything from these facts, we may infer that, where our oceans now extend, oceans have extended from the remotest period of which we have any record; and on the other hand, that where continents now exist, large tracts of land have existed, subjected no doubt to great oscillations of level, since the Cambrian period.”

There can be no question as to the force of this argument; but the more fully it is admitted, the more important do any exceptions to the volcanic character of oceanic islands become, and the fact must not be forgotten that the number of oceanic islands in which palæozoic or mesozoic beds have been found has been slightly increased within the last few years. The Falkland Islands, the palæozoic fossiliferous rocks of which were described by Darwin himself †, were not noticed by him in the paragraph quoted, doubtless because he did not regard them as oceanic: although 400 miles distant from the coast of S. America, they are connected with it by a bank of less than 100 fathoms deep, and they have an indigenous land-mammal. But the Archipelago of South Georgia, 800 miles further to the eastward and nearly 1200 miles from the American continent, has now been shown to consist of clay-slate‡. According to the chart issued with the recently published 'Challenger' narrative,

* Origin of Species, 6th ed. p. 288.

† Q. J. G. S. ii. p. 267.

‡ Geol. Mag. 1884, p. 225; 'Nature,' March 27, 1884, xxix. p. 509.

these islands are surrounded by ocean exceeding 1000 fathoms in depth. Another important island also, isolated by sea exceeding 1000 fathoms in depth, is New Caledonia, where both palæozoic and mesozoic fossiliferous beds are met with*. This, however, is a precisely similar case to that of New Zealand. The Auckland and Campbell Isles † south of New Zealand are said to be separated from it by a sea more than 1000 fathoms deep, but contain ancient sedimentary rocks. The sedimentary deposits of the Fiji Islands, formerly supposed to be ancient, have been shown by Mr. Brady ‡ to be of subrecent formation.

The occurrence of granitic and gneissic formations in islands differs from that of sedimentary beds in this respect, that the former may have consolidated at some depth below the bottom of the ocean. But such rocks, when in place, cannot have formed parts of ordinary submarine volcanic accumulations. A granitic or gneissic island must be part of an ancient land tract, for the rocks could only have been exposed after a long period of denudation. The most important instance of granitic or gneissic rocks occurring in oceanic islands is in the Seychelles §, and these are probably a continuation of the main Madagascar range, which is of similar formation; they are separated from Madagascar and from all other land areas by sea of considerable depth. It should also not be forgotten that granite and schist are said by von Buch to have been thrown out from the volcano of Caldera (I. de Palma) in the Canary Islands ||, that similar rocks have been ejected from the Cape Verde volcanoes ¶, and that hornblende granite was found by Darwin amongst the fragments thrown out at Ascension **. Granite and gneiss are also said to occur †† on the Marquesas Islands in the Pacific; but there appears to be some uncertainty about this. If confirmed, however, this occurrence would be of the greatest importance.

* Heurteau, 'Ann. Mines' (7), ix. p. 232 (1876).

† Tchihatcheff, 'Considérations sur les Iles Océaniques,' p. 34.

‡ Q. J. G. S. xlv. p. 1.

§ By some mistake, Wallace, in his recent work, 'Darwinism,' p. 342, has stated that the Seychelles are formed of coral rocks. There is, however, no doubt about their geological conformation, as may be seen by referring to the following writers: Velain, Bull. Soc. Géol. France, 1879, sér. 3, vii. p. 278; Perceval Wright, Brit. Assoc. Reports, 1868, sect. p. 143; E. Newton, Ibis, 1867, p. 335. This list of references could easily be increased considerably.

|| Von Buch, Phys. Besch. d. Can. Inseln, p. 289.

¶ Dölter, Die Vulkane der Capverden und ihre Producte (Graz, 1882), p. 159.

** Darwin, Volc. Islands, p. 40.

†† Jules Marcou, Expl. 2 éd. Carte Géol. de la terre, p. 185.

It will be seen at once that these examples do not very greatly affect the main argument, because there is still an enormous area of ocean left in which the only islands are volcanic. But still the instances mentioned are worthy of notice, because they show that there are exceptions to the general rule that no palæozoic or mesozoic rocks occur on oceanic islands, and the additions made to our knowledge in this respect of late years render it probable that other instances remain to be discovered. Of course much depends on the definition of an oceanic island; but the accuracy of the term can scarcely be contested in the case of South Georgia. As it is impossible for denudation to hollow out the sea-bottom beyond a few fathoms below the surface, the isolation must in all such cases be due to depression.

There are three other facts that should be remembered with reference to the point under discussion. The first is that our acquaintance with the geology of many oceanic islands is by no means sufficiently complete to justify our being confident that no sedimentary rocks of old date exist. The second is that the rocks of an island may be entirely volcanic, and yet the island may be a remnant of a continental mass. It must not be forgotten that typically volcanic rocks in some continental areas, as in the Western United States of North America, North-eastern Africa, and the Peninsula of India, form vast horizontal or nearly horizontal sheets, and completely cover the surface over areas the diameters of which are measured by hundreds of miles. Such rocks may be of considerable antiquity, and they are typically continental, being all, so far as is known, subaërial. It is, I think, far from clear that some oceanic volcanic islands, such as St. Paul's Rocks, Fernando Noronha, and Kerguelen, are not composed of volcanic formations of the continental type; and rocks of this class are well developed in some ancient continental islands, for instance, New Caledonia. At the same time, this only proves that such islands were formerly of considerable extent, not that they were attached to continents.

The third fact is even more important. This, which has been noticed by Prof. Bonney in one of his notes to the recent edition of Darwin's 'Coral Reefs' (p. 326), is that the occurrence of volcanic islands does not prove that the area in which they occur is not a sunken continent. If Africa south of the Atlas subsided 2000 fathoms, what would remain above water? So far as our present knowledge goes, the remaining islands would consist of four volcanic peaks, Camaroons, Kenia, Kilimanjaro, and Stanley's last discovery,

Ruwenzori, together with an island, or more than one, containing part of the Abyssinian tableland, which, like the others, would be entirely composed of volcanic rocks, but, unlike them, would consist of horizontal or nearly horizontal lava-flows, probably of Mesozoic age. In Southern Africa, too, the peaks of the Stormberg and Drakensberg, though not rising or scarcely rising above 10,000 feet, are the highest in the country and consist of volcanic rocks. The same is the case with the highest peaks in Madagascar, in Mexico, in the Caucasus, in the Elburz Chain south of the Caspian, and in many other parts of the world; though the case of Africa is perhaps the most remarkable.

III. *The Absence of Deep-sea Deposits in Continental Areas.*—This argument is, I think, of far greater importance than either of the preceding. It is perfectly true that the presence or absence of deep-sea deposits in continental areas is only indirectly connected with the condition of the present oceanic areas in past times; because, even if no change whatever has taken place in the former, that does not prove that none has taken place in the latter. Even if no part of the continental area has ever been deep sea, any oceanic area may have been land at one time or another, the necessary compensation having been provided by the deepening of another oceanic tract. But there can be no question that, unless the amount of ocean water on the earth's surface has greatly increased in the later geological epochs, there must have been deep sea over a considerable portion of the earth's surface at all times; and if the continental areas have remained unchanged, the oceanic areas have, in all probability, preserved their original limits. The question for us at present is, whether we have sufficient evidence to justify our belief that the continental areas have remained unchanged.

In this case, even more than in that of the oceanic islands, it appears premature to conclude that our knowledge approaches completion. Because in the extremely small area of the land surface, assuredly not one-twentieth of the whole, that has received close geological examination, no deep-sea deposits have been observed, we have no right to assume that none will ever be discovered in any part of the continental area. The recognition of the character of deep-sea deposits is too recent for geologists in general to have become acquainted with the peculiarities of such formations, so as to be able to recognize them at once. On the other hand if deep-sea deposits were not of exceptional occurrence on continental areas, some would probably have been noticed before this. It has I believe

been suggested that the Graptolite shales of the Silurian system were deposited in deep water, and, so far as the fauna is concerned, the hypothesis appears plausible enough; but the interstratification of coarse sandstones in places seems a fatal objection. The fine slates and interstratified volcanic tuffs of Silurian and Cambrian age are, however, sometimes of great thickness and extent, and are worth further examination to see if any of them are possibly of deep-water origin*.

Throughout a large oceanic area at present it is pretty evident that, practically, no deposits are being formed. The fact that teeth of what are believed, on good grounds, to be extinct forms of Shark have been dredged in a corroded state from the bottom of the ocean shows that such objects have lain for ages where no sediment was deposited to entomb them. There is no ground for surprise therefore if the abyssal red clay is unknown in the older rocks. But the absence of strata corresponding to the Globigerina- and Radiolarian ooze of the present oceans is, so far as our knowledge extends, in favour of the contention that the continental areas have not been depressed beneath the deep sea.

At the same time two recent discoveries of deep-sea deposits, each on the border of the continental area, serve to show how cautious we should be in coming to decided conclusions. These two instances are in the Solomon Islands†, concerning which I shall have some additional remarks to make when dealing with insular faunas, and in Barbadoes‡. The evidence in the latter case is very remarkable and peculiarly complete, for the deep-sea Radiolarian ooze rests upon sandstones and clays with coal, believed to be of older Tertiary age, and which are evidently littoral, estuarine, or fluviatile in origin. It is clear that the island must have formed part of a continent, that it must have been depressed to a depth of over 1000 fathoms, and then re-elevated; and there is, so far as I understand, no question that these changes have taken place within the Tertiary era and probably within the Miocene and Pliocene periods. Barbadoes is at present surrounded on all sides by seas over 1000

* There is so great a resemblance between some of these remarks and the views on the same subject expressed by Dr. Nicholson in the last edition of his 'Manual of Palæontology,' i. p. 75, that it is necessary to explain that all this part of the address was written before I had seen Prof. Nicholson's work, and, I believe, before it was published.

† Guppy, 'Solomon Islands, Geology,' &c., pp. 77, 81, &c.

‡ Feilden, *Ibis*, 1889, p. 478; Jukes-Browne and Harrison, 'Nature,' vol. xxxix. pp. 367, 607; Gregory, *Q. J. G. S.* xlv. p. 640.

fathoms deep. Moreover Barbadoes is said not to be the only West Indian Island in which Radiolarian deposits occur, so that there is a probability, as might have been anticipated, that subsidences and elevations of the character mentioned affected considerable areas.

IV. *Relations between Distribution of Animals and Land-areas.*—

The last argument may not be strictly geological, but all who recognize how intimately the story of the earth is bound up with that of its inhabitants will have little doubt that the present distribution of animals and plants is of the highest geological importance, and that the existence of particular forms of living beings in continents and islands is the result and the record of the history of those areas and of their connexions with each other. There can be no doubt, in short, that most important testimony as to the distribution of land and water in past epochs is afforded by the range of living species and genera. The information on the subject of distribution at the present day is considerable, probably more extensive and nearer completion, so far as regards vertebrate animals and phanerogamous plants, than that relating to the geology of the different regions. Moreover the question of zoological distribution has been ably treated by one of the first biologists of the day, Mr. Alfred Wallace, who has in his later works unhesitatingly given his adhesion * to the doctrine of permanent oceanic and continental areas in almost its extreme form. Just twenty years ago the question of distribution was dealt with by Professor Huxley in an address to this Society, and my only excuse for referring to a subject already treated by so high an authority, is that the aspect of the question has entirely changed since 1870, that our knowledge has greatly increased, that the subject has been widely discussed, that the oceans have been better surveyed, and that we are in the presence of an entirely different theory of the distribution of land in past ages from that which prevailed amongst geologists when Professor Huxley's address was written. It is essential to add that, whereas my great predecessor felt called upon to prove the theory of evolution before applying it, we may now regard the doctrine as firmly established.

In all the remarks which follow I shall assume as an accepted fact, not only that all species of a genus, all genera of a family, and all families in an order, class, or subkingdom, are descended from

* 'Island Life,' chap. vi.; 'Darwinism,' pp. 341, &c.

one stock in each case, but that similarity in organic structure is proportional, as a general rule, to the degree of affinity, animals and plants that are like being more nearly related by descent than those which are dissimilar.

As I have already said, I propose to treat the subject of distribution at some length, both because it is, I think, well worthy of the attention of geologists, and because I believe the whole question requires reconsideration. To understand why this is the case, it is essential briefly to recapitulate the history of the inquiry.

Although much had been previously done, the first contribution to which reference is necessary was a paper by Mr. P. L. Selater, published in 1858 *, “On the General Geographical Distribution of the Members of the Class *Aves*.” The terrestrial area of the world was in this paper divided into the following six zoological regions:—

1. *Palæarctic*: Europe, Northern Africa, Northern and Central Asia.
2. *Ethiopian*: Africa south of the Atlas, and Madagascar.
3. *Indian*, renamed *Oriental* by Wallace: India, South-eastern Asia, and part of the Malay Archipelago.
4. *Australian*: Australia, with New Guinea and adjacent islands, New Zealand, and Polynesia.
5. *Nearctic*: America as far south as Mexico.
6. *Neotropical*: Central and South America, with the West Indies.

These regions were founded solely on birds, and mainly on passerine birds (or on passerine and picarian). They were accepted for snakes and Batrachia by Dr. Günther in a paper published in 1858 †; but a far more extended study of the subject, and the great additions made to our knowledge within the last thirty years, have induced Dr. Günther to come to a very different conclusion, as will be shown presently.

The papers just mentioned appeared before the publication of Darwin’s ‘Origin of Species,’ and were, of course, written without any reference to the idea of relationship by descent amongst different genera of a family or different species of a genus. So soon, however, as Darwin’s great work had produced its effect, the importance of an inquiry into the distribution of animal- and plant-life was greatly increased.

* Journ. Linn. Soc. Zoology, ii. p. 130.

† P. Z. S. 1858, p. 373.

Various other schemes of regional subdivision have been proposed, but it is unnecessary to notice all. I have already alluded to the most important, that of Professor Huxley, who, on a general survey of terrestrial vertebrates*, proposed four primary distributional provinces, viz. :—

1. *Novo-Zelanian* (New Zealand).
2. *Australian*.
3. *Austro-Columbian* (Neotropical of Scater, South America).
4. *Arctogæan* (Palæarctic, Ethiopian, Oriental, and Nearctic united).

By far the most important work on the subject yet produced is Wallace's 'Geographical Distribution of Animals' (2 vols., 1876), in which the author adopts Scater's regions in their entirety for all terrestrial and freshwater forms of animal life. In this work lists of the families of Mammals, Birds, Reptiles, Batrachians (or Amphibia), Freshwater Fishes and diurnal Lepidoptera found in each region are given, and also of the genera of mammals and some birds (Passeres, Picariæ, Psittaci, and Accipitres). Numerous details are added relating to other terrestrial animals, but the regional arrangement is mainly founded on the birds of the orders named, and, as is especially stated, on Mammalia †. With the question whether the mammals quite agree with the classification proposed I shall deal presently; meantime it should be mentioned that Wallace, amongst the reasons given for adopting the regions named, assigns a high rank to the convenience of employing large subequal divisions.

There is one aspect of the whole question to which attention must be drawn. No one doubts that the present form of the great land-tracts extends back with but trivial modification to Pliocene times at least, the only important changes of later date being the opening of Behring's Straits, and severance of America from Asia, the separation from continents of certain continental islands, such as Great Britain and Ireland, Sumatra, Java, and Borneo, Ceylon, &c., and perhaps the reunion of North and South America. The changes since Miocene, and perhaps since Eocene, times have probably been neither very extensive nor very numerous. If, however, the principal divisions of the earth have remained the same or nearly the same for a longer period than the existence of most living genera of Vertebrata, the animals inhabiting those

* P. Z. S. 1868, p. 316; Q. J. G. S. xxvi. p. lv.

† 'Geogr. Distrib.' i. p. 57.

divisions must necessarily, if we accept the ordinary teachings of Evolution, have become materially differentiated, so that each modern natural division has many of its generic types peculiar.

The present distribution of all terrestrial organisms, as has been pointed out already by Huxley, Wallace, and other writers on the subject, is the combined result of several different factors. Of these the original centre of dispersion in the case of each organic unity, such as a family, genus, or species, is one; the distribution of land and water, firstly, at the time of dispersion, secondly, since that time are two others; whilst powers of migration and ability to live under varied conditions are of great importance, and it is notorious that the last two factors are as diverse in different organisms as I shall endeavour to show that the first is.

As regards origin, there is an important point in which mammals and birds, most reptiles and batrachians, probably all insects and arachnida, and all land-plants differ from freshwater fishes and crustacea, and from both freshwater and land-mollusca. The forms in the first category are in all probability derived from terrestrial or freshwater ancestors, differing very widely from them in structure, so widely, indeed, that the ancestral types would have been classed in distinct orders, or even classes. Even when there are marine representatives, such as Cetacea, sea-snakes (*Hydrophidæ*), marine turtles, and a few marine angiospermous plants, these are probably descended from terrestrial or freshwater forms. On the other hand, the fishes, crustacea, and mollusca found in rivers, and all land-shells are in all likelihood derived from various marine stocks, and some of them have living marine representatives belonging to the same family. Thus freshwater *Percidæ*, *Salmonidæ*, *Clupeidæ*, &c., differ sometimes generically, often merely specifically from the forms found in the sea, and when, as in the carps and in most existing ganoids, whole families are confined to fresh water at the present day, there can be no reasonable doubt that marine ancestors not differing greatly in structure flourished at a former period. The derivation of land-mollusca is similar, and will be dealt with presently. In the case of terrestrial and fluviatile animals derived from marine forms it is manifest that the geological date of origin of the different genera of one family, or even of species of one genus, and above all of different families was not necessarily the same, that is their origin as land or freshwater animals may have taken place, and in all probability did take place, not merely at different periods of the Earth's history, but in different parts of the land-area.

It is reasonable to suppose that all mammalia and all birds have spread from one part of the world in each case, whilst the carps may have originated in one continent at one geological epoch, and another family of freshwater fishes, for instance the *Characinidæ* or *Chromididæ*, at another place at a different epoch. This fact manifestly has an important bearing on distribution; for the original dispersal and evolution of each group must have depended on the position and connexion of land-areas at the time.

At the same time, when the whole of a family, as in the case of the carps or of the *Cyclostomatidæ*, is exclusively freshwater or terrestrial, it is highly probable that all members of that family are descended from one original marine type, and this probability is frequently borne out by the geographical distribution of the family. Thus carps (Cyprinidæ) abound throughout Huxley's Arctogæa, the Palæarctic, Ethiopian, Oriental, and Nearctic regions of Sclater and Wallace, but are absent in Australia and South America.

As in the class Pisces, so in the subkingdom Mollusca, the freshwater forms belong to widely different groups. Thus the *Unionidæ* and *Paludinidæ*, both purely freshwater families, belong to two widely different classes, the Lamellibranchiata or Pelecypoda and the Gasteropoda. Here too, as amongst the fishes, we find some families entirely confined to fresh water, as the examples mentioned above; others marine with freshwater genera, as the *Rissoidæ* or *Hydrobiidæ* with *Bythinia*, *Littorinidæ* with *Cremonconchus*, *Mytilidæ* with *Dreissensia* and *Byssanodonta*, and finally genera like *Neritina*, with some species marine or estuarine, others fluviatile and even inhabiting mountain-torrents.

Amongst land-mollusca, although there is by no means the same diversity as in the freshwater members of the subkingdom, there are nevertheless several families of very different affinities. The families are, as a rule, entirely terrestrial, but they are frequently allied to other families that are marine. The most important forms belong to the order Pulmonata, including the *Helicidæ*, *Limacidæ*, *Testacellidæ*, and several other purely terrestrial families, the *Limneidæ* and *Physidæ* freshwater, the *Auriculidæ*, *Oncidiidæ*, and *Amphibolidæ* essentially brackish water or estuarine, but with marine representatives, and in the *Auriculidæ* with at least one truly terrestrial genus *Camptonyx*, and lastly the marine *Siphonariidæ*. The estuarine and marine types are, however, without exception littoral, and the whole order may be as thoroughly terrestrial in origin as mammals. Very different is the case with the land-shells

belonging to the order Prosobranchiata and frequently known as Operculata, although some of these have no opercula. These comprise the *Cyclophoridae*, *Cyclostomatidae*, *Aciculidae*, and perhaps *Truncatellidae* belonging, like the freshwater *Paludinidae*, *Valvatidae* and *Ampullaridae*, and many of the commonest marine univalves, to the Tænioglossate division of the suborder Pectinibranchiata, and the *Helicinidae* and *Hydrocænidæ* allied to *Neritidae* and appertaining to the Rhipidoglossate division of the suborder Scutibranchiata*. In the immediate neighbourhood of the *Helicinidae* there is another terrestrial family, the *Proserpinidae*, without any operculum. The great bulk of all the divisions and orders of the Prosobranchiata, it is scarcely necessary to say, are marine.

There is nothing in the present distribution of the various families of operculated land-shells antagonistic to the idea of each family having originated from a distinct birthplace at a different period from any other family. The *Cyclophoridae*, though found in all the principal regions of the earth, are chiefly developed in the Oriental region, and are very largely continental in their distribution. The *Cyclostomatidae* are best developed on what Wallace has termed ancient continental islands, which have been separated from continents during the later Tertiary periods, and especially on the Antilles and Mascarene Islands; this family is represented only on the skirts of the Oriental region. The *Helicinidae*, also mainly insular, have a curiously different range from the *Cyclostomatidae*, although both are chiefly developed in the West Indies; *Helicina* extending through the islands of the Pacific to Australia, the Malay Archipelago and even Burma, but not to India. The last western straggler is found in the Seychelles, and the family is unknown in Madagascar or in Africa. The *Proserpinidae* are confined to Central America and the West Indies. The last, judging by the small amount of differentiation and dispersal that they have undergone, may be of more recent origin than the others, whilst the abundance of the *Cyclostomatidae* on old continental islands and their poor development on continents may show them to be of an older and less improved type than the *Cyclophoridae*. Fossil forms of several kinds have been found in Europe and elsewhere, but their affinities and even the families to which they should be assigned are in general extremely doubtful.

Now this fact, that different subdivisions of an order, class or subkingdom have in all probability originated at different periods in

* The terms are those of Fischer's 'Manuel de Conchyliologie.'

the earth's history and at distinct points of the surface, renders it impossible to accept the evidence of the larger groups as a whole. Neither the evidence of the freshwater fishes nor that of land and freshwater mollusca as to distribution can be viewed in the same light as that of mammalia, birds, or reptiles. In the latter cases all are homogeneous to that extent, at all events, that we are probably dealing with descendants of one terrestrial form, and there can be little doubt that all fresh groups have diverged from one centre; in the former case there may have been several centres and several ancestral stocks. In order to analyze the evidence afforded by freshwater fishes and land mollusca, we must take separately each family or other subdivision confined to land or fresh water.

Land and freshwater mollusca are probably for the most part very ancient, and but for two circumstances would afford invaluable evidence as to ancient distribution of land-areas. The two difficulties are:—(1) that we are too imperfectly acquainted with the animals of the majority of the species in the most important order of all, the Pulmonata, to classify them correctly; and (2) that the mystery of the means of migration by which some of them are transported across the seas is unsolved. The prevalent idea that land-mollusca or their eggs are transported by floating logs appears to me extremely improbable in a great number of forms, because, so far as is known, very few either hybernate in wood, or lay their eggs there; and as the wood is carried to the sea during floods, caused by heavy rains which would certainly make every snail leave its hiding-place, the notion that some would remain ensconced in the clefts appears quite opposed to the habits of the animals. A few shore-haunting forms, such as *Truncatellidæ* or *Auriculidæ*, might very possibly be thus transported, but not *Helicidæ*, as a rule, and still less *Cyclophoridæ**, the majority of which are very rarely or never seen on trees or wood.

The smaller forms and their ova are possibly, as Wallace in his later works has suggested, transported by wind, sometimes attached to dried leaves. This may account for the wide distribution of a small form like *Diplommatina*, which lives amongst dead leaves. But both the animals and eggs of many forms are ill suited for wind-transport; some, like *Acavus*, have round or oval calcareous eggs of considerable weight, not easily carried into

* The genus *Leptopoma* is an exception, as it is said to live on trees. But its distribution is also exceptional, some of its species being found widely dispersed in oceanic islands.

the air, whilst other forms, such as *Ariophanta*, have rather large soft membranous eggs, quite unsuited for wind-transport to any distance. Except with the minute forms, I suspect that transport by wind across the sea to any distance is extremely rare, and it is in favour of this view that the species found on oceanic islands are almost always peculiar, testifying to a long period of isolation. On the other hand, how rapid may be the migration of some fresh-water forms was shown by *Dreissensia polymorpha*, which, in about a century, spread over a large part of Europe from the Caspian to Scotland and the south of France.

If it be the fact, as undoubtedly it is, that different subdivisions of the animal and vegetable kingdoms have originated at different geological periods, the next important question is whether, independently of evidence from fossil remains, there is any clue to difference of age, whether any characters exist by means of which groups of more or less ancient origin can be recognized. It is probable that, as a general rule, the most recent groups are those in which the fewest breaks occur, and in which the distinctions between families and genera are most difficult to define; for these distinctions become better marked as, in course of time, links die out through exposure to the varying effects of change in climate and the distribution of land, the development of enemies and the struggle for existence. It is quite true that much depends upon the power of each group of organisms to resist the influence of change; thus omnivorous animals would have greater facilities for obtaining subsistence, should their usual food no longer be procurable, than forms that feed invariably on fruit or vegetables, or flesh or insects, and animals with the power of flight, as already mentioned, may escape by migration, or those adapted for an aquatic life by swimming, whilst creatures unable to fly or swim are overwhelmed by floods or destroyed by change of climate, famine, or enemies. Still, after taking all these circumstances into account, and bearing in mind that the process of evolution appears much slower in some groups of organisms than in others, we shall probably not be far wrong in concluding that, as a general rule, groups of living beings with all the members nearly related are of more recent origin than those in which there are broad distinctions between the different genera and families.

Amongst the whole of the Vertebrata there is, I believe, no large group all the members of which are so closely connected together as the passerine* birds. They comprise more than 6000 known species,

* Not including picarians such as *Pici*, *Coccyges*, *Cypseli*, &c.

or about half of the whole class Aves. The difficulties of classifying them are so great that no two authors agree as to the number or limits of the families into which they can be divided. They have undoubtedly great powers of migration, and many can adapt themselves to changed conditions, some of the higher forms, for instance, the crows, being omnivorous and ranging all over the world; but very many genera are restricted in food and range, and appear no better adapted to survive extensive changes than mammals or reptiles are. It may be safely inferred that the Passeres are of more recent origin than other orders of birds, and probably than any other order of Vertebrata. Geological evidence, so far as it is available, coincides with this; for no remains of the order have been found below the Miocene. It must be remembered, however, that remains of birds from older systems are very rare.

It will thus be observed that Scater's regions, adopted by Wallace and others, were chiefly based on what is very probably the most recently developed group of vertebrata, perhaps the most recent in the animal kingdom.

Huxley's scheme of zoological distribution, to which reference has already been made, was first proposed in a paper on the affinities and distribution of *Alecteromorphæ* and *Heteromorphæ*, or what are commonly known as Gallinaceous birds and their allies; but it was shown that other groups of the animal kingdom confirm the scheme first suggested by the distribution of these birds. Now as Huxley's system differs widely from Scater's, and as both were suggested by different orders of the same class (birds*), it is wise to examine a little more closely how far the distribution of other classes or orders agrees with that of the Passeres.

I have already noticed the great importance attached by Wallace to the mammalia. But there are serious difficulties in the way of accepting the Passerine regions for mammals. In the first place, the difference between the mammals of the Australian region and those of all the other regions is far greater than the distinctions between the latter, and point, as Huxley has noticed, to the Australian region having been divided from the rest of the world by a barrier

* Reichenow (Zool. Jahrb. iii. p. 671, 1888) has proposed the following regions for birds:—

Arctic.

Western,—North and South America.

Eastern,—Africa, Europe, and Asia.

Southern,—Australia, New Zealand, New Guinea, &c.

Madagascar.

Antarctic.

impassable by mammals since a very distant geological period. Secondly, as Huxley has also pointed out, the difference between South America and Arctogæa exceeds the difference between different parts of the latter. Thirdly, the northern part of North America contains so large a proportion, not merely of families and genera, but of species common to the Palæarctic region, that the mammalian fauna differs less from that of Northern Asia than the mammals of Central Asia do from those of Europe. Fourthly, the mammals of Madagascar differ more from those of Africa than those of the Palæarctic do from those of the Oriental region*.

* There are about a dozen mammalian genera found in Canada and the northern part of the Nearctic region that are wanting in northern Asia; of these, however, several of the most important, as the Skunk (*Mephitis*), Raccoon (*Procyon*), and Brush-tailed Porcupine (*Erethizon*), are Neotropical forms that have found their way north. On the other hand, the Lynx, Wolf, Fox, Glutton, both Bears, Marten, Elk, Reindeer, Wapiti, Bison, Wild Sheep, Beaver, Marmot, and some other N.-American forms, are either specifically identical with Palæarctic animals or very nearly allied to them. *Hesperomys* has been shown to be congeneric with *Cricetus* (Thomas, P. Z. S. 1888, p. 133). In Central Asia are found several well-marked types, like *Nectogale*, *Uropsilus*, *Ælurus*, *Æluropus*, *Budorcas*, *Pantholops*, *Poëphagus*, *Moschus*, and many others, that distinguish the fauna from that of the western Palæarctic area.

In the case of Madagascar, not only are two mammalian families, *Chiromyidæ* and *Centetidæ*, and one subfamily, *Cryptoproctinæ*, peculiar to the island, but out of about 24 genera of *Primates*, *Carnivora*, *Insectivora*, *Rodentia*, and *Ungulata* found in Madagascar, and about 100 found in Africa south of the Atlas, only two, *Potamocheerus* and *Crocidura*, exist in both. The oriental genera of the orders mentioned are about 80 in number, and the Palæarctic (omitting Seals) about the same; of these about 30 are found in both regions. Some 25 genera belonging to these orders are common to the Oriental and Ethiopian areas, and 22 to the Palæarctic and Ethiopian, or to put the matter more clearly, the African mammals comprise 25 per cent. of Oriental, 22 per cent. of Palæarctic, and only 2 per cent. of Madagascar genera, whilst the Madagascar forms comprise 8·3 per cent. of African genera. It must be remembered that the climates of Madagascar and Tropical Africa are similar, that of the Palæarctic region very different.

Omitting New Zealand and Polynesia, the following appears to be the division of the earth's surface into mammalian regions:—

- A. Marsupials predominating; placental mammals few; monotremes present.
 - I. *Australian region*, comprising, besides Australia and Tasmania, New Guinea, and the neighbouring islands east of Wallace's line.
- B. Placental mammals predominating; marsupials few or absent; no monotremes.
 - II. *South-American region*.
 - III. *Arctogæan region*, comprising the following major divisions:—
 1. *Madagascar*.

It may, however, be very fairly urged that the avifauna of Madagascar differs quite as widely from that of Africa as the mammalian fauna does, and that the question of the Nearctic region is, after all, of secondary importance. At the same time the objections noticed tend completely to invalidate the idea of equality in the different regions, so far as mammalia are concerned.

Passing on to the Reptilia, we shall find a greater difference. I have already mentioned that Dr. Günther, who at first accepted Sclater's regions, has been induced by the large additions to our knowledge in the course of the last 30 years to reconsider the whole subject; and he has published the result in the article on reptiles in the 'Encyclopædia Britannica.' He adopts a different set of regions for each of the three living orders of the Reptilia, of which numerous representatives are found in the world. The regions adopted for land and freshwater Tortoises are the following:—

Chelonian Regions.

1. All Europe and Asia, Northern Africa, North and Central America.
2. Africa.
3. *a.* Tropical America.
b. Madagascar.
4. Tropical Pacific (Australia, New Guinea, &c.).
5. New Zealand.

The divisions for Lizards will be found to differ materially.

Lacertilian Regions.

1. Africa with the Western Palæarctic region.
2. India with the Manchurian (Eastern Palæarctic) subregion.
3. Tropical Pacific (Australia, &c. as before).
4. Madagascar.
5. South and North America.
6. New Zealand.

Lastly, the regions adopted for Snakes show a third arrangement.

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2. *Africa*, south of the Tropic of Cancer.
 3. *Oriental*, South-eastern Asia and Malay Islands to Wallace's line.
 4. *Aquilonian*, Europe, Asia north of the Himalayas, Africa north of the Tropic of Cancer, and America north of about 45°.
 5. *Medio-Columbian*, America, between about 25° and 45° N. lat.

The last being of decidedly inferior value as a distinct division.

In some respects this rational distribution resembles that of Mr. Andrew Murray (Geographical Distr. Mamm. 1866; maps c. ci.).

Ophidian Regions.

1. Africa south of the Atlas.
2. Western Palæarctic region.
3. India with the eastern Palæarctic region.
4. North America.
5. Tropical America.
6. Tropical Pacific.
7. Madagascar.
8. New Zealand.

In the last case it is especially noticed that the relations of Madagascar to tropical America are closer than would be supposed from this classification.

There is, I believe, no zoologist living whose knowledge of the Reptilia exceeds Dr. Günther's, and as his attention was attracted to the question of distribution so long ago as 1858, the views now expressed are the results of a long study of the subject under the exceptionally favourable circumstances of being in charge of the largest collection in the world. I may add, from a long acquaintance with Dr. Günther, to whom I am indebted for calling my attention to the article I have quoted, that he is not in the habit of changing views once published without strong evidence. The following sentence from his article on Reptiles is therefore of great weight:—"The same arrangement of the so-called primary zoological regions is not applicable to all orders of reptiles, and the differences in their distribution are so fundamental that they can be accounted for only on the assumption of the various orders and families having appeared to spread over the earth at very distant periods when land and water were differently distributed over the surface of the globe."

The distribution of the Batrachia has been studied afresh by Mr. Boulenger, who has arranged the regions thus:—

- I. Northern zone: *Caudata* abundant; *Apoda* wanting.
 1. Euro-Asiatic region.
 2. North-American region.
- II. Equatorial southern zone. Either *Caudata* wanting or *Apoda* present or both *Caudata* wanting and *Apoda* present.
 - A. *Firmisternia* division.
 1. Indian region.
 2. African region.

B. *Arcifera* division.

1. Tropical American region.
2. Australian region.

The limits are the same as Wallace's. It should be mentioned, however, that New Zealand can scarcely be assigned to the Australian region, for its only Batrachian belongs to a family not known to occur in Australia. Madagascar, too, has strong claims to separation as a distinct region.

Dr. Günther also, in the 'Encyclopædia Britannica' and in his 'Introduction to the Study of Fishes' (1880, p. 217), proposed a scheme of distribution for the freshwater members of the class 'Pisces.' The following are the divisions:—

I. Northern zone.

1. Europo-Asiatic or Palæarctic region.
2. North-American or Nearctic region.

II. Equatorial zone.

A. Cyprinoid division.

1. Indian region.
2. African region.

B. Aeyprinoid division.

1. Tropical American region.
2. Tropical Pacific region (Australia, &c.).

III. Southern Zone (Patagonia, Tasmania, and New Zealand).

It will not be necessary to dwell long upon the Invertebrata. They have received less attention than Vertebrates, and except in a very few groups, more remains to be done both in ascertaining their distribution and in determining their structural relations. Wallace, in his work on Geographical Distribution, states that the Lepidoptera and the best-known families of Coleoptera have approximately the same distribution as mammals and birds; but he admits some differences—for instance, the occurrence in temperate South America of a well-marked insect-fauna allied to that of the north temperate zone, and not to neotropical types.

Among the land and freshwater Mollusca, the Pulmonata, and especially the *Helicidæ* and *Limacidæ*, need thorough revision. Without much additional information concerning the animals (the shells alone having been described in a great majority of species and even in many genera) no accurate knowledge of the affinities of

different forms is possible; and without this knowledge the study of geographical distribution is useless. Fischer, in his 'Manuel de Conchyliologie' (p. 196), has adopted regions corresponding with those of Selater and Wallace, except that a Neantarctic is separated from the Neotropical. So far, however, as the operculated Gasteropoda are concerned (and their affinities are far better ascertained than those of the Pulmonata), I cannot see the least resemblance in many cases to the distribution by regions of mammals and birds. I will only notice one case. The *Cyclophoridae* (with one genus of *Helicinidae* and one of *Cyclostomatidae*) of New Guinea and the neighbouring islands, so far as they are known, appear to differ from those of Borneo much as the latter do from those of Ceylon, as will be seen by the following lists of genera represented, compiled mainly from Fischer's:—

Operculated Land Mollusca.

New Guinea and neighbouring islands.	Borneo.	Ceylon.
Pterocyclus.	Pterocyclus.	Pterocyclus.
Cyclophorus.	Opisthoporus.	Aulopoma.
Leptopoma.	Cyclophorus.	Cyclophorus.
Cyclotus.	Leptopoma.	Leptopoma.
Diplommatina.	Cyclotus.	Cyathopoma.
Leucoptychia.	Diplommatina.	Diplommatina.
Pupina.	Opisthostoma.	Cataulus.
Pupinella.	Megalomastoma.	
Callia.	Alycæus.	
Helicina.	Pupinella.	
Omphalotropis.	Rhaphaulus.	
	Helicina.	
	Phaneta.	
	Omphalotropis.	

It is true that our knowledge of the Papuan mollusca is very inferior to that of the Bornean and Ceylonese, especially the latter; but sufficient is known to show that the three belong to one region as regards operculated land-shells. The same is the case with Northern Australia. It is scarcely necessary to point out that between the mammalia of Australia with New Guinea and those of Borneo or Ceylon there is the greatest difference.

The distribution of land-plants into six regions of approximately equal value has never, I believe, been accepted by any botanist. All schemes of repartition with which I am acquainted differ widely

from those of Selater and Wallace. Thus Mr. Thiselton Dyer, in his article on the distribution of plants in the 'Encyclopædia Britannica,' follows Bentham in recognizing "three tolerably ancient floras," which he divides thus:—

I. Northern.

1. Arctic-alpine.
2. Intermediate or temperate (in Europe, Asia, and N. America).
3. Mediterraneo-Caucasian (countries around the Mediterranean and part of S.W. Asia, extending east to Sind).

II. Southern.

1. Antarctic-alpine.
2. Australian.
3. Andine (temperate S. America, Andes, and New Zealand).
4. Mexico-Californian.
5. South African.

III. Tropical.

1. Indo-Malayan (including New Guinea and North Australia).
2. American.
3. African.

Another classification is that of Oscar Drude*, who has divided the land-surface of the world into the following fourteen botanical regions or, as he terms them, floral realms (Florenreiche):—

1. Northern (northern part of Asia and America, and nearly all Europe).
2. Central Asian (Tibet, Mongolia and Turkestan, and Caspian region).
3. Mediterranean and Orient (countries around Mediterranean, Persia, &c., to Indian frontier).
4. East Asian (China and Japan).
5. Middle North American (United States chiefly).
6. Tropical African (Africa S. of the Atlas, the Cape excepted).
7. East African Islands (Madagascar and Mascarene Archipelago).

* Pet. Mitth. Ergänzungsheft, No. 74, 1884, pp. 43, 44.

8. Indian (India and S.E. Asia, Malay Archipelago, Papuasia, Northern Australia, and Polynesia).
9. Tropical American.
10. Cape of Good Hope (a small region near the Cape).
11. Australian (Australia south of the tropics and Tasmania).
12. Novo-Zelanian.
13. Andian (Tropical Andes, Chili, and the Argentine Republic).
14. Antarctic (southern extremity of America and antarctic islands).

It is sufficient to point out that, in both these systems, the greater part of the two regions of the earth which in mammalia exhibit the greatest diversity, the Oriental and Australian, are combined into one region.

In many respects the distribution of plants accords very well with that of land-mollusca.

If now we proceed to consider, as a whole, the geographical distribution of such different subdivisions of the animal kingdom as have been noticed, it will be observed that the mammals, batrachia, freshwater fishes, and land-mollusca appear, at all events in the opinion of the naturalists who have paid especial attention to the subject, to approach the passerine birds in distribution more than the reptiles or plants do. But, as I have pointed out, the freshwater fishes and land- and freshwater mollusca are heterogeneous groups made up of families and genera of various origin, and having very often, probably as a rule, a distribution not agreeing with each other in the smallest degree. Under the circumstances it is easy to see how the conflicting distribution of different families amongst such groups as land-shells or freshwater fishes will produce a general result, in which the only dominant feature will be trivial generic or subgeneric distinctions, closely connected with the modern distribution of land and water. The batrachians to some extent are open to the same remark, for they consist of three orders, Anura, Caudata, and Apoda, having but little affinity and almost certainly of widely different antiquity. The reason why batrachia agree on the whole with passerine birds and mammalia better than reptilia, is not improbably that anurous batrachia (frogs and toads), the only important living order, are of comparatively recent development. Placental mammalia, too, may be less ancient than the reptilian orders, at all events in the present land area. There is, in short, a strong reason for believing that the more recently deve-

loped groups agree with the present distribution and connexion of land tracts better than those of more ancient origin. The relations between the modern range of ancient families or orders and the ancient distribution of land tracts is a problem which it may be hoped will not always be as difficult as it appears at present.

Reviewing the whole evidence, I can only come to one conclusion, namely, that whilst Sclater's regions adopted by Wallace are convenient, and whilst the recognition of them by well-understood names has been of use and has tended to increase our knowledge of geographical distribution, they are, so far as they are natural, a necessary result of the present and later Tertiary distribution of land and water, and that they are, to a large extent, artificial, whilst the idea of their equality is an error. The attempt to make all forms of life fit into the particular grooves that were designed to accommodate passerine birds appears to me Procrustean.

On the whole, the evidence is far too contradictory to be received as proof of the permanence of oceans and continents.

So far I have merely laid before you reasons for doubting whether the distribution of animals at the present day agrees so closely with the present arrangement of land and oceanic areas as to lead to the inference that these have always been the same. It is evident that if there are wide distinctions in the distribution of different groups of living beings, all cannot be cited as witnesses to the permanence of continents and oceans in past times. It is quite true, however, that within the continental limits there have existed at various geological periods seas that, even if of no great depth, were just as complete barriers to the migration of particular forms of life as deep oceans would be. The familiar example of the British Islands is sufficient to illustrate this fact. As noticed by Wallace in 'Island Life,' Germany possesses nearly 90 species of land mammals and Scandinavia 60, whilst in Great Britain there are only 40, and in Ireland only 22. Of reptiles and batrachia 22 occur in Belgium, 13 in Britain, and only 4 in Ireland. The removal of the isthmus of Suez and the substitution of a shallow inlet, the width of the Straits of Dover, would constitute an impassable barrier to many animals.

It remains to be seen whether indications exist of land-connexions in past times across areas now occupied by deep sea. All the discussion hitherto has been to a large extent preliminary to this.

It must be remembered that different groups of animals vary very

greatly in their power to cross the sea, thus land-mammals and batrachians are, as a rule, unable to cross any marine barriers. Mammals, however, can swim further in the sea than batrachians can, the latter and their eggs being killed by sea-water. Snakes are very rarely found in oceanic islands, and those found belong for the most part to particular genera. The occurrence of land-tortoises on what appear to be evidently oceanic islands, such as the Gallipagos, although unexplained, renders the *Chelonia* less important as evidence of land-connexion. Lizards, as a rule, have very small migratory powers across the sea, but some scinques and geckoes appear to form an exception. The powers of dispersal in land- and freshwater mollusca are very limited, though some of them are occasionally transported across oceanic barriers.

It must not be forgotten, too, that when we wish to inquire into the evidence of Pretertiary land-areas, we must examine as witnesses the descendants of the oldest inhabitants, and must turn for information to the types that occupied the region before the invading hordes of passerine birds and placental mammals had driven out so many of the aborigines. If we wish to know anything about ancient distribution of land and sea, we must scrupulously ignore the records of a later state of things. Before we can read the old writing on the palimpsest we must clear away all traces of the modern inscription.

I shall proceed to examine in some little detail (except in the first instance) the evidence of ancient land-connexion :—

1. Between New Zealand and Australia.
2. Between the Solomon Islands and New Guinea.
3. Between Africa and Madagascar.
4. Between Madagascar and India.
5. Between South Africa and South America.

1. *New Zealand and Australia*.—The question of a former union between New Zealand and Australia has been discussed with great ingenuity in 'Island Life' by Wallace, who concludes from the geological and biological evidence that New Zealand received its flora and fauna from Eastern Australia at a time when the latter was divided by sea from Western Australia, and that the characteristic marsupial and monotreme fauna, with all the peculiar temperate flora of Australia, must at the time have been confined to the western island, and consequently did not pass into New Zealand.

The time assigned to the union is the latter part of the Secondary era. Here it is necessary to remark that unless the two areas remained united in the latter half of the Cretaceous period, Dicotyledonous Angiospermous plants, which form the great majority of the forms common to New Zealand and Australia, must have existed in the Australian area before there is any evidence of their having appeared in the northern hemisphere. The essential point is, that Australia and New Zealand are now divided by a broad expanse of sea, between 1000 and 2000 fathoms in depth.

2. *The Solomon Islands.*—The next case to be mentioned is very simple, and is a rather curious illustration of the importance of biological evidence. I have already noticed the interesting account of the geology of the Solomon Islands given by Dr. Guppy, and his discovery in those islands of deep-sea deposits. He infers, on what appears at first sight good geological evidence, that the region has undergone upheaval of not less than 12,000 feet in Post-tertiary times. The Solomon Islands, with New Britain and New Ireland, are represented on the 'Challenger' chart as connected with New Guinea by a bank not exceeding 500 fathoms in depth, and they are said by Dr. Guppy to be separated from each other by channels about 400 fathoms deep*.

Now the fauna of the Solomon Islands comprises mammals, snakes, and batrachians in considerable numbers. As, in the seas around New Guinea, floating wood washed down by rivers is said to occur to an extent rarely met with in other parts of the world, the occurrence of the Solomon Island mammals might perhaps be accounted for, without supposing the islands to have been united to New Guinea. The forms † represented comprise, besides bats, several species of *Mus*, a genus that appears occasionally, by some means or other, to be able to traverse arms of the sea, and one kind of *Phalanger* or *Cuscus*, an arboreal marsupial. The same species of *Phalanger* is found in New Britain and New Ireland, and an allied variety, not specifically distinguished, occurs in New Guinea, Ceram, Bouru, and Amboyna. The *Phalanger* also extends to San Cristoval, the most eastern of the Solomon Islands, a matter of some interest, as will be shown presently.

The presence of the reptiles and batrachia is not, however, to be

* I am indebted to Captain Wharton for the information that no accurate soundings are recorded.

† Thomas, P. Z. S. 1887, p. 320, 1888, pp. 470-483.

explained without communication by land. The species have been described by Mr. Boulenger * and comprise—1 crocodile, 17 lizards, 10 land-snakes, and 13 species of frogs and toads belonging to 5 genera, representing 3 families, *Ranidae*, *Ceratobatrachidae*, and *Hylidae*, the second of which, so far as is known at present, is peculiar to the islands. Our knowledge of Papuan batrachians is, however, very imperfect.

It is a well-known fact, as I have already mentioned, that batrachians and their eggs are killed by sea-water, and that snakes, as a rule, are not found on oceanic islands. No batrachian or ophidian fauna resembling that of the Solomon Islands has ever been observed except in islands that have been part of a continental land. It is impossible to come to any other conclusion than that the Solomon Islands, with New Britain and New Ireland, once formed part of New Guinea, and that portions of the group have never been submerged since the separation.

Nor is this quite all the evidence. The species of frogs and snakes appear to be pretty generally distributed amongst the islands in such a manner as to show that the fauna is probably nearly uniform throughout, with the exception of the easternmost island, San Cristoval, the fauna of which is rather well known. Whilst from the next large island to the westward, Guadalcanar, 5 frogs and 4 snakes have been obtained, San Cristoval has only yielded 1 frog and 3 snakes. Moreover, 2 of the 3 snakes belong to the genus *Enygrus* of the family *Boidae*, probably all good climbers and swimmers. Both the species of *Enygrus* are widely dispersed, one ranging eastward to the Fiji Islands, the other northwestward to the Moluccas and Pelew Islands. The third snake, *Dendrophis salomonis*, found also in Duke of York Island, between New Ireland and New Britain, and in several other islands of the Solomon group, is a climbing tree-snake, that might be transported by floating trees. Most snakes are unable to climb trees, and would be washed off from floating branches &c. In other respects, too, the reptilian fauna of San Cristoval, as Mr. Boulenger has shown, is Polynesian; whilst Mr. Woodford has pointed out (P. Z. S. 1888, p. 250) that certain birds and butterflies, found in the other islands, are here wanting. Probably San Cristoval was separated from the mainland before the other islands, just as Ireland must have been separated from continental Europe before Great Britain. But the poverty in batrachians and snakes of San Cristoval serves to confirm the

* Tr. Z. S. xii. p. 35; P. Z. S. 1887, p. 333, 1888, p. 88.

necessity for land-connexion between the remaining islands and New Guinea; for if the snakes and frogs came over the sea to all the other islands, why have they not reached San Cristoval?

It is evident that the separation of the Solomon group of islands from the mainland and from each other is due to subsidence. This appears at first opposed to the geological evidence of elevation, and it undoubtedly proves that the islands, none of which are 12,000 feet high, cannot as a whole have been recently elevated 12,000 feet unless, since the elevation took place, they have undergone depression sufficient to isolate them. But the raised coral- and rhizopod-beds described by Dr. Guppy certainly appear to bear out his views of recent elevation, and he brings forward other evidence of much weight. On the other hand, not only are some of the forms of batrachia and reptilia peculiar, but the rodents, and especially the bats, show striking distinctive characters. Two new genera of fruit-eating bats (*Pteropidæ*) and one of *Rhinolophidæ* have been recently described from the Solomon Islands, and are not known to occur elsewhere. It is therefore probable that the Solomon Islands must be ancient land, and the explanation of the apparent contradiction may be that the elevation observed by Dr. Guppy has been partial and local, and has not extended to the whole area. It is also probable that the depression which has separated the different islands, with the exception of San Cristoval, from each other is much more recent than that which divided the group as a whole from New Guinea. It is far from unlikely that the channel separating San Cristoval from the other islands will be found, when accurate soundings are taken, to be deeper than the channels between the remaining islands of the group.

Another instance similar to that of the Solomon Islands is afforded by the Liu-Kiu (Loo-choo) Islands between Japan and Formosa. Here also the depths of the surrounding seas are not, I believe, ascertained; the islands are represented in the 'Challenger' map, like the Solomons, as within the 500-fathom line. From these islands several lizards, land-snakes, and batrachians, including a newt, have been obtained*. Most of the species are peculiar, but one frog is a common oriental form, and the newt is a variety of a Chinese and Japanese species.

3. *The Mozambique Channel between Africa and Madagascar.*— Before passing on to the question of an ancient land connecting

* Boulenger, P. Z. S. 1887, p. 146.

India and Madagascar, I wish briefly to call your attention to the Mozambique Channel. This channel is 250 miles broad at its narrowest part and upwards of 1000 fathoms deep throughout; the least recorded depth (which is close to the African coast in the narrowest part of the channel) being 1130. No one questions for a moment that Madagascar and Africa were united during part of the Tertiary era; the large mammalian fauna of Madagascar alone amply proves the fact. As already mentioned, only two genera of mammals are common to Madagascar and Africa, though a few species of reptiles and batrachians are found in both. One of the Mammalian genera common to both areas is *Crocidura*, probably an ancient type, but also possibly introduced by man; the other is *Potamochoerus*, a kind of pig. Now no other ungulate, except this pig, is found in Madagascar, and hence it is probable that all the South African Ungulata belong to the Miocene and Pliocene European fauna, which is believed to have migrated into South Africa after the separation of Madagascar. As Wallace has pointed out, all pigs swim well, and *Potamochoerus* is said to be more of a water-animal than most pigs, and may very probably have crossed from the mainland after the lemurs, insectivores, and other mammals had been isolated by sea. But how far could *Potamochoerus* swim? Surely it is not likely that it could cross the Straits of Dover. I think we are justified in assuming about 10 miles as a probable limit of its power of crossing the sea, but, to be safe, let us suppose double as much*. Then, in Pliocene or Pleistocene times, quite as probably the latter as the former, when *Potamochoerus* reached South Africa, Madagascar was separated by a channel not more than 20 miles broad. The conclusion is inevitable that nearly the whole depression of upwards of 1000 fathoms is of Pliocene or Post-pliocene date. Of course it must not be understood that this date is proved. What we may consider, however, as beyond any doubt is that the depression cannot be older than Middle Tertiary.

4. *Madagascar and India*.—The question whether there was in Secondary or Tertiary times land-connexion across the Indian Ocean between India and Madagascar has been treated at considerable length, with great ability and literary skill, by Mr. Wallace in the ‘Geological Distribution of Animals’ and in ‘Island

* Elephants are excellent swimmers, and have been known to swim, without a rest, for six hours, and, with a rest, for nine. But the pace is very slow, little, if at all, more than a mile an hour.

Life;' and, although this was not his first view, he has come in the last-named work to the decided conclusion that there is no evidence of any former land-connexion in the direction named. With one important exception, that of the remarks on the Upper Palæozoic and Lower Mesozoic flora*, concerning which I think Mr. Wallace has failed to appreciate the facts as a whole, there is scarcely anything in his arguments with which I am inclined to disagree. Upon the evidence noticed by him, relating chiefly to mammals and birds, his conclusions are, I think, reasonable, and I quite concur in his reasons for rejecting Selater's and Hartlaub's hypothesis of "Lemuria." But he has overlooked some of the evidence and is, I think, not acquainted with certain material facts.

I have already referred to the remarkable peculiarities of the Madagascar mammal-fauna, and its great difference from that of Africa. Precisely the same phenomenon is presented by birds †. The most characteristic African families, such as plantain-eaters (*Musophagidæ*), colies (*Colidæ*), and *Irrisoridæ*, barbets, hornbills, secretary-birds, and a number of genera, such as *Lamprotornis*, *Buphaga*, *Laniarius*, and *Telephonus*, that are the common and familiar birds of every part of Africa south of the Sahara, are entirely wanting in the Mascarene Islands, including the Seychelles, Mauritius, &c., whilst no fewer than four peculiar families and a number of genera confined to the archipelago replace them. Amongst the Mascarene birds, too, are found several representatives of Oriental genera, or genera closely allied to Oriental types, and without any near Ethiopian relations. Foremost amongst these are certain bulbuls, forming the genera *Ixocinclæ* and *Tylas*, the former composed of species which have been usually referred to the typically Oriental genus *Hypsipetes*, and the latter nearly affined. In fact, as was shown by Geoffroy St.-Hilaire, and as Hartlaub has since pointed out, there is in the Mascarene avifauna a more marked connexion with Indian than with Ethiopian types. In the Seychelles, especially, out of the 7 passerine genera represented by peculiar species, three, *Nectarinia*, *Zosterops*, and *Tchitrea*, are Indian and African, one, *Foudia*, is Ethiopian, but not Indian, and two, *Copsychus* and *Hypsipetes*, or *Ixocinclæ*, are Indian, but not African ‡.

Another singular case of distribution that corresponds with that

* 'Island Life,' p. 398, footnote.

† Hartlaub, 'Die Vögel Madagascars u. d. benachbarten Inselgruppen,' 1877.

‡ E. Newton, Ibis, 1867, p. 359.

of the birds is afforded by the large fruit-eating bats (*Pteropidæ*)*. The only African genus belonging to the family is *Epomophorus*, which is confined to the continent, whilst throughout the Mascarene archipelago, and even in the Comoro Islands in the Mozambique channel, the typically Oriental genus *Pteropus* occurs and is represented in various islands by 5 species, one or two of them only distinguished by critical characters from the common "flying-fox" of the Indian Peninsula.

So far as the *Pteropus* and birds are concerned, the explanation afforded by Mr. Wallace seems fully to meet the case. He points out that Madagascar was probably connected with Africa in Middle Tertiary times, before the present mammal and bird fauna of Africa, which in Miocene (and in Greece in Pliocene) times inhabited the Palæartic region, had been driven south by the approach of the colder Pliocene and Glacial epochs †, and that the connexion with Madagascar was severed before the southward migration of the palæartic fauna took place, leaving in Madagascar the old African forms which have since undergone no great modification. He, however, points out that the areas now occupied by the Laccadive, Maldive and Chagos atolls, the Saya de Malha and Cargados reefs, are clearly the remains of great islands now depressed beneath the sea, but which must have existed in late Tertiary times, and have afforded means of migration to bats and birds. In the case of *Pteropus*, which is a powerful flier ‡, though I should think certainly incapable of winging its way from India to the nearest Mascarene Islands, this explanation is highly probable, and it applies to such cases as *Copsychus*, but as regards *Hypsipetes* or, rather, *Ixocincla*, and *Tylas*, the derivation from India may be rather more ancient. It should be remembered, however, that distinct genera

* Dobson, Cat. Chiropt. B. M. Introduction, p. xxxii.

† It is, however, important to notice that Mr. Wallace's account of the wide sea occupying the Sahara and Northern India in Miocene times is founded on geological views once current, but now, I think, shown to have been erroneous. There is, as Zittel has shown, no reason to believe that any part of the Sahara has been sea since the Cretaceous period, and there is no evidence that marine conditions prevailed at any geological epoch whatever in the plain of Northern India from Agra to the Brahmaputra ('Manual Geol. India,' i. p. 393). Another error into which Mr. Wallace has been led by geological writers is that of supposing the Pikermi and Siwalik faunas to be Miocene instead of Pliocene. The fauna which was Pliocene in Greece may not have reached South Africa till Pleistocene times, as stated above.

‡ The Indian flying-fox, *P. medius*, has been captured 200 miles from land. Sterndale, Nat. Hist. Mamm. India, p. 39.

in passerine birds are founded on differences that would not be considered generic in other classes of Vertebrata, and that by no means indicate distant relationship.

The Reptiles and Batrachians of Madagascar have been much collected and described of late years, and I am indebted to Mr. Boulenger for some additions to Dr. Böttger's list and for other details*. The reptiles, the snakes excepted, are on the whole more allied to African types than the mammals or birds are, although there is the same remarkable absence of several characteristic Ethiopian families; for instance, there are no *Trionychidæ*, *Agamidæ*, *Lycodontidæ*, *Elapidæ*, or *Viperidæ*. The Oriental relations are very slight. The genus *Phelsuma* (Geckonidæ) is only represented outside of the Mascarene Islands by one species found in the Andamans. This, by itself, is not of much importance, for some geckoes are rather widely distributed on oceanic islands. The distribution of the genus *Acontias* and its allies is more important. This little group of scinques, with rudimentary limbs or none, and very peculiar head-shields, was formerly classed as a distinct family, but has now been placed, rightly, I believe, in the great family of *Scincidæ*. About 12 species are known with certainty, of which 4 are found in Ceylon, 3 in Madagascar, and 5 in Southern Africa. In the batrachians Oriental affinities are rather better shown, for in the Mascarene Islands are found 16 species of *Rhacophorus* (Ranidæ), all the other species being Oriental, and a species of *Calophrynus* of which the only other 2 species are Oriental, whilst the only member of the family *Dyscophidæ* found outside the Mascarene archipelago is the Burmese *Cebuella guttulata*. The *Dyscophidæ* comprise 7 genera and 11 species in Madagascar.

In freshwater fishes there is one very curious case of affinity. There is a family known to ichthyologists as *Chromides* (*Chromididæ*), entirely composed of freshwater species at the present time. This family occurs in South America and throughout Africa, being well represented in the Nile; and species belonging to two genera, *Chromis* and *Hemichromis*, are found in the Jordan and the Lake of Galilee, in Palestine. Three species have been described from Madagascar, one of these constituting a separate genus under the name of *Paretropus*, and forming a link between *Hemichromis* and the only Oriental genus, *Etropus*, which is peculiar to the Indian

* The data concerning the relations and distribution of reptiles and batrachians in the present address are chiefly taken from Mr. Boulenger's recently published British Museum Catalogues.

peninsula and Ceylon, not extending even into the Indo-Gangetic plain. Thus we appear, in this family of fishes, to have two lines of migration indicated from Africa into Asia; one by the Nile Valley to Palestine, the other by the Mascarene Islands to the peninsula of India, each branch terminating in types quite distinct from the terminal representatives of the other, and no form of the family being known to occur in Asia, except in the localities mentioned.

In the Seychelles, to which I have already referred as the only thoroughly authenticated case of oceanic islands composed of granitoid or gneissoid rocks, two Frogs and two Cæcilians are found. The latter belong to an order entirely unknown in oceanic islands elsewhere, and not yet recorded from Madagascar. One species pertains to a genus found also in Africa, the other to a peculiar generic type; but the order *Apoda*, consisting of the Cæcilians, is particularly well represented in Southern India. The presence of the Batrachia serves to prove the former union of the Seychelles to a continent; but this might have been Africa, or Madagascar when forming part of the African land.

The land and freshwater Mollusca of the Mascarene Islands are just as peculiar as the vertebrates, and exhibit the same remarkable affinities; nothing can better show that we are dealing with a very ancient fauna. A large proportion of the molluscan genera are peculiar, such as *Helicophanta*, *Ampelita*, and *Gibbus* amongst the Pulmonata, *Acroptychia*, *Hainesia*, and *Tropidophora* amongst the Prosobranchiata, but perhaps the chief claim to recognition is that in these islands, as in the West Indies, there is a remarkable development of the *Cyclostomatidae*, possibly due in both cases to the preservation, under insular conditions, of the members of a family exposed to too many enemies for vigorous development amongst the modern denizens of Africa and S. America. Attention has been directed by the late Mr. G. Nevill* to the connexion with the Oriental fauna exhibited by the land-mollusca of the Seychelles in particular. It would take up too much time to go into detail, and therefore I will merely say that some Madagascar shells of *Helicidae* so closely resemble Indian forms that I suspect them to be congeneric, but that without detailed knowledge of the animals it is impossible to speak with any certainty. A Comoro *Glessula* and a Seychelles *Streptaxis* have decided Indian affinities, however, whilst a species of *Cochlostyla*, a characteristic Philippine genus, and the small Indian *Helix barakporensis* have been obtained from Madagascar.

* P. Z. S. 1869, p. 62.

In the operculate land-shells the evidence is clearer. Of the *Cyclostomatidæ*, the genus *Cyclotopsis* is peculiar to the Mascarene Islands and the peninsula of India, and affords a case somewhat similar to that of *Etiopius* in the freshwater fishes, the only other members of the family found in the Oriental region being an *Otopoma*, met with in Cutch, and *Realia* (*Omphalotropis*)*, another Mascarene genus, in the Andaman and Nicobar Islands and some of the Malay islands †. But *Otopoma* is also found in Southern Arabia, Socotra, &c., and does not penetrate India further east than Cutch; whilst *Realia* is an insular type, probably possessing peculiar faculties for migration, and ranges through various islands to Polynesia and New Zealand. It is reasonable to suppose that, in whatever way the transfer may have taken place, *Cyclotopsis* reached India from the Mascarene Islands, where *Cyclostomatidæ* abound. On the other hand, there are found on the Seychelles *Cyathopoma*, a genus chiefly developed in Peninsular India, *Leptopoma*, a Malay type, found also in Ceylon, and *Helicina*, not found in India or Ceylon, but occurring in Burma and ranging throughout the Malay Archipelago and Polynesia to America and the Antilles. These types, belonging to two totally distinct families, *Cyclophoridae* and *Helicinidae*, must apparently have reached the Seychelles from the eastward, for not one of them is found in Africa. Now if there was not land-connexion between India and the Seychelles, these mollusks must have been transported either by floating objects, a means of migration concerning which I have already expressed grave scepticism, or through the air. But anything floating would be transported from the Seychelles to the Indian coasts, never the reverse, as is shown by the Seychelles double cocoonut, or *cocos de mer*, having been known long before its origin was discovered through being occasionally thrown upon the Maldives and Sumatra. I have examined the weather-charts of the Arabian Sea and neighbouring portions of the Indian Ocean, on which the currents for different periods of the year are shown, and I think it is evident that the westwardly currents which prevail in parts of the sea from November

* Many of the shells referred to *Omphalotropis* in works on land-mollusca really belong to *Assimineæ*, a brackish-water form belonging to a different family.

† The peculiar Madagascar shell called *Acroptychia metableta* is wonderfully like *Cyclophorus foliaceus* from the Nicobar Islands, and *C. Leai* from the Andamans. The Madagascar *Mascaria* is represented in Ceylon by *Cataulus*, in the Himalayas, Burma, and Borneo by *Coptochilus*, and in the Neotropical region by *Megalomastoma*.

till April are too slight and irregular, especially in the neighbourhood of the Indian coast, to transport any objects from India to the Mascarene Islands.

Wallace has suggested that in a stormy area like many parts of the Indian Ocean, small organisms, such as seeds of plants and eggs of invertebrates, may be transported by the winds across seas of considerable breadth, and he supposes that the Azores and some other Atlantic islands have thus been stocked with plants, insects, and mollusca *. In the latter case he especially points out that the efficient transport in this case is not by ordinary winds such as the trade-winds, for otherwise the Azores would have derived their plants, insects, and shells from America, but by violent gales and storms, which are in the north Atlantic very capricious and irregular in direction. With regard to storms in the Indian Ocean, I consulted my brother Mr. H. F. Blanford, who called my attention to the weather- and current-charts already mentioned, and he tells me that no storm in the Indian Ocean ever crosses the Equator, that the storms travel on each side, away from the equinoctial line, and that consequently, as the Mascarene Islands lie south of the Equator, and India to the northward, the transports of seeds or eggs from one to the other by storms is impossible. A good steady wind blows in the S.W. monsoon (May to October) in a somewhat circuitous course from the Mascarene Islands up the African coast, and thence eastward across the Arabian sea ; but this, like the trade-winds of the Atlantic, is not likely to transport solid objects to any distance. The N. E. monsoon in the neighbourhood of the Indian coast is too light and irregular to be of any importance.

Of course, under exceptional circumstances, light objects might be carried by violent upward currents, such as occur in tropical cyclones, into the higher regions of the atmosphere, as the volcanic dust was carried from Krakatao ; but independently of the fact that the eggs of tropical mollusca and insects would probably be killed by the cold, this mode of transport might explain diffusion throughout the world, but would not account for partial dissemination of special forms confined to certain islands in particular directions. It is true that the difficulty of transport, either by floating objects or by the wind, would be greatly diminished by the presence of large intervening islands as already explained ; but still it is doubtful whether the presence of these islands would have any important effect on the winds or currents, so as to obviate the difficulty of transport from India to the Mascarene Islands.

* *Island Life*, pp. 247, 251, 253, &c.

Numerous cases of affinity between Mascarene and Oriental insects have been noticed, and there are similar alliances amongst the plants, but it is impossible to enter into these. There can be no question that the Mascarene fauna and flora, taken as a whole, with the exception of the land-mammalia, contains a well-marked Oriental element. This has never been questioned, but it has been urged, with much force, that the presence of this element may be accounted for without its necessarily involving land-connexion between India and Madagascar. It is, however, admitted that the existence at a late Tertiary epoch of large intermediate islands is essential.

If, however, any geological evidence can be produced in favour of the view that the Indian Ocean, between India and South Africa, was bridged by land before either country was inhabited by placental, or perhaps by any mammalia, it is, I think, clear that all the peculiar relationships of the Mascarene Islands would be satisfactorily explained. I think that the requisite geological evidence does exist. In the first place, attention must be called to the remarkable flora that extended from Australia to India and South Africa in Upper Palæozoic times. No doubt until very recently the principal European palæontologists refused to admit that this flora was Palæozoic, and even now the statement is occasionally made that the Carboniferous * flora of northern lands had a world-wide range. But the mass of evidence now available to show that the Newcastle flora of Australia and the Damuda-Talehir flora of India are really Upper Palæozoic, despite the absence of European palæozoic plants and the presence of what are, in Europe, Mesozoic types, is so clear that I feel sure any geologist who will examine the question will be convinced of its truth. In Australia the facts have long been perfectly well known, but in India they have only recently been fully cleared up, chiefly by the progress of discovery in the Salt Range of the Punjab. In South Africa the evidence is less perfect, though some important additions to our knowledge have resulted from Dr. Feistmantel's examination of the fossil plants, the account of which he has been so good as to send to me. In this account, which only reached me two days since, the representation of the peculiar Damuda flora of India in South Africa is shown to be beyond question, and much more complete than has hitherto been supposed.

Now this flora is so strongly contrasted with the Carboniferous flora of Europe that it is difficult to conceive that the countries in which the two grew can have been in connexion, and the hypothesis

* In the following remarks, Carboniferous must be understood to include Permian.

of Gondwána-land, as it is termed by Suess*, a great continent including Australia, India, and South Africa, seems more in accordance with facts than Mr. Wallace's view that "fragmentary evidence derived from such remote periods" is "utterly inconclusive"†. For if each flora could be transported across the sea, why are no European Carboniferous plants found in the contemporaneous deposits of Gondwána-land and *vice versá*. Carboniferous plants of the European type are not confined to the northern hemisphere even, for they are found on the Zambesi in Africa and in Brazil. The accounts of their occurrence in Africa south of the Zambesi are as yet too indefinite for any clear idea of their relations to be formed, and it remains to be seen whether the *Lepidodendron* said to be found in Natal and the Transvaal is not Lower Carboniferous or Devonian, as in Australia.

There is some evidence, though less complete than that from Carboniferous strata, of similar floras in Jurassic beds in Australia, India, South Africa, and also in South America.

The evidence of the Carboniferous flora is, however, open to one objection. It may be urged that the distinction between the Northern and Southern floras is too great to be due solely to isolation, and that some other agents, such as climate, must be the cause of the difference. Very possibly the difference may be due to both isolation and climate; for in the lower part of the series in India, Africa, and Australia, the best-marked proofs, yet recorded, of glacial action in ancient rocks have been noticed, and, despite some curious occurrences of boulders in coal-seams, no such unequivocal evidence of glacial conditions has been noticed in the Carboniferous of the Northern hemisphere. But additional facts in favour of land-connexion between India and South Africa are met with in Cretaceous times, and in this case the evidence is derived from marine, not from fluvial deposits.

The Echinoderm-fauna of the Cenomanian beds found around Bág, near the Nerbudda, in Western India, comprises 8 species ‡, only 2 of which are not found in beds of the same age in Europe. The number of species found in the Cenomanian Utatur group of South India of the same age is 10 §, 4 of which, all species of *Cidaris*, are referred to European species, but three of the four are doubtful. The

* Das Antlitz der Erde, Bd. i. p. 768.

† Island Life, p. 398, note.

‡ Duncan, Q. J. G. S. xliii. p. 154.

§ Stoliczka, 'Palæontologia Indica,' ser. viii. vol. iv. p. (125). See also Manual Geol. India, pp. 290, 297, &c.

Arialur beds of Southern India (Senonian) contain 26 species, of which 4 only are known from European Cretaceous deposits, and of these 4 2 are doubtfully identified. Not a single species is common to the Nerbudda and S. Indian Cretaceous rocks; but this is far less important than the fact that the former contain 75 per cent. of European forms, and the latter a percentage certainly not exceeding 40 *, and probably considerably less. The fauna of the S. Indian beds generally is widely distinct from the Cenomanian forms of Europe, that of the Nerbudda beds, so far as known, is very similar. It is a reasonable conclusion, as I pointed out ten years ago †, that the Nerbudda beds were deposited in a sea in direct communication with the Cenomanian sea of Europe, and the Trichinopoly beds in waters that were separated by a land barrier.

But the European Cenomanian fauna is found again in Southern Arabia and in Palestine. The Trichinopoly fauna recurs in the Khási hills, south of Assam, 1200 miles N.E. of Trichinopoly, and again in Natal, more than 4000 miles to the S.W.; and it appears almost a necessary inference that these points were on the south coast of a tract of land that extended across the Indian Ocean. Since I first suggested this view in 1879, it has been strongly supported by Prof. Martin Duncan's revision of the Nerbudda Echinodermata.

Nor is this all. From a study of the Jurassic fauna of the world, that is to say from the consideration of an entirely different group of facts, Neumayr has come to precisely the same conclusion as to a land union between India and S. Africa across the Indian Ocean ‡, and this view is especially founded on the Neocomian fauna of Uitenhage §, in Cape Colony. It should, however, be noticed that near India, very possibly to the eastward, but not, I think, precisely in the direction indicated by Neumayr, there was probably in uppermost Jurassic or lowest Cretaceous times, some communication between the seas to the North and South. This would explain the occurrence of a few identical species of Mollusca, found in very high Jurassic or low Neocomian beds in Cutch on the one hand, and near the mouth of the Godávári on the other. A shallow strait would

* It must not be forgotten that this percentage is higher in the Cenomanian Echinodermata than in other groups, that the total percentage of European forms in the Echinodermata of the S. Indian Cretaceous rocks is only 18 per cent., and that of European species in the whole fauna 16.

† See *Man. Geol. India*, Introduction, p. xxxix, & p. 297.

‡ *Denkschr. k.-k. Ak. Wiss. Wien, math.-nat. Cl. Bd. 1. (1885), p. 132, map 1.*

§ *Loc. cit.* p. 54.

have sufficed, and if this was subsequently converted into land, the progressive diminution of European species in the three stages of the S. Indian Cretaceous beds would be explained by the increasing effect of isolation.

Since the above was written another and very noteworthy piece of evidence has been pointed out, again by Neumayr, in one of the last papers that he wrote *. In our Quarterly Journal of last year, as an appendix to Mr. Baron's paper "On the Geology of parts of Madagascar," a list of fossils identified by Mr. R. B. Newton was added †. Four of these fossils, all species of Belemnites, were Neocomian, and consequently of similar age to the Uitenhage beds of Cape Colony, formerly supposed to be Jurassic. In the Uitenhage beds a single Belemnite (*B. africanus*) occurs. Not only have none of the species recorded from Madagascar been found in the Uitenhage beds, but three of them belong to a group of Belemnites called *Notocæli*, and one to the *Hastati*; whilst *B. africanus* is referred to the *Absoluti*. Now the *Notocæli* are typically equatorial forms, whilst the *Absoluti* are as typical, in the northern hemisphere, of boreal regions. *B. pistilliformis*, the Madagascar representative of the *Hastati*, is also a distinctly southern form in Europe. The inference that the sea to the north-west of Madagascar in Neocomian times was part of the warm equatorial ocean, whilst the sea of the extreme south of Africa was part of a cold southern ocean with a distinct fauna, is inevitable, and agrees with the other points cited in showing that a belt of land probably extended from South Africa across the Indian Ocean in Cretaceous times.

The evidence relating to the old land-connexion between India and South Africa has been given at greater length than would otherwise have been necessary because of its importance, and because this is a crucial case. So far as I am able to judge, every circumstance as to the distribution of life is consistent with the view that the connexion between India and South Africa included the Archæan masses of the Seychelles and Madagascar, that it continued throughout Upper Cretaceous times, and was broken up into islands at an early Tertiary date. Great depression must have taken place, and the last remnants of the islands are now doubtless marked by the coral atolls of the Laccadives, Maldives, and Chagos, and by the Saya de Malha bank. It is immaterial whether Bourbon, Mauritius, and Rodriguez ever formed part of the Mascarene land or not.

* Neues Jahrb. f. Mineral. &c. 1890, p. 1.

† Quart. Journ. Geol. Soc. xlv. p. 331.

It is perfectly true, however, that the charts hitherto published, for instance, that accompanying the 'Challenger' narrative, show deep water between the various banks that support the Mascarene Islands and the Laccadives, Maldives, Chagos, and other groups. But the soundings in the portion of the Indian Ocean between these islands are insufficient to enable the contours of the sea-bottom to be laid down with any approach to accuracy; and I anticipate that, when the contours are better known, a bank will be found to connect the whole series from India to Madagascar. Even should this not be the case, the evidence of land-connexion appears so strong that it may be a question whether the whole of the ocean-bottom between Africa and India may not have sunk to its present depth since Cretaceous times.

5. *South Africa and South America.*—The only other hypothesis to which I shall ask your attention is that of an ancient southern continent, and especially the possibility of ancient land-connexion between South America and Africa on the one hand and between South America and Australia or New Zealand on the other. The latter, if it ever existed, must have been, I think, the later of the two, and I will give the biological evidence in its favour first. The most interesting relations are those of freshwater fishes, the peculiar distribution of which has already been noticed. Two families, *Haplochitonidæ* and *Galaxiadae**, are found only in the southern extremity of America, New Zealand, and Tasmania with Southern Australia, and they form a considerable proportion of the small river-fish-fauna of those countries.

There are some well-marked alliances between the frogs and tortoises of Australia and those of South America. The batrachian family *Cystignathidæ* and the chelonian family *Chelydidæ* are restricted to the two areas; but on the other hand no tortoises are found in New Zealand, and the only frog occurring there is a member of a family otherwise confined to the Palæarctic region. Moreover fossil representatives of *Chelydidæ* have been found both in Europe and in India, so that it is not improbable that the *Cystignathidæ*, which are not very high forms, may also have once had a more extensive range. The land- and freshwater shells, too, afford but little evidence of connexion. If, as Wallace has suggested, the New-Zealand, Tasmanian and Patagonian freshwater fishes or their ova can have been transported by floating ice from the Antarctic

* A *Galaxias* has been described from the Indian coast, but the determination appears somewhat doubtful.

continent, the biological evidence may be accounted for without the necessity for land-communication. Singularly enough, so far as our present information as to the depth of the southern oceans goes, there would appear at first sight to be less difficulty in supposing a former extension of the southern continent to Australia and South America than to Africa, the depth as shown on the 'Challenger' chart south of the former continents nowhere exceeding 2000 fathoms, whereas to the south of Africa there is represented a considerable belt of greater depth. But on an Admiralty chart, for which I am indebted to Captain Wharton, R.N., F.R.S., and on which all the known deep soundings are marked, none are shown south of the southern extremity of Africa; and it is clear that, in this and other regions, more soundings are required before the contours of the sea-bottom in the oceanic area can be considered as determined with accuracy. So far as our present information goes, the ocean south of the Cape of Good Hope may be no deeper than the Mozambique Channel, though probably the depth is greater in the former case.

The faunal relations between Africa and South America are very different from those between the latter and Australia. Here, again, there are marked cases of affinity between the freshwater fishes, the two important families *Chromididæ* and *Characinidæ* being (with the exception of the few Asiatic *Chromididæ* already mentioned) confined to the two continental areas. Nor is this all, for in the *Characinidæ*, a large and important family, three out of the eleven subfamilies into which the family is divided by Günther are both Ethiopian and Neotropical. The importance of this fact is so great that it deserves particular attention, for it proves a very large amount of communication between the two areas, it being manifest that members of all three subfamilies were transferred from one to the other continent after extensive differentiation had taken place in the family.

Again in the *Siluridæ*, two subfamilies are confined to the same two regions, and amongst the few living representatives of Dipnoans, two closely allied genera, *Lepidosiren* and *Protopterus*, represent each other, the former in South America, the latter in Africa.

In the reptiles the principal noteworthy cases of relationship are the following:—The Chelonian family *Pelomedusidæ* comprises three genera, all found in Madagascar; two are also met with in Africa, but not in South America, whilst one genus, *Podocnemis*, is also South American, but not African. The Lacertilian family *Amphisbenidæ*

is almost equally divided between South America and Africa, except that one genus extends north into the Mediterranean area, and that two are found in North America. That the original connexion was between the southern continents is, however, indicated by two of the genera, *Amphisbæna* and *Anops*, being represented in both, whilst the Palæarctic and Nearctic genera are not nearly related to each other. Another Lacertilian family peculiar to Africa and South America is that of the *Anelytropidæ*; but these are not of much importance. Some genera of snakes, e. g. *Ahætulla*, *Dryiophis*, *Dipsadoboa*, and *Leptodira*, have the same distribution. One genus of apodous Batrachians (*Ceciliidæ*), *Dermophis*, is also African and S. American. Amongst the *Batrachia* the most remarkable instance, however, is afforded by the *Aglossa*, a low but peculiarly specialized group of toads, of which one family, *Pipidæ*, is purely Neotropical, the other, *Xenopidæ* (*Dactylethridæ*), peculiar to Africa. It is possible that this may be a case of a group having formerly a much wider range, and the same may be the case with the dipnoans *Lepidosiren* and *Protopterus*; but it is difficult to account for the distribution of the *Chromididæ*, *Characinidæ*, and *Amphisbænidæ* on such an hypothesis. All three are well-marked and well-developed families in both areas. Of the *Chromididæ*, fossil representatives, especially *Pycnosterinx*, are said to have been found in the Cretaceous rocks of the Lebanon; but the relationship of these forms is not free from doubt, and in any case they were marine, and the marine representatives of the *Chromididæ* are extinct. It is also true that a wide-spread marine family, the *Labridæ*, is closely allied to the *Chromididæ*, so that although it is far from probable that the African members of the latter have originated separately from the American, such a contingency might be suggested but for the evidence afforded by the *Characinidæ*. This family is unknown in the fossil state, and there is nothing to indicate that it ever inhabited Europe or North America.

There is another piece of evidence. If Africa was formerly in land communication with South America, it is probable that before the Ethiopian fauna was profoundly modified by the incursion of Palæarctic types in the Pliocene and Pleistocene periods, several Neotropical forms that are wanting there at the present day existed in South Africa. If this was the case, and if, as has already been pointed out, there is a remnant of the old African fauna, preserved from contact with the improved Palæarctic forms, in Madagascar, several alliances with S. American types should be found there that can no longer be traced in continental Africa. This is precisely

what occurs. The case of the Chelonian family *Pelomedusidæ*, in which the American genus *Podocnemis* is represented in Madagascar but not in Africa, has already been mentioned. Besides this, two genera of the typically American Lacertilian family of *Iguanidæ* occur in Madagascar. It is true that another genus is Polynesian*, so this may be an instance of former wide distribution; but even in that case, the occurrence in Madagascar of two out of the only three genera that are not American is significant. Amongst Mascarene snakes, four characteristically American genera of *Colubridæ* are represented—*Heterodon* (2 species), *Liophis* (2), *Dromicus* (6), and *Phyllodryas* (2), whilst two other genera are common to America and to other regions. In fact the ophidian fauna of Madagascar, comprising 36 species, is very much more American than African. Lastly, amongst the *Batrachia*, the family *Dendrobatidæ* consists of one genus, *Mantella*, with 5 species inhabiting the Mascarene Islands, *Dendrobates*, the only other genus of the family (7 sp.), being Neotropical.

There is one case of affinity between the Neotropical and Ethiopian regions, amongst freshwater shells, that deserves notice. The very peculiar family *Ætheriidae*, consists of the genus *Ætheria*, which is African, and two genera *Mulleria* and *Bartlettia* confined to South America. If, however, the West Indies have the same biological relations to the Neotropical region that the Mascarene Islands have to the Ethiopian, and the Lower or Middle Tertiary fauna of each region has been preserved in the corresponding insular groups respectively, the extraordinary development of *Cyclostomatidæ* in the Antilles and in the Mascarene Archipelago may be due to the prevalence of the family in both Africa and South America at the time when they possessed means of communication no longer existing. The occurrence of a few scattered species in Africa and South America, and the extremely poor representation of the family elsewhere, are quite in favour of this view. Even amongst the mammalia there are some curious relationships; the only family of Insectivora belonging to the lower section of the order with narrow

* This genus is found in the Fiji Islands, which may possibly have been the eastern extension of the great continent which doubtless at one time included part of Australia, New Caledonia, and New Zealand. This possibility is admitted by Wallace. The occurrence in the Fiji Islands of three species of frogs, belonging to a genus represented also in the Solomon Islands, New Guinea, the Philippines, &c., affords a strong confirmation of the view that the Fijis are ancient continental islands. [Mr. Boulenger informs me that a genus of Elapoid snakes (*Ogmodon*) is peculiar to the Fiji Islands.]

V-shaped molars that is found out of Africa and Madagascar is that of the *Solenodontidæ* of the West Indies. These insectivores are some of the most lowly organized of all placental mammals, and may be more ancient than other members of the subclass. Amongst the rodents, another placental order of low organization, one family, *Octodontidæ*, is restricted to Africa and South America.

Of course some of the instances mentioned may be explicable by the former existence of allied forms in Europe and North America. But it is very difficult to conceive that so many cases of relationship between the lower vertebrata of Africa and South America can be explained in this manner. The biological evidence of a former land-connexion between South America and Africa is much stronger than that in favour of a belt of land between Africa, Madagascar, and India, although the latter is supported by geological data. It is probable that the land-barrier across the South Atlantic, if that was the form of union, lasted to a later geological epoch than that across the Indian Ocean.

The direction in which the communication between South America and Africa lay is very difficult to indicate. The relationship is chiefly shown by tropical forms, but these may have migrated far to the southward during warm periods. It is highly probable that the southern extremity of South America at one time extended to the eastward, beyond South Georgia, and land may have united this tract with South Africa; but there is nothing known of the sea-bottom to indicate the probability of union in this direction.

The only ancient palæontological evidence, so far as I am aware, is that pointed out by Neumayr in the paper already referred to*. He infers land-connexion between Africa and South America in the Jurassic and Lower Cretaceous periods from (1) the absence of Jurassic marine beds on the western coast of Africa and on the eastern coast of South America; (2) the evidence of ancient land in the Cape Verde Islands and St. Paul's; (3) the fact that the Neocomian Uitenhage fauna of the Cape of Good Hope differs entirely from the European, whilst the Jurassic fauna of western South America does not. The first two grounds appear insufficient, even if the facts were fully admitted; but the third has more force and would appear to indicate a westward or southward prolongation of the South-African land so as to meet a corresponding south-eastward extension of South America.

It must not be forgotten that the area around the South Pole as far north as about 60° of south latitude, so far as is known, is occu-

* *Loc. cit.* p. 132.

pied either by land or by sea of no great depth. If the difficulty about the depth of the intervening ocean is overcome, there is no improbability in the suggestion that at some period of geological history an important continent, having connexions with South America, South Africa, and New Zealand, may have occupied the Antarctic area. I have already referred to the fact that many biologists regard the present distribution of terrestrial life as evidence of original dispersion from an arctic centre. But unless we are acquainted with the distribution in past times of various groups of animals and plants, there is always a liability to regard the stage on the road of migration from which the present representatives of any group diverged as the original centre of distribution. Unless we can trace the actual line of migration (and that we may probably never succeed in doing), how are we to tell whether placental Mammals, for instance, appeared first at an arctic centre and diverged thence to Africa, Asia, and America, or whether the original stock came from a southern continent, for instance, South America, and after travelling to the northern hemisphere and migrating into Asia or Europe, ramified thence again into the Oriental and Ethiopian regions? During the period of migration and evolution great changes would take place in the country whence the type originally sprang; and as each fresh and improved branch appeared, it would spread forward to new regions and backward to the country of its ancestral stock, where it might either exterminate in the struggle for existence those descendants of its own ancestors who had not progressed in structure, or live on beside the more favoured races that had progressed sufficiently to hold their place.

That some families of living animals may have originated in the southern hemisphere is shown by such examples as the *Amphisbaenidae*, *Aglossa*, and *Characinidae*, and especially by the *Galaxiidae* and *Haplochitonidae*.

In this connexion there is one series of palæontological facts of some interest. At particular geological horizons, apparently throughout the world, there is a sudden appearance of terrestrial animals and plants belonging to orders or even subclasses not represented in older strata by any probable ancestors. Amongst the most remarkable instances is the sudden appearance in the Upper Cretaceous epoch, almost or quite simultaneously, of Acanthopterygian fishes and Dicotyledonous Angiospermous plants*, now the dominant and

* I have heard lately of Dicotyledonous Angiosperms in Lower Cretaceous beds in America, but the age of the beds appears to have been determined by the fossil plants, an unsatisfactory method which has often led to error.

most abundant types throughout the globe. A little later in the geological sequence, in the Eocene, there is a similar advent of placental Mammals, anurous Batrachia, Ophidia, and perhaps of modern types of Lacertilia. The origin of the placental Mammalia was discussed twenty years ago by Professor Huxley, in one of the most interesting and suggestive addresses ever delivered from this Chair, and the conclusion to which he came affords the only satisfactory explanation hitherto offered. He showed that the subclass had in all probability been developed for ages before the Eocene period in an isolated continental area that has now apparently disappeared, but which he suggested may have been in the Pacific.

I am inclined to believe that the origin of Dicotyledonous Angiosperms is even a more remarkable case than that of placental Mammals. There is much evidence in favour of the process of modification and evolution amongst plants being far slower than in the higher animals, and many of the Cretaceous and Eocene Angiospermous genera are undistinguishable from those existing at the present day. This Angiospermous flora could only have originated in a great tract of land, and unless that tract was isolated by ocean from all countries in which the earlier Mesozoic flora of Cycads, Conifers, Equisetaceæ, Ferns, &c., has been found, it is difficult to understand why no traces of the ancestral Angiospermous forms have been detected amongst the latter.

The Mesozoic flora itself appeared in a considerable portion of the northern hemisphere in the Triassic period as suddenly as the Angiospermous flora did in the Cretaceous. But in this case we have a clue to the origin of the invaders; for we now know that this Mesozoic flora came from the south, and had established itself in Australia, India, and in South Africa at an Upper Palæozoic epoch, whilst the well-known Palæozoic flora of gigantic *Lycopodiaceæ* and peculiar *Equisetaceæ* and Ferns still flourished in Europe, Northern Asia, and North America. There is, moreover, some evidence in favour of the view that the transfer of the southern plants to the northern hemisphere was caused by a period of low temperature that drove a southern temperate flora northward to the equator. It is known from the scanty remnants of an older Carboniferous (or Upper Devonian) flora found in Australia that Lycopodiaceous plants, similar to northern Palæozoic forms, occurred in the southern area at an earlier date, and it is quite possible that the Newcastle flora of Australia and the Gondwana flora of India, the evident precursors of the Mesozoic flora of Arctogæa,

came originally to Australia from an antarctic continent. It is highly probable that many other forms of terrestrial life besides the Mesozoic flora originated in the southern hemisphere; and unless a very considerable area of what is now deep ocean was occupied by land in Mesozoic and Palæozoic times, a change in favour of which there appears but slight evidence, it is far from improbable that the Antarctic continent was the original area of development.

The land-areas of the present day may differ in one important particular from those which existed at earlier periods of the earth's history. With the exception of America and Australia, all the great land-masses are joined together in the northern hemisphere, and there cannot be a question that the division in the case of America is of extremely recent date; for, as I have already mentioned, a considerable proportion of the higher land-animals, especially carnivores and ungulates, found in the northern parts of America, Asia, and Europe are identical, and it is evident that the duration of species in those orders is not great, for very few, if any, were living in Pliocene times. It is far from unprobable that formerly the great land-masses were more isolated, and consequently terrestrial organisms, such as mammals and most terrestrial reptiles, may have had far less facilities for spreading throughout the globe. The extraordinary diffusion of terrestrial forms in the Upper Cretaceous and Eocene periods may perhaps have been caused by some great breaks in the continuity of the general land-area having been then filled up. As plants have, as a rule, greater power of diffusion than mammals, it is not surprising that the dissemination of angiosperms throughout the northern hemisphere preceded that of placental mammals. There is just a possibility, if higher forms of terrestrial life originated in the southern hemisphere in Palæozoic and early Mesozoic times, that the origin may have been due to a greater development of land in that direction, and to the great land-masses being connected to the southward up to the Cretaceous or Eocene period, much as they have been united to the northward in the later geological epochs.

There may even, in the Mesozoic era, when South Africa was united to India *viâ* Madagascar on one side and to South America on the other, especially if the Indo-Malay continent was also connected with the Australian, have been a girdle of land, chiefly in low latitudes, round nearly three quarters of the earth's circumference from Peru to New Zealand and the Fiji Islands; and this

arrangement of the land-areas would perhaps explain the distribution of the modern flora in belts, as shown by Mr. Thistelton Dyer, and account for the dissemination round so large a part of the globe of a great tropical flora and of certain tropical forms of animal life, for instance, *Iguanidæ*, apodous Batrachians, and some families of land-mollusca.

It will thus be seen that whilst the general permanence of ocean-basins and continental areas cannot be said to be established on anything like firm proof, the general evidence in favour of this view is very strong. But there is no evidence whatever in favour of the extreme view accepted by some physicists and geologists that every ocean-bed now more than 1000 fathoms deep has always been ocean, and that no part of the continental area has ever been beneath the deep sea. Not only is there clear proof that some land-areas lying within continental limits have at a comparatively recent date been submerged over 1000 fathoms, whilst sea-bottoms now over 1000 fathoms deep must have been land in part of the Tertiary era, but there are a mass of facts both geological and biological in favour of land-connexion having formerly existed in certain cases across what are now broad and deep oceans.

I have not hitherto adverted to the question of the origin of coral atolls for two reasons, first that it is far better to discuss the question of the permanence of ocean-basins on evidence which is not a matter of dispute, secondly that I have a strong impression, almost amounting to conviction, that a belief in the unchangeable character of the oceanic area has been the origin of much of the opposition to Darwin's theory of the connexion between atolls and areas of subsidence*. It will, however, be manifest that if, as I think is probable, there was a belt of land across the Indian Ocean in Cretaceous times, represented during the greater part of the Tertiary era by large islands, and if the position of those islands is now indicated by the atolls of the Laccadives and Maldives and the great sunken atoll-shaped banks of Chagos and Saya de Malha, it is clearly consistent with this theory that atolls, as a rule, occupy areas of depression.

* I cannot but think that this is especially the case with one of the principal writers on the subject, Mr. John Murray, and to this I attribute the circumstance that, whilst calling attention to the submarine "elevations" which rise from considerable depths to within a few hundred fathoms of the surface, he has omitted to notice that such shoal-areas may be sunken islands, and result from subsidence, not elevation.

So far as I have been able to form an opinion, I entirely agree with the views expressed by my friend Prof. Bonney in the Appendix to the third edition of Darwin's 'Structure and Distribution of Coral Reefs.' The evidence brought forward by Mr. John Murray, Prof. Agassiz, Dr. Guppy, and others, certainly shows that an atoll with a shallow lagoon may originate in an area that is stationary or even undergoing slow elevation. At the same time I cannot concur in the theory of the origin or deepening of atoll-lagoons by solution. If sea-water were capable of dissolving corals to this extent, it is difficult to understand how any marine limestones can have originated, especially such as the chalk, which is chiefly composed of minute Foraminifera. It has been urged by Mr. John Murray that coral atolls may be founded on submarine banks raised to within the limits at which reef-building corals grow (whether this be 15, 20, or 25 fathoms or more) by the deposition of shells from small floating Mollusca, Crustacea, Foraminifera, &c. Some explanation is necessary why the sea-water should be incapable of dissolving these minute shells, but yet should have the power of forming deep lagoons by solution of the far more solid corals. In the lagoon, it must be remembered that the sea-water is far less quickly renewed than in the open sea, and must be quickly saturated, and also that the higher temperature of the lagoon-water, by diminishing the amount of carbonic acid in solution, would lessen the quantity of calcium carbonate that the water could dissolve. I believe, however, that very few observers are now prepared to accept the hypothesis of the formation of the atoll-lagoons by the solution of the coral rock *; and if this be not accepted, it is difficult to understand how lagoons 40 fathoms deep and upwards, as in some of the Maldive Islands and on the Chagos and Saya de Malha banks, can have been formed without subsidence.

There is another point to which Darwin especially called attention, but which has, I think, been greatly overlooked in the recent discussions, the cumulative nature of the evidence †. The frequent occurrence of atolls in groups is noteworthy. The Laccadive and Maldive atolls are together more than 30 in number, and on the theory of subsidence, with the understanding that, as the land sank, coral-reefs formed gradually and grew *pari passu* with the depression, it is easy to understand how it occurs that all are now at one

* Mr. G. C. Bourne's remarks, Proc. Roy. Soc. xliii. 1888, p. 449, are very important.

† See 'Coral Reefs,' ed. ix. pp. ix, 125, &c.

level. But on the theory of elevation or of gradual building up by volcanic outbursts, it is scarcely credible that all should have been brought within 20, 100, or even 500 fathoms of the surface, but that not one should have been raised above the sea. If the atolls occupied the site of rocky islands worn down to a little below the sea-level by marine denudation, the atoll-form remains to be explained; for marine denudation could not make lagoons 30 or 40 fathoms deep. Moreover the formation of the coral-reefs would surely here and there have protected and preserved some little knoll formed of the original foundation rock. Further, if, as has been urged, atolls are founded on the summits of submarine elevations formed by volcanic eruptions or on the remains of volcanic islands worn down to a little below the surface of the water by marine denudation, they should be most abundant amongst groups of volcanic islands, where both the forms of shoal just specified would be most likely to occur. But this is not the case: the atolls are found by themselves over large areas of ocean, where no other island emerges from the surface and where no trace of volcanic action is observed, and there are either no atolls, or, so far as I can learn, very few and small atolls, amongst the Archipelagoes that manifestly owe their origin to volcanic action.

Other and most important facts in favour of subsidence in the case of the Pacific atolls and barrier-reefs have been brought to notice so recently and so ably by Prof. Dana *, that it is unnecessary to do more than advert to them. The proofs afforded of subsidence in the eastern islands of the Fiji group, and in several other cases where islands indented by deep inlets are surrounded by barrier-reefs, must be convincing to all who have paid attention to the evidence of elevation and subsidence along coast-lines. The curious examples of vertical walls descending to depths of 300 and, in one case, 600 fathoms are also easily explicable as the results of subsidence, but not, so far as I can see, in any other way, unless the very improbable hypothesis be adopted that they are due to faulting.

It is necessary to recall attention to the leading points of evidence, because in the discussion of details the broad facts on which Darwin's theory was originally founded are liable to be overlooked.

In concluding what has, I fear, been a somewhat dreary recapitulation of details, one pleasant task remains. When I returned from

* Am. Journ. Sc. ser. 3, xxx, pp. 89, 169 (1885).

India, between seven and eight years ago, I never anticipated that I should be called upon to occupy the position in which you have done me the honour of placing me. I have, I fear, often fallen short of my predecessors; a life passed in great measure away from Europe has left me very imperfectly acquainted with the details of British geology, and it is to those details that this Society, which has done so much for the study of our science at home and abroad, must be mainly devoted.

I can only express my sincere thanks for the kindness with which I have been treated, and for the ready and kindly assistance that I have received from the Officers, Council, and Fellows of the Society, throughout my period of office. I do not think, too, that I should retire from this Chair without expressing my great obligations to the salaried Officers of the Society. Lastly, I have to congratulate you in having selected as your next President a geologist in whose hands, I feel sure, the position and reputation of this Society will suffer no abatement, and who is peculiarly fitted to occupy a Chair that has been filled by all of his predecessors in the high official position that he now occupies.

February 26, 1890.

J. W. HULKE, Esq., F.R.S., Vice-President, in the Chair.

Egbert B. C. Hambley, Esq., Salisbury, North Carolina, U.S.A.; C. Nicholson Lailey, Esq., 15 Great George Street, Westminster, S.W.; and Donald MacDonald Douglas Stuart, Esq., Oldland, Bristol, were elected Fellows of the Society.

The List of Donations to the Library was read.

The following communication was read:—

“On the Relation of the Westleton Beds or ‘Pebble Sands’ of Suffolk to those of Norfolk, and on their extension inland, with some observations on the Period of the final Elevation and Denudation of the Weald and of the Thames Valley.—Part III. On a Southern Drift in the Valley of the Thames, with Observations on the Final Elevation and Initial Subaerial Denudation of the Weald, and on the Genesis of the Thames.” By Prof. Joseph Prestwich, D.C.L., F.R.S., &c.

The following specimens were exhibited:—

Specimens from Pebble-Beds, exhibited by Prof. J. Prestwich, D.C.L., F.R.S., F.G.S., in illustration of his paper.

Three photographs of sections recording Glacial Action in East Berkshire, exhibited by the Rev. Dr. A. Irving, F.G.S.

Specimens and microscopic sections of Radiolarian Chert from the Ordovician strata (=Llandeilo-Caradoc) of the Southern Uplands of Scotland, exhibited by Dr. G. J. Hinde, F.G.S., on behalf of the Geological Survey of Scotland.

In explanation of the latter, Dr. Hinde said:—

“The specimens on the table are from strata of Ordovician age (the equivalents of the Llandeilo-Caradoc series of Wales) from the Southern Uplands of Scotland, in the Counties of Lanarkshire and Peebleshire. They were sent to me for examination by B. N. Peach, Esq., F.R.S.E., F.G.S., of the Geological Survey of Scotland, with the view of ascertaining if the Chert of this series resembles that of the Carboniferous rocks in being of organic origin.

“Sections under the microscope show that the rock is filled with minute spherical bodies, ranging up to one fourth of a millimetre in diameter, in the majority of cases without structure; but in one specimen they can be seen to consist of simple or concentric lattice-like shells, some with relatively long radial spines, precisely similar in character to the shells or tests of recent and fossil Radiolaria, and it is probable that they can be included in the same genera with recent forms.

“These Ordovician chert-beds, which are, I believe, of considerable thickness, are thus shown to be of organic origin, and to be composed principally of Radiolarians, sponge-remains being apparently rare in them, and in this feature they differ from the Yoredale Cherts.

“This is the first definite notice of the presence of undoubted Radiolarians in Palæozoic strata. To Prof. Dr. H. A. Nicholson*, F.L.S., F.G.S., of Aberdeen, belongs the credit of having first noticed these organisms in the Chert; but in his specimens only casts without structural characters were preserved, and they were conjectured to be Radiolarian—a conjecture which is now shown to be correct.”

March 12, 1890.

J. W. HULKE, Esq., F.R.S., Vice-President, in the Chair.

George Sweet, Esq., Brunswick, Melbourne; and Mount Ratnavêlacharia, Esq., Assistant-Conservator of Forests, H.H. the Nizam's Service, Hyderabad, Deccan, were elected Fellows of the Society.

The List of Donations to the Library was read.

The following communications were read:—

1. “On a Deep Channel of Drift in the Valley of the Cam, Essex.” By W. Whitaker, Esq., B.A., F.R.S., F.G.S.
2. “On the Monian and Basal Cambrian Rocks of Shropshire.” By Prof. J. F. Blake, M.A., F.G.S.
3. “On a Crocodilian Jaw from the Oxford Clay of Peterborough.” By R. Lydekker, Esq., B.A., F.G.S., &c.
4. “On two new Species of Labyrinthodonts.” By R. Lydekker, Esq., B.A., F.G.S., &c.

The following specimens were exhibited:—

Rock-specimens and microscopic sections, exhibited by Prof. J. F. Blake, F.G.S., in illustration of his paper.

Specimen and cast of Crocodilian Jaws, exhibited by R. Lydekker, Esq., F.G.S., in illustration of his paper.

Human skull, found 27 feet below the surface in the Manchester Ship-canal excavations in sand, exhibited on behalf of Mr. Abernethy, the Consulting Engineer, by Capt. A. W. Stiffe, F.G.S.

* Trans. Edinb. Geol. Soc. vol. vi. part i. p. 56 (1890).

With regard to this specimen Capt. Stiffe said that by the courtesy of Mr. Abernethy, Consulting Engineer of the Manchester Ship-canal, he was enabled to lay this specimen before the Meeting. The skull appears to be that of a man, probably from 20 to 25 years of age, and it was found at a depth of 27 feet from the surface, at a spot indicated upon a plan exhibited to the Meeting, in a bed of fine sharp sand, beneath a deposit of blue silt ($3\frac{1}{2}$ feet), overlain by red clay (6 feet). The skull is not remarkable in shape, but from its appearance it would seem to be of considerable age.

Three specimens from Trinidad, exhibited by N. F. Robarts, Esq., F.G.S.

March 26, 1890.

J. W. HULKE, Esq., F.R.S., Vice-President, in the Chair.

Isaac Ashmore, Esq., Rosemont House, Chetwynd, Newport, Salop; David Balfour, Esq., Mem.Inst.C.E., Myre Hall, Houghton-le-Spring, Co. Durham; Arthur Brown, Esq., 54 Warrington Road, Newcastle-on-Tyne; Edward Henry Davies, Esq., Hampden Club, London, N.W.; Edward Greenly, Esq., of the Geological Survey of Scotland, 16 Brondesbury Villas, Kilburn, N.W.; Joseph Macpherson, Esq., 4 Calle de l'Exposicion, Barrio do Monasterio, Madrid; David Davey Rosewarne, Esq., Government Inspector of Mines for South Australia, Adelaide, South Australia; Wilfred Ivanhoe Thomas, Esq., 33 Chancery Lane, W.C.; and David Tyzack, Esq., 71 Westgate Road, Newcastle-on-Tyne, were elected Fellows of the Society.

The List of Donations to the Library was read.

The following communications were read:—

1. "On a new Species of *Cyphaspis* from the Carboniferous Rocks of Yorkshire." By Miss C. Coignou. (Communicated by Professor T. M^cK. Hughes, M.A., F.R.S., F.G.S.)

2. "On Composite Spherulites in Obsidian from Hot Springs near Little Lake, California." By Frank Rutley, Esq., F.G.S., Lecturer on Mineralogy in the Royal School of Mines.

3. "A Monograph of the Polyzoa (Bryozoa) of the Hunstanton Red Chalk." By George Robert Vine, Esq. (Communicated by Prof. P. Martin Duncan, F.R.S., F.G.S.)

4. "Evidence furnished by the Quaternary Glacial-Epoch Morainic Deposits of Pennsylvania, U.S.A., for a similar mode of formation of the Permian Breccias of Leicestershire and South Derbyshire." By William S. Gresley, Esq., F.G.S.

[Abstract.]

In 1885 the writer communicated a paper to this Society* on certain fossiliferous nodules and fragments of hæmatite occurring in the Permian Breccias of Leicestershire; and, pointing to the fact that many of these nodules &c. were more or less covered with scratches, and occasionally exhibited polished surfaces other than slickensides, he had reasons for supposing, with Ramsay, that such markings were, in some way, the result of ice-action at the close of the Coal-Period.

Since that paper was written some large subangular, grooved or striated boulders of sandstone, about a ton in weight, have been met with in the workings of a coal-mine in South Derbyshire, lying immediately upon eroded Coal-measures, in Permian Breccia-beds, at about 600 feet deep.

Spread over the denuded Coal-measures in the anthracite regions of Pennsylvania, U. S. A., filling buried valleys and as morainic heaps on more elevated surfaces, are large and often thick irregular deposits of débris of rocks of various geological horizons, but chiefly Coal-measures (conglomerates, grits, sandstones, slates, shales, coal, fireclay, and ironstone), of all sizes up to hundreds of tons, mixed with clay and ground-up materials. Immediately below this drift excellent examples of glacial striæ are frequently found, *in situ*, upon the rocks; and some large "pot-holes" (one 48 ft. wide by 38 ft. deep) have been found in shallow excavations, which were met with incidentally in the ordinary course of mining the anthracite †. Probably no geologist questions the origin of these surface-accumulations, namely, that they are of "the Glacial Period."

The nodules of ironstone occurring in these Glacial deposits in Pennsylvania are scratched or striated in precisely the same manner as are those in the Permian deposits of Leicestershire and Derbyshire; in fact, except for colour, which goes for little or nothing, one could not tell one specimen from the other. Furthermore, these ironstones have been much more scratched than any other kind of rock-fragment in both the English and American deposits. We may satisfactorily account for this circumstance when we reflect that, putting coal and clay on one side, the ironstone nodules would suffer most in this respect, especially as the siliceous fragments largely predominate, and are not often visibly affected that way.

It cannot be supposed that these ironstone nodules in North America were scratched previous to the Quaternary Period, but those of the English Permian were previous to that epoch. We

* Quart. Journ. Geol. Soc. vol. xli. Proceed. pp. 109, 110.

† See 'Geological Survey Pennsylvania,' Annual Report 1885.

may therefore conclude that one and the same agency, namely, that of *ice*, has done the work at each period.

DISCUSSION.

Dr. SPENCER referred to his own glacial experiences in America, though in districts mostly north-west of Pennsylvania. In some cases he had known deposits nearly 1000 feet thick. The last of the till-deposits had been laid down before the beaches of the Great Lakes, which might be traced for hundreds of miles. These beaches have been much affected by subsequent terrestrial warpings, showing that there were no highlands north of the Great Lakes affording a breeding-ground for glaciers at the close of the Upper-Till episode. He concluded that in studying the drift deposits, no consideration had been taken of the deformation of the American continent due to warping.

Dr. HINDE said that as none of the pebbles referred to in the paper were exhibited, it was not possible to form an opinion as to the origin of the striations on them.

Prof. GREEN spoke of some striated pebbles which he had brought from South Africa, but it had been suggested that in landslips the action of one pebble sliding over another might have produced these.

Mr. MONCKTON failed to see how the American instance given helped the evidence, such as it was, in favour of the glacial origin of the Permian Breccias of Leicestershire.

The SECRETARY said that no further particulars were given: he had read the whole note.

The following specimens were exhibited:—

Specimen of *Cyphaspis*, exhibited by Prof. T. M'Kenny Hughes, F.R.S., F.G.S., in illustration of the paper by Miss Coignou.

Specimens and microscopic section of Spherulites in Obsidian, exhibited by Frank Rutley, Esq., F.G.S., in illustration of his paper.

Bryozoa (Polyzoa) from the Red Chalk of Hunstanton, exhibited by T. Jesson, Esq., F.G.S., in illustration of the paper by G. R. Vine, Esq.

April 16, 1890.

J. W. HULKE, Esq., F.R.S., Vice-President, in the Chair.

William Hew Coltman, Esq., B.A., 13 Queen's Gate Gardens, S.W.; and Robert S. Wyld, Esq., Jun., Memb.Inst.C.E., Oswestry, Shropshire, were elected Fellows; Dr. Dionys Stur, Vienna, a Foreign Member; and Magister Friedrich Schmidt, St. Petersburg, a Foreign Correspondent of the Society.

The List of Donations to the Library was read.

The following communications were read :—

1. "On the Disturbed Rocks of North-western Germany." By Prof. A. von Könen, For.Corr.G.S. (Communicated by Sir Warington W. Smyth, F.R.S., For.Sec.G.S.)

[Abstract.]

During the last eighteen years I have spent the better part of my vacations in investigating and mapping the geology of parts of North-western Germany. I have published, in the 'Jahrbuch der königlich preussischen geologischen Landesanstalt,' Berlin, for the years 1883–1887, some of the results in a series of notes on dislocations.

I have therein stated that the Palæozoic rocks of Rhineland, Westphalia, and Nassau, and of the greater part of the Harz, have been plicated with a north-east strike at the beginning of Permian times; and that all the other Mesozoic rocks appear to be in perfect concordance, except in cases in which discordance may be explained by erosion or abrasion. Only in Tertiary times did dislocations occur over a wide area, especially in Middle and later Miocene times—first, with the strike to the north-west, afterwards to the north or somewhat to the east. Dykes of basalt were intruded in both directions, and cones were formed at these periods in numerous places; but large areas between them remained without any perceptible disturbance.

I have pointed out that similar dislocations occurred even in Post-glacial times, and probably originated the valleys of North Germany with their peculiar directions, as well as most of the lakes of Prussia, Brandenburg, Mecklenburg, &c., and perhaps of Switzerland.

I also described how I have explained for many years past, in my geological lectures, the way in which the synclinal and anticlinal lines, faults, fissures, &c. were formed by lateral or tangential pressure; but I could mention only a few of these exceedingly variable cases which occur in that country.

As I have tried to describe these phenomena in as few words as possible, it will hardly be easy to follow my meaning without examining special maps; but I think I may venture to offer to English geologists a few observations which may help to explain volcanic action and volcanic energy.

In the synclinal as well as in the anticlinal lines the strata, for the most part, are not simply bent, as is generally supposed: in many cases they are broken and interrupted, so that the fractures converge downwards in anticlinals and diverge downwards in synclinals. The hollows thus formed were, more or less, filled by the sliding or falling down of the uppermost beds, from either one or both sides, so that fissures remained.

In the immediate neighbourhood of Göttingen there are very fine sections to be seen, which explain and corroborate what is above stated.

Now I have found that the basalts were generally erupted through

synclinal fissures. All the beds of lignite and brown coal worked near Cassel*, and at other places of which I have a knowledge, dip against the slope of the mountain, if they are penetrated by a basalt-dyke and covered by a layer of basalt; whereas valleys between such mountain-ridges are due to the anticlinal between the synclinal fissures.

This may, I think, be well explained in the following way:— During the process of folding and faulting the hard crust of the earth was pressed downwards more particularly in the synclinal lines, and, if in those places any molten magma existed beneath the crust, being compressed, it escaped by the readiest way, which was through the synclinal fissure opening downwards, like a reversed funnel (see the section in the above-cited ‘Jahrbuch,’ 1885, pl. i.).

Now our Middle and Upper Miocene basalts are in every way similar to many lavas of recent volcanoes, not only in petrological composition, but also in their geological conditions, for in several basalt cones in Hesse and in the Rhön, observed by Professor Streng and myself, the crater-form has escaped erosion by weathering, and these craters are associated with scoriæ or slags, tuffs, and lapilli.

It appears to me, therefore, not unlikely that the cause of eruption of recent lavas may also be similar, and that it may be the same as that of structural earthquakes; whereas the outburst of gas, vapours, dust, ashes, &c., may partly result from water, passing downwards through fissures and being overheated and vaporized. This may account for the statement of many authors that those violent detonations &c. of volcanoes are quite independent of the rather quiet outflowing of incandescent lava.

I would submit these observations to English geologists, as they are specially interested in volcanic energy and in all that is connected with volcanoes, and as we are indebted to them for a great deal of what we know about vulcanicity.

2. “On the Origin of the Basins of the Great Lakes of America.” By Prof. J. W. Spencer, M.A., Ph.D., F.G.S., State Geologist of Georgia.

3. “On Ornithosaurian Remains from the Oxford Clay of Northampton.” By R. Lydekker, Esq., B.A., F.G.S.

4. “Notes on a ‘Wash-out’ found in the Pleasley and Teversall Collieries, Derbyshire and Nottinghamshire.” By J. C. B. Hendy, Esq. (Communicated by Dr. W. T. Blanford, F.R.S., F.G.S.)

The following specimens were exhibited:—

Specimens of remains of *Rhamphorhynchus Jessoni*, Lyd., from the Oxford Clay of Northampton, exhibited by R. Lydekker, Esq., F.G.S., in illustration of his paper.

[* See also Quart. Journ. Geol. Soc. vol. xi. pp. 129 & 134, figs. 1 & 2.—Ed.]

April 30, 1890.

Dr. A. GEIKIE, F.R.S., President, in the Chair.

Edward Byron Lindon, Esq., Assoc.R.S.M., Brisbane, Queensland; and Edwin Melville Richards, Esq., Assoc.Memb.Inst.C.E., The Butts, Warwick, were elected Fellows of the Society.

The List of Donations to the Library was read.

The following name of a Fellow of the Society was read out for the first time, in conformity with the Bye-laws, Section VI. Article 5, in consequence of the non-payment of arrears of contributions—
J. W. BARRY, Esq.

The following communications were read:—

1. "On certain Physical Peculiarities exhibited by the so-called 'Raised Beaches' of Hope's Nose and the Thatcher Rock, Devon." By D. Pidgeon, Esq., F.G.S.

2. "The Devonian Rocks of South Devon." By W. A. E. Ussher, Esq., F.G.S., of H.M. Geological Survey.

The following specimens were exhibited:—

Specimens from the raised Beaches of Hope's Nose and the Thatcher Rock, Devon, exhibited by D. Pidgeon, Esq., F.G.S., in illustration of his paper.

Pebbles from the Raised Beach at Berry Head, exhibited by A. R. Hunt, Esq., F.G.S.

Specimens exhibited by W. A. E. Ussher, Esq., F.G.S., in illustration of his paper.

Specimens of *Entomis*-shale (Cypridinen-Schiefer) from Thuringia and the Eifel, exhibited by Prof. T. Rupert Jones, F.R.S., F.G.S.

May 14, 1890.

Dr. A. GEIKIE, F.R.S., President, in the Chair.

George William Lamplugh, Esq., Wellington Road, Bridlington Quay; and Arthur Timmins, Esq., Assoc.M.Inst.C.E., Argyll Lodge, Runcorn, were elected Fellows of the Society.

Percy H. Browne, Esq., Reigate; T. R. Maddison, Esq., Dirtcar House, near Wakefield; William Rogers, Esq., The Grange, Coppull, Lancashire; H. Rofe, Esq., Mem.Inst.C.E., 8 Victoria Street, Westminster; Major-General Alexander de Courcy Scott, late R.E., Assoc.M.Inst.C.E., 86 Cornwall Gardens, S.W., and Thomas Sullock

Stooke, Esq., Assoc.M.Inst.C.E., 31 St. John's Hill, Shrewsbury, were proposed as Fellows; Prof. H. Rosenbusch, Heidelberg, as a Foreign Member, and Dr. Felix Karrer, Vienna, as a Foreign Correspondent of the Society.

The List of Donations to the Library was read.

The following name of a Fellow of the Society was read out for the second time, in conformity with the Bye-laws, Section VI. Article 5, in consequence of the non-payment of arrears of contributions—
J. W. BARRY, Esq.

The following communications were read:—

1. "The so-called Upper-Lias Clay of Down Cliffs." By S. S. Buckman, Esq., F.G.S.

2. "On some new Mammals from the Red and Norwich Craggs." By E. T. Newton, Esq., F.G.S.

3. "On Burrows and Tracks of Invertebrate Animals in Palæozoic Rocks, and other Markings." By Sir J. William Dawson, LL.D., F.R.S., F.G.S.

4. "Contact-Alteration at New Galloway." By Miss M. I. Gardiner. Communicated by J. J. H. Teall, Esq., M.A., F.G.S.

The following specimens were exhibited:—

Specimens of *Dumortieria radians* (Reinecke), exhibited by S. S. Buckman, Esq., F.G.S., in illustration of his paper.

Specimens exhibited by E. T. Newton, Esq., F.G.S., in illustration of his paper.

A series of photographs exhibited by Sir J. W. Dawson, K.C.M.G., LL.D., F.R.S., F.G.S., in illustration of his paper.

Specimens of *Rusichnites*, *Arthropycus*, and other tracks and markings from the Ordovician and Silurian strata of Canada, referred to in the paper by Sir J. W. Dawson, K.C.M.G., exhibited by Dr. G. J. Hinde, F.G.S.

Rock-specimens and microscopic sections exhibited by J. J. H. Teall, Esq., M.A., F.G.S., on behalf of Miss M. I. Gardiner, in illustration of her paper.

May 21, 1890.

Dr. A. GEIKIE, F.R.S., President, in the Chair.

George Fletcher, Esq., 53 Sale Street, Derby ; and Thomas Ward, Esq., J.P., Brookfield House, Northwich, were elected Fellows of the Society.

The List of Donations to the Library was read.

The names of certain Fellows were read out for the first time, in conformity with the Bye-laws, Section VI. Article 5, in consequence of the non-payment of arrears of contributions.

The following communications were read:—

1. "On some Devonian and Silurian Ostracoda from North America, France, and the Bosphorus." By Prof. T. Rupert Jones, F.R.S., F.G.S.

2. "On the Age, Composition, and Structure of the Plateau-gravels of East Berkshire and West Surrey." By the Rev. A. Irving, B.A., D.Sc., F.G.S.

3. "Further Note on the Existence of Triassic Rocks in the English Channel off the Coast of Cornwall." By R. N. Worth, Esq., F.G.S.

[Abstract.]

Specimens of a Triassic breccio-conglomerate, trawled seven miles south of the Deadman Headland, and several miles east of the previously recorded* Lizard outlier, are described. These fragments were brought up in a small trawl used for dredging Pectens, and are considered to have formed part of a jagged submarine reef. They are thin slabs, both faces of which were clearly free, as they are covered with marine growths, animal and vegetable; and *in situ* they must have had an approximately horizontal projection, on account of the different extent and character of these growths. The rock contains angular and subangular materials, with small pebbles in the finer portions. Its constituents are—slate (apparently Devonian), fine grits, vein-quartz, quartz-felsites (some micaceous), and andesitic rock, like the "felspathic traps" found as far west as Cawsand; also rhyolitic rock and kaolinized felspathic matter.

4. "On a new species of *Coccodus* (*C. Lindstrœmi*, Davis)." By J. W. Davis, Esq., F.G.S., F.L.S.

* Quart. Journ. Geol. Soc. vol. xlii. 1886, p. 313.

The following specimens were exhibited:—

Specimens of Devonian and Silurian Ostracoda, exhibited by Prof. T. Rupert Jones, F.R.S., F.G.S., in illustration of his paper.

Specimens and photographs exhibited by the Rev. Dr. A. Irving, F.G.S., in illustration of his paper.

Specimens of Triassic Rocks from the English Channel, exhibited by R. N. Worth, Esq., F.G.S., in illustration of his paper,

June 4, 1890.

Dr. A. GEIKIE, F.R.S., President, in the Chair.

Percy H. Browne, Esq., Reigate; T. R. Maddison, Esq., Dirtcar House, near Wakefield; William Rogers, Esq., The Grange, Coppull, Lancashire; H. Rofe, Esq., Mem.Inst.C.E., 8 Victoria Street, Westminster; Major-General Alexander de Courcy Scott, late R.E., Assoc.M.Inst.C.E., 86 Cornwall Gardens, S.W., and Thomas Sullock Stooke, Esq., Assoc.M.Inst.C.E., 31 St. John's Hill, Shrewsbury, were elected Fellows; Prof. H. Rosenbusch, Heidelberg, a Foreign Member, and Dr. Felix Karrer, Vienna, a Foreign Correspondent of the Society.

The List of Donations to the Library was read.

The following names of Fellows of the Society were read out for the second time, in conformity with the Bye-laws, Section VI. Article 5, in consequence of the non-payment of their arrears of contributions:—E. EASTON, Esq.; J. R. EDDY, Esq.; R. GASCOYNE, Esq.; Dr. J. M. GRANVILLE; Dr. H. B. GUPPY; R. HENDERSON, Esq.; H. JOHNSON, Esq.; E. JORDON, Esq.; H. LEONARD, Esq.; Captain E. ST. F. MOORE; D. RUDDLE, Esq.; Rev. W. WILLIAMS; and Dr. J. YOUNG.

The PRESIDENT referred to the sad loss which the Society had sustained through the death of Mr. Dallas, and read the following resolution, which had been passed by the Council and ordered to be entered upon its Minutes:—

“The Council desires to record on its Minutes an expression of its deep regret at the death of the Assistant-Secretary, Mr. Dallas, which took place on the 29th ultimo, and of its sense of the loss inflicted on the Council and Society by the removal of one who, for the long period of twenty-two years, had done them invaluable service, and who, by his courtesy, kindness, and helpfulness, had endeared himself as a personal friend to the Fellows.”

It was moved by Dr. EVANS, seconded by Dr. HINDE, and carried unanimously, that the resolution passed by the Council be communicated to Mrs. Dallas on behalf of the Society.

The following communications were read :—

1. "As to certain 'Changes of Level' along the Shores on the Western side of Italy." By R. Mackley Browne, Esq., F.G.S.

[Abstract.]

After noticing the prevailing opinion that such changes as he treats of were caused by earth-movements of elevation and depression, the Author suggests that the altered levels were due to altered conditions of the Mediterranean. He brings forward objections to the prevailing theory :—such as, that there is an improbability of the upraising force being equally applied ; and that general earth-movements of upheaval and depression would necessarily involve altered level and distribution of ocean-waters. He also remarks on the possibility of periodical oscillating alterations in the tidal depth of the ocean.

After noticing the special characteristics of the Mediterranean :—such as, (1) non-participation in the Atlantic tides ; (2) its surface-level not being that of Atlantic high-water ; (3) terrestrial gravitation chiefly regulating the condition of its waters ; (4) its inflowing and outflowing currents,—he infers that submergence and emergence on the Bay of Baiae would follow equivalent alteration in the level of the Atlantic waters, such as would be probably developed by changed combinations of astronomical forces, similar to, but greater than the actual "changes of level" manifested in the ordinary tidal phenomena. After discussing the possible dates and periods of the changes at Pozzuoli, he makes the suggestion that within a period of two thousand years alterations may have taken place in the astronomical combinations, out of which a change in the surface-level of the oceans generally may have become developed, and wherefrom consequently a synchronous change in the Mediterranean would also occur ; and he observes that the amount of actual tidal effects has never been ascertained.

DISCUSSION.

The PRESIDENT had not gathered that the paper was the result of any personal investigation of the coast, and felt that the Author must expect opposition to his views.

Dr. EVANS thought that a small amount of travel would solve the question more effectually than any amount of speculation. The Temple of Serapis was built in immediate proximity to a volcanic centre that had been active in modern times, and he himself saw no difficulty in supposing small earth-movements to have occurred without any very violent disturbance. If the Mediterranean had

been moved in bulk, traces of this should be found all round the coast, and there ought to be historic records of the event, though the reverse was actually the case. The facts that the Temple had been depressed some 20 feet, had stood in this position some time, and had again been raised, were established, and these were against the theory brought forward.

Prof. JUDD felt certain that, had the Author visited the district, he would have found so many facts opposed to his theory that he would never have advanced it. Monte Epomeo gave evidence of elevation to an extent of nearly 1800 feet in the most recent geological times.

The PRESIDENT had recently spent some time on the borders of the Mediterranean, and was often struck with the proof of great stability of level, as shown by the position of Roman towns with a strip of alluvial flat between them and the sea, but yielding no evidence of submergence within the historic period. Had such a general rise of the water-level taken place as the Author demanded, there would surely have been abundant local evidence, as well as historic proof, of it along the low coasts of the Mediterranean.

The AUTHOR had visited the neighbourhood, and he believed unquestionable evidence of changes of level would be found all round those coasts, as they were all the world over. His argument as to the mean surface-level of the Mediterranean being dependent upon that of the part of the Atlantic which lies to the westward of the Gibraltar Straits, and as to probable alteration in the state of the Atlantic from astronomical causes, had not been met nor even referred to in the remarks which had been made upon his paper.

2. "North-Italian Bryozoa." By A. W. Waters, Esq., F.G.S.

[Abstract.]

The Chilostomatous Bryozoa dealt with in the paper are, for the most part, from known Vicentine localities, together with some from two new localities on the Monte Baldo, in the Veronese and Tyrol. Reuss described a number from the Vicentine, but at a time when the chief attention was given to the shape of the zoarium, and the oral aperture, avicularia, and ovicells did not receive the attention now given to them. The attempt is therefore made to bring our knowledge of these beds, which are the richest and most important known in the Lower Tertiaries, more nearly up to present ideas, so that more exact comparisons may be made between Tertiary and living forms.

Several cases are mentioned in which there is great difference of zoarial shape, and also some in which there is great range in the zoöcial characters.

The discovery of *Catenicella* in these beds is of considerable importance, which is enhanced by one of the species having both short beads and longer internodes.

Porina coronata and *Lepralia syringopora* both have a closure, formed by a plate with a tubule in the centre, a structure supposed to be exclusively characteristic of the Cyclostomata.

The position of the beds has been established by Suess, Bayan, Hébert, and Munier-Chalmas as of Bartonian age, and may therefore be called Upper Eocene.

3. "Notes on the Discovery, Mode of Occurrence, and Distribution of the Nickel-Iron Alloy 'Awaruite' and the Rocks of the District on the West Coast of the South Island of New Zealand in which it is found." By Professor G. H. F. Ulrich, F.G.S.

The following specimens were exhibited :—

Specimens exhibited by A. W. Waters, Esq., F.G.S., in illustration of his paper.

Specimens exhibited by Prof. J. W. Judd, F.R.S., F.G.S., for Prof. G. H. F. Ulrich, F.G.S., in illustration of his paper.

June 18, 1890.

Dr. A. GEIKIE, F.R.S., President, in the Chair.

Thomas David Williams, Esq., West Kirby, Cheshire, was elected a Fellow of the Society.

The List of Donations to the Library was read.

The following communications were read :—

1. "The Borrowdale Plumbago, its Mode of Occurrence and probable Origin." By J. Postlethwaite, Esq., F.G.S.

[Abstract.]

After giving details of the mode of occurrence of the plumbago (graphite) of Borrowdale in veins traversing diabase and diorite, which break through the Volcanic Series of Borrowdale, and in "sops" or pipes, of various sizes, at a little distance from the veins, the Author refers to the modes of occurrence of graphite in other regions, and contrasts these with the surroundings of the graphite in the Lake District. He points out that many thousand feet of volcanic rock supervened between the Borrowdale plumbago-bearing

rocks and the overlying carbonaceous shales of Silurian age. On the other hand, he finds similarities between the containing rocks in Borrowdale and the diamond-bearing rocks of South Africa, and considers that the conditions under which the graphite was formed in the Lake District approached much more closely to those which gave rise to the Kimberley diamonds than to those which originated the graphitic deposits in North America, though there is great dissimilarity in the chemical composition of the intrusive rocks in the two cases, especially with regard to the quantity of magnesia present. He suggests that the molten magma in its upward course passed through a deep-seated stratum of highly carbonaceous material, and tore off numerous fragments, the bituminous matter in which became acted upon by heat, a further alteration being subsequently caused by the intrusion of the diorite.

DISCUSSION.

Prof. SEELEY was not aware of any satisfactory description of the Kimberley diamond-mines, which contained rocks of an essentially brecciated deposit, and therefore, as he considered, very different from the rocks of which the Author had given a description.

The PRESIDENT believed there were two possible sources of supply for diamonds and graphite, viz. derivation direct or indirect from organic matter, and (as, *e. g.*, in the Archæan rocks and meteorites) as an original mineral.

2. "Notes on the Valley-Gravels about Reading, with especial reference to the Palæolithic Implements found therein." By O. A. Shrubsole, Esq., F.G.S.

The following specimens were exhibited:—

Specimens exhibited by J. Postlethwaite, Esq., F.G.S., in illustration of his paper.

Palæolithic Implements and Mammalian remains, exhibited by O. A. Shrubsole, Esq., F.G.S., in illustration of his paper.

ADDITIONS

TO THE

LIBRARY AND MUSEUM OF THE GEOLOGICAL SOCIETY.

SESSION 1889-90.

I. ADDITIONS TO THE LIBRARY.

1. PERIODICALS AND PUBLICATIONS OF LEARNED SOCIETIES.

Presented by the respective Societies and Editors, if not otherwise stated.

Acireale. Società Italiana dei Microscopisti. Bolletino. Vol. i. Fasc. 1-3. 1889 & 1890.

H. J. Johnston-Lavis. Su una roccia contenente leucite, trovata sull' Etna, 26.—O. Silvestri. Sopra due nuovi generi di Rizopodi (Foraminifere) appartenenti al Pleocene Inferiore d'Italia, 51.

Adelaide. Royal Society of South Australia. Transactions and Proceedings and Report for 1887-88. Vol. xi. 1889.

E. H. Rennie. On some so-called South-Australian Rubies, 17.—J. G. O. Tepper. Notes on the Surface Features and Rocks of Nuriootpa and its neighbourhood, 25.—J. Dennant. Notes on the Muddy Creek Beds, with brief Remarks on other Tertiary Strata of South-Western Victoria, 30.—R. Tate. The Gastropods of the Older Tertiary of Australia, 116.—W. Howchin. On the Occurrence of Coal Detritus in the Valley of the Murray, 215.

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II. ADDITIONS TO THE MUSEUM.

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