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COMPARISON OF THE CARBONIFEROUS AND PERMIAN FORMATIONS OF NEBRASKA AND KANSAS.

INTRODUCTION.

After having devoted three summers to the study of the Upper Carboniferous and Permian formations of Kansas, the writer recently reviewed quite rapidly the similar formations of southeastern Nebraska, and in this paper will give an outline of their general correlation.

No particular formation was traced from Kansas into or across Nebraska, nor were the stratigraphic details worked out carefully in Nebraska; still the work done, limited as it was in character, showed the geologic age and general relation of the rocks of Kansas to those of Nebraska, and as various opinions are entertained regarding these relations it seems important to give a brief description of this work.

NEMAHA COUNTY.

Wabaunsee formation.—It is desirable to select the three counties—Nemaha, Otoe, and Cass—in which the greater part of the field work was done, for the general subdivisions of this paper and then under each county to describe its geologic formations, beginning with the oldest.

The exposures in the eastern part of Nemaha county along the Missouri River were very fully described by Meek,[1] sections

[1] Final Rep. U. S. Geol. Sur. Nebraska and adjacent Territories, Pt. II, Paleontology, pp. 109–114.

were given, together with lists of fossils from the vicinity of the towns, Peru, Brownville, and Aspinwall,[1] and the following species were reported by him from these localities:

1. *Neuropteris hirsuta* Lesqx.
2. *Neuropteris Loschii* Brgt.
3. *Fusulina cylindrica* Fischer.
4. *Productus nebrascensis* Owen.
5. *Productus semireticulatus* (Martin) de Kon.
6. *Derbya crassa* (M. & H.) Hall & Clarke.
7. *Meekella striato-costata* (Cox) White & St. John.
8. *Spirifer cameratus* Morton.
9. *Spirifer* (*Martinia*) *plano-convexus* Shum.
10. *Spiriferina kentuckensis* Shum.
11. *Athyris* (*Seminula*) *subtilita* (Hall) Newb.
12. *Nuculana bellistriata* (Stevens) Meek.
13. *Myalina perattenuata* M. & W.
14. *Aviculopecten Whitei* Meek.
15. *Edmondia aspinwallensis* Meek.
16. *Allorisma subcuneatum* M. & H.
17. *Bellerophon percarinatus* Con.
18. *Straparollus* (*Euomphalus*) *catilloides* (Con.) Keyes = *Euomphalus rugosus* Hall.
19. *Nautilus occidentalis* Swallow.
20. *Deltodus* (?) *angularis* N. & W.
21. *Productus longispinus* Sowb. = Nor. & Pratt.
22. *Chonetes granulifera* Owen.
23. *Bellerophon carbonarius* Cox.
24. *Bellerophon Montfortianus* Nor. & Pratt.
25. *Productus pertenuis* Meek.
26. *Productus cora* d'Orbigny.
27. *Myalina subquadrata* Shum.
28. *Aviculopecten occidentalis* (Shum) M. & W.

The fossils of the above list are nearly all well-known Carboniferous species as was stated by Meek.[2]

Marcou referred the rocks along the Missouri River in this county to the Dyas[3] (= Permian) but this view was thoroughly

[1] Fin. Rep. U. S. Geol. Sur. Nebraska, etc., pp. 109, 110, 112, and the "Tabular list, illustrating the geological and geographical range of the fossils of eastern Nebraska," pp. 124–127.

[2] *Ibid.*, p. 114.

[3] Bull. Soc. Géol. France, 2e série, t. XXI, 1864, p. 134.

disproved by Meek, who criticised Professor Marcou's correlation in the following words: "but upon what evidence he [Professor Marcou] does not say, nor is it apparent to anyone who regards fossils as any guide in identifying rocks, as those found here consist of the same forms constituting the group so often mentioned as characterizing the Coal Measures of the Western States."[1]

Meek regarded the exposures along the Missouri River in Nemaha county as geologically above the Nebraska City beds, for he said: "At Nebraska City, and below there, at Otoe City, Brownville, and Aspinwall, there are, perhaps, altogether, near 150 to 200 feet of additional strata, all holding probably a position above the geological horizon of the top of the boring at Nebraska City."[2] On the contrary, Dr. Hayden regarded the Aspinwall section as somewhat older than that at Nebraska City, for he said: "The rocks at Aspinwall are all geologically at a little lower horizon than the Nebraska City beds, and mostly beneath the Brownville beds."[3] In the Aspinwall section Meek reported a stratum of coal one foot ten inches in thickness, eighteen feet above low water of the Missouri River and another six-inch stratum eleven and one-half feet higher. No opportunity was afforded me to study this section, hence I am unable to state whether the coal lies at the base of the Wabaunsee formation or not; but all the rocks of this county exhibited along the bluffs of the Missouri River belong to that geologic series usually termed the Upper Coal Measures, for which Dr. Keyes has proposed the very appropriate name of Missourian.[4]

[1] Fin. Rep. U. S. Geol. Sur. Nebraska, etc., p. 114.

[2] *Ibid.*, p. 137; also see p. 123, where a similar statement occurs.

[3] *Ibid.*, p. 17.

[4] Am. Geol., Vol. XVIII, July 1896, p. 25; also see Iowa Geol. Surv., Vol. I, 1893, p. 85. The writer would suggest the following classification for the Upper Coal Measures of the Western Interior province:

Missourian series (Keyes), - - -	Cottonwood formation (Prosser) Wabaunsee " " ——— ———

The formations below the Wabaunsee have been recently studied by Drs. Keyes and Haworth, to whom the writer leaves the selection of names for the lower part of the series.

With the exception of the region adjacent to the Missouri River, the geology of Nemaha county was not described by Meek or Hayden.

About twelve miles northwest of Aspinwall and some 235 feet above Nemaha City, which is near the level of the Missouri River, and near the center of Nemaha county, is Auburn, the county seat. To a large extent, the rocks of this region are concealed by the thick deposit of loess, but there are occasional exposures along the streams or at favorable places on the bluffs or hills. In the vicinity of Auburn are a few outcrops of rocks which are referred to the upper part of the Wabaunsee formation. Along the highway, one and one-fourth miles directly west of Auburn, the rocks show for a short distance. The top of the outcrop is some thirty-five feet higher than the Auburn hotel, or approximately 270 feet above the Missouri River, and is just west of the Sheridan cemetery on the east side of the South Fork of the Nemaha River. The following beds occur in descending order:

	Feet
5. Rough yellowish limestone	1 = 65
4. Soft light gray to yellowish shales	2 = 64
3. Drab hard limestone that weathers to a light gray color. A few fossils—*Aviculopecten occidentalis* (Shum.) M. & W. and fragments of other species	2 = 62
2. Light gray and greenish shales, the lowest very white 1. Covered to the level of South Fork of the Nemaha River	60 = 60

These rocks are considered to belong in the upper part of the Wabaunsee formation; for on the upland two and one-half miles farther west and perhaps fifty feet higher is a ledge of light gray limestone composed to a considerable extent of specimens of *Fusulina cylindrica* Fischer which the author regards as the Cottonwood limestone of Kansas. There are a number of outcrops and quarries of this limestone on the upland in the western central part of Nemaha county, as well as a few exposures of the underlying rocks, but as they are only a few miles northwest of this eastern outcrop of the Cottonwood limestone they may be described in connection with it.

Cottonwood formation.—The most eastern outcrop of the Cottonwood limestone seen in Nemaha county is the one which is known as the Van Court or Keyes quarry and is three and three-fourth miles directly west of Auburn. Unfortunately my barometer at the time of my visit was not reading accurately; but its altitude is estimated as some 345 feet above the Missouri River. The Cottonwood limestone forms a massive light gray stratum four feet thick, moderately hard and filled with large numbers of *Fusulina*. When freshly broken the *Fusulinas* though slightly darker in color than the limestone are less prominent than on the weathered surface and are only conspicuous when seen through a magnifying glass. On the weathered surface of the rock the shells resist decay longer than the limestone and stand out prominently. One who has visited the large quarries of Cottonwood limestone in northern and central Kansas would be immediately impressed with this very striking similarity. Few, if any, fossils other than *Fusulina cylindrica* Fischer occur in this limestone; only an occasional fragment of a spine of *Archæocidaris* or a bit of shell was noticed. The section at the Keyes quarry is as follows:

	Ft. In.	Ft. In.
3. Shaly limestone containing *Athyris* (*Seminula*) *subtilita* (Hall) Newb. and a few other fossils - - - - - - -	1	=6 9
2. Light gray shales to shaly limestone - - - - -	1 9	=5 9
1. *Cottonwood limestone*, light gray massive *Fusulina* limestone	4	=4

The *Nemaha county quarry* which is the most extensively worked is the next well-exposed section of the Cottonwood limestone and is one and one-fourth miles west of the Keyes quarry. It is located by the side of the Burlington and Missouri River Railroad, five miles due west of Auburn and one mile north of Hickory Grove. The average of three barometric readings makes the bottom of the quarry 130 feet higher than Auburn or approximately 365 feet above the Missouri River. This is twenty feet higher than the base of the Keyes quarry which gives a dip directly east of twenty feet in one and one-fourth miles or at the rate of sixteen feet per mile. The following section of the Nemaha county quarry gives a clear idea of the character of the Cottonwood limestone and associated rocks as they appear in Nebraska.

SECTION OF THE NEMAHA COUNTY QUARRY.

	Ft.	In.		Ft.	In.
5. Soil	3		=	12	10
4. Somewhat shaly light gray limestone used for riprap. Fossils common, especially *Athyris* (*Seminula*) *subtilita* (Hall) Newb.	2	10	=	9	10
3. Light gray shaly limestone changing to shales on weathered surface, used for railroad ballast. From 1 foot 1 inch to 1 foot 9 inches in thickness. Fossils not so common as in upper limestone	1	9	=		7
2. *Cottonwood limestone*, of light gray color, containing immense numbers of *Fusulina cylindrica* Fischer. In two layers, the upper 2 feet and the lower 1 foot thick,	3		=	5	3
1. Light gray to slightly yellowish limestone, which contains some almost white streaks and in places is bluish in color. Very few specimens of *Fusulina*. Bottom of the quarry	2	3	=	2	3

As stated above, No. 2 of the section contains immense numbers of *Fusulina cylindrica* Fischer with an occasional broken spine of *Archæocidaris* sp.; while in No. 1 there are very few specimens of *Fusulina*. This character agrees with the Cottonwood limestone at its typical localities in Kansas where the *Fusulinas* are only found abundantly in the upper part of the limestone. On this account it seems advisable to the writer to regard both Nos. 1 and 2 as representing the Cottonwood limestone of Kansas which will give it a thickness of five feet three inches in the Nemaha county quarry. The shaly limestones and shales above the Cottonwood limestone — Nos. 3 and and 4 of the section — contain a moderate number of fossils although none of the species are abundant. The following were collected:

Athyris (*Seminula*) *subtilita* (Hall) Newb.=*A. argentea* (Shep.) Keyes (c).[1]

Productus semireticulatus (Mart.) de Kon. (c).

[1] The relative abundance of the species is indicated in the following manner:

Derbya crassa (M. & H.) H. & C. (rr).
Pinna peracuta Shum. (?) only a fragment (rr).
Allorisma sp. fragment of an impression (rr).
Archæocidaris sp. fragment of spines (r).

Above the Cottonwood limestone in northern and central Kansas are about fourteen feet of yellowish, calcareous shales, the lower seven feet of which contain abundant fossils. In Nebraska no similar shales have been found above the Cottonwood shales. Perhaps the shaly limestones and shales — Nos. 3 and 4 of the above section — represent the Cottonwood shales, although the fossils are not nearly as abundant. If this supposition be correct, then they belong in the Cottonwood formation. Again it is possible that the Cottonwood shales are represented by the thin shale or shaly limestone, No. 3, which is between one and two feet in thickness; while No. 4 represents the shaly limestones at the base of the Neosho formation in Kansas.[1]

The *Gilbert quarry* region is six miles west and two and one-fourth miles north of Auburn or about two and one-half miles northwest of the Nemaha county quarry. Near the head of a small stream and by the highway are several quarries. One on the east side of the highway, just south of the Gilbert quarry, gives the following section:

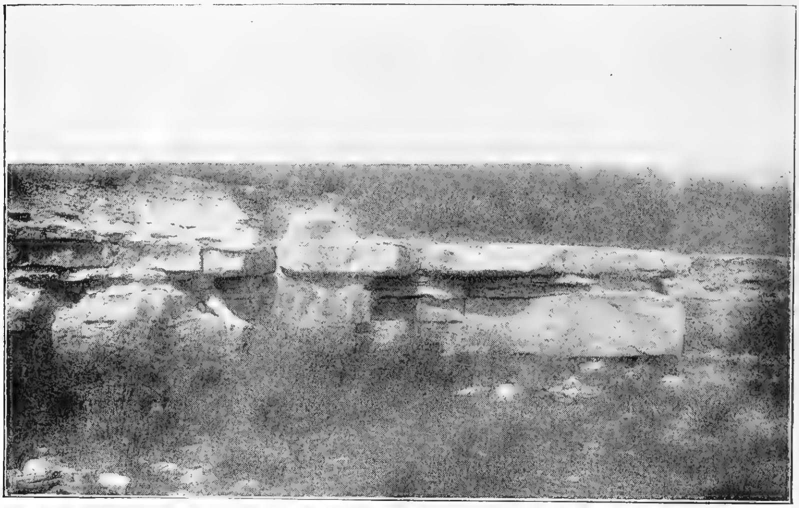
	Feet		Feet
5. Coarse grayish shales to rather shaly gray limestone at the base	3	=	10¾
4. Massive gray limestone, fragments of fossils numerous (2 feet in Gilbert quarry)	1½	=	7¾
3. Rather coarse, grayish shales (shaly limestone in Gilbert quarry)	1¼	=	6¼
2. *Cottonwood* limestone, massive *Fusulina* limestone with small amount of flint and an occasional *crinoid* segment, and fragment of *Athyris*	3½	=	5
1. Grayish to slightly buff limestone without *Fusulinas*. Bottom of quarry	1½	=	1½

a = abundant; aa = very abundant; c = common; r = rare; rr = very rare, when but one or two specimens are found.

[1] See JOURNAL OF GEOLOGY, Vol. III, 1895, p. 766.

The Cottonwood limestone and the succeeding Nos. 3, 4 and 5 of this quarry are fairly well shown in Fig. 1.

The *Fusulina* limestone is filled with specimens of *Fusulina cylindrica* Fischer all the way through the massive stratum;



1. View of Cottonwood limestone just south of the Gilbert quarry, northwest of Auburn. The Cottonwood limestone is the heavy layer at the bottom. Then in ascending order are shown Nos. 2, 3 and 4 of the section.

but as in the Nemaha county quarry both Nos. 1 and 2 are regarded as representing the Cottonwood limestone of Kansas. The base of this quarry is forty feet higher than that of the Nemaha county quarry or approximately 405 feet above the Missouri River. Since it is two and one-half miles northwest of the Nemaha county quarry it gives between the two a dip of sixteen feet per mile to the southeast.

In a small run a quarter of a mile north of the Gilbert quarry and some seventy feet lower, the outcrop shows a ledge of light gray to buff rather hard limestone with shaly layers above and below. Fossils are few. *Aviculopecten occidentalis* (Shum.) M. & W. and *Cythere nebrascensis* Geinitz (?) occur in the shaly layers and in some of them are large numbers of this minute Crustacean or a closely related species.

The *Carlisle quarry* is located on the northern edge of the rather steep bluff some distance south of the Nemaha River. It is nearly one mile north of the Gilbert quarry, and six miles west and 3 + miles north of Auburn. This is at the northern edge of the upland south of the Nemaha River and the farthest north that the Cottonwood limestone was found. In this quarry the base of the Cottonwood stone is about twenty feet higher than in the Gilbert quarry. The section of the G. W. Carlisle quarry is as follows:

	Feet	Feet
4. Shaly limestone	1½	= 7¼
3. Massive limestone	2	= 5¾
2. Shale	1¼	= 3¾
1. *Cottonwood* limestone. Bottom of quarry	2½	= 2½

Below the Cottonwood stone on the slope of the hill are thin ledges of smooth limestone alternating with shales. There is one stratum of limestone which on a weathered surface is rough and cellular something like the "dry bone" limestone in Kansas. There are also some reddish shales and the rocks, which for sixty feet below the Cottonwood limestone are partly exposed, resemble to some extent the upper rocks of the Wabaunsee formation in Kansas. These rocks are somewhat fossiliferous and in a bluish-gray shaly limestone from twenty to thirty feet below the Cottonwood limestone the following species were collected:

Aviculopecten occidentalis (Shum.) M. & W. (r).

Pleurophorus subcostatus M. & W. (?) Two rather large specimens which resemble the figures of this species quite closely (rr).

Allorisma (*Sedgwickia*) cf. *topekaensis* (Shum.) (Meek) (rr).

Edmondia sp. (rr).

Bellerophon sp. (rr).

In the region west of Auburn the highest rock found in place is the Cottonwood limestone with the shaly limestones immediately on top. The country to the west of the Nemaha county quarry rises from 100 to 125 feet higher, but a somewhat hasty search failed to reveal any ledges of rock in place, all being quite deeply covered by drift and loess. On this high country seven and one-fourth miles west and one mile north of Auburn is a Burlington and Missouri River R. R. cut of ten feet which only shows the recent deposits, so that it would appear to be a difficult undertaking to find the bed rock on the uplands. This difficulty was experienced by Dr. Hayden who stated that: "From Tecumseh [the county seat of Johnson county, twenty-two miles west of Auburn] to the source of the Nemaha, about forty-five miles, I did not discover a single exposure of rock, and I could not ascertain that any had ever been observed by the settlers."[1]

From the facts stated above it seems reasonably certain that the massive limestone west of Auburn may be correlated with the Cottonwood limestone of Kansas. Lack of time prevented the actual tracing of this limestone south to the exposures of Cottonwood limestone in northern Kansas, yet its biologic and lithologic characters are so similar to those of the Kansas stone that it appears quite certain they belong to the same formation. In Kansas, the Cottonwood limestone is reported by Professor Knerr in the northeastern part of Marshall county where he states that it "disappears under the drift about five miles north of Beattie in Marshall county."[2] This locality is about fifty miles southwest of the Nemaha county quarry of Cottonwood limestone in Nebraska.

JOHNSON AND GAGE COUNTIES.

Wabaunsee formation.—Johnson county lies directly west of Nemaha county to the west of which is Gage county which extends south to the state line and is crossed by the Big Blue River. At Tecumseh in Johnson county about fifteen miles west of the Nemaha county quarry and from 100 to 200 feet lower, as far as I can judge from the data at hand, Dr. Hayden reported a

[1] Fin. Rep. U. S. Geol. Sur. Nebraska, p. 34.

[2] Univ. Geol. Sur. Kansas, Vol. I, 1896, p. 142. Also see "A Geologic Map of Kansas (preliminary)," Pl. XXXI, in the above work on which the line of outcrop of the Cottonwood limestone is represented.

stratum of coal from ten to fifteen inches in thickness.[1] In this connection it is interesting to state that Professor Knerr noted the occurrence of "a shale bearing a four-inch stratum of coal" which is given as from 50 to 100 feet below the Cottonwood limestone.[2] Again, in the vicinity of Tecumseh Dr. Hayden stated that "in a bed of limestone, holding a high position in the hills, the following fossils were found: *Spirifer cameratus*, *Athyris subtilita*, *Syntrilasma hemiplicata* [*Entelctes hemiplicatus*], *Productus semireticulatus*."[3] In Kansas, where the writer has carefully studied the stratigraphy and palæontology of the Upper Carboniferous and Permian rocks along the Kansas and Cottonwood valleys where they, as far as known, are more clearly exposed than at any other locality in the two states, *Spirifer cameratus* Morton has not been found above the top of the Wabaunsee formation, and from this fact the writer is inclined to refer the limestone mentioned by Dr. Hayden to the Wabaunsee formation.

Permian.—In Gage county, which lies next west of Johnson county, Dr. Hayden reported grayish and yellowish argillaceous limestones which he stated—"are undoubtedly of Permian or Permo-Carboniferous age, though they contain fossils common to both Permian and Carboniferous rocks."[4] He was not confident of the presence of Permian rocks in Nebraska for he said: "It is not certain that the true Permian beds, as recognized in Kansas, extend northward into Nebraska, though thin beds may occur in some of the southern counties."[5] And he further said that the Permian rocks "pass beneath the water level at Beatrice," the county seat of Gage county, and westward are the yellowish and dark brown Cretaceous sandstones, now known as the Dakota sandstone.

In 1886 Professor Hicks published a short paper about the rocks along the Blue River in Gage county which he designated provisionally as Permian and said that they were "distinguished

[1] Fin. Rep. U. S. Geol. Sur. Nebraska, p. 34.

[2] Univ. Geol. Sur. Kansas, p. 142.

[3] Fin. Rep. U. S. Geol. Sur. Nebraska, p. 34.

[4] *Ibid.*, p. 28.

[5] *Ibid.*, p. 28, footnote.

from the underlying Coal Measures by the absence of coal and black shales, and by the prevailing magnesian character of its limestones, by the presence of certain characteristic indurated marls and oölitic limestone, as well as by the new and distinct types of animal life."[1] These rocks are undoubtedly of Permian age and it is probable that the Neosho formation and possibly a part of the Chase occurs in Gage county. This supposition is supported by the statement of Professor Knerr that in Marshall county, Kansas, which adjoins Gage county on the south, there are about 250 feet of Permian above the Cottonwood limestone.[2]

OTOE COUNTY.

HISTORIC REVIEW OF THE GEOLOGY OF THE COUNTY.

To the north of Nemaha and Johnson counties is Otoe county which extends from the Missouri River on the east to Lancaster county on the west. This is an important county in the history of the geology of southeastern Nebraska because the cliffs near Nebraska City have been fully described by several geologists.

Owen in 1852 gave some account of the rocks along this part of the Missouri River, referring them to the Carboniferous. He briefly described the rocks in the bluff near Fort Kearney (the old name for Nebraska City) and reported *Productus costatus*, *P. Flemingii* = *P. cora*, and *Fusulina cylindrica*, which he says "previous to this discovery was only known in Ohio."[3]

Swallow in 1855 mentions strata at Fort Kearney and the mouth of the Little Nemaha which he referred to the "Upper Coal Series" of the Upper Carboniferous.[4]

In 1855 Marcou published a geological map of the United States on which the rocks along the Missouri River from the mouth of the Big Sioux to that of the Kansas River are colored

[1] Am. Naturalist, Vol. XX, p. 882.

[2] Univ. Geol. Sur. Kansas, Vol. I, p. 144.

[3] Rep. Geol. Sur. Wisconsin, Iowa and Minnesota, pp. 133, 134. See sections 34 and 35 M.

[4] 1st. and 2d. Ann. Rep. Geol. Sur. Missouri, p. 79.

as belonging to the "Terrain du nouveau Grès rouge" (Triassic system.)[1]

Marcou republished this map as a frontispiece of his *Geology of North America*, in which occurs the statement that "beds of *New Red Sandstone* . . . . cover and form the majority of the immense prairies bordering the rivers Missouri, Platte, Arkansas, and Red River of Louisiana." [2]

In 1857 Dr. Hayden published a geological map of Nebraska on which the rocks along the Missouri River valley from about fifty miles north of the mouth of the Platte River, south to the Kansas River in Kansas, are colored as belonging to the Carboniferous age.[3] The following year Dr. Hayden published a second edition of the above map on which the Carboniferous area remains about the same. To the west of the Carboniferous, the Permian system, which was not indicated on the earlier map, is mapped. This system is represented as beginning at a point a number of miles northwest of Nebraska City and then extending southward increasing in breadth to the southern part of Kansas. The base of the system is represented as crossing the Republican and Smoky Hill rivers several miles west of Ft. Riley, while its upper boundary crosses the Grand Saline and Smoky Hill rivers a number of miles west of the present city of Salina. In Kansas, small areas of Permian are represented on the high divides to the east of the main Permian area. Immediately west of the Permian or the Carboniferous where the Permian is absent, rocks are represented that are referred to the Lower Cretaceous.[4]

In 1863 Marcou and Capellini studied the Missouri River section along the eastern border of Nebraska and the following January Marcou published quite a full description of the rocks

[1] Carte Géologique des Etats-Unis et des Provinces Anglaises de l' Amerique du Nord. In Bull. Soc. Geol. France, Vol. XII.

[2] Op. cit., Zurich, 1858, p. 11.

[3] Proc. Acad. Nat. Sci., Philadelphia, Vol. IX, opposite p. 109 and on p. 110 the description of the area of the system.

[4] *Ibid.*, Vol. X, p. 139. For a statement of the distribution of the Permian, see p. 144.

in the vicinity of Nebraska City and referred them to the Upper Dyas or Permian.[1]

The following year Meek criticised the correlations of this paper, stating that "all the rocks seen by Mr. Marcou on the Missouri, from St. Joseph to the Cretaceous above Bellevere, belong to one unbroken series of Upper Coal Measures, as was first shown by Professor Swallow; with possibly the exception of some of the highest outcrops near Nebraska City, where there is a downward undulation, that may have left portions of the Permian on the high parts of the country."[2]

In 1866 Geinitz described the fossils collected by Marcou in Nebraska together with some from the Permian of Kansas,[3] and also concluded that the rocks in the vicinity of Nebraska City belonged to the Dyas.[4]

Meek in 1867, reviewing at length Professor Geinitz's work, failed to agree with him in many instances concerning the identity of Nebraska species with those of Europe;[5] he also reaffirmed his previous statement that the Nebraska City rocks with possibly the exception of the highest beds, belonged in the Upper Coal Measures.[6]

[1] Bull. Soc. Géol. France, 2e sér. Jan. 1864, Vol. XXI, pp.134–137. Marcou's conclusion, based on the fossils he collected being expressed as follows: "Les fossiles que j'ai trouvés dans cette section [Nebraska City] m'ont rappelé tout à fait le faune dyasique du Zechstein de la Saxe, et je regarde ces couches de Nebraska-City comme appartenant et représentant en Amérique la partie supérieure du dyas d'Europe," p. 137.

[2] Am. Jour. Sci., 2d ser., Vol. XXXIX., March 1865, p. 165.

[3] M. d. K. Leop.-Carol. Akad. d. Naturl.— Carbonformation und Dyas in Nebraska. Dresden, pp. vii+91. 5 plates.

[4] *Ibid.*, p. 89, where he says: "Die bei Nebraska-City vorkommenden Versteinerungen gehören einer Zone an, welche den untersten bis mittelren Schichten der deutschen Zechsteinformation (oberen Dyas) entspricht."

[5] Am. Jour. Sci., 2d ser., Vol. XLIV, Sept. 1867, pp. 170–188; Nov., pp. 327–340.

[6] Meek's statement was as follows: Those [rocks] by both of them [Marcou and Geinitz] referred to the Upper Dyas at Wyoming and Bennett's Mill and Nebraska City, with *possibly* the exception of divisions C and D [the higher beds] at the latter place, belong to the horizon of the Upper Coal Measures. The only point in regard to which there can be any reasonable doubt is, whether the divisions C and D at Nebraska City belong more properly to the horizon of the rocks Dr. Hayden and I termed Permo-Carboniferous in Kansas, or to the Coal Measures proper." (*Ibid.*, pp. 336–337.)

In 1868 Professor Marcou reaffirmed the Dyassic age of the Nebraska City rocks, stating that: "In Nebraska the Dyassic rocks form the right bank of the Missouri River from Aspinwall to Plattesmouth and Aureopolis, that is to say, all the bluffs of the counties of Nemaha, Otoe, and Cass. . . . . The best section of the Dyas of Nebraska and the most easy to be studied, is that formed by the bluff at the Nebraska City landing, at Otoe City, at Peru, and at Brownville, where the strata are higher in the Dyassic series than at Nebraska City; whilst at Rock Bluff, Plattesmouth, and Aureopolis, on the contrary, we find the lower layers forming the base of the Nebraska Dyas."[1] Following the above is a detailed section of the rocks at the Nebraska City landing accompanied by lists of fossils which were identified by Professor H. B. Geinitz. In 1892 Professor Marcou still regarded the Nebraska City rocks as of Lower Dyassic age.[2]

In the summer of 1867 Meek and Hayden spent about two months in carefully studying the rocks along the Missouri River from Omaha to Kansas. In 1872 an excellent work based upon this study was published in which Hayden discussed the general geology of southeastern Nebraska, and Meek gave a detailed account of the stratigraphy of the Missouri River region accompanied by a very careful description of the fossils.[3] This work has become a classic in palæontology for the Upper Carboniferous of the Mississippi Valley. The conclusion in reference to the age of these Missouri River beds agrees with the former opinion of Meek and is clearly expressed in the following sentences: "From all of the facts, therefore, now determined, it must, I think, be clearly evident that all of these strata under consideration along the Missouri, that have been by some referred in part to the Mountain limestone, in part to the Permian or Dyas, and in part to the Coal Measures, really belong entirely to the true Coal Measures; unless the division C, at

[1] Trans. Acad. Sci., St. Louis, Vol. II, p. 562.

[2] Am. Geol., Vol. X, pp. 369, 373.

[3] Final Rep. U. S. Geo. Sur. Nebraska and portions of the adjacent Territories, pp 245, 11 plates.

Nebraska City, and some apparently higher beds below there on the Missouri, may possibly belong to the horizon of an intermediate series between the Permian and Carboniferous, for which, in Kansas, Dr. Hayden and the writer proposed the name Permo-Carboniferous. . . . . It is true that in first announcing the existence of Permian rocks in Kansas, we also, upon the evidence of a few fossils from near Otoe and Nebraska cities, resembling Permian forms, referred these beds to the Permian; but on afterwards finding that these fossils are there directly associated with a great preponderance of unquestionable Carboniferous species; and that there is also in Kansas a considerable thickness of rocks between the Permian and Upper Coal Measures containing, along with comparatively few Permian types, numerous unmistakable Carboniferous forms, we abandoned the idea of including these Otoe and Nebraska City beds in the Permian. And all subsequent investigations have but served to convince us of the accuracy of the latter conclusion."[1]

It is to be noted in reference to this correlation of the Upper Palæozoic rocks of Nebraska with the Upper Coal Measures, that Meek did not intend to include the rocks in Kansas which he and Hayden had called Permian,[2] a fact which has been misapprehended by certain writers on the geology of this region. Since the report of Meek and Hayden, no contribution of importance has appeared relating to the geology of the Upper Palæozoic of Nebraska, consequently it is especially interesting to compare their conclusions with our present knowledge which has been enriched by the labors of the last quarter of a century.

CHARLES S. PROSSER.

[1] Fin. Rep. U. S. Geol. Sur. Nebraska, etc., pp. 130, 131.

[2] Trans. Albany Inst., Vol. IV, 1858, p. 76; Proc. Acad. Sci. Phil., Vol. XI, 1859, pp. 20, 21; and Am. Jour. Sci., 2d ser., Vol. XLIV, 1867, p. 37.

(To be continued.)

EVIDENCES OF RECENT ELEVATION OF THE SOUTHERN COAST OF BAFFIN LAND.[1]

CONTENTS.

Introduction.—This paper is the outgrowth of the opportunity afforded for studying the lands at several places in and north of Hudson Strait, during the past summer, while a member of the Cornell Greenland party, with the sixth Peary expedition. Four stops were made in all along the coast of Baffin Land, three going up, as follows: Big Island; the mainland, just north of the island; and Icy Cove on Meta Incognita. The fourth landing was at Niantilik Harbor in Cumberland Sound on the return homeward.

[1] The writer is greatly indebted to various members of the expedition for valuable suggestions and help, especially Mr. Bonsteel, who stopped with him on the island; but, whatever value this paper may contain is largely due to Professor R. S. Tarr, who kindly directed the work throughout. To all the writer wishes to express his thanks and add his most grateful acknowledgments.

BIG ISLAND.

Location, description and topography.—The location of the island is immediately off the southern coast of Baffin Land, in Hudson Strait, and separated from the mainland by a narrow channel of water, ten to twenty miles wide, known as White Strait—in north latitude 62° 30′ to 63° and west longitude 70° to 71° 10′. It is some twenty-five to thirty miles in the direction of its longest axis, which is northwest and southeast, and has an average width of from five to ten miles. The coast is a steep and irregular one, being much cut up by fiords and embayments. The highest land reached on the island was 470[1] feet above sea level. Its surface has been deeply incised by interlocking fiordic[2] valleys, which are quite broad at their tops, with the ridges or divides between, of a typical moutonnéed form. These, of course, are on their tops narrow in proportion as the valleys are wide. The rise and fall of the tides is about thirty feet. The topography shows marked signs of glaciation, though, in places, it has been greatly modified by weathering, which has been chiefly of the mechanical kind and on a large and rapid scale. Notwithstanding the great amount of mechanical weathering, due almost entirely to frost action, chemical disintegration is distinctly noticeable. Many sections which have been but recently uncovered by ice are rough and angular, with nearly every trace of glaciated form obliterated.

Kind of rock.—The rocks consist of regularly banded hornblende-biotite gneiss, complexly folded and gray in color, the intensity of which varies according to the amounts of the dark minerals present. The gneisses are intersected by numerous pegmatite veins composed of the same minerals.

Proofs of elevation in raised beaches.—In nearly every valley studied, one of its most prominent and striking characteristics was the occurrence of shore lines in the form of distinct beaches. Sometimes a full and complete series of half dozen or more of these would be found in a single valley at different elevations,

[1] All altitudes were measured with an aneroid barometer.

[2] The term "*fiordic*" is here used in the sense of "fiord-like."

while in others only one or two would occur. These were, in most cases, well developed, level topped, and composed of well-rounded, water-worn material, four-fifths of which was distinctly

SKETCH MAP OF THE HUDSON BAY REGION.
BAFFIN LAND AND LABRADOR.

FIGURES REPRESENT THE LOCATION OF RAISED BEACHES WITH MEASURED ELEVATIONS ABOVE PRESENT SEA-LEVEL
X. LOCALITIES IN WHICH RAISED BEACHES HAVE BEEN NOTED WITHOUT ELEVATIONS ABOVE SEA-LEVEL.
THOMAS L. WATSON
1896

derived from the local gneisses. However, they contained as well quite a noticeable quantity of foreign material, *e. g.*, shale, limestone, quartzite, etc. This material was variable in size in the lower beaches, and also in several of the higher, though noticeably uniform and coarse for the higher ones. With reference to the size of the materials composing these beaches, several different types were represented, from the true sand and gravel, on the one hand, to the typical bowlder beach on the other, with all gradations between these two extremes. Except for the materials being covered with lichens, these are as fresh and perfect in every respect as though they had been formed but yesterday. In the majority of cases the beaches extended entirely across the valleys from side to side, although it was not uncommon to find them thinning out at one end, and only reaching from one-half to two-thirds the entire distance. They were variable in dimensions, in width from 10 to 50 yards, and in length from 60 to 110 yards. Their length depended upon the width of the valleys in which they were formed. In elevation they ranged from 270 feet above, down to sea level; and, so far as studied, could be correlated throughout.

The best developed and most uniform and regular series of beaches found were in a valley[1] which began at the north end of Ashe Inlet, with a direction[2] S. 13°.5 W. The divide in this valley is located nearer the southwest end, and about 1000 yards from its northern terminus in Ashe Inlet. Unlike most of the other divides on the island, which are composed of loose material, either glacial or beach deposits, this one is formed of the gneissic rock, in situ, and is exposed for the entire width of the valley with an elevation of 185 feet above sea level. The first beach is built immediately against this rocky divide at an elevation of 175 feet above sea, with an average width of some forty feet. The second beach is 165 yards beyond the first one, northward, at 125 feet above sea, and is the best developed one of the series in this valley, with a width of some one hundred feet. Between these two slight fragmentary ones are scat-

[1] It was on the south side of this valley, only a short distance from Ashe Inlet, that the Hudson Bay Company established their scientific station, or Observatory No. 3, in 1884; and it was in their house that we camped during our stay on the island.

[2] Through the kindness of Mr. G. R. Putnam, of the U. S. Coast and Geodetic Survey, the writer has been enabled to give all bearings in terms of true North and South readings. Mr. Putnam states that the compass needle is rather unstable in these regions; also, there may be daily changes of several degrees, and the effect of local attraction is likely to be great.

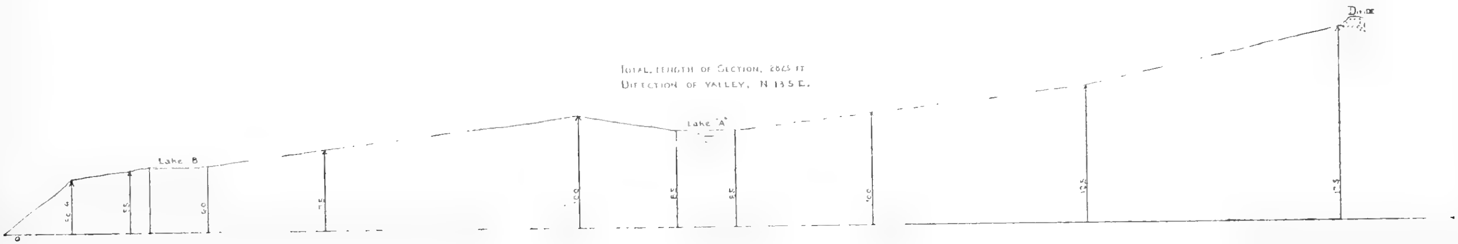
BIG ISLAND

Profile from Sea Level to top of Uppermost Beach.

1896.

Profiles show the height of beaches above sea level.
Beach ridges, shown by inverted Vs.
Height above sea level indicated in feet.

Section 2



Section 1.

Figure 1

tered, within a few feet of each other. The third and fourth beaches are found at the same elevation, 100 feet, and about equally distant from the opposite sides of a rock-basin lake which has been formed in the intersection of this, with a second valley, whose direction is N. 53°.5 E. The fifth beach is found at an elevation of 75 feet, and at a distance of about 165 yards from the fourth one, with an average width of some 60 feet. This is the last well-developed beach in this valley, though there are two fragmentary ones found at the respective elevations of 55 and 50 feet above sea. These are located on the north side of and at a short distance from a second small lake, whose surface is 60 feet above sea and 75 yards from the fifth beach.

In the southwest half of the valley, which has been mentioned above as crossing the one just described, are found two well-developed beaches at the respective elevations of 50 and 75 feet, which are correlated with the two corresponding beaches in the above series.

In the next valley immediately beyond, eastward, and approximately parallel to the one trending S. 13°.5 W., is found the largest, and by far the best-developed, beach seen on the island. It is distinctly a sand and gravel beach, 40 feet high, with its crest 175 feet above sea, and about 120 feet wide by 330 long. It serves as the divide in its valley, and is the correlative of the 175-foot beach in the first series.

Proofs of elevation in differential weathering and unlike surface conditions.—The fact of recent elevation of this island does not rest alone upon the evidence of raised beaches, though this, to be sure, is entirely satisfactory in itself. It is confirmed by other geological evidence of a very strong nature. Apparently there exist on this island two sharp and well-defined zones, whose surface conditions, in nearly every respect, are very markedly different from each other. The first zone, which begins at present sea-level, and has its upper limit about 300 feet above sea, includes all the land below that level. This zone includes the hilltops for a distance of from two and one-half to three miles back from the sea, and the bottoms of all the major valleys observed on the island. Excepting the valley bottoms, which are filled with quantities of unusually large and well-rounded bowlders, this belt has been stripped of its loose material in the form of glacial drift; consequently the bare and naked rock is exposed on the hilltops. The attack of the agencies of weathering upon the surface of this area has been in progress, more or less, ever since the rock was exposed, but the effect is far less than that over the areas above an elevation of 300 feet. This would naturally follow, since it will be shown that up to this elevation the waters have but recently subsided or fallen. By far the larger quantity of loose materials which are scattered here and there over this zonal surface is rounded and waterworn. Mechanical weathering has in places shown its effect, and angular masses are seen scattered about somewhat sparingly, in the form of small talus deposits. This zone will embrace at least three-fourths of the total land area of that part of the island visited.

The second zone has its lowest level and beginning at the 300-foot elevation and includes all the surface above, including an area which is not continuous, being merely the tops and sides of the hills for two-thirds of their distance downward. In this zone the bedrock is seldom seen, but is covered to an unknown depth with very large and loose angular blocks; in a few places, however, the bedrock outcrops at the surface in the shape of small knolls of somewhat decayed rocks. These angular rocks are clearly derived from the local gneisses, presumably largely, if not entirely, by frost action. In some cases they are weathered to a thoroughly crumbled condition. The scarcity of glacial bowlders in this angular mass was very striking, yet a few, which proved in each instance to be of foreign source were seen.

Along the sides, at an elevation of from 50–75 feet above the valley bottom, which was 220 feet above the sea, were noted patches of pebbles and bowlders, mostly the latter. These were deposited in small channel ways which had been carved by temporary streams flowing down the valley sides. Fully a half dozen of these were seen at different places on the same hill-side and at the same elevation. A short distance above this the loose angular material commenced to cover the surface. These conditions would seem to indicate that the waters of the sea had their level near this elevation, when these deposits were formed in what then were the mouths of the present channel ways. Such loose and angular material as may have extended below that line was subjected to sea action. It was ground up and distributed in the usual way over the sea bottom. It might be of interest to mention that in this valley was found a series of beaches, four in number, which were distinct and perfect pebble beaches, deposited on a shelf rising some 50 feet above the valley floor.

For the sake of a brief comparison let us note the salient features of the two zones. The first zone is characterized by a seaward strip of land, some two and one-half to three miles wide, reaching an elevation of some 300 feet, with deeply incised valleys (a feature common to both areas) and occupied by raised beaches. This zone skirts the higher interior land area, which has been termed the second zone. Furthermore, this area has its rock bare and more or less polished by glacial action with but little material strewn over its surface, which, for the most part, is waterworn, with occasional talus slopes of angular rock. The second zone, which includes all the land above 300 feet, is covered deeply with large angular blocks, has its bedrock exposed in a few places only, and all glacial form mostly destroyed. The contact between these two areas is marked in places by pebble and bowlder patches along the hillsides in some of the valleys.

Palæontological evidence of elevation.—In one of the valleys, 270 feet above sea level, was found a large deposit of well-preserved shells, representing two genera living at present, *Macoma calcarea*, Chemnitz,[1] and *Mya truncata*, Linn. (?). These were not found in direct association with the beaches, but were only a short distance from one series, and were taken from a small area of black mud, not covered by vegetation.

Dawson refers to several cases in southern and eastern Can-

[1] The writer is indebted to MR. E. M. KINDLE for the identification of species.

ada where vertebrate remains, especially the whale, are associated with raised beaches. In speaking of the lower St. Lawrence in the neighborhood of Little Meta,[1] he says, "Bones of large whales occasionally occur on this terrace." After describing a beach on the island of Anticosti,[2] he says, "The bones of a whale were found on this beach." He further states that the same condition is observed along the shore of the St. Lawrence[3] and at Smith's Falls,[4] Ontario. The beach at the latter place has an elevation of 420 feet above the level of the sea.

Packard[5] refers to the same association on the lower Savage Islands. In each case invertebrate shells representing several genera and species were found occurring with the vertebrate remains, but in greater abundance, as would be expected.

Southern coast of Baffin Land, about twenty miles north of Ashe Inlet.[6]—Three stops were made on the mainland at different places, and at each one proofs of recent elevation were seen in the form of raised beaches. At the first landing, which was across White Strait to the north, and opposite the middle, of Big Island, about twenty miles from Ashe Inlet, the beaches were associated with other forms of evidence, above mentioned, as being present on the island; viz., fossils and difference in degree of weathering above certain heights. The rock of this part of Baffin Land is a fine-grained, garnetiferous gneiss, and thus differs from the rock of the island. The land is low near the coast, but rises into a series of hills which at a distance of a mile or more back from the sea reach an elevation of 700 feet, continuing to rise inland.

Raised beaches.—These did not attain so perfect a degree of development as those on the island. They were formed in very narrow valleys, crescentic in shape and concave seaward, damming back small ponds or lakelets. In one place, where this condition

[1] The Canadian Ice Age, 1894, p. 65.

[2] *Ibid.*, p. 159.

[3] *Ibid.*, p. 161.

[4] *Ibid.*, p. 203.

[5] Memoirs Bost. Soc. Nat. Hist., 1867, I, Part II, p. 226.

[6] The writer was landed on Big Island and did not visit this part of the mainland. For what follows he is indebted to PROFESSOR R. S. TARR, who has very kindly furnished him with all the facts.

was especially noticed, it looked in every way as though it were artificial; the crescentic beach, which held up a lake behind it, had been so regularly constructed that had it been in an inhabited region Professor Tarr states that he should have ascribed it to the hand of human beings instead of to nature's handiwork. These crescentic lines were composed of large bowlders, weighing from fifteen to twenty pounds, and in length were from 100 to 125 feet, rather narrow topped, probably six feet across, but several times this width at base. The exact counterpart of these was seen in process of formation in one place at sea level, in which the ice was an important factor in their construction. The ice, moving in strong tidal currents, bore along bowlders and ground them against the coast, forming a bowlder pavement of a very perfect kind.[1] Professor Tarr states that, due to the narrowness of the valleys, it would be impossible for these to form without the aid and action of the ice, for no waves could exist here which would transport and pile up such an accumulation of bowlders, particularly when below the zone of ice action the bottom is clayey.

Fossils.—The following genera of living shells were found: *Mya*, *Saxicava*, *Pecten*, *Terabratula*, *Balanus*, and several other living species. These were found in a blue mud, some patches of which were fifty to sixty feet across, in some cases covered with moss, and in others not. Fossils were also found at lower levels.

Weathering.[2]—Professor Gill independently suggested recent elevation purely on the basis of the weathering of the rock in place. In chipping and breaking off petrographical specimens he found a striking difference in degree and intensity of weathering, which he placed at an elevation of from 300 to 400 feet. The rocks below this elevation were found to be much less

[1] For action of similar kind described by PACKARD and FEILDEN along the Labrador coast see references in Bibliography.

[2] I am indebted to PROFESSOR A. C. GILL for kindly furnishing me with this fact. The exact elevation of contact marking the difference in degree of weathering was not determined.

affected or changed by the weathering agencies than those above this height.

Icy Cove, southern part of Meta Incognita.—Our second landing place was on the southwest coast of a peninsula lying between Frobisher Bay and Hudson Strait, and about sixty miles east of Big Island. This land is known as Meta Incognita, and the landing was at "Icy Cove," where the only Eskimo settlement in the Straits was found, called "Noogla."

The topography here was much the same as that of the other two places—very rugged—and like Big Island the coast was steep and rough, indented with embayments and rocky capes or headlands. The rock is a very coarse-grained granitic gneiss.

Raised beaches.—Two beaches were noted, composed of coarse, rounded material. No elevations were taken, but these looked to be about 50 and 100 feet, respectively, above sea level. A bench between the two beaches was seen, which appeared to be a wave-cut terrace, at an elevation of about 75 feet.

Niantilik Harbor, Cumberland Sound.—This was our last landing on the Baffin Land side. Niantilik Harbor is a fiord on the south side of Cumberland Sound. A stream of considerable size enters at this point, having its head waters in a series of true rock-basin lakes of rather large size.

Raised beaches.—It is along the west side of this valley that we have a series of unusually large and well-developed beaches. Unlike those described from the other localities, these are composed of fine material, excepting the topmost one, which consists of coarse shingle. The direction of the two principal beaches is approximately parallel to the stream, N. 75° 55′ W. The first one is at an elevation of 110 feet above low tide, 200 yards long, with an average width of 30 yards, and is composed of sand, gravel and pebbles.

The second beach is from 50–100 feet above the first one, fully three-quarters of a mile long and with an average width of 75 feet, and is built of very large bowlders. It is not so well preserved as the lower one, as it lies against a very high and steep scarp, with its flat-topped condition seen in only a few places, and for rather short distances, the rest being almost entirely masked by the piling up of the products of weathering. An intermediate stage is represented by a beach some 50 yards long and as many wide, composed of very fine material, mostly sand and gravel, and acting as the divide in the very shallow valley in which it is built. The two large beaches grade or run into rock-basin lakes at their eastern ends.

The cemetery of Black Lead Island is built on a well-defined beach composed of sand and gravel, and is at an estimated elevation of between 100 and 125 feet above sea level. Beaches were noticed at several other places, but time would not admit of their study.

A condition, unlike that seen at any of the other places, was noticed on all of the lands enclosing this harbor, which, in itself, would have a tendency to indicate or suggest elevation. The condition was that of a form of rocky headland or cape of peculiar development, cut out of the solid rock, primarily, by wave-cutting and perhaps, subsequently, by ice erosion to an unknown extent. They were very numerous, extended seaward for quite a long distance, were very narrow—only a few yards at widest—and were of a remarkably level-topped condition, rising five to ten and twenty feet above sea level. At about the same level notches of wave-cut origin were more or less distinctly noticeable, and while time would not admit of their study, they apparently were in correlation with the capes. Partial evidence was found which seemed to indicate recent elevation of some 50–100 feet above the highest beach mentioned.

Evidence of present rising of the land on Big Island around Ashe Inlet region and at Niantilik Harbor.—At each of these places, in nearly every valley studied, was found a beach built of fine material, sand and gravel, at an elevation of from five to ten feet above high tide. The evidence of present upward movement at Niantilik is made stronger by the peculiar type of rocky headland, extending seaward.

Bell[1] has shown evidence of a like kind indicating a similar

[1] Canad. Geol. Survey, Rept. of Prog. 1882, 1883, 1884, pp. 26, 31, 33 and 35, DD.

uplift of the lands to the west of the region herein described, and with Tyrrell[1] has proven the raised or elevated condition along the west and southwest shore of Hudson Bay. Again, Bell[2] has produced sufficient evidence, although doubted by Tyrrell,[3] that the Hudson Bay region has been elevated in historic times; the elevation being believed to be in progress at present.

No landing was made on the lands along the south side of the straits, but during the summer of 1884 Dr. Robt. Bell of the Canadian Geological Survey was sent out as the geologist by the Canadian government, through the straits and into Hudson Bay, and he has described raised beaches on some of the islands to the west and southwest of Baffin Land. For convenience I quote from Dr. Bell's report:

Speaking of Cape Prince of Wales,[4] he says: "Beaches of shingle, as fresh looking as those on the present seashore, except that the stones are covered with lichens, may be seen at all levels, up to the tops of the highest hills in this vicinity. . . . . The materials of the raised beaches above referred to consist principally of gneiss with milk quartz from the veins of the neighborhood, together with a few fragments of yellowish gray dolomite, with obscure fossils, a hard and nearly black variety of siliceous clay slate, with an occasional bowlder of dark, hard crystalline diorite."

Concerning Digges Island,[5] he says: "Between this and the western extremity of the island the hills have a rounded outline, and raised beaches, composed mostly of coarse shingle, form a prominent feature on their slopes, all the way from high tide mark to their summits, the highest of which is between 300 and 400 feet."

Mansfield Island,[6] he says: "For many miles, the whole of the eastern slope of the island presents a succession of steps or

[1] Geological Magazine, Decade 4, Vol. I, 1894, p. 398.

[2] Am. Jour. Sci., Vol. I, Fourth Series, 1896, pp. 219–228.

[3] *Ibid*, Vol. II, Fourth Series, 1896, pp. 200–205. For other references to this region see Bibliography.

[4] Canad. Geol. Sur. Rept. Prog. 1882, 1883, 1884, p. 26, DD.

[5] *Ibid*, p. 31, DD.

[6] *Ibid*, p. 33, DD.

small terraces, mostly too low to be distinctly counted, but there might be a hundred of these between the sea level and the highest parts of the island visible. These appeared to be partly ancient beaches, and partly the outcropping edges of nearly horizontal strata."

Marble Island,[1] he says: "Even the bowlders and coarse shingle forming the raised beaches remain quite white, and these beaches appear as conspicuous horizontal lines against the dark vegetable matter."

Degree of rapidity of the uplift.—It is strikingly noticeable from the description of the beaches given above, as also from their study in the field at the various localities in which they occur, that the conditions suggest a difference in the rapidity of movement with which the land was raised above the waters at the successive stages and levels. The movement seems to have varied in intensity or rate for the same locality. In the case of the two highest beaches on Big Island and at Niantilik harbor, the conditions point very strongly indeed to a uniformly slow change in level. The interval between the two beaches at each of these places is marked by intermediate fragmentary lines. Materials are strewn thickly over the area between in an interlocking manner. This condition is strikingly absent from the land areas between the lower beaches. Thus the change in level from the second highest beach downward was sudden and rapid, and is better described as having taken place by *jumps*, so to speak; while above this line the change in level must have been less sudden and violent, and in character slow and gradual. At Icy Cove and the mainland to the north of Ashe Inlet, the conditions indicate the same sudden or rapid *jumping* movement as in the lower levels at Niantilik and Ashe Inlet.

Going still farther westward the lands along the west coast of Hudson Bay have been described as containing raised beaches, thus indicating recent elevation in that region. In speaking of the raised beaches in the Aberdeen Lake region, Mr. Tyrrell[2]

[1] Canad. Geol. Sur. Rept. Prog. 1882, 1883, 1884, p. 35 DD.

[2] Geol. Mag., 1894, Vol. I, decade 4, p. 398.

says that they are found at the following elevations above the lake, 290, 220, 180, 150, 105, 90 and 60 feet; also, "Similar raised beaches are found in favorable localities all along the shore of Hudson Bay." In Mr. Tyrrell's[1] account of his first expedition through the barren lands of northern Canada, he mentions raised beaches in two localities, one at Doobaunt Lake with an elevation of some 400 feet above sea level; the second at the mouth of Chesterfield Inlet and on the south side. In Tyrrell's[2] second trip through these regions raised beaches are mentioned near Ferguson Lake at an elevation of from 400 to 500 feet above sea level, and on the southwest side of Churchill River in the region of Deer River with an elevation of some 600 feet.

Conclusions.—1. The evidence favoring recent elevation of from certainly 270 to 300 feet above present sea level on the lands along the south and southeast coast of Baffin Land has been shown to be of the most conclusive character, and can be briefly summed up under three general headings.

a. In the form of raised beaches.

b. Unlike surface conditions intimately associated with a difference in degree of weathering at a well-defined elevation.

c. In the form of extinct life. The remains of several genera and species of living shells were found to be in greater or less degree directly associated with the beaches.

Furthermore, that the conditions attending this upward movement at least show that the rate of movement was not alike for all the localities studied, but rather indicates that for some the uplift was sudden and rapid, rising by jumps or strides, while for others it was more uniformly slow and gradual.

2. Conditions strongly favor a present movement on Big Island and in Cumberland Sound. This is shown in beaches found in a great number of the fiordic valleys, which are at present out of the reach of high tide by some five to ten feet, but so recently formed that not a sign of vegetation has commenced

[1] Geog. Jour. (London), 1894, July–Dec., Vol. IV, pp. 444–447.

[2] *Ibid.*, 1895, July–Dec., Vol. VI, pp. 445–447.

to grow on the beach materials. Also, by the peculiar type of rocky headland and wave-cut notches above described, and at about the same elevation as the lowest beaches.

3. It would further appear that the uplift along south Baffin Land was coextensive with that described by Bell and Tyrrell in the Hudson Bay region.

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ITHACA, N. Y.,
December 10, 1896.

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ITALIAN PETROLOGICAL SKETCHES.

III. THE BRACCIANO, CERVETERI AND TOLFA REGIONS.

Bibliography.—The modern papers dealing with these three regions petrographically are extremely few, and since some of them are not confined to the description of only one they will be noticed together here.

We begin, as usual, with vom Rath,[1] who devotes parts of one Italian "Fragment" to Bracciano and to Tolfa. The descriptions are largely topographical, though in the Tolfa paper the "trachyte" is described and an analysis given, and considerable space devoted to the alum mines of the district. With exception of the paper just cited and a few stray notices of rocks in Rosenbusch's "Massige Gesteine," practically all the other articles on the regions are by Italians. Of these the following are the only ones which need be named here.

Struever[2] published in 1885 an account of the ejected blocks and their minerals which are found to the east of Lake Bracciano, but does not touch upon the eruptive rocks proper. Many of the eruptive blocks, and enclosures of Lake Bracciano, are described by Lacroix.[3]

In the same year Tittoni[4] describes the so-called Agro Sabatino, which includes the trachytic hills immediately to the west of Lake Bracciano, the region southwest of it, and the masses of eruptive rock near Cerveteri.[5] He gives a good geological map on a scale of 1 : 50,000. The first half of the paper is

[1] VOM RATH, Zeit. d. d. geol. Ges. XVIII, 561–576, 585–607, 1867.

[2] STRUEVER, Atti Acc. dei Lincei, Series 4, I, 1, 1885.

[3] LACROIX, Enclaves des Roches, Macon, 1893.

[4] TITTONI, Boll. Soc. Geol. Ital. IV, 1885, 337–376.

[5] He states that he was the first (in 1879) to discover the eruptive character of these hills.

devoted to the sedimentary terranes, while the latter half is taken up with brief megascopic descriptions of the eruptive rocks and their tuffs, and with their distribution. He considers that all of the eruptives are post-Pliocene.

The rocks of the Agro Sabatino collected by Tittoni, as well as others of the same region from other sources, were examined by Bucca[1] who also later[2] adds a note on the enclosures in the eruptive rock of Monte Calvario. His papers are entirely petrographical, and will be referred to later on in detail. Busatti[3] in the same year gives a description of a trachyte from Tolfa, to which Lotti adds some remarks on the genetic relationships. De Stefani,[4] later, also gives an account of the regions of Tolfa and Cerveteri.[5]

It will be evident from the above that the literature of the regions in question is of a very scanty description, the important leucitic rocks of Lake Bracciano being practically untouched, and the others not having been studied very fully. The regions in question are shown on the Tolfa and Bracciano sheets (Foglii 142 and 143) of the Italian Geological Map (scale 1 : 100,000).

THE BRACCIANO REGION.

Topography.—The center of this region is the large Lake of Bracciano. This is almost circular in shape and with a diameter each way of 9^{kms}. The surface of the lake is 164^{m} above sea level. On the north at Trevignano its symmetry is broken by a small bay which apparently represents a small explosive crater.

The depth of the water is not stated, though it seems to be much deeper than Lake Vico. There are no islands in the lake.

[1] Bucca, Boll. Com. Geol. Ital., 1886, 212–223.

[2] Bucca, Loc. cit., 377–379.

[3] Busatti, Proc. verb. Soc. Tosc. 4, Luglio, 1886.

[4] De Stefani, Boll. Soc. Geol. Ital. X, 487–499, 1891.

[5] In a paper received just before going to press, P. Moderni (Boll. Com. Geol. Ital. 1896, Nos. 1 and 2), describes the Bracciano center. He regards the mass as the product of eruptions from about 50 centers surrounding the lake, and this not as a true crater-lake but as due to a sinking in of the surface. He does not touch on the petrography.

Surrounding it is a circle of hills, whose steep inner sides come down close to the water's edge, leaving only a narrow shore margin. These hills are highest on the north, where they reach their maximum elevation in Monte di Rocca Romana (602^{m}), and from this gradually diminish in height around the lake toward the southern shore, where their height at Monti is only 336^{m} above sea level. From this circular crest the land here, as at Bolsena and Vico, slopes gradually down on all sides at a low angle, and presents much the same characteristic features.

To the east of the lake are three maar-like craters described by vom Rath. The largest of these is the dry circular Valle di Baccano, about 3^{km} in diameter. Between this and Lake Bracciano lie Lake Martignano (whose water level is 43^{m} above that of Lake Bracciano), and the Stracciocappa Marsh. These are all surrounded by ridges of tuff.

The walls and sides of the Bracciano Volcano are built up of leucitic lava flows and tuff beds, except on the west. On this side we find two small non-leucitic centers. About 3^{km} due west of Bracciano is the group of low hills which include Monti Oliveto and San Vito. These are partially covered by leucitic tuffs, so that they are older than some of these eruptions. To the north of them is a small solfatara, whose floor is white through decomposition of the rocks, and where sulphurous vapors are abundantly given off. To the north of this again is Monte Calvario,[1] a domal mass of eruptive rock. According to Tittoni this rests on Pliocene beds.

Petrography.—In this region my stay was of very short duration, so that the specimens collected and the observations made were few. A study of the geological map and my own observations are, however, sufficient to show that we have to deal here, as in the other centers, with two prominent groups of rocks, a non-leucitic and a leucitic. The group of phonolites proper seems to be lacking, or perhaps is present in only small amount.

[1] It may be noted that BUCCA speaks of this last eruptive center as Monte Virginio. The hill of this name, which lies just north of Monte Calvario, is composed of tuffs enclosing blocks of leucitite, as shown on the geological map.

Toscanite.—The non-leucitic eruptive rocks of this region resemble the vulsinites and ciminites in containing basic plagioclase, as well as orthoclase, and are consequently quite rich in lime. They differ, however, in being much more acid, with SiO_2 from 63–72, and sometimes contain quartz. They, therefore, occupy a place intermediate between the rhyolites and the dacites. They correspond, in fact, very closely, both mineralogically and chemically, with the rocks of Monte Amiata described by J. F. Williams.[1] They also resemble the quartz-trachytes of Campiglia[2] and Roccastrada.[3] As these earlier known localities are in Tuscany (Ital. *Toscana*) this group of acid effusive rocks, characterized mineralogically by the presence of basic plagioclase, as well as orthoclase, with occasional quartz, and chemically by high silica and alkalies and (for the acidity) high lime, and low alumina, may be called *toscanite.* It may be mentioned that they also resemble certain rhyolites from Ponza and from the Euganean hills near Padua. They thus occupy the place in Brögger's[4] table filled by the group of quartz-trachyte-andesites, and in some cases are so acid as to fall in with his dellensite (dacite-liparite). They approach this especially in their low alumina. Analyses of typical toscanites will be found in Table I.

The rock of Monte Calvario is very much decomposed, so much so that good fresh specimens are difficult to find. I finally obtained some which are quite, though not entirely, fresh at a quarry on the southeast side where work was going on. The rock is rather coarse-grained and resembles many of the porphyries of our western states. The groundmass is light gray, and glassy feldspar phenocrysts abound, which are colored light yellow by the infiltration of ferruginous water. They are chiefly of sanidine with a smaller quantity of acid labradorite. Some

[1] WILLIAMS, Neu. Jahr. B. Bd. V, 381, 1885.

[2] VOM RATH, Zeit. d. d. geol. Ges. XVIII, 639, 1866. Also DALMER, Neu. Jahr. 1887, II, 206.

[3] MATTEUCCI, Boll. Com. Geol. Ital. 1890, 284 ff., and Boll. Soc. Geol. Ital. X, 670 ff., 1891.

[4] BRÖGGER, Eruptionsfolge bei Predazzo, Kristiania, 1895, 60.

quartz grains are present. Biotite flakes are not rare, though these and the augite phenocrysts have suffered much through weathering, being represented by brown limonitic spots in some of the specimens. Some large enclosures of a darker, fine-grained, vesicular rock were seen, which will be described presently.

In thin section the sanidine phenocrysts are seen to predominate over those of plagioclase. Examination of suitable sections of the latter shows it to be a labradorite of the approximate composition Ab_3An_4. They are clear, but inclusions are not uncommon, nearly always of brownish glass, and often in the shape of the host. A few instances of parallel growth were seen, a plagioclase core being surrounded by a border of alkali feldspar. This, however, forms one crystal individual with the plagioclase, and belongs to the same general period of crystallization, being sharply outlined and distinct from the groundmass. It is thus of a different character from the alkali feldspar mantles already noticed. A few rounded crystals of quartz are to be seen. The ferromagnesian minerals are represented by brown biotite and fewer pale green diopside crystals, both of which are much decomposed. The groundmass, which is almost holocrystalline, is made up chiefly of alkali feldspar flakes, very few laths being present, with some brown spots representing original pyroxene microlites. A little quartz may be present, but no plagioclase could be detected, though the rock is in such a condition that a satisfactory study of it was impossible.

This rock is described by Bucca as a quartz-trachyte. His description agrees closely with my own limited observations. He mentions, however, the presence of hypersthene, whose existence in my specimens may have been concealed by its well-known liability to decomposition.

The *enclosures* in this trachyte are apparently fragments of an early lava stream, brought up from probably no great distance below. They are dark gray, fine-grained and compact, and quite vesicular, though far from being scoriaceous. The line of junction between the enclosed and enclosing rock is sharp, and no great amount of contact metamorphism is apparent. In the gray groundmass are large tabular glassy sanidines and some rounded grains of quartz, but no ferromagnesian phenocrysts are to be seen. In many of the vesicles are slender brownish black needles of breislakite, and hexagonal scales of tridymite.[1] These enclosures are much less decomposed than the trachyte surrounding them, though the sanidines are stained slightly yellow.

Under the microscope the structure is strikingly like that of a dolerite. Very numerous prisms of colorless diopside, slightly brownish on the edges, and long plagioclase laths, whose extinctions show them to be labradorite of the composition Ab_1An_2, with fewer orthoclase laths, lie in a holocrystalline mesostasis of orthoclase. Some comb-like skeleton forms of labradorite are also seen. Magnetite is present though not abundant. A few larger phenocrysts of violet augite are seen, and the few sections of the large tabular sanidine phenocrysts met with are clear and show only a few inclusions of glass and apatite. A narrow orthoclase mantle surrounds them. There were found a number of grains of the peculiar brown barkevikite-like hornblende noticed in a leucite-tephrite of Bolsena. The extinction angle of $\mathfrak{c}$ on c was 17° and the pleochroism was identical. No olivine is present, but apatite needles are quite abundant.

The vesicular structure of this rock shows that it is not a segregation proper, but an inclosure of an earlier solidified lava mass which had been erupted on the surface. The breislakite and tridymite were formed prior to the eruption of the toscanite, since they are present in cavities revealed by breaking open good sized masses of the enclosures. The rock corresponds mineralogically, and probably more or less closely chemically, with the vulsinites, though the structure is quite different. It probably represents one of the earliest outflows of the volcanic center, carried up by the later toscanite. Bucca (*op. cit.* 377) gives a very good description of these enclosures which agrees closely

[1] Bucca also notes hypersthene and augite crystals.

with the above. The hypersthene he speaks of as present is perhaps to be referred to the barkevikite just mentioned.

The toscanite of Monte San Vito is structurally quite different from that of Monte Calvario. The predominating dark brownish black mass is highly vitreous, with a few irregular cavities which are lined with a light blue gray opal. Through this are scattered many quite large glassy tabular sanidines, in almost every case twinned according to the Carlsbad law. They are stained slightly yellow and many carry the bluish opal in the crevices. Some irregular quartz grains are also visible, but phenocrysts of ferro-magnesian minerals are wanting.

The large sanidines are seldom met with in thin sections, but of the smaller phenocrysts those of feldspar are the most abundant. Those of plagioclase are in the majority over those of orthoclase, and Michel-Levy's method shows this to be labradorite of the composition Ab_2An_3. The crystals, both of labradorite and of orthoclase, are automorphic and sharp in outline, showing the usual planes. They are clear and quite free from even incipient alteration. Inclusions of pale brown glass are common, often with a bubble and sometimes of the shape of the host. Pale diopside, apatite and magnetite are also included in the feldspars. These feldspars are often clustered together, but no distinct relative order of crystallization could be made out between the two. The diopside is in stout well-formed crystals, usually with a pyramid largely developed. It is almost or quite colorless, and inclusions are rare and almost wholly of brown glass. A number of small thick tables of brown biotite are present which invariably show a narrow border of fine-grained augite-magnetite aggregate. A few large grains of magnetite and some apatite needles complete the list. In my few specimens I could detect none of the hypersthene mentioned by Bucca as abundant. The groundmass is highly vitreous, consisting of a largely predominating light brown glass base, in which are sprinkled, with little evidence of flow structure, many minute orthoclase and fewer prismatic diopside microlites. Small magnetite grains are rare and are perhaps derived from altered biotite, as may also be the case with part of the diopside microlites. An analysis of this rock by Dr. Röhrig is given in Table I, No. 1. It is seen to be as high in silica as a trachyte, low in alumina, with rather andesitic amounts of lime and magnesia, and in alkalies standing between the two groups, though the relative amounts of potash and soda are not what we might expect.

The rock just described, as well as similar ones from other localities in the region, are called by Tittoni "trachytic retinites." Bucca describes them as augite-andesites, with which name his descriptions agree very well, though it seems to me, as it does to de Stefani, that he unreasonably neglects the abundant sanidines and quartz. He speaks of hypersthene as abundant, and gives extinction angles for the plagioclase[1] from which he concludes that they must be very basic—"from labradorite to anorthite." According to him orthoclase only occurs as the large tabular phenocrysts, which is certainly not the case in my specimens.

Leucitite.—The leucitic rocks collected by me belong to three groups, leucitite, leucite-tephrite, and leucite-phonolite. Specimens of the first were obtained south of Lake Bracciano, from a flow at Crocicchie, from a similar, or the same, flow about one kilometer west of this and from the quarry at L'Uomo Morto southwest of the lake. A similar rock was seen also at Oriolo, northwest of the lake, but I have no specimen of it. They are all compact, dark gray, basaltic looking rocks, with some fresh well-shaped leucite phenocrysts (0.2 to 1 ^{cm}) and a few smaller ones of augite.

Under the microscope the phenocrysts present no remarkable features. The leucites are clear, somewhat cracked, show quite strong double refraction, and contain few inclusions. The augites are well shaped, pale green and not pleochroic, generally darker toward the center, and with an extinction angle of about 42°. Some are seen with a fringe of later dark green augite at the ends, which extinguishes at an angle of 50° and includes some magnetite grains.

[1]He says that they vary from 35° to 59°. There seems to be some error here.

The groundmass is almost holocrystalline, and is made up chiefly of small round leucites. In two cases these contain only few peripheral inclusions of augite and apatite needles, a peculiar feature being that around the leucite crystals proper as defined by these rings, is a late growth of leucite which extends irregularly and acts as a mesostasis for the other constituents. In rock from the second locality mentioned the inclusions are more numerous, and in spots due to skeleton growth, as has been previously described, though the skeleton forms are not as perfect as some of those seen elsewhere.

Between these leucites is an interstitial mass of green or greenish brown augite needles and grains, with some magnetite grains, with the latter being associated flakes of orange red hematite. Spots of a colorless feebly doubly refracting substance, giving bright grays of the first order in my very thin sections, are referred to alkali feldspar, as treatment with acid revealed no nepheline. No melilite was seen. Glass base is present in a very small amount. An analysis of one of these leucitites is given in Table I, No. 5.

The leucitite of Santa Maria di Galera,[1] which belongs to this volcano, resembles the above very closely under the microscope, though it is much coarser in structure. A rock very similar to these is found as loose blocks in the yellow tuff of Monte Virginio. This is very much finer grained than any of the preceding; contains some plagioclase but no glass.

Leucite-tephrite.—This seems to be quite common in the region though not so much so as leucitite. It is represented by a specimen from a lava stream in the crater wall just below the town of Bracciano. It is rather dark and fine grained, but rough in texture and not aphanitic. Scattered through the groundmass are very many small clear leucites and some very small black augites.

Under the microscope it closely resembles the similar rock of the Bolsena region, having the same doleritic structure. The irregularly shaped leucites show strong double refraction, and

[1] ROSENBUSCH, Mikr. Phys. II, p. 1233, 1896.

carry few inclusions. The augite is in stout prismatic crystals, green in color and generally darker toward the center. Large grains of magnetite abound, which are accompanied by orange hematite flakes. Many lath-shaped crystals of a basic labradorite, with a little orthoclase, are present with these, and the interstitial colorless glass base contains only few augite microlites and some minute opaque grains. An analysis is given in Table I, No. 6.

Leucite-phonolite.—My only specimen of this was collected at a rather thick flow on the northwest shore of the lake close to the water's edge. The groundmass is compact and fine-grained, of a very light gray color and with a slightly greasy luster. Clear rather glassy leucites and minute black augites occur as phenocrysts. Examined with the microscope the large leucites show the twinned structure very finely, and the prismatic augites are of an olive-green color, with the pleochroism and other characters of aegirine-augite.

In the holocrystalline groundmass are many small olive-green aegirine-augite prisms, a few colorless haüynes showing the characteristic inclusions, and some magnetite grains. The feldspars are represented by stout crystals and grains of alkaline feldspar, which are occasionally twinned. There is also present a residual base of colorless, feebly doubly refracting nepheline, whose identity was established by treatment with acid and fuchsine. Plagioclase is absent. A peculiar feature of the groundmass is the presence of round spots of a clear substance, whose outlines are defined by rings of minute augite microlites with some magnetite grains. These seem at first sight to be groundmass leucites. Close examination under crossed nicols, however, reveals the fact that only a small percentage of them is really of this mineral. The majority are composed of nepheline, with some orthoclase grains and crystals, the latter occasionally in fan-shaped aggregates. We have here, then, a case of paramorphism of leucite into "pseudo-leucite"—a mixture of nepheline and orthoclase, such as has been observed in Arkansas,[1]

[1] J. F. WILLIAMS, Ark. Geol. Sur., 1890, II, 267.

Brazil,[1] and Montana.[2] It is difficult to understand why the small groundmass leucites should suffer this change, while the larger phenocrysts remain preëminently fresh and unaltered.

Bucca does not describe any of the leucite rocks of the Bracciano region.

THE CERVETERI REGION.

This region[3] lies about 10^{km} southwest of Lake Bracciano and north of the small town of Cerveteri, so famous for its Etruscan tombs. It consists of a small group of hills, extending about 8^{km} W. N. W. and E. S. E. (about parallel with the coast line, and 4 to 5^{km} broad. They are of no very great altitude, the hills reaching their maximum height of 384 meters in Monte Cerchiara, in the center of the group. I could only spend the better part of one day at the eastern end, but as far as my observations permitted me to judge they are a mass of domal eruptions resting, as Tittoni points out, on Pliocene beds.

They are composed almost exclusively of acid non-leucitic rocks and their tuffs. Some leucitite is met with at the eastern end, but these leucitic lava streams probably belong to the Bracciano volcano proper. Since this leucitite is met with beneath the "trachytic" masses, its occurrence is of great interest as showing that the earliest leucitic outflows of Bracciano are of an earlier date than those of Cerveteri, though they continued after these latter had ceased. There seems to me to be an intimate connection between the Bracciano center and that of Cerveteri, and probably also that of Tolfa, but my opportunities for observation were so few that I do not feel able to discuss this point at present.

Toscanite.—To this group belong all the specimens collected by myself, and also apparently all those described by Bucca, except those of a few leucitites. Their prominent mineralogical and chemical characteristics have already been noted.

[1] HUSSAK, Neu. Jahrb. 1892, II, 146.

[2] PIRSSON, Am. Jour. Sci., II, 194, 1896.

[3] It is included on the Bracciano Sheet (Foglio 143) of the Italian Geologic Map.

The rock of which Monte Cucco, at the extreme east end of the region, is composed, is a light gray porphyritic rock, many glassy feldspar phenocrysts and some of biotite lying in a rather vitreous brownish groundmass. Under the microscope there appear well shaped and uncorroded clear orthoclase and plagioclase phenocrysts, the former in the majority. The plagioclase is shown by Michel-Levy's method to be labradorite of the composition $Ab_2 An_3$, the symmetrical extinction angles of the lamellæ of the Carlsbad individuals being in one individual 26° and in the other 29°. There are also many tables of an olive green biotite, which shows no corrosion or alteration phenomena. A few large colorless diopsides also appear. There is no magnetite, and no quartz could be detected.

The groundmass is highly vitreous, the glass base being colorless or of a very pale brown. It shows perlitic cracking in great perfection. Through it are sprinkled small (0.01–0.02) microlites of diopside, and a few stout orthoclase microlites which often show "horns" at each end. An interesting feature is the occurrence in abundance of very small (about 0.05^{mm}) forked and sheaf forms of orthoclase, which correspond to the so-called keraunoids in Ischian trachytes already described by the writer.[1] These keraunoids are of such minute dimensions that they exert only a feeble action upon polarized light, but examination of the largest shows that the axis of greatest elasticity $\mathfrak{a}$ lies parallel to the length, and that therefore they are elongated in the direction of the axis *a*. The use of high powers proves that they are in every way identical with those described from Ischia, except that they are of much smaller dimensions and more delicate.

Bucca's description of this rock closely agrees with the above, though he speaks of the biotite as being brown, and the small augites and keraunoids seem to have been lacking in the groundmass of his specimens. Though no quartz is present he is of the opinion that these rocks are to be referred to the same acid group as those of Monte Calvario. This opinion is con-

[1] WASHINGTON, Am. Jour. Sci., I, 375, 1896.

firmed by my analysis given in Table I, No. 2, which may be taken as representative of the rocks of this region.

The rocks of Monte Lungo and Monte Ercole, west of Monte Cucco, are rather darker and rougher in groundmass, and look like the Arsotrachyte of Ischia, minus olivine. The plagioclase is, however, rather more basic, having a composition Ab_1An_2, and the biotite rather browner in tone though still green, and colorless diopside phenocrysts rather more frequent. The glass base is rather dark brown, and the small orthoclase keraunoids are much more abundant, as are also the diopside microlites, which are here prismatic in habit. The rock of Belvedere del Principe south of Monte Ercole, is also closely similar in general characters, but the orthoclase keraunoids are here so abundant as to give the base a hyalopilitic structure. The glass is brown and the diopside microlites are prismatic in habit and show some flow structure.

It may be noted that absolutely no magnetite is to be found in any of these rocks. Small apatite needles are found in all, especially as inclusions in the feldspars. Bucca mentions a brown hornblende as present, known by its prismatic angle and oblique extinction, but careful research failed to reveal it in my specimens. As has been said, analysis No. 2 of the Monte Cucco rock may be regarded as representative of them all, and its close resemblance to that of the Tolfa and Calvario rocks will be noted. Further remarks on these points must be reserved for the final paper.

Leucitite.—This is represented by a specimen from a flow met with at the bottom of the deep ravine immediately to the west of Monte Cucco, whose rocks overlie it, though tuffs and soil conceal the contact. It is almost identical with the leucitites from the south of Lake Bracciano, and is composed essentially of round and irregular leucites with insterstitial green augite needles. Some magnetite and a very little orthoclase are also present.

The rock of which the ruined Castle Dannato is built was obtained from some now forgotten quarry in the neighborhood.

It is also a leucitite, and of the same composition as the preceding. It is, however, of much finer structure and closely resembles the leucitite of Sassi Lanciati near Bolsena. It carries segregations of coarse-grained, granitic masses, made up of large grains of green augite and a few well formed crystals of olivine, with much leucite which shows excellent twinning lamellæ, and which takes the place of the feldspar in typical gabbros. Some cavities are filled with calcite. These segregations closely resemble the leucitic blocks briefly described by Lacroix from Lake Bracciano, and may be compared with the Missourite recently described by Pirsson.[1]

THE TOLFA REGION.

This region consists of a triangular group of hills, lying a little more than 10^{km} northeast of Civita Vecchia and some 20^{km} west of Lake Bracciano. Its highest point is Monte Sassicari, 525^{m} above sea level. Since my visit of a few hours was confined to the southern angle I will not go into the topography, which moreover presents little of interest here. It may only be noted that the hills are composed essentially of toscanite, which in general is so extremely decomposed to alunite that a fresh specimen of rock is indeed a *rara avis*. De Stefani points out that the eruptions in all probability took place in post-Pliocene time, differing in this from Ponzi and others, who would place them earlier.

Petrography.—According to vom Rath there are two distinct kinds of "trachyte" represented in the region. The one is a "sanidine-oligoclase-trachyte" with light gray compact groundmass, in which lie phenocrysts of sanidine, oligoclase and biotite. This is more abundant in the northeastern part of the region, often shows a bed-like parting, and is comparatively little subject to decomposition. The other is more like a pitchstone, and is almost universally decomposed. Its groundmass is dark brown and resinous, with phenocrysts of sanidine, biotite and

[1] PIRSSON, Am. Jour. Sci., II, 315, 1896.

augite. To these Busatti adds a third variety, though his description hardly seems to warrant the separation.

I am inclined to agree with de Stefani in thinking that there is only one kind of rock, and that the differences noted are of very small importance. From vom Rath's analysis of the pitchstone-like trachyte and from mine of the rock from Tolfa it will be seen that the two varieties closely resemble each other chemically and that the rock belongs to the group of Toscanites as already defined.

The only fresh specimens which I obtained were collected at the hill on which stands the old castle above the village of Tolfa. In all other places I found it so decomposed as to be absolutely worthless for petrographical study. The groundmass is very compact and bluish gray, and speckled with minute black spots of augite. Very many large glassy feldspar phenocrysts, which often show twinning, with some biotites are scattered through it.

Under the microscope this rock presents an appearance almost identical with that of the Monte Cucco rock. The rather abundant plagioclase is an acid labradorite having the composition Ab_1 An_1, as determined by the extinction angles (22° and 23°) of the albite-twinned lamellæ of the two individuals of a Carlsbad twin.[1] The feldspar phenocrysts are quite often corroded. The hyalopilitic groundmass has a colorless glass base, which is thickly crowded with diopside prisms and laths, rather than keraunoids of orthoclase.

De Stefani[2] mentions a leucitic rock which he obtained at the base of Monte Elceto between the toscanite and the underlying Cretaceous rocks. Rosenbusch, to whom a specimen was sent for examination, reports that it is a "leucitite perfectly identical with the leucitic rocks of Albano and the vicinity of Rome."

[1] BUSATTI states that the plagiolase is oligoclase, but his determination seems to rest on insufficient data, as he only mentions its "polysynthetic structure" but gives no angles, as neither does VOM RATH.

[2] DE STEFANI, Boll. Com. Geol. Ital., 1888, 224.

TABLE I.

	1	2	3	4	5	6	7
SiO_2	64.04	66.24	65.19	67.61	47.89	49.73	55.87
Al_2O_3	14.48	15.64	16.04	14.04	18.25	19.20	21.82
Fe_2O_3	1.73	1.16	1.16	....	4.93	5.50	2.34
FeO	4.35	2.19	2.48	5.40	3.64	2.41	1.10
MgO	1.03	0.89	0.99	0.65	3.68	2.63[1]	0.48
CaO	4.00	2.17	2.92	3.71	8.70	7.96	3.07
Na_2O	4.14	2.05	2.26	5.50	2.60	1.99	4.81
K_2O	3.65	6.60	6.11	2.41	8.23	9.39	10.49
H_2O	2.06	3.25	1.85	2.28	0.65	1.19	0.34
TiO_2	0.28	....	....	....	0.77	....	....
	99.76	100.19	99.00	101.60	99.34	100.00	100.32
Sp. Gr.	2.542	2.455	2.509	2.537	2.781	2.655	2.551

1. Toscanite, Monte Calvario, Bracciano, A. Röhrig anal.
2. Toscanite, Monte Cucco, Cerveteri, H. S. Washington anal.
3. Toscanite, Castle Hill, Tolfa, H. S. Washington anal.
4. Toscanite, Tolfa, vom Rath, *op. cit.*, 596.
5. Leucitite, Crocicchie, Bracciano, H. S. Washington anal.
6. Leucite-tephrite, Bracciano, H. S. Washington anal.
7. Leucite-phonolite, Lake Bracciano, H. S. Washington anal.

HENRY S. WASHINGTON.

[1] By difference, through loss of Mg precipitate.

MODE OF FORMATION OF TILL AS ILLUSTRATED BY THE KANSAN DRIFT OF NORTHERN ILLINOIS.

Perhaps at no time during the Quaternary era were the climatal conditions of Illinois of such a nature as to originate a glacier independently of the ice introduced into the territory by outflow from the vast *névé* to the northeast. Consequently, when near the culmination of the Kansan epoch, a very early representative of the Lake Michigan glacier overspread nearly the whole of the territory of the present state of Illinois, it advanced across a region in which the indurated rock was but thinly covered by a nearly continuous mantle of residuary material, mostly clay, sand and angular gravel; and the ice thereupon proceeded to manufacture this into till. In a part of northwestern Illinois, especially in Stephenson county, the glaciation was of short duration and never repeated, and this district therefore, presents one of the best fields for the study of the contact phenomena between the base of the glacier and the preglacial land surface. There are scattered over the area incomplete deposits representing every stage in the process from solid rock to typical till. By a careful study of these imperfectly formed masses of till we may infer the process by which the ice manufactured the residuary material and underlying rock into the various types of deposits due directly to glacial action. The necessarily limited nature of this paper will compel me to state the hypothesis which seems to best explain the phenomena known to me, and simply refer to the localities where each stage is illustrated, mentioning a few of their most significant features.

The ice, in advancing across Stephenson county, moved westwardly, and within fifteen miles of the Driftless Area, in a decidedly northwesterly direction. During this time of general advance, glacial abrasion was at a minimum, and had the ice then melted from this district, without further movement, its drift phenomena would be insignificant and uninteresting. But it so happened that, during the general recession of the glacial front, there were repeated slight readvances, forming a peculiar variety of incipient moraine, consisting of knolls and short ridges of angular limestone débris and of stratified water-worn gravel and sand. Between the marginal accumulations of a distinctly morainic type, there are other deposits of somewhat similar nature, but which belong to the so-called ground moraine. In other words, the period of most pronounced glacial action in the Kansan epoch in northern Illinois, occupied a position considerably later than the culmination of the epoch. This I attribute to a milder climate, causing a recession of the ice-front, but yet giving more free movement to the glacier and softer material to work upon. I have gone into this short explanation of the glacial history of Stephenson county, so as to exactly locate the age of the deposits the significance of which I propose to discuss.

We may gain some idea of the condition of the surface previous to the arrival of the ice by a study of a north-south belt along the eastern boundary of Stephenson county, and about thirty miles back from the glacial boundary. Here we will find frequent exposures of the semi-decayed upper portion of the Galena limestone with its overlying undisturbed residuary clay.[1] The Galena formation is usually a heavy-bedded, sub-crystalline dolomite, shaly in certain thin layers and extensively jointed and fissured. Within ten to fifteen feet of the surface, weathering has opened certain deposition-planes, separating the rock into layers from two to four inches in thickness. As the rock is composed of small rhomboidal crystals, the next stage of decay consists of a solution of the bond between the crystals resulting in a loose mass of angular grains, macroscopically

[1] This is finely displayed in a road cutting one mile south of Egan in Ogle county, and in an excavation of the Chicago and Great Western railway, two miles east of German Valley in Stephenson county.

resembling fine yellow sand. By a continuance of the process the crystals are dissolved, leaving a slight residue which, accumulating to a thickness of two to ten feet, becomes a highly oxidized, dark red, very fine-grained, structureless clay. Certain layers of the dolomite abound in chert, which breaks up into angular fragments, averaging about the size of a walnut. These abound in the residuary clay, and on hillsides often pass horizontally from the solid rock into the red clay, with but little disturbance of the lines of stratification. This is one of the strongest proofs of the undisturbed nature of the residuary clay at the localities previously mentioned. In fissures and pit-shaped holes in the surface of the rock, the red clay may extend down from ten to thirty feet. This particular form of its occurrence can be observed in almost any rock-cutting in the county.[1]

1. The first effect of the contact between the base of the glacier and the mantle of residuary clay, was a rearrangment of the latter. It was pushed forward and downward, but as its downward progress was limited to a slight compression, the effect was a crushing or kneading of the mass. The faint evidence of stratification in the undisturbed deposit furnished by the layers of chert, was totally destroyed and the fragmental chert scattered indiscriminately through the mass. All deposits of rearranged residuary clay are referred to this stage when they contain no foreign material whatever. As they, in many cases can be proven to have been moved but a very short distance, their transportation and deposition were clearly exclusively subglacial.[2]

[1] For a thorough discussion of the residuary material accumulating over the Galena limestone in unglaciated areas, the reader is referred to CHAMBERLIN and SALISBURY'S excellent report on the superficial geology of the Wisconsin Driftless Area in the Sixth Annual Report of the U. S. Geological Survey.

[2] A careful study of the county of Stephenson would probably afford several hundred localities — of very limited extent, however — where the process of till making was stopped in this first stage. Good exposures can be found by following the C. G. W. R. R. from South Freeport to Egan, or the I. C. R. R. from Feeeport to Everts. Another, exposed in a small ravine on the south side of Yellow creek, is important from the fact that the rearranged residuary cherty clay has been pushed off of its original rock ridge onto the surface of a lake deposit.

2. The process in the second stage is merely a continuation of the last. The material has been transported farther, kneaded longer and more thoroughly commingled. In addition, a small percentage of foreign drift, mostly well-rounded pebbles of small size, has been worked into the deposit. Still, at the completion of this stage, the fine-grained, dark red clay basis and predominance of angular white chert indicate the close relation between this very incomplete till and the undisturbed residuary material. This is the nature of the ground moraine over practically the entire northern half of the county. But in looking for exposures of it, it is necessary to remember that the upper three feet of the typical or completed till in this district have been highly oxidized during the following interglacial epoch, so that in color they often resemble the deposits of stage No. 2. The latter never were of any other color than dark red and reddish brown.[1]

The mode of transportation of this imperfectly formed till appears to have been exclusively subglacial. In a very large proportion of exposures in Stephenson county, there is a continuous section from an undisturbed preglacial residuary clay, through every gradation to what may be considered typical of the "semi-residuary" class of drift. There is absolutely not an iota of evidence that any of this material has been lifted from the earth's surface and enclosed in ice. Clear evidences of a kneading or rolling over of the mass are abundant.

3. There existed under the glacier, certain areas where deposition was being carried on at the same time that abrasion was active in others. So that, while in many portions of the county, the manufacture of till was carried into the second stage only, on certain closely adjoining areas this was but the beginning or early stage of the glacial action. In these latter, the ice after having removed the red clay, proceeded to attack the loose sand-like mass of dolomite crystals, which it quickly disposed of by incorporating with the deposits of stage No. 2, furnishing their first

[1] This red till is best exposed in several cuttings of the I. C. R. R., about three miles southeast of Winslow, in Stephenson county.

supply of calcareous material. A few sections show it interstratified with till, and it can sometimes be traced back to its original undisturbed position.[1] Having been transported but a score or at most a few hundreds of feet, there is no room for anything but subglacial action.

We have disposed for the present of all the loose material on the surface of the solid rock, and we now come to the most interesting part of the process.

4. Stephenson county is a comparatively hilly region, although the hills are not high, steep, or close together. A section through a hill would show the Galena limestone as a series of practically horizontal layers, not cemented, but held in position by gravity and the projections on the upper and under surfaces of the layers. The ice in moving westwardly across the country, upon ascending the eastern slope of a hill from which the loose material had been removed, exerted a powerful pressure on the edges of these layers. Near the top of the hill, the pressure overcame the friction, and the upper layers of the rock were pushed forward, sliding on a lower unmoving stratum. In many cases, these transported rock ledges were not broken up, but moved forward as a solid mass, being found in that condition to day. They may be ten or fifteen feet in thickness, and several hundred feet in length, and perfectly horizontal, so that the fact of their not being *in situ* would not be known were it not for their unusual position, partially obstructing valleys, producing a topography radically different from the preglacial; and from their overlying drift of various kinds, including stratified water-worn gravel; and more often than otherwise underlain by loose angular gravel from ten to thirty feet in thickness.[2] In transportation they were clearly pushed in front of or under the extreme marginal portions of the ice. None of them have been removed far from their original position, and this with much

[1] Small exposures of it, after being disturbed but before being combined with the red clay, may be seen at nearly every outcrop of the latter, notably in the railway cuttings of the southeastern part of the county.

[2] Locality where best exposed — six miles east southeast, of Freeport, in a high ridge, on the north side of the I. C. R. R.

other evidence, negatives the idea that the basal portion of the glacier "plucked" these huge masses of rock from the ridges and transported them in its body.

Sometimes the pressure of the ice resulted only in a slight folding, or a tilting and faulting of the rock strata without moving them to a distance from their original position. This may affect them to a depth of twenty or thirty feet, and may include some of the solid, heavy-bedded, unweathered layers. In these cases, at least, no question can remain that the action was extra-glacial or marginally subglacial. Their importance lies chiefly in the fact that they prove beyond dispute that even the Kansan ice-sheet could, at times, exert powerful forward pressure on the rock over which it moved.

5. The forward movement of the unbroken rock mass was rarely continued many scores of yards before some obstruction was encountered, often in the form of an upward slope of the land, increasing the friction to such a degree that the transported ledge was unable to withstand the pressure and general fracture resulted.[1] In a few cases, the impression made on the observer is that the mass remained unbroken while the stress accumulated, until, becoming too great, the entire ledge was suddenly fractured into innumerable small angular pieces, under a well-known principle recognized as a condition of the formation of certain limestone breccias in various portions of the earth. Usually, however, there is clear evidence of a kneading or rolling over and crushing of the mass, producing an internal structure which cannot be simulated by the product of any other known process. When a series of semi-decayed or loosely compacted strata being forced forward in front of the ice, are checked by some obstruction, they tend to corrugate in a manner somewhat similar to the Appalachian type of mountain building; and the disturbance is greatest in the vicinity of the obstruction. But when the ice

[1] The deposits representing this stage are quite numerous in the Pecatonica basin, over an area about three miles in diameter, lying immediately southwest of the village of Dakota, and another west of the village of Everts. They are usually in the form of dome-shaped knolls and short ridges, and forming conspicuous features of the drift topography, it is unnecessary to more minutely describe their localities.

overrides the deposit, if the basal friction is great enough, it will turn up the strata in contact with it, twist them over on to the as yet undisturbed strata, and inaugurate a motion in the mass which may be not inaptly compared to the movement of a roller under a heavy weight. Rarely, however, will the actual action be as perfect as it should theoretically be, but usually there is combined with the rolling process a forward and downward thrust which crushes the mass. The more resistant portions of the ledge break into huge angular blocks, the semi-decayed layers into smaller fragments intermingled with a great quantity of calcareous sand. The rolling is obviously produced by the "drag" of the forwardly moving glacier, while the thrust is the result of its great weight. This kneading process is not only theoretically probable, but has given rise, as I have already intimated, to phenomena in Stephenson county, Illinois, which are explainable only under the supposition of having been produced by its action.

6. By a continuance of the kneading process, the larger blocks are crushed, all evidences of the original lines of stratification are destroyed, and the deposit for the first time bears a slight resemblance to certain very stony tills. Few of the particles are smaller than the crystals of which the original limestone was composed, and, therefore, the deposit may still be classed with the "transported rock ledges." Moreover, in this stage there are practically no foreign rock fragments although a few Canadian pebbles may be found imbedded in it far from the surface, proving its glacial age.[1]

7. The process of manufacture between the last stage and the typical glacial till may proceed along several lines, all similar in the general features of the method, but differing in details. Several deposits along the Galena road, one mile northwest of Freeport, and along the C. G. W. R. R. between German Valley and Egan, seem to represent a stage slightly in advance of that just described. Here the angular limestone débris is com-

[1] A deposit representing this stage is finely exposed in a gravel pit, one mile north of Freeport, where the angular gravel overlies water-worn drift gravel.

mingled with a considerable quantity of rounded drift of which a large portion consists of Canadian bowlders. The foreign material may reach as high as 50 per cent. of the mass, but usually falls below 10 per cent. The bowlders belong to the "englacial" drift, and the deposits containing them are marginal, but I introduce them here because by a marked readvance of the glacial front, they may be reworked into till.

8. In other cases, the ice was transporting the red, imperfectly formed till, described under stage No. 2, contemporaneously with the angular limestone débris, and they often came in contact, either becoming thoroughly commingled or perhaps only interstratified. When the intermingling is complete, the deposit has the appearance of a very stony till of a light brown color, and the material of which is evidently mainly of local derivation.[1]

9. Just previous to the incursion of ice into the Pecatonica basin, in Stephenson county, its area was occupied, at the lower levels, by several successive extra-glacial lakes, which deposited glacial silts, some of which resemble typical loess, and others a modified or water deposited till. During the glaciation of the region, the abrasion of these comparatively soft silts was remarkably small, yet sufficient to leave an impress on the character of the till which now overlies them. For it is observed that, while the ground moraine over the northern half of the county, where these silts were poorly developed and rarely reached by the ice, is very similar in color and texture to the residuary clays, over the southern third of the county, where the land lies lower and the extra-glacial silts were strongly developed, the ground moraine is in general of a quite different character. The marginal deposits are similar in both districts (consisting largely of angular limestone débris and stratified water-worn gravel and sand), but on the inter-incipient-morainic tracts in the southern district, there is often seen a till identical in all important respects with that which is exposed in long and repeatedly glaciated regions

[1] Typically developed along the road between Egan and Lightsville in Ogle county, about two miles north of the latter village.

and which I have referred to as "typical till." It is a stiff, unstratified, light yellowish gray clay, containing irregularly disseminated subangular blocks, largely of local derivation, but also an appreciable percentage of foreign rock fragments, many of which are Canadian in origin. The Niagara limestone pebbles are next in abundance to the Galena limestone and chert, and are often beautifully striated. A belt of this variety of glacial clay occupies the country between Yellow creek and a high upland area about four miles south of it. Its eastward and westward limits are indefinite, but its length may properly be included within ten miles. It can be observed best by proceeding due south from Freeport, where at the distance of about four miles, it will be seen to assume distinct drumloid characters. In particular, one of these *pseudo* drumlins, while it has a core of stratified sand and gravel, is overlain by an eight-foot stratum of yellow till so nearly identical in constitution with the typical till of a highly glaciated region, that no appreciable difference could be detected. This drumlin (?) is also the best locality in this county for securing finely striated stones. Now, a careful study of the composition of this till belt shows that, (*a*) the mass of its clay may be referred to abrasion of the silt formations which it frequently overlies: (*b*) its foreign rock fragments must have been brought into the district by the ice-sheet, but independently of the accumulation of the till, their occurrence in which is an accident of deposition; (*c*) the iron in the till was derived from the residuary clay of the region, as was also the large amount of angular and subangular white chert; and (*d*) the subangular Galena limestone blocks which are quite abundant but generally overlooked because of the more attractive appearance of the foreign drift, must have been derived from the country rock, very close to its present position, by the process which has been described in this paper.

It may be objected to the first proposition that the difference between the till in this limited belt and that in the remainder of the county, may be due to a greatly increased introduction of foreign material along some line as the broad, shallow basin which occupies the southern third of the county. The existence of this basin I recognize as the cause of the much larger proportion of foreign drift pebbles in its vicinity, for it favored subglacial transportation of them, but I do not think it alone can explain the phenomena connected with the above described belt of typical till. For (1) when we go east on the line of glacial movement, the characteristics of this till disappear, and in the extreme eastern portion of the county, what little till we do find in the Pecatonic basin, is mostly of the very imperfectly formed "semi-residuary" variety; and (2) if we study the limits of this characteristic till belt and the direction of ice movement, in connection with the limits of the main body of the extra-glacial lake clays and silts, we find such a relation between them as to clearly indicate the derivation of a large portion of the former from the latter.

In short, the composition of the till in the belt now under discussion, points to its being only a stage in advance of that described under stage No. 8, this advance being due chiefly to the introduction of a large amount of clay and silt, the result of an accidental passage of the ice over a semi-plastic lake deposit, which resisted erosion comparatively well, but yet suffered some abrasion at its surface. Therefore, as the yellow till occurs over and in the immediate vicinity of the stratified clays, there is no room for an englacial transportation, which is, moreover, quite unnecessary, and in opposition to the comparative abundance of striated pebbles.

In summarizing the evidence presented in the preceding pages, I would subdivide the product of direct glacial action, in the central Pecatonica basin, into classes as follows:

Class I. Semi-residuary drift. Till composed largely of rearranged red residuary clay and chert, with comparatively few foreign pebbles.

Class II. Angular local limestone débris. Varies between contorted, tilted, and transported unfractured rock ledges, and fine limestone breccia.

Class III. Consisting largely of a combination of the two preceding with the addition generally of Canadian pebbles and small bowlders. Usually seen in marginal deposits.

Class IV. Typical till. Light yellow gray calcareous clay containing pebbles and small bowlders of local and foreign derivation, many of the latter beautifully striated.

The divisional lines between these classes, in the Pecatonica basin, must always be arbitrarily placed, as there are gradations from those deposits which are typical of one class to those which are typical of another. There is, also, no definite rule in their distribution for, while the four classes evidently represent four successive general stages in the process of manufacturing typical till, and should, therefore, naturally be expected to occupy successive belts from the outer glacial boundary back or east, they are in reality scattered indiscriminately over the entire district. However, Class I prevails in the northern half of the county; Class II in a north and south belt which, extending across the county, has its western boundary on a meridianal line which passes a few miles west of Freeport, and dies away to the east near the Winnebago county line; Class III prevails over a belt several miles in width extending diagonally from the southeastern corner of the county to near Freeport; and Class IV is principally developed south of Yellow creek, over and near to the remnants of the Lake Pecatonica clays.

Perhaps the most remarkable feature of the drift of this county is its anomalous distribution. Over the western one-third of the county, the drift, although comparatively thin, is generally distributed. Over the central belt, the evidence of vigorous glacial action is strongest. While in the extreme eastern one-fourth of the county, which was glaciated longest, there is very little drift of any kind, and there are areas, several square miles in extent, of nearly bare rock, and others where the preglacial residuary clay still remains undisturbed. It is evident that the conditions which controlled glacial action varied locally within wide limits, so that excessive abrasion of the rock surface might occur with a less weight of ice and a less length of glaciation, than on a neighboring area with similar topography would not suffice even to remove the residuary clay. When I make the statement that the four classes of glacial deposits discriminated in this district, occupy hills equally as high, as narrow, and as steep, also occupy valleys equally as

FIG. 1.—The Kansan ice at work in northwestern Illinois.

deep and broad, and trending in the same direction, we are prepared to accept the following conclusions :

1. That certain glaciers, notably that which glaciated northwestern Illinois, in passing over a slightly hilly region, exerted very unequal pressure on the land surface, *this inequality not always being directly due to the topography of the immediate vicinity.*

2. In crossing hills of moderate height, they sometimes strongly abraded the crests, while on closely adjoining areas they deposited ground moraine on hills of similar height and shape.

3. The areas of maximum and of minimum glacial action were generally permanent, or approximately so, throughout the time of glaciation.

4. In studying areas in the Kansan drift region or at least that portion of it which is in northwestern Illinois, the relative length of the glaciation in different localities cannot be even inferred from the apparent severity of the glacial action.

In conclusion, I will state in more definite language what I conceive to have been the position with relation to the mass of the ice, of the unstratified drift of Stephenson county, Illinois. The derivation, transportation, and deposition of the material occurred mainly under the peripheral portion of the glacier. Here, through the thinning of the edge, the weight was less, and the force of the ice movement having decreased, there was a tendency of the extreme marginal portion to turn up, producing a base of a form somewhat as in the accompanying figure.

There was a struggle for the mastery between the advancing ice and the accumulating débris. The incipient morainic or marginal deposits of Stephenson county, including the transported rock ledges, belong to the extreme outer border of the ice and were transported least. Those which are most thoroughly kneaded belong to a position at about *b*. The drumlin (?) area south of Freeport may be placed at *c*, while much of the ground moraine was formed and deposited still farther back under the ice. By recession and repeated slight readvances of the ice-front, with a partial reworking of old deposits, the apparently indiscriminate distribution of the drift of this county may be accounted for. When the ice melted away entirely, the englacial bowlders which had become superglacial through ablation of the border portions of the glacier, and are so represented in the figure, came to rest upon the surface of all the other drift of the district and the areas of nearly bare rock represented at *a*.

If the advance was continued far, the ice overrode the coarse angular gravel at *a*, crushed it finer, brought up "semi-residuary" till and a little foreign drift from farther back, and combined them into typical till. This gradually fell behind the advancing border of the ice, and was redeposited as ground moraine, locally accumulating into drumlins and smoothly undulating drift areas, while the extreme outer portion of the glacier was forming a new deposit of angular local limestone débris.

OSCAR H. HERSHEY.

FREEPORT, ILL.,
January 5, 1897.

THE GEOLOGY OF THE SAN FRANCISCO PENINSULA.

The Coast Ranges of California embrace an extensive region in which are presented complicated but exceedingly interesting geologic problems. Much attention has been given to these mountains for many years, but with the exception of a study of the quicksilver deposits, it is only recently that we have had presented in a thorough manner the results of the detailed examination of local areas.

Professor Lawson's recent report upon the geology of the San Francisco Peninsula[1] is perhaps the best yet made of any local area in the Coast Ranges and illustrates well what modern methods of research can accomplish in a complicated field. Notwithstanding the excellencies of the report, there is an infelicity displayed in the discussion of several problems which is regrettable in a study of this kind. This has, however, necessarily resulted from the method pursued, in that the investigator has given his attention almost exclusively to a narrow field of complex geology and has failed to make use of the results of the work of others, concerning questions which the phenomena in that field did not illuminate. It is absolutely necessary for the appreciation of many facts in any local area, and for the philosophic discussion of the history of that area, that the student should have a general knowledge of the relations existing over the region as a whole.

As a result of some experience in the Coast Ranges I feel called upon in the interest of geological progress to express most profound objections to a number of conclusions reached by Professor Lawson concerning some of the vital questions involved in the geological history of this region. Consequently in answer to his frank request for friendly criticism, I will take up the dif-

[1] U. S. Geol. Sur., 15th Annual Report, pp. 405–476.

ferent points which I feel are open to question in the general order in which they occur in the report. There are several statements in a synopsis of this report,[1] published a year and a half ago, which will be included in the criticism. There is a failure, which is without doubt due to an oversight, to give recognition to some contemporaneous and earlier work in the same general field and upon the same topics.[2]

Passing over the Montara granite and the associated marbles which exhibit the same relations and have without doubt the same history as similar rocks in the Gavilan and Santa Lucia ranges, we come to the author's Franciscan series, the oldest uncrystalline terrane. Professor Lawson divides it into five petrographic divisions. The lowest consists of conglomerate, sandstone, shale, etc., and is well exposed at Point San Pedro. He considers that this division may possibly be older and underlie the strata north of San Pedro valley unconformably, because fragments of shale similar to that at the point occur in the sandstone north of the valley. The fact seems not to have been noticed that fragments of similar shale are found in the basal conglomerate on the point. The conglomerates are identical in character with those at the base of the Golden Gate series on the Monterey coast, and are without much doubt of the same age.

The "foraminiferal limestone" and "radiolarian chert" form perhaps the most interesting portions of the series. They are dwelt upon in detail, particularly the "cherts." According to Professor Lawson the latter are hard siliceous rocks of varying degrees of purity, and are "prevailingly of a dull brownish red color, although other shades occur." He says that "in many

[1] Am. Geol., June 1895.

[2] Bull. Geol. Soc. of Am., Vol. XI, pp. 71–102. The results of this work were read before the Geological Society of America nearly a year in advance, and published six months prior to the first of the papers under discussion. The subjects concerned were the position and character of the marbles of the Coast Ranges, and especially the rocks constituting the Golden Gate series (Franciscan series of Professor Lawson), the nature of the sandstones and the radiolarian origin of the jaspers, as well as the geologic position of the series.

cases they are true jaspers and have been so designated in some of the earlier descriptions of them." After discussing their variability he again says: "In view of this variation in petrographic character, it has been deemed best to refer to these rocks by the old and familiar name of 'chert.'" It seems to me that, on the contrary, the designation "chert" is not only not as appropriate for rocks of this character but it does away with "an old and familiar name" for no sufficient reason. The designation "jasper" was used by Blake, Newberry, and Whitney. According to Geikie, "Chert is a name applied to impure calcareous varieties of flint in layers and nodules which are found among the Palæozoic and later formations, especially but not exclusively in limestones."

The siliceous bands in the foraminiferal limestone which are referred to by Professor Lawson as "veins" I do not consider such in any true sense of the word; they are more properly cherts or phthanites according to the original use of the terms, but in regard to the great body of siliceous rocks occurring independently there seems to be no use in making a change in terms.

The nature of the so-called "veins" in the limestone seems not to have been clearly understood. On exposed surfaces of many feet in extent these siliceous bands stand out with great distinctness. Some of them are as even and regular as the limestone strata, while others are discontinuous and more uneven. They sometimes blend into the limestone but more commonly are quite sharply distinguished. These bands of chert are contemporaneous deposits, being always conformable to the stratification of the limestone, and differing most markedly from the veins of secondary origin. Thin slides prepared from a number of specimens show them to be thickly filled with organic remains of radiolarian character.

After a description of the jaspers several theories of their origin are considered. The theories are as follows: (1) siliceous springs in the bottom of the ocean, similar to those well known in volcanic regions; (2) radiolarian and other siliceous remains which may have become entirely disssolved in sea water; (3)

volcanic *ejectamenta* which may have become similarly dissolved. The two latter are rejected and the first received, as having the most to support it, in the following words: "The hypothesis of the derivation of the silica from siliceous springs and its precipitation in the bed of the ocean in local accumulations, in which the radiolarian remains became imbedded as they dropped to the bottom, seems, therefore, the most adequate to explain the facts, and there is nothing adverse to it as far as the writer is aware."

Some time since I proposed a theory[1] to account for the origin of the jaspers substantially equivalent to the second given above. Professor Lawson's chief objection to the view of the organic origin of these rocks consists in the fact that they occur in lenticular masses instead of evenly bedded deposits. In his petrographic description it is stated that the "cavities of the radiolaria have been filled with chalcedonic silica and are in definite contrast with the non-chalcedonic matrix." With this last statement my experience is not often in accord. I have found every gradation in the specimens from those in which the radiolaria are distinctly marked, as Professor Lawson says, to those in which they are only faintly distinguishable from the matrix, or apparently absent. In my opinion this state of things gives good ground for the view that, owing to possible transformations through the action of sea water, and the secondary changes which are known to have taken place, there is no valid reason for denying the organic origin even when no organic remains are distinguishable.

Professor Lawson has failed to recognize that the siliceous bands in the limestone must have had an origin similar to those occurring in aggregates by themselves. If the theory of formation by springs is applicable to one it is to the other. The occurrence of these radiolarian jaspers interstratified with the limestone is a most suggestive fact. Similar conditions of sedimentation must have obtained in the one case as in the other, the only difference being that at one time calcareous layers were

[1] Bull. Geol. Soc. Am., Vol. VI, p. 85.

formed, and at another siliceous. The local bands of silica, a few feet perhaps in lateral extent, wholly surrounded by limestone and sharply differentiated from it could not in all probability have been formed through the action of siliceous springs. The large lens-shaped bodies of massive jasper are also abruptly marked off from the inclosing sandstone or shale. If each lens were due to the action of one or more springs the currents must of necessity have been weak near the edges of the deposit and could not possibly be conceived as "sufficient to deflect sediment-laden counter-currents." If sedimentation were going on around the springs it is impossible that the silica could have been precipitated without more or less commingling with the sand. The presence of similar radiolarian jasper in the limestone is suggestive of the view that to whatever cause the lenticular form of the latter is due the same cause conditioned the similar outline of the former.

Turner[1] says of the limestones in the Knoxville at Mount Diablo, and of the older limestones in the Sierras that "each calcareous layer is rather a series of lenticular bodies than a continuous limestone stratum. This applies to the Sierra Nevadas as well, only there the limestone bodies are hundreds of feet in diameter." The belt of foraminiferal limestone described by Professor Lawson is equally bunchy, reaching a very considerable thickness in places, as on the northern slope of Black Mountain, and then contracting to very limited proportions. It thus appears that as far as the shape of the deposits is concerned the spring theory of origin is equally applicable to the limestone.

The statements in the report concerning the condition of the formation of the jaspers do not exactly accord. For instance, on page 426, Professor Lawson says: "If the springs were strong the currents engendered might in some places have been sufficient to deflect sediment-laden counter-currents, and this way serve to explain the general absence of clastic material in the chert." On page 466 he says: "At different more or less pro-

[1] Bull. Geol. Soc. Am., Vol. III, p. 394.

longed periods during the accumulation of the series the bottom of the sea sank sufficiently rapidly to be out of the reach of littoral sediments."

According to the observations of the author the body of the limestone is as free from detrital matter as the jasper, and except for the thickly scattered calcareous remains shows no more traces of organic origin than portions of the jasper.

I cannot see that the origin through springs has anything whatever to support it. It is undoubtedly true that a subsidence or change in ocean currents gave rise to conditions favorable to the accumulation of beds of jasper and limestone. It is, however, rather difficult to believe that this movement, which could not have been of a catastrophic kind, should have accorded exactly with the flow of hundreds, if not thousands, of springs over the sea bottom, which at one period were purely siliceous, and at another deposited nothing but pure carbonate of lime. If the currents were as strong as the author supposes, it does not seem possible that the radiolaria should have settled so thickly as we frequently find them, and besides the springs possibly being fresh would not form a congenial place for marine organisms.

A short discussion is given by the author to deposits which he terms silica-carbonate sinter,[1] the true nature of which seems not to be understood. He says: "Its occurrence in extensive sheets, roughly parallel with the bedding, suggests that it is a contemporaneous deposit, but it may possibly be a vein formation. Its occurrence in the Aucella sandstones elsewhere, and in the San Francisco sandstones of the peninsula is of interest as a possible factor in the correlation of these formations." This is a case in which wider familiarity with the Coast Ranges and their mineral deposits would have readily settled a very simple question. These deposits of sinter are almost always associated with quicksilver ores forming their gangue. The quicksilver deposits are known to date from post-Miocene times, and owing to their recent formation it is to be expected that

[1] Am. Geol., June 1895.

they would occur at all geological horizons. Consequently the correlation of the Knoxville with the Franciscan series (Golden Gate series) by this means is out of the question. The sinter is very similar all through the Coast Ranges, and any deposit is a possible source of quicksilver.

Professor Lawson's discussion of the structure of the older uncrystalline rocks shows, although he minimizes the importance of the disturbances which they have undergone, that it is often difficult of elucidation. The earlier observers have all remarked upon the difficulties connected with a study of the so-called metamorphic rocks, and we cannot admit that all of their work is "superficial." While the author is probably right in asserting that the larger structural features are comparatively simple in the area under discussion, yet it seems to me that there is good reason for believing that the structure is very complex in detail. This is shown by the fracturing and folding of the jasper bands; the frequent occurrence of crushed shale, and thin-bedded sandstone in a ruptured condition; and the presence of innumerable cracks and shear planes in the more massively bedded sandstones. Local areas occur, it is true, totally free from the effects of strain, but they do not dominate. A comparison of the sandstone at Point San Pedro with that north of the valley of the same name affords a good illustration. Both in the cliffs and on top of the point the sandstone weathers out in large blocks in a manner closely simulating the sandstone in the Cretaceous and older Tertiary in the Coast Ranges. On the contrary the similar sandstone in the hills north of San Pedro Valley breaks up in angular fragments; being permeated in many places with veins of quartz and calcite, or linear seamlike cavities. This fracturing and veining is also almost everywhere to be noted in the jaspers and limestone. Professor Lawson considers that because the number of parting planes decreases downward from the surface they are due in great part to atmospheric agencies alone, although he recognizes some shear planes. I believe, however, that we have good reason for holding that a large part of these planes which separate the sandstone into angular fragments are not due to atmospheric agencies alone, but that they are capable of being produced in thick-bedded rocks as well as in thin-bedded which have not been greatly sheared, but subjected to a rending strain. Such rocks under proper conditions can become recemented and apparently as massive as before. The cracks may thus become completely closed, or left slightly open and filled with calcite or quartz. Subjected to atmospheric agencies lines of weakness are soon developed, and the rock crumbles in angular pieces. A similar rock which has not undergone this breaking strain will weather either in large rounded knobs, or, if it be soft and argillaceous, break up into fragments more or less conchoidal.

Professor Lawson remarks further upon this subject as follows: "The superficial study of this phenomenon has led to grossly exaggerated views as to the amount of disturbance (shattering) to which the Coast Ranges have been subjected. The sharply marked alternation of wet and dry seasons, combined with the treeless character of many of the ranges, is peculiarly favorable to this disintegration."

It is only necessary to compare the most of the sandstones of the Golden Gate series with those of the Cretaceous or Tertiary to see the vast difference in the manner of weathering. As a result of my experience through nearly the whole of the Coast Ranges, I feel satisfied that peculiarities of climate have not been the cause of the phenomenon under discussion. The abundance of cracks and shear planes in the older rocks is one of the chief reasons why it is so difficult to obtain good building stone from them, although the sandstones are characteristically thick bedded.

I think that Professor Lawson has underestimated the amount of disturbance to which the Golden Gate series has been subjected. It is not necessary for the folds to be involved or intricate, although they certainly are in many places, for it to have undergone a large amount of strain, fracturing, and shearing.

Professor Lawson professes to be entirely ignorant of the "orogenic movements which effected the deformation and faulting of the Franciscan series" as well as of the relative sequence of these disturbances and the peridotitic intrusions. This is, of course, excusable in one studying only a narrow field where a part of the record is wanting, but too much is at present known of the wider field of Coast Range geology for one to plead ignorance on these questions.

The initial disturbance of the Golden Gate series, with the exception of that produced by the contemporaneous intrusions and flows, dates from the post-Jurassic upheaval. Leaving out of account the serpentine, there is evidence that many of the eruptive bodies associated with this series were subsequently formed. The intrusive nature of the diabase at Hunters point is recognized by Professor Lawson, and he is certainly correct. To the presence of these eruptives, I believe, is to be attributed the extreme disturbance in local areas.

As to the age of the Franciscan series[1] of Professor Lawson nothing more definite is advanced than the evidence of a few imperfect fossils, which cannot be determined specifically and in many cases not even generically. These fossils are supposed to favor the old view of a Cretaceous age. He says: "Evidence, such as it is, is confirmatory of the opinions of Whitney and Becker. . . . . The series as a whole is very probably older than the Knoxville Aucella horizon of California. The writer has no doubt upon this point."

Professor Lawson gives no reason for assuming the series to be older than the Knoxville, and since Mr. Stanton's[2] work places the Knoxville *Aucella* horizon at the base of the Cretaceous, it is difficult to understand how these pre-Knoxville rocks can be included in the Cretaceous.

[1] This designation (American Geologist, June 1895) embraces the same aggregate of strata to which I have given the name Golden Gate series (JOURNAL OF GEOLOGY, May–June 1895) from its characteristic exposures at the entrance to San Francisco Bay. As to which name shall finally be accepted I am, for my part, willing to rest the case, although another claim might with great justice be added, on the truth or falsity of my published statements as to its age and stratigraphic position.

[2] Bull., No. 133, U. S. Geol. Sur.

Again Professor Lawson argues for the post-Jurassic age of the granites in the Coast Ranges, and in order to account for the fact that the pre-Knoxville rocks rest on the granite with a basal conglomerate, he is obliged to assume that they are a part of the Cretaceous. The correctness of one view argues much for the other; if one falls both must be considered invalid.

Again he says: "Fairbanks has combated the views of Whitney and Becker, and has pronounced the series to be of pre-Cretaceous age. He has not yet, in the writer's opinion, established the correctness of his contention." I wish to call especial attention to this statement because of the fact that Professor Lawson has not advanced one particle of evidence in refutation of my published statements as to the existence of a nonconformity between the Knoxville and these lower beds. It is hardly probable that we shall soon find any fossils in good enough condition to be decisive concerning the question at issue, and the main dependence must be placed upon stratigraphy. The fact that these rocks (Golden Gate series) lie unconformably beneath the Knoxville is shown by the most strongly marked contrast, structurally as well as lithologically, in addition to the stratigraphic break which I have described in previous publications.

In closing his description of the stratigraphy and structure of the Franciscan series, Professor Lawson says in regard to the disturbance of the strata: "The most of it seems to have long antedated the uptilting of the Montara fault block, so that the latter differs from most tilted blocks with which we are familiar. These are commonly tilted blocks of strata previously undisturbed, and the tilting is recognized by the attitude of the strata and the presence of fault scarps. In the present case, however, the region has been moderately folded and profoundly faulted with local sharp plication." As far as I am conversant with the geology of California and adjacent parts of Nevada, the fault blocks are commonly not tilted blocks of previously undisturbed strata, but exactly the opposite; that is, the strata have been more or less highly folded and tilted previous to the faulting, much of which now recognizable, is of quite recent date, geologically speaking.

In the last sentence quoted Professor Lawson seems to recognize quite fully the complicated structure of the Franciscan series.

The serpentine in the area covered by Professor Lawson's report is divided into three linear tracts. One extends across the city of San Francisco from Fort Point to Hunters Point, a distance of ten miles, with a width of one and one-half miles. Another large tract extends from San Andreas Lake to San Mateo Creek, having a length of eleven and one-half miles and a maximum width of one mile.

According to the description these bodies occur as laccolites, laccolitic sills, or dikes. From a careful perusal of the report, and an examination of several of the more important areas covered by these eruptives, I cannot understand the reason for applying to them the designation laccolite. This term was originally given by Gilbert to an eruptive mass which in the course of being forced upward, instead of reaching the surface, finally spread out between the strata, forming a thick lens, and arching them over it in dome form. Professor Lawson is certainly right in the statement that the main bodies are not true dikes, but it seems to me that the term sheet or sill which he uses quite frequently is the really proper one for these eruptives. If the term laccolite has any exact meaning it is certainly not synonymous with sheet or sill.

I have carefully examined the so-called laccolites of Hunters Point, Potrero and Fort Point and can find no evidence that these eruptive masses were ever covered by an arched roof. In my opinion the field relations indicate that they cooled as sheets or dikes. They have no appearance of being lens shaped, and if it is true, as Professor Lawson supposes, that they are all connected through the distance of ten miles, we have then a long sheet inclined at an angle of 35° to 40°; and though in a general way intruded along the bedding planes of the sandstone and shale, yet, owing to the marked irregularities of the surface of the eruptive sheet, the inclosing strata have been much disturbed and show locally a marked variation in strike and dip.

The remnant of a supposed laccolite roof on Hunters Point I would interpret to be a body of jasper and sandstone or shale inclosed in the serpentine, as a portion of it occupies a sag between higher serpentine ridges, and apparently extends down into a small ravine.

It is fully as difficult to believe that the Fort Point occurrence is a laccolite. The stratum of shale, sandstone, and occasional bodies of jasper, which appears in the cliffs and along the beach south of the fort, dips into the cliffs at an average angle of not less than 30°, and it seems to me that it can be nothing else than an inclusion between two sheets of serpentine.

The exposures at the Potrero are good and bear out the opinion which I have already expressed.

That the two dominant ridges, Montara Mountain and San Bruno Mountains, are fault blocks of such importance, or their diastrophic history so clear as Professor Lawson outlines it, does not seem evident to me. The San Bruno Mountains are said to be the older block, but the southern slope facing the supposed fault is remarkably bold and steep, not showing an advanced stage of degradation, and in addition the northern slope is almost as abrupt. The supposed fault of 7000 feet appears almost incredible, and it does not seem at all necessary to postulate it in order to account for the position of the Merced series. That this series should once have existed over the whole of the northern end of the San Francisco peninsula appears very problematical at least. That a series over a mile in thickness, and of so late an age, should have been so completely removed as not to leave a trace north of the supposed fault it is not easy to believe.

I cannot find any evidence either of the supposed great fault on the southern slope of Montara Mountain. The topography as a whole does not support the idea, and that the ridge is a simple tilted block is not supported by the evidence which Professor Lawson adduces of important faults on the northern slope. Professor Lawson's suggestion in another place that Montara Mountain has been forced up through the strata in the manner of a telescopic thrust appears to me to have an important element of truth in it. This thrust probably resulting from lateral compression produced the elevation of the granite, partly, at least, through shearing.

It would appear that the evidence in favor of the successive appearance of the "two dominant fault blocks" is exceedingly slight. While the San Bruno Mountains are considered to have been above the sea level and the Pliocene undergoing erosion, there is believed to have been no such subaërial period for Montara Mountain until the final uplift resulting in the terrace deposits. This is opposed to the observation of Mr. Ashley[1] as well as to my own views concerning the general post-Pliocene elevation of the coast. By this elevation I do not mean that to which the terraces are due, but an earlier one resulting from the same influences which deformed the Pliocene sediments the whole length of the California coast.

In regard to the age of the granite Professor Lawson[2] says: "The simplest and most natural hypothesis that suggests itself is that the granite corresponds in age with that of the Sierra Nevada, and this hypothesis has not yet been exhausted of its strong probability of truth. The granites of the Sierra Nevada, in so far as their age is known, are clearly post-Jurassic. Granites of about this age are extensively developed along the west coast of North America from Alaska southward. The granites of the southern and northern Coast Ranges seem to be geologically continuous with those of the Sierra Nevada. The fact that the Sierra are separated from the Coast Ranges by the valley of California is immaterial to the discussion, since the latter is clearly a delta-filled geosyncline of late Tertiary or post-Tertiary origin. There is therefore a strong presumption in favor of the view that the granites of the Coast Ranges and those of the Sierra Nevada are of common origin and common history. This presumption must be steadily kept in view till it is negatived by positive evidence."

[1] Neocene Stratigraphy of the Santa Cruz Mountains, p. 334.

[2] Am. Geol., June 1895.

It does not seem to me that there is any validity whatever in the above reasoning, and in the light of the true position of the Golden Gate series there is a strong presumption in favor of an opinion exactly opposite to that just quoted. In fact the presumption is so strong that it amounts almost to a certainty that the granite in the Coast Ranges is older than the main body of the granite in the Sierras. What we at present know of the position of the Golden Gate series points to the fact that its first upheaval was contemporaneous with the last great upheaval recorded in the rocks of both the Sierras and Klamath Mountains. The Mariposa beds involved in this upheaval in the Sierras are held to be Upper Jurassic. The Knoxville beds deposited after this upheaval are believed on the best authority to be Lower Cretaceous; and if we make the granite in the Coast Ranges the same age as that in the Sierras, we must crowd into the break between the Mariposa beds and the Knoxville, a series of beds thousands of feet in thickness and separated from the Knoxville by a break as profound as that between the Knoxville and the Jurassic.

There is every reason for assuming that the granitic rocks of California are not all of the same age. Granitic bowlders occur in the Mariposa beds south of Colfax, a fact pointing to a pre-Jurassic granite body in that region.

The youngest fossiliferous rocks associated with granite in southern California are probably of Carboniferous age, and while the extension of the crystalline basement rocks of that region northwestward into the Coast Ranges is not likely to be much younger than the Carboniferous, for all that we know at present it may be much older.

HAROLD W. FAIRBANKS.

BERKELEY, CALIFORNIA.

EDITORIAL.

THE success of the recent meeting of the Geological Society of America was undoubtedly due to the fact that it was held in Washington. No other city in the country offers so many attractions to geologists in the winter time as the national capital. Containing as it does the largest body of geological investigators to be found in any one place in the world, it has become a center of geological activity and the repository of many valuable collections. Located within easy reach of the universities of the East and South and of the Middle West it has become a favorite rendezvous for geologists scattered throughout these parts of the country. For these reasons the suggestion made by Mr. Walcott, Director of the United States Geological Survey, that the society hold all its winter meetings in Washington and its summer meetings elsewhere, is an excellent one, and was heartily endorsed by the retiring president, Professor Le Conte. Since the present method of entertaining the society would prove a burden upon the Washington members if repeated annually, it would be proper to allow the visiting members to share the expense by dividing the cost *per capita*. It is to be hoped that the proposition to meet annually in Washington be considered seriously by the society.

The necessity of more expeditious methods of conducting the presentation of papers and the need of a livelier sense of obligation to fellow-members on the part of those misusing the time of the meeting were apparent. It ought not to require long reflection to convince one that beyond a reasonable use of time the tax on the patience of an audience defeats the object of an address, and is more than a waste of energy.

It is to be noted that the present unsatisfactory process of conducting the annual election resulted in the only regrettable incident connected with this otherwise highly successful meeting. The present method should be changed speedily. It has been suggested that a process should be adopted by which the secretary should send to every member blanks for nominations for each officer; each member to nominate one person for each office. Upon receiving these nominations the secretary should ascertain those having the two highest numbers of nominating votes, and mail to each member a ballot placing these in nomination, and requesting a vote.

The extent of the interest taken in the meeting is shown by the number of papers presented, which reached forty-nine, and by the fact that discussions were quite generally participated in. The presence of ladies at the banquet and the efforts of the committee on entertainment and those of the toastmaster, Professor Emerson, combined to render this feature of the meeting most enjoyable. J. P. I.

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IN the October-November number of the JOURNAL OF GEOLOGY (p. 811) Mr. J. B. Tyrrell's paper on the "Genesis of Lake Agassiz" includes incidental reference to the application of the name "Laurentide Glacier," upon which it may be useful to make some comment. When it had been shown by the writer that the Cordilleran ice-sheet of the West was self-contained, it became evident that the great eastern division of what had previously been referred to as a "continental glacier" required some distinctive appellation. The name Laurentide glacier was then proposed in the following terms: "Recognizing, however, the essential separateness of the western and eastern confluent ice-masses, and the fact that it is no longer appropriate to designate one of these the 'Continental glacier' the writer ventures to propose that the eastern *mer de glace* may appropriately be named the *Laurentide glacier* while its western fellow is known as the *Cordilleran glacier*."[1] Thus it appears that the

[1] American Geologist, Sept. 1890. See also Trans. Royal Soc., Canada, Vol. VIII, Sec. IV, p. 56.

term Laurentide glacier was intended to designate an ice-sheet developed upon the entire Laurentian plateau or protaxis — the Canadian shield of Suess — which extends itself, as a relatively elevated tract of U-shaped form around the depression of Hudson Bay, from Labrador on the east to the Arctic Ocean near the mouth of the Mackenzie on the west.

Mr. Tyrrell's investigations relate particularly to that arm of the protaxis which lies to the west of Hudson Bay, and upon the northern part of this he has been able to define a center of dispersion of glacier-ice to which he has applied the name "Keewatin glacier." He suggests that the name Laurentide glacier may now be relegated to the similar center of radiation of ice shown by Mr. A. P. Low to have existed on the Labrador peninsula, and supposes that ice from the latter gathering-ground (at a date subsequent to that of the greatest spread of the Keewatin glacier) crossed the southern part of Hudson's Bay to the Winnipeg basin as well as to that part of the continent in the vicinity of the Great Lakes. It is, however, tacitly assumed that no general occupation of the Laurentian plateau by glacier-ice occurred at a period antecedent to that in which the Keewatin glacier became defined; although, to the writer, it seems probable that at one time this plateau or axis was thus covered by ice in all its length and that this ice moved down from higher to lower levels in conformity with the normal slope in all directions.

A second assumption (to which, however, several writers on this subject besides Mr. Tyrrell have given credence) is that implied in the suggested passage of glacier-ice originating in the Labrador region across the watershed to the north of the Great Lakes. The actual evidence on this point appears to the writer to be slight and inconclusive in its nature. Our knowledge of the rocks of the great region involved is, it is believed, insufficient to prove that any erratics from the basin of Hudson Bay have actually crossed this watershed to the south or southwest. Nor can the observed directions of striation be taken as definitely indicating ice-movement in a southerly sense in all cases, for at the time of observation of many of these, it cannot be doubted that a southerly rather than a northerly motion was naturally assumed, in consequence of hypotheses then unquestioned, and without the critical examination called for in view of later discoveries. So great an extension of an ice-sheet originating on the Labrador peninsula, is all the more doubtful in the light of Mr. Chalmer's investigations, which show that no glacier-ice from the northward crossed the highlands to the south of the St. Lawrence below Quebec. These highlands developed in New Brunswick and northern Maine, an independent center of dispersion, which Mr. Chalmers suggests may be referred to as the Appalachian system of glaciers or the Appalachian glacier.[1] If, therefore, we may admit the existence of a Laurentide glacier of early date and such as to envelop the whole Laurentian plateau, the Keewatin glacier of Mr. Tyrrell, with that which may be named the Labradorian glacier,[2] as known to us by Mr. Low's work, may be regarded as relatively local (although still very important) centers of dispersion connected with a diminishing stage of the glacial period. In this case the overriding of the area at one time covered by the southward extension of the Keewatin glacier by ice from the eastward (as demonstrated by Mr. Tyrrell) may be attributed merely to a still later reëxtension, due to climatic changes, of that part of the Laurentide glacier situated to the east of Lake Winnipeg. If, on the other hand, it should ultimately be shown that no continuous ice-sheet ever covered the entire length of the Laurentian plateau, the several great glacier masses actually known to have been developed upon these highlands may still be appropriately considered as constituting together a Laurentide group, as distinguished from the great western Cordilleran ice-mass.

In the case of the Keewatin and in that of the Labradorean glacier, it has been shown by Messrs. Tyrrell and Low that the centers of dispersion changed, giving rise to superposed series of striations, and it appears probable that in the study of this

[1] American Geologist, Vol. VI (1890), p. 325.

[2] This has, I believe, already been proposed by Mr. F. B. Taylor.

migration of gathering-grounds of glacier-ice on the Laurentian highlands, the explanation of many otherwise anomalous circumstances will yet be found. Any inquiry into the causes of such migration opens a wide field of discussion, including particularly meteorological and possibly changed orographical conditions. Other things being equal, it is obvious that the places in which the accumulation of glacier-ice began would also in all probability be those where the last centers of its dispersion continued longest and ultimately failed. It is very important to trace the migration of these centers from which the ice flowed, and if possible to ascertain the conditions which, in all probability, may have interfered with the coincidence of the initial radiant areas and those marking the close of the epoch of glaciation.

G. M. D.

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It would appear from the papers of Professors Tarr and Barton read at the recent meeting of the Geological Society at Washington, abstracts of which appear in this number of the Journal, that Professor Salisbury and myself must have invited misinterpretation of our views respecting the former extension of the inland ice-sheet of Greenland by infelicities of expression not altogether evident to us. What we have thus far published has consisted, in the main, of brief statements intended rather to show the bearing of the topography of the coast upon the larger questions of glacial prevalence than to indicate the precise local extension of the ice. In the series of papers entitled "*Glacial Studies in Greenland*" (not yet complete, having been interrupted to give earlier place to contributions awaiting publication), the specific subject of former glacial extension has not yet been reached. When it shall be, however, we shall not wish to be understood as attempting to map the precise limit of former glaciation on the thousand miles of borderland along which we coasted, but merely as endeavoring to indicate its general limitations. We believe, neverthless, that our observations and inferences are thoroughly trustworthy in the general sense in which they are intended to be received, and that they are decisive in their bearing upon two general hypotheses of wide interest; the one, that the ice-cap of Greenland formerly stretched across Baffins Bay and Davis Strait and became the source of the mainland ice-sheet; the other, that, in a former supposed state of elevation, the ice-cap pushed out into the heart of Baffins Bay or into the Atlantic until it reached adequate conditions of wastage by flotation or by low-level extension. In either case, the borderland of Greenland must, presumably, have been effectively glaciated for a long period, and should manifest this in the subjugation of its topographic contours. In its bearings upon these general problems, an advance of a few miles, more or less, an ineffectual overtopping of a few heights, more or less, are relatively inconsequential. Our language is to be interpreted in the light of the major questions whose solution we sought.

There does not appear, however, to be any essential lack of harmony between the data of Professors Barton and Tarr and the interpretations of Professor Salisbury and myself, unless it be in relatively unimportant details. Professor Salisbury makes the following statement relative to the region (this JOURNAL, Vol. III., pp. 876–7):

> On the whole, judging from topography alone, it seemed more probable that the coast from about latitude 70° north to the end of the Nugsuak peninsula [the southern one] had not been recently smothered in ice, though it is well possible that the ice-cap may have once extended beyond its present limits, and that isolated glaciers occupied the valleys leading down to the sea. The northwest end of the peninsula bears the marks of the passage of ice over a considerable part of the coastal front. North of Nugsuak peninsula, and from that point to the south side of Melville Bay, the topography of the coast, so far as seen, indicated general, though not universal, glaciation. Thus the southwestern end of Svarten Huk peninsula (71° 30′) has a topography denoting the absence of glaciation.

This embraces both of the districts in question.

Relative to the region of Professor Barton's studies, I made the following (unpublished) note on July 18, 1894, at the conclusion of detailed notes on Hare island, the Nugsuak peninsula, (the one south of Umanak fiord), Ubekyendt and Upernivik islands, Svarten Huk peninsula, and Disco Island:

I infer that the inland ice once pushed out into Baffins Bay through the Waigat and through Umanak fiord and overlapped the adjacent lands, but did not overtop the highest parts of Disco, Upernivik and Ubekyendt islands and Svarten Huk peninsula. The ice border rose 2000 feet above the present sea surface, but probably not 3000 feet on the coastal line, quite certainly not 4000 or 5000 feet. I have traced on the chart a theoretical outline of the farthest ice. This of course does not include local ice on the uncovered land. It, on the contrary, presumes it.

This hypothetical line starts with the northwestern part of Disco Island and swings outside of Hare island and some distance off the extremity of Nugsuak peninsula, touches the outer side of Ubekyendt Island, and thence connects with the southern portion of Svarten Huk peninsula. The outer curve of this line is *sixty miles away from the present border of the inland ice* and embraces the entire territory of Professor Barton's special studies, as I understand them.

I have no notes on the northern Nugsuak peninsula which was the special field of Professor Tarr's studies, the Falcon having turned away from the coast somewhat south of it to attempt the "middle passage" of Melville Bay, and, failing in this, returned to the vicinity of the coast a little north of the peninsula. On the region next south I made the following note on July 19:

With the exception of Sanderson's Hope and a few other prominences south of it, the whole region shows rounded contours, so far as seen. The small islands are well-rounded domes of rock that appear entirely bare. I could not detect any bowlders or other débris upon them. They are simple *roches moutonnées*, but not strikingly typical as such. The reduction has not completely subordinated them to glacial types. I have no doubt the ice pushed out well into the bay here. Some of the higher peaks may have remained as nunataks.

These small islands are rather farther away from the edge of the inland ice than the similar ones described by Professor Tarr.

It appears, therefore, that we explicity recognized predominant glaciation reaching out from 30 to 60 miles, and trespassing on the borders of Baffins Bay, and that we excepted only some of the higher points. It is only by demonstrating that these were submerged by the inland ice that any notably greater extension can be established, and the most of these points were not visited by the members of the recent expedition, nor were comparable heights of like situation near the coast line studied. Sanderson's Hope is charted as 3467 feet; a point on Svarten Huk peninsula, as 5230; a point on Disco Island as 5110, and many other points range from 3000 feet upwards. At most, therefore, the differences between us are merely matters of minor detail so far as observational determinations are concerned.

This advance of 30 to 60 miles seemed to one party to call for expressions of amplitude, to the other, instinctively making comparison with the many hundreds of miles of ice invasion of the mainland, to call for diminutives. Here is, indeed, a wide *psychological* difference, and we can contribute nothing to minimize this difference. Under the widest permissible interpretation of the facts as seen by either party the advance seems to us emphatically small, and very significant in its smallness.

The reliefs of the region seemed to the earlier party to belong to the semi-subdued type. The later party appear to have supposed them to represent the *unsubdued* type of the earlier party. The determinations of the later party are, however, in close accord with the classification of the earlier party.

It is possible that Professors Tarr and Barton unconsciously transferred to this region our rather emphatic descriptions of certain markedly serrate tracts farther south, and of certain ragged islands lying to the north, *e.g.*, Dalrymple Island (figured in this JOURNAL, Vol. II, p. 661), and Cone Island (Fig. 1., Vol. III., p. 772). As indicated above, we did not class the topography of the region in question under the markedly ragged and serrate type but under an intermediate one of partial subjugation. The figures referred to illustrate our standard of the former class. The courteous suggestion that the differences of interpretation were due to our point of view on the leeside of the prominences is inapplicable to the important case of Disco Island, for Professor Salisbury passed on the stoss side. It is only measurably applicable to the rest of the territory, as the oblique views of approach and retreat gave traversing lines of vision that partially reached the stoss contours.

This rather extended note has its purpose in a desire to make clear the narrow limits of such differences of observation as may exist and to show that the two main questions of general interest are essentially unaffected by them. Glacialists may feel sure that the conclusions derived from the topographic study of a thousand miles of the coast, even though cursory, and limited by conditions, will be found decisive on the main issues.

T. C. C.

REVIEWS.

Manual of Determinative Mineralogy, with an Introduction on Blowpipe Analysis. By GEORGE J. BRUSH. Revised and enlarged by Samuel L. Penfield. New York: John Wiley & Sons, 1896.

Since its first appearance in 1874, Brush's *Determinative Mineralogy and Blowpipe Analysis* has filled the demand for a text-book in this science almost to the exclusion of others. The tables, especially, proved to furnish an exceptionally ready and accurate means of identifying mineral species. The use of the book has of late years, however, been confined largely to the tables, since its opening chapters, while valuable for reference, were hardly adapted for class instruction, if, indeed, they were intended to be so used. This lack in the book Professor Penfield has most satisfactorily filled in the new form in which he now presents it. In its present form it furnishes not only a complete text-book for class use, but also a work which should enable even the novice without further aid to gain a practical knowledge of determinative mineralogy.

Opening with a statement of the chemical principles especially applicable to mineralogy, for the author remarks that mineralogy is chiefly a chemical science, the next chapter treats, with excellent illustrations, of the apparatus and reagents to be employed and of the nature and uses of flames. Several new experiments incorporated here add much to the value and interest of the chapter.

In the following chapter the reactions of the elements, arranged in alphabetical order, are given with great fullness, while carefully described experiments show how many of the typical reactions can be obtained. Every detail is here given with a care and precision that might at first sight seem superfluous, but the necessity for each, Professor Penfield, it may be believed, has fully proved in his long experience as a teacher of the subject. The student will at least be impressed with the need of care and accuracy in making the tests and will not be led to expect satisfactory results if they are not so performed. If there be any criticism to be made of this portion of the work it is to wish that more mention had been made of possible interfering elements, for the field mineralogist rarely has cabinet specimens to deal with.

In the next chapter the blowpipe and chemical reactions are tabulated in a form which will be recognized as a distinct improvement on those of the earlier book. The tables are models of clearness and completeness. With an introduction to the use of the tables, the revised portion of the work closes, but promise is made of an early revision of the tables, including the introduction of new species and many changes and corrections in the chemical formulæ. To express the hope, which will be general, that this promise may soon be fulfilled, is to bestow the highest praise on the work which has been already done.

O. C. Farrington.

The Dinosaurs of North America. By Othniel Charles Marsh. Sixteenth Annual Report of the United States Geological Survey, Part I, pp. 133–414.

Under this title Professor Marsh has published, in an article of 101 pages of text, a résumé of his long series of papers on the Dinosauria of North America. Intended as it is for the general reader, there are few new facts brought out, and the specialist finds little of value to himself beyond the convenience of a condensed statement of Professor Marsh's views, and the large collection of illustrations which form so important a part of the paper. There are eighty-four plates and sixty-six figures in the text. Most of the plates are familiar to the readers of the *American Journal of Science*, as they are enlarged copies of the ones accompanying the author's papers in that journal.

The author's aim is "to give the general reader a clear idea of some of the type specimens of one great group of extinct animals that were long the dominant forms of life in this continent." Of especial interest to such a class must be the restorations attempted by Professor Marsh, and it is well to issue a warning against receiving as entirely accurate restorations which, made in many cases from incomplete material, can only represent the author's idea of the most probable form of the skeleton. In the same spirit of warning we must call attention to the statement that "the best authorities regard them (the Dinosauria) as constituting a distinct subclass of Reptilia;" indeed, it should be remembered that some of the "best authorities" are among those who assert "that these reptiles do not form a natural group, but belong to divisions remotely connected and not derived from a common stock." It is, to say the least, a very open question whether the groups defined as the orders *Theropoda*, *Sauropoda*, and *Predentata* are not distinct and unrelated.

The Dinosaurs are discussed in the order of their appearance in time. The Triassic Dinosaurs come under Part I and are followed by the Jurassic and Cretaceous forms in Parts II and III. These parts are confined to descriptions of the anatomical characters of the various forms and their distributions. The author discusses briefly in this connection the European forms and their relations to the North American forms.

Part IV is taken up with a general discussion of the relationship of the Dinosauria to the Aëtosauria, Crocodilia, Belodontia, and Aves, to all of which groups he finds many points of similarity.

Part V is devoted entirely to a classification of the group which he regards as a distinct subclass *Dinosauria*, with three orders *Theropoda*, *Sauropoda*, and *Predentata*. The order *Theropoda* contains ten families and the four suborders *Cœluria*, *Compsognatha*, *Ceratosauria*, and *Hallopoda*. The order *Sauropoda* contains six families and no suborders. The order *Predentata* contains eleven families and the suborders *Stegosauria*, *Ceratopsia*, and *Ornithopoda*.

Professor Marsh has retained the opinions which he has expressed in his former publications on the same subject, many of which have been criticised and controverted in current scientific literature, so that, while the work will find its chief, and a great value, to the reader who has not access to scientific periodicals, he must not lose sight of the fact that the taxonomic position of the animals comprising the heterogeneous group called Dinosaurs is still an unsettled question.

E. C. C.

ABSTRACTS.

PAPERS READ AT THE WASHINGTON MEETING OF THE GEOLOGICAL SOCIETY OF AMERICA.

Glacial Observations in the Umanak District, Greenland. By GEO. H. BARTON.

A party consisting of six persons under the direction of Professor Alfred E. Burton, of the Massachusetts Institute of Technology, was landed by the Sixth Peary Expedition at the village of Umanak, Lat. 70° 30′, on an island in Umanak fiord, August 5, 1896. On September 9 the party was again taken on board for the return home. Between these dates observations were carried on upon the marginal area of the continental ice-cap to a distance of fifteen miles inland, and upon the glacial tongues passing down from the ice-cap by the various valleys leading into the Karajak and Itivdliarsuk fiords.

The region of the Umanak District was selected for investigation because of the facilities offered for much to be seen in the short time at the disposal of the party. Easy access to the edge of the inland ice by means of the larger fiords, the many glaciers large and small descending near or into the waters of the fiords, the great number of icebergs constantly passing out into the open waters of Baffin's Bay, and finally the fact that this region had not been visited by Americans, caused the selection.

Access to the surface of the inland ice was obtained from the nunatak lying between the Greater and Smaller Karajak glaciers. Considerable difficulty was encountered in getting upon the surface owing to the precipitous, generally vertical, sometimes overhanging character of the edge, rising from ten to forty feet. In only three places for a distance of over twenty miles did the edge present an inclined surface sufficiently gentle in slope to allow of ascent or descent.

In attempting to pass inland upon the ice the crevassing of the Greater Karajak glacier was found to extend far backward so that our course had to be deflected for several miles and finally to pass along the neutral ground between the two Karajaks. The elevation of the ice surface where first reached was about 1500 feet above sea level, while our fartherest point inland was about 2950 feet in elevation.

For a distance of about two miles the surface of the ice is very rough, consisting of a series of billows, very much like a frozen short, choppy sea. Over this it was very difficult to drag the sledge which constantly upset. This area was also full of dust holes from the size of a pencil to three feet in diameter and an average depth of about two feet. These were filled nearly to the surface with water and had a layer of dust in the bottom, an inch or two in thickness.

Beyond this we passed through a crevassed area for two or three miles and then came to a broadly rolling, undulating area which stretched away as far as the eye could reach looking like the American prairies in winter. The surface here was hard and crisp so that walking was very easy.

One lake was seen with several small streams flowing into it and one large stream flowing from it toward the land. Small streams were constantly encountered except in the crevassed area all flowing toward the land or toward the lake. One large stream, twenty to thirty feet across, and twenty to twenty-five feet deep, including five feet of water, was found at the farthest point reached flowing directly away from the land toward the interior.

No detritus was found on the inland ice except the dust in the dust hole area. Outside of this area the water of the streams was clear and their channels showed only clear ice.

The two important glaciers studied were the Greater Karajak and the Itivdliarsuk glaciers. The first of these has a width of about five miles and a length of from ten to fifteen miles from the edge of the inland ice to the waters of the fiord at its frontal face, but the crevassing of its current passes backward several miles into the mass of the inland ice. The elevation of the surface of the glacier as it first leaves the margin of the inland ice is about 1500 feet above sea level while directly at its frontal face it is about 500 feet. This gives a gradient of about 1000 feet in a distance of about ten miles, or 100 feet to the mile.

The rate of motion was carefully studied by Professor Burton during a period of nearly thirteen days. The result showed that there was an eddy in the ice at the point where the observations were made, as the ice near shore was moving slightly upstream. At a distance of 1708 feet it was stationary, while at a distance of 3396 feet the motion amounted during this time to 30.20 feet or 2⅓ feet per day. Up to this distance stakes had been set in the ice. At a distance of 2.4 miles a peculiarly shaped pinnacle furnished a point of observation. This was found to move during the same time a distance of 236 feet or about 19 feet per day.

This was the only case in which the actual rate of motion was determined. The Itivdliarsuk, three miles in width, was crevassed completely to the shore margin so that it could not be traversed with any safety, and no attempt was made to determine the rate of the smaller ones. Neither of these large glaciers carry any detritus either superglacial or englacial, except in the case of the Itivdliarsuk. Small nunataks near its source furnish two medial moraines which can be traced nearly throughout its length on the surface but are largely incorporated as englacial material before reaching the terminus. The edge of the larger glaciers like that of the inland ice is almost always nearly vertical with a height of from ten to forty. The structure is distinctly banded usually, apparently due to a shearing of the upper portions over the under from the central portions of the stream shoreward, the layers being inclined away from the shore.

Lateral streams flowing along the margin often cut caverns into the ice by means of which opportunity is furnished to study subglacial action. Small bowlders caught between larger ones or between a larger one and a projecting ledge are often broken into small fragments or ground to powder. In the case of rapid motion of the ice, distinct vacant spaces are left between the lee of a boss of rock and the ice, but where the motion is slow the ice is kept pressed against the lee side of the boss taking on a fanlike structure as it is pressed downward.

Lateral moraines along the sides of the glaciers are always present. They consist of a mixture of angular, subangular and rounded fragments, usually with considerable sand and a little clay, and occasionally largely made up almost entirely of till-like material.

From the edge of the inland ice and also from the detached icecaps of the Nugsuak peninsula a large number of smaller glaciers descend the more or less narrow gorges, some reaching sea level and discharging icebergs, but the majority terminating from 100 to 1000 feet above the sea. The gradient of descent varies strongly in the various ones. In some it is very steep, in some very gentle, while many have a great change in various portions of their own length.

With two exceptions all the glaciers show evidence of diminution in length and depth, in older terminal moraines and glaciated surfaces farther down the valleys and older lateral moraines higher up the sides.

The two exceptions, near Sermiarsut on the Nugsuak peninsula seem to be overriding terminal moraines of not great age but these were seen toward the last of my work and were not carefully studied.

Everywhere throughout the regions visited there is evidence of the former greater extension of the inland ice, it having covered all the highest peaks, passed out over the ends of the promontories, filling the fiords and passing into the waters of Baffin's Bay.[1]

The peaks which present sharp serrated edges toward Baffin's Bay are distinctly rounded on the sides toward the inland ice; the highest points visited show abundant roche moutonnée forms, and everywhere erratics are freely scattered.

The Origin and Relations of the Grenville and Hastings Series in the Canadian Laurentian. By FRANK D. ADAMS and ALFRED E. BARLOW, with observations by R. W. Ells.[2]

This paper may be regarded as a continuation of two former papers[3] by Adams, treating of the Laurentian of Canada and presenting the results of further work. It deals more especially with the probable origin of the Grenville series in the light of recent studies by the authors of a very large Laurentian area in central Ontario, along the margin of the protaxis and north of Lake Ontario.

The northwestern portion of the district in question is underlain by the Fundamental Gneiss, which is believed to form part of the original crust of the earth and to be of igneous origin. The south-eastern portion is occupied chiefly by the thinly bedded calcareous rock of the Hastings series, a series of undoubtedly sedimentary origin, but of unknown age, separated, however by a long erosion interval from the overlying Cambro-Silurian, and having certain petrographical resemblances to the Huronian of the typical area north of Lake Huron. Between these two series of rocks is an irregular belt of the Grenville series, identical in all respects with that of the original Grenville area in the province of Quebec. The character of these several series is described and their resemblances and points of difference indicated.

[1] See paper by writer in American Geologist, Vol. XVIII, pp. 379–384, 1896.

[2] The paper appears in the American Journal of Science for March 1897.

[3] Ueber das oder Ober Laurentian in Canada. Neues Jahrbuch für Mineralogie. Beil. Bd. VIII, 1893.

A Further Contribution to our Knowledge of the Laurentian.—Am. Jour. Sci., July 1895.

The Grenville series differs from the Fundamental Gneiss in that it contains certain rocks whose composition marks them as highly altered sediments. These rocks are in part limestones and in part certain peculiar gneisses, rich in sillimanite and garnet, having the composition of shales, or very rich in quartz and passing into quartzite, having thus the composition of sandstones. These rocks, as has been shown in one of the papers above referred to, usually occur in close association with one another, and are quite different in composition from any igneous rocks hitherto described. These rocks it is which are considered as characterizing the Grenville series. They usually, however, form but a very small proportion of the rocky complex of the areas in which they occur, and which, owing to their presence, are referred to the Grenville series. They are associated with, and often enclosed by, much greater volumes of gneisses and amphibolitic rocks, identical in character with those of the Fundamental Gneiss. The limestones are also almost invariably penetrated by great masses of coarse pegmatite, and in some cases large bodies of the limestone are found imbedded in what would otherwise be supposed to be the Fundamental Gneiss. The whole thus presents the character of a series of sedimentary rocks, chiefly limestones invaded by great masses of the Fundamental Gneiss, and in which possibly some varieties of the gneisses present may owe their origin to a partial admixture of sedimentary material with the igneous rocks by actual fusion. There is, however, no reason to believe, from the evidence at present available, that any considerable proportion of the series has originated in the last mentioned manner.

From the relations of the several series, as displayed in central Ontario, it is believed that the sedimentary portion of the Grenville series is but a modified part of the Hastings series, that in fact the present relations of the Grenville series are due to a commingling of portions of the Hastings series with the Fundamental Gneiss along their line or zone of contact. The Fundamental Gneiss upon which the Hastings series was originally laid down having at a subsequent time been softened by the influence of heat, and having under the influence of dynamic action eaten into and fretted away the overlying Hastings series, giving rise to an intermediate zone of mixed rocks which constitutes the Grenville series. The relations of the two series being thus very similar to that shown by Lawson and Barlow to exist between the Huronian and the Fundamental Gneiss in the districts about Lake Superior and Lake Huron.

The appended remarks by Dr. Ells deal with the district to the east and northeast of that studied by Adams and Barlow, and show that here also the same series can be recognized and that the same relations between them obtain.

The Origin and Age of the Gypsum Deposits of Kansas. By G. P. GRIMSLEY.

Among the minerals of economic importance in the state of Kansas, gypsum occupies a prominent place, and it has attracted the attention of geologists for many years. At the present time the state stands first in the Union in value of its gypsum product. The deposits of ecomic value occur in a belt trending northeast–southwest across the state with a length of 230 miles and in width varying from five miles at the north to thirty-six miles near the southern line. There are three important areas: northern, central, and southern. Intermediate deposits connect the northern and central areas, while the interval between the central and southern is occupied by salt beds. The topography increases in ruggedness southward. In the northern area three companies are engaged in plaster manufacture. There are six mills in the central area, and two in the southern. The rock is white or a gray mottled, with a saccharoidal texture in the upper portion, but becomes more compact below. The dip is toward the west. In the central area occur a number of secondary gypsum dirt deposits, which form the basis of the greater portion of the plaster manufacture. This material is a granular dirt of an ash-gray color. It is soft, and readily shoveled into cars, so that it is ready for calcining with less labor and expense than in the case of the solid gypsum. At the present time four of these deposits are worked. Under the microscope the dirt is seen to consist of a mass of small angular gypsum crystals of varying size. Mingled with the gypsum crystals are small quartz crystals, some calcite poorly crystallized, and traces of organic material. The deposits are found in low, swampy ground near small creeks, and strong springs occur in most of them. Usually there is a ledge of rock gypsum at the same level, or ten to twenty feet below. The gypsum beds are all Permian, ranging from the Neosho epoch to the close, and they rise geologically to the south. The northern and central rock gypsum deposits appear to have been formed in the same gulf cut off from the western Permian sea; while the gypsum dirt deposits are secondary and of recent age. The southern deposit was formed in a shallow gulf cut off from the Permian sea at a later period not far from the close. Salt appears to have been deposited with the gypsum, but now it is only found farther out in the old gulf where it was thicker.

The Cornell Glacier, Greenland. By RALPH S. TARR.

In this paper attention is called to the recently published conclusions of Professors Salisbury and Chamberlin that glaciation on the Greenland coast has not in recent times extended much further than the present ice margin. The evidence upon which this is based is stated, and it is pointed out that another interpretation of the rugged topography of the high parts of the Greenland coast is possible. This is, briefly, that the peaks seen from a passing vessel present the face which is least likely to be glaciated; also that they have been longer exposed to denudation, both preglacial and postglacial, and that, being higher than the surrounding land, they were more rugged before the ice came, and reaching up into the glacier they were less scoured by the ice than is the case with the lower lands.

The description of the geological conditions and evidence of glaciation upon the Upper Nugsuak peninsula (latitude 74° 10′–15′) follows, and it is pointed out that the higher points in this region have all been covered by ice notwithstanding the fact that, as seen from the sea, the topography of the peaks is as rugged as that of other parts of the Greenland coast. Small beds of till and numerous transported pebbles, whose origin is somewhere within the ice-sheet, are found on the highest points. The Devil's Thumb, rising 2650 feet above the sea, has been glaciated; Wilcox, 1400 feet high, and twenty-five miles from the margin of the ice, has also been ice covered, and the glacier has extended over the Duck Islands, which are eight or ten miles further to sea than this. Adding to the land height the depth of the water in the neighboring bays, it is certain that at the Devil's Thumb the ice-sheet was not less than 3000 feet thick; that at Wilcox Head, twenty to twenty-five miles from the present ice margin, there was glaciation to a depth of certainly not less than 2000 feet, and that at the Duck Islands, thirty or thirty-five miles from the present glacier, the ice-sheet had a depth of not less than 600 feet. In other words, in this part of the Greenland coast all the land now visible has been recently glaciated, and so far as evidence here is concerned, there is no reason to place a limit to its advance. The presence of shells in a recently abandoned moraine, as well as in the moraine now being made, and in the ice itself, appears to prove a recent retreat of the glacier, for these shells are of species now living in the waters of the fjord. They are found at a distance of five miles from the sea and at an elevation of 586 feet above it, and at various levels below this. The description of records left near the margin of this glacier is given, with the idea of putting forward facts which will permit accurate measurement of the change of ice front in the future. This seems all the more desirable, since evidence is abundant that the glacier in this part of Greenland is now retreating at a notable rate, and that it has recently withdrawn from a considerable area. The evidence of this is found in the presence of moraines at a distance of 100 or 200 feet from the present margin of the glacier, and so recently abandoned that no vegetation has begun to grow upon the soil. Moreover, freshly scratched bedrock has been so recently uncovered by the glacier that lichens have not begun to grow.

Unconformities in Marthas Vineyard and Block Island. By J. B. Woodworth.

Beginning below, plant-bearing beds of Cretaceous age appear in both islands, without their base being exposed. On Marthas Vineyard marine Cretaceous strata overlie the non-marine beds; although the contact has not been worked out, unconformity is inferred from the occurrence of lignitic fragments in the overlying marine beds. Above the Cretaceous at Gay Head, and on an eroded surface rests the Miocene of Lyell and Dall, composed of the osseous conglomerate and the greensand. Overlying these beds is a yellowish greensand, possibly Miocene but probably Pliocene. Fragments of a Pliocene formation have been identified at Gay Head by Dall. There was erosion in the area during or just after Eocene time, again between the greensand and the osseous conglomerate, and between the time of the greensand and the latest Neocene, the yellowish greensand. A bowlder formation now appears, composed of rocks derived from the mainland on the north. It was preceded by local folding of the underlying beds and by erosion along narrow channels, the Miocene being locally swept away. On Block Island the earliest Pleistocene rests upon the Cretaceous at Clay Head, the Miocene being entirely wanting. Succeeding the bowlder deposits there are from twenty-five to thirty feet of granitic gravels and sands, the deposition of which was brought to a close by profound folding over Marthas Vineyard and Block Island. The Tisbury beds on Marthas Vineyard and the Mohegan Bluff beds on Block Island were now laid down upon the eroded surface of the upturned beds of older strata. These horizontal beds are evidently of glacial origin. After their deposition there came a long period of fluvial erosion, the Vineyard subepoch, in which the islands were deeply denuded, as pointed out by Shaler in 1888. On Marthas Vineyard the capture and beheadal of streams is shown in the existing topography as the work of this time. Then followed the last glacial epoch with the deposition of moraines and sand-plains.

The older Pleistocene deposits denominated Weyquosque by Shaler in 1888 appear to be the equivalent of the Columbia which in the region of the New England Islands is divisible into an upper and lower horizon, separated by unconformity of dip and erosion marking the Gay Head diastrophe. The author is unable to accept the hypothesis of glacial thrust for the deformation on the islands named because in each case the fold preceded the evidence of glaciation found in overlying bowlder deposits. Those who accept the ice-thrust hypothesis, it is insisted, must consider the work to have been done by two advances of an ice-sheet long anterior to the last glacial epoch.

In the discussion Professor Wm. B. Clark called attention to the evidence of unconformity found by him in New Jersey between the non-marine or Potomac beds and the marine Cretaceous, and also to the meagerness of the horizons in this northern extension of the coast-plain as compared with more southern fields. He suggested that an examination of the foraminiferal greensand might show that, as in New Jersey, the Miocene foraminiferal casts had at least in part been derived from preëxisting Cretaceous beds. Mr. Gilbert noted that the long erosion interval on the islands, preceding the last glacial epoch, was consistent with the history made out for the rest of the United States.

Homology of Joints and Artificial Fractures. By J. B. Woodworth.

A synopsis of the structure of a typical joint as described in a previous paper (*Proc. Boston Soc. Nat. Hist.*, Vol. XXVII, 1896, pp. 163–183) showed a central area of fracture termed the joint-plane, which is traversed by feather-fracture. Marginal to this is a border of overlapping fractures, traversed by cross-fractures, forming the "joint-fringe." This system of fractures *en echelon* pervades the entire joint. Specimens were exhibited showing the joint structure above described, and also examples of fracture produced by blasting in a quarry, in which specimens there was a central warped surface corresponding to the joint-plane, and a system of marginal fractures comparable to the joint-fringe. The oblique imbricating plates formed by this fracture suggest a comparison with the "diagonal fissility" of Van Hise. The obliquity in the case of joints is found of value in determining the axis of breaking tension, whatever the nature of the force which produced the joint or fracture. This axis is a normal to the oblique marginal fractures. In mapping joints, a short straight line like the "strike" line crossed by short oblique lines having the obliquity of the observed marginal fractures of the fringe was proposed as a symbol. (Not to be published in the Bulletin of the Geological Society.)

Notes on Rock Weathering. By GEORGE P. MERRILL.

This paper was in direct line with those read at previous meetings of the Society, and had to do with the ultimate products of decomposition as shown in the transition of a fresh micaceous gneiss to the condition of a bright red residual soil. The results of physical and chemical analyses were presented, and on the assumption that the alumina had remained essentially constant during the decomposition, it was shown that 44.67 per cent. of original matter had been lost through the solvent and leaching action of water. The writer stated that on the basis that such results were rather under than above the actual amounts he had from a large number of analyses been led to the conclusion that an ordinary crystalline siliceous rock of a granitic or gneissoid type in passing by decay from its fresh condition to that of soil might lose about 50 per cent. of its original constituents.

The cause of the red color of the residuary material was discussed. The writer agreed with Professor Crosby in that the color was wholly superficial, but thought that such color might be due not wholly to dehydration of the ferric oxides present, but also to the presence of a large amount of coloring matter, the iron oxides having been shown to be largely insoluble, and hence accumulating in the residue along with the alumina. The subject of zeolites in soils, and their efficacy as conservators of potash was discussed, the conclusions being that not only is there no proof of the formation of zeolites, during the ordinary processes of true weathering, but also that even did zeolites exist in the soils, such could hardly be of interest for the reason stated, since potash is not, on the whole, a prominent constituent of zeolitic minerals. In this connection Mr. Merrill suggested that the term weathering as applied to rocks should be limited to those processes going on within the zone of oxidation and resulting as a rule in the destruction of the rock was as a geological body, while the more deep-seated processes which result in the production of new minerals of the nature of zeolites, chlorite, epidote, etc., and which are really of mineralogical rather than geological moment, should be looked upon as metamorphic and designated as products of hydrometamorphism. In discussing the probable condition of the soluble constituents of soil, a brief table was given showing that in rocks of as diverse types as granite, phonolite, diabase and basalt, the percentage amount of soluble constituents in both fresh and decomposed materials may be very nearly equal.

Notes on the Potsdam and Lower Magnesian Formations of Wisconsin and Minnesota. By JOSEPH F. JAMES.

The observations recorded in this paper were made on a trip through Wisconsin and Minnesota during 1889. Starting from Madison, Wis., the route was through Lodi, Devil's Lake, Baraboo, Ableman's, Ripon, Winneconne, New London, Morritan, Hudson and River Falls, Wis., to Stillwater, Winona, and Dresbach, Minn. Natural and artificial exposures, especially in quarries, were studied at all of these places and others, and nearly all of them are illustrated by sections drawn to a scale. The most extensive section is that made between Knapp and Wilson stations on the line of the Chicago, Milwaukee, St. Paul and Omaha R. R. The distance between these two places is about five miles. There is a continuous up grade with many cuts and a number of exposures. The section extends from well down in the Potsdam up to and into the Lower Magnesian, with an estimated vertical range of about 140 feet. Two slabs of worm trails from the Potsdam of Dresbach and the Lower Magnesian of Prairie du Chien are also illustrated.

Preliminary Note on the Pleistocene History of Puget Sound. By BAILEY WILLIS.

During the past season the drift deposits about the southeastern edge of Puget Sound have been studied in some detail. They are found to consist of several beds of till, separated by stratified deposits of clay, sand and coarse gravel, together with widely distributed lignite beds. The character and extent of the glaciation of the Puget Sound region are indicated in these deposits, and it is found that the principal flow of ice was rather from the north than from the mountains on the southeast. Two problems are presented by the phenomena: (1) The sequence of glacial advance and retreat and the extent and duration of climatic changes indicated by the presence of lignites; (2) the bearing of the peculiar conditions of glacial development upon the physiography of the sound. Either the deeper valleys of the sound have been eroded during a period of high level from the once more extensive sheets of drift or, as suggested by Russell, the channels represent the beds repeatedly occupied by glaciers which in their advance and retreat built up the plateau-like eminences of the region, probably upon the divides of the preëxisting topography. The past condition of Puget Sound under confluent glaciation is probably now represented by the Malaspina glacier and its attendant phenomena.

The Leucite Hills, Wyoming. By J. F. Kemp.

The paper opened with a brief statement of our earlier knowledge of the distribution of leucite, and of the special interest that attaches to it. Outside of the European mainland localities were cited on the Lipari Islands, the Cape Verde Islands in Asia Minor, Siberia, Java, New South Wales, Kilima-Njaro, Argentina, Brazil, New Jersey, Arkansas, Lower California, Yellowstone Park, Montana, and British Columbia. The presence of the rich alkaline magmas from Montana to the Mexican line, and in or near the eastern Rocky Mountains, was commented on. The previous observations of Zirkel on the rock of the Leucite Hills were briefly summarized so as to show that the only minerals observed by him in the very limited materials gathered by the geologists of the fortieth parallel were leucite in great abundance, small prisms of augite, biotite, apatite, and magnetite, and that the remarkable absence of feldspar, haüyne, and nepheline, was a cause of surprise to him. The geographical situation of the Leucite Hills and their areal distribution was then shown by lantern slides. There are three mesas or buttes in the main group, of which the southern, or Leucite Hills proper, is the largest. Orenda Butte, two or three miles north, is next, and Black Rock Butte, five miles northeast, is the smallest of all. The two former consist of several lava sheets resting on Laramie sandstones. From them arise cones 300 feet and less in height that resemble craters, but that are solid lava. Black Rock Butte has no cone. The lava sheet is more or less dissected, but the fragments are found but a very short distance from the escarpment. Specimens from all the buttes, and from various parts of the southern one, show that while the leucite is almost always present it varies greatly in amount and may be replaced almost entirely by sanidine. Haüyne was observed, and in Black Rock Butte large augites with surrounding borders of the peculiar yellow biotite. All these points of petrographical interest were illustrated by lantern slides from photo-micrographs. The two published analyses were cited, and in view of the abundant sanidine the rock was called a leucite-phonolite rather than a leucitite. The cones were explained as due to the upwelling of a viscous lava in the final phases of activity. No tuffs or dikes were met. Pilot Knob, an isolated butte lying twenty miles further west and north of Rock Springs, was also described, and the rock was shown to consist of small needles and larger crystals of augite in an isotropic groundmass that was regarded as glass. The determinations of the rock as trachyte in the Fortieth Parallel Survey must have been due to a confusion of slides.

The Pre-Cambrian Topography of the Eastern Adirondacks. By J. F. Kemp.

The paper opened with a review of the geological formations in the Lake Champlain Valley. It was shown that Palæozoic sediments formed all the eastern shore except for a small area at the south. In Vermont the Georgian strata of the Cambrian are met, but Acadian representatives are lacking. The Georgian is only seen at a distance from the crystalline nucleus of the Adirondack Archæan (Algonkian) Island, whereas the Potsdam and Ordovician lie now well up on its flanks. Prolonged search has failed to show on the west shore of Lake Champlain anything below the Potsdam. Mr. Walcott has already pointed out these relations. The writer stated that the crystallines had all been formed and greatly metamorphosed long before the Cambrian times, whose strata on their flanks lie flat and show no metamorphism whatever. He further stated that the crystallines must have been land with an encroaching shore line during the Cambrian, and that the land was deeply carved by erosion, whose results he freely admitted had been greatly modified by faulting. Then, with a series of lantern slides based on the topographic maps of the United States

Geological Survey, he traced the relations of the Palæozoic rocks to the pre-Cambrian strata, showing that they set up into embayments at Willsboro, Essex, Westport and Port Henry. The most interesting of all are, however, at Crown Point and Ticonderoga. Small outlines of Potsdam were shown in the valley of Trout Brook, west of Rogers Rock on Lake George, and over a high divide; from the lake and in the valley of Lake George itself. The old depressions up which the encroaching sea of the late Cambrian set are still discernible. Then, with a succession of adjacent maps, the speaker traced out an old depression back from Lake Champlain through Crown Point, with several scattered outliers of Potsdam, thence southward past Penfield Pond, and up a branch in central Ticonderoga, where another Potsdam outlier is found; thence through the valley of Paragon and Paradox lakes into the Schroon Lake valley, where a few acres of Calciferous flinty limestone remain under Schroon Lake P. O. The last named exposure is nearly twenty miles from Lake Champlain, and is forty miles from the next outcrop down the Schroon and Hudson rivers. Attention was called to the little outlier containing Potsdam, Calciferous, Trenton, and Utica strata at Wells, on the Sacondaga River, as recently figured by Mr. Darton. All these outliers are quite flat, seldom reaching fifteen degrees, and as a rule dip northwest and strike northeast. The original depressions were developed especially where there is crystalline limestone.

Stratigraphy and Palæontology of the Laramie and Related Formations in Wyoming. By T. W. STANTON and F. H. KNOWLTON.

The separation, in recent years, of the Denver, Arapahoe, and similar formations in Colorado, and of the Livingston in Montana, from the coal-bearing Laramie series, has called in question the unity of the beds usually referred to the Laramie in Southern Wyoming. Several facts in the reported stratigraphy and palæontology of the region suggested the possible presence of the Denver beds. The same horizon was suggested by the vertebrate fauna of the "Ceratops beds" in Eastern Wyoming as described by Messrs. Marsh and Hatcher. In view of these facts and queries the authors undertook the examination of the Ceratops area in Converse county, and of the coal-bearing localities along the Union Pacific Railroad, giving special attention to the stratigraphy and to the branches of palæontology—invertebrates and plants—in which they are respectively interested. The areas studied in

Converse county, the Laramie Plains, and Bitter Creek valley are described somewhat in detail, and more general observations are given on other localities treated, including Evanston and Hodge's Pass, Wyoming; Coalville, Utah, and Crow Creek, Colorado. The results are negative so far as the Denver and later related formations are concerned. That is, no division of the beds between the base of the Laramie and the Fort Union was found possible, and the Laramie age of the Ceratops beds of Converse county, as well as of the Black Buttes coal horizon, was confirmed. On the Laramie Plains most of the coal-bearing localities are on a horizon lower than the Laramie, and overlain by marine Fox Hills beds. The coal-bearing series at Point of Rocks is also in a similar position, and the considerable flora it has yielded must now be referred to the Montana formation instead of to the Laramie. In this connection all the non-marine invertebrates and plants now known from the Montana formation are brought together in lists, and the more general questions of the upper and lower delimitation of the Laramie are discussed.

A Complete Oil-Well Record in the McDonald Field between the Pittsburg Coal and the Fifth Oil Sand. By I. C. WHITE.

Geologists have long desired a careful and accurate measurement of the rocks passed through by the borings for oil in southwestern Pennsylvania. Mr. Carll, during the life of the second geological survey of Pennsylvania, had several careful records kept of the borings in Clarion and adjoining counties, but as the strata dip to the southwest, and thicken somewhat, it was very desirable to have a new standard of comparison in southern Pennsylvania. The writer happily found in Mr. T. J. Vandergrift of Jamestown, N. Y., a successful oil operator of many years' experience, the right man to undertake the work purely as a labor of love in the interest of geology. The well in question was drilled by the Woodland Oil Company, of which Mr. Vandergrift is president, on the S. B. Phillips farm in the famous McDonald field, near the line between Allegheny and Washington counties, Pa., about twenty miles southwest from Pittsburg. The producing rock of this region is the lowest member of the Venango Oil Sand group, or what is known to oil operators as the Fifth Oil Sand. This rock, it will be remembered, has yielded petroleum in greater quantity than any other yet found on the American continent, since some of the wells of the McDonald region produced oil for a short time at the rate of 15,000 barrels daily. It is no slight task to keep one of these deep-well records with the necessary care, since to be reliable a sample of the drillings must be washed, dried, and properly labeled every time the tools are withdrawn from the well. Then, too, as all rope measurements are not reliable to within ten to fifteen feet, steel-line measurements must be taken frequently, all of which was done in the present instance, so that the 2342 feet of strata, penetrated from eighty-six feet above the Pittsburg coal down to seven feet under the base of the Fifth Oil Sand, is represented by 570 samples of drillings and fifty-five steel-line measurements, from which data a very complete account of the rocks from the Pittsburg coal down nearly to the top of the Chemung may be obtained, for all of which geologists are certainly under great obligations to Mr. Vandergrift. The writer will publish the log of the well, as noted by the party keeping the same, and also a condensed record in more strictly geological terms.

A Note on the "Plasticity" of Glacial Ice. By ISRAEL C. RUSSELL.

Experiments by McConnell, Kidd, and Mügge have demonstrated that a bar of ice cut from a single crystal, with the optic axis perpendicular to two of the side faces, when subjected to a bending stress, will bend freely in the plane of the optic axis, but not at all in a plane perpendicular to that axis. In the bent crystals the optic axis in any part is normal to the bent face in that part. As stated by McConnell, the crystals behave as if they were composed of an infinite number of thin sheets of paper, normal to their optic axis, and attached to each other by some viscous substance which allowed one to slide over the next with great difficulty. The greatest freedom of movement was found to occur when the ice experimented on was near the melting point, and became less and less with a decrease of temperature. In certain of the experiments referred to the freedom of movement at $-2°$ C. was twice as great as at $-10°$ C. When thin sections of glacial ice are examined by means of polarized light, as shown by Deeley, Fletcher, and others, it is seen that the granules of which it is composed are fragments of ice crystals, or perhaps imperfectly formed crystals which interlock one with another so as to resemble the structure of coarsely crystalline dolomite.

The optic axes of the granules are without definite arrangement, but have all directions. Pressure brought to bear on such granular ice in a definite direction would cause movement in the crystal fragments or granules, whose optic axes were in the plane of pressure, but would not change the forms of the crystal fragments not thus oriented. The crystal fragments having their optic axes in the plane of pressure would be changed in shape, as in the experiments cited above, by movements along gliding planes. The stresses in glaciers are manifestly in various directions, and owing to the flow of the ice, inequalities of the rock surfaces beneath, etc., must be exceedingly complex. As the crystal fragments of which glaciers are composed are without orderly arrangement it is evident that some of them will be properly oriented to be deformed by a differential movement of their parts along gliding planes, by pressure acting in any direction. Under diverse stresses the resultant motion would be in the direction of least resistance. That is, the granular ice would behave like a plastic solid. The yielding of glacial ice to pressure, we conceive, is due to movements along gliding planes in the granules of which it is composed. If this process is continued the granules will evidently be destroyed by being divided along the planes on which movement occurs, but the resulting subdivisions, or "plates" perhaps we may term them, are reunited probably by the process of regelation. The plates, which after uniting have the same orientation, would form new granules. The longer this process is continued, or, in other words, the farther a glacier flows the greater the chances that a large number of "plates" will come together with similar orientation and the larger will be the resulting granules.

Under the hypothesis here suggested the granules of glacial ice are considered as an inheritance from the granules in the ice formed by partial melting and refreezing of névé snow. The granules at first are minute, but under the pressure of ice at higher levels they yield along gliding planes, and a resultant motion similar to that of plastic solids under like conditions is initiated. The granules are destroyed by this process, but progressive motion leads to the union of a constantly increasing number of the plates into which they are divided, and the growth of larger granules.

Work of the U. S. Geological Survey in the Sierra Nevada. By H. W. Turner.

To the north of the Fortieth Parallel Mr. Diller has published one folio on the Lassen Peak area, and has a very extensive series of notes which are as yet unpublished. The gold deposits of the Sierra

Nevada are, with minor exceptions, pretty closely confined to the belt of Palæozoic and Juratrias slates with their associated greenstones and included granitic masses. The area covered by these rocks forms the real gold belt of the Sierra Nevada. It is gratifying to announce that the geological work covering this area is now nearly completed. The Marysville, Smartsville, Sacramento, Placerville, and Jackson folios are published, and the Bidwell Bar, Downieville, Truckee, Pyramid Peak, Big Trees, and Sonora sheets are soon to be published. Attention was called to the very extensive beds of Juratrias tuffs in the foothills, indicating enormous volcanic activity in Juratrias time. Later in the Tertiary the scene of volcanic activity was transferred to the crest of the range, and nearly the whole area of the gold belt was flooded with lavas chiefly of a rhyolitic and andesitic character.

Shore Lines of Lake Warren and of a Lower Water Level in Western-Central New York. By H. L. Fairchild.

This paper describes the eastward extension of the Warren shore line as discovered and traced by the author during the past summer. The beach, in excellent form, with the various shore-line phenomena, as cliffs, bars, spits, and hooks, has been traced from Crittenden to Lima, somewhat east of the meridian of Rochester; while sufficient evidence of static water at a corresponding level is found much further eastward. The altitude of the beach between Batavia and LeRoy is 880 feet above tide. The altitude at Lima, subject to possible correction of datum, is 877 feet. This water plane would lie just about 500 feet over the Iroquois plane and would apparently lie below the plane of Watkins Lake or of Lake Newberry, the early local glacial waters in the Seneca embayment. It therefore seems certain that the Warren waters never found outlet by the Horseheads channel. The comparison of the beach phenomena east of Indian Falls with the same phenomena at Crittenden and westward is difficult to make on account of the difference in the topography of the country. East of Indian Falls the beach is transverse to the drumloid molding of the land surface, and the beach is not of so mature a character as south of Lake Erie, but nevertheless indicates a long period of wave action. Another beach at an altitude of 700 feet has been found at Geneva, New York, and traced westward continuously nearly to the meridian of Canandaigua. Abundant evidence of the same water plane is found in terraces and cliffs nearly to the Genesee River. The phenomena of this shore line are nearly as strong as those of the Warren waters in the Genesee region. This beach is specially interesting as being entirely new and unexpected, and indicating a long pause of the waters at an altitude between the Warren and the Iroquois plane, while the correlating outlet is unknown. The body of the paper is a detailed description, for record, of the phenomena of these two beaches.

Principal Features of the Geology of Southeastern Washington. By ISRAEL C. RUSSELL.

A brief statement of the results of a six weeks' reconnoissance in the southeastern portion of the state of Washington, made for the United States Geological Survey.

Practically all of that portion of Washington which lies south of the Big Bend of the Columbia is occupied by a succession of basaltic lava flows. This is a portion of a vast lava-covered region embracing northern California, central and eastern Oregon, central and southeastern Washington, and southern Idaho. The great fissure eruptions which supplied the Columbia lava, as the basalt is termed, occurred in the Miocene. The Columbia lava in Washington to the west of the Columbia, south of the Big Bend, as ascertained during a previous reconnoissance, is broken by extensive faults and the blocks thus formed variously tilted. In the region here treated, however, the basalt is horizontal over extensive areas, and deeply dissected by Snake River and its tributaries. Many lava sheets, one resting on another, were seen. Between some of the flows there are widely extended sheets of lacustral clay, sand, gravel, volcanic dust, and lapilli. In some instances leaves, and the silicified stumps and trunks of trees occur in these layers. The Columbia lava flowed about the bases of the mountains of eastern Washington and the adjacent portion of Idaho, in a series of inundations which covered the low country to the south. The level basaltic plateau meets the mountains of metamorphic rock in much the same manner that the sea joins a rugged and deeply indented coast. The lava entered the valleys and gave them level floors of basalt; the deeply sculptured ridges between the valleys were transformed into capes and headlands; outstanding mountain peaks became islands in the sea of molten rock. After the last of the lava sheets was spread out, the rivers flowing from the mountains began the excavation of channels across the basaltic plateau and have deeply dissected it. The most important of these channels is the one excavated by Snake River. From the mouth of Snake River to Lewiston, the stream is a narrow, deep-sided canyon, about 2000 feet deep. Where Snake River forms the boundary between Washington and Idaho, its gorge is about 4000 feet deep and fifteen miles broad. Within this vast canyon there are many lateral ridges, and a great variety of topographic forms due to erosion. This portion of Snake River canyon compares favorably with even the most magnificent parts of the Grand Canyon of the Colorado, except that it lacks the gorgeous coloring to which so much of the charm of its southern rival is due. The thickness of horizontally bedded basalt exposed in the walls of Snake River canyon and in the adjacent Blue Mountains, is in the neighborhood of 5000 feet, but the maximum thickness is not exposed. In the walls of the canyon at three localities, the summits of steep, angular mountain ranges are revealed. One of these buried peaks rises about 2500 feet above the river and is covered by fully 1500 feet of horizontally bedded basalt. The sheets of clay, sand, and gravel interleaved with the basalt, especially near its junction with the bordering mountains, furnish conditions favorable for obtaining artesian water. A number of flowing wells derive their water supply from this source. The Blue Mountains, at least at their northern extremity, consist of a low, flat-topped dome of Columbia lava, which has been deeply dissected by consequent streams. The surface of the basaltic plateau is covered with residual soil which has an average depth of sixty to eighty feet over thousands of square miles. The soil is exceedingly fine, dark brown or black in color, and of wonderful fertility. This is the soil of the celebrated wheat lands. The subsoil is fine, light yellowish in color, without stratification, and in many localities traversed by minute, irregular, but, in general, vertical tubes. In many ways the subsoil closely resembles loess. Its origin from the disintegration and decay of the underlying basalt is clearly manifest.

Topographically the Columbia lava presents great diversity. In the Blue Mountains there is an intricate series of sharp-crested ridges, separated by a labyrinth of canyons, having in general a depth of about 3000 feet. Between the Blue Mountains and Snake River there are broad remnants of the nearly level plateau, separated by narrow, steep-sided canyons, in general 2000 feet deep. North of Snake River there is a vast area without deep canyons, but diversified by short hills from fifty to eighty feet high, none of which, however, rises above a certain general level. Along the eastern portion of this hilly plateau, or rolling prairie as it was before cultivation began, there are a few prominent, island-like buttes of quartzite, which rise through the basalt. Among the details noted in the Columbia lava are certain horizontal joints which cut the vertical columns of basalt and may be traced for several miles. The large vertical columns of lava when weathered sometimes show that they are composed of small horizontal columns or prisms which radiate from a confusedly jointed central core. The joints which bound the large vertical columns furnished the cooling surfaces for the rock they enclose. The bases or ends of the radiating columns are frequently revealed on the surfaces of the slightly weathered vertical columns by a network of lines resembling shrinkage cracks. A report on the observations outlined above will be published by the United States Geological Survey.

Old Tracks of Erian Drainage in Western New York. By G. K. Gilbert.

The glacial Lake Warren occupied the Erie and parts of the Huron and Ontario basins. In the next important stage Lake Erie was established as a non-glacial lake, being separated from the glacial Lake Algonquin at the west and the glacial Lake Iroquois in the Ontario basin. As Warren drained westward and all the lakes of the succeeding stages drained eastward, it was inferred as probable that the revolution was initiated by the opening of an eastward passage for Warren waters. Such eastward passage was sought and found in western New York. In fact several passages were found, which succeeded one another as the northward retreat of the ice-front exposed lower and lower cols on the north-south ridges which diversify the general northward slope of that region. Between the ridges there were lakelets, walled by ice on the north, and these lakelets received the material scoured out by the waters in crossing the ridges, so that the surviving phenomena are chiefly channels and scourways through the higher lands, with gravel deltas at their eastern ends. Most of the drainage lines descend to the Iroquois level, but some terminate at higher levels, and it is thought probable that for a short time a glacial lake occupied the middle Mohawk valley, being doubly dammed by ice lobes on the east and northwest.

The district traversed by the channels extends from Le Roy to Chittenango, and the relation of the channels to one another and to the Iroquois shore show that during the channel epoch the trend of the ice-front in that region was approximately east-west.

It was found also that when the water first fell to the level of the Niagara escarpment, so as to cascade over its edge, there were five points of discharge. Three of these were short-lived, but Lockport for a considerable period divided the water with Niagara.

The Physical Nature of the Problem of General Geological Correlation. By CHARLES R. KEYES.

The main object of this communication has been to formulate briefly certain suggestions which have arisen in the course of recent attempts to parallel some of the geological formations in the Mississippi valley. They appear to have a much more than local bearing, and to affect the whole problem of general geological correlation, and perhaps also even our present system of geological classification.

Regarding as the principal function of correlation the establishment of a practical scale of geological succession to which may be referred the strata of all parts of the globe, the critical criteria adopted became essentially the real basis of geological classification or historical geology. A rational classification of geological phenomena reflects the genesis of the events recorded, and this is manifestly the ultimate aim of all methods of paralleling strata. In the correlation, or comparison of geological formations, experience has shown that the subject may be viewed from at least four very different points of vantage. The aspects presented are: local, provincial, regional, or general. With the various methods which have been followed from time to time in correlative inquiry the almost universal practice has been to attempt to base the broader generalizations upon criteria that are in reality applicable only to limited areas.

Passing by a review of the various methods of correlation which have been used, a little consideration shows that all are necessarily local in application and not general. This distinction between the two sorts of correlation which is usually entirely overlooked should be clearly borne in mind. When widely applied the almost total failure of the several methods that have been tried is only too apparent. The inherent weakness of the most common criteria — the fossils — is readily gleaned from the writings of Huxley, Irving, Van Hise, McGee, Walcott, Brooks and others. The problem is manifestly a physical and not a biological one. We must look therefore to physical criteria for its solution. The nearest approach to an absolute foundation for a system of geological synchrony is to be found in the work of Irving, in his work on the pre-Cambrian crystallines of the northwest, in which unconformities are given great prominence; by McGee in his investigations of the coastal plain deposits of the Middle Atlantic slope, in which similarity of genesis, or homogeny, is the governing factor; and by Davis and others in physiographic work, in which periods of base-leveling are made the all-important features in the cycle of land degradation, and inferentially the consequent sedimentation in adjoining seas.

Without considering all the available physical and biotic criteria of correlation in these various local and general phases it may be said that general correlation finds a fertile suggestion for a rational foundation in the factors which govern sedimentation. Its chief criterion is a function of continental growth and decline, and is dependent upon orogenic movement. This has recently be encalled correlation by mountain-building cycles, or orotaxis. The division planes cutting the geological columns into systems, series, or smaller parts, are actually, as well as theoretically, the lines of unconformities and their representatives. In the case of the more extensive ones they do, no doubt, represent base-leveled surfaces, or peneplains.

Modified Drift in St. Paul, Minnesota. By WARREN UPHAM.

Within the limits of St. Paul (fifty-five square miles) are numerous plateaus of drift gravel and sand, 225 to 240 feet above the Mississippi River, and about 100 feet above the highest plains and terraces of similar modified drift in the Mississippi valley. The courses of marginal moraines in this city and its vicinity, the glacial striæ, and diverse origin of the glacial and modified drift on the east and west, show that the slopes and currents of the ice-sheet converged to this area from the northeast and the northwest. On account of the sigmoid course of the Mississippi valley here, during the final melting and retreat of the ice-fields the tract where they had been confluent was occupied by a small glacial lake named Lake Hamline, which extended over the greater part of the western half of the area of St. Paul, having an outlet toward the southwest and south, across the present watershed between the Minnesota and Mississippi rivers, to Rich Valley and the Mississippi. In this temporary lake the modified drift plateaus were accumulated, their material being thought to be supplied from exceptionally abundant englacial drift brought to the area of glacial confluence. The surface of the glacial lake during the early part of its existence, as shown by the Hamline and Como plateaus, was about 250 feet above the present river, or 930 to 940 feet above the present sea level. A little later, when the plateau a mile east of Lake Como was formed, the lake level had fallen apparently five or ten feet. At the time of formation of the Summit Avenue plateau, it had been further lowered several feet, having then apparently an elevation of about 915 feet; and still later and smaller plateaus show that this lake finally was reduced to 875 or 870 feet above the present sea level. In one section it was observed that the till, exposed to a depth of twenty to twenty-five feet, at an elevation of about 875 to 900 feet above the sea, has throughout that thickness an imperfect stratification. The author attributes this to the action of the water of Lake Hamline, receiving the till from a previously englacial and superglacial position in and upon the melting ice-sheet. It is an observation almost exactly like that made by him a year earlier in the drift section of the Lake Erie shore in Cleveland, Ohio; and here, as there, he concludes that the volume of the englacial drift is represented by the thickness of the obscurely bedded or laminated till. In another section a sheet of till ten to twelve feet thick, resting on striated Trenton limestone, is shown, as the author thinks, to have been wholly englacial, this being indicated by deflection of the glacial striæ. Many of the striæ, intersecting the southward courses of earlier glaciation, run N. 60°–75° W., perpendicularly toward the neighboring Lake Hamline and its long plateaus of water-deposited drift.

(Abstracts to be continued.)

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PROFESSOR GEIKIE'S CLASSIFICATION OF THE NORTH EUROPEAN GLACIAL DEPOSITS.

IN Vol. III of this JOURNAL, Professor James Geikie gives a concise account of his present ideas concerning the classification of the north European glacial formations. His statement involves a comparison of the drift formations of various north European localities with one another, and with those of the Alps. He differentiates six glacial epochs, separated by five interglacial epochs, which he names after typical localities, as follows:

First glacial epoch, Scanian.

First interglacial epoch, Norfolkian or *Elephas meridionalis* stage.

Second glacial epoch, Saxonian.

Second interglacial epoch, Helvetian or *Elephas antiquus* stage.

Third glacial epoch, Polandian.

Third interglacial epoch, Neudeckian.

Fourth glacial epoch, Mecklenburgian.

Fourth interglacial epoch, Lower Forestian.

Fifth glacial epoch, Lower Turbarian.

Fifth interglacial epoch, Upper Forestian.

Sixth glacial epoch, Upper Turbarian.

1. *Scanian stage.*—The oldest glacial formation of north Europe appears in Schonen and points to a Baltic glacier. In England perhaps the Chillesford Clay and Weybourn Crag with

their arctic molluscan fauna belong to this stage. Here also Geikie places the oldest Alpine glacial deposits as well as the old "Diluvium" of the plateau of central France. In another part of his work he expresses the opinion that the oldest ground moraine in the Baltic region of Germany belongs to this stage.

2. *Norfolkian.*—To this stage belongs the Forest bed of Norfolk, during the formation of which a climate prevailed at least as temperate as that of today. In Alpine districts the lignite of Leffe and elsewhere, as well as the interglacial deposits of the Hötting breccia, indicating a climate warmer than that of the present day, correspond to this stage.

3. *Saxonian.*—In this epoch the ice reached its greatest expansion. In north Europe the formations of this epoch extend to the borders of the Carpathians, the Sudetic Mountains, the Erzgebirge and the Thuringian Mountains. In the Alps, the corresponding formation covers a more extensive area than that of the Scanian epoch, while in Great Britain the corresponding sheet of drift is more widespread than that of any preceding or following epoch. To this stage belongs the lower bowlder clay of the British Isles, the Lower Diluvium of Holland and north Germany, the outer moraines and the associated gravels of Alpine lands, as well as the older moraines of the numerous mountain chains of middle and southern Europe.

4. *Helvetian.*—The character of the flora and fauna is variable, being here more arctic and there more temperate. To this stage belongs the interglacial deposits in Lanarkshire, Ayrshire, Edinburghshire, etc., and the Hessle gravels of East Anglia, the beach deposits of Sussex, and certain cave accumulations of mammalian remains, the interglacial beds of Holstein and Kottbus, the sands of Rixdorf, the interglacial beds of Moscow the interglacial deposits of Cantal, as well as numerous old river deposits of the Thames, Seine, Rhine, etc.

5. *Polandian.*—To this stage belong the glacial and fluvioglacial deposits of a Scandinavian *mer de glace*, which was smaller than the second, and the similar deposits of Great

Britain, the Alps and other districts. This stage includes the upper bowlder clay of the British Islands, the Upper Diluvium of central north Germany, Poland and central west Russia, the ground and terminal moraines of the "inner zone" of the Alps, together with the attendant gravels, and the younger valley moraines in various mountain chains.

6. *Neudeckian.*—The deposits of this interglacial stage are best observed in the southern coast lands of the Baltic. They originated partly in salt, and partly in fresh water, and are intercalated between two ground moraines, which are designated the lower and upper bowlder clay respectively. The fauna points to a temperate, not to an arctic climate.

7. *Mecklenburgian.*—To this stage belong the ground moraines and end-moraines of the latest Baltic glacier, and it reaches its southern extremity in the terminal moraine of the Baltic *Höhenrücken.* Of the same age as these north German deposits (Upper Diluvium of northern north Germany) are the moraines of the first postglacial stage in the Alps, the great valley glaciers of the British Islands, the Yoldia deposits of Scandinavia, the 100-foot beach of Scotland with its arctic fauna, and certain arctic plant beds below the Turbaries of Great Britain, Denmark and Scandinavia.

8. *Lower Forestian.*—To this stage belong the deposits of the large fresh water lake (Ancylus-beds) filling a part of the basin of the Baltic, the older buried forests under the peat bogs of northwest Europe, and to some extent the Scandinavian Littorina beds. In the Alps no equivalent is known. The land in Europe possessed at that time a greater extent and a warmer climate than at the present day.

9. *Lower Turbarian.*—Marked by expansion of the sea, moister and colder climate, glacial formations in Scotland and Norway, where some of the valley glaciers extended to the sea, though most terminated at a considerable distance from it. In the Alps, the deposits of the second postglacial stage, the moraines situated in the inner valleys, correspond to this stage. This stage is represented in Britain by certain peat beds, in

Scandinavia by calcareous tufa, and certain Littorina beds and in Scotland by beach lines.

10. *Upper Forestian.*—In northwestern Europe a second forest bed, overlying 8, represents this stage. The area of land is greater than in the preceding glacial stage, but is still less then in the preceding interglacial epoch. The flora and fauna indicate a temperate climate drier than that of the 9th stage.

11. *Upper Turbarian.*—Characterized by a new advance of the sea on the land. The shores are no longer reached by the ice, but it is highly probable that the moraines in the upper parts of the valleys of Scotland and Norway, and belonging to the last glacial period, are of the same age as the lower beach lines. With the close of this glacial epoch recent conditions begin.

This is the new scheme by which Geikie would correlate the whole of the European glacial deposits, The following is given in tabular form, for the sake of simplicity.

Stage.	Great Britain.	Sçandinavia.	Alps.	North Germany.
1.	Chillesford clay. Weybourn crag.	Deposits of the oldest Baltic glaciers in Schonen.	Oldest ground-moraine of the Baltic.	*Deckenschotter* and moraines belonging to it.
2.	Forest-bed of Norfolk.			Lignite of Leffe. Hötting breccia.
3.	Lower Bowlder clay.	Moraines and fluvio-glacial formations.	Lower Diluvium.	Outer moraine. High terrace gravels.
4.	Marine deposits of Lanarkshire, Ayrshire, etc.; Hessle gravel, beach deposits of Sussex.			Peat bed in Holstein and Lignites of Switzerland and Altgau near Kottbus. Sands of Rixdorf.
5.	Upper bowlder clay.		Inner moraine and lower terrace gravels.	Upper Diluvium south of the Baltic terminal moraine.

Stage.	Great Britain.	Scandinavia.	Alps.	North Germany.
6.				Marine deposits in West Prussia.
7.	Valley glaciers and 100-foot beach of Scotland.	Yoldia clay.	Moraines of the first post-glacial stage.	Upper Diluvium north of the Baltic terminal moraine.
8.	Lower forest-bed.	Ancylus beds, Littorina beds (in part).		
9.	Terminal moraines in the valleys.	Littorina beds (in part).	Moraines of the second post-glacial stage.	
10.	Upper forest bed.			
11.	Terminal moraines in the upper parts of the valleys.			

The high authority of Professor Geikie on all questions concerning the European Ice Age has caused this classification, of the correctness of which Geikie himself is not thoroughly assured, to be received and used as final by many German writers who are not in a position thoroughly to appreciate the significance of the questions involved. Thus R. Credner[1] writes:

Folgen wir den Anschauungen, zu welchen neuerlich einer der hervorragendsten Glacialgeologen James Geikie, auf Grund vergleichender Untersuchungen sämmtlicher europäischer Vergletscherungsgebiete, vor Allem der britischen, der alpinen und der skandinavischen, gelangt ist, so haben wir für unser baltisches Becken vier durch Interglacialzeiten von einander getrennte Eisausbreitungen anzunehmen; und . . . . es entstand schliesslich, den Rand des letzten baltischen Eisstromes andeutend, der Zug echter Endmoränen, welcher in Gestalt wallartig gestalteter Blockschüttungen nordischen Ursprunges von Preussen bis nach Schleswig-Holstein hinein den Landrücken krönt.

In opposition to the preceding, and in full concert with my colleague in the Royal Prussian Geological Survey, who with me is

[1] Entstehung der Ostsee, pp. 540 and 646.

concerned in the geological exploration and mapping of the north German plain, I am bound to say that the fourfold classification of the north German glacial formations, given by Geikie, in no way corresponds to our observations, nor to the statements published in the "Explanations to the geological special map of Prussia and the Thuringian states," or in the annual report of the Royal Prussian Geological Survey, and in other places. After many years of careful work in the territory referred to, we find no conclusive reason for ascribing the ground moraine, designated by us as the upper bowlder clay, to more than one ice epoch. On the contrary, all of my colleagues who are or were occupied in the territory of the terminal moraine of the Baltic range, are, like myself, firmly of the opinion that the youngest ground moraine in front of and behind the terminal moraine, was deposited at one and the same time, by one and the same *mer de glace* distinct from and younger than that which deposited the upper bowlder clay of the territory of middle north Germany.

I must next consider the reasons which guided Geikie in his reference of the Upper Diluvium (drift) of north Germany to two glacial periods. They are stated in the second edition of the *Great Ice Age*, and seem to me to be essentially traceable to the four following points of view :

1. In different localities the ground moraine of the epoch of most extensive glaciation (Saxonian stage) contains (on account of the different directions of movement, radiating from the north of Scandinavia) bowlders quite different from the ground moraine of the younger inland *mer de glace*, which moved in the direction of the Baltic. According to Zeise the lower ground moraine of Schleswig-Holstein, is, so far as concerns its constitution, in no way different from the lower ground moraine of the moraine district, so the former cannot be the equivalent of the lower bowlder clay of the Mark, Posen, etc.

2. In Finland two systems of glacial striæ are developed ; an older one, which thus far has been observed only outside the territory enclosed by the terminal moraine, and a younger one

which thus far has been observed only inside the territory enclosed by the terminal moraine. The latter owes its formation to a glacier which moved in the direction of the Baltic, and which cannot have exceeded the line occupied by the terminal moraine. The ground moraines before and behind this moraine must belong to two different ice epochs.

3. The upper bowlder clay of Great Britain contains Scandinavian bowlders, and the Scandinavian *mer de glace*, in this third ice epoch came in contact with the Scottish one. But the ice depositing the Upper Diluvium of the Cimbric peninsula did not quite reach the North Sea; therefore this Upper Diluvium cannot be of the same age as the Scottish Diluvium of the third ice period, but must belong to a later fourth ice period. We come now to a comparison, if we suppose that the terminal moraine of the Baltic range represents the outermost edge of an independent glaciation, differing in point of time from that left behind by the Upper Diluvium of middle north Germany.

4. The separation is also shown by the appearance of the interglacial formations at Neudeck in West Prussia.

On the other hand we must remark (1) that continual study of bowlders in the different ground moraines has convinced German geologists, more and more, that no fundamental difference in this respect, is to be found; that, in other words, no single stone can be considered as a guide stone of the ground moraine of a definite ice epoch throughout the whole of its duration. Therefore we must form no far reaching conclusion from the local differences between bowlders belonging to two ground moraines lying one over the other.

2. Geikie believes that the Finnish terminal moraine is identical in point of time with that of the Baltic range. The line of union which he draws from east Prussia to Finland is, to my knowledge, purely hypothetical, and supported by no observations. I look for the easterly continuation of the Baltic terminal moraine much farther south, in the interior of Russia, and am of the opinion that the Finnish terminal moraine belongs with that

of middle Sweden and southern Norway, a view which is shared by Herr Vogt in Christiania.

3. It seems to me unnecessary entirely to repudiate the opinions of the north-German geologists in order to explain the occurrence of Scandinavian bowlders in the upper bowlder clay of Great Britian. It remains also to be proved that these Scandinavian bowlders have not been taken from the terminal moraines of the second ice period and incorporated in the drift of the third, and it may also be questioned whether the ground moraine of Scotland with northern bowlders really belongs altogether to the third glacial period, or whether the connection of the Scandinavian with the Scottish ice in the third glacial period is more than imaginary. I am prompted to raise these questions, because there are extremely weighty reasons against the acceptation of the Baltic terminal moraine as the outermost extremity of a separate (fourth) glacial epoch. On the contrary, the similarity in age of this moraine with the so-called upper bowlder clay of the Mark, Posen, etc., seems undisputed. I will state these reasons more definitely.

Of the terminal moraine of the Mark-Brandenburg, seventy-five square kilometers have been carefully mapped (scale 1 : 25,000) by the geological survey, and the investigation and surveying of the bordering territory on both sides reaches almost to Stettiner Haff in the north, and nearly to the northern edge of Lausitz in the south; therefore the territory investigated stretches in round numbers seventy-five kilometers from the terminal moraine in both directions. I have myself mapped a strip of country in the territory of the Baltic range between the Oder and Vistula extending thirty-four kilometers from east to west, and 100 kilometers from north to south. The terminal moraine passes through this strip for a distance of forty-five kilometers, and a territory twelve to twenty-four kilometers in breadth south of the terminal moraine is included within it. I have also by general surveying of the 500 kilometers of terminal moraine between the Oder and the Vistula, crossed the range in many places. All this work, and particularly the special mapping of about

150 field sheets (1 : 25,000) has now shown that the uppermost bowlder clay north and south of the terminal moraine are identical, that they belong to one glacial epoch, and that one sees in the terminal moraine[1] not the external margin, but only a stage of retreat of the latest glacier of these countries. In numerous places the ground moraine passes smoothly under the terminal moraine and in this manner several bridges are formed between the inner and outer ground moraine, and their identity is so firmly established, that stronger arguments than Geikie's are required to overturn the results of long years of careful, special inquiry. Those parts of the ground moraine passing under the terminal moraine are joined together in large masses to the north and south with the extensive ground moraines which Geikie maintains belong to two different ice epochs.

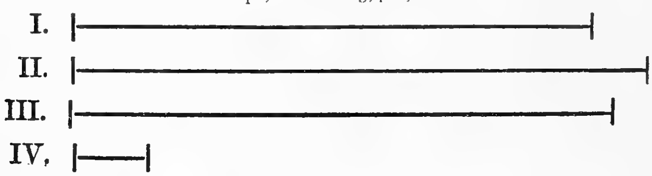
4. By mentioning as proof of his position, the existence of marine interglacial formations at Neudeck in West Prussia, Giekie plainly reaches a false conclusion, for he assumes what has still to be proven, that the last ground moraine but one of Neudeck is of the same age as the last (uppermost) ground moraine south of the Baltic. Without this proof the marine layers of Neudeck have no demonstrative significance, especially as their underlying beds are not known, and no observations have been made as to the number of ground moraines beneath them. Granted, however, that Geikie's view is right, that the Baltic terminal moraine is the southern limit of a distinct glaciation, one cannot understand why each of the other terminal moraines of north Germany may not also represent the edge of the ice during a distinct glacial period. On this basis the so-called "last glacial epoch" would have to be divided into four if not five epochs, so that even the most fanatical advocate for as many glacial periods as possible would be terrified.

I see a farther argument against Geikie's classification in the great difficulties of his comparison and in the inequality of the layers placed in the same stage. While with regard to the older

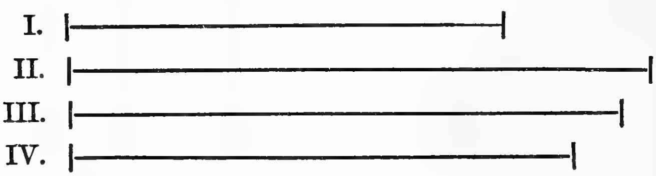
[1] I think Dr. Keilhack here uses "terminal moraine" in the German, not in the American sense (see p. 136 this number of this JOURNAL). R. D. S.

glacial periods there is a satisfactory conformity between the ice expansions of Great Britain and those of north Europe and the Alps, such conformity is altogether wanting in Geikie's assumed fourth epoch. The Baltic glacier supposed by him to belong to the fourth period is still of such immense size, and is so little inferior to those of the earlier epochs, that it is almost impossible to correlate it with the valley glaciers of the Alps which Penck has described, and it seems to me with perfect right, as representing only postglacial episodes. Hensen has regarded the similar deposits of Norway as epiglacial projections of existing glaciers. A graphic representation, such as that of Fig. 1 shows better than words can, the unnaturalness of Geikie's classification. If we suppose the expansion of the north European and Alpine glaciations to be expressed by lines which represent the extent of glaciation from the northern end of the Gulf of Bothnia, and from the central Alps respectively, and if the lines which represent the greatest extremity of ice be represented by unity in both cases, we obtain the proportions expressed by the following figures:

Alps, scale 1 : 3,400,000.



North Europe, scale 1 : 23,500,000.



If, however, one considers the Baltic terminal moraine as well as all others which lie further south, only as stages in the retreat of a single ice-sheet, as the Prussian Geological Survey has done, and so unites Geikie's No. 3 and No. 4 into No. 3, all difficulties of comparison at once disappear. 1, 2 and 3, in north

Europe correspond respectively with 1, 2 and 3 in the Alps, and the small extension of ice in the fourth and fifth ice epochs, recognizable in the Alps, Norway, and Scotland, and of approximately equal extent, are represented in north Germany, not by the reappearance of a *mer de glace*, but by climatic depressions only.

On the other hand I can agree with Geikie in his view that the principal glacial period (Saxonian stage) is the second glacial epoch, which had a predecessor in the so-called Scanian stage. The undeniable proof of three extensive glaciations of the Alps must awaken the suspicion that the north European glacial period also possesses a threefold division, and this suspicion would be increased still more in the mind of the present writer, by a number of other phenomena. The reason, however, why the special surveying has so far produced no conclusive evidence of a pre-Saxonian glacial period, lies simply in the fact that the mapping has been confined almost exclusively to districts in which no ground moraines of the inland ice of the Scanian stage exists, but where the deposits of this epoch are almost exclusively fluvio-glacial, and these for the most part fine. It is known, morever, that such formations in north Germany found due appreciation much later than those in the Alps, and that today even eminent geologists, such as H. Credner, will not acknowledge that they possess any demonstrative power. What has led me to recognize in the lower sands and clays of the Diluvium of middle north Germany the fluvio-glacial equivalent of a glacial period older than that which deposited the lower bowlder clay of the Mark, is the fact that between these layers are to be found a flora and fauna which point to a mild, temperate climate like that of today, if not indeed a warmer one. Because, however, the underlying layers contain certain northern material, such as feldspar, fragments of bryozoans, flints, and occasionally even large bowlders, the conclusion is not to be gainsaid that the ice lay at no very great distance from the territories in which those northern sands were deposited. The superimposed layers, however, contain a forest vegetation with deciduous trees, a water vegetation with plants of southerly character, such as Trapa natans, and even Cratopleura. Such, however, can never thrive in a flat country, if the latter is partly covered with glacier ice and the climate of that country arctic. Therefore a period with a warm climate must necessarily have existed between the deposition of the oldest northern sands and those of the ground moraine of the lower bowlder clay, and therefore for north Germany a third oldest period must be assumed besides the two glacial periods which deposited the upper and lower bowlder clay. The ground moraines of this oldest glacial period I recognize not only in Schonen, but also in the deepest ground moraines of the Baltic range, especially in that part of it lying to the east of the Oder. On the other hand, no observations have hitherto been made which point to an extension of these ground moraines in the district south of the range.

If I attempt at the conclusion of these remarks, which I consider necessary for the verification and defense of the standpoint adopted in the official survey in north Germany, to give a classification of the north German diluvial deposits in tabular form, I beg that this attempt may be considered only as a private opinion, which I should like to submit to a wider circle, for criticism and examination.

Preglacial.—Not yet determined with certainty. No deposits between the Miocene and the first glacial epoch certainly recognized.

First glacial epoch.—Oldest ground moraines in the region of the east Baltic Lake district. Fluvio-glacial formations, reaching to Hanover, and the southern part of the Mark, *e. g.*, the sands under the deposits of the first interglacial period.

First interglacial epoch.—Clays and marls rich in Paludina (Paludina deposits) in the understratum of Berlin. Peat of Klinge near Kottbus. Fresh water lime of the Flaming (Belzig, Görzke, Ziesar) and of the heath of Lüneberg. Diatomaceous layers of the Soltau, Oberohe and Rathenow. Yoldia clay in West Prussia, Cyprina clay in Holstein, fauna of Burg in western Holstein, Cardium sands of Lauenburg, etc.

Second glacial epoch.—Lower bowlder clay of north Germany. Red bowlder clay of the Altmark; numerous fluvio-glacial sands and clay (Glindower clay) under and over it.

Second interglacial epoch.—Mammalian fauna of Rixdorf, marine and fresh water deposits of west and east Prussia, oyster-banks of Slade, Blankanese, Fahrenkrug; peat of Lauenburg, Beldorf, Fahrenkrug, and elsewhere. Calcareous tufas of Madgeburg, fresh water formations of Rathenow and the district of Potsdam.

Third glacial epoch.—Upper bowlder clay of north Germany. Terminal moraines of the Baltic Range and more southerly districts. Valley sands of the great valleys and ice-dammed seas. Clayey deposits (valley clay, *Deckthon*).

Postglacial epoch.—Arctic flora beyond the north German Turbaries.

K. KEILHACK.

BERLIN.

THE AVERAGE SPECIFIC GRAVITY OF METEORITES.

In order to determine for purposes of hypothesis the density of a body formed by the aggregation of a multitude of meteorites, it is desirable first to learn the average specific gravity of those which have thus far fallen to the earth.

The writer is aware of but one attempt, the results of which have been published, to determine this quantity in a general way. These results are given in a paper by Rev. E. Hill in the Geological Magazine for 1885.[1] From Flight's "Chapters on Meteorites" this writer obtained the specific gravities of sixty-five different masses. The addition of these and division by 65 gave 4.84 as an average specific gravity. As this result took no account of the weights of the specimens, however, a recalculation was made from those whose weights and specific gravities were known, and an average of 5.71 obtained. As this sum again, however, included the great Cranbourne meteorite, whose weight of 3½ tons far exceeded that of all the rest, all masses over 250 pounds in weight were excluded. From the 52 cases thus averaged, a specific gravity of 4.58 was obtained.

Another method of arriving at the desired result was based on the ratio of metallic to stony meteorites, as they occur in the British Museum collection. This ratio is 205 stony to 55 metallic meteorites. Separating according to this ratio the 57 cases referred to, an average specific gravity of 4.55 was obtained.

R. P. Greg has also[2] found the specific gravity of about 70 stony meteorites to be 3.4. He says, however, that "as those possessing the smallest specific gravity are necessarily the most destructible and fragile, and after meteoric explosion less likely to arrive on the surface of the earth in an entire or tangible state, we may very fairly take their average density nearer the

[1] New Series, Decade III, Vol. II, p. 516.

[2] London Phil. Mag., 4th Series, Vol. VIII, p. 337.

mean of these two extremes, say, 3.0." As this density is intermediate between that of Mars, 5.3, and Jupiter, 1.4, he considers it as confirming the theory that meteorites belong to the series of planets, and have their orbits at a greater mean distance than that of the earth's from the sun.

A careful consideration of the results above quoted makes it difficult to accept any of them as final. The chief objection to Hill's results lies in the fact that there can be no assurance that the 57 cases which were listed by Flight, represented the average constitution of meteoric matter. Only an average obtained from the largest number of cases possible can be considered trustworthy, even though such an inquiry involve, as Hill states, "enormous labor of research." Again, it should be borne in mind that all the data which can at best be obtained, form but a small part of the whole, so that it is desirable that the relation of this part to the whole should be determined as accurately as possible. Daubree has calculated[1] that the fall of a meteorite on some portion of the earth is a phenomenon of daily occurrence, yet the number of *observed* falls during the past century has averaged not over one for every four months. This gap between possible and observed falls, due, of course, to the fact that a large portion of the earth's surface is covered by water, or is uninhabited by persons capable of intelligent observation, makes the collection of as large a number of data in regard to observed falls as possible, desirable.

It is only, however, during the present century that any systematic record of meteorite falls has been made at all. To include specimens preserved from earlier falls, is, therefore, likely to weaken rather than strengthen the probability of accuracy in the average.

Again, it seems incorrect to include any meteoric "finds" in obtaining data for the desired average. The stony meteorites, owing to the oxidation of the metallic grains which they contain, and the easy decomposability of olivine and others of their mineral

[1]Annales des Mines, 1868.

constituents, disintegrate and decay far more rapidly than the metallic. The metallic meteorites are, therefore, likely to be found long after stony ones of their time have gone to decay. The unusual weight of the metallic meteorites, moreover, and the silvery appearance of their interior, often lead to their being picked up and preserved where the stony meteorites escape observation. That the metallic meteorites are much more likely to be found than the stony, is indicated by the fact that of 263 meteorite "finds" now preserved in collections, 205 are wholly metallic, 28 largely so and only 30 are stony. To determine the average specific gravity of meteoric matter by striking an average of meteorites preserved in collections, seems, therefore, manifestly incorrect.

The amount of the correction which, according, to Greg should be made for meteoric matter that does not reach the earth in an entire or tangible state, must be at best a matter of speculation. I am of the opinion that the amount of such meteoric dust which reaches the earth is small, for few traces of it have ever been found. Since its amount is probably small and its specific gravity can only be guessed, I have thought it safe to omit it altogether from the calculation.

Considering, then, the desirability of using as many data as possible while at the same time excluding all that might be misleading, I can think of no better method of arriving at the desired result than to determine the average specific gravity of the meteorites observed to fall during the past one hundred years, this being the period within which a fairly complete record of meteorite falls has been kept. Such a method, will, of course, exclude a large number of metallic meteorites with high specific gravity, for only seven, or at most eight, of these have been known to fall within the past century. But it is not unreasonable to suppose that these may represent the proportion of iron to stone falls in all periods of the earth's history ; for, as has been stated, the iron meteorites found may have endured for many centuries, while the stony ones of similar epochs have gone to decay.

Greg[1] has considered the proportion of stone to iron falls to

[1] London Phil. Mag., 4th Ser., Vol. VIII, p. 453.

be 25 to 1, *i. e.*, that 96 per cent. of all meteorites that fall consist of stony matter. Hence it may be assumed that, for 34 iron masses, for example, found, 25 times as many or 850 stone falls have taken place.[1] The ratio deduced from the falls of the last century would be somewhat higher than this, viz., 40 to 1. There is, therefore, strong reason for belief that there is normally a great excess of stone over iron falls. The alternative supposition, which has been urged by some, is that metallic falls have been more abundant during earlier periods of the earth's history than now, but there is no proof that these were not accompanied by a similar proportion of stone falls to that which now prevails.

If it be granted that the desired average can best be obtained from the observed falls of the past century, then again there must be recognized the fact that data for calculation on this basis suffer serious limitations owing to the lack of records of the specific gravity and weight of many of the falls. The specific gravity, so far as known, of most of the falls up to 1860, can be found in Buchner's catalogue,[2] but since that time analysts have been lamentably negligent in giving specific gravities in their published descriptions of meteorites. In searching for weights of falls too, one finds great scarcity of data, the records of earlier falls being most at fault in this respect. But though the amount of data obtainable is comparatively small, enough is at hand to permit conclusions of value.

Brezina's latest catalogue[3] gives 298 falls as having taken place since the Wold Cottage fall of 1795. For 175, or more than one-half of these, I have been able to find specific gravities given in some one or more of the records. These range between 1.70 for Alais to 7.84 for Cabin Creek, but by far the larger number lie between 3 and 4 in specific gravity. The average obtained from these 175 cases is 3.65.

[1] There is evidently a clerical error in his statement that 96 times as many, or 3624 stone falls may have taken place.

[2] Die Meteoriten in Sammlungen, Dr. Otto Buchner, Leipzig, 1863.

[3] Annalen der K. K. Naturhistorisches Hof Museum, Band X, Heft 3 und 4, Vienna, 1896.

As noted by Hill, however, an accurate result can only be obtained by taking into account the weights of the specimens, since a number of small weights of high or low specific gravity would considerably raise or lower an average obtained from individual specific gravities, while their effect on the density of a mass made up of large weights of nearly uniform specific gravity would be insignificant.

Unfortunately, a calculation on this basis reduces somewhat the number of cases from which an average can be drawn, since in many of the cases where specific gravity is given, no record of the weight of the meteorites can be obtained. By considerable searching, however, I have been able to obtain records of 142 falls, the specific gravity and weights of which are known. These include, fortunately, all but one of the metallic meteorites and most of the larger falls, such as Weston, Juvenas, New Concord, Estherville, Mocs, Alfianello and Winnebago county. By reducing these weights to the unit of water, adding and dividing, an average of 3.69 is obtained for the whole, a result nearly in accord with that deduced from the specific gravities alone.

It is possible that from records of a larger number of falls, a slightly different average might result, but it seems fair to assume that the difference would not be more than .2 or .3 from the figures given. Until further data are at hand, therefore, the value of 3.69 may be regarded a fair one for the average specific gravity of the meteoric matter which has come to the earth within the period of intelligent human observation.

To determine the probable density of a body formed by the aggregation of such matter is not a part of the purpose of this article, for this involves elaborate considerations of the effects of pressure. The present investigation has at least shown how desirable it is that those who in the future publish descriptions of meteorites should take pains to determine the specific gravity and weight of each fall. The accurate statement of these will be of great service in further investigation.

Oliver C. Farrington.

DRIFT PHENOMENA IN THE VICINITY OF DEVIL'S LAKE AND BARABOO, WISCONSIN.[1]

THE study of the drift about Devil's Lake and Baraboo, Wisconsin, has brought out facts and relations of more than local interest, which it is the aim of this paper to state.

Location.—The region is in the central part of the southern half of the state, about thirty-five miles northwest of Madison, and on the western limit of the area covered by the Green Bay lobe of the last great ice-sheet—the ice-sheet which deposited the Wisconsin drift. Since the ice of this epoch advanced as far to the west in this region as that of any earlier epoch, the region concerned is also on the border between the glaciated country to the east, and the driftless area to the west.

General topographic relations.—The accompanying map, Fig. 1, shows the surroundings of the region especially concerned, and Fig. 2 the topography of a small area about Devil's Lake. Extending in a general east-west direction and rising 500 feet to 800 feet above the surrounding country, is the great Baraboo quartzite range (shaded area Fig. 1) in which Devil's Lake (*a*) is situated. This range, and especially the larger range to the south, is the most prominent topographic feature of the region, and, as will be seen, had not a little influence on the behavior of the ice at its margin. Devil's Lake divides the range into an eastern and a western portion, known respectively as the east and west bluffs (or ranges). The highest point of the range, about four miles east of the lake, has an altitude of 1620 feet. The eastward extension of the west range (see Fig.

[1]This paper is based on work done in connection with the field course in geology in The University of Chicago. Other students than those whose names appear in connection with this article, had something to do with the development of the facts here set forth. This is especially true of Messrs. H. R. Caraway, E. C. Perisho, D. P. Nicholson, L. Wolff and O. J. Arnold.

2), lying south of the lake, and popularly known as the "Devil's Nose," has an elevation of 1500 feet.

North of the main range there is a lesser ridge of quartzite, more or less interrupted, rising 300 feet to 500 feet above the

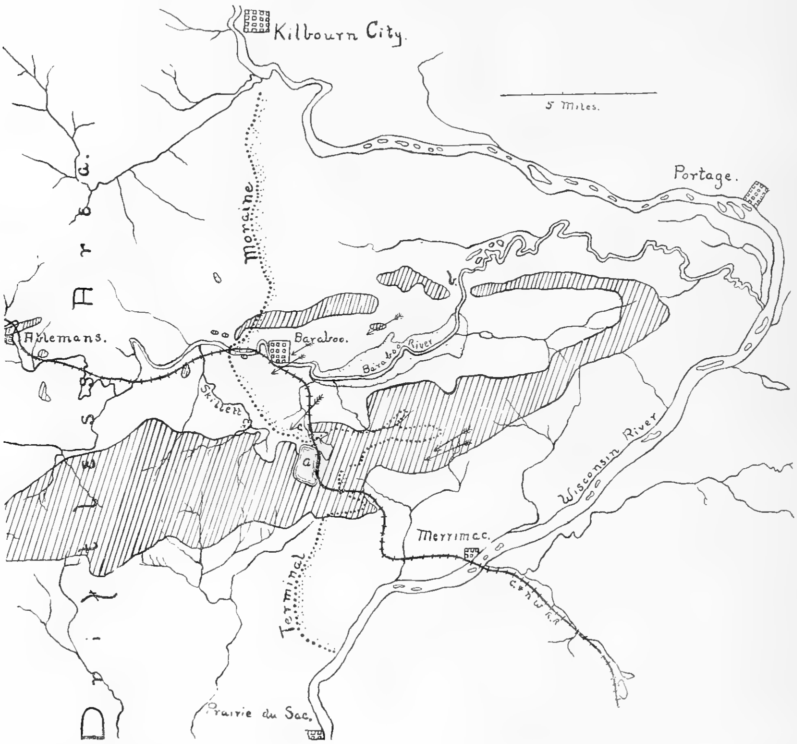


FIG. 1. Map of the area about Baraboo and Devil's Lake. The shaded area is quartzite. The unshaded area is underlain by Potsdam sandstone.

Baraboo River, and reaching its greatest prominence at the "Lower Narrows" of that stream (*b*, Fig. 1). Between these quartzite ranges is the capacious valley, partly filled with drift, through which the Baraboo River flows.

About the quartzite ranges, and within the area covered by the ice, the surface is marked by those varied features which usually affect the surface of a region heavily covered with drift.

West of the limit of the ice, the topography is equally characteristic of the driftless area, though modified along the flats by the deposits of the glacial drainage.

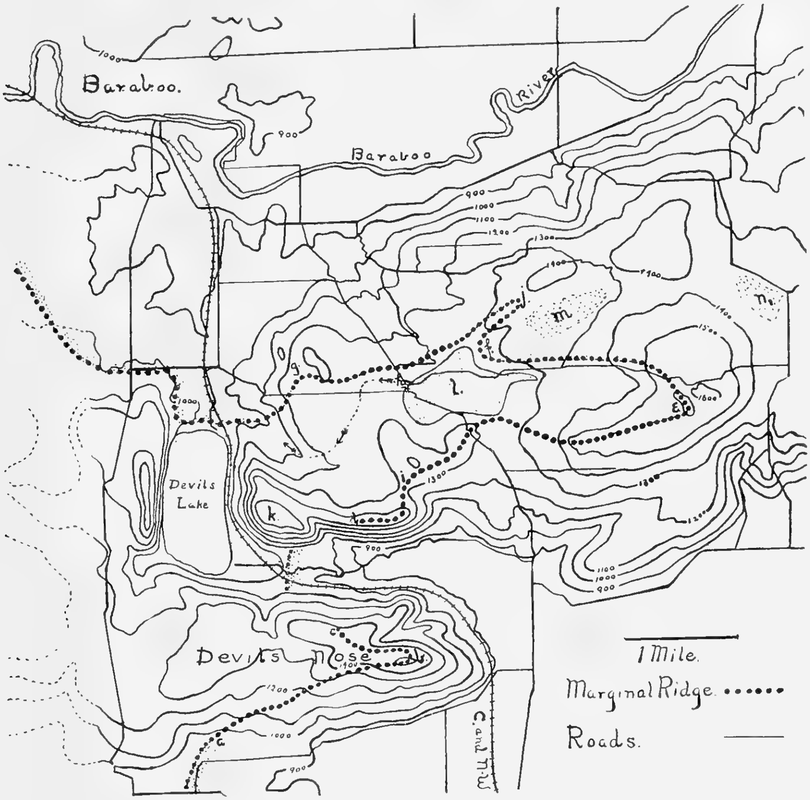


FIG. 2. Topographic map (contour interval 100′) of a small area about Devil's Lake, taken from the Baraboo sheet of the U. S. Geological Survey. The dotted western continuations of the contours represent extensions of the contours beyond the published map.

Ice movement.—From the course of the striæ, it is known that, as the ice advanced into this region, its general direction of motion was west-southwest. This is in accord with the general direction of movement in the western portion of the Green Bay lobe. The location and direction of recorded striæ appear on the map shown in Fig. 1. With but one exception they vary from W. 20° S. to W. 30° S. The exceptional direction, W. 60° S., is found on the north side of the main quartzite range (*c*, Fig. 1), where the normal deploying of the ice was prevented by the steep face of the bluff. It illustrates the tendency of glacier ice to move in a direction essentially at right angles to its margin.

The terminal moraine.—The limit of the ice advance is marked by a well defined terminal moraine, the outer margin of which west of the Wisconsin River is shown on the accompanying map (Fig. 1). Swinging southward from Kilbourn City in in gentle curves, it turns westward in the great valley between the quartsite ranges, and then loops back to the east along the north face of the quartzite range *nearly seven miles* before crossing it. Across the crest of this range it turns promptly to the west in the valley between the east range and the Devil's Nose. About the elevation which bears this name, the moraine again loops back to the east, and after rounding the "Nose" turns promptly to the west. After following this direction for about two miles, it turns southward, reaching the Wisconsin River about seven miles below Merrimac.

On the low lands, the terminal moraine has the characteristics which usually affect such formations. In width it varies from half to three-quarters of a mile. Approached from the west, that is, from the driftless side, it is a somewhat prominent topographic feature, often appearing as a ridge thirty, forty or even fifty feet in height. Approached from the opposite direction it is notably less prominent, and its inner limit, wherever located, is a more or less arbitrary line. Beyond its notably irregular course, the terminal moraine on the low lands about the quartzite ranges possesses no unusual features. A deep, fresh cut southeast of the lake illustrates its complexity of structure, a complexity which is probably no greater than that of terminal moraines at many points where less well exposed. The section is represented in Fig. 3. The stratified sand to the right preserves even the ripple marks which it received when deposited. To the left, at the same level, there is a body of till over which is a bed of stoneless and apparently structureless clay. In a depression just above the clay, with till both to the right and left, is a body of loam which possesses the normal characteristics of loess, both as to constitution and structure. It also contains calcareous concretions, but no shells are found.

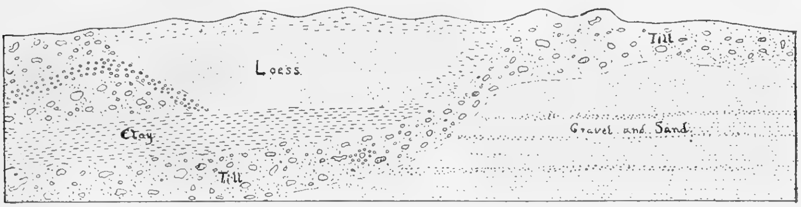


FIG. 3. Section of the moraine southeast of Devil's Lake, as exposed in a railway cut (1896).

Away from the ridges the outer face of the moraine from Kilbourn City to Prairie du Sac is bordered by overwash plains, or morainic aprons, in their normal positions and relations, except that in one locality just west of Barbaoo and south of the river, the moraine edge of the overwash plain is built up even with the crest of the moraine itself.

The margin of the ice across the quartzite range.—In tracing the moraine over the greater quartzite range, it is found to possess a unique feature in the form of a narrow but sharply defined ridge of drift, formed at the extreme margin of the ice at the time of its maximum advance. For fully eleven miles, with but one decided break, and two short stretches where its development is not strong, this unique marginal ridge separates the drift-covered country on the one hand, from the driftless area on the other. In its course the ridge lies now on slopes, and now on summits, but in both situations preserves its identify. Where it rests on a plain, or nearly plain surface, its width at base varies from six to fifteen rods, and its average height is from twenty to thirty feet. Its crest is narrow, often no more than a single rod. Where it lies on a slope, it is asymmetrical in cross section (see Fig. 4), the shorter slope having a vertical range of ten to thirty-five feet, and its longer a range of forty to one hundred feet. This asymmetrical form persists throughout all that portion of the ridge which lies on an inclined surface, the slope of which does not correspond with the direction of the moraine. Where it lies on a flat surface, or an inclined surface the slope of which corresponds in direction with the course of the ridge itself, its cross section

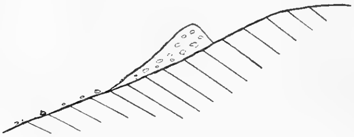


FIG. 4

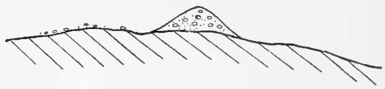


FIG. 5

FIG. 4. Diagrammatic cross section of the marginal ridge as it occurs on the south slope of the Devil's Nose. The slope below, though glaciated, is nearly free from drift.

FIG. 5. Diagrammatic cross section of the marginal ridge as it appears when its base is not a sloping surface.

is more nearly symmetrical (see Fig. 5). In all essential characteristics this marginal ridge corresponds with the *End-Moräne* of the Germans.

For the sake of bringing out some of its especially significant features, the ridge may be traced in detail, commencing on the south side of the west range. Where the moraine leaves the lowlands south of the Devil's Nose, and begins the ascent of the prominence, the marginal ridge first appears at about the 940-foot contour (*a* Fig. 2). Though at first its development is not strong, few rods have been passed before its crest is fifteen to twenty feet above the driftless area immediately to the north (see Fig. 4) and from forty to one hundred feet above its base to the south, down the slope. In general the ridge becomes more distinct with increasing elevation, and except for two or three narrow post-glacial erosion breaks, is continuous to the very summit at the end of the Nose (*b* Fig. 2). The ridge in fact constitutes the uppermost forty or forty-five feet of the crest of the Nose, which is the highest point of the west range within the area shown on the map. Throughout the whole of this course the marginal ridge lies on the south slope of the Nose, and has the asymmetrical cross section shown in Fig. 4; above (north of) the ridge at most points not a bowlder of drift occurs. So sharply is its outer (north) margin defined, that at many points it is possible to locate it within the space of less than a yard.

At the crest of the Nose (*b* Fig. 2) the marginal ridge, without a break, swings northward, and in less than a quarter of a mile turns again to the west. Bearing to the north it presently reaches (at *c*) the edge of the precipitous bluff, bordering the great valley at the south end of the lake. Between the two arms of the loop thus formed, the surface of the Nose is so nearly level that it could have offered no notable opposition to the progress of the ice, and yet it failed to be covered by it.

In the valley between the east bluff and the Nose, the terminal moraine lies further west than on the elevations. The ice moved against the Nose from the east, and mounted to its highest point, but in this achievement it so far spent its strength as to be unable to continue, even over the comparatively level surface beyond. Divided by the Nose as by a wedge, it moved westward over the lower land on either side, but failed to occupy the intervening crest of the ridge.

In the great valley between the Nose and the east bluff, the marginal ridge does not appear. In the bottom of the valley the moraine takes on its normal form, and the slopes of the quartzite ridges on either hand are much too steep to allow any body of drift, or loose material of any sort, to lodge on them.

Ascending the east bluff a little east of the point where the drift ridge drops off the west bluff, the ridge is again found (at *d*) in characteristic development. For some distance it is located at the edge of the precipitous south face of the bluff. Farther on it bears to the north, and soon crosses a col (*i*) in the ridge, building it up many feet above the level of the bed rock. Here again, as on the Nose, the ice that had surmounted the elevation had spent its strength and was unable to move forward, even though forward movement would have been down grade.

From this point eastward for about three miles the ridge is clearly defined, the slopes about equal on either side, and the crest as nearly even as the typography of the underlying surface permits. The topographic relations in this part of the course are shown in Fig. 5.

At *e* (Fig. 2) this marginal ridge attains its maximum elevation, 1620 feet. Here again, the ice having surmounted this great elevation, the greatest of the region, was unable to move forward down the slope, although it had had energy enough to climb fully 300 feet in the last mile of its advance.

At this great elevation, the ridge turns sharply to the northwest at an angle of more than 90°. Following this direction for little more than half a mile, it turns to the west. At some points in this vicinity the ridge assumes the normal morainic habit, but this is true for short distances only. Further west, at *f*, it turns abruptly to the northeast and is sharply defined. It here loops about a narrow area less than sixty rods wide, and over half a mile in length, the sharpest loop in its whole course. The driftless tract enclosed by the arms of this loop is lower than the drift ridge on either hand. The ice on either side would need to have advanced no more than thirty rods to have covered the whole of it.

From the minor loop just mentioned, the marginal ridge is continued westward, being well developed for about a mile and a half. At this point the moraine swings south to the north end of Devil's Lake, loses the unique marginal ridge which has characterized its outer edge across the quartzite range for so many miles, and assumes the topography normal to terminal moraines. At no other point in the United States, so far as known to the writers, is there so sharply marked a marginal ridge associated with the terminal moraine, for so long a distance.

From Fig. 1 it will be seen that the moraine as a whole makes a great loop to the eastward in crossing the quartzite range. From the detailed description just given of the course of the marginal ridge, it will be seen that it has three distinct loops; one on the Devil's Nose (west of *b*, Fig. 2); one on the main ridge (west of *e*) and a minor one on the north side of the last (southwest of *j*). The first and third are but minor irregularities on the sides of the great loop, the head of which is at *e*.

The significant fact in connection with these irregularities in the margin of the moraine is that each loop stands in the lee of a prominence. The meaning of this relation is at once patent. The great quartzite range was a barrier to the advance of the ice. Acting as a wedge, it caused a reëntrant in the advancing margin of the glacier. The extent and position of the reëntrant is shown by the course of the moraine in Fig. 1. Thus the great loop in the moraine, the head of which is at *e*, (Fig. 2) was caused by the quartzite range itself.

The minor loops on the sides of the major are to be explained on the same principle. Northeast of the minor loop on the north side of the larger one (*j*, Fig. 2) there are two considerable hills, reaching an elevation of nearly 1500 feet. Though the ice advancing from the east-northeast overrode them, they must have acted like a wedge, to divide it into lobes. The ice which reached their summits had spent its energy in so doing, and was unable to move forward down the slope ahead, and the thicker bodies of ice which passed on either side of them, failed to unite in their lee. The application of the same principle to the loop on the Devil's Nose is evident.[1]

Constitution of the marginal ridge.—The material in the marginal ridge, as seen where erosion has exposed it, is till, abnormal, if at all, only in the large percentage of widely transported bowlders which it contains. This is especially true of the surface, where 90 per cent. of the large bowlders are in some places of very distant origin, and that in spite of the fact that the ice which deposited them had just risen up over a steep slope of quartzite, which could easily have yielded abundant bowlders. In other places the proportion of foreign bowlders is small, no more than one in ten. In general, however, bowlders of distant origin predominate over those derived close at hand.

[1] It is at k, Fig. 2 that the preglacial gravel referred to in Vol. III (pp. 655–67) of this JOURNAL is found.

The slope of the upper surface of the ice at the margin.—The marginal ridge on the south slope of Devil's Nose leads to an inference of special interest. Its course lies along the south slope of the Nose, from its summit on the east to its base on the west. Throughout this course the ridge marks with exactness the position of the edge of the ice at the time of its maximum advance, and its crest must therefore represent the slope of the upper surface of the ice at its margin.

The western end of the ridge *a* (Fig. 2) has an altitude of 940 feet, and its eastern end *b* is just above the 1500-foot contour. The distance from the one point to the other is one and three-fourths miles, and the difference in elevation, 560 feet. These figures show that the slope of the ice along the south face of this bluff was about 320 feet per mile. This, so far as known, is the first determination of the slope of the edge of the continental ice sheet *at its extreme margin*. It is to be especially noted that these figures are for the extreme edge of the ice only. The angle of slope back from the edge was doubtless much less.

Devil's Lake.—At the north end of Devil's Lake, and again in the capacious valley leading east from its south end, there are massive terminal moraines. Followed southward, this valley leads off toward the Wisconsin River, and is probably the course of a large preglacial stream. It is now occupied by a small tributary to the Wisconsin, the head of which is separated from the lake by the massive moraine. To the north of the lake, the head of a tributary of the Baraboo comes within eighty rods of the lake, but again the terminal moraine intervenes. From data derived from wells it is known that the drift both at the north and south ends of the lake extends many feet below the level of its water, and at the north end, the base of the drift is known to be at least fifty feet below the level of the bottom of the lake. The draining of Devil's Lake to the Baraboo River is prevented only by the drift dam at its northern end. It is nearly certain also, that, were the moraine dam at the south end of the lake removed, all the water would flow out to the Wisconsin, though the data for the demonstration of this conclusion are not to be had. There can be no doubt that the gorge between the east and west bluffs was originally the work of a pre-Cambrian stream, though the depth of the pre-Cambrian valley may not have been so great as that of the present. Later, the valley was filled with the Cambrian (Potsdam) sandstone,[1] and reëxcavated in post-Cambrian and preglacial time. Devil's Lake then occupies an unfilled portion of an old river valley, isolated by great morainic dams from its surface continuations on either hand. Between the dams, water has accumulated and formed the lake.

While the ice was at its maximum stand, it rose above the moraine dams at either end of the lake. The melting of the ice supplied abundant water, and the water of the lake stood above its present level. The height which it attained is not known, but it is known to have risen at least sixty-five feet higher than now. This is proved by the presence of a few drift bowlders lodged on the west bluff at this height. They represent the work of a berg or of bergs which at some stage floated out into the lake.

The preglacial stream flowing through the Devil's Lake gorge.— The great gorge in the quartzite bluffs, a part of which is occupied by the lake, was a narrows in the preglacial valley. If the Baraboo was the stream which flowed through this gorge, the comparable narrows in the north quartzite range — the Lower Narrows of the Baraboo — is to be accounted for. The stream which occupied one of these gorges probably occupied the other, for they are in every way comparable except in that one has been modified by glacial action, while the other has not.

The Baraboo River flows through a gorge — the Upper Narrows — in the north quartzite range at Ablemans, nine miles west of Baraboo. This gorge is much narrower than either the Lower Narrows or the Devil's Lake gorge, suggesting the work of a lesser stream. It seems on the whole probable, as suggested by Irving,[2] that the Wisconsin River in preglacial time, flowed south

[1] This fact was made known by IRVING, Geology of Wisconsin, Vol. II. Irving also advanced the explanation here given, of the lake.

[2] Loc. cit., p. 508.

through what is now the Lower Narrows of the Baraboo, thence through the Devil's Lake gorge to its present valley to the south. If this be true, the Baraboo must at that time have joined this larger stream at some point east of the city of the same name.

Extinct glacial lake on the east quartzite bluff.—Between the arms of the main terminal moraine loop on the quartzite range, about two miles east of Devil's Lake, is a notable flat. Its location and extent are shown in Fig. 2 (*l*). With the exception of the north side, and a narrow opening at the northwest corner, the flat is surrounded by high lands. When the ice occupied the region, its edge held the position shown by the line marking the limit of its advance, and constituted an ice barrier to the north.[1] The area of the flat was, therefore, almost shut in, the only outlet being a narrow one at *h*, Fig. 2. Excavations in the flat show that it is covered with stratified sands, gravels, and clays of glacial origin, to a depth of at least sixty-five feet. If this filling were removed, the bottom of the area would be much lower than at present, and it is evident that when the ice had taken its position along the north side of the flat, an enclosed basin must have existed. Into this basin water from the melting ice flowed, forming a lake. At first it had no outlet, and the water rose to the level of the lowest point (*h*, Fig. 2) in the rim of the basin, and thence overflowed to the west. Meanwhile the sediments borne in by the glacial drainage were being deposited in the lake in the form of a subaqueous overwash plain, the coarser parts being left near the shore, while the finer were carried further out. Continued drainage from the ice continued to bring sediment into the lake, and the subaqueous overwash plain extended its delta-like front farther and farther into the lake, until its basin was completely filled. With the filling of the basin the lake became extinct. Further drainage from the ice followed the line of the outlet, the level of which corresponds with the level of the filled lake basin. This little extinct lake is of interest as an

[1] The moraine line on the map represents the crest of the marginal ridge rather than its outer limit, which is slightly nearer the lake margin. Stratified drift of the nature of overwash also intervenes at points between the moraine and the lake border.

example of a glacial lake which became extinct by having its basin filled during glacial times, by sediments washed out from the ice.

Near the northwest corner of this flat, an exposure in the sediments of the old lake bed shows the curiously contorted

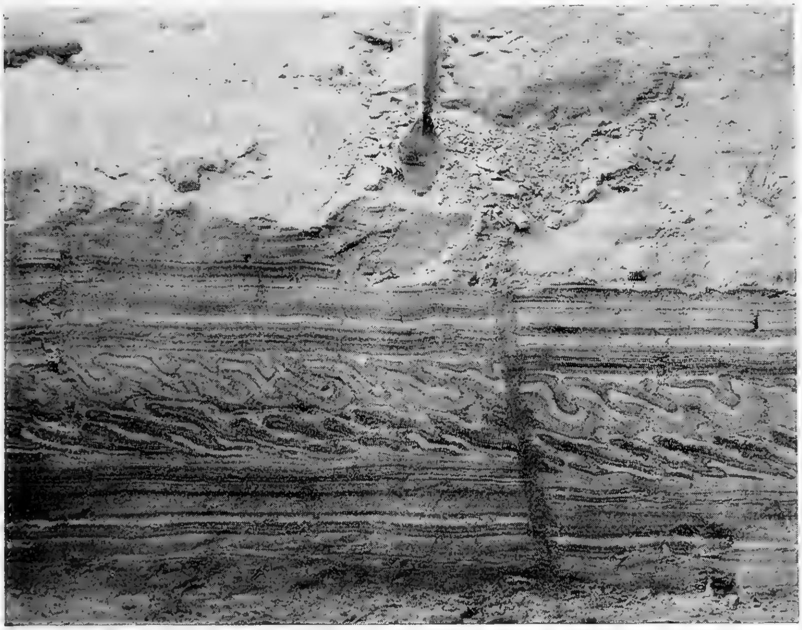


FIG. 6. Contorted layers of sand and silt, in the bed of the extinct glacial lake.

layers of sand, silt, and clay represented in Fig. 6. The layers shown in the figure are but a few feet below the level of the flat which marks the site of the lake. It will be seen that the contorted layers are between two series of horizontal ones. The material throughout the section is made up of fine-grained sands and clays, well assorted. That these particular layers should have been so much disturbed, while those below and above remained horizontal, is strange enough. The grounding of an iceberg on the surface before the overlying layers were deposited, or the action of lake ice may have been responsible for the singular phenomenon.

Skillett Creek.—Skirting the morainic apron or overwash plain southwest of Baraboo, is a little stream, tributary to the Baraboo, known as Skillett Creek. For some distance from its head (*a* to

FIG. 7. Skillett Creek, illustrating the points mentioned in the text.

b, Fig. 7) its course is through a capacious preglacial valley. The lower part of this valley was filled with the water-laid drift of the overwash plain. On reaching the overwash plain the creek therefore shifted its course so as to follow the border of that plain, and along this route, irrespective of material, it has cut a new channel to the Baraboo. The postglacial portion of the valley (*b* to *c*) is everywhere narrow, and especially so where cut in sandstone.

The course and relations of this stream suggest the following explanation: Before the ice came into the region, Skillett Creek probably flowed in a general northeasterly direction to the Baraboo, through a valley comparable in size to the preglacial part of the present valley. As the ice advanced, the lower part of this valley was occupied by it, and the creek was compelled to seek a new course. The only course open to it was to the north, just west of the advancing ice, and, shifting westward as fast as the ice advanced, it abandoned altogether its former lower course. Drainage from the ice then carried out and deposited beyond the same, great quantities of gravel and sand, making the overwash plain. This forced the stream still further west, until it finally reached its present position across a sandstone ridge or plain, much higher than its former course. Into this sandstone it has since cut a notable gorge, a good illustration of a postglacial valley. The series of changes shown by this creek is illustrative of the changes undergone by streams in similar situations and relations all along the margin of the ice.

Damming of the Baraboo.—West of the terminal moraine on either side of the Baraboo River are broad flats, extending at least as far up the stream as Ablemans. At various points, exposures show the material of the flat to be laminated clay of lacustrine type. The tributaries to the Baraboo in this region are bordered by similar flats composed of similar material. These flats, together with the flats along the main stream, represent the bottom of a glacial lake. The outlines of this lake cannot now be given. At Ablemans there is a body of loess,[1] the upper surface of which corresponds in elevation with the flat of the Baraboo below.

When the ice lay in the valley of the Baraboo with its edge just west of the city, the stream was effectually dammed. The waters which were held back by the ice dam, reinforced by the drainage from the ice itself, soon developed a lake in the valley of the Baraboo, above the point of obstruction. This body of water likewise extended up the lower course of every tributary, presumably rising until it found the lowest point in the rim of the drainage basin. The location of this point, and therefore its

[1] JOURNAL OF GEOLOGY, Vol. IV, p. 929.

height, and the height of the lake when at its maximum, are not known. But at a point three miles southeast of Ablemans on the surface of a sandstone slope, water-worn gravel occurs, the pebbles of which were derived from the local rock. On the slope below the gravel, the surface is covered with loam which has a suggestion of stratification, while above it, the soil and subsoil appear to be the product of local rock decomposition. This water-worn gravel of local origin on a steep slope facing the valley, probably represents the work of the waves of this lake, perhaps when it stood at its maximum height. This gravel is about 125 feet, according to aneroid measurement, above the Baraboo River.

This lake did not entirely disappear when the ice retreated, for the drift which the ice left, especially the terminal moraine, still obstructed drainage to the east. The moraine, however, was not so high as the former outlet of the lake had been, so that as the ice retreated, the water flowed over the moraine to the east, and drew down the level of the lake. The postglacial valley cut through the moraine is about ninety feet deep.

Besides being obstructed where crossed by the terminal moraine, the valley of the Baraboo was clogged to a lesser extent by deep deposits between the moraine and the Lower Narrows. At one or two places near the city of Baraboo, such obstructions, now removed, appear to have existed. Just above the "Lower Narrows" there is positive evidence that the valley was choked with drift. Here in subsequent time, the river has cut through the drift-filling of the preglacial valley, developing a passage about twenty rods wide and thirty-five deep. If this passage were filled with drift, reproducing the surface left by the ice, the broad valley above it would be flooded, producing a lake. At the outset, this lake must have been considerably lower than the one above the moraine to the west, but drainage from the latter into the former soon lowered the barrier between them, bringing the upper lake to the level of the lower. The lake below Baraboo was much less extensive than the one above, and probably shorter lived. It became extinct by the cutting of its outlet above the Lower Narrows down to the level of its bottom. The location of this extinct lake is shown on the map, in Fig. 1.

Other extinct lakes.—The beds of at least two other extinct ponds or small lakes above the level of the Baraboo are known. These are at *m* and *n*, Fig. 2. They owe their origin to depressions in the drift, but the outflowing waters have cut down their outlets sufficiently to bring them to the condition of marshes. Both were small in area and neither was deep.

From the foregoing it is seen that the small area centering about Devil's Lake presents a number of interesting drift phenomena, some of which are possessed of unusual significance. This is particularly true of the phenomena of the terminal moraine in its passage over the quartzite ridge, and of the phenomena which have led to the determination of the slope of the ice at its extreme edge, along the south side of the quartzite range.

ROLLIN D. SALISBURY,
WALLACE WALTER ATWOOD.

COMPARISON OF THE CARBONIFEROUS AND PERMIAN FORMATIONS OF NEBRASKA AND KANSAS.[1] II.

THE WABAUNSEE FORMATION.

Nebraska City.— On account of the historic interest attached to the Nebraska City section care was taken to examine the particular exposures studied by Marcou, Meek and Hayden. As a result of this study I have no hesitation in stating that I fully agree with Meek in referring the lower beds of the section (divisions *A* and *B* of Marcou and Meek) to the Upper Coal Measures (Missourian series).[2] On the geological "Map of Nebraska and Dakota" accompanying this report, the Permian is represented as entering the state from Kansas in Jefferson county, west of the Big Blue Valley, then extending to the northeast as a narrowing belt across Lancaster county and down the valley of Saline Creek to the Platte River and thence up the Platte River to Fremont. The town of Lancaster near the present city of Lincoln in Lancaster county, which is the next county west of Otoe, is represented as about halfway across this Permian area. However, in general, on this map the Permian is represented too far to the west, as for example in the Smoky Hill Valley in Kansas, the *base* is represented as near the city of Salina, which in fact is very near the *top;* while the system is mapped as extending some twenty-five miles west of Salina, nearly all of which is now known to belong in the Cretaceous. The same is true in reference to the northern tier of counties where the Permian was represented in Washington and Republic counties in what is known to be Dakota and Ft. Benton. Further-more, it is perfectly clear that the upper part of the section

[1] Continued from p. 16, this JOURNAL.

[2] See the Nebraska City section of Meek in Fin. Rep. U. S. Geol. Sur. Neb., etc., pp. 101, 102.

(divisions *C* and *D*), in reference to the correlation of which Meek was in some doubt,[1] also belongs in the Missourian. Meek plainly saw that there was no basis for referring the upper part of the section to one formation and the lower part to another, for he said: "I can see no reason whatever for drawing any important line of division between the beds included in *C* and those of *B*, or for separating either from the Coal Measures,"[2] though in the closing part of the report he was not sufficiently confident to make an unqualified statement to that effect. However, sections in higher rocks to the north and west of Nebraska City, which will be described farther on in this paper, show conclusively that all the Nebraska City rocks belong in the Missourian.

Meek gave a very complete list of the fossils from divisions *B* and *C* at the former Nebraska City landing (near the present Burlington and Missouri River railroad bridge) which are mostly well-known Upper Coal Measure species.[3] A short distance south of this locality is the quarry of the Nebraska City Vitrified Brick Co. which uses about twenty feet of the upper shales of division *C* of the sections of Marcou and Meek. These shales are mostly of a drab color, somewhat micaceous as well as clayey, and resemble those used for vitrified bricks at the Topeka, Kansas, works. Above the shales of the quarry are ten feet of very sandy shales, changing to soft sandstones, which represent division *D* of the early sections. On the farm of the Hon. J. Sterling Morton, about seventy-five feet above the level of the Missouri River, and again on the river bank one mile below the Nebraska City landing and thirty feet above river level, Meek found a stratum of "black bituminous shale, with a few inches of coal" having a total thickness of one foot, six inches, which was not shown in the Nebraska City section and which he thought must belong above it.[4] The position of this shale has an important bearing upon Meek's correlation, for in an argillaceous limestone immediately above the black shale he found a fauna

[1] Fin. Rep. U. S. Geol. Sur. Neb., etc., p. 130. [2] *Ibid.*, p. 103.

[3] *Ibid.*, p. 101; also see "Tabular list," pp. 124–127.

[4] *Ibid.*, pp. 103, 104.

which "agrees exactly, so far as they go, with that of division *B* of the section [its lower part] at the landing, with the exception of *Fusulina*."[1] Since the time of Meek's exploration, the construction of the B. & M. R. R. R. along the river bluff below the old steamboat landing has exposed the rocks and shown Meek's supposition regarding the position of the shale to be correct. The following section is shown above the railroad at some distance below the Vitrified Brick quarry:

	Feet.
8. Massive somewhat calcareous sandstone - - - - -	$2\frac{1}{2}=37\frac{1}{2}$
7. Rather arenaceous shales - - - - - - - - -	15=35
6. Limestone with fossils, *Fusulina cylindrica*, etc. (No. 3 of Meek's section on p. 103 of his report) - - - - -	$1\frac{1}{12}=20$
5. Black, very bituminous shale with thin layers of coal, one foot, eleven inches (No. 2 of Meek's section) - - - -	$1\frac{11}{12}=18\frac{11}{12}$
4. Mainly argillaceous shales - - - - - - - -	9=17
3. Arenaceous shales, with thin, irregular sandstone at top -	5=8
2. Massive, soft and friable brownish sandstone (about railroad level) 2 and 3 equal division *D* of Meek's section - -	3=3
1. Argillaceous shales that furnish material for the vitrified bricks (the upper part of division *C* of Meek) - - -	3=

Numbers 2 and 3 of the above section form division *D* of Meek's section. If the sixty-nine feet measured by Meek, which are below No. 4 of the above section, be added to it there will be a thickness of ninety-eight feet of Palæozoic rocks for the river bluff below Nebraska City. The rocks may be traced along the bluff continuously the greater part of the distance from the Vitrified Brick quarry to the above section, which shows that the stratum of shale and coal is above the sandstone (division *D*) of Meek's section as he supposed.[2]

The dip in the bluff where the above section was measured is nearly 1° to the east of south. From the rocks just above and below the black shale and coal in the quarry and along the bluff to the south the following species were collected. Meek spent nearly a week in the vicinity of Nebraska City, and made

[1] Fin. Rep. U. S. Geol. Sur. Neb., etc., p. 103.

[2] See Meek's discussion of the stratigraphic position of this coal on p. 104 of his report.

a practically complete list of the fossils of that region. No attempt was made to duplicate his work, and only the few species noted below were collected:

Productus (*Marginifera*) *splendens* Nor. & Pratt (c). Meek referred this to *P. longispinus* Sow. with which identification Keyes agrees, and probably this is correct.

Productus costatus Sowb. (rr).

Productus punctatus (Martin) Sowb. (rr).

Spirifer cameratus Morton (?) (rr). Imperfectly preserved specimen.

Chonetes granulifera Owen (rr).

Enteletes hemiplicatus (Hall) H. & C. (rr). Formerly *Syntrilasma hemiplicatus* (Hall) Meek & Worthen.

Edmondia sp. (rr). The specimen has rather high beak but is narrower than the figures compared, with quite sharp concentric lines.

Macrocheilus intercalaris M. & W. (rr) var. *pulchellus* M. & W. changed by Keyes to *Sphærodoma medialis* (M. & W.) Keyes.

Fusulina cylindrica Fischer (c).

Cythere nebrascensis Geinitz (?) (c).

Meek found *Spirifer cameratus* in the limestone above the coal associated with plenty of other fossils characteristic of the Upper Coal Measures, so that it is clearly shown by the stratigraphy and palæontology that all of the Palæozoic rocks in the vicinity of Nebraska City belong in the Upper Coal Measures (Missourian) instead of in the Dyas (Permian) as claimed by Marcou. The writer is not confident whether the Nebraska City beds should be referred to the upper part of the Missouri formation or to the Wabaunsee formation of the Missourian series. However, the faunal and lithologic characters of the beds near Nebraska City agree quite closely with those of the lower half of the Wabaunsee formation as shown along the Kansas River above Topeka, and so the writer refers them provisionally to it.

Dunbar.—This station on the B. & M. R. R. R. is eleven miles west of Nebraska City and nearly 150 feet higher than the Missouri River at that point. One mile south and one and one-half miles east, or about two miles southeast of Dunbar, on the south side of the B. & M. R. R. R., is the McCartney quarry.

The rocks are well exposed nearly to the level of the railroad, which is about 140 feet higher than the Missouri River at Nebraska City, and above it is a section fifty feet in thickness. The base of this section must be considerably higher than the top of the one at Nebraska City unless there be a reversal in the direction of the dip from that noted there.

SECTION OF THE M'CARTNEY QUARRY.

		Ft. In.		Ft. In.
11.	Soil - - - - - - - - - -	4	=	56
10.	Yellow, very fossiliferous shales. *Spirifer cameratus*, etc. - - - - - - - - - -	1	=	52
9.	Slightly reddish shales - - - - - - -	1 9	=	51
8.	Yellowish shales with thin, greenish-gray layers of rather hard limestone which contain abundant specimens of *Myalina perattenuata* and *Pleurophorus occidentalis*. A little black shale - - - - - - - -	6 3	=	49 5
7.	Yellowish, rather soft limestone containing fossils. The quarry stone 1 foot 2 inches thick - - - - -	1 2	=	43 2
6.	Yellowish and drab to greenish argillaceous shale -	6	=	42
5.	Red argillaceous shale - - - - - - - -	2	=	36
4.	Drab to bluish very soft argillaceous shales - -	11	=	34
3.	Yellowish and rather coarse shales - - - - -	7	=	23
2.	Shaly yellowish limestones - - - - - -	3+	=	16
1.	Yellowish to drab shales for the upper part; below are reddish shales and the base is covered - - - -	13	=	13

(Railroad level about 140 feet above Missouri River at Nebraska City, or approximately 1050 A. T.)

No. 7 of the above section is a rather soft limestone averaging a little more than one foot in thickness which is used to some extent for foundation and abutment work. This limestone contains some fossils, mostly large Lamellibranchs, as for example:

Myalina subquadrata Shum.
Allorisma subcuneatum M. & H.
Aviculopecten occidentalis (Shum.) M. & W.

The greenish gray slightly arenaceous limestones of No. 8 contain abundant specimens of two specimens of Lamellibranchs. The species collected are:

Pleurophorus occidentalis M. & H. (aa). Many of the specimens are external impressions, showing only the concentric lines ; one shows radiating lines somewhat indistinctly and there are a number of internal impressions which show very clearly the furrow made by the interior ridge.

Myalina perattenuata M. & H. (a).

Aclis Swalloviana (Geinitz) M. & H. (?) (rr).

The yellow shales above the quarry stone are quite fossiliferous, No. 10 especially. From these shales of Nos. 8 and 10 the following species were collected, the larger number, however, coming from No. 10:

Chonetes granulifera Owen (aa)

Chonetes lævis Keyes=(*Chonetes glabra* Geinitz) (c). Some of the specimens are worn and show the radiating fibrous shell structure.

Hustedia mormonii (Marcou) H. & C. (c).

Spirifer (*Martinia*) *planoconvexus* Shum. (aa).

Spirifer cameratus Morton (c).

Spiriferina kentuckensis Shum. (rr).

Athyris (*Seminula*) *subtilita* (Hall) Newb.

Productus longispinus Sowb.=(*P. splendens* N. & P.) (r).

Productus cora d'Orbigny (c).

Productus nebrascensis Owen (rr).

Productus semireticulatis (Martin) de Kon. (c).

Productus symmetricus McChesney (rr).

Enteletes hemiplicatus (Hall) H. & C. =(*Syntrelasma hemiplicatus* (Hall) Meek) (rr).

Orthis carbonaria Swallow (?) (rr). Small specimen that seems to be *Orthis* instead of *Enteletes*.

Derbya crassa (M. & H.) H. & C. (rr).

Lophophyllum proliferum (McChes.) Meek (c).

Rhombopora lepidodendroides Meek (a).

Fistulipora nodulifera Meek (aa).

Zeacrinus (?) *mucrospinus* McChesney (r).

Archæocidaris sp. spines and plates (c).

Crinoid stems (r).

Coral sp. (rr). A small branching coral something like *Aulopora*.

Spirifer cameratus Morton as well as numerous other Upper Coal Measure shells are common in these upper yellow shales. The faunal and lithologic characters of the section agree closely with those of the Wabaunsee formation, to which it is referred. Inasmuch as the rocks of this section are still higher than any of those exposed at Nebraska City we have conclusive proof that no part of that section belongs in the Permian. Time did not permit me to continue this section as far west as the Cretaceous; but in the soil and on the surface to the south and west of Dunbar are numerous loose specimens of the brownish-red Dakota sandstone.

CASS COUNTY.

THE WABAUNSEE FORMATION.

Nehawka.—Directly north of Otoe county is Cass county, whose eastern border is formed by the Missouri River, and the greater part of the northern by the Platte River. In the southern part of the county is Weeping Water Creek, along which are rather low bluffs in which the rocks are quite well shown from Nehawka to the vicinity of Wabash. Meek described a section on this creek called Cedar Bluff, about six miles above its mouth. The section had a thickness of 88+ feet, all of which he correctly referred to the Upper Coal Measures.[1]

The village of Nehawka is sixteen miles by rail northwest of Nebraska City and about one-half mile east of it is the Van Court and Lemist quarry which has been worked for six years. The floor of the quarry is between 90 and 95 feet, according to surveyor's level, above the Nehawka Railroad station, which makes its elevation 170 feet or more above the Missouri River level at Nebraska City, or approximately 1085 A. T.

SECTION OF THE NEHAWKA QUARRY.

		Ft.	In.		Ft.	In.
10.	Loess	10		=	42	3
9.	Light gray to slightly bluish limestones that weather yellowish, all of which are worked for quarry stone. They are moderately fossiliferous, especially the shaly parts, *Athyris subtilita* being the most common	18		=	32	3
8.	Shaly limestones	2		=	14	3
7.	Yellow shales that are used for bricks	1		=	12	3
6.	Limestone used for bridges, the strongest in the quarry		10	=	11	3
5.	Yellowish shale used for vitrified bricks	1		=	10	5

[1] Fin. Rep. U. S. Geol. Sur. Nebraska, pp. 97–99.

SECTION OF THE NEHAWKA QUARRY—*continued.*

		Ft.	In.		Ft.	In.
4.	Black shale that is quite bituminous	1	4	=	9	5
3.	Limestone, best building stone in quarry		7	=	8	1
2.	Limestones at base of quarry. Floor 90 to 95 feet above railroad level	1	6	=	7	6
1.	Yellow to buff arenaceous shales in railroad cut under quarry	6		=	6	

The dip is small and toward the east. About twenty-two feet of the limestones are worked, the stone being crushed and used for railways and highways. Some of it is also burned for quicklime. The shale was formerly sent to Louisville, where it was burned for vitrified brick. There are some fossils in the upper limestones, especially in the shaly partings, yet, with the exception of *Athyris subtilita*, no species can be said to be abundant. These upper limestones, No. 9 of the section, furnished the following species:

Athyris (*Seminula*) *subtilita* (Hall) Newb. (aa).
Spirifer cameratus Morton (c).
Derbya crassa (M. & H.) H. & C. (r).
Productus (*Marginifera*) *longispinus* Sowb. (r).
Productus costatus Sowb. (?) (rr).
Productus semireticulatus (Martin) de Koninck. Fragment of specimen (rr).
Hypothyris (*Pugnax*) *uta* (Marcou) H. & C. (r).
Hustedia mormonii (Marcou) H. & C. (rr).
Meekella striato-costata (Cox) White & St. John (r).
Spirifer (*Martinia*) *lineatus* Martin (rr).
Lophophyllum proliferum (McChesney) Meek (c).
Zeacrinus (*?*) *mucrospinus* McChesney (rr).
Fusulina cylindrica Fischer (rr).
(?) *Chætetes* cf. *carbonarius* Worthen (r).
Coral or *sponge* sp. Large one, genus not yet determined (rr).
Crinoids. Fragments of stems (rr).
Naticopsis nana M. & W. Small and imperfectly preserved (rr).

On account of the faunal and lithologic character of the rock the above exposures are referred to the Wabaunsee formation. The quarryman reported an outcrop of coal in the bed of the creek near Nehawka and estimated that the bottom of the quarry was about 200 feet higher than the coal at Nebraska City.

Weeping Water.—This village is nine miles up the Weeping Water Creek from Nehawka, and for about seven miles the valley is bounded by low rounded bluffs. Beyond this the bluffs are steeper, their crest being formed by heavy limestones. This type of valley is conspicuously shown in the vicinity of the village, the sides of the bluffs being partly covered by large blocks of the massive limestone that have fallen from their original position. They continue steep, being marked by a prominent limestone stratum, for rather more than two miles above Weeping Water, when they again become lower with rounded slopes.

The first outcrop studied above the Nehawka quarry is seven miles up the Weeping Water valley, at a locality known as the "Swede quarry" on the north side of the Missouri Pacific Railway. It is only a few rods from the railroad, between twenty-five and thirty feet higher, with an approximate elevation of 1080 feet A. T.

SECTION OF THE SWEDE QUARRY.

	Ft.	In.		Ft.	In.
6. Massive yellowish to brownish gray limestone, that weathers whitish - - - - - - - -	1		=	18	9
5. Yellowish shale - - - - - - - -		10	=	17	9
4. Somewhat reddish limestone - - - - -	1	4	=	16	11
3. Rather irregular, massive limestone, of yellowish to pinkish color, containing large numbers of *Fusulina cylindrica* Fischer, 2 to 2¼ feet thick. This limestone resembles somewhat the chocolate limestone of Swallow as it occurs along the Kansas valley near Maple Hill, Kansas - - - - - - - - - -	2	3	=	15	7
2. Yellowish soft shales, immense numbers of *Fusulina*. *Spirifer cameratus* is also common; 2½–3 feet thick	3		=	13	4
1. Massive limestone of rather light gray to buff color. The quarry rock. Flint in upper part of stratum and all of it quite free from fossils - - - -	10	4	=	10	4

The following species were collected in the above quarry, the greater number from the yellow shales of No. 2:

Athyris (*Seminula*) *subtilita* (Hall) Newb. (c).
Spirifer cameratus Morton (a).
Enteletes hemiplicatus (Hall) H. & C. (rr).
Productus semireticulatus (Martin) de Koninck (?). Only fragments (rr).
Chonetes granulifera Owen (rr).
Spiriferina kentuckensis Shum. (r).
Hustedia mormonii (Marcon) H. & C. (rr).
Rhombopora lepidodendroides Meek (c).
Lophophyllum proliferum (McChes.) Meek (rr).
Zeacrinus (?) *mucrospinus* McChesney (r).
Fusulina cylindrica Fischer. Very abundant in some shaly limestones (aa).
Campophyllum torquium (Owen) Meek (rr).
Phillipsia scitula M. & W. (rr).
Archæocidaris sp. Plate and spines (r).
Productus nebrascensis Owen (rr).
Fistulipora nodulifera Meek (c).
Crinoids. Segments of large stems (r).

The above fauna is that of the Wabaunsee formation and the reddish to pinkish limestones are similar in appearance to limestones near the middle of the formation in Kansas.

The heavy limestone near the crest of the bluff on the northern side of the creek is very prominent both above and below Weeping Water for some distance, as well as in the village itself. Perhaps the best section of the limestone and underlying rocks is afforded by the Reed quarry, one-half mile east of the village. It is north of the railroad, the base of the *Fusulina* shaly limestone being about eighty feet above railroad level or approximately 1160 feet A. T.

SECTION OF THE REED QUARRY.

	Ft.		Ft.
9. Loess, 10 to 12 feet - - - - - - -	12	=	63½
8. Massive light gray limestone weathering to a whitish color. This is the main quarry stone. It is crushed for railroad ballast and burned for lime which slacks and sets very quickly. In some places it reaches a thickness of 12 feet. Some flint and iron pyrites in upper part -	9	=	51½
7. Shaly buff to yellowish fossiliferous limestone containing abundant *Fusulinas* in the upper 4 feet and in lower part *Spirifer cameratus*. Used for riprap. Base about 80 feet above railroad level - - - - - -	6¾	=	42½

SECTION OF THE REED QUARRY—*continued.*

		Ft.		Ft.
6.	Yellowish shale with plenty of *Spirifer cameratus*	1 1/3	=	35 5/6
5.	Buff to yellowish limestone (not valuable) - -	1	=	34 1/2
4.	Black, bituminous shale - - - - - -	2	=	33 1/2
3.	Limestone quarried for building stone - - -	1 1/2	=	31 1/2
2.	Greenish argillaceous shales - - - -	30±	=	30
1.	Red shale, thickness undetermined. This stratum shows in the village and also in a railroad cut above it.			

The shaly yellowish limestone, No. 7, of this quarry contains quite a number of fossils, especially in its lower part. The following species were collected:

Athyris (*Seminula*) *subtilita* (Hall) Newb. (a).
Spirifer cameratus Morton (c).
Enteletes hemiplicatus (Hall) H. & C. (c).
Hypothyris (*Pugnax*) *uta* (Marcou) H. & C. (r).
Chonetes granulifera Owen (rr).
Productus longispinus Sowb. (rr).
Spirifer lineatus Martin (rr).
Spiriferina kentuckensis Shum. (rr).
Lophophyllum proliferum (McChes.) Meek (a).
Fusulina cylindrica Fischer. Abundant in some layers of the yellowish shales (aa).
Coral or *sponge* sp. Large, undetermined species (c.)
Chætetes cf. *carbonarius* Worthen (r).
Crinoid stems (rr).

The main quarry stone, No. 8, which is a very light gray compact limestone, contains but few fossils, except *Athyris subtilata* (Hall) Newb. Sections of this species, the interior of the shells filled with calcite crystals, are not uncommon in the limestone. In places there are crystals of iron pyrites, some of them large, that on weathering stain the stone as may be seen in some of the buildings in Weeping Water. The following species were collected in the massive limestone of the Reed quarry:

Athyris (*Seminula*) *subtilita* (Hall) Newb. (c). In the somewhat rough partings and apparently in the massive limestone.
Productus longispinus Sowb. (rr).

Meekella striato-costata (Cox) White & St. John (rr).
Lophophyllum proliferum (McChes.) Meek (rr).
Pleurotomaria sp. Small and imperfectly preserved (rr).
Crinoid stems. Some flint with iron in the limestones (rr).

This massive limestone, which from its great prominence in the vicinity of Weeping Water might be termed the Weeping Water limestone,[1] may be followed in the bluffs for three miles above Weeping Water. At the turn in the highway on the north side of the creek about halfway between Weeping Water and Wabash is the last exposure of the Weeping Water stone that was seen. The limestone at this locality is a light gray massive one that weathers to a whitish color, and closely resembles the heavy ledge in the vicinity of Weeping Water. Below are yellowish, shaly limestones with abundant specimens of *Fusulina cylindrica* Fischer, the same as in the Reed quarry. Estimated from one barometric reading, the elevation of the base of the above limestone is 1180 feet A. T., and as the base, in the Reed quarry, three and one-half miles to the east, is 1166 feet there is a dip of four feet per mile to the east. At this place the following species were collected from the Weeping Water limestone:

Athyris (*Seminula*) *subtilita* (*Hall*) Newb. (c).
Productus longispinus Sowb. (c).
Hypothyris (*Pugnax*) *uta* (*Marcou*) H. & C. (rr).
Productus pertenuis Meek (rr).
Meekella striato-costata (Cox) White & St. John (rr). Very imperfect specimen.

Dr. Hayden briefly described the Weeping Water stone as a "limestone, hard, whitish, and yellowish white; cropping out at the summits of the hills, and lying on the slopes in large masses eight to ten feet thick,"[2] accompanied by a rather general section of the bluff. He also described the following shaft beginning in the Weeping Water valley near creek level :

[1] This is not intended as a formation name, but is merely used for convenience in speaking of this limestone stratum.

[2] Loc. cit., p. 14.

	Feet.		Feet.
9. Sandstones that form the creek bed - - -	10	=	30
8. Slate and clay - - - - - - - - - -	3	=	20
7. Coal, nine inches - - - - - - - - -	¾	=	17
6. Whitish, fire clay - - - - - - - - -	3	=	16¼
5. Crystalline quartz, three inches - - - - -	¼	=	13¼
4. Bluish clay - - - - - - - - - -	4	=	13
3. Whitish, fire clay - - - - - - - -	6	=	9
2. Red clay - - - - - - - - - - -	3	=	3
1. Soft white limestone - - - - - - -			

The above section is important from the fact that it shows a stratum of coal, nine inches thick, about 100 feet below the base of the Weeping Water limestone.

The very light gray to whitish color on the weathered surface of the Weeping Water limestone suggests at first the Permian limestones of Kansas, as, for example, the Strong flint at the base of the Chase formation; but the fauna, especially of the shaly limestones just below, indicates that they belong to the Wabaunsee.

One mile below Wabash, on the south bank of Weeping Water Creek, is the small Flowers' quarry.

SECTION OF FLOWERS' QUARRY.

	Feet.
4. Yellowish, coarse shales, containing plenty of fossils. Thickness not determined.	
3. Drab, compact limestone in three layers, containing a good many fossils, especially *Productus pertenuis* in the shaly parting, - -	3½
2. Thin layer of black bituminous shale, - - - - -	5 (2 and 1 together)
1. Bluish coarse shales to creek level, - - - - - -	

The quarry stone, No. 3, has been worked to a limited extent for foundation stone. One reading of the barometer compared with the R. R. elevation at Weeping Water makes this limestone 1150 feet A. T. This indicates that it is below the Weeping Water stone, which is exposed two miles farther east on the north side of the creek. The following fossils were found in this limestone:

Spirifer cameratus Morton (r).
Chonetes granulifera Owen (r).

Productus pertenuis Meek (c).
Productus nebrascensis Owen (r).
Spiriferina kentuckensis Shum. (c).
Productus longispinus Sowb. (c).
Athyris (Seminula) subtilita (Hall) Newb. (c).
Hustedia mormonii (Marcou) H. & C. (rr).
Phillipsia scitula M. and W. (rr).
Rhombopora lepidodendroides Meek (rr).
Spirifer (Martinia) planoconvexus Shum. (rr).

The yellowish shales, No. 4, above the quarry stone have the following fauna:

Athyris (Seminula) subtilita (Hall) Newb. (aa).
Chonetes granulifera Owen (a).
Spirifer cameratus Morton (r).
Productus nebrascensis Owen (c).
Productus longispinus Sowb. (r).
Productus cora d'Orbigny (c). Perhaps one of the specimens is *P. costatus* Sowb. as it has a faint sinus.
Derbya crassa (M. & H.) H. & C. (c).
Productus pertenuis Meek (rr).
Productus semireticulatus (Mart.) de Koninck (rr).
Myalina swallowi McChesney (r).
Myalina subquadrata Shum. (rr).
Myalina perattenuata M. & H. (rr).
Myalina kansasensis Shum. (?) (rr). Small specimen. Characters not clearly shown.
Fusulina cylindrica Fischer (aa). In some layers of the yellowish shales.
Aviculopecten occidentalis (Shum.) M. & W. (rr).
Rhombopora lepidodendroides Meek (r).
Lophophyllum proliferum (McChes.) Meek (rr).
Septopora biserialis (Swallow) Waagen (r).
Zeacrinus mucrospinus McChesney (rr). Calyx and spine.
Crinoids (r). Segments and parts of quite large stems.

These were the last rocks found in place along Weeping Water Creek which are shown by their fauna to belong in the Wabaunsee formation.

One mile to the west of Wabash and rather more than 100 feet higher than the Flowers' quarry, the general level of the upland is reached. There are very few exposures on these higher slopes along the upper part of the Weeping Water valley, the country being gently rolling and the rocks deeply covered by loess and soil. According to a residing farmer on this upland, a well fifty-six feet deep did not strike hard rock but was dug "in dirt" for its entire depth.

Louisville.—Ten miles due north of Weeping Water is Louisville on the Platte River. The Missouri Pacific Railroad station is 1042 feet A. T. or thirty-eight feet lower than that at Weeping Water. The Platte River is shallow, with numerous sand bars, and at this locality is nearly one-half mile wide, lined on both sides with moderately steep bluffs. In these bluffs, both above and below the town, are a number of quarries which have been or are extensively worked and so afford an excellent idea of the geology of this region. On the south side of the river are several quarries and a section of one, the Parmlee, about three-fourths of a mile west of the town and south of the B. & M. R. Railroad was measured. According to the barometer, the floor of this quarry is some sixty feet above the Platte River which makes it approximately 1070 feet A. T.

THE PARMLEE QUARRY SECTION:

	Ft. In.		Ft. In.
8. Loess - - - - - - - - - - -	10±	=	32 8
7. Rather rough light gray to yellowish, very fossiliferous limestone - - - - - - - - - -	3 6	=	22 8
6. Yellow, very fossiliferous clay shales. *Spirifer cameratus*	1 2	=	19 2
5. Light gray limestone, not in western part of quarry -	2	=	18
4. Green argillaceous shales - - - - - -	6	=	16
3. Red or maroon argillaceous shales - - -	6	=	15 6
2. Rather shaly, slightly greenish limestone and shale -	2 6	=	9 6
1. Quite massive light gray limestone, somewhat fossiliferous. Quarry stone. Bottom of quarry approximately 1070 feet A. T. - - - - - - -	7	=	7

The massive limestone, No. 1, of the Parmlee quarry, contains some fossils, the larger number of specimens occurring in the somewhat shaly partings. The following species were obtained:

Athyris (*Seminula*) *subtilita* (Hall) Newb. (a).
Productus longispinus Sowb. (c).

Productus nebrascensis Owen (rr).

Spiriferina kentuckensis Shum. (rr).

Fusulina cylindrica Fischer (a). Abundant in certain layers.

Archæocidaris sp. (rr). Spine.

Bellerophon carbonarius Cox (?) (r). Imperfectly preserved specimens of the size and shape of this species; one specimen shows concentric striæ that are not mentioned in the description.

Crinoids. (c). Segments of stems.

The yellow shales, No. 6, contain a larger number of species and more numerous specimens. The list is as follows:

Athyris (Seminula) subtilita (Hall) Newb. (c).

Chonetes verneuiliana N. & P. (aa).

Chonetes granulifera Owen (c).

Productus longispinus Sowb. (rr).

Productus nebrascensis Owen (r).

Spirifer (Martinia) planoconvexus Shum. (r).

Spirifer cameratus Morton (r).

Derbya crassa (M. & H.) H. & C. (rr).

Spiriferina kentuckensis Shum. (rr).

Lophophyllum proliferum (McChes.) Meek (rr).

Rhombopora lepidodendroides Meek (c).

Septopora biserialis (Swallow) Waagen (c).

Chætetes cf. *carbonarius* Worthen (rr).

Scaphiscrinus (?) *hemisphæricus* (Shum.) Meek (r).

Crinoid, loose plates and also segments of stems.

Along the bluff on the northern side of the Platte River, opposite the Parmlee quarry, in Sarpy county, are several quarries that afford excellent exposures. These qnarries contain reddish shales above the light gray limestone and when seen from the southern side of the river in bright sunshine form a very striking feature of the landscape. The Rock Island railroad follows the valley just below the bluff and the quarries have been worked extensively for both building stone and rock ballast. The Green quarry, near the eastern end of the quarries, gives a good section from a little above the railroad level nearly to the crest of the bluff. It may be considered as divided into a lower and an upper section, separated by thirty-nine feet of covered slope. A few rods to the east is another small quarry in rocks belonging to the same strata as those of the lower Green quarry.

SECTION OF THE GREEN QUARRY.

		Ft.		Ft.
16.	Soil containing bowlders of Dakota sandstone 2 to 3 feet thick - - - - - - - - - -	3	=	112½
15.	Light gray sandstone - - - - - - -	5+	=	109½
14.	Shale with abundant ferruginous concretions (probably the base of the Dakota sandstone) - - - - -	½	=	104½
13.	Brownish yellow shales containing large flint pebbles mixed with others - - - - - - - - -	1	=	104
12.	Yellowish brown shale - - - - - - -	1	=	103
11.	Red shale more compact than that in the Parmlee quarry on the south side of the Platte River - -	4	=	102
10.	Yellowish shaly limestones - - - - - -	4	=	98
9.	Gray limestone, in some places very light gray and in others yellowish. Fossiliferous (same as quarry stone No. 7 of Parmlee quarry on south side of the Platte)	7	=	94
8.	Covered slope - - - - - - - -	39	=	87
7.	Brownish yellow limestone that weathers to an ochre color. Contains large numbers of fragments of shells	2	=	48
6.	Very yellow soft shales - - - - - -	3+	=	46
5.	Grayish, somewhat shaly limestone - - -	1+	=	43
4.	Massive grayish limestone with brownish specks and blotches. Some *Fusulinas* and other fossils. Lower part brownish-red in places - - - - - -	6½	=	42
3.	Yellowish shaly limestone and shales - - -	1½	=	35½
2.	Light gray to drab and bluish limestone; the upper part is more shaly. Contains fossils, especially *Athyris subtilita* - - - - - - - - -	12	=	34
1.	Coverėd slope, level of Platte River, near 1010 feet A. T. - - - - - - - - - -	22	=	22

The limestones, Nos. 2 and 9, of the above section are quite fossiliferous, especially the more shaly layers. In No. 2 the following species were collected:

Athyris (*Seminula*) *subtilita* (Hall) Newb. (a).
Spirifer cameratus Morton (r).
Productus costatus Sowb. (r).
Productus longispinus Sowb. (rr).
Productus nebrascensis Owen (rr).

Productus semireticulatis (Mart.) de Kon. (?). Imperfectly preserved (rr).
Spiriferina kentuckensis Shum. (rr).
Fistulipora nodulifera Meek (rr).
Fusulina cylindrica Fischer (r).
Zeacrinus (?) *mucrospinus* McChesney (rr).
Archæocidaris sp. Spines (rr).
Crinoids. Large column (rr).

FIG. 2. View in western part of Green quarry north of Platte River at Louisville, showing line of unconformability between Dakota sandstone and Carboniferous limestone. The hammer marks the limestone, No. 3 of section, on which the Dakota sandstone rests, and only three feet to the west, marked by the pick, the limestone is wanting and the Dakota rests on shales of No. 2.

The shaly layers of No. 9 did not furnish as large a number of species as No. 2, though the first two species of the following list were more abundant in the upper than in the lower limestone. The fauna is :

Athyris (*Seminula*) *subtilita* (Hall) Newb. (a).
Productus longispinus Sowb. (c).

Productus costatus Sowb. (rr).
Productus semireticulatus (Mart.) de Kon. (rr).
Spiriferina kentuckensis Shum. (rr).
Derbya crassa (M. & H.) H. & C. (rr).
Archæocidaris sp. Plate and spines (r).

A little farther west in the upper Green quarry is an excellent exposure that differs somewhat from the one just described The section is as follows, commencing at the top of the red shales, No. 11, of the eastern part of the Green quarry:

	Ft.	In.		Ft.	In.
6. Soil	1		=	10	5
5. Light gray to whitish arenaceous deposit (very friable sandstone probably belonging to the Dakota)	5	6	=	9	5
4. Dark to yellowish brown sandstone; base of Dakota sandstone. Prominent line of unconformity		8	=	3	11
3. Massive light gray limestone	1	3	=	3	3
2. Yellowish and greenish shales,	2		=	2	
1. Top of the red shales (No. 11 of the eastern part of the quarry).					

This part of the quarry shows very clearly the line of unconformity due to erosion between the Carboniferous (Wabaunsee) and Cretaceous (Dakota) systems. In places the dark brown Dakota sandstone rests on the gray limestone, No. 3; while not more than three feet away the gray limestone is entirely absent, having been worn away before the deposition of the Cretaceous, and the Dakota sandstone rests on the yellowish shales, No. 2, of the section. When this section was studied the upper rocks for several rods had been recently removed, so that the several strata and the line of unconformity were clearly shown. The line of unconformity is shown in the accompanying picture, where the small hammer shows the Dakota resting on the limestone of No. 3, and the pick shows it resting on the shales of No. 2. Many of the large blocks of rock from the wall of the quarry showed clearly the line of contact, the non-calcareous brown Dakota sandstone closely united to the yellowish calcareous shales in which were fragments of shells. A few rods west of the quarry just described, and across a small run, is another large quarry called the Cooley, which gave the following section:

		Ft. In.		Ft. In.
11.	Soil, - - - - - - - - - - -			
10.	Light gray compact limestone - - - - -	1	=	30
9.	Red shale in upper part, green shale in lower part -	2 6	=	29
8.	Very compact light gray limestone, with some flint	1 6	=	26 6
7.	Coarse, grayish shale - - - - - - - -	1	=	25
6.	Greenish argillaceous shale - - - - - -	3 6	=	24
5.	Massive grayish compact limestone, with fossils -	2 4	=	20 6
4.	Yellowish shales that are greenish at the base - -	2	=	18 2
3.	Red, argillaceous shales - - - - - - -	6 6	=	16 2
2.	Shaly grayish and yellowish limestones changing to shales - - - - - - - - - -	2 6	=	9 8
1.	Massive, grayish limestone (bottom of the quarry,) -	7 2	=	7 2

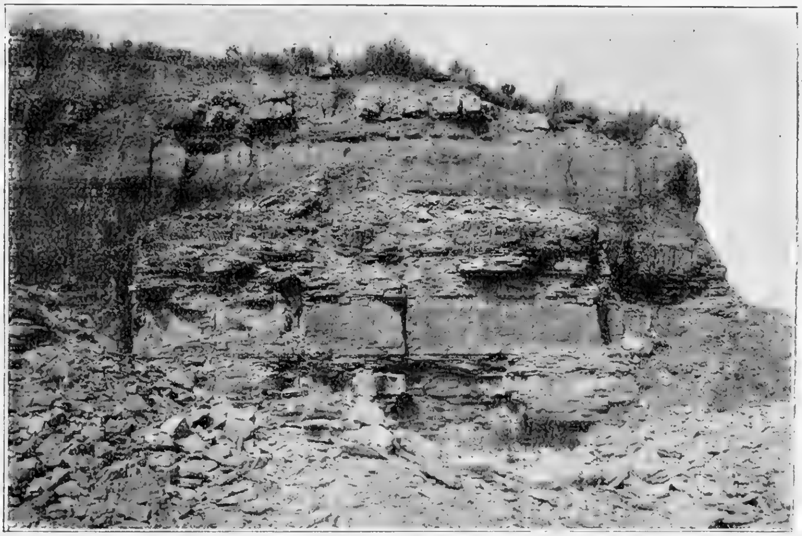


FIG. 3. View in eastern part of Cooley quarry, north of Platte River at Louisville Nos. 1–5 of the section are shown.

From the somewhat shaly layers of No. 1 of this quarry the following fossils were collected:

Athyris (Seminula) subtilita (Hall) Newb. (r).
Productus costatus Sowb. (rr).
Productus cora d'Orbigny (r).

Myalina cf. *recurvirostris* M. & W. (rr). Beak is gone and the specific identification is not positive on that account.

The rocks at the eastern end of this quarry are well shown in Fig. 3 of the pictures, the heavy stratum near the bottom of the picture forming the top of No. 1, which is succeeded by Nos. 2–5 of the section.

The quarry limestone, No. 1, of the above quarry is the same stratum as No. 9 (the quarry limestone) in the eastern part of the Green quarry. The yellowish shales, Nos. 12 and 13, of the eastern part of the Green quarry, No. 2 of the western part, and No. 4 of the Cooley quarry are the same stratum. In the Green quarry the Dakota sandstone rests on either these yellowish shales or the overlying limestone (No. 3) of the western part of the Green quarry; but in the Cooley quarry there is no Dakota sandstone, though Carboniferous rocks with a thickness of eleven feet ten inches are shown above the yellowish shales. In the Green quarry these rocks, with the exception of the limestone, No. 3, in its western part, were eroded before the deposition of the Dakota sandstone. The above data obtained on comparing the Cooley and Green quarries show that the Dakota sandstone was deposited in a very irregular Carboniferous floor.

The massive quarry limestone in the quarries north of the Platte River, No. 9 of the Green and No. 1 of the Cooley, is the same stratum as that quarried in the Parmlee quarry, No. 1, on the south side of the river. The difference in elevation of the base of this limestone on opposite banks of the river, 1097 feet A. T. on the north side, and 1070 on the south side, may be due partly to an error in the barometric record, though there is probably some dip in that direction. In the Parmlee quarry fifteen feet, eight inches of Carboniferous rocks are exposed above the top of the quarry limestone, No. 1 of the section, without showing the Dakota; in the Cooley twenty-three feet are exposed, and in the eastern part of the Green quarry there are ten feet capped by the Dakota. This comparison between the north and south sides also shows the irregularity of surface upon which the

Dakota sandstone was deposited. Dr. Hayden saw the contact of the Carboniferous and Cretaceous rocks; but apparently at localities where there is not such a clear line of unconformity, for he said: "We find at one or two localities the Cretaceous and Carboniferous beds in apposition; and though the eye can observe no apparent want of conformity in these beds, yet we can readily imagine the tremendous effects of the erosion prior to the deposition of the sandstone, from the fact that hundreds of feet of clays and limestones must have been swept away."[1]

In the lower limestone, No. 2, of the Green quarry are specimens of *Spirifer cameratus* associated with other species of the Wabaunsee formation; while in the Parmlee quarry a similar fauna with *Spirifer cameratus* is found in the yellowish shales, No. 6, above the quarry limestone. On account of this fauna and their stratigraphic position, all of the Carboniferous rocks in the vicinity of Louisville are referred to the Wabaunsee formation. On the Platte River, the Permian is not represented and the Dakota sandstone rests unconformably on the limestones and shales of the Wabaunsee formation. This is consequently a very important section as it shows that the 800 feet of Permian rocks exposed along the Kansas and Smoky Hill rivers in Kansas have disappeared and the Dakota sandstone of the Cretaceous system rests on the Wabaunsee formation of the Missourian series or Upper Carboniferous. This conclusion agrees with that of Dr. Hayden who on his "Geological Map of Nebraska" published in 1858 represented the Lower Cretaceous (now known as the

[1] Fin. Rep. U. S. Geol. Sur. Nebraska, p. 9. Also on p. 8 is the statement that "near the old Otoe village, eight miles above the mouth of the Platte [is] a good exposure of the sandstone resting conformably on the Carboniferous limestone." As early as 1858 Meek and Hayden reported the Cretaceous sandstone on the Platte River as resting "directly upon Carboniferous rocks" near the mouth of the Elk Horn River which is some twenty miles above Louisville (Proc. Acad. Nat. Sci. Phil., Vol. X, p. 259). However, it appears that in these early explorations of Meek and Hayden they did not recognize the unconformity between the Carboniferous and Cretaceous for in January 1859, they published the following statement: "In conclusion we would state that, there is no unconformability so far as our knowledge extends, amongst all the rocks of Nebraska and northeastern Kansas, from the Coal Measures to the top of the most recent Cretaceous" (Am. Jour. Sci., 2d ser., Vol. XXVII, p. 35).

Dakota sandstone) on the Platte River as resting on the Carboniferous.[1] On this map the Permian was represented as thinning out and disappearing at a locality apparently several miles north of Dunbar and northwest of Nebraska City; while in the report of 1872 Dr. Hayden clearly expressed this conclusion in describing the geology of Douglas and Sarpy counties. Dr. Hayden said: "If the Permo-Carboniferous and the Permian were ever deposited over this area, they were swept away by erosion prior to the deposition of the Cretaceous rocks. If we follow the valley of the Platte westward on the northern side, we shall see the junction of the two great periods, Carboniferous and Cretaceous, and we shall find that the beds of the Dakota group, or what we suppose to be the Lower Cretaceous beds of the west, rest directly down on the limestones of the Upper Coal Measures."[2] There seems to have been some error in coloring the geological map accompanying this report, for on it the Permian is represented as reaching the Platte valley at Saline, now called Ashland, thirteen miles above Louisville, and then extending up the Platte some twenty miles to Fremont. As a matter of fact along the river to the east of Ashland are fine exposures of the Dakota sandstone.

Meek described a section of rocks on the north side of the Platte River between three and four miles above its mouth (about ten miles northeast of Louisville) which by their fossils are shown to belong to the Upper Carboniferous, probably the Wabaunsee formation.[3]

On the ridge to the south of Louisville are exposures of the lower part of the Dakota formation. One of these is in the "Fire Clay" quarry of Captain Hoover, one and one-half miles south of the village (Sec. 27, Tp. 12, Range 11) where an opening of about fifty feet has been made in working the middle part of the section for fire clay. The exposure begins on the bank of a small run with an approximate altitude of 1100 feet A. T.

[1] Proc. Acad. Nat. Sci., Phil., Vol. X.

[2] Fin. Rep. Geol. Sur. Neb., p. 7.

[3] *Ibid.*, pp. 90–93.

SECTION OF CAPTAIN HOOVER "FIRE CLAY" QUARRY.

	Feet.
7. Soil containing bowlders of hard, dark brown Dakota sandstone	1 = 53
6. Light brown to rusty brown color friable sandstone with streaks of iron brown. In the upper part, some of the hard, dark brown sandstone (line of irregular bedding) -	14 = 52
5. Brownish friable sandstone, six inches to two and one-half feet thick, the difference in thickness being due to the irregular line limiting the top of this stratum - - -	2½ = 38
4. Very hard dark brown sandstone - - - - - -	½± = 35½
3. Brown conglomerate with plenty of small pebbles of quartz, flint, etc. - - - - - - - - - - -	½ = 35
2. Somewhat arenaceous fire clay of light gray to almost white color with pinkish layers. Some layers of friable light gray to whitish sandstone; also of brownish yellow color. About fifteen feet of this part of the section used for fire clay - - - - - - - - - -	30 = 34½
1. Yellowish, very soft and friable sandstone with dark brown streaks (bottom of exposure below the quarry) -	14½ = 14½

In the other quarry of Captain Hoover (Sec. 23, Tp. 12, Range 11) the Dakota sandstone has been quarried and used to a considerable extent in the village buildings. The stone out of which Captain Hoover's house was built some thirty years ago has hardened somewhat on exposure, and in many of the blocks the marks of the tools used in dressing may still be seen. According to the Captain there is about twenty feet of this dark brown sandstone that may be quarried. It is interesting to note the difference in consolidation of the same layers of the Dakota sandstone when separated by only a short distance. The Hoover quarries are only about one-half mile apart and still the comparatively massive brown quarry sandstone just described is the same stratum as the friable light brown sandstone, No. 6, of the "Fire Clay" quarry.

Below the sandstone on section 23 is from fifteen to twenty feet of the light gray to pinkish fire clay. The clay from both of these quarries is made into pottery and is also used in Union Pacific foundry shops and for crucibles and the lining of retorts in smelters. A considerable amount of it is shipped to Omaha for use in the gold and silver smelters. Samples were shown me of similar colored fire clay from a pit near the edge of the village. The conglomerate stratum, No. 3, of the "Fire Clay" quarry is also present at the base of the sandstone in the Hoover sandstone quarry. Near Captain Hoover's house, below the sandstone and fire clay, the Wabaunsee limestone is shown; but the contact between the Wabaunsee and Dakota formations is covered by soil.

CHARLES S. PROSSER.

UNION COLLEGE,
Schenectady, N. Y., October 1896.

THE GEOLOGY OF SAN FRANCISCO PENINSULA.

Dr. Harold W. Fairbanks accuses me in a paper published in the last number of the Journal of Geology of ignoring him. I have written a "Sketch of the Geology of the San Francisco Peninsula" and in doing so I have "given my attention almost exclusively to a narrow field of complex geology and have failed to make use of the results of the work of *others*." "Others" is a modest euphemism for Dr. Harold W. Fairbanks, as appears from a succeeding statement to the effect, that, in my paper "there is a failure to give recognition to some contemporaneous and earlier work in the same general field," which statement is annotated by a reference to a paper of his published as a bulletin of the Geological Society bearing the date December 1894. If the charge applies to this particular paper it is baseless. My "Sketch" was forwarded for publication in June 1894, six months or more before the appearance of the bulletin which he insists should have been recognized. If it applies to earlier papers I must plead charitable motives in gently passing them over without comment. Justice, too, joined with mercy in barring me from quoting from his earlier papers statements which he has since repudiated, as for example, regarding the age of the granite of the Coast Ranges. It would have been scarcely fair to quote from himself views in which it now "seems to him there is no validity whatever." Dr. Fairbanks is fortunately not to be measured by his earlier papers, and the marked improvement in his later work, due in some measure to good University laboratory discipline, commands the respect and recognition which it deserves.

Evidently grieved at the supposed discourtesy with which he charges me, Dr. Fairbanks proceeds to subject my "Sketch" to a "friendly criticism." The friendliness is gratefully appreciated but the object of it is troubled with an uncanny curiosity as to what manner of criticism he should deal out to his *enemy*, should that unfortunate be so foolish as to discuss Coast Range geology in print.

The review, in spite of the peculiar friendliness which animates it, and the voluminous *beliefs* and *opinions* with which it is inflated, contains some more serious elements of scientific criticism. Were my work in this field closed, I should feel it incumbent upon me to reply promptly. As my studies are, however, still in progress, so far as my limited time will permit, and as I hope on a future occasion to offer a further contribution to the geology of the central Coast Ranges I shall for the present defer the discussion of the points raised by my critic, and so, conceding nothing, avoid a controversy distasteful to me by reason of the personal feeling which vitiates its scientific worth.

ANDREW C. LAWSON.

BERKELEY, Feb. 26, 1897.

NOTE ON THE GEOLOGY OF SOUTHWESTERN NEW ENGLAND.

In two papers entitled respectively, "On the Geological Structure of the Mount Washington Mass of the Taconic Range" and "On the Geological Structure of the Housatonic Valley lying East of Mount Washington,"[1] the writer has considered the limestone and schist masses of the area covered by the papers to be each separable into two formations, the limestone alternating with the schist and together comprising a series corresponding to that of Greylock some thirty-five miles to the north. This conclusion was reached from both lithological and structural considerations. The strongest reason for believing the full Greylock series to be present was the apparently anticlinal character of certain ridges of Berkshire schist. These ridges were represented as Riga schist (equivalent to Berkshire) and the limestone surrounding them as Egremont limestone which was supposed to correspond to the Bellowspipe limestone of Greylock. The areal continuity of this limestone with the limestone of Canaan, which immediately overlies the Cambrian quartzite and must therefore be considered Stockbridge, was explained by an important strike fault which can be shown to follow approximately the course of the Housatonic River for a considerable distance.

As fully explained in the first of the papers the area is one in which the structures indicating bedding have been largely effaced during the folding and new structures have been developed. In only a few instances has it been possible to obtain a sufficient number of reliable dip observations to determine with certainty the nature of the folding.

Since the papers above referred to were written further study has been given to the area in the effort to find a locality where

[1] Journal of Geology, Vol. I, pp. 717–736, 780–802.

the structure of the apparently anticlinal ridges of Berkshire schist could be determined with certainty. In the ridge of schist immediately to the south of the east Twin Lake in the township of Salisbury and in the mass of Tom Ball near Housatonic village the observations obtained have been sufficiently numerous and reliable to show that the folds are either overturned anticlines with easterly dipping axial planes or nearly recumbent *fanned* synclines with the axial planes inclined to the eastward. In Tom Ball attempts to follow the fold in the direction of the strike taking note of the pitch of the axis with a view of determining whether the surrounding limestone goes below or above the schist on the end of the fold, afforded no positive results. On the other hand the ridge south of Twin Lakes was followed southward into Watawanchu Mountain where the limestone can be seen to pass under the schist on the end of the fold. This latter locality is therefore a crucial one and shows that the apparent anticlines of schist are nearly recumbent synclinal folds with the necks compressed so as to produce a fan structure.

Turnip Rock in Salisbury was shown to be a syncline by Dana, and the writer has referred to it as one of the best observed localities to show the superior position of much of the schist (formerly called Everett schist) to the valley limestone. A study in detail of this hill shows that it is made up of a fold similar to those of the apparent anticlines, though here the limestone completely surrounds the hill and dips so as to form a shallow basin. The peculiar character of the fold is only revealed in the dips of the schist high up on the slopes of the hill.

In view of the definiteness of the above determinations it is best to substitute for the local terms Canaan limestone and Riga schist the terms Stockbridge limestone and Berkshire schist, which they were supposed respectively to represent and which they are now shown to be. The Egremont limestone should be replaced by the Bellowspipe limestone, which it was thought to be, and its distribution is limited to that of the calcareous schist and limestone of the summit plain of Mt. Washington, the limestone of the Housatonic Valley being included in the Stockbridge limestone. The Everett schist which is here shown to be identical with the Riga schist, should like it be mapped as Berkshire schist. I am glad to be able to acknowledge my indebtedness to Dr. Van Hise for much valuable assistance in reaching a definite settlement of this problem.

Wm. H. Hobbs.

Studies for Students.

DEFORMATION OF ROCKS. V.

SUPPLEMENTARY NOTES.[1]

Separation of the outer part of the earth into zones.—In dividing the outer part of the crust of the earth into an upper zone of fracture, a middle zone of combined fracture and plasticity, and a lower zone of plasticity,[2] three factors should be taken into account, (1) the depth of burying, and therefore the vertical pressure, (2) the relative strength and plasticity of the materials, and (3) rapidity of deformation.

If the last two factors were constant, as a result of the first factor the zone of plasticity would be directly below the zone of fracture with a possible narrow transition zone. The greater the strength of materials, and the greater the rapidity of deformation, the deeper is the zone of plasticity. The weaker and more plastic the materials, and the slower the deformation, the nearer the surface is the zone of plasticity. However, as these factors vary greatly there is a wide middle zone of combined fracture and plasticity. Some rocks may be deformed by plastic flow very near the surface, and others by microscopical fracturing at a great depth. As illustrating this, a bed of mud may be deformed without fracture at or near the surface. Upon the other

[1] Figure 101, on page 595, of my paper on the Principles of North American pre-Cambrian Geology, in the Sixteenth Ann. Rept. of the U. S. Geol. Survey, Part I, was taken from Dr. Carl Futterer. The statement, "After Futterer" was in the manuscript list of illustrations, but by mistake this was omitted in printing.

[2] (A) Principles of North American pre-Cambrian Geology, by C. R. Van Hise; with an appendix on Flow and Fracture of Rocks as related to Structure, by L. M. Hoskins. Sixteenth Ann. Rep. U. S. Geol. Surv., Part I, 1896, pp. 589–603.

(B) Deformation of Rocks, by C. R. Van Hise. Jour. of Geol., Vol. IV, 1896, pp. 195–213.

hand the strongest, brittlest rocks in the deepest zone observable may be partly deformed by complex fracturing along intersecting shearing planes, but, however, without spaces between the particles. In the deepest seated zone the fracturing of the mineral particles may be so uniformly distributed as to give slight undulatory extinction only, the ultimate particles between which differential movements have occurred or differential stresses are at work not being discriminated as such even with the most powerful objective. However, in some of the deformed strong rocks even such stress effects as undulatory extinction are not marked, and in this case, the material must have been largely released from strain, just as in the case of viscous liquids which for a time after deformation show stress effects, but which later free themselves from them. Such profound changes are believed to involve recrystallization, water being the agent through which alteration took place.

It is also conceivable that where the deformation is very slow, even strong, brittle rocks may be deformed by plastic flow comparatively near the surface. But as shown by deep tunnels, some of which have in places a superincumbent load of rock a mile thick, if flow does occur, it is very slow indeed. This, too, is in spite of the fact that a tunnel is substantially a cylinder, very long in comparison to its width, and therefore that if the stress amounts to one half of the elastic limit of the rock, flowage would result.[1] But in estimating the stress in the case of tunnels, it is to be considered that the mountain mass does not have vertical but sloping sides, and hence is really a flat cone. While from the above it is clear that the superincumbent weight of thousands of feet of rock is not sufficient to cause flowage in very strong rocks, it is equally certain that in softer rocks, such as shale and coal, flowage occurs under much less weight than this, as shown by the creeping and closing of some galleries in mines, which at a depth of one thousand feet or less, have from time to time to be cut out, so as to compensate for the creeping flow which has tended to close them.

[1] Loc. cit., (A), pp. 592; (B), p. 199.

Notwithstanding all of the foregoing difficulties and qualifications, it is still possible in the field to place most masses of rock somewhat definitely in one of the three zones, the predominant phenomena in most cases of tolerably homogenous rocks being either fracture or flowage, while in heterogeneous rocks of many districts fracture and flowage are both of importance.

Plastic flow produces folding.—It has been pointed out that the zone of plastic flow is in the zone of folding.[1] Under the conditions of flowage, where the laws of hydrodynamics obtain, there is a constant tendency to approach equilibrium. But because rocks are heterogeneous both in strength and magnitude of elements, this tendency results in very complex flowage, and the resultant forms of deformation include all varieties of rock folds. However, this complexity of flow presents no exceptions to the laws of hydrodynamics.[2] At any moment, for any homogeneous small plastic area, for any forces which may be at work, the deformation obeys the laws of hydrodynamics, *i. e.*, the material moves in the direction of least stress.

Complex folds.—It has been stated that the two sets of simple folds making up complex folds have a tendency to be at right angles to each other. This appears to follow as a necessity from the laws of mechanics.[3] Any number of pressures in all directions may be analyzed into three pressures at right angles to one another, these being maximum, mean, and minimum pressures. At the outset of the action of the folding forces, because the beds and formations act as transmitters of forces, there will be a tendency for two of the principal directions of stress to be parallel to the bedding, and the other of the principal directions of stress to be normal to the bedding. Even after the layers are inclined it will still be true that at any moment the tangential forces may thus be analyzed. Thus we have the explanation of rectangular systems of folds in districts of complex folding. The closer folds are at right angles to the greater horizontal pressure, and the more open cross folds are at right

[1] Loc. cit., (A), p. 594; (B), p. 202.

[3] Loc. cit., p. 627 (A); (B) p. 345.

[2] In my previous articles on deformation by plastic flow I have used the word *hydrostatic*. The word *hydrodynamic* should have been used.

angles to the less horizontal pressure. It may be that the tangential forces in either direction constitute a vertical couple, and in such cases monoclinal folds may be produced.[1]

While for a given district it may be assumed for definite areas that the average direction of the maximum and mean forces remain the same for considerable intervals of time, it does not follow that in the adjacent districts, or in another part of the same district, the relative values of these may not be reversed, and thus the direction of the closer folds for one part of the dis-district be that of more open folds of another part of the district.

Moreover, as a result of the action of the formations as transmitters of forces, plications may be formed intermediate between the two prevalent directions. Minor plications deviating from the general directions of folding are particularly likely to be seen when the two tangential forces are about equal, thus forming domes, and at places where a strong formation plunges below the surface as a result of the cross folding. In such cases the strata, especially the weaker strata, may be in a set of radial minor plications, mantling around the dome or mantling around the plunging mass of strong material. At each point the axes of the minor plications represent the dip of the slopes of the dome or of the stronger bed. Such plications result from the necessary readjustment between the beds. To illustrate—when a piece of leather is placed upon a hemisphere, it will fit closely at the top, but cannot be made to fit along the sides of the hemisphere unless portions be cut out. In nature the rocks cannot be cut out, and as a consequence we have the radial flutings, which in the case of anticlines plunge away from the crest, and in the case of synclines plunge toward the trough. These flutings, and the consequent radiating or converging character of the minor axial planes, are frequently of great assistance in determining whether a given mountain mass is an anticlinorium or a synclinorium. However, it appears that the arrangement of these flutings is no exception to the general law, for there is always a marked tendency for strong beds to decompose the

[1] Loc. cit., (A), pp. 626–627; (B), pp. 343–345.

forces into components parallel to their strike and dip at any given point, and thus the axes of these minor plications would correspond to the local directions of greater and less thrust.

Monoclinal anticlines and synclines.—In regions of close monoclinal folds, the axial planes of which have a low dip, and especially if there be a little fanning, it may be difficult to discriminate between anticlines and synclines. This principle is well illustrated by the relations of the limestone and schist in the Housatonic

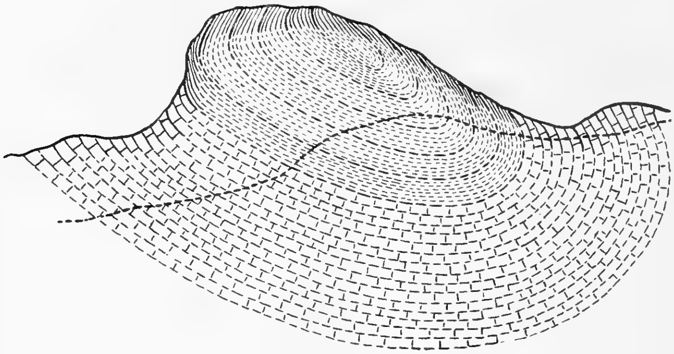


FIG. 1.

Valley. The Stockbridge limestone composes the lowlands for the most part. Rising from the lowlands are numerous schist ridges, varying from small hills to mountains such as Tom Ball and Lenox, the summits of which are from several hundred to a thousand or more feet above the valley. These schist ridges are, in fact, synclines which rest upon the limestone. However, observations of the dip across the ridge would in many cases lead to the conclusion that they are anticlines, as upon opposite sides of the ridge there is a divergence downward in the dip (Fig. 1). Of course dip of bedding is here meant,—not dip of schistosity, which, while variable, dips with considerable regularity to the east. This anticlinal appearance is well illustrated by the hill called Turnip Rock and the larger hill known as Barack M'Teth, and also by Tom Ball, all in, or partly in, the area covered by the Sheffield topographic sheet of Massachusetts. In each of these cases, if the dips of the schist observed in crossing a ridge were alone considered, the ridges would unquestionably be called anticlines. Also if the layers of limestone immediately adjacent to the schists were taken into account, the same con-

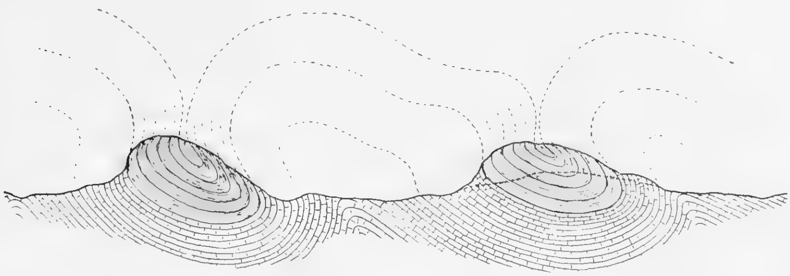


FIG. 2.

clusion would be reached (Fig. 2). While the dips in each case, both on the east and west sides of the ridges, are generally to the east (locally west dips are formed on the west sides of the ridges), on the east side of each ridge the dip is flatter than on the west side, thus making a divergence downward. Fortunately, however, in the case of Turnip Rock, the limestone at both the north and south ends of the hill is traced to the schist, and is found to plunge under it. In fact, at the south end of the mountain the limestone can be almost continuously traced under the schist, and seen to bend suddenly from an almost flat position to its overturned position. A study of Barack M^tTeth and other mountains and their relations shows that Turnip Rock is unquestionably a type of the remainder of the ridges of the district. They are nearly recumbent, slightly fan-shaped synclines. In the areas between the schist ridges the limestone has for the greater part of the distances a continuous rather moderate dip to the east. It is only near the east side of the ridges that the sudden turning over of the anticline may be found. A section through two synclinal schist ridges, with intervening limestone, is generalized in Fig. 2. It is to be noted that if the plain of denudation had cut somewhat lower, so as to remove all but remnants of the schist (see dotted, lines Figs. 1 and 2), these lower parts would appear as ordinary synclines, with little or no evidence of fanning. Indeed, in the case of a number of the schist ridges in the Housatonic Valley, erosion has so far advanced as to have left only the lower part of the synclines. Thus one who studies two adjacent schist ridges cut to different depths and overlooks the intermediate anticline of limestone, which is difficult to discover because of the poor exposures, might infer that one is an anticline and therefore is overlain by the limestone, and that the other is a syncline and is therefore underlain by the limestone. (See Fig. 2.) The conclusion would thus be reached that there are two schist formations, one of which is older than, and the other of which is younger than, the limestone, whereas there is only a single schist formation, and all ridges whether apparently anticlines or synclines, are parts of synclines of the same type and all overlie the limestone.

Positions of cleavage in anticlines and synclines.—In another place I have given the general law:[1] "On opposite limbs of a fold the cleavage usually dips in opposite directions. Upon opposite sides of an anticline the cleavage usually diverges downward, and on opposite sides of a syncline it usually converges downward." No instance of this principle was given. Since this was written it has been found that this principle is well illustrated on Mount Barack M'Teth above mentioned, upon the southern part of Mount Washington in Massachusetts, and upon all of the various synclines of Manhattan schist of Manhattan Island and of the area to the northward. In each of these cases the areas are synclinal, and in all of them the cleavage on opposite sides of the ridges converges downward. Subordinate anticlines of the Manhattan schist, in synclinoria which illustrate the above principle, show the reverse principle, that is, the cleavage diverges downward upon opposite sides of the minor anticlines. This principle is also illustrated at the anticline of Fordham gneiss a short distance south of Harlem Bridge. In many of these cases the folds are monoclinal, and

[1] Loc. cit., (A), pp. 649–650; (B), p. 474.

in some of them the cleavage is also monoclinal, but still shows divergence or convergence downward upon opposite sides of a fold according to the law. In the monoclinal syncline the monoclinal cleavage on opposite sides of the limb converges downward, and in the monoclinal anticline the monoclinal cleavage on opposite sides of the limbs diverges downward.

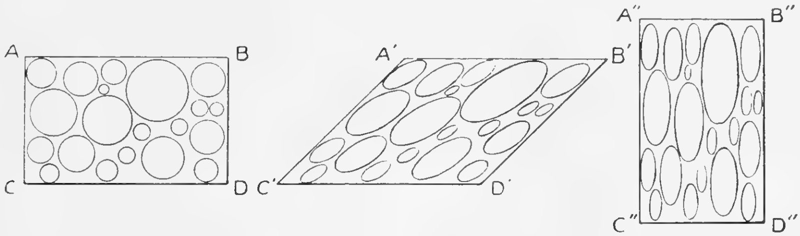


FIG. 3.

It may be suggested that in cases where metamorphism has gone so far that it is difficult to determine bedding this principle of the convergence downward of cleavage on opposite sides of a syncline, and divergence downward of cleavage on opposite sides of an anticline, may be used to determine whether a series of folded exposures are anticlinal or synclinal. In another case, where the bedding is somewhat obscure and dips difficult to get, it may be used as confirmatory evidence of the observations made upon the bedding.

Relations of cleavage produced by shearing to shortening.— In the production of cleavage as a result of simple shearing, Professor Hoskins has pointed out that the cleavage approaches parallelism to bedding faster than does a line originally normal to the bedding.[1] As the actual positions of the cleavage resulting from definite shears and the relations of original circles to equivalent flattened ellipses (Fig. 3) are matters of some practical importance in the field, Mr. E. C. Bebb was asked to tabulate the positions of the major axes of the flattened ellipses, the values of

[1] Flow and Fracture of Rocks as Related to Structure, by L. M. HOSKINS. Appendix to Principles of North American pre-Cambrian Geology, by C. R. VAN HISE, Sixteenth Ann. Rept. U. S. Geol. Surv., Part I, 1896, pp. 870–871.

the major and minor axes of the ellipses compared with those of the diameters of equivalent circles, the ratios between the last two, and the ratio between the diameters of the original circles and the minor axes of the equivalent ellipses, for rotations of a vertical line at intervals of 5°.[1] This table is as follows, the positions of the major axes of the ellipses being calculated to the nearest 1′:

1 Deviation of a vertical line from the perpendicular, as a result of simple shearing	2 Angle between major axes of ellipses and the vertical, resulting from shearing circles	3 Complements of the angles given in (2) or the dip of the cleavage	4 Length of minor axes of ellipses compared with diameters of original circles	5 Length of major axes of ellipses compared with diameters of original circles	6 Ratios between minor and major axes of ellipses	7 Ratios between minor axes of ellipses and diameters of original circles
5°	46° 15′	43° 45′	.957	1.045	1 : 1.091	.957 : 1
10	47 31	42 29	.916	1.092	1 : 1.193	.916 : 1
15	48 49	41 11	.875	1.143	1 : 1.306	.875 : 1
20	50 10	39 50	.834	1.198	1 : 1.436	.834 : 1
25	51 34	38 26	.794	1.260	1 : 1.587	.794 : 1
30	53 3	36 57	.752	1.329	1 : 1.768	.752 : 1
35	54 39	35 21	.709	1.410	1 : 1.987	.709 : 1
40	56 23	33 37	.665	1.504	1 : 2.262	.665 : 1
45	58 17	31 43	.618	1.618	1 : 2.618	.618 : 1
50	60 24	29 36	.568	1.759	1 : 3.096	.568 : 1
55	62 46	27 14	.515	1.943	1 : 3.775	.515 : 1
60	65 27	24 33	.457	2.188	1 : 4.787	.457 : 1
65	68 30	21 30	.394	2.538	1 : 6.446	.394 : 1
70	71 58	18 2	.325	3.073	1 : 9.446	.325 : 1
75	75 55	14 5	.251	3.983	1 : 15.868	.251 : 1
80	80 17	9 43	.170	5.842	1 : 34.30	.170 : 1
85	85 2	4 58	.0866	11.517	1 : 134.9	.0866 : 1

The facts of this table are graphically represented by Fig. 3 for a rotation of a vertical line amounting to 45°.

It is of interest to note that the table shows that with the least possible shearing the greater diameter of an ellipse is inclined 45° to the vertical, or 45° is the smallest or limiting

[1] The position of the major axis of a flattened ellipse with reference to the position of a vertical line rotated a definite amount, and vice versa, resulting from shearing, may be calculated from the following relation: The tangent of twice the angle between a horizontal line and a rotated vertical line (complements of the angles of column 1) is equal to twice the tangent of the angle between a horizontal line and the corresponding major diameter of the flattened ellipse (angles of column 3). Assigning any possible value to either angle, the other is easily calculable.

angle. That is to say, the highest possible dip which a cleavage can have as a result of simple shearing is 45°. The greater differences between the positions of the rotated vertical lines and the major axes of the flattened ellipses result from the smaller rotations and the largest or limiting value is 45°. The differences between the positions of the rotated verticals and the corresponding major axes of the flattened ellipses rapidly diminish in amount with the increased rotation of the verticals, and for rotations of 75° and above the differences are less than 1°. The last column (7) shows the relative efficiency in the production of cleavage of simple shearing, as compared with shortening in a single direction with consequent elongation in another direction. From this column it is seen that shearing which rotates the vertical by 10° is equivalent to a shortening of somewhat less than one-tenth ; that a rotation of the vertical of 20° is equivalent to a shortening of about one-sixth ; that a rotation of the vertical of 30° is equivalent to a shortening of about one-fourth ; that a rotation of the vertical of 45° is equivalent to a shortening of a little more than one-third ; that a rotation of 60° is equivalent to a shortening of a little more than one-half ; and that a rotation of 75° is equivalent to a shortening of about three-fourths. Of course the ratios between the minor and major axes of the ellipses are the same for shortening and corresponding shearing.

In the actual production of cleavage, shortening and rotation are combined in various proportions. It would be interesting to know certainly the amount of simple shearing and of shortening which is necessary to produce ordinary slaty cleavage. I have pointed out in another place[1] that cleavage develops more largely from the formation of new minerals than from the flattening of the old mineral particles, and I am inclined to believe that a very moderate amount of shearing or shortening is sufficient to produce the structure imperfectly—possibly as little as that represented by a shortening of 10 per cent., or a rotation of the vertical of about 10°. Upon the other

[1] Loc. cit., (A), p. 635; (B), pp. 451-453.

hand it is certain that in many schists the actual shearing and shortening is several times this amount. The major axes of the flattened ellipses in the extreme phases of deformation are sometimes from 10 to 20 times as long as the minor axes.

Relations of cleavage and fissility to faults. — It has been explained that the shearing resulting in cleavage or the shearing resulting in fissility may accomplish the same kind of deformation as does thrust faulting.[1] It is equally true that if, after a fissility is produced, the rocks are under conditions of tension, numerous minor slips along planes of fissility may result, the effect of which is equivalent to normal faulting. In different districts, in the Appalachians, for instance, at various places in the Cranberry sheet, at Blowing Rock, N. C., and in Georgia and Alabama, there have been observed during the past season the results of widespread, somewhat uniformly-spaced, differential movements between laminæ at intervals varying from $\frac{1}{32}$ to $\frac{1}{4}$ of an inch. In numerous cases, as a result of these differential movements, the formations of district are brought into the same abnormal positions as would be produced by ordinary normal or thrust movement. The many slight differential movements equivalent to thrust faults, so far as my obervations have gone, are more frequent than the many slight differential movements equivalent to normal faults. In the Cranberry area a granite-gneiss, normally belonging below the Linville series, is brought forward on the north and south sides of the area by innumerable minute movements between the laminæ, to a position above the Linville series. The same sort of irregular distribution due to minute differential movements is seen in the formations of the Linville series itself. In these cases one cannot find a certain plane, or even a narrow zone, and say that here a fault has occurred. However, it is certain that in a zone of considerable width a differential movement has occurred as great as could be accomplished by a great normal or great thrust fault. For this particular form of deformation spread over a considerable area, which does not have the clear cut character of an ordinary fault,

[1] Loc. cit., (A), pp. 659–660; (B), pp. 597–598.

and yet accomplishes the same mass deformation, the term *distributive fault* is proposed. There may be distributive normal or tension faults and distributive thrust or compressive faults.

Relations of joints to bedding.—Joints have been classified into tension joints and compression joints.[1] Tension joints ordinarily form nearly normal to bedding. This results from the fact that the layers act as transmitters of forces, and that at any given place one of the principal directions of stress is ordinarily nearly normal to the layer, and the other two principal directions of stress lie in the plane of the layer. That this tendency to thus decompose the forces exists cannot be doubted. That it would be the controlling tendency in the majority of cases could not be asserted from analysis alone. However, examinations of various regions during the past season has shown me that this is often a controlling tendency, and that tension joints ordinarily do form nearly at right angles to the bedding. It has already been explained that in regions of simple folding there is one set of tensile joints,[2] and that in regions of complex folding there are two sets of tension joints. The reverse statement may be made,—that is, that where there are two sets of intersecting tension joints at right angles to each other normal to bedding, these are evidence that the region is one of complex deformation.

Compressive joints, in contrast with tensile joints, because formed in shearing planes, are ordinarily inclined to the bedding.[3] This also results from the fact that one of the principal directions of stress is usually nearly normal to bedding. Supposing the maximum stress to be in the direction of the arrows of Fig. 4, the mean stress at right angles to the plane of the figure, and least stress in the plane of the figure and at right angles to the maximum stress, in other words normal to the bedding, the position of the joints will be as shown, their planes being normal to the figure in which they are represented in section. This results from the fact that the direction of least stress

[1] Loc. cit., (A), pp. 668-671; (B), pp. 609-613.

[2] Loc. cit., (A), p. 669; (B), pp. 609-610,.

[3] Loc. cit., (A), p. 671; (B), p. 613.

is that of relief, and after rupture the differential slipping between joints will cause shortening in the direction of maximum stress and elongation in the direction of minimum stress.

When it is remembered that all the forces at work at any place may be decomposed into three principal directions of stress

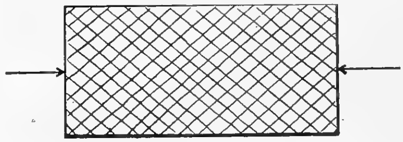


FIG. 4. Cross-section of a bed showing joints.

at right angles to one another, it would seem to follow that there would ordinarily be produced only two sets of compressive joints at the same time. To suppose that more than two sets are simultaneously produced would require that the ultimate strength was exceeded at the same moment in two of the principal directions of stress, and this is probably not a common case. One would expect, if the forces in two of the principal directions of stress are equal or nearly so, that the ruptures would be conchoidal, and this may be the explanation of some of the cone-in-cone structures. Supposing the compressive stresses to be unequal, the ruptures are produced by the maximum stress, and any one of three strains may result: (1) shortening in one direction, (2) simple shearing, and (3) shortening in one direction combined with shearing. In the first case, that of shortening in one direction and consequent elongation in a single direction, there are produced two sets of joints, but not exactly at right angles to each other. The maximum force probably bisects the acute angles (Fig. 4).[1] Subsequently, however, by differential movement between the fractured parts, it is possible that the joints may be so rotated as to change the originally acute angles to obtuse angles. The two sets of joints would only be at right angles in case the rotation stops at a definite stage. In the second case, that of simple shearing, there is one set of compressive joints

[1] Loc. cit., (A), pp. 643, 873; (B), p. 465.

and one set of tensile joints. The compressive joints lie near the longer diagonal of the deformed rectangle, and the tensile joints are near the shorter diagonal (Fig. 5). Ordinarily the former are closer together than the latter. In the third case (1) and (2) are combined; whether there are two sets of compression

FIG. 5. Cross-section of a bed showing joints.

joints, or one is a compression and the other a tension set, will depend upon the relative amounts of shortening and shearing.

After rupture occurs as the result of tensile or compressive forces, producing one or two sets of joints, if the force in the plane of bedding at right angles to the first direction of force accumulates so as to exceed the ultimate strength of the rock, it may produce other sets of joints. In case this force is tensile, one set of joints will be produced in the normal planes. If it is compressive, any of the three cases of compressive joints above given may occur. Thus there may be produced three or four sets of intersecting joints.

From the foregoing, the criteria by which tensile and compressive joints may be separated are easily inferred. Tensile joints are ordinarily nearly normal to bedding. Compressive joints are ordinarily much inclined to bedding. Between the walls of tensile joints there is ordinarily a small space; the walls of compressive joints are, or were originally, pressed closely together. The walls of tensile joints are not likely to show differential movements nor slickensided surfaces; the walls of compressive joints generally show slight differential movements and more or less slickensided surfaces.

Relations of joints to folds.— Many cases of apparent bending of the strata are really not due to bending but to jointing. It has been pointed out that the first is a phenomenon of the zone of flow age, and the second is a phenomenon of the zone of fracture. The special point to which I wish here to call attention is that as a result of the displacements of jointing, the strata may appear in generalized curves of anticlinal and synclinal character (Fig. 6). In various districts rocks which have not been so

Fig. 6.

deeply buried as to be in the zone of flowage appear to be in anticlines and synclines. In these cases it is believed that the phenomena are explained as above suggested. This principle is illustrated by the slightly undulating rocks of the upper Mississippi valley. Cutting these everywhere, and in many districts in two directions at right angles to each other, are systems of joints. These joints are phenomena of fracture, and the slight bowing, which one might represent as a fold, really is not a fold in the sense of the deformation of the strata by flowage, but is bowing as a result of very slight but abrupt changes in direction at the numerous joints, the general effect being to produce a folded appearance.

The apparent bowing due largely to jointing, so well illustrated in the Mississippi valley, is still more finely illustrated by the Allegheny Mountains. The limestones and sandstones of this mountain system, ordinarily regarded as deformed mainly by folding, are largely deformed by jointing. If the course of the strata be roughly platted, they will appear to be in continuous undulating curves. However, the rocks are everywhere cut by two intersecting sets of joints at right angles to each other, and it appears to be the case that the curved deformation is really not mainly that of folding, but mainly that of fracture

(Fig. 6). However, I would not assert that to some extent the material had not also flowed at various times before the stresses exceeded the ultimate strength of the rocks and ruptures occurred. Even if the apparent gentle curves of the strata can be more accurately represented diagrammatically by placing end to end a large number of broken lines with slight changes of direction, the curves indicated by the lines would have the forms of folds given under Analysis of Folds.[1] In the weaker shaly layers between sandstones and limestones the deformation is in many cases largely that of shearing, this being due to the differential movement between the two bounding strong layers. In the weaker layers the jointing is therefore in two diagonal sets.

In the case of the Mississippi valley it is clear that the stresses producing the jointing are locally still at work. For instance, at the combined rocks at Appleton,[2] a recent rupture occurred which was sufficient to make considerable displacements in the artificial works. Other cases of a similar kind have been given by Reade.[3] The foregoing cases show that the apparently horizontal rocks of the Palæozoic at the present time, are locally under such stress that when a slight amount of material is removed, and thus the beds not held so firmly in their position, the ultimate strength is exceeded and rupture occurs. Denudation is ever lightening the load of the strata, and from time to time, as a result of this, the abrupt deformations of jointing or faulting may occur. Before the time of rupture, it may be that the stresses, while not sufficient to produce rupture, may still surpass the elastic limit and result in slow flowage.

C. R. Van Hise.

[1] Loc. cit., (A), pp. 603–633; (B), pp. 312–353.

[2] On a recent Rock Flexure, by Frank Cramer. Am. Jour. Sci., Vol. XXXIX, 1890, pp. 220–225.

[3] On the Cause of active compressive Stress in Rocks and recent Rock Flexures, by T. Mellarde Reade. Am. Jour. Sci., Vol. XLI, 1891, pp. 409–414.

EDITORIAL.

THE proposition to hold the winter meetings of the Geological Society of America in the city of Washington, as advocated by Professor Iddings, in the last number of this JOURNAL, is not without objections.

The members of the society may be classified in two groups; those engaged chiefly in investigation, and those who devote a part of their time to teaching. The interests of these groups differ and in arranging for the winter meetings of the society should have equal consideration. The members who reside in Washington are for the most part engaged in investigation, while the majority of the non-Washington members are occupied principally in teaching. It has been said by one eminent in our science, that the three requisites in geological training are travel, travel, travel. Under the proposed arrangement, members residing in Washington would be deprived in a measure of the opportunities which might otherwise be secured by them of seeing the laboratories, collections, etc., at various other centers from which geological information is disseminated. It is evident that it would be unfair to thus deprive our Washington friends of a means of education which might be of profit to them. Members of the society who are engaged principally in teaching, probably have as earnest desires to see the lecture rooms, laboratories, and collections of their colleagues and to learn their methods of teaching, as they have to study the methods of investigation carried on in Washington.

To enable both classes of members to profit by the opportunities afforded by our winter meetings and at the same time insure the desired attendance, it seems highly desirable that for some years to come, the meetings referred to should be held at the various educational centers on the Atlantic coast between the Merrimac and the Potomac.

Without wishing to detract in the least from the debt of gratitude due the local committee which arranged for our convenience and comfort during the last Washington meeting, I wish to suggest that the lecture room of the National Museum is, in many ways, objectionable as a place in which to hold the sessions of the Geological Society. If the society elects to hold all winter meetings in Washington, a more suitable assembly room, and also rooms for the display of maps, collections, etc., as well as a conversation room, should be provided.

In reference to the expenses of the meetings being shared by the visiting members, as proposed by Professor Iddings in case the winter meetings are held regularly in Washington, it may be suggested that if each of the Washington members should subscribe an amount equal to the average traveling expenses of the visiting members, the expenses of the meeting could not only be met but a surplus would remain which might be devoted to publication or other useful purposes. I. C. R.

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It is gratifying to be able to call attention to the carefully made collections of rock specimens, which Mr. Oscar Rohn, of Madison, Wis., has prepared to illustrate the petrographical descriptions found in the writings of Pumpelly, Marvine, Irving, Van Hise, and Bayley, upon the famous mineral-bearing districts in the Lake Superior region. As is well known, collections of rocks representing the most important petrographical types at European localities may be obtained for purposes of study and instruction. But no systematic attempt has been made to furnish collections of typical rocks from American localities, with the exception of the proposed Educational Series which the United States Geological Survey has undertaken to gather together. A reason for this is in some cases evident, namely, the remoteness of the districts and the expense of collecting the specimens. The collection of Lake Superior rocks offered for sale by Mr. Rohn is a step in the direction of such systematic collecting, and places within reach of students and teachers of petrology material of the highest value, making it possible to follow intelligently the descriptions by the investigators already named, of the rocks in the Keweenaw, Penokee, and Marquette districts. The collector had the advice and counsel of Professor Van Hise, who vouches for the care with which the work has been carried on. Not the least valuable part of the undertaking is the furnishing of a catalogue in which specific references to the monographs of the region are given in connection with each specimen. The hand specimens are accompanied by chips from which thin sections may be prepared. The enterprise is to be heartily commended, and it is hoped that a sufficient number of petrologists will avail themselves of the opportunity of securing the collections to compensate Mr. Rohn for the time and money expended upon them. J. P. I.

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EMM. DE MARGERIE and his colaborers of the bigliographical committee of the international congresses of Washington and Zürich merit the warmest commendation of all working geologists for their disinterested labors in preparing and issuing a voluminous report under the title *Catalogue des Bibliographies Géologiques.* This is a book of 733 pages, and represents a very protracted and laborious search for bibliographical lists through a scattered and voluminous literature whose very unequal nature must have taxed the patience, skill and discretion of the committee to the utmost. The catalogue contains nearly 4000 references to bibliographies and works containing bibliographic references of some note, and thus it constitutes an invaluable key to geological literature. Provision has been made whereby those who were not members of the international congresses under whose auspices the work was prepared and published may secure it, together with the *Compte Rendu* of the Washington congress. The two volumes will be sent to individuals or libraries who will transmit $5 to the American member of the committee, G. K. Gilbert, of the United States Geological Survey, Washington, D. C. We would particularly urge upon libraries the purchase of this catalogue. T. C. C.

REVIEWS.

Geology and Mining Industry of the Cripple Creek District, Colorado. By WHITMAN CROSS and R. A. F. PENROSE, JR. Extract from the Sixteenth Annual Report of the Survey, 1894–5. Part II: Papers of an Economic Character.

This report of Messrs. Cross and Penrose is to be classed as one of the most valuable of the publications on economic subjects issued by the Geological Survey. Though less elaborate and accompanied by fewer maps and illustrations than the bulkier monographs of past years, these considerations are largely offset by the timeliness of appearance and the handiness of the separate form in which the report was first issued. For no matter how great the intrinsic merit of the publication or the labor devoted to its preparation, its value lies to a great extent in its appearing at the right time and in a form suitable for ready use, and this particularly with a work relating to mining in a new camp. The report is the outcome of the joint field labors of the authors, prosecuted during three months in the autumn of 1894. It was written, printed, and issued in 1895, and the edition of the separates, as well as of the related Pikes Peak folio, was exhausted before the end of 1896.

The combined report covers about 200 pages of the large octavo size of the annual reports. It is illustrated by thirty-seven figures, seven plates, and one supplementary geological and topographic map which is inserted at the end of the report. The report is divided into two parts. The first, of 109 pages, by Mr. Cross, treats of the general geology and is in great part devoted to the important subject of the petrography of the district; Part second, by Mr. Penrose, deals with the mining geology of the district. The latter is exclusively the subject of this review, Mr. Cross' valuable report requiring the attainments of a specialist for adequate treatment.

Chapter I. of Mr. Penrose's report consists of a brief outline of the history of mining in the camp. Operations were practically begun there in 1891. It is a very remarkable fact, this recent development in a well-known and traveled part of Colorado, within a stone's throw of what has been a much frequented summer resort for years. It is a fact of hopeful suggestion in relation to future discoveries of ore deposits in this country; but it is a fact also liable to much abuse by promoters as a warrant for the conclusion that gold ores may be found anywhere. It is likewise remarkable that the productive area is included within a district of only six miles square, the area of one township, and, further, as the map shows, a considerable part of this is unproductive ground. The surprising growth of the camp is illustrated by the fact that from an output of only a few thousand tons in 1891, the production increased in the years 1892, 1893, and 1894 to a total variously estimated at from $5,500,000 to $7,000,000. Since that time the growth has continued, and a conservative estimate for the year 1896, kindly furnished by Mr. T. A. Rickard, the geologist for the state, places the value of the production at $9,000,000, and others who are well posted estimate it between $8,000,000 and $9,000,000. During 1895 the value of the output was in the vicinity of $6,500,000. The total for the five years is thus about $22,000,000, or a little less than one-half of the present annual output of gold for the whole country.

It is to be regretted that more space could not have been given in the report to the statistics of the camp. The expense of an assistant for this special work would have been well repaid. The difficulty of obtaining complete and exact figures is undoubtedly great, if not insurmountable; but more could have been gathered than is contained in the two paragraphs of the report, which would have given some idea of the distribution of the shipments both as to time and localities. The difficulty is one which is met with to a greater or less extent in all mining camps of the West, and is partly due to a very natural desire of mine operators not to make their private business public property, especially where no unanimity of action can be secured. Yet such facts are highly valued by mining men and the public and are valuable guides to investors. The gathering of complete statistics would do much towards placing mining on a sound basis. Public effort could well be exerted in this direction and provision made for the collection of such statistics by judicious legislation.

Chapter III is devoted to the ores of the camp, or more precisely to the minerals of the ore deposits. As Dr. Penrose says in his summary, the ores consist of the country rock, more or less completely replaced by quartz, with fluorite, opaline silica, and kaolin, and containing iron pyrites, and other sulphides, as well as various other minerals in limited quantities.

Gold is the only metal which occurs in amounts of commercial value. It is found normally as a telluride, or in a free state as a result of the oxidation of the former. It is possible that some of the gold is present as auriferous iron pyrites, but this must be quite rare as most of the pyrites is valueless, and, as a rule in the camp, rock impregnated with this mineral is considered of little significance.

The free gold appears to be confined to zones of oxidation and these frequently extend to depths of several hundred feet. It is generally in a very fine condition, but sometimes pieces up to a quarter of an inch in size are found. It is usually rusty, but is otherwise remarkably pure, with hardly any appreciable silver, even less than is found in the telluride ores. The telluride of gold appears to be principally the mineral calaverite, according to examinations made by Mr. W. F. Hillebrand and Dr. S. L. Penfield; but there is probably also some sylvanite and other compounds.

Silver occurs only in very small quantities in most of the ores, though at the Blue Bird and a few other mines it has been found in considerable amounts, though not enough to make any showing in the production of the camp.

As an accessory mineral, galena has been found at a number of places, but in small quantities. Some spahlerite occurs at a few mines. Copper minerals are extremely rare, as are antimony compounds also. Fluorite is common in many ores and is frequently prominent by reason of the coloration it gives to the rocks. It is sometimes intimately associated with quartz. Quartz is the most common secondary mineral. It is sometimes found in bodies and occurs also as well-defined quartz veins, but more frequently it is homogeneously disseminated throughout the ore or country rock, simply making them harder. Such silicified rock is often confused with dikes by the miners.

Kaolin is common along fissures, resulting from decay of the feldspar of the eruptives; it is either white or stained a brown or black color. Calcite is not abundant and occurs lining the face of rocks or filling small cavities. Gypsum, though not of frequent occurrence, is found in bodies of some size in one mine. Barite and other minerals also occur in small quantities.

Superficial alteration of the rocks is apparent to depths of 300 and 400 feet with the usual effects of hydration, oxidation, and leaching.

The value of the ores shipped varies from $20 to $400 per ton; an average is perhaps between $50 and $85. During the first year's operation, the camp was essentially a shipper of high-grade ores. Recently, however, there has been a change with the establishment of a number of cyanide and chlorinating plants, which has reduced treatment charges to $7.50 per ton. It is to be feared, however, that an understanding between the managers of these plants will prevent a further reduction in these charges, if it does not cause an increase over the above rate. It is of great importance to the future of the camp that low freight and treatment charges be reached and maintained as otherwise great quantities of low-grade ores will have to be thrown aside. Any such movement, therefore, to maintain high charges is to be opposed and may seriously damage the camp.

Chapter III deals with the mode of occurrence of the ores. This subject is one of special value and interest here. It is well summarized in the statement of the first paragraph, which is to the effect that the ores generally occur in fissures in the country rock, which usually represent slight faulting and that the veins have been formed mostly by replacement along these fissures and not by the filling of open gaps. Indeed, there is often no cavity recognizable and little, if any evidence of one ever having existed, the solutions apparently having filled the imperceptible space between the flat joint or fault planes of the rock, the gold minerals having been deposited on the surface and the rock itself having been merely silicified. Thus, in these deposits, the scrapings from such surfaces often run very high in gold, while the rock itself is valueless. This is a very peculiar form of deposit and is almost exclusively confined to this district.

The deposits occur in a region of Tertiary volcanic breccias or tuffs. The breccias are cut by numerous bodies of intrusive eruptive rocks, such as phonolite and andesite, and they also surround eruptive masses which are older than the breccia. The latter are themselves surrounded by what Cross terms the granite-gneiss complex of the Colorado range. The dikes intersect all of these rocks, passing from granite into breccia, and they also intersect each other. They are evidence of several epochs of fissuring. The veins also intersect all these rocks in their courses. The vein fissures seem to be later than the dikes, though some were apparently formed at the same time.

The courses of both vary from northeast to northwest, but there are exceptions to this rule.

The fissures are not open gaps, as already stated, but are closed lines of fracture along which replacement has occurred. In Dr. Penrose's words: "Sometimes there are two or more main parallel cracks or fissures and numerous minor ones, while very commonly the zone of fracturing seems to be represented by no especially well-defined break, but by numerous parallel or approximately parallel cracks, each of about the same magnitude and from a fraction of an inch to several feet apart." . . . . "In fact the district may be regarded as an area intersected by numerous zones of fissuring which are separated by an area of less marked but very noticeable fissuring." The ore is found lining both sides of the fissures.

Faulting is evidenced by grooves and slickensided rock surface. The movements were small in amount, the greatest observed being between twenty and twenty-five feet.

The minerals of the ore bodies are generally promiscuously arranged, the ore usually being simply the country rock containing greater or less amounts of secondary minerals. Ore is found along some of the fissures or cracks, while others, almost identical in appearance, are barren. These fissures are often taken by miners for vein walls beyond which no ore will be found. They hence neglect to cross cut. Dr. Penrose gives a valuable suggestion in advising miners not to be misled by these apparent walls, as valuable deposits will often be found within a short distance beyond them. As an illustration, in a mine operated by the writer about a dozen such fissures, variously mineralized, were encountered in a cross cut of about 100 feet.

A noticeable feature of this camp is that the veins follow the dikes, either in contact, or more commonly in proximity to them. Sometimes they cross the dikes and follow them on different sides. The association of dikes and veins is a fact well known by mining men and the presence of a dike, especially of phonolite, causes a claim to be held in much higher estimation.

In their mode of occurrence the dikes and fissures give evidence of a limited erosion of the district. Thus their upper parts often differ markedly from their deeper parts. "The dip near the surface is frequently at a different angle from that at a depth, and veins which occur in one well-defined fissure at a depth sometimes fork near the surface and appear in separate outcrops. Both these phenomena can be attributed to the fact that at a depth the fissures occupied by the dikes or veins were confined to the original line of breakage on account of the superincumbent pressure, while nearer the surface this pressure was relieved and numerous transverse breaks of more or less superficial character were encountered and the fissures were more easily deflected and divided."

It is of special importance with these deposits to distinguish between shrinkage cracks and fissures, both along dikes and elsewhere. The reason for this is that fissures are more persistent and likely to extend to greater depths than are shrinkage cracks.

The ore of the veins, as elsewhere, occurs in chutes. That is, certain parts of the fissures are barren while others contain ore of value. These chutes are of greater vertical than horizontal dimensions. They differ from the chutes generally recognized in other mining regions in being isolated bodies of ore along the fissure planes, rather than rich portions of otherwise clearly defined veins. They vary in breadth from one to several hundred feet, and from a few inches to several feet in width. Their distribution is not influenced by a difference in country rock, as that is uniform. They are probably due more to the location of cross fractures and fissures, and to localization of the ore-bearing solution. They are also affected by the distribution of the dikes.

Chapter IV treats of the source and mode of deposition of the ores.

The ore, Dr. Penrose concludes, was probably derived from both deep and shallow sources, from the whole area tributary to the fissures. An investigation of the actual gold contained in the country rocks was not made, but the metal doubtless exists in both the old and new formations, though he is of the opinion that the later eruptives were probably the most prominent source, as in them the conditions for concentration were best realized, as they were in the neighborhood of volcanic vents where the rocks were penetrated by hot waters impregnated with the mineral solutions. The solution and deposition of gold along with quartz from alkaline solution is readily understood, but the formation of the telluride of gold requires further investigation before it can be explained.

As regards the associated minerals, the fluorite was probably evolved from the phonolite magmas, in a volatile or soluble form, and acted on solutions carrying lime; if it was in the form of hydrofluorsilic acid, the association of the quartz with the fluorite is readily explained.

The fluorite has possibly also some connection with the presence of the telluride, as fluorite is common elsewhere where telluride ores occur.

The ore constituents were probably introduced in a liquid form, probably hot and probably hastened by steam and other vapors. The process of deposition was largely one of replacement; this may have been by chemical action or by deposition in minute cavities after the removal of constituents of the country rock. The latter Dr. Penrose thinks more probable. The deposition was caused principally by chemical reaction with other solutions rather than by reaction with the country rock.

It is to be regretted that a direct investigation of the problems of the source of the ores and their mode of deposition could not have been made. The study given to the subject is confessed to have been inadequate for final results. Though the conclusions reached by the author seem quite probable, they can be classed only as probabilities pending complete inquiry.

As a final criticism of this in so many respects valuable and excellent report, the cuts or the figures illustrating it might have been improved upon. They are somewhat too diagrammatic and most of them seem to be more of illustrations of the writer's ideas than actual sketches "from life" in the mine. This does not apply to all of the figures, nor to the small mine maps or plates which are inserted. These are excellent and appear to have been carefully compiled from the mine surveys.

ARTHUR WINSLOW.

TELLURIDE, COL.,
January 5, 1897.

Glacier Bay and its Glaciers. By HARRY FIELDING REID. United States Geological Survey, 16th Annual Report, 1894–5, pp. 415–461. Plates LXXXVI–XCVI.

The studies of Muir glacier conducted by Professor Reid in the summer of 1890, and the results published in the *National Geographic Magazine*, Vol. IV, were continued and extended in the summer of 1892 and the results recorded in the report named above. During the earlier expedition, attention was restricted to Muir glacier and its tributaries, of which an excellent map was published; the later expedition had for its main object the exploration of the western extension of Glacier Bay with its numerous inlets and many glaciers.

The topographic work of the two expeditions referred to is combined on the map accompanying the report under review. This map showing ice, land, water, and moraines, is published on a scale of six miles to one inch, and embraces the entire extent of Glacier Bay, and its inlets. The extremities of all of the tidewater glaciers which discharge into the waters of the bay and the greater portion of Muir glacier with its many feeding ice streams, are also included. The numerous fine illustrations, reproductions of photographs, give a more graphic idea, especially of the characteristic features of the ends of the tide-water glaciers, than can be conveyed by written descriptions.

The general features of the shores and islands of Glacier Bay are described, special attention being given to the glaciers and inlets. Glacier Bay to the west of Muir glacier, has seldom been visited and was never surveyed previous to Professor Reid's careful examination. In this new field many important discoveries were made, and a number of geographical features named. Several glaciers were appropriately named in honor of distinguished European geologists.

There are eight glaciers to the westward of Muir glacier which discharge bergs into the waters of Glacier Bay. The extremity of each of these was examined and carfully mapped. The most extensive ice front of any of the nine tide-water glaciers, is that of the Grand Pacific at the extreme western extension of the bay. This glacier at present is divided by a high rockmass, in part island and in part nunatak, but presents an actual ice front 12,500 feet in length. A small recession will separate the ice from the land that divides it and increase the length of its magnificent ice cliffs to fully three miles. The combined extent of the ice frontage of the several tide-water glaciers of Glacier Bay, is between twelve and thirteen miles.

The hard geology about the shores of Glacier Bay and to a limited extent, of the mountains from which Muir glacier receives tributary glaciers, receives attention. Large areas of diorite, quartz-diorite, argillite, limestone, sand and gravel, are shown on a sketch map. A few fossils obtained from loose débris indicate that the limestones are of Carboniferous age.

The stratified gravel and sand containing stumps and trees, beneath the extremity of Muir glacier, and on the adjacent shores, to which considerable attention had previously been given by Professor Reid and others, were again studied and fresh observations made which sustain the conclusion that gravels, etc., were laid down by streams from the glaciers during a period of recession and overridden when the ice readvanced. Some important modifications of this general history are suggested.

Among the many interesting results reported, are observations on variations in the extension of Muir glacier between 1880 and 1892. Records of the position of the extremity of the glacier in 1880, 1886, and 1890, showed an apparently continuous recession of about 250 yards a year, but in 1892 the ice front had advanced on an average of approximately 300 yards beyond its position in 1890. The most marked advance was in the central portion where the ice current is known to be most rapid. In a footnote it is stated that photographs taken in 1894, show a recession to the position occupied in 1890.

The rate of flow of the ice near the end of Muir glacier, as measured by G. Frederick Wright in 1886, and by Reid in 1890, showed great discrepancies which could not be reconciled. This question which has led to some discussion during the past five years, is briefly considered and the accuracy of the measurements made in 1890 maintained. It will be remembered that the maximum rate of flow in the central portion of the glacier near its terminus, was stated in the report of the expedition of 1890 to be about seven feet per day.

A map of the end of Girdle glacier on a scale of 500 feet to an inch, shows the manner in which it thrusts its extremity into the side of Muir glacier, to which it is tributary, so as to cause the lateral moraines on the main glacier to curve about it in rude semicircles. Stakes were placed along the margin of the expanded terminus of Girdle glacier and their direction and rate of movement measured twenty-four days later. The rate of motion varied from 1.8 to 2.6 inches per day; the direction of movement revealed a spreading of the ice of Girdle glacier, and a slow movement in common with the general flow of Muir glacier. Other instructive facts concerning the unique phenomena revealed by Girdle glacier are recorded. The stakes placed in the ice melted out, but their positions were preserved by placing three small iron plates about each one. The plates, as is the rule with small dark objects lying on the ice, sank into it as melting progressed, and thus maintained their position.

Peculiar holes in the surface of Muir glacier, from a few inches to six or eight feet deep, with a diameter of six to eighteen inches, were found to be due to the lowering of the surface by melting, so as to expose cavities that previously existed in the ice. The holes within the ice contain water, and are thought to be due to the closing of water-filled crevasses. The presence of water-filled cavities within the ice of glaciers shows that the winter's cold does not penetrate far below the surface.

An ingenious arrangement consisting of two sticks placed in diverging auger holes and inclined toward each other and securely bound together with wire at the surface of the ice, gave accurate measures of the rate of surface melting. In general, the waste on the surface of Muir glacier was two inches per day. Soundings in Muir inlet, which also furnished water samples from various depths, measurements of temperatures for the surface to the bottom, and samples of the bottom, gave a series of instructive records, which are briefly discussed. Tidal observations made in Tidal inlet, a small fiordlike bay, five miles west of the head of Muir inlet, furnished data for establishing a permanent bench mark on the shore by means of which changes of level of the land can be measured. It is hoped that future travelers will repeat these measurements and also profit by the instructions which are given for photographing the extremities of the tide-water glaciers, so that a record of their variations may be obtained.

The report before us contains the records of the only systematic survey that has been made of any of the Alaskan glaciers, and is of special value on account of the painstaking accuracy that characterizes the work. A splendid beginning has been made in the study of the great system of ice drainage that pours into Glacier Bay. It is to be hoped that other students of glacial phenomena, having before them this example of what can be accomplished during a summer vacation, will continue the work and explore the unknown regions surrounding the area represented in Professor Reid's map on every side.

ISRAEL C. RUSSELL.

Water Resources of Illinois. By FRANK LEVERETT; Seventeenth Annual Report U. S. Geological Survey, pp. 695–849, Washington, 1896.

This paper contains much of distinct geological interest, as may well go without saying, both on account of the intimate connection of hydrology with geology, and, in especial, because of the author's thorough study of the Pleistocene formations of the state. The effect of the drift upon topography and drainage is set forth with considerable detail. On the newer drift, within the Shelbyville moraine, preglacial features are for the most part concealed. The drainage systems are comparatively young, although the streams have the advantage of working on a surface of higher altitude and greater diversity of relief than that of the older drift of central and southern Illinois Streams follow the axes of drift basins included between successive morainic ridges, their longer tributaries being carried on the longer slopes of these basins which lie toward the west and south. A preglacial divide is traced from below Elgin and Lemont to the Indiana state line, and it is highly probable that the headwaters of the Fox, Des Plaines and Kankakee rivers were in preglacial times tributary to the Lake Michigan basin. In northwestern Illinois instances are noted of displacement of the rivers and their beheading by drift deposits. The data supplied by artesian well records suggests several important conclusions as to the deeper strata. The altitudes of the St. Peter sandstone and the base of the Coal Measures are worked out in detail over much of the state. Three thousand feet is considered a liberal estimate for the thickness of the Palæozoic formations of northern Illinois. A maximum of 6000 feet is set for the thickness of the Palæozoic in southern Illinois, of which from 1200 to 1500 feet is allotted to the Coal Measures. The terms Potsdam and Lower Magnesian are retained, and a thickness is assigned to the latter at Rock Island of about 800 feet. In this instance it seems probable to the reviewer that this measure includes the Jordan and Saint Lawrence as well as the Oneota or Lower Magnesian. Remarkable variations in well records are noted, and, like all workers with such data, the author has no doubt felt the embarrassment of riches when more than one well record is extant in any district. At Chicago, for example, the recorded thickness of the St. Peter sandstone ranges from 89 to 420 feet. Surely in the latter measurement the driller, or the authority for the record, has either reckoned in arenaceous beds of the Oneota and the New Richmond, or has been misled by St. Peter sand in drillings far below the lower limit of the formation.

The Potsdam, the St. Peter, the Galena, the Lower Magnesian, and the Niagara, are the chief artesian water-bearing strata.

The author does not find it easy to separate flowing from non-flowing wells in which water rises under hydrostatic pressure, and designates both classes as artesian. He instances wells in Chicago which pass from one class to the other each week, flowing only for a brief period after the Sunday intermission from pumping of neighboring wells.

An interesting fact is the control of artesian head by the height of ground water in the cover area, and several instances are adduced of the head being raised by true influx of surface waters. Under the most favorable conditions the head from the St. Peter and the Galena appears to reach about 675 feet A. T., while from the Potsdam it appears to rise slightly above 700 feet. Few wells in northern Illinois can be depended upon to maintain a head much exceeding 600 feet A. T. A few examples are added to the many on record of local artesian regions whose head is lowered by over draft. In the Chicago district the head of the St. Peter water has been drawn down nearly 100 feet, and this loss of pressure extends ten miles and over west and south of that part of the city where the wells are now numerous. At Joliet heavy pumping of a single well has been found to lower the head several feet in wells nearly one-half mile distant. The increase of mineralization of artesian waters with increase of distance from the area of intake is amply illustrated, sodium chloride, for instance, ranging from about three grains to the gallon at Chicago to about 30 at Rock Island and 277.7 at Barry.

Of less interest to the geologist are the chapters treating of the rainfall, the run off of the streams, and kindred topics. In the chapter on the water supply of the cities and towns, the statement that "the Chicago intakes are affected by sewage only when the Chicago River is at high stages, which seldom amounts to more than a few days each year," is certainly one that does not err from lack of moderation. The final chapter, by Professor J. A. Udden, treats with fullest detail of the artesian district of Rock Island and vicinity. The report is amply illustrated with maps and sections, and it places on permanent record a mass of valuable statistics in several fields. The details, however, are so handled that they do not interfere with the author's direct and luminous treatment of the subject. W. H. NORTON.

The Geology of Santa Catalina Island. By WILLIAM SIDNEY TANGIER SMITH. Proceedings of the California Academy of Sciences, 3d Series, Geology, Vol. I, pp. 1–71, 2 plates and map.

The chief interest in this paper lies in the clear and generally convincing manner in which the author has discussed the physiographic problems presented by his very attractive field; his work being in that respect a continuation of the previous work of Lawson.

Santa Catalina Island is one of the group known as the Channel Islands, and lies about twenty miles off the coast of southern California. Its general trend is northwest by west, with a length of twenty-one miles, and an average width of three miles. It is traversed from end to end by a dominant ridge, culminating at 2100 feet. The general character of the surface is bold and rugged, but it can be differentiated into two topographic types, the one characterized as a young topography, with steep sharp ridges and acute V-shaped canyons, and the other as an older topography, composed of rounded forms, and restricted to the higher portions of the island. In transverse section, the island shows a general slope towards the mainland; the valleys on this side are broad and open, while on the ocean slope they are "long and trough-like." The sea-cliffs, which make up the greater part of the coast line, are in such rapid recession that the narrow V-shaped canyons frequently merely gash their upper fronts, not having been allowed time to cut down to sea level.

A little more than half the island, including most of its western half, is made up of a basement series consisting of quartzite, mica-schists, talc and amphibolite-schists, and serpentine. The eastern portion is mainly occupied by an intrusive mass of porphyrite (in Iddings' sense) with accompanying dioritic dykes, and by andesitic flows of later date. The various intrusive and effusive rocks are described in detail, but present few features of general interest. The occurrence of a small area of rhyolite is noteworthy on account of the few cases in which rocks of this character have been described in the Coast Range region of California. Its age relative to the andesite was not determined. Some small areas of light-colored shale were found on the northeast side of the island, associated with volcanic tuffs, and were correlated with the widespread Miocene shale of the Coast Ranges. In this case the shale is shown to contain over 70 per cent. of opaline silica, and to be made up largely of diatoms and forminifera, as identified by Dr. Hinde.

The serpentines are derived from ultra basic eruptive rocks, and are associated with small amounts of blue-amphibole-schist, the latter probably the result of contact metamorphism.

In a concluding chapter the writer ably sums up the geomorphogeny of the island. Submarine contours show that the Catalina land-mass preserves its form down to a depth of 1800 feet. Near the shore the water deepens rapidly down to 250 feet. At this depth a submarine platform of varying width encircles the island, beyond which the water again deepens. Submarine profiles indicate that the island began its history as an orographic block, tilted to the north, and forming a part of the mainland. It stood 2000 to 3000 feet higher than at present. Following the tilting came the intrusions of porphyrite and diorite. Erosion made considerable progress upon this tilted block, and toward the close of this period the andesitic flows were erupted, accompanied by a slow subsidence. Santa Catalina became an island, depressed, at the close of the downward movement, 1400 to 1600 feet below its present level. During the Miocene a long period of erosion reduced the unsubmerged portions to a peneplain. A gradual elevation of 1850 feet followed, with at least one pause in the movement. The last oscillation is exhibited in the present period of rapid sinking.

The discussion and exposition (very inadequately summarized in a review of this length) is in general admirable. Exception might, however, be taken to the statement, made twice within the paper, that the shortening of a stream's course by the drowning of its lower reaches will cause it to cut down into its alluvial fan.

F. L. RANSOME.

Geology of the Castle Mountain Mining District, Montana. By W. H. WEED and L. V. PIRSSON. Bull. U. S. Geol. Surv., No. 139, pp. 164, 7 plates. Washington, 1896.

Recently considerable study has been directed to the isolated mountains which form the foothills of the Rockies. Such mountain masses offer an inviting field, since they are usually much simpler than the main ranges, and by working out in detail the history of such independent centers of eruption the general order and, perhaps, the causes of differentiation in rock magmas seem likely to be easiest learned.

The Castle Mountain is a dissected volcano, now rising about 3600 feet above the surrounding plain, itself having an altitude of about 5000 feet. The mountain mass is about ten miles in diameter, and stands in central Montana between the Little and Big Belt Mountains. The stratified rocks of the region include representatives of the Algonkian, Cambrian, Silurian, Devonian, Carboniferous, Jurassic, and Cretaceous, preceding the eruption, and certain Neocene lake beds and glacial drift later than it. The rocks had been folded and eroded before the eruption began, but have been little disturbed since. In general the igneous rocks represent the types resulting from the differentiation of a granitic magma. The more abundant rocks are highly siliceous and rich in alumina and the alkalies. They include granite, granite-porphyry, quartz-porphyry, rhyolite, rhyolitic-obsidian, rhyolitic tuffs and breccias. More basic rocks, including augite-diorite, porphyries, passing into porphyrites, lamprophyric dikes and bosses and basalt flows occur in less abundance. The rocks belong to five groups: (1) The massive plutonic rocks represented by the main mass which is a miraolitic granite becoming porphyritic at the edge, and a second smaller mass, which is dioritic. The latter becomes a quartz-diorite-porphyrite at the edge, and is cut by aplitic dikes, probably from the granite mass. (2) The porphyritic rocks of the intruded sheets and flows include among the acid types micro-granite, quartz-porphyry, granite-porphyry, feldspar-porphyry and porphyrites. The basic types are lamphrophyric rocks, with phenocrysts of mica, augite, hornblende and olivine. Dikes are, upon the whole, rather rare, and in this particular the region stands in sharp contrast with the neighboring Crazy Mountain region. Minettes occur here as intruded masses and sheets rather than in the usual form of dikes. (3) The extrusive rocks include rhyolites and breccias from the granitic mass, and basalts in the region of Volcano Butte. (4) The tuffs and breccias have yielded largely to erosion, as would be expected, and now make up the Smith Lake beds. (5) There are certain igneous rocks in the region which do not seem to belong to this center of eruption. These include a diabase sheet intruded in the Belt shales (Algonkian), and presumably very ancient, certain ash deposits in the Dakota, and certain dikes of porphyrites, acmite-trachytes, trachytes and theralites of Crazy Mountain types.

The general order of eruption seems to have been: first, the diorite (possibly not belonging to the main mass); second, the granite; third, the rhyolite and pitchstone; and, fourth, the basalt and basic dikes. It will be seen that the rocks became successively more highly differentiated. The excellent analyses show that the alkali ratio K_2O : Na_2O is about 1 : 1.55 — 1 : 1.30, with the most rapid variation at the extremes. This ratio is independent of geologic position or coarseness of crystallization, and seems to be characteristic of the magma. A number of interesting petrographical facts are brought out in the discussion of the rocks. Certain included masses in the granite, apparently resembling those common in orbicular granites, are shown to be fine-grained hornblende-mica-syenite, and it is suggested that their origin may be due to liquation. It is pointed out that the occasional reference of micropegmatitic structure to secondary changes as suggested by Irving, Hobbs, and Romberg, rests upon slight evidence and involves rather violent assumptions as to the method of corrosion.

Aplitic dikes carrying floated fragments of biotite and feldspar similar to the inclusions in the minette dikes at Aschaffenberg were noted. Ilmenite was found altering to leucoxene, which proved to be anatase rather than titanite. A quartz-tourmaline-porphyry is described. The rock occurs as an intruded sheet having a felsitic groundmass, quartz phenocrysts, feldspar flecks, and radial and stellate groups of fibrous tourmaline. It carries fluorite, and is referred to pneumatolitic processes. Among the lamprophyres are augite-vogesites, minettes and monchiquites. The latter are of interest as occurring here in connection with a granitic mass rather than with eleolite-syenite. In connection with this description of the monchiquites is given a note by Kemp correcting an analysis of a similar rock published by him in Bull. U. S. G. S. 107. The basalt carries occasional quartz, but offers no new evidence as to its primary or secondary origin. It is pointed out that the term divitrification, as used in petrography, does not necessarily mean strictly secondary action, since certain spherulites are produced in the process of cooling and while the rock is still viscous. Johnston-Lavis' theory that the variation in rocks is produced by the solvent action of the magma upon the conduit is shown to be untenable so far as this area at least is concerned. The molecular ratio between the alkalies of the most basic and most acid rocks of the series is 125 : 50. This would then require for the production of the latter the solution of at least an equal bulk of rock wholly free from alkali. Furthermore, the acid rocks which, according to the theory, should be first erupted was not first but relatively late. Finally, the dioritic mass, erupted through very basic shales, becomes more acid rather than more basic towards the periphery.

The report is well illustrated, and is of interest, not only from the fact that it deals with a hitherto practically unknown area, but because of the light shed by it upon these more general problems.

H. F. Bain.

The Ancient Volcanic Rocks of South Mountain, Pennsylvania. By FLORENCE BASCOM. Bulletin U. S. Geological Survey, 136, Washington, 1896.

When the work on the porphyries of South Mountain was taken up, little was definitely known regarding the occurrence of ancient volcanic rocks in the eastern United States outside of the region in Massachusetts in which certain felsites had been found. Having come across a specimen of the porphyry from South Mountain, Professor G. H. Williams and Miss Bascom visited the region to learn more with regard to its occurrence, and finding unmistakable evidence of the presence of an ancient igneous rock with pronounced flow structure and indications of spherulitic crystallization, it was decided to make a special investigation of the region. This was carried on in the summer of 1892, Professor Williams studying the northern part of the region and Miss Bascom the southern part. The latter also undertook a detailed study of the igneous rocks there found. Preliminary notices of the general geology of these volcanic rocks have been published by Professor Williams, and of the petrography of the most siliceous varieties by Miss Bascom. The present publication presents the complete investigation of all the igneous rocks of the region.

It reviews the literature bearing upon the district from 1755 to 1896. From this it is clear that the true character of the more siliceous rocks was not understood by previous investigators. Three types of rock occur, one a sandstone, conglomerate and quartzite, with occasional argillaceous shale; another an acid volcanic rock, and the third a basic volcanic rock. The sandstone is referred to the Lower Cambrian Age, though not definitely; and the igneous rocks are found to be older than the sandstone, being extrusive lavas overlaid unconformably by the sandstone. They are considered to be of pre-Camrian Age, and their petrographical resemblance to the Keweenawan volcanic rocks of the Lake Superior region is pointed out. The acid rocks are probably older than the basic ones. But this could not be definitely determined.

Before entering upon the petrographical description of the acid eruptive rocks the author finds it necessary to devote four pages to a discussion of the nomenclature of the aphanitic, porphyritic and nonporphyritic varieties of these rocks — an excellent commentary on the present condition of petrographic terminology. At its conclusion the author proposes to designate "all acid volcanic rocks the structures of which proves them to have once been glassy, *aporhyolites*, while such as were originally holocrystalline, or whose original character is in doubt, will be termed quartz-porphyries." The prefix *apo* is intended to indicate the fact of a special kind of alteration, namely, that of devitrification of a solid glass. Its application is therefore limited to a certain class of rhyolites, that is, the hyalorhyolites.

The varieties called quartz-porphyry are briefly described, and call for no special comment, except to note the occurrence in them of the unusual mineral piedmontite together with ordinary epidote, both being secondary minerals. The aporhyolites are described at length. They are characterized by numerous spherulites and some lithophysæ, most clearly reorganized on weathered surfaces of the rock. Their form and distribution are the same as in recent, unaltered obsidians. The description of the phenocrysts of feldspar is not entirely satisfactory and their actual character is left in doubt, except that they are undoubtedly alkaline varieties.

The microscopical study of the groundmass has been very thoroughly carried on, and the descriptions make it evident that there once existed in these rocks textures commonly found in modern rhyolites, such as flow-structure, taxitic structure, perlitic cracking and spherulitic crystallization, making it highly probable that these rocks originally solidified in a partially glassy condition. They are at present holocrystalline and exhibit a microcrystalline and also a micropoikilitic texture. The latter is discussed at great length and its secondary character in these rocks is clearly established. The author recognizes the fact that the same or a similar texture is also a primary crystallization in certain other rocks. Flow-breccias and tuft-breccias are found in connection with the massive lavas. In places the massive rock is metamorphosed into a sericite-schist, in which often the original phenocrysts are still preserved. The chemical compositions of the two rocks are nearly identical.

The petrographical description of the basic eruptives begins with a discussion of the nomenclature relative to these rocks, which is short and leaves the subject in a confused condition; the confusion being carried throughout the chapter. The confusion is based on the conclusions arrived at in the paper by Professor W. S. Bayley, which is quoted by the author. The mistake is made in assuming that the definition of the groups within the gabbro class of rocks as suggested by Professor Bayley is final, or even that it is acceptable to the majority of petrologists. So far as a distinction between gabbro and diabase is made to rest on purely textural grounds, one being granular and the other ophitic, Professor Bayley's conclusions are good, but the effort to relate these textures to the mode of occurrence of the rock, as intrusive or extrusive, is futile, and the suggestion that the term diabase be applied to holocrystalline extrusive lavas having the composition of gabbro, and the term basalt to those that are hypocrystalline (partly glassy) is wholly impracticable. Throughout the chapter the terms melaphyre, augite-porphyrite and diabase are used as synonyms. It does not appear from the description in what sense the term augite-porphyrite is to be understood, since the structure and mineral constituents of these basic rocks at South Mountain are said to be markedly uniform (*op. cit.* p. 72.); the texture is micro-ophitic and the porphyritic structure is inconspicuous, the largest feldspars being 0.8^{mm} long. Since it is not possible to prove that the original lavas were or were not glassy, they are classed as having been originally crystalline and for this reason are called diabase in the sense suggested by Professor Bayley. The term apo-basalt could not have been used without question.

Although the rocks have been greatly altered, enough of their original texture has been preserved to render their identification satisfactory. They had the mineral composition and texture found in many recent basalts. In some cases olivine still remains, in others its outline only is left. In some cases lime-soda-feldspar, augite and magnetite still exist. The secondary minerals formed are quartz, epidote, actinolite, chlorite, and leuxocene. Their relative proportions vary in different places. With very complete change in mineral composition there is surprisingly little change in the texture of the rocks. The chemical analyses of the altered rock shows considerable divergence in some constituents from the composition of normal basalts. Amygdaloidal, brecciated and tuffaceous forms of the rock occur, which clearly indicate the extrusive character of the lavas. The amygdaloidal varieties have been specially liable to metamorphism, resulting in schists, or slates, spotted where the former amygdales have been dragged into flattened disks.

The bulletin closes with a summary of the facts and conclusions regarding the occurrence and nature of the rocks, and with a brief notice of the occurrences of similar ancient volcanic rocks in North

America, and also with a valuable list of papers in which points of resemblance between ancient and modern acid volcanic rocks have been emphasized, and those treating of devitrification and of spherulites. The paper is well illustrated by twenty-eight plates and is a valuable contribution to our knowledge of ancient and more or less metamorphosed volcanic rocks.

The restriction of the prefix apo to those altered rocks that originally contained glass, leaves unsatisfied the demand for a general term which can be applied to all more or less metamorphosed lavas that once corresponded to unaltered rhyolites, basalts, andesites, etc., whether glassy or holocrystalline. In this case it would seem advisable to adopt the prefix eo, proposed by Nordenskjold[1] without regard to any particular age, indicating simply that the altered rock had originally been what the remainder of the term signifies. In this sense the volcanic rocks of South Mountain might be called eorhyolites and eobasalts.

J. P. IDDINGS.

[1] *Ueber archæische Ergussgesteine aus Småland.* Bull. Geol. Instit., Upsala, No. 2., Vol I., 1893.

ABSTRACTS.

Upper Cretaceous of the Northern Atlantic Coastal Plain. By WM. B. CLARK.

This paper was prepared in coöperation with Messrs. R. M. Bagg and Geo. B. Shattuck who have been Professor Clark's geological assistants for several years. The authors divide the upper Cretaceous into (1) the Matawan formation (including the Crosswicks clays and Hazle, sands), (2) the Monmouth formation (including the Mount Laurel sands, the Navesink marls, and the Redbank sands), (3) the Rancocas formation (including the Sewell marls and Vincentown lime sands), (4) the Manasquan formation. Conformably overlying the last and probably of Eocene Age is the Shark River formation. The areal distribution of these five formations was represented upon a large map on the scale of one mile to the inch, which embraced the area between New York Bay and the Potomac River. The variations in distribution and structural relations presented throughout this distance of over 200 miles were discussed as well as the faunal characters of the several formations. The unconformity existing between the lowest of the Cretaceous formations and the Potomac formation below was pointed out as well as the clearly defined unconformity of the Miocene upon the uppermost member of the green sand series; at the same time the evidence for and against unconformity between the Monmouth and Rancocas formations was discussed without a final decision being rendered upon this point, the evidence being somewhat conflicting in this matter. The Matawan-Monmouth formation was held to be equivalent to the Eutaw, Rotten Limestone and Ripley groups of Alabama and the Pamunkey formation equivalent in all probability to all or the greater part of the Lignitic, Buhrstone and Claiborne of the same area, so that the Rancocas, Manasquan and Shark River formations must represent the interval between the Ripley and Lignitic of the Gulf. The first two are regarded as of Cretaceous, the last of Eocene Age. The different Cretaceous formations of the Atlantic coastal plain were shown to be approximately equivalent to the Senonian and Danian of Europe.

Age of the Lower Coals of Henry County, Missouri. By DAVID WHITE.

Under this title was presented a discussion of the evidence derived from extensive collections of fossil plants as to the stage of those coals in other American and European sections. Although the stratigraphic palæobotany of the Pennsylvania–Ohio bituminous series is but very imperfectly known, the indicated position of the basal coals of Henry county is apparently higher than the Mazon Creek stage or Brookville and Clarion coals, and presumably lower than the Middle Kittanning, it being perhaps near the Lower Kittanning in that series. Compared with the plants from the section of the Northern anthracite field the Missouri flora is considered by Mr. White as hardly so recent as the E ("Pittston" or "Big") vein though probably as late as the D ("Marcy") vein with which it seems to be nearly synchronous.

Concerning the relations of the Missouri flora to the floras of the Old World, to which forty-two of the forty-four American genera are common, the conclusions are very interesting if, as the author maintains, the occurrence of the same species in the different basins was approximately contemporaneous. The comparative study of the geographical and the vertical distribution of the species from the basal coals of Henry county shows that this flora is probably later than the Middle Coal Measures of Great Britain, the closest alliance being with that found in the "transition series" between the Middle Coal Measures and the Upper Coal Measures, with the flora of which ours has much in common. A similar strikingly intimate relationship, involving a large percentage of identical species, exists between the Henry county flora and that of the Valenciennes series (*Houiller Moyen*) in the Franco-Belgian field. The American flora is clearly not older than the third or upper zone of this series, to which M. Zeiller would also refer our Mazon Creek plants. The correlative conclusions respecting the British and the Franco-Belgian measures are corroborated by the relations of our flora to the plants of the Geislautern beds, which shows that the stage of the Missouri plants is in the upper part, probably near the top of the *Sarrbrücker Schichten* (Westphalian).

The local stratigraphic position of the phytiferous beds of Henry county, the Jordan coal, and another seam about forty-five feet higher, is, as described in the state reports, somewhat peculiar, since these beds lie, at some points, in almost direct contact with the deeply eroded floor of Mississippian rocks. The plants offer therefore criteria by which to approximately fix the date when the early Meso-Carboniferous inundation reached the vicinity of Clinton, and they mark the close for that district, of the post-Mississippian erosion period, during which the entire Pottsville series, reaching at some points a thickness of two thousand feet or more, and a portion of the Lower Productive Coal Measures were laid down in the Appalachian basin.

Crater Lake, Oregon.[1] By J. S. DILLER.

Crater Lake of southern Oregon is deeply set in the hollow base of a large cone upon the summit of the Cascade range. Its rim rises by moderate slopes a thousand feet above the general level of the range, and the descent within to the lake is precipitous. The lake, with an altitude of 6239 feet above the sea, has no outlet. It is approximately circular, with an average diameter of about five miles, and is completely surrounded by cliffs ranging from over 500 to nearly 2000 feet in height. The steep slopes continue beneath the water to a depth of 2000 feet. The great feature of the region is not the lake, but the caldera which it half fills and thus partly conceals but greatly beautifies. The rim has the structure of the peripheral portion of the base of a great volcano. It is composed of lava streams and sheets of volcanic conglomerate radiating from the lake. Sections of the coulées appear upon the inner slope of the rim where their broken ends form cliffs toward the lake, and it is evident that they once converged, forming a large volcano on the site of the lake, from which they issued. In some cases, as for example under Llao Rock, the valleys filled by great flows upon the outer slope of the central volcano are clearly visible in the section afforded by the rim. The earlier lavas of the rim are andesites, and the later ones rhyolites, while basalts, which are also of late eruption, are confined to small adnate cones low down upon the outer slope of the rim. The rim is cut at a number of points by dikes radiating from the lake, and this feature taken in connection with the succession of lavas, and especially the structure of the rim, clearly points to Crater Lake as a great volcanic center. The rim of the lake has been deeply scored by glaciers, but this phenomena is confined wholly to the outer slope. Striæ and moraines are found on the very crest of the rim overlooking the lake. Deep U-shaped canyons extend directly through the rim ending on

[1] Published in the American Journal of Science for March 1897, and in a more popular form in the National Geographic Magazine for February 1897.

the brow of the cliff which rises many hundreds of feet above the lake level. All of these features must have been formed by glaciers descending from the peak represented by the rim. In other words, during the glacial period Crater Lake did not exist, but in its place there towered a great volcanic peak, rivaling Shasta in size, from which emanated the coulees of the rim as well as the glaciers for its striation. The relation of the striæ to the later flows shows that the volcano was yet active in the glacial period. The removal of so great a volcano and the production of the large caldera is due to subsidence. This is shown by the absence of a fragmental rim, such as would have been formed if the material had been removed by an explosion, and also by the action of the final coulée from the volcano. It flowed not only over the outer slope of the rim, but also over the inner slope toward the abyss into which the mountain disappeared. Since this engulfment several smaller piles of volcanic material have been formed by eruptions upon the bottom of the caldera. One of these rises so high as to form an island in the lake, and furnishes an excellent example of a cinder cone and lava field.

Nipissing-Mattawa River, the Outlet of the Nipissing Great Lakes. By F. B. Taylor.

When the waters of lakes Superior, Michigan and Huron were making the Nipissing beach, their outlet was eastward over the Nipissing pass at North Bay, Ontario, to the Ottawa valley. This outlet river is called the Nipissing–Mattawa River and the three upper Great Lakes of that time are called the Nipissing Great Lakes. Mr. G. K. Gilbert visited North Bay in 1887, Professor G. F. Wright in 1892 and the writer explored some of the ground at North Bay in 1893, and more, with a visit to Mattawa, in 1895. Last autumn a canoe trip of six days in fine weather was made from the head of Trout Lake to Mattawa, thus covering the whole length of the Mattawa valley.

The Nipissing beach is well developed at North Bay at an altitude of about 700 feet above sea level. On the present col at North Bay the old outlet bed is somewhat over a mile wide, 30 to 35 feet deep at the maximum and perhaps half that on the average. The average here, however, is not easy to get, for there was an archipelago on the south side, and not much is known as to the number and capacity of the old channels between the islands. The first swift water of the ancient outlet was at the foot or east end of Trout Lake about twelve miles east of North Bay. The Nipissing beach though faint can be followed to the foot of Trout Lake.

The effects of the flowing current of the ancient outlet river are well marked at several points. The places of several ancient rapids and one cataract were found. The cataract was at the present Talon Chute and the four most notable rapids were, (1) below Turtle Lake, (2) below a lake called Pimisi Bay, (3) at the modern Des Epines Rapids and (4) at Mattawa. The falls were 25 to 30 feet high and the postglacial gorge made by them is very distinct. It is not quite half a mile long, but it is deep and averages only about 300 feet in width. The walls are of red granite and vertical 40 to 100 feet. A thin and highly inclined bed of crystalline limestone passing down into the gorge from the west may have hastened the cutting somewhat. The ancient river was expanded to a lake in the Lake Talon basin, and made faint but distinct shore lines by wave action. One is 20 feet above the present lake and the other ten or twelve feet higher. The mark of the surface level of the river was quite plain at some of the rapids. On the north side at Des Epines rapids this mark is 55 feet above the present river. The channel at that level was between 600 and 700 feet wide and averaged 35 to 40 feet in depth, and the current was strong enough to move gravel and pebbles of small size. This corresponds in a general way with the size of the modern St. Clair River.

Ancient rapids were recognized in three ways. There are several narrow passages that are heavily bowlder-paved. They mark the points where moraines cross the channel. At Des Epines and Mattawa the bowlders of gneiss and granite are worn and scoured into many curious forms. Many were found with basins or potholes bored in them and a few bored clear through so as to become ring-bowlders. At each of these rapids a stream enters just above and furnished a constant supply of gravel, sand and pebbles for the current to roll over and among the bowlders. The rapids below Turtle Lake and Pimisi Bay are of the same sort except that the water issued from lakes, and so had no supply of gravel to scour with. The third way of recognizing rapids was by inference indirectly. Such rapids were in narrow defiles or canyons with walls of bare rock and the fact that rapids had existed there was inferred from the observed drop in the surface level of the river above and below. The remains of the ancient Nipissing–Mattawa River agree with the Nipissing beach in indicating that the Nipissing Great Lakes endured for a relatively long period of time. And so long as it lasted, Niagara had only the discharge of Lake Erie.

A detailed account of the scoured bowlders appears in the current (March) number of the *American Journal of Science.*

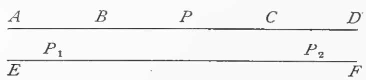
The Grain of Rocks. By ALFRED C. LANE.

The grain of rocks is dependent on the chemical composition and the causes that produce solidification, cooling, gas diffusion, etc., the general law being, the more rapid the action the finer the grain. The paper discusses the grain from the threefold standpoint of theory, observation upon the Keweenawan rocks, and experiment.

In regard to chemical composition, the augite of the luster-mottled melaphyres shows plainly the empirical law that the less there is of it the finer is its grain, other things being equal.

The following laws of cooling are mathematically applicable to an indefinite sheet:

(*A*) The case where we consider the adjacent rock symmetrically heated by the sheet can be solved by aid of a solution for the case that the walls are kept at a fixed temperature. For the temperature at any point P of the affected zone $A\ D$ (the sheet and its contact zone) is the average of the temperatures that two points P_1 and P_2 would have that were at the same distances from the walls of a hypothetical dike $E\ F$, as broad as the whole zone affected (its walls being kept at a constant temperature) as the point whose temperature is sought is from the two walls of the smaller sheet; the sum of the temperatures being



taken if said point is within the small dike, the difference if it is outside in the contact zone (time and initial conditions being the same).

(*B*) Taking the case of a sheet originally of a uniform temperature where the sides of the sheet are kept at a fixed temperature, we can divide the cooling into three periods:

(1) Before the center has cooled appreciably. During this period the rate of cooling is as the square of the distance of the margin, and independent of the size of the sheet otherwise.

The augite of the Keweenawan ophites follows in its grain this law, the average area of cross sections being proportional to the square of the distance from the margin, and independent of the size of flow.

Consolidation in this period may *a priori* be expected to be especially characteristic of effusive and porphyritic rocks.

(2) While the center is cooling down one-fourth of original difference in temperature between sheet and margin. This period is about four times as long as the first.

(3) Thereafter the rate of cooling when given temperature is reached will be independent of the position of a point. Hence the grain will be uniform and the same for all parts of the sheet that consolidate in this period. The solidification will tend to fall into this period for high initial temperatures of the magma and hot walls, compared with the temperature of solidification and broad contact zones. Hence solidification in this period may be taken as typical for abyssal rocks.

Dikes of the Keweenawan in the Huronian show a marginal zone where the grain appears to have been formed in the first period of solidification, and a central belt where the solidification appears to have been in the third period.

Similar phenomena may be reproduced in melted sulphur, and in sugar and water. In the latter case we have phenomena of aqueo-igneous fusion, and the temperature of solidification being comparatively low, there is a strong tendency toward the appearance of the central zone of uniform grain. The tendency to solidify as glass is dependent upon the escape of the water.

If the sides are not kept at a fixed temperature, the sides will cool more slowly than the center, for temperatures half way between the initial temperatures,—a possible explanation lies here for a certain kind of porphyritic facies of granites.

A Study of the Nature, Structure, and Phylogeny of Dæmonelix. By E. H. Barbour.

Additional expeditions to the Dæmonelix region have added new data showing the apparent steps in the phylogeny of this anomalous group.

The simplest expression of Dæmonelix seems to be a fiber found in the sand rock, which shows unmistakable plant structure, and is, in every respect, like the fiber found in all the Dæmonelix series. The author's present belief is that the various forms of the Dæmonelix group result from the aggregation of these simple fibrous, fresh-water seaweeds into variously shaped bunches, clusters, and spirals.

Ascending to higher beds one comes next to Dæmonelix "cakes," which are about the size of common camp griddle-cakes. So far as can be determined by the eye or the microscope they are nothing more nor less than colonies, or aggregations of Dæmonelix fibers. Vertical range twenty-five feet.

Next above the "cakes" come the Dæmonelix "balls," which resemble in size and shape the old New England codfish ball. These are but aggregations or bunches of Dæmonelix fibers. Vertical range about twenty-five feet.

Next come slender forms of nearly vertical and somewhat spiral habit, called Dæmonelix "cigars." The weathered and broken ends of these occur in immense abundance. They are about the size and length of an ordinary walking stick. These, too, are but aggregations of the simple Dæmonelix fiber. Though practically confined to a range of twenty nor more feet they occur, in decreasing numbers, almost through the upper Dæmonelix beds.

The forms encountered next are frail and slender, scarcely thicker than the wrist, yet positively spiral and vertical in habit. They are viewed as the immediate progenitors of Dæmonelix regular. They are but aggregations of the primitive Dæmonelix fiber. Vertical range scarcely twenty feet.

Above all, comes the "Devil's Corkscrew," the first forms of which are smaller, more regular, and more mathematically exact than are the larger and strangely modified forms characteristic of the topmost beds. Some are free spirals, some are fixed about an axis, some have no transverse trunk, others have one, two, or three; others, called "twin screws," have, in each case, a large screw and transverse trunk, ending in a smaller reversed screw and trunk. These are thought to be the first complete specimens of Dæmonelix. Continued study makes it only the more apparent that these magnificent screws are but spiral aggregations of the simple Dæmonelix fiber first encountered.

More than one hundred micro-sections have been cut from all parts of all forms. Without exception all show precisely the same simple, cellular, non-vascular structure, to be likened only to sea-weed. Numerous photomicrographs of these have been made and are ready for publication.

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GLACIAL STUDIES IN GREENLAND. X.

The Bowdoin glacier.—The Bowdoin glacier is a lobe of the great inland ice-sheet which descends from the north into the head of the valley of Bowdoin Bay. It is joined on the east by ice pushing in through the intervals between a row of nunataks that lie on the plateau border. On the west it is confluent with the trunks of the Tuktoo and Sun glaciers which debouch into the broad flat valley at the head of McCormick Bay. This is only separated from the Bowdoin Bay valley by nunataks of which the Sierra and the Sentinel are the most conspicuous. These lie in the lower part of the common valley and have already been mentioned in connection with the Tuktoo glacier (see sketch map, p. 668, Vol. III). No very precise point can be fixed upon as the place of parting of the Bowdoin glacier from the main ice-cap, but it may fairly be regarded as having a length of six or eight miles. In its lower half it is joined on the east by the Obelisk glacier which comes in below the North nunatak and by the East Branch glacier which pushes in more directly from the east on the south side of the Obelisk nunatak. The East Branch glacier appears to terminate by lateral wastage almost at the point of joining the Bowdoin glacier and apparently never becomes really confluent with it. But the Obelisk glacier blends with and becomes a part of the Bowdoin glacier without being distinguished from it even by a medial moraine. The Bowdoin glacier in its lower part has a breadth of about two miles. It is the master glacier of the vicinity both in respect to dimensions and activity.

The descent of its floor is apparently between 2000 and 3000 feet. This is accomplished by a somewhat steep fall from the

Fig. 64. Transverse view of Bowdoin glacier seen from the heights on the east looking northwesterly. The glacial movement is from right to left. The dark longitudinal line represents the sunken medial moraine. The undulations of the surface are fairly well indicated. The slope just beyond the crevassed area in the right foreground and between that area and the medial moraine inclines *backward, i. e.*, to the right, and a brook flows in that direction. The notable feature of the surface is the crevassing. The nunatak beyond the Bowdoin glacier on the right is the Sierra, that on the left the Sentinel. The Tuktoo glacier is seen between these and in the distance a glimpse of the Sun glacier is obtained. The ice-capped heights beyond are a part of the border of Prudhoe Land. Lieutenant Peary's first route across the ice-cap lay along these heights. Photograph by Professor Wm. Libbey, Jr.

upland to the valley, and then by a notable but unequal decline throughout its remaining course. The inequality of the decline is indicated not only by the undulation of its profile, but by intensive crevassing which distinguishes it from most of the valley glaciers of the vicinity. The crevassed condition is well shown in Fig. 64 and is worthy of thoughtful consideration when the relatively slight undulations and the relatively slow movement of the glacier are taken into consideration. Such pronounced crevassing emphasizes the slight ductility of the ice. The failure of the ice to fill up the inequalities and form a continuously declining surface after the fashion of liquids is a further feature of interest. The undulations are so great as to

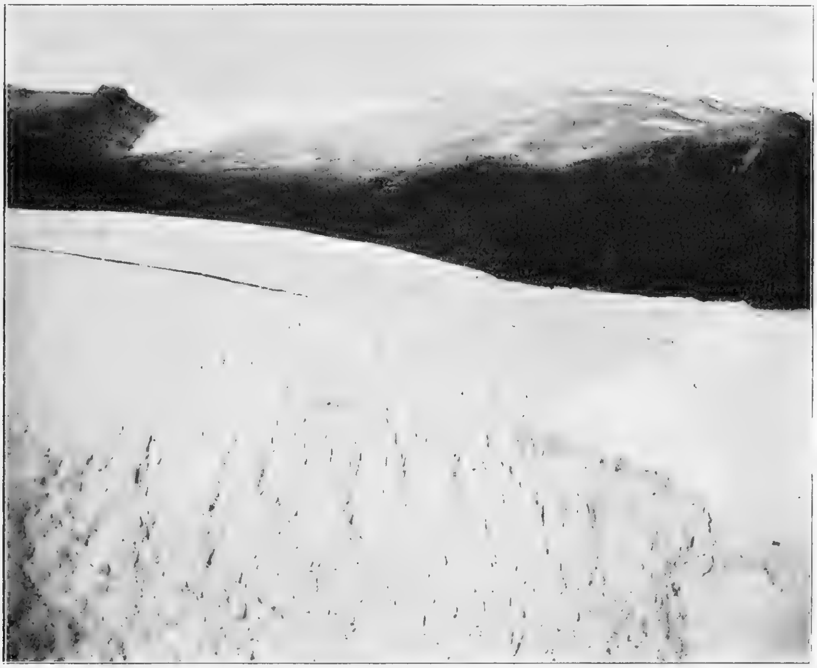


Fig. 65. The end of Bowdoin glacier. The head of Bowdoin Bay is seen at the right and the crevassed end of the glacier in the center and left. The dark line represents the medial moraine. The absence of other débris is notable. A portion of the ice-cap and the Mirror glacier are dimly seen in the distance. (The sky has been a little penciled.) The rounded embossment on the right is Bartlett Mountain, about 2600 feet high, the name being specifically applied to the frontal promontory. Sugar Loaf is seen at the left of Mirror glacier.

give rise to irregular surface drainage. In one instance at least, to which I was guided by Lieutenant Peary, the drainage is reversed. A considerable brook runs in a direction *opposite* to that of the motion of the glacier. It flows northward while the glacier flows southward. The northward slope may be seen at the right hand of Fig. 64 a little this side of the medial moraine.

The Bowdoin glacier debouches at its lower extremity into the head of Bowdoin Bay and discharges icebergs of considerable dimensions, Fig. 65. This discharge seems to vary very greatly with the nature of the summer season. My observations happened to fall upon a season of relative quiescence. From the sixth to the twenty-third of August I occupied, through the kindness of Lieutenant Peary, a lodge overlooking the sea wall of the glacier and so near at hand as to be within easy hearing distance of any notable disruptive action but during this time I was not fortunate enough to witness the discharge of a single notable mass of ice, or even to hear it. A more substantial evidence of quiescence is found in the fact that within less than 200 yards of the extremity of the glacier on the east side there was an ice bridge spanning the lateral stream and connecting the glacier with a spur of rock. Lieutenant Peary informed me that the bridge had remained intact for two years and had been used as a means of communication with the glacier whose vertical face at other points rendered access difficult. It would be an error, however, to draw conclusions from these facts, for during the succeeding season the bridge was not only broken away but extensive discharges of icebergs took place along the sea face of the glacier. I presume that this unequal and somewhat spasmodic action represents the habit of the glacier. It seems probable that during a succession of severe seasons the motion of the ice is quite slight and the extremity of the glacier makes but little advance. But an exceptionally warm season following such a succession of severe ones, during which thickening and steepening of the gradient may have taken place, probably causes a notable thrusting forward of the glacial foot accompanied by corresponding iceberg discharge.

On its west side the Bowdoin glacier does not present an extensive vertical wall in accordance with the prevailing fashion of the region. In its upper part the glacier runs side by side with the trunk of the Tuktoo glacier, as already observed. Below this it rubs hard against the Sierra and Sentinel nunataks and its activity is such as to prevent the development of the fossæ which often lie between nunataks and adjacent glaciers. Between the two nunataks named the glacier protrudes westward to meet the reciprocal eastward protuberance of the Tuktoo glacier, and the two jointly impound two small triangular lakes in the angles between themselves and the nunataks. Where the protuberances are opposite to each other their extremities are not vertical, though steep and somewhat stepped. This is perhaps due to the absence of the reflecting frontal plane which I have thought might be one of the factors in the development of the vertical faces. Each glacier standing opposite to the other covers the ground which would otherwise act as a reflecting surface.

On the east side of the Bowdoin glacier, however, there is the usual vertical face with its accompanying sharp triangular valley between the ice and the adjacent rock slope. This extends from the extremity of the glacier to the point of its junction with the East Branch glacier, a distance of perhaps three miles. At a few points spurs of rock close the valley. East Branch hill projects notably into the path of the glacier and not only closes the lateral valley but crowds the border of the ice out of its path. At these points of interruption the stream, which as usual runs between the glacier and the valley side, is forced to tunnel under the glacier. After a cold day or two, the water in the stream becomes low and the tunnels then afford a means of penetrating to limited distances beneath the ice, Fig. 66. The phenomena so disclosed, however, do not essentially differ from those seen to better advantage in the vertical sides. The amount of débris appears more scant because it is not concentrated by surface melting nor exaggerated by surface wash. In some instances where blocks of ice had recently fallen away from the roof, opportunity was given for the study of exceptionally fresh unweathered ice which had not been subjected to the sun's rays, except as they reached it through considerable depths of ice. Even here the ice is far from being really compact and transparent. It varies from translucency in the more dense layers to nearly complete opacity in the more porous layers. This is an expression of lack of solidity and may be noted as specially instructive since the ice is here near

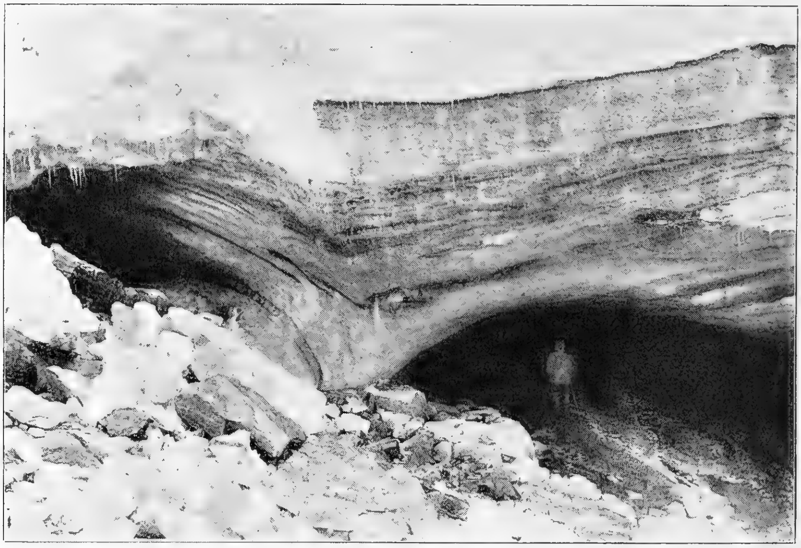


Fig. 66. Entrance to a tunnel under the side of Bowdoin glacier, looking downstream. The shoulder of rock which caused the undercutting of the stream is partially shown at the left. The peculiar arching of the beds is an interesting feature. Photograph by Professor Wm. Libbey, Jr.

the end of its career as a part of the glacier. As it was derived from the main ice-cap it may possibly have had as long a glacial history as often falls to such ice.

The stratification and the basal loading of the ice exhibited along the extended vertical face are much the same as in the glaciers previously described, but differ somewhat in the fact that the layers of ice are more warped and contorted, a result doubtless of the greater inequalities of the glacier's bed. Very notable dips of the glacial layers, both up stream and down stream, were frequently observed and sometimes reached large angles, in one instance 70°. These dipping planes were sometimes marked by débris (though more commonly not) showing that they were genuine planes of acquired stratification. But the distortion often went far beyond mere changes of dip, how-

FIG. 67. Upthrusted and contorted ice layers on the east side of Bowdoin glacier just north of the East Branch hill. Lines of shearing, sharp flexures, localized belts of contortion and thrust, are among the notable features.

ever great or abrupt. It amounted to crumpling and even to faulting. A special instance is illustrated in Fig. 67.

The débris does not rise so high in the Bowdoin glacier as in some of the others already described. This fact is perhaps worthy of special note as this is a tongue of the great ice-cap and has descended over an undulatory bottom nearly to the sea level. It is perhaps further worthy of note because this glacier discharges into the sea. The basal layers are not forced upwards at their extremities to the same degree that was observed in some glaciers that have less free termination. A measurement of the upper limit of the débris-bearing layers at a point about two miles distant from the end of the glacier gave a height of only twenty-eight feet. Between this point and the extremity of the glacier the débris was usually confined to less heights, and at some points near the end it was not visible at all in the lateral face of the glacier. The amount of débris even within the limited range indicated was often relatively small and never very heavy. The accompanying photographs substantiate this. The bowlders of this glacier were usually more rounded than those previously described, and this rounding was of such a nature as to imply very considerable wear. The débris was composed wholly of crystalline rock, so far as observed, no admixture of clastic material being seen. The considerable rounding of the material, the small amount of débris and its low position at the base of the glacier are facts worthy of special note. They will be seen to have special significance when it is remembered that this is one of the larger (though not by any means the largest) tongues of the great ice-cap.

The rubbing of the glacier against shoulders of rock projecting from the side of the valley gave opportunity for observing some of the special phenomena of such situations. At one point the process of "plucking" was well indicated (though not actually observed) on the lee slope of a spur of gneissoid rock. Blocks ranging up to three or four feet in width and length and one or two feet in thickness had been detached in considerable numbers. The process involved much breaking and bruising with relatively little wear. Corners and angles were broken off and heavy bruise marks were observed both on the blocks and on the sides and edges of the cavities from which they had been removed. At some points considerable crushed rock was observed. On the other hand, systematic grooves and striæ were not abundant nor pronounced. The dynamic impression given was that of a forceful tearing out of blocks by the action of a relatively rigid agency which did not press the blocks hard upon the lee slope after their removal.

At the point where the glacier grinds against the projecting side of the East Branch hill, the ice was notably crevassed, the fractures being most open at the side and gradually closing as they passed away toward the axis of the glacier. They were directed obliquely up stream according to the general law of lateral crevasses. Immediately against the obstructing projection the ice was broken up into numerous blocks and fragments and somewhat piled up against the side of the hill or tumbled back upon the upper surface of the glacier. The same thing occurs on the opposite side where the glacier rubs hard against the Sierra nunatak.

Just north of the point of forceful contact with the East Branch hill, a very interesting instance of contortion and upward thrust was observed. The accompanying figure (67) shows the nature of this better than any verbal description. It may be observed that near the base there are two quite pronounced lines which have the appearance of special shear planes. The contortion of the central belt in being forced obliquely upward is well displayed in the photograph. While the cause of the phenomena cannot be positively stated, it associated itself in my mind with the obtrusion of the projecting point of East Branch hill immediately below it. Whether this be the cause or not, the phenomena impress me as a clear case of forceful localized thrust with resulting foliation and shear planes.

At the point where the East Branch glacier joins the Bowdoin glacier, a large amount of débris had accumulated from a medial moraine derived from the Obelisk nunatak lying between the East Branch and the Obelisk glacier. The accumulated rubbish was the terminal dump of the medial moraine. There appeared to be much ice beneath this accumulated débris. It was obvious that both it and the extremity of the East Branch glacier had become essentially stationary. The more active Bowdoin glacier (or the Obelisk glacier, for the two are continuous) had forced itself over the edge of this débris. The result was the bending upwards of the edges of the layers of the Bowdoin glacier. Accompanying this there was a phenomenon which seemed at the time to be a clear and unequivocal expression of the shearing of these layers over each other, due to the resistance of the morainic material. Subsequent studies, as elsewhere remarked, led to some skepticism as to the validity of this interpretation. This point was not visited after the skeptical spirit arose, and hence I am only able to reproduce the observations and interpretations as they impressed themselves at the time. On the nearly vertical face of the glacier where it was most strained in being thrust over the morainic mass, there were as many as nine distinct projections of upper layers over under layers. The over-projection was sharp and definite and at once attracted the notice of my companion, Mr. E. B. Baldwin, who called my attention to it. The ground for skepticism regarding the interpretation of phenomena of this class is the presence of débris bands which may give rise to differential melting. There is no question that projections of a kind much like those here observed are due to such unequal melting. It seems to be demonstrable also that overthrust shearing takes place in this way. Each case must therefore be judged by itself. The limited amount of débris in this glacier encourages less skepticism regarding overthrust here than in some other cases. My notes state that pebbles and bowlders were sometimes lodged between these layers and that they appeared to have been pushed along the face of the layers in the shearing process, sometimes making grooves in the ice. Both notes and memory imply scantiness of débris between the layers. Unfortunately my photographs at this point were not a success. The overjutting of the layers ranged from a few inches to eighteen inches. They were most pronounced where the strain resulting from the obstruction would naturally be greatest and they died away in either direction. At another point somewhat farther on the phenomenon was repeated, but here there were but five chief planes of displacement in the vertical section. The maximum displacement of two adjacent layers, however, exceeded two feet. The adjacent faces appeared to be very distinctly fluted by the movement. Skepticism with reference to the interpretation of the fluting was subsequently raised on the

FIG. 68. Sunken medial moraine on the back of Bowdoin glacier; seen from a point near the moulin looking northerly. The ice motion is toward the foreground. The width of the moraine is about four rods and its depth below the general surface ten or fifteen feet. The stream's trench is shown at the left. It falls into the moulin at the lower right-hand corner. Glimpses of the main ice-cap are caught beyond the heights.

ground that it might perhaps be due to unequal melting by water trickling down the face of the ice, but, as elsewhere noted, in one instance at least, the débris in the junction plane was corrugated. It was noted here that a shearing plane was offset; that is, the shearing plane passed from the contact between two given planes to a similar contact between two planes below. The offset was downward and to the right or up-stream side. The overthrust was about six inches and the offsets, two of which were sketched, about eight inches.

The back of Bowdoin glacier is marked by an interesting medial moraine that takes its rise far up toward its junction with the main ice-cap, Fig. 68. I did not see its origin, but Lieutenant Peary informed me that it came to the surface from beneath the ice at a point north of the north nunatak, but south of the descent of the ice from the main plateau. On account of this he could not be certain whether it was derived from a nunatak that lies still farther north on the border of the main plateau, or from some concealed embossment. Undoubtedly the material was picked up from a prominence on or near the edge of the plateau. The débris is so thinly spread that it catches the sunlight and by conversion and conduction makes its heat available to the ice. As a result the moraine is sunken ten or fifteen feet below the surrounding surface. In breadth and form it is not unlike a depressed street strewn with coarse débris. On one side of it a stream has cut a notable trench through which a considerable body of water flowed during the warm days of August. Fig. 68 illustrates the moraine and its depressed condition, as also the channel on the west side. The latter terminates in a moulin at the right-hand lower corner of the illustration. The moraine is also illustrated in the general transverse view of the glacier shown in Fig. 64.

T. C. Chamberlin.

ITALIAN PETROLOGICAL STUDIES.

IV. THE ROCCA MONFINA REGION.

THE volcano of Rocca Monfina, was long celebrated as one of the classical examples brought forward in favor of von Buch's hypothesis of Craters of Elevation. Its historical interest is equaled by its interest from a petrological point of view, since, apart from the character of the rocks of which it is built up, their order of succession forms an exception to that met with elsewhere among the Italian volcanoes. My visit to the locality was extremely brief and was confined to a trip from Teano on the eastern border, past the central mass of Mte. Sta. Croce to Conca, with one or two short excursions. I must therefore rely for most of my knowledge of the volcano on the work of others— a resource which in this case is somewhat meager.

Rocca Monfina has been in fact one of the most neglected of Italian volcanoes. The early works, chief among which are those of Abich[1] (who gives views and a map), Daubeny[2] and Pilla[3] are devoted to an exposition of their views in favor of von Buch's theory and the examination of the volcano from this standpoint. They are therefore chiefly of historical value, though Abich gives some descriptions of the rocks. Vom Rath[4] devotes a few pages of Part IV of his "Italian Fragments" to a description and analyses of two of the rocks, which we shall have occasion to notice later. A few others are briefly described by J. Roth,[5] and Bucca's descriptions are quoted by Rosenbusch. The only modern writers who deal at all fully with the region

[1] ABICH, Vulk. Ersch. der Erde. Braunschweig, 1841.

[2] DAUBENY, Volcanoes, London, 1848. 174.

[3] PILLA, cf. Neu. Jahrb. 1845, 843, and references in Moderni.

[4] VOM RATH, Zeit. d. d. geol. Ges. 243, 1873.

[5] ROTH, Geologie, II, 245, 275, 354.

are Bucca[1] and Moderni.[2] The former gives petrographical descriptions of the rocks collected by Moderni; and the latter describes the region from a geological point of view, giving a quite detailed geological map on a scale of 1:100,000. Deecke[3] also touches upon the tuffs of the region in an article on the tuffs of Campania.

Topography.— The volcano of Rocca Monfina lies about 70 kilometers northwest of Naples, west of the main railroad line from Naples to Rome. In the center is the trachy-andesitic dome of Mte. Sta. Croce, 1005 meters above sea level, with the smaller similar dome of Mte. Lattani (847 meters) adjoining it to the northeast. These are steep well-wooded hills, made up of solid masses of eruptive rock, with no tuffs nor signs of separate lava flows. At the eastern foot of Mte. Sta. Croce is the small town of Rocca Monfina, and extending around the two domes, especially to the east and south, is the plain of the same name. This plain (from 500 to 650 meters above sea level) is bounded by the remains of a large crater ring, which is almost circular in form and with a diameter of about 6 kilometers. At the west and south the ridge, which is called Mte. Cortinelli, is quite high and sharp, reaching its maximum elevation on the west at Mte. la Frascara (926 meters). Its inner slope is very steep, while on the exterior it is very gentle, between 6° and 10°. On the northeast and southeast the plain is bounded by a series of hills which become less high as they are farther from the center. This part of the crater ring has suffered much from erosion, being furrowed by many deep radiating ravines.

In regard to the age of the volcano Moderni says that little can be stated positively, except that at various places volcanic material is seen resting on Middle Eocene beds. Deecke notes the superposition of Rocca Monfina tuffs on the gray Campanian tuffs. It is probable that like the other volcanoes previously

[1] BUCCA, Boll. Com. Geol. Ital., 1886, 245.

[2] MODERNI, Boll. Com. Geol. Ital., 1887, 74.

[3] DEECKE, Neu. Jahrb. 1893, I, 62, 65.

described the eruptions date from the Pliocene. The date of extinction of the volcano is likewise uncertain, though probably quite recent. Some lead objects and ancient buildings, with frescoes have been found beneath the tuffs, and the date 269 B.C. has been proposed for this period—on what authority I am unable to state as Moderni's reference is inaccessible to me. Moderni however, taking into consideration the silence of the ancient writers, the want of exact data, and the liability of objects being buried by the easily transported tuff, rejects this view and leaves the question an open one.[1] The hot springs of Sujo[2] are the last symptoms of volcanic activity manifest at the present day.

Petrography.—Moderni recognizes three phases of activity in the volcano, distinguished by different products of eruption: (1) the leucitic, the oldest, which is subdivided into two sub-phases characterized by leucitites and leucite-tephrites; (2) the trachytic; (3) the basaltic, which is the youngest. As my own observations were not extended enough to enable me to judge of this point for myself I shall accept Moderni's views. The volcano is thus seen to form a notable exception to most of the composite volcanoes of Italy—the order of succession of the leucitic and non-leucitic rocks being reversed. Before entering on the petrographical descriptions it will be as well to give a brief résumé of Moderni's work.

While it is difficult to unravel certain portions of the history of the volcano one fact is certain, that the first lava erupted was leucitite. This is shown by the fact that it is found beneath all the others. The flows of this rock are the greatest in amount of any of those of the region. They form a large part of the ridge of Mte. Cortinelli, with flows at many points elsewhere round the crater ring which it is unnecessary to enumerate here. There are certain eruptive centers on the flanks of the volcano which gave vent to this type of rock, but the last flows of the western half seem to have been poured out of the central crater. Lying above

[1] This is also the conclusion to which Daubeny comes in the second edition of his Volcanoes, London, 1848, p. 178.

[2] JOHNSTON-LAVIS, South Italian Volcanoes, Naples, 1891, 73.

the leucitites, and covering almost all the western part of the cone, are leucite-tephrites, whose amount, while great, is not equal to that of the leucitite. These also appear as small flows in the northern and eastern parts. Belonging to this period are certain tuffs, the most extensive of these being a gray lithoidal tuff which covers the flanks and extends for a great distance to the north, east, and south of the volcano. Moderni estimates that the volcano at the close of this period had an altitude of nearly 3000 meters.

The second or trachytic phase was inaugurated by the blowing out of the large central cavity, which involved the destruction of the greater part of the northern and eastern wall. It was during the first part of this phase that the double dome of Mti. Sta. Croce and Lattani was formed. These form, as already observed, a homogeneous compact mass, and are a good example of a "domal" eruption of a pasty magma which was not sufficiently fluid to flow to any great distance. The material of this eruption was of a trachy-andesite approaching the vulsinites already described, while the other eruptions of this period were of a more acid and more nearly trachytic rock and were all flank eruptions. While stating that it is impossible to decide definitely whether the central domal or the flank eruption took place first, Moderni thinks it more probable that the former was the earlier. He bases this conclusion on the ground that the large domal eruption choked up the main central vent, so that any further ejection of volcanic material had to take place through the flanks of the volcano. It is needless to mention in detail the various trachytic flows, which moreover are not nearly as large in amount as the flows of the first phase. With the trachyte there was also erupted a small quantity of leucitic rock. Several areas of trachytic tuffs also belong to this phase.

The third and last phase of activity was characterized by the eruption of basaltic rocks in which leucite is entirely wanting. These eruptions were of small amount, the quantity of basalt being even less than that of the trachytes. They formed a number of small parasitic cones, the lava poured out being often scoriaceous. Most of these small cones were formed on the outer flanks of the volcano, but three are found in the interior, one being in the valley of Pratolungo between Mte. Sta. Croce and Mte. Lattani. The tuffs belonging to this phase are few and of small amount. That the eruption of the "basalts" was posterior to those of the leucitites and trachytes is made evident by several facts. The small cones formed by them are the best preserved of all, in many cases quite intact and covered with lapilli and bombs and with their lava flows quite bare. At Sipicciano on the northwest flank of Mte. Cortinelli a basaltic flow covers the leucitites and leucite-tephrites; while in the central eruption at Pratolungo the flow of "basalt" is seen to be superposed on the trachy-andesite of Mte. Lattani.

Leucitite.—This is represented by only one specimen in my collection, from a flow below Preta, on the outer northern side of the volcano. This shows a very compact, fine grained, dark gray groundmass, through which are scattered many small but quite glassy leucites, with rare specks of augite. In thin sections these large leucites are seen to be perfectly clear, and they show very weak double refraction for such large fresh crystals. Over the greater part of their area they carry almost no inclusions, but at the edge of almost all is a very narrow peripheral line of small augite microlites, which in turn is surrounded by a narrow mantle of leucite. This shades into the groundmass, and is quite analogous to the alkali feldspar mantles so frequently noticed in the preceding papers. Apart from the leucites only rare light green augite phenocrysts are seen, which also carry no inclusions.

The groundmass is fine grained and composed essentially of small leucites with interestitial greenish gray augite prisms and anhedra and a little magnetite. These small crystals are imbedded in a colorless isotropic substance. It is possible that this is glass, but, judging from the leucitic mantles around the leucite phenocrysts and from the fact that there is no difference in refractive index between this base and the small leucites, it seems probable that it is leucite. It would thus correspond to the nepheline base of certain phonolites and other nepheline rocks, such as have been noticed previously. A very few flakes of alkali feldspar are also met with.

Leucite-tephrite.—One specimen of this rock was collected at Mte. San. Antonio (707 meters high), which forms one of the girdle of hills around the plain and lies due north of Mte. Lattani. The rock shows a fine grained gray groundmass in which, with the exception of very rare augites, the only phenocrysts visible are leucites. These are extremely abundant, making up a large portion of the rock. They are apparently fresh, with a waxy luster; the smaller ones pale gray, while the larger show a core of dark gray and an outer shell of light gray. This rock is extremely tough. In thin sections the large leucites are very prominent. They are clear and show strong double refraction. Inclusions are abundant, of small crystals of anorthite and green augite. They include also many small slender needles of diopside, minute grains of magnetite and spots of glass, which are very commonly clustered toward the center of the crystal, thus accounting for the dark gray cores. Beside the leucites only one or two dark green augite phenocrysts were seen in the slides. The groundmass is composed largely of irregularly shaped greenish yellow augite grains, a few small leucites, considerable magnetite, many small crystals of a plagioclase which is shown by its extinction angles to be anorthite, and some small flakes and laths of alkali feldspar. A little residual glass is also present.

A peculiar leucite-tephrite is that, from what appeared to be a small flow on the road to Conca, below Orchi. It is very dark gray and fine grained, but rather rough in texture. A few phenocrysts of augite and leucite are visible. Under the microscope it shows the doleritic structure which is so common to the Italian leucite-tephrites. None of the phenocrysts were met with in the single section which was made of this rock. In the groundmass stout columnar, pale green augites are very abundant, the largest showing cores of darker green; while these are clear and contain few inclusions (of magnetite and glass), their outlines are very irregular, most of the prisms showing deep embayments due to corrosion. A little brown barkevikitic amphibole and a few flakes of brown biotite are also present. There are also numerous grains of magnetite and a few apatite needles.

Leucite is present in abundance, but shows an unusual habit. While often in the form of small, rounded or trapezohedral crystals, it generally occurs in irregularly shaped masses, occasionally showing crystal planes here and there, or with small, definitely shaped crystals attached to the larger mass. These leucites are extremely clear, and show a remarkably faint double refraction. Indeed so faint is the action of these leucites on polarized light, that in most of the crystals recourse must be had to the quartz wedge before any such action can be perceived, a proceeding not often necessary in the Italian leucitic rocks.

Later than the leucites, and often enclosing them micropoikilitically,[1] are flakes and large patches of a plagioclase with generally well developed twinning lamellæ, whose high symmetrical extinction angles refer it to anorthite. There are also some patches of a feldspar, which, though not showing any signs of twinning, may also be referred to anorthite on the ground of the equality of its refraction with that of the striated anorthite. There is also considerable colorless base, which, while in general isotropic, shows in places a very faint double refraction. Since treatment of the powdered rock with acids produces abundant gelatinous silica, this base may be regarded as nepheline, or at least as a glass corresponding to nepheline in chemical composition. An analysis of this rock made for me by Dr. A. Röling of Leipzig is here inserted:

SiO_2	47.40
Al_2O_3	19.84
Fe_2O_3	2.72
FeO	4.40
MgO	4.23
CaO	9.88
Na_2O	2.93
K_2O	5.91
H_2O	1.66
TiO_2	0.30
	99.27

[1] The marked difference in refractive indices between the leucite and anorthite serve to bring the structure out very nicely in ordinary light, while the dark spots of

A leucite-tephrite from Mte. San Antonio is described by vom Rath,[1] which seems to be more like the Conca tephrite than the other just described. Megascopically only few phenocrysts of augite, leucite and feldspar are visible, while under the microscope the groundmass resembles that of many leucitites already described. Sanidine phenocrysts are few, but smaller ones of plagioclose are abundant. Vom Rath's analysis is inserted here:

SiO^2	58.48
Al_2O_3	19.56
FeO	4.99
MgO	0.53
CaO	2.60
Na_2O	3.14
K_2O	10.47
H_2O	0.24
	100.01

Leucite-trachyte.—The occurrences of this rock which I observed seemed to belong to the second (trachytic) phase of the volcano, though on this point I cannot speak with certainty. My specimens may be referred to two different varieties, an augitic and a biotitic. To the former belongs the rock of a well marked flow at Acqua Rotta, about a kilometer and a half northwest of Teano. The groundmass of this is very compact and fine grained, and of a dark gray color. Leucite phenocrysts are not abundant, but many small black augites and a few flakes of biotite are visible. Under the microscope a few large leucite sections met with are clear, with quite strong double refraction, and show few inclusions. The pale green augite phenocrysts are clear, carry inclusions of magnetite, especially toward the edges, and generally show corroded outlines. The biotites present are all altered to an almost opaque, finely granular mass of augite and magnetite, generally to such an extent that but little of the original mineral remains. The groundmass resembles that of many leucitites, being composed largely of small round leucites,

leucite show out with striking clearness against the background of bright anorthite between crossed nicols.

[1] VOM RATH, op. cit. 243.

with interstitial prisms of green augite, many magnetite grains, and flakes and laths of alkali feldspar. Some larger crystals of anorthite are also seen. No glass seems to be present.

To the biotite-leucite-trachytes belong specimens from Tuoro west of Acqua Rotta, and from below Orchi on the northern flank of the volcano. Their groundmass is lighter gray than that of the preceding, small leucite and augite phenocrysts are not very common, but there is an abundance of flakes of biotite of a dark brown color and bronzy luster. In thin section they very much resemble the preceding. Augite phenocrysts are, however, rare, their place being taken by biotite. In the rock from Tuoro its color is of a deep orange red, while in that from Orchi it is much paler. It is much altered at the edges to the usual fine grained aggregate. In the groundmass of the former the alkali feldspar is in the form of laths, in the latter it is rather in the form of flakes and interstitial cement. Some basic plagioclase is present, but in small amount.

A rock which occupies a position between the above and the following group is represented by a specimen also from below Orchi. Megascopically this closely resembles the other, the only important difference being that here leucite phenocrysts are entirely wanting, and replaced by glassy sanidines. There is also considerable augite along with the biotite. The rock in thin section resembles more one of the vulsinites to be described presently than a leucite-trachyte. The sanidine phenocrysts are rarely met with. Large greenish gray augites are not uncommon, which carry inclusions of brown glass and magnetite and are somewhat corroded. The biotites are all profoundly altered, usually so much so that the crystal is almost completely disintegrated. The groundmass is made up of flakes and laths of an alkali feldspar, with a considerable number of laths and basic plagioclase which are usually surrounded by mantles of orientated alkali feldspar. Small grayish green irregularly shaped and corroded augite crystals with magnetite grains are common. There are also present many small round spots of leucite, recognized by their characteristic inclusions and by their analogies with other occurrences. A scanty glassy base is also present. No nepheline was detected in any of the above rocks.

Biotite-vulsinite.—In the descriptions of the volcanic centers which form the subject of the preceding papers we have had occasion to examine certain members of a group of effusive rocks which, both chemically and mineralogically, stand in a position intermediate between the trachytes and the andesites. The Rocca Monfina region resembles the others in furnishing—and very prominently—members of this group. We find here in fact effusive rocks showing the mineral combination of alkali feldspar and basic plagioclase, which approximate closely to the ciminite of the Viterbo region in chemical composition. Mineralogically, however, they come closer to vulsinite of Lake Bolsena, no olivine being present, but augite and especially *biotite* being abundant representatives of the ferromagnesian minerals. So much indeed do they resemble vulsinite that they were considered at first to belong to this group, forming a species which would be called a biotite-vulsinite, as was briefly noticed in the paper on the Bolsena Region.[1] A chemical analysis, however, which I completed after the printing of that article and which will be found on page 252, shows that this determination is not quite correct. It will be seen that the silica is notably lower than in the vulsinites, and furthermore that lime, magnesia and iron are very much higher, while the alkalies are considerably lower. Comparison with the analysis of the Viterbo ciminite (which is inserted for convenience) will show that the trio are *chemically* almost identical. We have then a rock which is chemically a ciminite and mineralogically, a biotite-vulsinite.

In regard to the name by which they should be called there may be some doubt. From a mineralogical standpoint they are obviously not ciminite, nor chemically can they strictly be called vulsinite. Since, however, in the schemes of classification in general use at the present time, the mineralogical composition takes precedence over the chemical, and bearing in mind the unadvisability of adding new names to the already

[1] JOUR. OF GEOL., IV, pp. 551–553, 1896.

overburdened nomenclature, I shall designate these rocks as *biotite-vulsinite*.

The most important occurrence of biotite-vulsinite is that of Mti. Sta. Croce and Lattani, which are, as far as can be seen, entirely formed by a domal eruption of the rock just noted. This was called "trachy-dolerite" by Abich,[1] he considering it a link intermediate between trachyte and dolerite, while Pilla and von Rath consider it a trachyte. Bucca calls it an augite-andesite, and refers the greater part, if not all, of the feldspar to plagioclase. Otherwise his description agrees closely with mine.

The Santa Croce rock is trachytic in appearance, having a fine grained, but not very compact, light gray groundmass of a slightly reddish tone. Through this are scattered very many small, dark brown flakes of biotite, some small augites, and a few small feldspars. The groundmass of the Mte. Lattani rock is rather darker and of a bluish gray color, more compact, biotite flakes are less abundant, and feldspars more common. My specimen of this latter is not quite fresh. In thin section the feldspar phenocrysts are quite common. They consist of an alkali feldspar, apparently a soda-orthoclase, and a larger number of plagioclase, which is shown by its extinction angles to have the composition Ab_2An_3. These are well shaped, but contain many inclusions of glass with small opaque grains and augite microlites. The biotites are of a greenish brown color, quite fresh in the interior, but surrounded by a thin alteration border of fine augite and magnetite grains. The large, irregularly shaped augites are pale green. The groundmass is trachytic in character and shows well-marked flow structure. There is an abundance of small laths, chiefly of alkali feldspar, with some of plagioclase. Magnetite grains and small diopside microlites are present in abundance, and there is a residue base of alkali feldspar.

The rock of Mte. Lattani closely resembles the above, though there are certain differences, the rather more abundant feldspar-phenocrysts are identical, as is also the augite. The biotites are,

[1] Abich, Vulk. Ersch., Brunswich, 1841, 100.

however, all completely, or almost completely, altered, the product being rather coarsely granular. The grains are very slightly coherent with one another, and show in a very striking way the distribution of such augite and magnetite grains through the groundmass of certain rocks, as has been already pointed out.[1] The groundmass is holocrystalline, and composed largely of flakes of alkali feldspar, with few laths. The augite and magnetite grains resulting from the disintegration of the biotite are very abundant. Bucca refers this Mte. Lattani rock to the trachytes, though, as will presently be seen, he is struck by their andeistic character.

An analysis of the rock of Mte. Santa Croce (I) made by myself is given below, II being an analysis of the same occurrence by vom Rath,[2] and III being an analysis of the ciminite of Fontenu Fiesole, near Viterbo,[3] inserted for convenient comparison.

Abich (p. 114) gives the silica percentage as 57.41 and the specific gravity as 2.79.

	I	II	III
SiO_2	55.69	55.08	55.44
Al_2O_3	19.08	17.25	18.60
Fe_2O_3	4.07	——	2.09
FeO	3.26	9.33	4.48
MgO	3.41	2.77	4.75
CaO	6.87	7.34	6.76
Na_2O	2.89	1.86	1.79
K_2O	4.41	5.32	6.63
H_2O	0.17	0.17	0.25
TiO_2	tr.	——	0.16
P_2O_5	——	——	tr.
MnO	tr.	——	——
	99.85	99.12	100.75
Sp. gr.		2.713	

Belonging to the same group is a specimen from a flow met with in the valley east of Casi, to the west of Teano. This is a

[1] Cf. JOUR. OF GEOL., IV, 270, 1896.

[2] VOM RATH, Zeit. d. d. geol. Ges., XXV, 245, 1873.

[3] H. S. WASHINGTON, JOUR. OF GEOL., IV, ——, 1896.

medium gray compact rock showing small biotite, augite, and feldspar phenocrysts. In thin sections the phenocrysts of alkali feldspar and basic plagioclase are present in about equal amounts. They contain many glass inclusions. The biotite phenocrysts are all deeply altered, and a few large augites met with show no noteworthy features. The groundmass is trachytic and composed of flakes and laths of alkali feldspar, with laths of plagioclase, diopside needles, and magnetite grains. There is little or no glass present.

Rocks which represent transitional forms between the above and true trachytes are found in specimens from the ravine at Molino di Casa Fredda, from a flow northwest of Tuoro, near Teano, and from a loose block in the valley of Casi. They resemble the rocks already described, but plagioclase is much less abundant, and in some almost entirely wanting. The groundmass of the Casi rock is much darker and finer grained than in the other cases; feldspar phenocrysts are abundant, but few of ferromagnesian minerals are seen. Some good examples of microperthite seen in it indicate that the alkali feldspar contains considerable soda. In the specimen from Tuoro a noteworthy feature is the presence in one slide of a single, large, well-shaped crystal of colorless diallage, showing its characteristic dusty inclusions and parting parallel to the orthopinacoid These, as well as other rocks similar to these, are all described by Bucca under the head of trachytes, his descriptions agreeing very closely with the characters of my specimens. He closes, however, with the significant remark (p. 257) that they "approach so closely to the andesites that I was tempted several times to refer them to these."

Trachyte.—A rock from a small quarry on the road to Conca, on the northern outer flank of the volcano, belongs to the trachytes proper rather than the vulsinites. It is the same as a rock described by Bucca (p. 255), whose description agrees very well with the characters of my specimens. The main mass of the rock is compact and light gray, showing few phenocrysts of augite and feldspar. Scattered through this are rounded black masses, which often attain diameters of five centimeters. These are coarsely crystalline and not very compact, with miarolitic and vesicular cavities. Under the microscope the only phenocrysts visible are of pyroxene. These are usually well formed, but occasionally quite fragmentary. The interior consists of a colorless diopside, which is uniformly surrounded by a rather narrow border of yellowish green non-pleochroic augite. The substance of this border corresponds exactly with that of the small groundmass augites, so that it is due to the same late period of growth to which they belong. The large augites are hence a good instance of the growth and enlargement of crystals brought up from below by the late accretion of isomorphous substance of somewhat different composition. Apart from the not very abundant small augites and magnetites, the groundmass is made up of feldspar and some residual glass. The feldspar forms laths with somewhat ragged edges, and they, with the augites, show well-marked flow structure. The greater part of these laths are of orthoclase, or at least an alkali feldspar; only very few showing twinning striations and extinctions which would refer them to plagioclase. No suitable sections of these latter were found by which their approximate composition could be determined, though I am inclined to think that they belong to the middle of the plagioclase series rather than to the basic end. The powdered rock, on treatment with acids, furnishes abundant gelatinous silica, which probably comes from the glass base. The dark spots referred to above are seen under the microscope to be holocrystalline, and composed of a few large diopsides with augite borders and very many smaller prismatic augites lying in a cement of orthoclase or alkali feldspar. The line of junction with the surrounding rock is quite sharp. They are true segregations and are to be classed with the *enclaves homœogènes* of Lacroix.[1]

Bucca also mentions briefly the rock of Mte. Ofelio, near Sessa, on the southwest flank of the volcano, as a true trachyte. It seems to be much decomposed.

[1] LACROIX, Enclaves des Roches, Macon, 1893, 8.

Basalt.—Of the rocks of this class described by Moderni and Bucca, I was unfortunately unable to obtain specimens. This is the more to be regretted, inasmuch as the feldspar basalts are only sparingly represented along the main line of Italian volcanoes, and at Rocco Monfina they are, according to Moderni, the last product of volcanic activity. Bucca describes a number of them, and his observations may be summarized here so as to complete as far as is possible, the petrographical description of the region.

The basalts of the region are apparently quite feldspathic, and are quite free from leucite or nepheline. In the majority of cases they are olivine-bearing, this mineral being generally phenocrystic, and seldom forming part of the groundmass. It is usually somewhat altered, especially on the borders, to a dark red substance. A few specimens are free from olivine and approach the augite-andesites, but are classed by Bucca with the basalts on account of their basic character. These last are of a light gray color, while the olivine basalts are dark. Augite is abundant, of a slightly bluish green, and not pleochroic. In two specimens a dark reddish brown biotite is present, which is for the most part largely altered to the usual augite-magnetite aggregate. The plane of the optic axes is perpendicular to the plane of symmetry. Feldspar which is referred to plagioclase rarely appears as phenocrysts, but is abundant as laths in the groundmass. Its optical characters are not noted, so that we are unable to judge of its place in the series. Small magnetite grains are abundant and a colorless glass base is usually present.

Although Bucca constantly refers to the feldspar as plagioclase, yet he does not mention twinning lamellæ, and indeed treats it in a rather cursory way. Certain facts, indeed, incline me to the belief that there is some, if not quite a good deal, of orthoclase in the rock. In the first place all the rocks which I have examined from this and the other volcanic centers are eminently rich in potash, even the phonolite of Viterbo containing 9.14 per cent. of it. It would then be quite anomalous to find here such a rock as a normal basalt containing a minimum amount of this alkali. If the feldspar is all plagioclase, as Bucca's description would indicate, there would be no mineral capable of taking up any notable amount of potash, as its percentage in biotite is never over 10., and the amount of this mineral in these rocks is small.

Furthermore we find at Radicofani, which is on the same main line, "basalts" containing very considerable orthoclase along with the plagioclase, and showing in one instance: $SiO_2 = 55.13$; $K_2O = 2.43$, and $Na_2O = 2.07$. Again Abich (*op. cit.* page 114) gives the silica percentage of the "basalt" from the foot of Santa Croce as 54.62, and classes it as a trachy-dolerite, though a rather basic one resembling the dolerites, while the rock of Monte Santa Croce is more acid and like the trachytes. It seems then very probable that these "basalts" of Rocca Monfina are in reality not normal plagioclase basalts, but rather approach the ciminites in composition both mineralogically and chemically.

HENRY S. WASHINGTON.

ARE THE BOWLDER CLAYS OF THE GREAT PLAINS MARINE?

SEVERAL trains of evidence show that the western plains, as well as the Cordilleran region, have been affected by great changes in elevation relatively to the sea level and to that of the eastern parts of the continent in later Tertiary and Pleistocene times. Facts bearing upon these changes have been detailed by the writer in previous papers and more particularly in those entitled respectively "Later physiographical geology of the Rocky Mountain region," and "Glacial deposits of southwestern Alberta in the vicinity of the Rocky Mountains."[1]

The observations made are in effect such as to lead the writer to believe that the bowlder clays and other deposits of the glacial period covering a large part, at least, of the Great Plains in Canada, are glacio-natant deposits, not directly due to an ice-sheet and not calling for an extension of glacier ice as such to this part of the continent. He has further ventured to suggest that the water covering the western plains at this time may have been at the level of that of the sea and in more or less direct communication with it. The present note relates, however, to the discovery in the bowlder clays of the Great Plains of marine organisms which appear to be contemporaneous with their deposition, and the general observations above alluded to need only be mentioned in introducing the subject.

Some time ago Mr. T. Mellard Reade, writing in comment on the paper last referred to above, and in the light of his own investigations and those of Mr. Joseph Wright on the bowlder clays of Great Britian,[2] suggested that a search should be made for

[1] Trans. Royal Soc. Can., Vol. VIII, Sec. 4 (1890). Bull. Geol. Soc. Am., Vol. VII, (1895).

[2] Cf. Present Aspects of Glacial Geology, T. M. READE, Geol. Mag. (IV,) Vol. III, p. 542. Bowlder Clay a Marine Deposit, J. WRIGHT, Trans. Geol. Soc. Glasgow, Dec. 1894 and May 1895.

micro-organisms in the bowlder clays of the plains. In conjunction with Mr. B. W. Thomas, I had some years ago examined several of these clays microscopically, but, as pointed out by Mr. Reade, the material examined in this case, was, in consequence of the mode of preparation adopted, that resulting from the elimination of all lighter particles by successive decantations, and not likely to include any foraminiferal forms still unfilled with mineral matter, which as a rule contain sufficient air to float to the surface of the water employed. In respect to the existence of forms contemporaneous with the deposit of the bowlder clays, the results arrived at by me were scarcely more than negative, but foraminifera evidently derived from the Cretaceous strata of the region were found in some of the clays from the Northwest.[1] Mr. Wright having very kindly offered to examine some of the western bowlder clays by the methods found applicable by him to those of Great Britian, several specimens were collected for the purpose and submitted to him. The results arrived at form the subject of this note, which is, however, essentially of a preliminary character, and is intended to be followed by further investigation as soon as it may be possible to obtain additional material.

The specimens sent to Mr. Wright were from the following places:

Nos. 1 and 2. Saskatchewan River, twelve miles below Victoria, collected by Mr. R. G. McConnell. These represent a bed of bowlder clay about fifty feet thick, the first being from its upper, the second from its lower part. Present height above the sea level about 1850 feet.

No. 3. Bowlder clay from near Victoria, Saskatchewan River, one and one-half miles up Egg Creek, also collected by Mr. McConnell. Height about 1900 feet.

No. 4. Bowlder clay from Selkirk, Red River, Manitoba. Collected by Mr. J. B. Tyrrell. Height above sea, 720 feet.

To these specimens from the West was added one collected by Dr. H. M. Ami, at Ottawa (No. 5).

It is not certainly known whether the bowlder clay represented by the first three specimens is the "lower" or "upper"

[1] Bull. Chicago Acad. Sci., Vol. I, No. 6 (1885).

bowlder clay elsewhere recognized in the western part of the plains,[1] but it is probably the latter. Microzoa were found only in the three samples from the Saskatchewan Valley. In giving the results of his examinations Mr. Wright writes as follows:

"In the clays from Victoria (1, 2 and 3) I find foraminifera (and Radiolaria) and I am of opinion that they are contemporaneous with the clay and not derived from Cretaceous strata—I judge by the general resemblance of the foraminifera to those we find in British bowlder clay. The foraminifers in the Cretaceous rocks of Canada may possibly be different to those which occur in the rocks of this age with us—I have never seen Cretaceous microzoa from Canada and so can give no opinion on this subject.

"Our chalk foraminifera are invariably of a dull white chalky appearance, the tests alone being calcareous, the interior being usually siliceous. On the other hand, our bowlder clay foraminifera differ in no respect from recent specimens, except in being usually smaller in size, the species being such as are now met with in shallow water around our coasts.

"All the species which I have been able to identify in the clays you sent me, are referable to recent species, and with the exception of *Cristellaria Italica* and *Rotalia orbicularis*, have been found in British bowlder clay. *Nonionina depressula* is the most abundant form in our bowlder clay, and it is instructive to find the species, so common with us, also occurring in your clay.

"*Bolivina lævigata*, *Cristellaria Italica*, as also some of the other specimens, have the clear hyaline luster of recent specimens. If Cretaceous, we would expect to find *Globigerina Cretacea* and *Textularia globulosa* plentiful."

The above references to Cretaceous foraminifera, are explained by the fact that Mr. Wright's attention had been called, when the specimens were sent, to the probable existence of such forms in the bowlder clays.

In replying to the letter from which I have just quoted, half a dozen specimens of Cretaceous foraminiferal material from the

[1] Cf. Bull. G. S. A., Vol. VII, p. 60.

Canadian Northwest, collected by Mr. J. B. Tyrrell, were sent to Mr. Wright, and allusion was also made to the report by Messrs. A. Woodward and B. W. Thomas on the "Microscopic Fauna of the Cretaceous in Minnesota, Nebraska and Illinois."[1] In this report, all the foraminifera found in bowlder clays, as well as those actually obtained from Cretaceous rocks, are classed together as Cretaceous.

After carefully examining the Cretaceous material sent, and preparing lists of the forms represented, Mr. Wright notes the occurrence in it of a great preponderance of the two species already mentioned by him as likely to be characteristic. He further points out that these Cretaceous foraminifera are filled with calcite, differing in that respect from most of those of the same age in Great Britain, but none the less stony and unlikely to float during the treatment of the clays. In Yorkshire he has met with clays containing about equal proportions of Cretaceous (derived) and Pleistocene (contemporaneous) foraminifera, but found no great difficulty in separating the two lots by the criteria already alluded to. Referring to Messrs. Woodward and Thomas' report, he expresses the belief that it really comprises a mixed fauna of the same kind, stating that of twenty-nine species recognized by these gentlemen, ten had not before been recorded from rocks of Cretaceous Age, according to Brady's monograph in the Challenger report.

One of the localities mentioned by Messrs. Woodward and Thomas for foraminiferal bowlder clay, that of South Chicago, lies so far from known Cretaceous outcrops and away from the line of any recognized drift from such outcrops, that I ventured to address a question on the subject of the probable origin of the microzoa to Professor T. C. Chamberlin. The foraminifera found in this bowlder clay, appear to be in part, at least, undoubtedly Cretaceous in age. In reply, Professor Chamberlin quotes observations made in northern Wisconsin which tend to show the existence of Cretaceous outliers there, as well as perhaps beneath the northern part of Lake Michigan, or even further east. He

[1] Geology of Minnesota, Vol. III, Part I (1895).

writes: "Taking the evidence all in all, I do not think there is any serious difficulty in accounting for Cretaceous forms in the drift of this region" (Chicago). After referring to the interest attaching to Mr. Wright's observations, he adds the following interesting suggestion concerning them: "It has occurred to me to raise the question whether a certain number of marine microscopic forms are not to be expected in any slow-accumulating deposit like a clay, in the interior of the continent, having been borne there by the wind with other dust picked up from marine flats on the windward side of the continent."

The purpose of this communication is accomplished in stating as above, briefly, the new facts which appear to bear upon the question asked in its title. It seems to be at least very probable that, in addition to derived Cretaceous foraminifera often found in the drift deposits of the Great Plains, we have contemporaneous forms of the sea of the glacial period, still unfilled with mineral matter, unaltered, hyaline in aspect, and representing the same species elsewhere commonly found in deposits of this period. Should further investigation confirm the contemporaneous and autochthonous character of this fauna, it will greatly assist in enabling the formation of definite hypotheses respecting events of the glacial period in the western part of the continent.

Mr. Wright's notes on the specimens of bowlder clay from the Saskatchewan, are as follows:—

No. 1. Bowlder clay, twelve miles below Victoria. Weight 4 lbs. 4.5 oz Troy. After washing—Fine 1 lb. 3.7 oz. Course 0.7 oz. Stones mostly rounded, some angular.

Gaudryina Sp., very rare.
Bulimina pupoides D'Orb., frequent.
Pulvinulina Karsteni (Rss.), very rare.
Nonionina depressula (W. & J.), very rare.
Rotalia orbicularis, D'Orb., very rare.
Radiolria, frequent.
Sponge spicules, rare.

No. 2. Bowlder clay, twelve miles below Victoria. Weight 2 lbs. 6.2 oz. Troy. After washing—Fine 8.9 oz. Coarse 0.5 oz. Stones mostly rounded, some angular.

Bulimina pupoides D'Orb., rare.
Bolivina lævigata (Will.), very rare.
Cristellaria Italica, Defr. (young), very rare.
Truncatulina Sp., very rare.
Rotalia orbicularis, D'Orb., very rare.
Radiolaria frequent.
Sponge spicules, rare.

No. 3. Bowlder clay near Victoria. Weight 3 lbs. 1.6 oz. Troy. After washing — Fine 1 lb. 0.1 oz. Coarse 0.6 oz. Stones mostly rounded, some angular.

Gaudryina Sp., frequent.
Bulimina pupoides, D'Orb., rare.
Rotalia orbicularis, D'Orb., frequent.
Nonionina depressula (W. & J.), very rare.
" *scapha* (F. & M.) ? very rare.
Radiolaria, frequent.
Sponge spicules, rare.
Ostracod, very rare.

It may be of interest to add for comparison, the species actually recognized by Mr. Wright in the several small samples of Cretaceous material supplied to him. These are, nearly in order of relative abundance, as follows :—

Textularia globulosa Ehr., very common.
Globigerina Cretacea, D'Orb., very common.
" *digitata*, Brady, rare.
Anomolina ammonoides, (Rss.), rare.
Nodosaria Zippei, Rss., very rare.

GEORGE M. DAWSON.

GEOLOGICAL SURVEY OF CANADA,
March 10, 1897.

THE BAUXITE[1] DEPOSITS OF ARKANSAS.

CONTENTS.

THE geological survey of Arkansas was begun in June 1887. In that month I discovered some of the bauxite beds of Pulaski county, but the nature of these deposits was not announced until January 1891, when I gave a short account of their distribution and character.[2]

The many inquiries concerning the Arkansas bauxites, both from geologists and manufacturers, furnish sufficient reason for the present more extended account of them. This is made still more necessary by the fact that my report on the clays, kaolins, and bauxites of Arkansas has not yet been published, and it seems improbable that it ever will be published by that state.

In view of the fact that Owen was State Geologist of Arkansas from 1857 to 1860, and that other surveys were carried on

[1] This is also sometimes written *beauxite*. The word is derived from Les Baux or Les Beaux, the name of a town in the south of France. Pronounced *bozite*, not *bawksite*.

[2] A letter on this subject was addressed to Governor James P. Eagle and was printed in the *Arkansas Gazette* and the *Arkansas Democrat* of January 8, 1891, and reproduced in the *Arkansas Press* in several numbers from January 18, 1891, until 1893, and also in the third and fourth biennial reports of the Commissioner of Mines, etc., of the state of Arkansas. A brief notice of the deposits was also published in the *American Geologist* for March 1891, pp. 181–183.

from 1871 till 1874,[1] it is somewhat remarkable that the bauxite deposits were not sooner discovered. The rocks were seen and mentioned by two geologists, but their true character and importance were not suspected. As long ago as 1842 Dr. W. Byrd Powell published a brief paper on the geology of Fourche Cove, near Little Rock, in which he says:[2] "There is an extensive amygdaloid formation within the cove, and also upon the eastern side of it (page 11) . . . . The amygdaloid proper is of a light brick color. In some localities it is darker, and in others lighter . . . . At one locality the amygaloids are small, resembling a mass of peas, ... but each amygaloid, or pea-like body, is hollow, having a shell not thicker than that of an egg. At another the amygdaloids are filled, but they, as well as the cement or gãngue, are earthy and more or less friable." There can be no doubt that some of these so-called amygdaloids are the bauxites.

It is evident, however, that some of the tertiary conglomerate beds were regarded by Dr. Powell as variations of these "amygdaloids," for he says that some of them consist of jasper (p. 12).

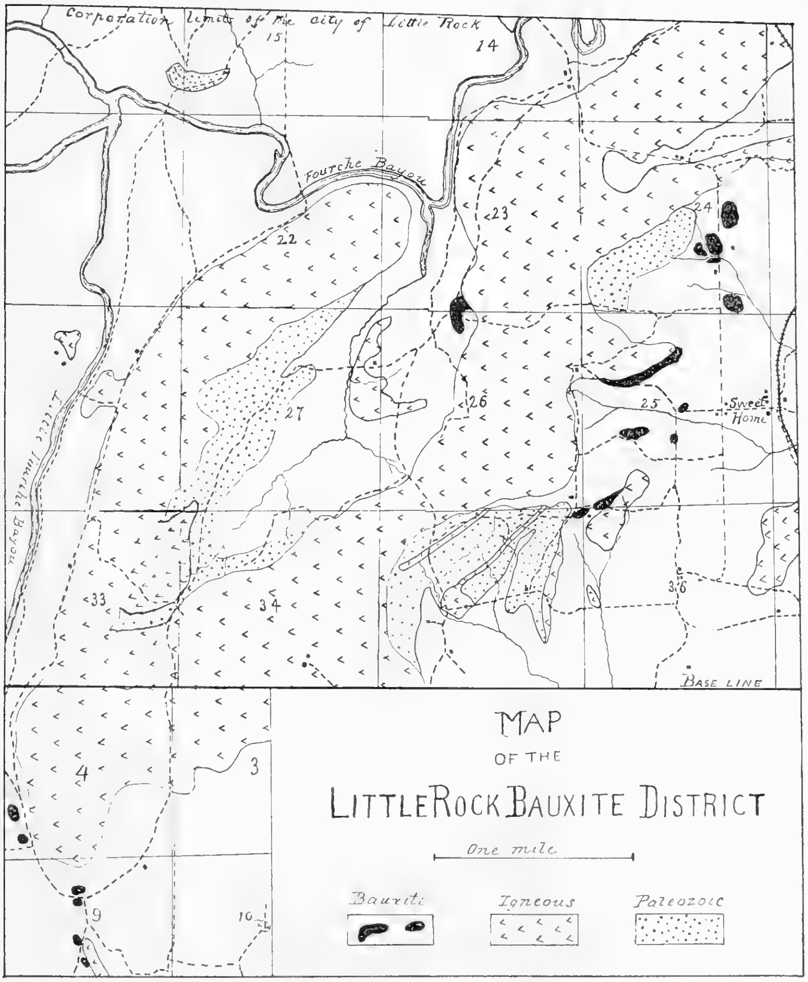
Owen also mentions this "ferruginous amygdaloid of rather a peculiar character," and says that "the amygdules are very globular, so that the rock has much the appearance of peastone, the cavities being mostly empty."[3] The description of the rock and the locality given make it clear that the bauxite rock is here referred to, and yet there is no word to show that either Powell or Owen knew or suspected the true nature of the material.

That these observers did not recognize this mineral is probably due to the fact that bauxite was, at that time, but little

[1] See the Geological Surveys of Arkansas, by J. C. BRANNER. JOUR. OF GEOL. II, November–December 1894, 826–836.

[2] A geological report upon the Fourche Cove and its immediate vicinity, by W. BYRD POWELL, M.D., Little Rock, 1842, 11–13. This is a very rare pamphlet; I know of but one copy of it, and that is in the library of the U. S. Geological Survey.

[3] Second report of a geological reconnoissance of Arkansas. By DAVID DALE OWEN, Philadelphia, 1860, 70.


Corporation limits of the city of Little Rock
15
14
Fourche Bayou
22
23
24
27
26
25
Sweet Home
Little Fourche Bayou
33
34
36
Base Line
4
3
9
10
MAP
OF THE
LITTLE ROCK BAUXITE DISTRICT
One mile
Bauxite
Igneous
Paleozoic

known even in Europe, and it was altogether unknown in America.

At the time when it was found that this rock was bauxite (1887) it was being used extensively for making the roadbed of the Little Rock and Sweet Home turnpike, especially along the part of the road near one of the bauxite beds. It had also been recommended by a former state geologist, Mr. W. F Roberts, Sr., as a "pisolitic iron ore," and attempts had been made to mine some of the highly colored Saline county beds for iron.

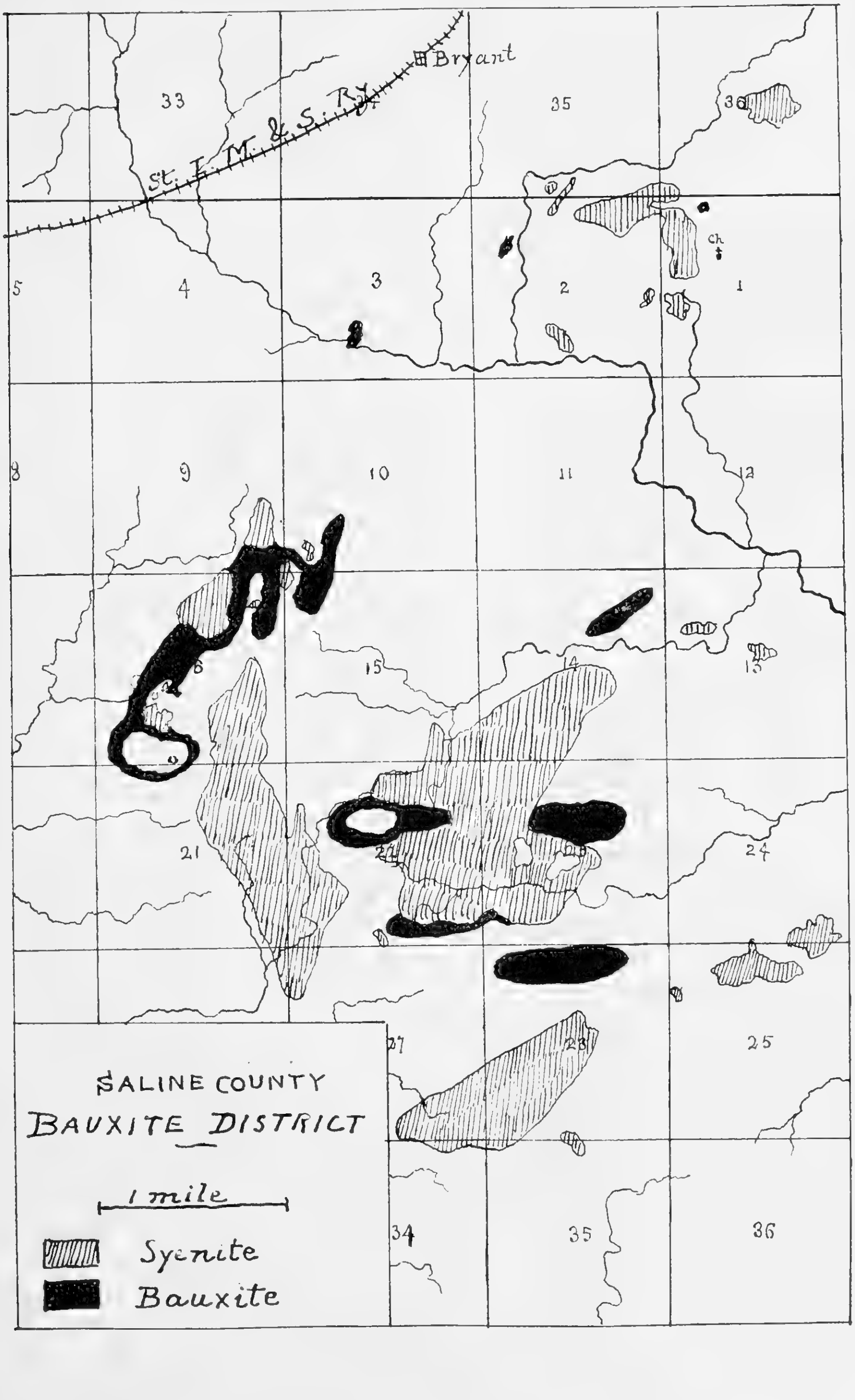
Definition and composition.—It is practically impossible to draw a sharp line of division between bauxite as defined mineralogically and what appears in a hand specimen to be the same thing, but which on analysis is found to contain one or another impurity in such proportions as to throw it out of the bauxite list. Mineralogically bauxite is a hydrate of alumina,[1] but it is never found without certain impurities, the common ones being iron, silica, potash, soda, and titanium. All these impurities are found in the Arkansas bauxites, and in some cases the iron is so abundant that the beds have been prospected with a view to using the material as an ore of iron. The following analyses of some of the more ferruginous varieties show its iron contents:

ANALYSES OF FERRUGINOUS PISOLITIC BAUXITE.

Number	Percentage of iron	Phosphorus	Silica
1	66.85	.043	not det.
2	54.2	.048	not det.
3	59.2	.031	not det.
4	54.9	.10	1.99

No. 4 was collected by the writer in 2 S. 14 W. section 1, northwest quarter; the other numbers are from the Saline

[1] St. Claire Deville regards it as a variety of Diaspore ($Al_2O_3H_2O$); Dufrenoy thinks it is close to Gibbsite ($Al_2O_33H_2O$), while Liebrich shows it to be closely related to or identical with Hydrargillite.


St. L. M. & S. Ry.
Bryant
33
34
35
36
Ch
5
4
3
2
1
8
9
10
11
12
15
14
13
21
22
23
24
27
26
25
34
35
36
SALINE COUNTY
BAUXITE DISTRICT
1 mile
Syenite
Bauxite

county deposits, but they were collected by prospectors for iron ore, and their exact locations are not known.

In other cases the bauxite contains so much silica and so little water that it is not to be distinguished by analysis from ordinary kaolin. And these varieties grade so insensibly into each other that no line of demarkation can be drawn between them. The following analyses show the similarity in composition between a kaolin and a variety of bauxite, which, properly speaking, is simply a pisolitic kaolin.

ANALYSES OF PISOLITIC AND ORDINARY KAOLINS.

	Pisolitic kaolin 1 S. 13 W., sec. 10 N. E. of N. E.	Pisolitic kaolin Same sec., S. E. of N. W.	Washed kaolin from Brandywine Summit, Pa.
Silica, SiO_2	48.05	45.20	47.24
Alumina, Al_2O_3	38.92	37.60	37.27
Ferric oxide, Fe_2O_3	1.19	3.00	1.94
Lime, CaO	0.58	.89	0.52
Magnesia, MgO	0.45	.00	trace
Potash, K_2O	0.18	.06	0.22
Soda, Na_2O	0.28	.69	0.13
Water	10.86	13.54	13.62
Total	100.51	100.98	100.94

Water at 110°–115° C.......0.46 %.............................1.48 %

In the following table are brought together all the analyses of the Arkansas bauxite, and a few analyses of representative bauxites from other parts of the world.[1] These analyses are of individual examples, however, and must not be accepted as if made of car-load lots.

[1] In the article published in the *American Geologist* for March 1891 I gave an average of fourteen partial analyses of bauxite from France, Austria, and Ireland. I wish here to express my disapproval of such a method of making comparisons. Owing to the extreme variability of bauxites, even from the same beds, such an average can scarcely fail to be misleading. If material is wanted with a low percentage of silica the high percentage in some of the samples will so increase the silica in the average that one may be led to infer that none of it is low enough to be available — a conclusion entirely unwarranted.

ANALYSES OF ARKANSAS AND FOREIGN BAUXITES.

	Silica SiO_2	Alumina Al_2O_3	Iron Fe_2O_3	Titanic oxide TiO_2	Water H_2O	Color
1	10.13	55.59	6.08	....	28.99	Light brown
2	11.48	57.62	1.83	....	28.63	Gray
3	3.34	58.60	9.11	....	28.63	Light red
4	4.89	46.44	22.15	....	26.68	Brick red
5	5.11	55.89	19.45	....	17.39	Black
6	33.94	44.81	1.37	2.00	17.88	Gray, surface
7	2.00	62.05	1.66	3.50	30.31	Pink
8	10.38	55.64	1.95	3.50	27.62	Surface
9	16.76	51.90	3.16	3.50	24.86	
10	45.20	37.60	3.00	....	13.54	Lime 0.89; Potash .06; Soda .69; White, pisolitic
11	21.70	58.10	3.00	3.20	14.00	White
12	2.80	57.60	25.30	3.10	10.80	Red
13	6.29	64.24	2.40	some	25.74	

1. 1 north, 12 west, section 24, north side of the southeast quarter. On Little Rock Sweet-Home turnpike, cut near road.

2. 1 north, 12 west, section 25, southwest corner, and section 36, northwest corner. Tarplay's.

3. 2 south, 14 west, sections 9 and 10; extending also from 10 into northwest of 15.

4. 2 south, 14 west, section 3, southeast of the southwest.

5. 2 south, 14 west, section 3, southeast of the southwest.

6. 2 south, 14 west, section 16, northeast corner of the southwest quarter near Sol. Nethercut's.

7. 1 south, 12 west, section 9, northwest quarter of the northeast quarter, at the end of the Arch Street Pike, and just north of the fork of the road at the point mentioned.

8. 1 south, 12 west, section 4, middle of the south side of the northwest of the southwest quarter on the west side of the Arch Street Pike leading south from Little Rock. Exposure in the field, a stone's throw from the road.

9. 1 south, 12 west, section 9, northeast quarter of the northwest quarter, west of the pike and west of small stream, about 100 feet south of bridge.

10. 1 south, 13 west, section 10, southeast quarter of the northwest quarter.

11. Baux, near Arle, France (Sainte-Claire Deville).

12. Revest, near Toulon, France (Sainte-Claire Deville).

13. Near Feistritz, Styria.

The analysis must determine the value of bauxite, but it should not be forgotten that varieties not available for one purpose may sometimes be used for some other purpose. As a rule, however, silica, iron, and titanium are the objectionable ingredients. When the percentage of silica reaches that in kaolin or clay the bauxite has no advantage over kaolin or clay for the purposes for which it is used.

Mr. McCalley, in his valuable paper upon Alabama bauxite, calls attention to the fact that the surface material contains more silica than samples taken at a depth.[1] This had escaped attention in my brief examination of the Arkansas bauxite, but since reading Mr. McCalley's paper I recall the fact that this view is borne out by the analyses of the Arkansas materials so far as they have been made. If this is a fact that can be depended upon as constant, it is one of great importance in mining bauxite.

In the ferruginous, earthy, and kaolin-like varieties the pisolitic structure is always more or less pronounced in the Arkansas bauxite.

Structure and appearance.—Bauxite is very light; its specific gravity is about 2.4. In gross structure, color, texture, and general appearance Arkansas bauxite varies greatly. The colors are red, pink, brown, black, gray of various shades, white and yellow, and these colors are also more or less mixed in the same deposit, and even in the same hand specimen.

The several classifications or subdivisions proposed by Coquand, Laur and others will, in all probability, hold with the Arkansas deposits, but inasmuch as these divisions all grade insensibly into each other it seems unnecessary to give those classifications or to lay any stress upon them. Chemical analyses and the practical availability of the different varieties can alone be

[1] Proc. Ala. Ind. and Sci. Soc., Vol. II, 1892, p. 29.

depended upon. I may add, however, as a suggestion of possible utility that the red varieties are not all high in iron as one might suppose; some of the reddest examples found in Saline county contain very little iron.

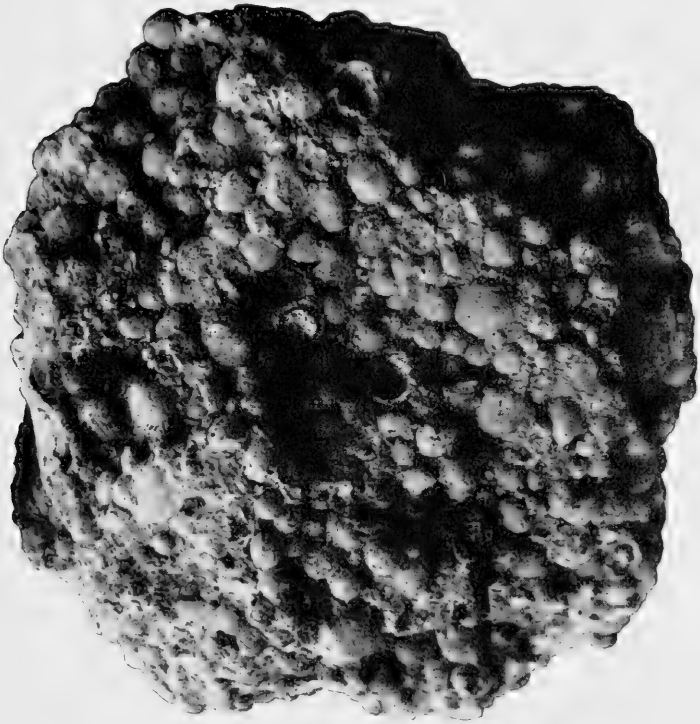


FIG. 1. Pistolitic Bauxite from near Little Rock.

Some of the pisolites are solid and some of them are hollow; sometimes they are scattered through a more compact and homogeneous groundmass, and at other times they make up the body of the rock and resemble a great mass of peas cemented together.

The accompanying illustration (Fig. 1) shows a specimen of the more pisolitic variety taken from the deposits in township 1 south, 12 west, section 4, southwest quarter.

The pellets are in some place much larger, the biggest being the size of one's two fists or even larger.

Bauxite is sometimes compact. Mention should be made of the fact that while one often sees small pieces of the compact variety, there are, so far as I know at present, no beds or considerable deposits of the compact kind in Arkansas.

I have seen in the Royal College of Sciences in Dublin specimens of the compact bauxite of Ireland. That material looks very like a compact and homogeneous clay, and has no evidences of pisolitic structure. Bauxite of this variety I have not found in Arkansas.

The heavy beds in Saline county are in some respects different from those at the other Arkansas localities. In small fragments this material is not distinguishable from that found near Little Rock, but the beds are, in places, made up of what seem to be cobbles or rolled and waterworn lumps of the same material. Some of these lumps are as large as a man's head.

Under the microscope one specimen shows the pisolites to be concentric in structure, while here and there through them are thin bands or veins of quartz. This suggests that the silica found by analysis is sometimes free.[1]

Geologic age.—Bauxite has been found in Arkansas only in Tertiary areas and in the vicinity of eruptive syenites with which I believe them to be genetically related. This statement concerning areal distribution must be accepted simply as a statement of fact, but one that may be of considerable importance in Arkansas, and possibly of none whatever in other bauxite regions. The evidence of the Tertiary age of the Arkansas bauxite is not abundant, but it all points in one direction.

At the village of Ridgewood, about five miles south of Little Rock, a well dug on lot 11 exposed the following section:

Section of well on lot 11, village of Ridgewood.—

3 feet surface soil.
7 feet pisolitic bauxite.

[1] For a good microscopic view see paper of C. W. Hayes in the 16th Ann. Rep. U. S. G. S., Part III, Plate XXIII.

2 inches iron (limonite.)
6 inches pink and white clays.

The pink and white clays at the bottom of this well belong with the horizontally stratified Tertiary beds of the neighborhood. There are no fossils, however, in these clays, and they are considered as Tertiary solely upon lithologic and stratigraphic grounds.

At Tarplay's place in the northwest corner of section 36, 1 north, 12 west, the bauxite has a thin bed of Tertiary or post-Tertiary sandstone overlying it. At Mabelvale in 1 south, 13 west, section 10, northwest quarter, the same kind of ferruginous sandstone overlies bauxite. It should be added also that the bauxite at several places overlies the eruptive syenites or so-called "granites," while at several others it is very probable that there are syenites beneath them. These syenites are apparently of late Cretaceous or post-Cretaceous Age.

It is not to be inferred, however, that bauxite is confined to Tertiary rocks, except perhaps in Arkansas. I see no reason why the conditions that produce this mineral might not exist in one age as well as in another, though these conditions are likely to occur in one age in one place and in another age at another place.

The statement of Laur that "the phenomena which gave rise to the bauxites in Europe occurred with great intensity toward the end of the Cretaceous epoch, and has never been repeated"[1] is probably unwarranted.

In southern France bauxite is said to form the parting between the Cretaceous and the Jurassic. Coquand says it is in the *Lychnus* beds of the Upper Cretaceous.[2] Collot shows that it lies between the Urgonian below and the Cenomanian above, that is, about the junction between Lower and Upper Cretaceous.[3] Rouville says the pisolitic iron of Herault is in the "Oxfordian" or Upper Jurassic, if by "Oxfordian" he means

[1] Trans. Amer. Inst. Min. Eng. 1896.

[2] Bull. Soc. Géol. 1870–1, XXXVIII, 111.

[3] Compt. Rend. 1887, CIV, 129–130.

the Oxford clays of the English geologists.[1] Fabre found it in crevices in Jurassic rocks,[2] but deposited in early Tertiary times, while that referred to by Dr. Raymond in a corundum mine in North Carolina is believed to be in eruptive rock,[3] the age of which is not stated. The Irish bauxites are associated with eruptive rocks of Tertiary Age.[4]

The Alabama bauxite deposits are said[5] by McCalley to be of Lower Silurian Age, but Hayes thinks[6] the Alabama and Georgia deposits were formed "toward the close of the Eocene."

These cases are cited simply to show that bauxite is not confined to rocks of any particular age, except perhaps in a given region. I have seen it stated that bauxite has been found recently near the Maumelle Pinnacles, about fifteen miles up the river from Little Rock. This would bring the deposits into rocks of Carboniferous Age. This report lacks confirmation; I know of neither bauxite nor syenite in that region. It is important to notice, however, that if the writer's theory of the origin of these deposits is correct, search for them in Arkansas should be confined to the neighborhood of the eruptive syenites,[7] though not all these syenites have bauxite deposits in their vicinity. The eruptive rocks at Magnet Cove are mostly syenites, but no considerable bauxite deposits have been found associated with them. Some small fragments were found by me in the Cove on the north slope of the hill just south of the Baptist church.

Origin of the Arkansas bauxite deposits.—In searching for new deposits and in determining the limits of those already known, we must be guided to a certain extent by a knowledge of the method

[1] Bull. Soc. Géol. de France XXV, 1867–8, 935.

[2] Bull. Soc. Géol. de France, 1869–70, XXVII, 518.

[3] Trans. Amer. Inst. Min. Eng. VII, 86.

[4] Memoirs of the Geol. Survey [of Ireland] to accompany sheets 7, 8, 14, 20. By R. G. Symes.

[5] Alabama bauxite. By Henry McCalley. Proc. Ala. Ind. and Sci. Soc., 1892, II, 21.

[6] Bauxite. By Charles W. Hayes, 16th Ann. Rep. U. S. Geol. Sur., Part III, 592. Washington, 1896.

[7] For the distribution of eruptive rocks in Arkansas see Vol. II of the annual report of the Geological Survey of Arkansas for 1890.

by which the deposits have been made, for it is only in this way that we can anticipate the peculiarities of its distribution. There is therefore given below, as briefly as possible, the several theories that have been advanced to explain the method by which bauxite deposits have been made.

The Arkansas beds appear to have been laid down in water near the shore, but the material does not seem to have been car-

FIG. 4. Ideal Section through Fourche Cove.

ried far from the spot at which it originated, or to have been widely distributed by the water. They are all at or near the contact between the palæozoic sediments and the eruptive syenites. Several of them, however, have no palæozoic rocks exposed near at hand, and one of them has no syenite exposures. These conditions are shown in part by the following ideal section illustrating the relations of the rocks about the Fourche Cove.

The concretionary structure of the bauxite suggests that it has been formed in some such manner as the oölites or sprudelsteins of the well-known hot springs at Carlsbad. At this last named place the oölites are made of carbonate of lime. The water is charged with lime, and as it issues the lime collects about centers. These masses are kept in motion in the rising waters until by accretion they become so heavy that they sink to the bottom.

Oölites are also made in various other ways, such as the rolling of grains upon a shore and in waters heavily charged with lime, by lime secretions of certain algæ[1] and other organisms,[2] and possibly by insect eggs as suggested by M. Virlet d'Aoust.[3]

[1] On the formation of oölite. By DR. A. ROTHPLETZ. Amer. Geol. X, 279–282.

[2] The formation of oölite. By E. B. WETHERED. Quar. Jour. Geol. Soc., LI, 1895, 196–209.

[3] The Geologist (I), 1858, 72–73.

Attention is directed to the peculiar nature of some of the great beds of Saline county; there the strata are composed of rolled or waterworn lumps as large as one's head which, when broken open, show the same pisolitic structure as that found at other places. It looks as though the material had been deposited in water near the shore, and that it had been partly uncovered at low tide or broken up by storm waves, and that its earthy material had been broken and rolled by the waves, and finally left at or near where it had originally lain. None of the beds examined show the lamination or thin bedding planes so characteristic of sedimentary rocks.

These facts seem to point to an origin for bauxite very similar to that of calcareous pisolites, and its association with the syenites suggests that the latter have something to do with the matter. I am of the opinion that the explanation offered by Coquand, Augé, de Rouville,[1] Virlet d'Aoust,[2] Daubrée,[3] and Hayes is the correct one so far as hot waters are concerned, but I am unable to see why they should have been geyser waters. Augé has cited[4] from Hayden's report of 1878, Part II, p. 416, what he considers a case of bauxite actually forming in a geyser. This, however, is a mistake: I have examined in the United States National Museum the material referred to; it has no resemblance to bauxite, and Professor George H. Merrill tells me that it is a geyser mud or kaolin mechanically churned up by the water and from which the silica has been removed. Strangely enough this error has been extensively copied and is found in many of the papers on bauxite, even as late as that by M. Lauer published in 1895.

Dr. Genth holds that the bauxite may be derived by hydration from corundum, but frankly admits that he cannot explain the transformation.[5]

[1] Bull. Soc. Géol. de France, 1867–8, XXV, 935.

[2] Op. cit., XV, 199; XXII, 418–420.

[3] Op. cit., XXVI, 915.

[4] Bull. Soc. Géol. de France, 1888, XVI, 345–350.

[5] Proc. Am. Phil. Soc. Vol. XII, 373 and 405.

Coquand says:[1] "The aqueous origin of the bauxites is as well marked by their structure as by their stratification and alternation with sandstones, limestones, and clays. It is evident that the sedimentation (at the time the deposits were made) began at the bottom of a lake by the deposition of aluminous and calcareous matter brought in from mineral sources and to which a certain movement of the waters gave a pisolitic form." It is not altogether clear what M. Coquand means by the "mineral sources" to which he refers several times and to which he attributes the material of the bauxites. His paper ends with the conclusion that the several bauxite localities of France "are of the same age and fall under the head of irregular deposits of geyser origin," from which it must be inferred that he thinks the hot waters of geysers are the "mineral sources" from which the bauxite has been derived.

M. Stanislas Meunier holds[2] that salt water penetrating to great depths can, on account of its high temperature and the pressure upon it, dissolve the ferruginous shales and form chlorides of alumina and perchlorides of iron. When these chlorides come to the surface and spread over limestones, as they usually do, a change of bases takes place, alumina and peroxide of iron are precipitated, chloride of lime is carried away and the carbonic acid of the limestone is set free, while the iron and alumina is deposited as bauxite.

Augé, as stated in the article already referred to, was led to reject Meunier's theory by finding bauxite resting on rocks other than limestones. To this Meunier replies that the chemical changes demanded by his theory might be produced by the waters carrying the material passing over limestones and depositing the bauxite further on in their course.

Daubrée says[3] that while generally associated with sedimentary beds, the bauxite beds show their relations to deep-seated emanations by the presence of anhydrous peroxyde of iron or

[1] Bull. Soc. Géol., 2me ser., 1870–1, XVIII, 98 ff.

[2] Bull. Soc. Géol., 3me ser., XVI, 1888, 345–346.

[3] Bull. Soc. Géol. de France, XXVI, 1868–9, 915.

oligiste, which generally colors them, and by its ramifications generally penetrating underlying beds and by the juxtaposition to granite.

R. G. Symes thinks that the bauxite at Estertown, County Antrim, Ireland,[1] "seems to be a mud lava."

The most exhaustive study yet made of bauxite is that of Dr. A. Liebrich, the title of whose treatise is given in the bibliography at the end of this paper. He quotes Streng as holding that the Vogelsberg bauxite is derived from basalt by decomposition, and, in general terms, Liebrich endorses this view. Further on, however, he states that it is "not the decomposition product of an underlying basalt, but of a completely disintegrated anamesite lying above a compact basalt." Again he says: "There is nowhere bauxite containing a kernel of stone which is not a decomposition product." Again "the transition between bauxite and basaltic hematite may be traced step by step in thin sections." Also; "it is to be regarded as a concretionary formation which has originated in the clay formed by decomposition of rock, and that it is therefore not a simple process but several different processes following each other." He thinks, however, that other kinds of basalt than anamesite can yield bauxite. He also concludes from his microscopic and chemical studies of bauxite that it is the same as hydrargillite. The chemical process and the method of forming the pisolites, he says, is unknown.

Of the theories above mentioned the only one that appears to be applicable to the Arkansas deposits is that of hot waters. This however is not necessarily in conflict with the theory of Liebrich that they are decomposition products, though they are not, in the present case, associated with basalts, and are certainly not formed by the decomposition of any rock *in place*. It is my opinion that before the eruptive syenites had cooled they were sunk beneath the Tertiary sea, and that either by the contact of the sea water or by the issuing of springs whose waters

[1] Memoirs of the Geological Survey of Ireland, Mem. accompanying Sheet 20, p. 12.

had been in contact with the hot syenites the aluminous materials were seggregated as pisolite and sank near where they were formed. Thus if the process is one of decomposition it is decomposition in the presence of and due to high temperature.

The irregular forms of the deposits, their variable thicknesses and characters, and, in fact everything known about them, is in keeping with this theory of their origin. Stress has been laid by Meunier upon the fact that so many bauxites rest upon[1] or are associated with limestones; and this fact was used by him to explain the precipitation of the material from chlorides of aluminium in hot sea water. But, as Augé has pointed out, limestones are not always present,[2] and there are certainly none associated with the Arkansas deposits.

Forms of the deposits.—From what has been said it is evident that the bauxite deposits must be very irregular in form. Although associated with marine sediments of wide and regular distribution, the bauxite deposits are local, irregular and of uncertain extent, for the influences that produced them were local, and the rocks (syenites) with which they are associated are in all probability concealed in many places. The figure given under the head of "origin" on page 275 will give as definite an idea as can be had of the forms of the deposits without prospecting. If, at any time, it should become necessary to prospect for other deposits, the prospecting should be confined to the region in which bauxite is now known and to the soft Tertiary beds. It does not now seem advisable to look for this mineral above an elevation of 350 feet or below 250 feet above mean tide.

Method of mining.—Stripping and quarrying in open cuts is the method to be used in nearly all the deposits known. Of course when the cover becomes too thick it cannot be removed economically, and such deposits will either have to be abandoned or the mining will have to be done by drifts. Persons experienced in the driving of tunnels and mine timbering should

[1] Comptes Rendus, 1883, XCVI, 1737–1739.

[2] Bull. Soc. Géol. de France, 1888, XVI, 346.

have charge of the work in this stage. The roof is likely to be soft and to require lagging. Furthermore, unless discretion is used in opening quarries and driving tunnels, the operators are likely to have difficulty with the draining of the mines.

THE DISTRIBUTION OF BAUXITE IN ARKANSAS.

In thickness the bauxite beds vary greatly, the greatest found being forty feet, and even in this case the full thickness of the bed is not exhibited. In vertical distribution it has a range of about sixty feet, lying, so far as observed, between 260 and 320 feet above mean tide level. This observation, however, refers only to the Pulaski county deposits, no observations having been made on the vertical range of the Saline county beds, which, however seem to be at, or near, the same elevation. It is not supposed that the exposures now known are the only ones in the state, for it has not been possible to make detailed search throughout the area in which the deposits may reasonably be expected. The number of exposures will probably not only be considerably increased, but it should be added, that inasmuch as sedimentary beds overlie or have overlain some of the known deposits, it is quite possible that there are others yet uncovered by natural processes of erosion.

These bed should be sought only in the areas of soft sands, clays, and gravels and in the neighborhood of the eruptive rocks of Saline and Pulaski counties.

THE USES OF BAUXITE.

Many attempts have been made to use bauxite as an ore of iron, but with poor success or with no success at all. The kaolinic varieties may be found available as kaolins, though I know of no attempts to use them for such purposes. Bauxite has been successfully used for the manufacture of the following materials:

1. Alum.
2. Sulphate of alumina.
3. Aluminum (the metal).

4. Refractory wares, such as furnace linings.

5. It is also available for increasing the refractoriness of fire clays used in the manufacture of fire bricks, furnace linings and the like.

I shall say nothing of the methods employed in the utilization of the raw material. Some of them are described in the works mentioned at the end of this paper, others are guarded as trade secrets, or are covered by patents.

There is one use, however, for which bauxite is available to which I wish to direct especial attention, and that is as a refractory material in the manufacture of iron and steel.

Bauxite as a refractory material.—Bauxite is one of the most refractory materials used in the arts. It is especially valuable for lining blast furnaces where it outlasts the best artificial fire bricks. It is used alone and also as an ingredient for increasing the percentage of alumina in other refactory materials.

In his "Feuerfesten Thone," Bischof speaks as follows of bauxite:[1] "This natural aluminium hydrate which has as yet been found only in a few places, ... when not impure on account of the admixture of foreign substances, especially of iron, which generally occurs in considerable quantities in compounds of alumina, is extremely refractory. . . . The addition of the varieties free from iron, or the white ones, to other refractory clays offers the only *important means known* of increasing their percentage of alumina, and at the same time their refractoriness. On account of a large percentage of chemically combined water this material shrinks considerably in burning, a fact to be noted in using it." In another place Bischof says:[2] "Bricks made from calcined bauxite are especially useful in the production of iron and steel in the Siemens revolving furnace."[3]

Bruno Kerl, an excellent authority on this subject, says:[4] "Bauxite bricks and crucibles of bauxite, recommended by

[1] Die Feuerfesten Thone, C. Bischof, pp. 193–4,

[2] Op. cit., p. 277.

[3] See also Dingler's Polytechnisches Journal, Vol. CXCVIII., p. 156; ibidem, Vol. CCX., p. 109.

[4] Thonwaarenindustrie, p. 526.

Gaudin as long ago as 1858, should, when low in iron, withstand heat which would fuse all other refractory materials.

"Bauxite is a compound having a composition intermediate between diaspore and limonite, and consists of hydrate of alumina combined with hydrated oxide of iron.

"On account of the large quantity of water present this mineral shrinks greatly on heating, is usually refractory, and, if it does not contain too much iron, when added to fire clays, increases their refractoriness.

"Siemens used bauxite bricks with 50 per cent. of alumina, 35 of iron oxide and 3 to 5 of silica, which lasts five or six times as long as Stourbridge first-brick. Schwarz recommends for crucibles for manufacture of cast steel a composition of one to two parts Goettweiher clay and two parts of burnt bauxite from Wochein. The bricks of the Compagnie Parisienne at the Vienna Exposition withstood the heat of molten platinum, yet their fracture was like that of stoneware."

Sir William Siemens tested bauxite as a furnace lining and says[1] of it: "A series of experiments to form solid lumps by using different binding materials have shown that 3 per cent. of argillaceous clay suffice to bind the bauxite previously calcined. To this mixture about 6 per cent. of plumbago powder is added, which renders the mass practically infusible, because it reduces the peroxide of iron contained in the bauxite to the metallic state. Instead of plastic clay as the binding agent, waterglass or silicate of soda may be used, which has the advantage of setting into a hard mass at such a comparatively low temperature as not to consume the plumbago in the act of burning the brick. A bauxite lining of this description resists both heat and fluid cinder in a very remarkable degree, as I have proved by lining a rotative furnace at my sample steel works at Birmingham, partly with bauxite, and partly with carefully selected plumbago bricks. After a fortnight's working the brick lining was reduced from six inches to less than half an inch; whereas the bauxite lining was still five inches thick and perfectly compact. It is

[1] The scientific works of Sir Wm. Siemens, I., London, 1889, 296.

also important to observe that bauxite when exposed to intense heat is converted into a solid mass of emery of such extreme hardness that it can hardly be touched by steel tools, and is capable of resisting mechanical as well as the calorific and chemical actions to which it is exposed.

"The bauxite used in the above mentioned lining was of the following composition:

Al_2O_3	53.62
Fe_2O_3	42.26
SiO_2	4.12"

Speaking of the value of bauxite as a refractory material Professor Thomas Egleston of the Columbia School of Mines says that it "lasts five or six times as long as the best Stourbridge bricks. Nothing has yet been found which resists the corrosive action of basic slags so well."[1]

In a letter to the author regarding bauxite as a refractory material Professor Egleston writes:

"If the material is pure there would be a very large demand for it. With the introduction of basic processes, the demand for basic lining has increased steadily, but on account of the uncertainty of the composition of bauxite, it is being very generally replaced by carbonate of magnesia, which is found in several localities in Europe and is imported both to England and this country."

The results of several analyses of Aakansas bauxites were sent Professor Egleston when he wrote:

"The subject is a very interesting one and may be of great value to the state if it should prove that any of these are aluminates. In some of them I fear there is too much silica, but in any case I think valuable fire bricks could be made of them. I have often tried to interest the fire-brick people in the new proccesses for the manufacture of these bricks which have been developed within the past ten or fifteen years in Europe, and in the hope of so doing have published several articles on the subject, but the manufacturers have been generally unwilling to

[1] Transactions Am. Inst. M. E., Vol. IV., 261–2.

invest any more capital in their business, which, they say is already very much cut up. If a new industry were started, it could be started on altogether a different basis and I think would easily compete with the old manufactories. This is all the more true since the development of the basic open hearth and Bessemer process in the South calls for a higher grade of fire-brick. I had, while recently in Europe, some important interviews with the proprietors of the magnesite quarries in the west with regard to the introduction of that material into the United States. If your material should prove to be aluminates you could easily compete with them."

Markets.—The processes by which bauxite is manufactured are in some cases patented and the parties owning the patents are alone entitled to use or to dispose of them; in other cases the processes are guarded as trade secrets. Partly for these reasons and partly because the utilization of bauxite is confined to but few companies, the public knows but little of the uses to which the raw materials are put, or of the processes employed in their manufacture.

One thing that has thus far prevented the Arkansas bauxite getting into the market is the fact that the samples sent away have been selected without a knowledge of the composition required or of the material sent. As has been stated, iron, silica, and titanium are the objectionable ingredients, and the percentages of these cannot be determined by simple inspection, though familiarity with analyses of types will enable one to form an opinion of value on this subject.

Another matter of importance is that the freight rates charged by the railways out of Little Rock are so high as to prevent its profitable shipment.

Still another is that extravagant ideas of the value of the ore have induced those who would otherwise have done the mining and shipping to expect very large profits from it. As a matter of fact the value of bauxite at the place of production in the United States during the year 1895 averaged about four dollars[1]

[1] Engineering and Mining Journal, Jan. 2, 1897, 3.

a ton. The question for owners and miners is whether the market price will leave them a resonable margin of profit. The cost of plants for the utilization of bauxite is so great, and the local market for manufactured products so small, that, in my opinion, it is useless to think of factories being established in Arkansas. The factories are all in the north,[1] and the probabilities are that they will remain there for some years at least. In the meantime, if the bauxite beds are to be utilized, the material must be mined and transported cheaply. Labor and teaming are low, but railway freights are high at present. This necessarily prevents Arkansas' competition with the Georgia and Alabama deposits. It is to be hoped that the railways may see their way to offering rates that will allow of bauxite mining in Arkansas.

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[1] The Pennsylvania Salt Company, Natrona, Pa. The Solvay Process Company, Syracuse, N. Y. The Pittsburg Reduction Company, Pittsburg, Pa.

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EDITORIAL.

As THE time for the meeting of the International Congress of Geologists approaches interest in the series of events connected with it increases. The several circulars that have been issued have made evident the extent of the preparations that are being made at St. Petersburg and the largeness of the generosity of His Majesty the Emperor of Russia. Opportunity has been offered for all geologists taking part in the congress to visit many of the most important regions of Russia, presenting widely different geological phenomena — the crystalline rocks of Finland and the glacial phenomena in the north; the vast expanse of slightly disturbed and little-altered Palæozoic strata in the central portion of the country; the far-famed mining districts of the Urals, and the grand scenery and varied features of the Caucasus and of Transcaucasia. Seldom may geologists have such an opportunity to contrast within the brief period of a few weeks the forest-clad, moist north lands with the barren, arid regions of the south, or experience in quick succession the sensations produced by the boundless horizon of the steppes and by the deep gorges and lofty summits of the Caucasian Alps.

* * *

THE liberality of the Czar in presenting the geologists with first-class tickets over all the railroads under Russian control is an act of hospitality fitting the ruler of so great an empire, and one fully appreciated by the geologists of all parts of the world. That it should have been accepted by many who would not otherwise have been able to travel so extensively was to have been expected. And it is not surprising to hear that many persons not having claims to the title of geologists have applied for the privileges, to the embarrassment of those in charge of the management of the great excursion. It is proper that a scrutiny of the lists of applicants should be undertaken for the purpose of limiting the numbers to those who are actually geological workers or teachers of the science, and who will derive the most benefit from the instruction which will be given by the geologists acting as leaders of the several excursions. It would be unfortunate if, by the presence of many untrained excursionists, the object of the expeditions should be defeated. It is reasonable, then, that the committee in charge at St. Petersburg should propose to test the geological knowledge of all those wishing to join the excursions, when their attainments in the science of geology is not already known. We understand that those not known to the committee to be geologists will be required to pass an examination in various branches of geology before being permitted to take part in the excursions.

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A RECENT circular from St. Petersburg calls attention to the fact that there was established at the London congress a permanent committee that should have charge of the selection and elaboration of questions to be submitted to each subsequent session, as well as of the preparation of reports relating to such questions. After citing the report of the committee relative to the unification of stratigraphical nomenclature, and after noting the fact that the matter received no attention at the Washington and Zurich meetings, the committee of organization at St. Petersburg suggests that the question of the general principles involved in any stratigraphical classification be discussed, first, as to whether it be *artificial*, based solely on historical data, or *natural*, based as well on general physiographic changes as on faunal data ; second, as to laws that should govern the introduction of new terms into stratigraphical nomenclature. It is also suggested that the principles that should govern petrographical nomenclature ought also to be considered.

The confusion in these nomenclatures which is constantly increasing owing to rapid accession of new facts and to lack of system in the creation of new terms makes apparent the need of some organization of terms and of the establishment of some general principles of nomenclature. The committee, realizing the magnitude of the undertaking and the shortness of the time of a single session of the congress, nevertheless expresses the hope that enough may be accomplished at the coming session to lead to the satisfactory solution of these problems. Certainly the discussion of the more general and fundamental principles of nomenclature by which a common usage of terms may be brought about is the proper function of an international congress of geologists, and it is to be hoped that the proceedings of the coming session may be along these lines. J. P. I.

REVIEWS.

SOME RECENT PAPERS ON THE INFLUENCE OF GRANITIC INTRUSIONS UPON THE DEVELOPMENT OF CRYSTALLINE SCHISTS.

MICHEL-LÉVY: *Contribution à l'étude du Granite de Flamanville et des Granites Français en général.* Bull. des Services de la carte géol. de la France, No. 36. Paris, 1893, pp. 41.

L. DUPARC and L. MRAZEC: *Nouvelles Recherches sur le massif du Mont-Blanc.* Archives des Sciences Physiques et Naturelles. Tome XXXIV, 1895, pp. 39.

L. DUPARC: *Le Mont-Blanc au point de vue géologique et pétrographique. Ibid.* 1896, pp. 8.

J. VALLOT and L. DUPARC: *Sur un Synclinal schisteux ancien formant le coeur du massif du Mont-Blanc.* Comptes Rendus des Séances de l'Académie des Sciences. Paris, Mars 1896, pp. 3.

J. HORNE and E. GREENLY: *On Foliated Granites and their relation to the Crystalline Schists in Eastern Sutherland.* Quarterly Journal of the Geological Society. London, Vol. LII, 1896.

A. SAUER: *Geologische Specialkarte des Grossherzogthums Baden.* Erläuterungen zu Blatt Gengenbach. Heidelberg, 1894, pp. 87.

A. SAUER: *Ibid.* Erläuterungen zu Blatt Oberwolfach-Schenkenzell. Heidelberg, 1895, pp. 76.

F. SCHALCH: *Ibid.* Erläuterungen zu Blatt Petersthal-Reichenbach. Heidelberg, 1895, pp. 82.

A. ANDREÆ and A. OSANN: *Ibid.* Erläuterungen zu Blatt Heidelberg. Heidelberg, 1896, pp. 60.

G. KLEMM: *Beitrage zur Kenntniss des krystallinen Grundgebirges im Spessart.* Abh. der Gross. Hessischen Geologischen Landesanstalt zu Darmstadt. 1895, pp. 87.

In one of the oldest and best known of the German universities there is delivered annually a very able and exhaustive course of lectures on petrography, in which no less than fourteen lectures are devoted to a presentation of our knowledge of the single rock, granite, but it is nevertheless somewhat depressing to consider on how many important questions connected with this, the most common and ordinary of all the plutonic rocks, there are still grave differences of opinion among those justly considered as authorities. Thus all do not agree even as to the order of the crystallization of the constituents of the rock, some holding that there are two generations and others that there is but one, while again a marked difference of opinion exists concerning the effects produced by granite upon the rocks through which it is intruded.

As the result of a whole series of careful studies on various contact zones, chiefly in Germany, Austria, and Scandinavia, it is commonly believed in these countries that the granite magma, by its heat, pressure and escaping vapors, causes a recrystallization of the country rock, the process being one of diagenesis, the granite giving nothing to the rock through which it breaks, except in places, perhaps, a small amount of boracic acid.

In France, however, and everywhere within the French "sphere of influence" different opinions prevail, and it would actually appear from the studies made in these parts of Europe that the laws of nature changed upon crossing the political boundaries. Contact zones have been described by Barrois, Michel-Lévy, Delage, and other French petrographers, in which the country rock adjacent to the granite has become completely "granitized" by the transfusion of granitic material into it, and in a well-known paper by Michel-Lévy, which appeared in 1887,[1] he stated it as his belief that by this process gneisses, leptynites, dolomitic schists and amphibolites, indistinguishable from those of the Archaean, are produced, and that in fact the so-called primitive rocks have really originated in this way, by the intrusion of igneous rocks into clastic sediments, which sediments have undergone a profound metamorphosis with the addition of an immense mass of material, the process being essentially one of a metasomatosis.

In the first section of the Bulletin, whose title is given above, Michel-Lévy describes an additional contact zone of this kind occurring about the granite of Flamanville, which granite cuts shales, sandstones, and quartzites, chiefly of Silurian and Devonian Age. On approaching the granite the shales present successively the usual zones of the spotted clay slate, micaceous clay slate, and hornstone, but in the vicinity of the actual contact they are broken up, eaten into, and partially dis-

[1] Sur l'origine des terrains cristallins primitifs. Bull. Soc. Géol. de France, III 1887, 103.

solved by the granite, which holds many inclusions and also injects itself into the rock in narrow veins—*lit par lit*—along its plains of lamination or foliation, altering it intensely and at the same time giving to it a granitic character. In the second half of the Bulletin the author presents some observations on granites in general, more especially in relation to their contact effects, reaffirming and somewhat enlarging upon the views put forward by him in 1887. He holds that the conclusions arrived at by Rosenbusch and commonly held by petrographers, that feldspar is not usually produced in contact zones except in comparatively small amount by the diagenesis of the altered rock, and that there is no transfusion of granitic material into the invaded rock, although true of the individual contact zones investigated, are not true of contact zones in general, but that there is frequently developed immediately along the contact a zone in which an intimate admixture of the granitic material with that of the injected rock is a dominant characteristic. This admixture is brought about in part by the injection of the granite in thin layers—*lit par lit*—into the stratified rock parallel to its lamination, in part by a transfusion in some obscure way by means of mineralizing solutions of the elements of quartz and feldspar through the schists, causing these minerals to crystallize out through the substance of the altered rock, and in part by the actual solution of the injected rock in the granite magma. In this zone, which in ordinary granite intrusions is usually but a few yards in width, there can be found all the rocks characteristic of the great regions of crystalline schists—mica schists, granulites, gneisses, amphibolites, etc., formed by the action of the granite on the ordinary sedimentary strata of the earth's crust.

This zone, moreover, although often narrow as exposed, where the deeper seated parts of the "appareils granitiques" are laid bare to our study by the process of denudation, is found to become much wider and often of great stratigraphical importance. Barrois is cited as having found in Brittany cases where there has been an undoubted transformation of whole districts of Cambrian schists into gneiss by the process of "granitization" above referred to, it being possible to follow bands of quartzite which resist the general "feldspathization" from the margin of the area into parts of the district where the associated schists have been completely transformed into gneiss.

The work of Duparc and Mrazec, on the massiv of Mont Blanc is also cited as affording conclusive demonstration of similar transformation, while the gneissic zone about the granulite of the Saxon Granulitgebirge is cited as another case in point. It is believed that the granite magma first rises along lines of fracture in the crust. Its presence leads to a heating of the rock into which it is injected, and its intrusion is accompanied by a "*circulation intense*" of mineralizing fluids, probably rich in alkalis. These produce at first a transference of quartz from one part of the mass to another and the development of biotite, which is a marked feature in contact zones. Then follows "feldspathization," which commences by the development of little strings of quartz and feldspar following for the most part the schistosity of the invaded rock, and which grow in size until the whole mass of the schist is transformed into granite, the texture of the schist being broken down and its elements set in motion to form with the transfused material new combinations. The granitic magma or emanations thus slowly dissolve, alter or incorporate, whichever we may choose to call it, the wall rock, transforming it first into a gneiss, then into a gneissic granite, and finally into a granite. The original intrusion thus slowly enlarges its boundaries and increases its volume.

This process, we are told, is at work wherever granitic magmas come in contact with clastic rocks in the deeper parts of the earth's crust, and it is thus that, as before mentioned, the crystalline schists are produced. The granite does not therefore, as Suess has supposed, fill great cavities in the earth's crust which have been produced by tangential stresses, thus giving rise to batholites, but starting from some line of fracture eats its way into the surrounding rocks and develops itself largely at their expense in the way above described.

According to Professor Duparc and his associates, this process of granitization plays a very important rôle in the development of the crystalline rocks of the Mont Blanc massiv. This massiv has usually been considered as composed of protogine, that is of a somewhat altered granite, massive in the center and progressively more gneissic or schistose as the outer portions are approached, the whole enveloped by a mantle of mica schists. These mica schists contain bands of amphibolite, eclogite, and other similar rocks found in corresponding positions about other protogine masses elsewhere in the Alps.

Messrs. Vallet and Duparc have however found that the central part of the massiv is composed largely of various micaceous gneisses and crystalline schists, associated with and invaded by the protogine and even passing into a protogine gneiss. Some of these included rocks are very basic and cannot therefore, it is thought by the authors, be in any way considered to be derived from the protogine by dynamic action, but are to be considered as sediments, depressed by a synclinal fold and bounded by the protogine on either side. The whole series of rocks, both protogine and surrounding schists, are penetrated by a series of more recent granite veins or dykes, and these it is believed have brought about the profound metamorphism of the surrounding rocks, injecting and "granitizing the schists everywhere in the vicinity of the protogine, so that the gneissic zone which immediately borders the protogine is not in any way connected, genetically, with the protogine itself, but results from the profound alteration of the mica schists surrounding the protogine by these newer granite dykes. The varying character of the different schistose rocks in this gneissic zone is considered to be due to the varying resistance offered to this "granitizing" action by the different beds in question. Thus, for instance, the eclogites retain their basic character and have not been transformed into orthoclase gneiss, because they are too compact to allow of a free circulation through them of the solutions producing the alteration. In the paper by Duparc and Mrazec, a number of analyses of the several varieties of protogine and granitized schists are given.

The crystalline schists of eastern Sutherland, described by Messrs. Horne and Greenly, consist of a series of gneisses, granulites, mica schists, etc., some few members of which show conclusive evidence of a sedimentary origin while the origin of others is doubtful. The whole series has been intensely deformed. Not a cubic inch can be found which has not suffered deformation, but distinct cataclastic structure is not seen, so that recrystallization must have taken place during or after the movements. The series is invaded by masses of intrusive granite, which have broken across the schists, anastomozing through them and often penetrating them as a series of thin leaves, parallel to their foliation, in the manner termed by the French writers *lit par lit* injection. The boundary between the injecting granites and the schistose series is often rather ill-defined, owing to the fact that the granitic constituents seem to interlock with those of the wall rock with which they are in contact. The granite never shows any finer grained sahlband, indicating injection to a cold rock, but is usually coarse-grained and pegmatitic on the borders. It seems reasonable to infer, therefore, that the igneous material was introduced when earth movements were in progress and when the country rock was at a high temperature.

On approaching large masses of granite, the schistose series becomes more highly altered, sillimanite and other contact minerals making their appearance, but the invaded rocks often take upon themselves a character so closely resembling that of the invading granite as to "amalgamate the two rocks into one great gneissose complex." Thus the foliation of the invading granite, which can often be seen to be parallel to that of the invaded gneisses, is in many cases certainly due to the biotite foliæ of the latter, having retained their original position, while the associated "quartzo-feldspathic elements have been incorporated with those of the granite," as every gradation can be traced from inclusions retaining their natural orientation to the merest trains of mica flakes in a granitic rock. In other cases, however, the foliation of the invading granite does not coincide with that of the invaded gneiss but cuts it. Powerful movements were the "initial cause of the whole series of phenomena. . . . . . With regard to the granites, it is difficult to believe that they are wholly foreign matter; though here it is necessary to observe the utmost caution, the chemical difficulties being so great." Although Messrs. Horne and Greenly are guarded in their statements, their studies being rather general in character, it is clear that they believe the processes at work to be very similar, if not identical with, those described by Michel-Lévy and Duparc.

The views put forward in these papers lead us back to the time of Hutton, who, in his *Theory of the Earth* states that the kind of granite which shows banding and foliation is probably an altered sediment, the foliation being a survival of the bedding of the original rock. This fact, however, does not by any means discredit the view as many of Hutton's opinions after long neglect have finally proved to be correct. The views also have certain features in common with the crenitic hypothesis of Hunt. The whole process is, however, very recondite and mysterious in character.

One of the great difficulties in the way of the acceptance of these views is the absence of chemical proof. In those contact zones on which accurate chemical work has been done, it has been shown that no considerable transference of material has taken place. In these other cases where this enormous transference of material is assumed, no accurate chemical work seems to have been carried out to support the contentions. In Duparc's work, as has been mentioned, a number of analyses of various normal and "granitized" rocks are given, but no attempt is made to follow out the changes undergone by a single bed, and it is impossible to make out in how far the differences in composition shown to exist, are primary differences in the composition of the rocks analyzed. The chemical evidence adduced is, therefore, by no means conclusive. The question also arises as to the ultimate source of the enormous amounts of silica and alkalis required for the conversion of hundreds of cubic miles of the miscellaneous rocks of a sedimentary system into granite.

It is furthermore a question as to how far dynamic action is responsible for many of the phenomena described. When, for instance, a schist is shattered and granite is intruded into the cracks and fissures, masses of the invaded rock being found scattered through the granite, and, after cooling, the whole complex is stretched or rolled out by dynamic movements, as is usually the case in districts where crystalline schists occur, the injected arms of the granite, great and small, become pulled apart and eventually appear as little discontinuous strings and lumps of quartz and feldspar in the enclosing schists, following the line of movement, while a schistose structure parallel to these strings is given to the whole rock by the same movements.

In certain parts of the Laurentian of Canada, schists and gneisses are found full of such strings and lumps of quartz and feldspar, presenting exactly the characters described by the French petrographers as resulting from the granitization of sedimentary rocks. The Canadian rocks, however, have undoubtedly been produced in the way just described, every possible transition from the massive injection to the foliated complex being observed in a hundred different cases. In the Lepontine Alps, moreover, to the east of Mont Blanc, where the *Schieferhülle* of the several protogine masses have been very carefully studied by Heim, Schmidt, and many other observers, the phenomena attributed to "granitization" by Duparc are everywhere considered to be the results of crushing under the influence of such movements, with, in certain cases, the infiltration of secondary cracks and rifts by materials deposited from ordinary terrestrial waters, which in such positions would probably be more or less heated. Even in the Saxon Granulitgebirge, cited by Michel-Lévy as a case where transference of material could be distinctly observed, and where certainly the granulite does seem to have eaten its way into the schists, only however for a short distance back from the immediate contact, the appearance presented bearing a striking resemblance to that, very familiar to the tyro in assaying, when his slag being too basic has eaten its way into the clay crucible appearing when the crucible is broken through its substance here and there in spots and streaks; Lehmann, who has made a most exhaustive study of the whole region points to the fact that this zone is not always present, and states it to be his belief that the granitic material forming the *flammen* in the schist has not been derived from the granulite magma, but is due to the deposition of the granitic material in spaces formed by the separation of the foliæ of the schist, under the great stresses to which the region has been subjected, the granitic material in question having been derived from later intrusions which elsewhere can be clearly seen to cut the granulite. From personal observation, however, I must say that appearances are strongly in favor of Naumann's view, that along the narrow zone of the immediate contact the granulite magma has eaten into the schist to a certain distance, a phenomenon which is quite intelligible and perhaps in certain cases to be expected, but which is quite distinct from the wholesale transformation of the schist into granite by the mysterious process of "granitization."

In how far this process of transfusion which is considered by Michel-Lévy and other French geologists to play so important a part in the origin of the crystalline schists is really active, must be determined by detailed studies of the deeper seated granite contacts and of the so-called Archean areas in various parts of the world.

Such studies in the case of Archean areas are presented in the recent maps, with accompanying explanatory texts, issued by the geological survey of Baden, and whose titles are given above. This survey, following the lead of those of Prussia, Saxony, and Hessen, was constituted in 1888 for the purpose of mapping in detail the Grand Duchy of Baden, an area of 5843 square miles, on a scale of $\frac{1}{25000}$. For this purpose the territory in question has been divided into 170 sections. Work was begun in 1889 and maps of twelve sections have already been published. As about one-quarter of the Grand Duchy of Baden is underlain by *Grundgebirge* including the well-known area of the Black Forest, ample opportunity is given for a thorough study of these ancient rocks. Six of the maps already published are in areas of the Grundgebirge; of these three have been mapped by Dr. Sauer, to whom we are already indebted for his valuable contributions to our knowledge of the ancient crystalline rocks of Saxony. The maps are among the best which have yet appeared of any Archean region, and serve to bring out clearly the complex relations of the several members of the system.

Two distinct classes of gneissic rocks are recognized in the areas examined, in addition to the numerous intrusions of igneous rocks of various kinds. To each of these classes a collective name has been assigned, taken from a locality where it is well exposed; the first being known as the Rensch Gneiss and the second as the Schapbach Gneiss. A few of the most notable varieties of each class of rock are distinguished in mapping, but no attempt is made to map separately the bewilderingly numerous and minute petrographical variations of the gneissic rocks attempted in the survey of Saxony. The Rensch gneisses consist chiefly of orthoclase, biotite, and quartz. The mica is usually abundant, and sillimanite is a characteristic accessory constituent, often occurring as a paramorph after andalusite. Garnet and sphene are seldom found. The rock often shows in the arrangement of the constituents a structure similar to that seen in the hornstones of contact zones. The presence of small lenticular segregations of quartz, or of quartz and orthoclase, scattered through the rock is also a characteristic feature of the gneisses of this class. Conformably interbanded with these Rensch gneisses are subordinate masses of quartz schist, graphitoid schists and gneisses, pyroxene gneisses and amphibolites.

The Schapbach gneisses are much more uniform in character, usually poorer in mica, and have a marked tendency to assume a granitic aspect, often passing over into granulites. Quartz lenses and fine-grained, highly quartzose bands are absent, but garnet and orthite are frequently present. The only inclusions found in the gneisses of this class consist of a gabbro-like amphibolite. The gneisses of the two classes sometimes seem to pass into one another along the contacts, but the distinction is usually sufficiently well marked to enable them to be properly separated in mapping.

Although no direct expression of opinion concerning the origin of these gneisses is given in the publications in question, it seems to be the opinion of the survey that the two classes probably differ in origin, the Rensch gneisses representing highly altered sediments and the Schapbach gneisses being of igneous origin. The chemical evidence afforded by a number of analyses of typical gneisses of each series which are given, tend to support this view as does also the structure of the rocks, and the character of the subordinate intercalated masses in the case of the Rensch Gneiss. The evidence one way or the other will, however, be greatly extended as the mapping with concomitant chemical investigation progresses, and the Director of the survey, Professor Rosenbusch, evidently desires to await this further evidence before making any decided statements concerning the genetic relationships of the complex. If the Rensch gneisses prove to be altered sedimentary rocks their high content of feldspar and the presence in them everywhere of lenticular masses and strings of quartz and feldspar will certainly be cited by the French authorities as evidences of "granitization." But two questions remain to be decided—first, whether the high content in feldspar is not due to a high content of alkalis in the original sedimentary rocks, these having been perhaps of the nature of feldspathic sandstones, arkoses and greywackes, and secondly, whether the strings and lenses of quartz or quartz and feldspar do not fill spaces opened by the dynamic movements to which the rocks have been subjected, quite independent of any granitic intrusion. Whether in fact any mysterious cementation-like transfusion of granitic material through these rocks has really taken place. The detailed chemical work which is now being carried out will, when completed, undoubtedly decide whether the supposed altered sediments have or have not a composition which can be attributed to a sedimentary series.

A similar twofold origin is claimed by Klemm for the crystalline Grundebirge of the Spessart, although here the sedimentary portion is believed to be of late Palæozoic age and is possibly equivalent to a series of schistose hornstones, graphite schists and garnet rocks, quite distinct from the gneissic series of the Black Forest, which were found by Andreæ and Osann in the Odenwald to the north of Heidelberg.

These studies bearing upon the vexed question of the origin of the crystalline schists have at present an especial interest for petrographers in America, where such enormous areas of these rocks are now under investigation.

FRANK D. ADAMS.

Glaciers of North America, a Reading Lesson for Students in Geography and Geology. By ISRAEL C. RUSSELL. Boston: Ginn & Co., 1897.

The preparation of a work of this high grade by a busy university professor of large professional experience and demonstrated investigative ability, as a reading lesson for students of geography and geology, is worthy of special note as one of the signs of the educational times. It is significant both as an indication of a demand and as exemplifying a supply. It is a gratifying mark of progress that there should have grown to be a place for a work of this character as a supplement to the usual treatises on geography and geology. It is a not less gratifying mark of progress that such a demand should be appreciated and met by a careful and competent scientist of high position.

The work opens with a clear and brief statement of the nature of glaciers, and of their varieties and of the work done by them. Their distribution in North America is then sketched comprehensively, after which individual glaciers and glacial districts are described in detail. It is in the study of these glaciers individually, aided by the numerous photographic illustrations, that the real characters of glaciers will come to be realized by the students. The average reader will doubtless be surprised at the number, variety and instructiveness of American glaciers. They very greatly surpass those of all other accessible continents.

Following the individual descriptions are chapters on the climatic changes indicated by the glaciers of North America, upon the cause and mode of glacial motion, and upon the life history of a glacier. The discussions of theoretical questions are conservative and judicial in tone, and manifest a notable tendency to eclectic conclusions. Professor Russell's comprehensive statement of the various hypotheses of glacial motion will doubtless be found one of the most interesting sections of the volume by advanced glacial students. The work is heartily commended to teachers and general readers as well as students.

T. C. C.

Former Extension of Cornell Glacier near the Southern end of Melville Bay. By RALPH S. TARR. Bull. Geol. Soc. Amer., Vol VIII, pp. 251–268. Plates XXV to XXIX, March 1897.

An abstract of this paper was given in the January-February number of this JOURNAL, pp. 95–96. An editorial relative to it appeared in the same number, pp. 81–85. Communications in reference to it have also appeared in *Science*, Vol. V, No. 113, February 26, p. 344; No. 114, March 5, pp. 400–401, and No. 117, March 26, pp. 515–516. This further notice is introduced mainly for the purpose of presenting

THE DEVIL'S THUMB

Elevation 2,650 feet; glaciated surface in the foreground; rugged angular topography in background on left. Transported pebbles obtained on crest of the Devil's Thumb. Photograph by J. O. Martin. (Author's legend.)

to the readers of the JOURNAL the chief photograph of the paper for comparison with those previously presented in this JOURNAL in the series entitled "Glacial Studies in Greenland." It need only be added that Professor Tarr regards this photograph as presenting a "rugged, angular topography," and offers it with similar photographs in sub-

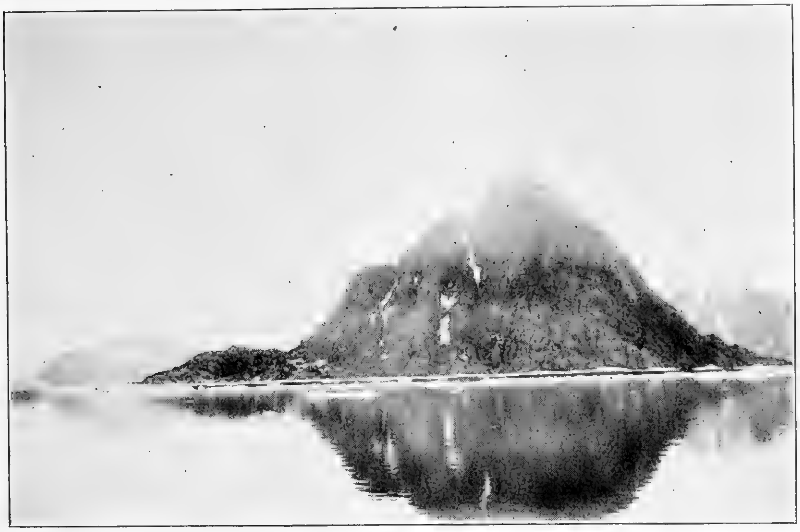

FIG. 1. Dalrymple Island, an illustration of unglaciated topography.

stantiation of his claim that topographic contours cannot be trusted as indices of glaciation. As glaciation seems to the reviewer to be expressed with much clearness and definiteness in the contours of the promontory here cited as a proof to the contrary, it seems the fairest mode of review to reproduce the photograph and permit geologists to judge for themselves. For comparison there is added a photographic illustration of Dalrymple Island, which has been previously published in this JOURNAL as an illustration of unglaciated asperities. The reviewer does not see how anyone trained in glacial topography can fail to see glacial modification in the one and the absence of it in the other. The humorous feature of the issue raised in the paper and the outgrowing discussion is that contours of the type illustrated by Professor Tarr's photographs were identified as moderately glaciated by those whose conclusions he seeks to overthrow and his observations of the drift and other positive indices confirm the correctness of their identifications.

It is infelicitous to call the promontory in the photograph the Devil's Thumb. The author remarks in a footnote: "This is the Devil's Thumb as given on the Danish and British Admiralty charts.

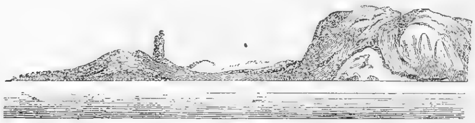

FIG. 2. Devil's Thumb, S.E.ᵇE. (True) S.S.W.½W. (Magᶜ.) (Legend on British Admiralty Chart.)

The real Devil's Thumb of the Arctic explorers is some forty or fifty miles north of this" (p. 254). The true Devil's Thumb is, however, sketched on the British Admiralty chart and the sketch there given is herewith reproduced. It is topographically an object of a very different order from the promontory of the photograph. As it has been cited in the articles in this JOURNAL in its bearings upon the limitations of glaciation, it seems unfortunate to introduce another Devil's Thumb of so different a nature. Confusion has already arisen by reason of this. An error in the location of the Devil's Thumb, in a region where the charts are confessedly inaccurate, does not seem to us to justify the transfer of the name to the false location.

The author makes passing mention of the driftless area in the Inglefield Gulf region, and although he declines to discuss it, as it was not seen by him, he remarks in a footnote that "he cannot let this opportunity pass without raising the query whether the topography in the neighborhood of the Greenland driftless area is not such that an area of this sort would naturally be expected. Was not the movement of the ice outward and the main stream down the Inglefield Gulf? And is not the driftless area located in the place where the high Red Cliff peninsula would naturally have clogged the ice and hence prevented its action of erosion and notable transportation?" The driftless area is part of the same ancient peneplain as the summit of the Red Cliff peninsula (JOUR. GEOL., pp. 205–206, Vol. III, 1895). It lies on the *east side of Red Cliff peninsula* (see map on p. 668, Vol. II, JOUR. GEOL.). It lies *between it and the great ice-cap*. It is separated from the peninsula by the valley of Bowdoin Bay about two miles wide and 2000 feet deep. How an isolated part of a peneplain can protect from glaciation another part of the same plain lying between it and the source of the glacial motion, and several miles distant, is not easily understood. The suggestion does not seem to have sprung from a serious consideration of the conditions of the problem.

T. C. C.

Report on the Valley Regions of Alabama (Palæozoic Strata). Part I. On the Tennessee Valley Regions. By HENRY MCCALLEY.

The palæozoic area in northern Alabama may be divided into two regions. That to the northwest, drained chiefly by the Tennessee River and its tributaries, is characterized by the nearly horizontal and undisturbed condition of the strata. The region to the southeast, drained by the Coosa River, is a region of greater disturbance with the geologic features much complicated by the folding and faulting of the strata. The first of these regions is described in the present report; part two of the report, not yet published, will treat of the second or Coosa valley region.

The report is divided into two sections, the first of which is a general treatment of the physical features, geology, natural resources, soils, agricultural features, timber, waterpower, climate, rainfall, drainage, and health. Much the larger part of the report is devoted to the second section which treats of county details.

Chapter two of the first section entitled Geology describes the stratigraphy of the region and is the only portion of the report of general interest. The following table of formations is given:

(8) Tertiary	(k) Lafayette	
(7) Cretaceous	(j) Tuscaloosa	
(6) Carboniferous	(i) Coal Measures	200–500 feet
(5) Upper Sub-Carboniferous	(h) Bangor limestones,	200–450 feet
	(g) Hartselle sandstones	150–400 feet
(4) Lower Sub-Carboniferous	(f) Tuscumbia or St. Louis limestones	75–200 feet
	(e) Lauderdale or Keokuk chert	100–250 feet
(3) Devonian	(d) Black shale	0–45 feet
(2) Upper Silurian	(c) Red Mountain or Clinton (Niagara)	3–350 feet
(1) Lower Silurian	(b) Pelham or Trenton (Nashville,	700–1000 feet
	(a) Siliceous (Knox) dolomite and chert	2000 feet

The physical characters of each of these formations is briefly described, though no lists of fossils are given by which the faunas may be compared with those of the supposed equivalent strata elsewhere.

The remainder of the report will have its chief interest and usefulness among the local geologists of the region described.

STUART WELLER.

Final Report on the Geology of Minnesota. Palæontology. Vol. III, Part II. Minneapolis, Minn., 1897.

Part II of the *Palæontology of Minnesota*, a volume of about 600 pages, illustrated by forty-eight plates besides 133 figures, has just appeared. Like its companion volume, Part I, it treats only of the Ordovician fossils. Besides the introduction, which is a paper by N. H. Winchell and E. O. Ulrich upon "The Lower Silurian deposits of the Upper Mississippi province; a correlation of the strata with those in the Cincinnati, Tennessee, New York, and Canadian provinces, and the stratigraphic and geographic distribution of the fossils," the volume contains the following papers:

1. The Lower Silurian Lamellibranchiata of Minnesota. By E. O. Ulrich.
2. The Lower Silurian Ostracoda of Minnesota. By E. O. Ulrich.
3. The Lower Silurian Trilobites of Minnesota. By J. M. Clarke.
4. The Lower Silurian Cephalopoda of Minnesota. By J. M. Clarke.
5. The Lower Silurian Gastropoda of Minnesota. By E. O. Ulrich and W. H. Scofield.

The first three of these papers were published separately in small editions and distributed during the period from June 16, 1894, to September 27, 1894. The last two papers appear for the first time with the publication of the complete volume.

The volume supplies a long-felt want to students of the Ordovician faunas of the West, and will doubtless be the standard work upon these faunas in the Mississippi region for many years. The author of the chapters upon the Lamellibranchiata and Gastropoda should perhaps have been more conservative in establishing new genera and species; however the classification of the greater number of the classes of organisms abundantly preserved as fossils in the palæozoic rocks, is at present in a transition state, and any attempt to make more natural, and to give more definiteness to their classification is a step in advance.

STUART WELLER.

Bulletins of American Palæontology. Vol. I. Published by PROFESSOR G. D. HARRIS, Ithaca, N. Y.

THE publication of a purely palæontological bulletin has been undertaken by Professor G. D. Harris, of Cornell University, and the first volume has just been completed. The undertaking of Professor Harris is truly a commendable one, and should receive the encouragement of American palæontologists. Heretofore palæontology has had, in America, no organ of publication purely its own. The literature of the subject has been scattered through a score or more of proceedings or transactions of learned societies and periodicals. If, from now on, Professor Harris' bulletin meets with the coöperation of American investigators which it deserves, our literature will become more concentrated and consequently much more accessible.

The bulletin appears, not at stated intervals, but at such times as material may be ready for publication. Volume I consists of five numbers, which have appeared at intervals since May 25, 1895.

1. "Claiborne Fossils," by G. D. Harris. Pp. 1–52. Plate I. (May 25, 1895.)

Part I of this bulletin is a "Synonymy of the Claiborne sand species of Conrad and Lea, as determined by an inspection of the type collections now at the Academy of Science of Philadelphia." This paper will be welcome to all students of the Eocene faunas of eastern America. The description of species from the Claiborne sands by the two authors, Conrad and Lea, during the same period of time, and without the slightest recognition on the part of either of the work being done by the other, brought about a most confusing state of synonymy. Professor Harris has straightened out this confusion by an inspection and comparison of the type specimens of both authors.

Part II of the bulletin is a description of six new species from the Claiborne sand.

2. "New or little known Tertiary Mollusca from Alabama and Texas," by T. H. Aldrich. Pp. 53–82. Plates II–VI. (June 24, 1895.)

3. "Neocene Mollusca of Texas, or fossils from the deep well at Galveston," by G. D. Harris. Pp. 83–114. Plates VII–X. December 2, 1895.)

This paper was noticed in this JOURNAL, Vol. IV, p. 126, and needs no further comment.

4. "The Midway Stage," by G. D. Harris. Pp. 115–270. Plates XI–XXV. (June 11, 1896.)

In this paper it is shown that between the basal Eocene deposits, or Midway Stage, and the uppermost Cretaceous, there is in the southern states a decided break, both stratigraphic and faunal, so that not a single species is known certainly to have crossed from one formation to the other. These initial beds of the Eocene are treated both geologically and faunally by Professor Harris. The field investigations were carred on in the states of Texas, Arkansas, Tennessee, Mississippi, Alabama, and Georgia. From his studies Professor Harris is led to believe that a considerable time interval elapsed between the close of the Cretaceous deposition and the beginning of the Eocene deposition in the Mississippi basin, and that wherever good contact exposures are found, there may be found, on careful study, ample evidence of nonconformity.

This initial Eocene fauna is discussed at length, all the old species of Mollusca and many new ones are described and figured.

5. "A reprint of the palæontological writings of Thomas Say; with an introduction, by G. D. Harris. Pp. 271–354. Plates XXVI–XXXII. (December 7, 1896.)

The republication of these papers, originally published from 1819 to 1825, long since out of print and accessible only in the larger libraries, will be appreciated by all those who have had occasion to refer to such literature, and have been unable to find access to it. The following papers are republished, word for word, line for line, and page for page, as written and punctuated by the original author:

1 and 2. "Observations on some species of zoöphites, shells, etc., principally fossil. *Am. Jour. Sci.*, 1st ser., Vols. I and II (1819–1820).

3. "Fossil shells found in a shell mass from Anastasia Island." *Jour. Acad. Nat. Sci., Phil.*, 1st ser., Vol. IV (1824).

4. "An account of some fossil shells of Maryland." *Jour. Acad. Nat. Sci. Phil.*, 1st ser., Vol. IV (1824).

5. "On two new genera and several species of Crinoidea." *Jour. Acad. Nat. Sci. Phil.*, 1st ser., Vol. IV (1825). STUART WELLER.

Eocene Deposits of the Middle Atlantic Slope in Maryland, Delaware and Virginia. By WM. BULLOCK CLARK. U. S. Geol. Sur., Bull. 141, 167 pp., 40 pls., 1896.

During the first half of the century the Tertiary formations of eastern United States were among the most carefully studied and best known deposits of the country. However, for nearly two generations little has been done to extend our knowledge of these interesting beds. Since the brilliant work of Rogers and Conrad ceased practically nothing has been attempted in the way of keeping the information regarding these strata abreast of the times. It is, then, with peculiar pleasure that the recent revival of interest in these formations is noted; and none of the late contributions is more welcome than the one just issued, on the Eocene of the Middle Atlantic region.

The memoir contains a complete review of the literature and results of past observations in this field. The author exhaustively investigates both the stratigraphy and the fauna of this important member of the coastal plain series. He traces the limits of the formation from its most northern occurrence in Delaware across Maryland into Virginia, where it gradually becomes buried beneath later formations.

A detailed study of the 300 feet of Eocene deposits in the central portion of the district shows two distinct faunas, which are named the Aquia Creek and the Woodstock faunas, the former occupying a sequence of beds extending some 60 feet from the base of the formation, while the latter apparently does not reach quite to its upper limits. The Aquia Creek stage, which contains an assemblage of forms closely allied to the middle Lignitic, probably stands, with its underlying poorly fossiliferous zone, as an equivalent, in a broad way, of the whole of the Lignitic of the Gulf; while the Woodstock stage, which contains a group of forms closely allied to the *Ostrea sellæformis* zone of the Claiborne, stands, with the overlying and underlying beds, as the equivalent, in a broad way, of the Buhrstone and Claiborne, yet it is not assumed that the lower and upper beds are exactly synchronous with the lowest portions of the Lignitic and the highest portions of the Claiborne. The much slower accumulation of the Atlantic coast materials is shown in the fact that in Alabama more than 600 feet of deposits are found between the two fossiliferous horizons above cited, while in Maryland and Virginia a thickness of but little over 100 feet is found, and without the differentiation into the fossiliferous zones which characterizes the Gulf area. The middle Atlantic Slope Eocene, therefore, represents, according to the author, only the Lignitic, Buhrstone, and Claiborne of the Alabama geologists.

These results, together with others lately obtained in a study of the Cretaceous strata throw much light upon the character of sedimentation along the Atlantic coast during the late Mesozoic and early Cretaceous time.

Regarding the criteria of correlation which were followed the author significantly remarks:

"As the different methods of correlation are examined in retrospect, the interdependence which exists between the various classes of physical and biological criteria becomes clearly manifest.

"The faunal and floral characteristics of a formation find their full interpretation only as the physical factors are clearly understood, since the geological and geographical range of forms is determined to a large extent by conditions of sedimentation. The physical characters of a formation therefore bear a close relationship to its contained fossils, and cannot be ignored in the correlation of the deposits.

"Although the most trustworthy correlations are based upon palæontological data, the possibilities of variation in the succession of organic forms, in two distant areas, are so great that detailed correlations can seldom be satisfactorily attempted, even where general equivalence is recognized.

"The geologist, therefore, must take into consideration both the geological and the palæontological criteria in the correlation of the sedimentary rocks. No class of facts can be ignored."

CHARLES R. KEYES.

The Elevated Reef of Florida. By ALEXANDER AGASSIZ. *With Notes on the Geology of Southern Florida.* By LEON S. GRISWOLD. Bull. Mus. Comp. Zoöl., Vol. XXXVIII, No. 2 (pp. 29–62, 26 plates).

The work upon which this double paper is based consists of a trip made by Mr. Agassiz somewhat over two years ago, and one made by Mr. Griswold early in 1896. The purpose of the latter was to clear up if possible, some of the obscurity which surrounds the geology of the Everglades. The paper opens up much that is new in the story of the organic portion of the peninsula; and it is to be regretted that low water prevented Mr. Griswold from reaching Long Key, which was one of the most important goals.

The reef has been elevated from six to twenty feet, the amount decreasing southward. At Key West the coastal plain is found at a depth of 50 feet (Pliocene), while Eocene strata are 700 feet from the surface. At Key Largo the reef has "a probable width of at least nine miles from the outer reef patches." Very great weight is given to solutional action. Not only are the Everglades in great measure explained by it, but the sounds and mud flats between the line of keys and the mainland. The disconnection is increasingly great southward, until between Key West and Cape Sable the mud flats and mangrove islands "are all that give evidence of the former continuity of the land." Thus Florida is constantly losing territory, instead of gaining it, as the older views maintained. The Marquesas, formerly considered an atoll built upon a raising bank, are, according to the author, merely a very perfect sound, and the "lagoon" is an area of greater solution. Mr. Griswold, however, does not carry the solutional theory to the extent to which it is borne by the senior author.

In many places on the keys the elevated reef is capped by an oölite. Mr. Agassiz states positively its æolian origin; but Mr. Griswold, who was last on the ground, says that, for several reasons, which he enumerates, "the topography favors an origin for the limestone in water." This guarded statement does not seem too strong for the evidence presented. This oölite was traced by Mr. Griswold much farther into the Everglades than any geologist has penetrated heretofore. Mr. Agassiz interprets the formation as modified dune sand, obtained from the beaches of the elevated reef, and blown inland by prevailing east winds. J. EDMUND WOODMAN.

Correlation of Erie-Huron Beaches with Outlets and Moraines in Southeastern Michigan. By F. B. TAYLOR. Bull. Geol. Soc. America, Vol. VIII, pp. 31–58, with map.

In this paper there is given an account of observations in a region hitherto little studied but containing evidences of a most interesting glacial and postglacial history. As stated in the title, the paper deals with features observed in southeastern Michigan chiefly in the northward projecting portion between Saginaw Bay and the lower end of Lake Huron, commonly called the "Thumb." Having spent two months during the past season in geological investigations in this region the reviewer is prepared to lend corroborative evidence as to the general conclusions of the paper and to testify to the scientific acumen displayed in the interpretation of the phenomena observed. The paper constitutes the first published account of detailed observations of glacial phenomena in this portion of the state. Almost the entire region is heavily covered with glacial drift. Very few outcrops of country rock occur. All the moraines of the region show two distinct phases. Above a contour of approximately 200 feet, which marks the upper limit of submergence, they have an irregular rolling surface, while below this line they lose their irregular features and are in fact so subdued as often to be distinguished with difficulty from the ground moraine. These water-laid moraines, however, are distinct though faint topographic features and mark the former position of the ice front as surely as the hilly land laid form.

In the paper cited a description is given of all the different moraines and beaches formed in this part of the state though the chief interest centers in those found in Sanilac and adjoining counties. In the vicinity of Imlay City a channel occupied by a swamp and bounded by beach lines was discovered extending north and west past this place and North Branch, then southwestward toward Flint. This, called the Imlay Outlet, is regarded as the outlet of a lake (unnamed) at the time the ice foot rested on its northern side. The position of the ice front is marked by a rugged moraine—the Toledo moraine.

On the retreat of the ice from this position there was next formed the Detroit moraine which, except for a tract near Yale is nearly all water laid. North of Yale near Melvin it is represented by kames and kame moraines. In this area which the author of the paper did not examine we have observed a well-marked series of kame ridges marking the northernmost limit of the eastern limb of the Detroit moraine. Northward the land fades away into the great swamp which extends north from Capac past Valley Center and Brown City to Shabona Post Office and into the almost imperceptible divide between this and the Black River swamp toward the east.

The last moraine is the Port Huron Saginaw moraine which extends from a point six or eight miles northwest of Port Huron along the east side of Black River to Tyre, thence curving around toward the southwest to Vasser. From the 200 feet contour, around the northern and eastern side of this moraine, the land slopes evenly away toward the present shore. West of the eastern limb of this moraine lies the great Black River swamp.

As the ice front retreated over this swamp region to its last halting stage at the Port Huron-Saginaw moraine, the water from the wasting glacier evidently found its way westward along the ice front, the position of several of these outlets being noted. The last of these, the Ubly channel, was the most important. The position of this channel is now marked by the north branch of Cass River, a small stream flowing in a wide valley filled with valley gravels. At Tyre, a branch was received from the southeast. The relation of a great ice dam and the outlet of the waters is here admirably shown. The evidence of reversed drainage in the case of Black River is unmistakable. Previous to the opening of the Ubly channel when the ice-front was on the south side of the north branch of Cass River the outlet which Taylor calls the Cumber spillway was close along its edge. This position is now marked by a long narrow swamp extending from the valley of the Freiburger channel north of Cumber, parallel with the North Branch, southwest across the South Branch of Cass River and on toward Deford. In this swamp is the famous "stone wall" consisting of a low embankment of earth and bowlders extending for a considerable distance parallel with the edge of the swamp. Locally it is regarded as the work of pre-historic man. The "wall" is about eighteen inches high and was until recently obscured by vegetable mold. It was exposed by fires in clearing the swamp. Mr. Taylor refers to its resemblance to ice beaches but regards the explanation as unsatisfactory. We spent some time in this vicinity and from a study of the surroundings were convinced that the ice-beach theory is an adequate and the only adequate explanation of the phenomena. It is of interest as constituting the only instance known to us of a bowlder wall formed by ice-push in a lake now wholly extinct.

Our own observations on the beach lines of Sanilac county shows a marked northward elevation corresponding to previous observations in the lake region, the result probably of resilience following the withdrawal of the ice and to which was evidently due the reversal of the Black River drainage. This river now flows south and then east into the Saint Clair River at Port Huron. An indication of reversed drainage is seen in the direction of the branches of Black River as, for example, that of Elk Creek which rises in the southwest part of Sanilac county and flows northeast to its junction with Black River which here flows nearly due south.

While Mr. Taylor has carefully described all the glacial features observed by him, and also by G. K. Gilbert who accompanied him on a part of the trip, he has described no eskers. A well-marked example occurs about ten miles northeast of Marlette. It consists of a well-marked gravel ridge (or "hogback") extending for several miles in a westward direction bearing to the north from the southeast corner of Lamotte township. This was evidently formed at the time the ice front rested on the Detroit moraine. Other interesting features not observed by Mr. Taylor, though suggested by him, are the well-marked kame deposits in the southern part of Sanilac county. In the vicinity of Melvin and Peck they consist of hills and ridges of gravel and sand thirty to fifty feet in height.

The name Erie-Huron is offered for the whole series of lakes represented by all the beaches, while Lake Warren is restricted to one of the separate lakes which most closely corresponds to the original idea of Spencer who proposed the name. Taylor concludes that if the relations of the moraine and beaches have been correctly interpreted then he has found outlets for three and possibly four stages, and these so related to the topography of the region and to the moraines that in at least three cases there is no reasonable doubt as to the contemporary place of the ice front. The continental ice-sheet was obviously the great dam that held all these waters up.

While testifying to the general excellence of the paper we find ourselves unable to follow the author in the degree of confidence he seems to repose in his barometer. As the correlation of some of the beach lines depends upon the identification of beaches having a vertical interval of twenty to forty feet only, and several miles apart and was made by means of a common aneroid barometer, it must be said that the conclusions in some cases are not without an element of doubt. Thus, for example, the Belmore beach is identified near Applegate at an elevation of 770 feet. Forrest Beach six or seven miles east of this has an elevation of about 735 or 740 feet. Near Cass City Mr. Taylor identifies the Du Plain beach which he says is twenty to thirty feet above the Forrest beach. The Belmore and Du Plain though so nearly related are regarded by Mr. Taylor as distinct, while between them he postulates still another stage represented by the Arkona beach which is said to have an elevation of 755 feet northeast of Spring Hill. Allowing for northward rise this beach would have about the elevation given the Belmore beach near Applegate. The question then arises which beach does the Applegate beach represent, the Belmore, Arkona or Du Plain, and what is the actual relation of these to the Forrest beach? Beaches twenty to forty feet above the Forrest beach have been identified with each of these. Our own barometer readings westward from Croswell gave 765 feet for the altitude of a shore line stated by Mr. Taylor to be 780 feet above sea level. In an area so little diversified, more exact measurements are needed to settle some of the questions raised. Notwithstanding these questions, however, we regard the paper as an important contribution to the literature of the glacial recession. C. H. GORDON.

Elementary Geology. RALPH S. TARR, B.S., F.G.S.A. The Macmillan Company, 1897. Pp. xx+499. $1.40.

This is the most attractive elementary text-book on geology which the writer has seen. The style is generally simple, the illustrations numerous, well selected, and with but few exceptions clearly reproduced, and the mechanical execution, including the binding, is unsurpassed. The wealth of illustration is shown by the twenty-four full page plates and 268 figures, which adorn its pages. This work differs from most other text-books on geology in the greater stress laid upon the dynamic aspect of the subject. The stratigraphic and historic phases are treated briefly and concisely in 100 pages as against 275 pages given to the dynamic and 92 to the structural side. The development of life during the various periods is outlined, but no attempt has been made to teach palæontology, or to give long lists of fossils. The chapter on the life development precedes the chapter on the evolution of the land and the geography of the different periods. This departure from the more common custom of considering first the geography and then the life of each period will perhaps find favor with some teachers but not with all. Whatever be the success of this arrangement, there can be but little doubt but that the author has done well to lay the greater stress upon the dynamic phases of the subject in a book meant for high-school pupils.

In judging this book due regard must be had for the author's purpose, *i. e.*, to "furnish a companion and adjunct" to his *Physical Geography.* It is his hope that the two books will be used together, the geology being taken after a study of the air and ocean, and before the physiography. Knowing the author's purpose, the omission of some topics, such as "river cycles" and "base levels" can be understood, since they have been treated in the *Physical Geography.* In spite, however, of some omissions, there is considerable repetition in the two books—something hardly to be avoided. The *Geology* is a more elementary book than the *Geography*, whereas the present practice in high schools, one recommended by the Conference on Geography appointed by the Committee of Ten, is to place physical geography in the earlier part of the curriculum and geology, when studied at all, near the end. For these reasons, and because of the size of the two books, it is questionable whether they will ever be widely used together. Where such use is attempted, considerable culling and dovetailing will be necessary. This would be easier for the teacher if the paragraphs were numbered. But doubt as to the feasibility of the author's plan does not mean condemnation of the book as a whole. It is admirably adapted for high-school pupils, and it is to be hoped that it will be widely used.

There is so much that is to be commended in it that it is to be regretted that a few slips have passed uncorrected. On page 118 the language implies that the term "oxidation" embraces all the chemical changes caused by percolating water; and the expression "limy shells" (p. 132) as applied to corals is hardly accurate. The statements in the text concerning normal and reversed faults (pp. 293, 324) do not correspond with the diagrams (p. 292) and the following sentence, "Mountains are present in nearly all parts of the world" (p. 314) does not agree well with another statement that "the formation of mountains occurs in only a few comparatively small parts of the whole earth" (p. 328). It may seem hypercritical to refer to some of these points, but too much care cannot be taken in a text-book to be used by immature pupils, and perhaps by teachers, who have not a wide knowledge of the subject. But these are not vital and do not detract greatly from the value of the book. Professor Tarr can be congratulated upon the degree of merit to which the book has attained.

Lewis Institute. Henry B. Kümmel.

Abstracts.

The Solution of Silica under Atmospheric Conditions. By C. Willard Hayes.

While it is well known that under conditions prevailing at considerable distances below the earth's surface silica is one of the more easily soluble substances entering into the composition of the earth's crust, it is commonly regarded as the mineral least liable to be affected by solvents under ordinary atmospheric conditions. Some recent observations, however, show that even quartz pebbles are not proof against chemical as well as mechanical erosion. At several widely separated points in West Virginia and Tennessee occur coarse conglomerates, in two cases Carboniferous and a third Cambrian in age, in which the projecting portions of the pebbles have been deeply etched, evidently by solution. The pebbles vary in size up to an inch in diameter and are composed chiefly of vein quartz and quartzite together with a few of chert and feldspar, embedded in a coarse sandstone matrix. The projecting portions of these pebbles, particularly those composed of quartz and quartzite, are deeply pitted with rough, irregular surfaces, in many cases as much as a third of the pebble having been removed. From the form assumed by most of the pebbles, it would seem that their interior was more easily soluble than the outer portions. The latter usually forms a sharp rim within which is a depression with a slight elevation at the center. The etching is not confined to the larger pebbles, for on closely examining the surface of the matrix it is seen that in many places the projecting portions of the sand grains have been removed, leaving a more or less smooth mosaic. A comparison of these etched pebbles with the glyptoliths or facetted pebbles described by Woodworth and others shows clearly that they are not produced by the same agency as the latter, namely wind-driven sand. Everything, on the other hand, points clearly to solution.

Again, numerous geodes from the Carboniferous limestone in Tennessee, collected by Campbell and Taff, show etching similar to that described above. They vary from three inches to a foot in diameter and beneath the rugose opaque surface are colorless and translucent, resembling in texture extremely fine-grained quartzite or slightly granular vein quartz. Under the microscope this is seen to be made up of spherulitic aggregates of quartz grains with much coarse granular quartz but no cryptocrystalline or amorphous silica could be detected. Many of these geodes are deeply etched upon one or both sides, not only the opaque shell being removed but also portions of the translucent interior. From its microscopic character, the silica of which they are composed would appear to be but little more liable to solution than vein quartz or quartzite. Minute quantities of amorphous silica may, however, be present and by their solution facilitate the removal of the crystalline grains by solution or otherwise. Hence less importance is attached to the solution of these geodes than to the etching of the conglomerate pebbles.

The wide separation of the localities at which these cases of the undoubted solution of silica occur, renders it improbable that they are due to some peculiar and exceptional conditions, such as the presence of thermal, alkaline waters. It seems rather that they must be attributed to the action of widespread agencies working in these cases under more than ordinarily favorable conditions so that the effect is exceptionally striking. All the cases occur in a heavily forested region where there is a thick layer of humus and doubtless an abundant supply of the humus acids. Further, the region is one in which forest fires are frequent and considerable potassium carbonate must be supplied to surface waters by leaching of the resulting ashes. The conditions, therefore would appear to be favorable for a chemical process somewhat as follows: By the oxidation of the vegetable tissues in the process of decay, the humus acids are formed, chiefly humic and crenic. These absorb varying quantities of free nitrogen from the air forming the azo-humic acids, which, in turn, combine with free silica. The resulting acids combine with alkaline carbonates, particularly potassium carbonate, to form easily soluble salts. In most cases the etched surfaces of the pebbles described above support a more or less abundant growth of cryptogamic vegetation which might facilitate the solution in two ways: first by supplying humus acids directly from its own decay, and, second, by absorbing solutions of those acids from other sources and keeping the rock surfaces moist so that their solvent action might be practically continuous.

While it is readily granted that such agents seem inadequate to produce the effects observed, no others at all comparable with them in efficiency suggest themselves. And if the above conclusion is correct, a solvent capable of removing a third of a quartz pebble an inch in diameter, while still imbedded in its matrix, must be an extremely important factor in gradation when acting under the much more favorable conditions prevailing in the humus layer itself where the surface exposed by the quartz grains is vastly greater in proportion to their bulk and where the solvent action is not interrupted as it must be on exposed rock surfaces.

The Crystalline and Metamorphic Rocks of Northwest Georgia. By C. WILLARD HAYES and ALFRED H. BROOKS.

The region discussed in the paper extends southward 100 miles from the Tennessee line and westward twenty to eighty miles from the Atlanta meridian. It embraces about 4000 square miles, forming a belt to the east and south of the Georgia-Alabama Palæozoic area. The rocks of this region naturally fall into three groups: (1) the granites, gneisses and crystalline schists of the basal complex — probably Archean; (2) the slates and conglomerates of the Ocoee series — probably Algonkian; (3) intrusives in the other two series.

The first group includes the Acworth gneiss, Austell granitoid gneiss, Corbin granite and the Piedmont gneiss and crystalline schist. In the second or clastic group only four members are distinguished and formation names have not yet been assigned to them since this classification is not regarded as final. These four members are (*a*) basal conglomerate resting on the Corbin granite; (*b*) black slate often graphitic; (*c*) a series of interbedded slates and felspathic sandstones; (*d*) garnetiferous slate probably an altered phase of (*b*) and (*c*). The intrusives, which are found in association with members of both the other groups, but most abundantly in a belt from ten to twenty miles broad along their contact, named in the order of their intrusion, are (*a*) amphibolite schists and diorite; (*b*) gabbro and basic greenstone schist; and (*c*) Villa Rica granite and associated coarse pegmatites.

The above classification as well as the map accompanying the paper is to be regarded as only preliminary since the necessary petrographic study of the rocks has not yet been completed. The region discussed is embraced within the limits of the Dalton, Cartersville, Marietta, Tallapoosa, and Anniston folios of the United States Geological Survey which are now in course of preparation.

The Age of the White Limestone of Sussex County, New Jersey. J. E. Wolff and Alfred H. Brooks.

The principal new observations contributed to this well-known field by the authors were those indicating the presence of several longitudinal faults along the boundaries between the Cambrian limestone and sandstone and the white limestone and associated crystalline rocks; and the discovery, at a new quarry in Franklin, of a crevice in the white limestone which has been filled up by the overlying Cambrian arkose, which contains bowlders and fragments of the white limestone, and fragments of mica, feldspar and other minerals characteristic of the white limestone or associated rocks. From this and other localities, they conclude that the Cambrian sandstone contains the débris of the white limestone granite and associated rocks and explain the apparent transition between the blue (Cambrian) and white limestones as due to fault brecciation and shearing, and the apparent interbedding of the white limestone and quartzite as due to the deposition of the latter on the irregular surface of the white limestone, with local faulting in some places. They conclude that the white limestone is of pre-Cambrian age and an integral part of the gneissic formation. This paper will appear in full in the 18th Annual Report of the Director of the United States Geological Survey.

Erosion at Baselevel. By M. R. Campbell.

Some late observations by Mr. C. W. Hayes and the writer on the solubility of quartz under atmospheric conditions and the writer's own study of local baselevels in the Appalachian coal field seem to throw some light on the question of the ultimate result of undisturbed erosion, a result which has hitherto received but little attention from physiographers.

The conditions which seem to facilitate the solution of quartz are those which would probably prevail during the final stages of the process of baseleveling to a much greater extent than under ordinary conditions of erosion; consequently it seems probable that most, if not all, of the waste of the rocks which is washed in from the surrounding slopes is removed by solution and does not accumulate on the surface of the plain.

This conclusion is still further substantiated by the fact that in the local basins observed in the coal field, the surrounding slopes are sharply separated from the bottoms of the basins, showing that even in these small examples there is some action going on by which the waste is carried off in solution leaving the floor of the basin unobstructed and a nearly perfect plain.

If these conclusions are correct, the baseleveling epochs of the past may have been marked by very completely formed plains, and the slopes of the unreduced areas may have been sharply separated from, instead of blending with, the surface of the plain.

Origin of Certain Topographic Forms. By M. R. CAMPBELL.

The recognition of apparently abnormal physiographic forms in limited areas has induced the writer to undertake an investigation of their probable cause. Since the abnormal types are limited in their geographical distribution, they are doubtless caused by local variations in some of the conditions governing erosion. Climate and rock character are variable, but changes in them could not produce the forms in question. Declivity must be accountable. Declivity may be changed by crustal movements, but those which operate over a broad area change the declivity as a whole, and hence cannot produce local variation. Movements which are limited in their extent are the ones which must be looked to for local variation and the production of abnormal forms. Local uplifts may result in the production of normal faults, monoclinal folds, symmetrical folds, and dome-shaped uplifts; each of these structural forms, when produced during the final stage of an erosion cycle,—for at that time alone will they introduce new erosion conditions,—will be marked by physiographic features peculiar to itself.

The production of a scarp from a monoclinal fold is perhaps the most remarkable form, and it is due to a peculiar combination of slow, regular uplift, homogeneous rocks, and baseleveling conditions outside of the area affected by the uplift.

This principle is applied to the solution of the Blue Ridge scarp in North Carolina, and it is shown that the physical features of that region could have been produced by a monoclinal uplift in a broad peneplain. On this supposition the Blue Ridge plateau was once continuous with the Piedmont plain, but the latter remained at sea level while the former was slowly elevated 2000 feet. There were halts in this movement, during which partial peneplains were formed on the western side of Blue Ridge. The final result of such a combination of crustal movements and periods of baseleveling is that all of the peneplains on the western side of the Blue Ridge, collectively, represent approximately the same time interval as that represented on the eastern side by the Piedmont plain.

This theory also explains the present condition of the New River-Roanoke divide, and why the former stream has not been captured by the latter,—a crucial test for all theories relating to the origin of this scarp.

The same explanation is also suggested for the Black Hills of South Dakota,—a dome-shaped uplift in which the outer rim of Dakota sandstone is in the zone of maximum erosion, and consequently is kept at baselevel, while the inner belt of limestone owing to its more rapid upward movement is unreduced. This is offered merely as a suggestion to geologists in the hopes that it will be entertained as a working hypothesis and its applicability tested by persons familiar with the field.

Dikes in Appalachian Virginia. By N. H. DARTON.

An account was given of further discoveries of diabase dikes and of certain dikes of acidic eruptives among the Palæozoic rocks near Monterey in Highland county, Virginia. The diabase dikes are similar to those described by Messrs. Diller and Darton some years ago, but the acidic rocks are very great novelties for this region. The rock is porphyritic diorite containing quartz, mainly in rounded grains, with plagioclase, biotite, and hornblende phenocrysts, in a white groundmass. The dikes are of small extent and appear to be restricted to a limited territory. The area is one in which the most prominent anticline of central Appalachian Virginia reaches its culmination.

The abstracts in this and the previous issue of this JOURNAL were read before the Washington Meeting of the Geological Society of America.

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THE LAST GREAT BALTIC GLACIER.

In a recent number of this Journal[1] Dr. Keilhack criticises certain views which I have been led to entertain as to the glacial succession in northern Europe. He does not agree with me that the great terminal moraines of the Baltic Ridge are the products of a separate and independent glacial epoch. On the contrary, he and his colleagues on the Royal Prussian Geological Survey are persuaded that the moraines in question simply mark a stage in the retreat of the third ice-sheet. In the last edition of the *Great Ice Age* I have stated somewhat fully the evidence for the conclusion which my critic now disputes, and a short outline of the subject subsequently appeared in this Journal[2].

Geologists who may wish to know what my views are will, I hope, take my own account of them rather than that which Dr. Keilhack has presented to his readers. Doubtless the discussion has been conducted by him in good faith and with every intention of being just, but, all the same, he has not succeeded in giving an accurate outline of the reasons which compelled me to dissent from the opinions maintained by him and his eminent colleagues. Some of the more important evidence adduced he either ignores or slurs over, while in certain other matters he has strangely misunderstood and thus unwittingly misrepresents me. Having carefully considered Dr. Keilhack's paper, I find that his criti-

[1] Vol. V, No. 2, pp. 113-125.

[2] Vol. III, p. 241.

cisms go wide of the mark; he has failed to meet my argument, and I have nothing to modify or withdraw. Under these circumstances I might well leave what I have already written on the subject, and simply appeal to it as a sufficient reply to Dr. Keilhack. Silence on my part, however, might be misunderstood, and I would not appear to be discourteous to a geologist whom I highly esteem, and whose work no one can value more than myself. At the risk of being tedious, therefore, I shall again shortly state my reasons for the faith that is in me, and take due note of my critic's objections.

It was while studying certain glacial phenomena in Britain that I was first led to inquire more fully into the grounds upon which German geologists base their belief that the terminal moraines of the Baltic Ridge were deposited during the retreat of the third ice-sheet (Polandian). The evidence which impressed me in Britain may be very shortly outlined. We have two well-recognized bowlder clays developed in the low grounds of our country—the lower of which belongs to the epoch of maximum glaciation (Saxonian), at which time the British and Scandinavian ice-sheets were coalescent. The upper bowlder clay is the ground-moraine of a less extensive, but still immense, ice-sheet, which, like its predecessor, also occupied the basin of the North Sea, so that continuous inland ice extended as before between Norway and Britain. During the formation of the lower bowlder clay the Scandinavian ice invaded East Anglia and the midlands of England, but this invasion was not repeated by the succeeding ice-sheet. Nevertheless, we have no doubt that the British and Scandinavian ice-sheets were again confluent. Along the whole eastern seaboard of Britain, from Flamborough Head to the extreme north of the Scottish mainland—a region over which the upper bowlder clay is strongly developed—all the evidence indicates that the British ice, underneath which that clay accumulated, was steadily deflected to right and left as it passed outwards into the North Sea basin. North of the Firth of Forth the trend of all the stones in the upper bowlder clay, as well as the direction of drumlins, of roches moutonnées and striæ are towards northeast, north, and, eventually, northwest. South of the Firth, on the other hand, the direction of glaciation is southerly. In a word, it is demonstrable that *during the formation of the upper bowlder clay the British ice did not follow its natural course and flow directly outwards into the basin of the North Sea. It was deflected just in the same way as the earlier inland ice of the Saxonian stage had been.* So far, indeed, as Scotland was concerned, the ice-sheet of Polandian times was hardly less important than its predecessor.

The upper bowlder clay is the chief glacial accumulation in our lowlands, and its surface is often concealed under more or less continuous sheets of gravel and sand, while here and there it is dotted over with large erratics and traversed by eskers. All these obviously belong to the period of melting. Nowhere, however, is a vestige of terminal moraine encountered until the base of the uplands and mountains is approached. Here well-developed terminal moraines suddenly put in an appearance—the relics of large valley-glaciers and local or district ice-sheets. For a long time the general belief was that these moraines had been accumulated during the retreat of the last general ice-sheet (Polandian). Further investigation, however, proved that the outermost moraines had been laid down by advancing glaciers, which had everywhere ploughed into the upper bowlder clay, sweeping it out of the valleys, and so modifying its surface in the low grounds at the base of the mountains as to impress upon it a new configuration. The dimensions of the moraines, the extent of their fluvio-glacial gravels, and the amount of erosion experienced not only by the upper bowlder clay, but by the solid rocks themselves, all indicate that these valley-glaciers and local ice-sheets mark a distinct stage of the Glacial Period.

Again, there is evidence to show that after the retreat of the ice-sheet of the upper bowlder clay, and before the valley-glaciers in the west of Scotland had descended to the coast, the maritime districts were slightly submerged. Loch Lomond at that time formed an arm of the sea, and was tenanted by a fauna which consisted for the most part of existing British forms.

Subsequently a large valley-glacier entered the fiord, filling it up, and ploughing out preëxisting marine deposits. By this time, however, the climate had become arctic, as is proved by the character of the fauna in the contemporaneous undisturbed shelly clays of the 100-feet terraces and beaches.

Such, stated as shortly as may be, are the main facts that led me to conclude that our 100-feet beach and the contemporaneous morainic accumulations indicate a distinct stage of the Glacial Period. There was clear proof that a readvance of active glaciers had taken place after the ice-sheet of the upper bowlder clay had vanished from our low grounds, and from the lower reaches at least of our mountain valleys. But, as I remarked in my former communication to this JOURNAL, it was not quite so evident that the readvance in question had been preceded by a definite and prolonged interglacial epoch. The only evidence of preceding relatively genial conditions are the shells which the Loch Lomond glacier took up from the old sea floor and included in its moraines.

It was with these facts and inferences in view that I approached the examination of the Upper Diluvium of North Germany. Perhaps it may be objected that I had no right to expect that the glacial succession in Britain should correspond with that of the Continent, and, if we descend to details of minor importance, that is no doubt true enough. But so far as the chief stages of glacial accumulation are concerned, these must have followed in the same order throughout Europe. I do not suppose, for example, that any geologist will doubt that the epoch of maximum glaciation was one in Britain and the Continent, and the same must be true of other well-marked divisions of the glacial system. I think, therefore, that I was justified in my expectation that the Upper Diluvium of Germany would prove no exception to the rule. If the valley-moraines of the British mountains, which I formerly took to be the degenerate relics of our minor ice-sheet, mark in reality a recrudescence of glacial conditions, it was not improbable that the German Upper Diluvium would have a similar tale to tell.

Now, in the first place, the Upper Diluvium of North Germany closely resembles, in all essential particulars, the British upper bowlder clay with its associated deposits. Along the southern limits reached by the former we encounter banks and undulating hillocks and sheets of gravel and sand, just as is the case with our upper bowlder clay. Like the latter, also, the upper *Geschiebelehm* is often covered with wide stretches of water-worn materials and sprinkled with erratics. So, again, no terminal moraines present themselves as we traverse the country from south to north, until we are suddenly confronted with the great moraines of the Baltic Ridge. Here, then, we cannot but recognize a general resemblance, at least, between the glacial phenomena of Britain and North Germany. In the published works of German geologists I could meet with no evidence to show that the bowlder clay in front of the Baltic Ridge moraines was identical with the bowlder clay behind them. This identity appeared to me to have been taken for granted. At all events, no doubt had been expressed upon the subject, and no attempt made to demonstrate that the two upper bowlder clays are one and the same. Even in the paper to which I am now replying Dr. Keilhack does little more than reiterate his and his colleagues' opinions that the bowlder clays in question are contemporaneous. Apparently he thinks that their interpretation of the evidence ought to be accepted on the ground of their intimate knowledge of the glacial accumulations of their country. I need hardly say that the accuracy of their observations is not called in question. I doubt if their works have, out of Germany, gained the attention of a more admiring student than myself. Their descriptions, wherever I have been able to test them in the field, have proved, as might have been expected, full and exact. It was not without hesitation, therefore, that I found myself unable to accept their explanation of the evidence. I was consoled, however, by the reflection that they themselves are not agreed as to the precise mode of formation of the Baltic Ridge moraines. When geologists, who claim a long acquaintance with the same facts, cannot yet agree amongst themselves as to how those facts are to be interpreted, I may be excused for forming an independent opinion. Having for many years mapped and studied glacial deposits in my own country—and such deposits are much the same in all well-glaciated lands that I have visited—I did not feel incompetent to weigh the evidence and judge for myself as to its meaning.

Dr. Keilhack does not, in my opinion, strengthen his position when he states that in numerous places the ground-moraine in front of the great terminal moraines of the Baltic Ridge passes smoothly under these. If continuous sections showing such connection are in existence, I confess I have never seen or heard of them. Possibly Dr. Keilhack only infers that the bowlder clay which he sees passing under the moraines is the same as that which overspreads the region on the other side. Be that as it may, I have not said and do not maintain that all the bowlder clay lying north of the terminal moraines is younger than the bowlder clay which occurs south of them. I am quite prepared to believe that in many places the terminal moraines have been dumped upon the bowlder clay of the Polandian stage. Further, I do not doubt that the same bowlder clay actually extends over wide areas behind the moraines, but, if such be the case, it must be largely worked up into or concealed underneath the ground-moraines and other accumulations of the great Baltic Glacier.

I now come to Dr. Keilhack's criticism of certain facts which have been adduced by me in support of the conclusion that the terminal moraines of the Baltic Ridge are deposits of a separate and independent glacial epoch.

(1) In Denmark and Schleswig-Holstein two bowlder clays have been for a long time recognized. Both of these occur over the eastern section of that region. To that region the upper bowlder clay is confined, while the latter extends westward to the shores of the North Sea. Both clays are charged with the same assemblage of erratics, the character of which shows that the ice which brought them moved out from the Baltic and traveled in a general westerly direction. In Holland

there is only one bowlder clay—that of the Saxonian stage or epoch of maximum glaciation—and it is crowded with erratics which have come from the north. The lower bowlder clay of Schleswig-Holstein and Denmark cannot, therefore, have been formed at the same time as the Dutch deposit. The latter indicates an ice flow from north to south—the former an ice flow from east to west approximately. The "lower bowlder clay" of the Cimbric peninsula is not the product of the Saxonian ice-sheet, but of its successor, the Polandian. This inference is greatly strengthened by the fact that the so-called "lower bowlder clay" of Schleswig-Holstein is underlaid by well-marked interglacial beds, which in their turn rest upon a yet older bowlder clay—in all probability belonging to the Saxonian stage. Thus we have actually three bowlder clays in the Cimbric peninsula. The uppermost and youngest of the series is confined to the eastern or Baltic side of the peninsula, and is, I believe, the product of the last great Baltic Glacier—the terminal moraines of which appear to form its outer margin. It may be added that freshwater deposits, containing relics of a characteristic interglacial flora (indicative of genial climatic conditions) have quite recently been detected in the neighborhood of Copenhagen, and thus well within the area overflowed by the Baltic Glacier. The deposits referred to are covered by the morainic accumulations of that glacier, and are underlain by diluvial gravels and bowlder clay of an earlier glacial epoch. Dr. Gunnar Andersson remarks of these interglacial beds that they have certainly been accumulated during the time that elapsed between the melting of the great Scandinavian ice-sheet and the invasion of Zealand by the last Baltic Glacier.[1]

Dr. Keilhack's remarks on the evidence cited by me and the inferences I have drawn are somewhat vague, and he ignores the occurrence of the interglacial beds and underlying bowlder-clay, which are proved to occur below the so-called "lower bowlder clay" of Holstein. He states, what is quite true, that

[1] Bihang till K. Svenska Vet.-Akad. Handlingar. Bd. 22. Afd. iii. No. 1 1896.

no single erratic can be taken as a guide to the direction in which an ice-sheet has flowed. But if by this he means that we cannot decide upon the direction of ice flow from a consideration of the general assemblage or facies of the stones in any given bowlder clay, I cannot possibly agree with him. I am well aware of the fact that every now and again erratics occur in bowlder clay, whose presence would seem to indicate a different direction of ice flow from that suggested by the others in their neighborhood. In regions which have been overflowed by ice at different times and in different directions, such occurrences must be expected. But in the case of the bowlder clays of the Cimbric peninsula it is not merely a few sporadic stones of eastern derivation that we have to deal with. The whole mass of the materials of the two bowlder clays which appear at the surface has traveled from east and northeast, So, again, the bulk of the stones in the Dutch bowlder clay have come from the north.

(2) Following De Geer, I maintain that the strong belt of terminal moraines which extends from Hango Head in a northeasterly direction through Finland, are contemporaneous with those of the Baltic Ridge. Referring to the observations of the accomplished geologists of the Geological Commission of Finland, I cite the fact that two distinct systems of glacial striæ are apparent in that country. "The striæ of the one system run in parallel directions, and extend far east and southeast of the terminal moraines. The other and younger system, on the other hand, is bounded by these moraines—the later striæ crossing the older series at various angles. When striæ belonging to both systems appear on one and the same rock-surface, the younger are always the fresher of the two, the older ones being worn and abraded. The latter, according to Rosberg, are the products of a general *mer de glace*, which attained so great a thickness that minor inequalities of the ground had little or no influence in deflecting the ice flow, which extended far beyond the limits of the terminal moraines. The ice, underneath which the younger system of striæ came into existence,

must have been relatively thin, in consequence of which the inequalities of the ground produced endless local divergences from the general direction of ice flow."[1] The small sketch map of the great Baltic Glacier given in my book is largely a reproduction of De Geer's map, published some years ago. According to Dr. Keilhack the line of union drawn from East Prussia to Finland is "purely hypothetical and supported by no observations." Here, however, he is mistaken. Let him consult De Geer's recent work, *Om Skandinaviens geografiska Utveckling efter Istiden,*" and he will find that a great terminal moraine, marking the edge of the Baltic Glacier, traverses the islands of Ösel and Dagö in a north-south direction, and can even be traced for some distance on the bed of the sea. This can hardly be other than a continuation of the terminal moraines (Salpausselkä) at Hango Head.

Dr. Keilhack says he looks "for the easterly continuation of the Baltic terminal moraine much further south, in the interior of Russia." Well, it is never safe to prophesy, but I shall be surprised if his anticipations prove correct. That much gravel and sand and many erratics will be met with in the regions he refers to I can well believe, but all these, I think, will be found to be similar in character and age to the diluvial gravels, etc., which overspread the bowlder clay in the lands to the south of the Baltic Ridge. According to Dr. Vogt, of Christiania, with whom Dr. Keilhack agrees, "the Finnish terminal moraine belongs with that of middle Sweden and Norway." On the other hand, De Geer shows that the terminal moraines which occur in Norway, somewhat south of Lake Mjösen, represent the front of the Baltic Glacier during a stage in its retreat. He traces the position occupied by the ice edge right across Sweden in an easterly and northeasterly direction. The glacier is represented as filling the upper section of the Baltic basin and reaching as far south only as Åland. The great gravel-ridge at Hämeenkanga, in the middle of western Finland, would appear to be its terminal moraine in that country. This moraine occurs

[1]Great Ice Age, 3d edit., p. 474.

about 125 miles north of the older belt that extends from Hango Head to the north of lake Ladoga.

(3) Dr. Keilhack's third criticism has already been met by the remarks I have made on the subject of the upper bowlder clay of Britain. My worthy critic could not have read my work with attention or he would hardly have attributed to me the strange statement that my belief in the confluence of Scandinavian and British ice-sheets, during the formation of our upper bowlder clay, was suggested by and based on the occurrence in that deposit of Scandinavian erratics! He says: "It seems to me unnecessary entirely to repudiate the opinion of the north German geologists in order to explain the occurrence of Scandinavian bowlders in the upper bowlder clay of Britain." I have nowhere said that Scandinavian bowlders occur in our upper bowlder clay. So far as I am aware such erratics are confined to the lower bowlder clay of East Anglia and the midlands of England. Not one has been met with in any bowlder clay of East Britain north of Flamborough Head. The evidence which shows that our upper bowlder clay was formed at a time when "inland ice" filled up the basin of the North Sea, and the Scandinavian and British ice-sheets were confluent, has nothing whatever to do with the occurrence in our country of Scandinavian erratics. The great extension of ice which characterized the formation of our upper bowlder clay is demonstrated, as I have shown above, in quite another way. When Dr. Keilhack has duly weighed our evidence he will no longer consider "whether the connection of the Scandinavian with the Scottish ice in the third glacial period is more than imaginary." The fact of that connection is as well established as one can expect it to be.

(4) Believing as I do that the terminal moraines of the Baltic Ridge are the products of a distinct glacial epoch, I naturally hold that the superficial or youngest morainic accumulations which lie behind those moraines are of later age than the ice-sheet of Polandian times. Thus, I maintain that the upper bowlder clay throughout the region extending from the

Baltic Ridge to the shores of the Baltic Sea, is a younger deposit than the bowlder clay that stretches south from the Baltic Ridge to the valley of the Elbe. Further, I hold that the youngest interglacial beds, which occur between the upper and lower bowlder clays of the Baltic coast lands, are necessarily of later date than the interglacial beds which are met with in the regions lying to the south of the Baltic Ridge. Dr. Keilhack remarks that this is a "false conclusion," by which I suppose he means merely that he does not agree with me. It will be time enough, however, to call my conclusions false when he has succeeded in proving that the upper and lower bowlder clays of the Baltic coast lands are of the same age as the upper and lower bowlder clays of the Elbe valley. At present he merely assumes that they are, and expects me to accept his dictum in lieu of direct evidence or reasonable argument.

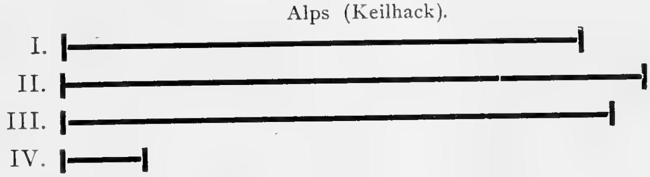
Dr. Keilhack further remarks that if I am right in my view that the terminal moraine of the Baltic Ridge defines the southern limits of a distinct glaciation, he cannot understand why each of the other terminal moraines occurring to the north of it may not also represent the edge of the ice during a distinct glacial epoch. "On this basis," he says, "the so-called 'last glacial epoch' would have to be divided into four if not five epochs, so that even the most fanatical advocate for as many glacial periods as possible would be terrified." I am sorry if Dr. Keilhack cannot distinguish any difference between the position and character of the very pronounced terminal moraine of the Baltic Ridge and the distribution and character of the minor moraines of retreat which lie behind it. For myself I have no more difficulty in distinguishing between the two sets of moraines than I have in the case of the morainic ridges of the inner zone of the Alpine *paysage morainique*. In Britain, just as in the Alpine Vorland and in north Germany, the large moraines of our district- and valley-glaciers are succeeded by numerous smaller moraines of retreat. In North America, also, geologists find no difficulty in differentiating between the first zone of great moraines of the Wisconsin formation, which mark the edge of a separate ice-sheet, and the moraines of retreat that occur behind them.

The southern limits of the Polandian ice-sheet in Britain and Germany alike is bordered by more or less thick banks and sheets of morainic gravels. These are the only terminal moraines connected with the ground-moraine of that ice-sheet. Although the surface of that ground-moraine is often abundantly strewn with fluvio-glacial detritus it shows no lines of terminal moraines comparable to those of the Baltic Ridge in Germany and of the valley-glaciers and local ice-sheets in Britain. The latter bear witness to vigorous glacial action—they have not merely been dumped upon the ground, for the local ice-flow has in many places ploughed into and pushed up preëxisting bowlder clay and ground out hollows in the solid rocks. The terminal moraines of the Baltic Ridge no doubt consist largely of water-worn materials, just as is the case with the moraines of all sheet-like or Piedmont glaciers, and much of the material has been dumped. But they also yield evidence of glacial push, for ground-moraine, confusedly commingled with gravel and sand, not infrequently enters into their composition. The lines of moraines and the irregular mounds, banks, and sheets of water-worn materials which are distributed over the ground between the Baltic Ridge and the shores of the Baltic Sea are simply moraines of retreat and fluvio-glacial deposits, and I hope no "fanatical" glacialist will "terrify" either himself or Dr. Keilhack by suggesting that they indicate "four if not five" separate glacial epochs.

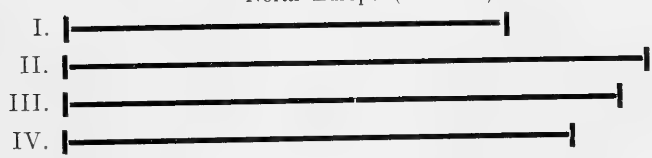
(5) Dr. Keilhack further objects to my conclusion that the terminal moraines of the Baltic Ridge mark the limits of an independent glaciation, because he thinks these moraines cannot be correlated, as I have supposed, with the Alpine valley-moraines belonging to Professor Penck's "first postglacial stage." The Baltic Glacier of my fourth glacial epoch (Mecklenburgian), according to him was of such immense size and so little inferior to the ice-sheets of earlier stages that such correlation as I have attempted is almost impossible. And he gives a graphic repre-

sentation to show the "unnaturalness" of my classification. Such graphic representations, however, unless they are constructed on sound principles, are apt to express rather the views of the draughtsman than the actual facts of nature. Dr. Keilhack's diagrams are, in my opinion, constructed on a wrong principle, and were I to draw similar diagrams they would show a different result. But as my critic would probably be no more satisfied with my graphic representation than I am with his, I prefer to give one constructed a year or two ago by an independent authority—Dr. Du Pasquier, whose recent untimely death every student of glacial geology must deplore. For purposes of comparison Dr. Keilhack's diagrams are also given.

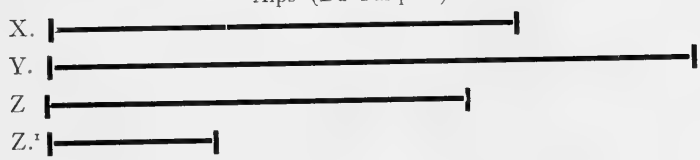
Alps (Keilhack).



North Europe (Keilhack).



Alps (Du Pasquier).



The first thing that strikes one in comparing Dr. Keilhack's representation of the Alpine glacial system with that given by the eminent Swiss geologist is the discrepancy between the lines representing the last three glacial stages (II,III, and IV of Keilhack; Y, Z, Z[1], of Du Pasquier). Dr. Keilhack obtained his lines by simply measuring the length of individual glaciers on the north side of the central Alps, but Du Pasquier has followed a different plan. He says: "La longueur des lignes représentant les glaciations successives est proportionelle aux aires glaciées. Le rapport des aires glaciées aux différentes époques X, Y, Z, Z^1, est presque identique dans le Nord de l'Europe et dans les Alpes, et paraît devoir être exprimé par: 0,7 (?) : 1 : 0,66 : 0,27 en moyenne."[1]

If Dr. Keilhack, instead of estimating the extent of the several ice-sheets of northern Europe by drawing lines from the north end of the Gulf of Bothnia into Germany, will contrast the superficial areas of the successive glaciations he will probably come nearer the truth. He will, at all events, ascertain that De Geer's great Baltic Glacier (Mecklenburgian) large though it was, yet covered a much smaller area than that occupied by the preceding Polandian ice-sheet. Nothing could be more absurd than to describe the last great Baltic Glacier as being "little inferior to those of earlier epochs." It was very much inferior, and quite comparable, as Du Pasquier has said, with the Alpine valley-glaciers which are represented in his diagram by the line Z^1.

In correlating the Alpine valley-moraines of Professor Penck's "first postglacial stage" with the terminal moraines of the great Baltic Glacier I was well aware that no interglacial beds had been observed underlying the former. I knew quite well that the valley-moraines in question were generally considered to mark pauses in the retreat of the great glaciers of the inner zone. Latterly, however, Du Pasquier had begun to doubt if such were really the case. Quite recently he had detected evidence to show that the formation of the moraines of the "first postglacial stage" had been preceded by an interglacial interval of fluviatile or lacustrine accumulation. As Du Pasquier's observations are the first of the kind recorded, I shall quote what he says on the subject:

> Au-dessus de l'étage glaciaire Z (see his diagram) encore deux ou trois systèmes de moraines au moins, se terminant vers l'aval en nappes d'alluvions précèdent les moraines actuelles. Ces systèmes, très clairement marqués

[1] See Bulletin de la Soc. Neuchat. de Geogr., VIII (1894–5).

dans les Alpes, se retrouvent en Ecosse ; ils ne paraissant pas avoir encore été suffisamment étudiés ailleurs. Ces moraines terminales, échelonnées le long des vallées, marquent-elles simplement, comme on l'admet d'ordinaire, des moments d'arrêt dans la retraite générale des glaces? Il nous paraît bien douteux qu'il ne s'agisse que de cela. D'abord, comme nous l'avons dit en traitant des glaciers actuels, les moraines terminales ne se produisent guère que pendant l'arrèt qui sépare une phase de crue d'une phase de décrue consécutive. D'autre part, dans notre Jura en particulier, certaines localités nous présentent, entre les moraines Z et d'autres subséquentes soit Z^1, des dépôts fluviaux ou lacustres assez considérables qui font penser que le drainage glaciaire avait fait place à un drainage fluvial. Ces moraines jurassiennes Z^1, nous paraissent être équivalentes à certaines moraines alpines qui forment un ensemble bien caractérisé et qui seraient elles-mêmes équivalentes aux moraines dites baltiques de l'Europe septentrionale. Nous pensons donc plutôt que ces moraines Z^1, marquent une époque glaciaire distincte, sans préjuger en aucune façon de la valeur de l'intervalle interglaciaire qui les sépare de l'époque Z et qui dut, à en juger par l'importance relative des phénomènes d'altération, être bien plus court que les précédents. [1]

I have now I think taken note of all Dr. Keilhack's remarks and criticisms which seem to call for any reply.

James Geikie.

[1] Loc. cit.

THE POST-PLEISTOCENE ELEVATION OF THE INYO RANGE, AND THE LAKE BEDS OF WAUCOBI EMBAYMENT, INYO COUNTY, CALIFORNIA.

THE following notes are the result of observations made in the summers of 1894 and 1896. My routes were: first, from Alvord Station on the Carson and Colorado Railroad eastward on the Saline Valley road, passing through Waucobi Canyon and over the divide seventeen miles E. S. E. of Alvord; second, from Alvord through Soldier Canyon, over the range to Deep Spring Valley.

As seen from the foothills of the Sierra Nevada, looking across Owens Valley, the axis of the low portion of the Inyo-White Mountain Range, between Soldier Canyon and the ridge south of Waucobi Canyon, arches strongly to the eastward, and forms a broad embayment between Soldier Canyon on the north and the head of Waucobi Canyon on the south. (Fig. 1.) The range from east of the divide at the head of Owens Valley to Owens Lake is practically one, but unfortunately it has been given the name of White Mountain to the north and of Inyo Range[1] to the south of the embayment. Inyo is here used to include the range south of Soldier Canyon. For the broad embayment formed I use the name Waucobi, and for the ancient lake in which the lake beds were deposited the name Waucobi is also adopted. It was the examination of the lake beds deposited in Waucobi embayment that led me to conclude, from their position, that a marked orographic movement had taken place in the Inyo Range since Pleistocene time.

In crossing Owens Valley, from Alvord Station eastward, the lake beds are met with about a mile and a half east of the station, at an elevation of 100 feet above the railroad track. (*a*, Fig. 2.) They extend north of this point along the western

[1] Am. Jour. Sci., March 1895, 3d series, Vol. XLIX, p. 169.

foot of the White Mountain Range for fifteen miles or more. Near Black Canyon they occur well up the slopes, and traces of them were seen north of a line passing through Bishop Station; to the south they appear for a short distance beyond the entrance to Waucobi Canyon. As seen from Alvord Station, the

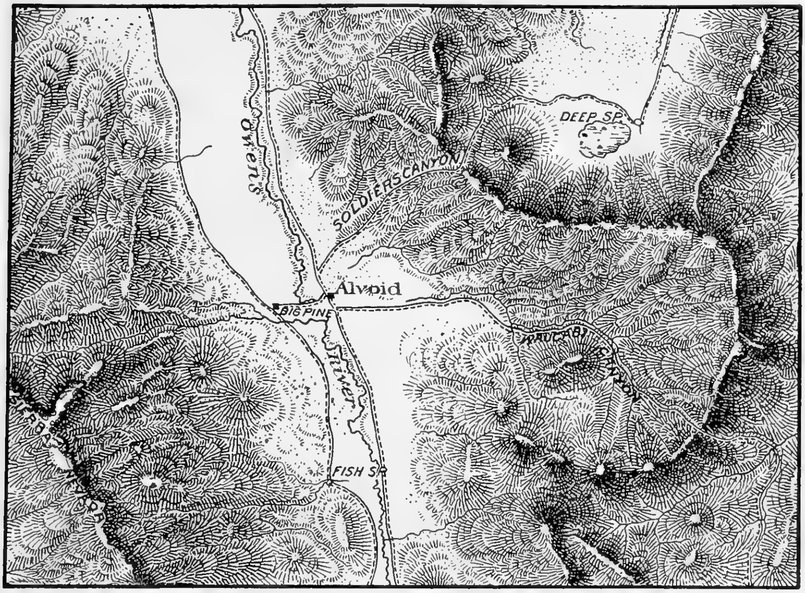


FIG. 1. Map showing the general relations of Soldier and Waucobi Canyons to Owens Valley and the Inyo Range. (Taken from Lieutenant Wheeler's map.)

beds extend from the south side of Waucobi Canyon north across the broad embayment to Soldier Canyon, and westward from three to ten miles, rising with the slope to the foot of the encircling ridge of Cambrian quartzites. (*b*, Fig. 2.) The beds at the Devils Gate in Waucobi Canyon are 2250 feet above the lowest bed exposed east of Alvord, and appear to be the same as those at the lower level; they extend on up the canyon to a level 3100 feet above the valley bottom at Alvord Station and within about three miles of the summit (below *c*, Fig. 2) at the head of the canyon.

The strata of the lake beds section three miles up the canyon are largely a fine calcareous deposit, with more or less arenaceous and argillaceous matter in the form of fine sand. Some of the white beds are made up almost entirely of the remains of fresh-water shells of the following genera, as identified by Dr. W. H. Dall: Valvata, Planorbis, Pisidium ?, and possibly Amnicola and Pampholyx. The species are undetermined, but resemble *Val-*

FIG. 2. View of Waucobi embayment from the foothills of the Sierra Nevada. *a* Lake beds at the level of Owen's Valley; *b*, contact of lake beds with the Cambrian quartzites; *c*, point above the highest exposure of the lake beds in Waucobi Canyon; *d*, point of Inyo Range overlooking Deep Spring Valley on the east; *e*, Waucobi Mountain south of Waucobi Canyon.

vata sincera Say and *Planorbis parvus* Gld. "Any of them might be recent or Pliocene; my impression from the mass is that they are Pleistocene."

As the beds approach the steeper slope of the mountain, about ten miles above the mouth of Waucobi Canyon, the sediments become coarser and coarser, and brown arenaceous beds predominate over the drab and light gray sediments. Near the contact with the quartzites, a little below Devils Gate, bowlders of the quartzite a foot or more in diameter occur in the coarse sediments, and the contact of the lake beds and the Cambrian quartzites is finely shown on the south side of the canyon.

At a point about two miles above Devils Gate, and 3000 feet above the lowest lake bed observed in Owens Valley, there is a fine exposure on the south side of the Saline Valley road, which is the highest seen in the canyon that might be referred without doubt to the lake beds. The band exposed is about six feet in thickness, formed of layers of white, very finely granular sediment, which crumbles under strong pressure. It is capped by

FIG. 3. Lake beds, Waucobi Canyon, Inyo Range. About five miles above Owens Valley. The dark Cambrian rocks of the White Mountain Range north of Soldier Canyon are shown on the left upper half of the plate.

layers of fine conglomerate formed of small angular fragments of quartzite.

The greatest thickness of the beds observed at any one point was estimated at 150 feet. The finer, light colored calcareous beds vary from sixty to seventy-five feet in thickness. Near the valley the average dip is 3° to 5°. About two miles up it increases to 10° for a short distance and then changes to from

3° to 5° in its continuation up the canyon. The rise of the canyon bottom is nearly coincident with that of the lake beds.

The upper surface of the lake beds throughout the Waucobi embayment is covered by a layer of débris formed of fragments of arenaceous limestone, siliceous shale, and quartzite that have been brought down from the mountain slopes. Numerous washes and canyons have cut through this mantle of drift and more or less into the lake beds beneath. The general character of the deposit is well shown in the accompanying figure (Fig. 3).

The lake beds are of essentially the same character as those described by Mr. G. K. Gilbert as occurring in the Lake Bonneville basin, and by Professor I. C. Russell as occurring in the Lake Lahontan basin.[1] They were evidently deposited in the bottom of a lake, into which, near the shore line, coarse material was washed from the mountains, the finer sand and silt being carried farther out and deposited with the calcareous sediment and remains of fresh-water shells.

There may be no *a priori* reason why such deposits should not have been made upon a lake bottom sloping from 3° to 5°, but this is improbable, and it would presuppose the existence of a lake 3000 feet in depth over the site of the present Owens Valley. If such a lake existed, there must have been a barrier to the south of Owens Lake, of which no trace now remains. This is not at all probable. South of Owens Lake the divide is about 220 feet above the lake.[2] There is no appearance, as viewed from the south end of the Inyo Range, of the remains of a great barrier between Owens Lake and the drainage basin to the south.

A second conception is that the Inyo Range has been elevated, the range and the country to the eastward rising and tilting the lake beds toward Owens Valley and the Sierra Nevada.

The accompanying diagrammatic sketch (Fig. 4) illustrates the relations of the Sierra Nevada, Owens Valley, the Inyo Range, and the lake beds resting on the westward slope of the Waucobi embayment.

[1] Mon. U. S. Geol. Survey, Vols. I and XI.

[2] Owens Lake, 3567 feet above sea level; Hawai meadows, 3782 feet at divide. Wheeler).

The view of the lake beds taken from the foothills of the Sierra Nevada, looking eastward across Owens Valley, shows the lake beds at *a*, Fig. 2, at the level of the valley, and various outcrops from point to point toward the foot of the mountain at *b*.

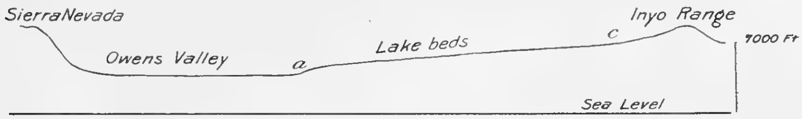


FIG. 4. Diagrammatic outline section from the Sierra Nevada to the summit of the Inyo Range, a little north of Waucobi Canyon.

The lake beds continue up Waucobi Canyon to a point approximately beneath the letter *c*, where, as previously stated, they are 3000 feet higher than the lowest beds at *a*.

The view includes the greater part of the Waucobi embayment, but does not extend on the north (left) as far as Soldier Canyon. The high point at *d* forms the summit of the ridge east of the Waucobi embayment and overlooks Deep Spring Valley to the northeastward. This part of the range, from *d* to the head of the Waucobi Canyon above *c*, forms the eastern portion of the block which appears to have been tilted toward the base of the range at *a*. On the northeastern side the slope of the range extends down to the level of Deep Spring Valley. It was on the southeastern side of this valley that I found evidence of a comparatively recent fault which is of great interest in connection with the view that the Inyo Range has been raised to the eastward and tilted to the westward within comparatively recent times. The best locality at which to examine the fault line is on the southern side of the valley, at a point about seventeen miles north of the head of Waucobi Canyon. Here there is evidence that the bottom of the valley is sinking in relation to the mountains on the southeastern side. This is shown by the presence of a comparatively recent fault scarp at the foot of the ridge and the truncating of the spurs along the base of the ridge where the fault scarp is not otherwise defined. Great springs flow out along the line of the fault, and Mr. Lewis Payson informed me that he had been unable to find bottom, by any means at his command, in the large pools into which the springs flow, and that where wagons formerly crossed, at the southeastern end of the flat surrounding the springs, animals are frequently mired in the soft mud of the flat. The fault cuts through the Pleistocene, leaving a northward-facing wall from twenty to thirty feet in height overlooking the pools and bogs. A distant view of the ridge on the southeastern side of the valley is shown in Fig. 5. The fault scarp mentioned is directly beneath *a*, and the extension of the fault crosses the ridge a little to the right of *a*.

The eastern slopes of the Inyo Range ten miles south of Waucobi Canyon, and south of the road which passes east from the divide to Saline Valley, are very steep and join the bottom of Saline Valley as abruptly as the ridge on the southeastern side of Deep Spring Valley meets the level valley bottom. (Fig. 5.) Until a good topographic map of this region is made, it will be impossible to trace and connect the relations of the various faults and evidences of comparatively recent disturbance; but I think that there is sufficient evidence in the sinking of the southern margin of Deep Spring Valley, in the phenomena observed to the south in Saline Valley, and in the position of the Waucobi lake beds, to sustain fairly well the view that the range has been elevated to the eastward and tilted to the westward.

The total amount of the uplift cannot be accurately determined, as there was undoubtedly a slope at the bottom of Waucobi Lake from its margin toward the present site of Owens Valley. It was probably not much greater than, if as great as, the elevation of the present divide south of Owens Lake, which is about 220 feet. It is to be borne in mind, however, that perhaps in the tilting of the range the western edge under Owens Valley has been depressed, and that the valley has been silted up by the wash brought down by the river and from the adjoining mountains, quite as rapidly as, if not more rapidly than, the tilting of the Inyo Range has carried down the floor of the valley. If this is correct, the total elevation of the range since the lake beds were deposited may be as great as or greater than the difference in the level of the lake beds at the margin of the valley and the highest point in Waucobi Canyon, or 3000 feet. There are so many factors that might be considered with more data, that only an approximation can now be made of the total displacement. We are justified, I think, in placing it at about 3000 feet, and

FIG. 5. View of southeastern portion of Deep Spring Valley, showing pond near spring, and the north face of the ridge that extends northeastward from the Inyo Range. *a*, Position of fault cutting through the ridge; *b*, southwestern end of the ridge where it unites with the Inyo Range.

thus recording the fact that a movement of considerable magnitude has occurred. That the movement is comparatively recent is proved by the characters of the lake beds and their contained fossils, which indicate the age of the deposits to be late Pliocene or Pleistocene.

It is interesting to note in this connection the account of the earthquake that occurred in Owens Valley in 1872. This earthquake, according to Professor J. D. Whitney,[1] originated in Owens Valley, and its occurrence was accompanied by a sinking of strips of land. Mr. G. K. Gilbert visited Owens Valley eleven years later, and in his observations on the subject he says

[1] The Owens Valley earthquake. Overland Monthly, Vol. IX, 1872, pp. 130–140 and 266–278.

that "the principal scarp produced by the earthquake follows the base of the alluvial foot slope of the Sierra Nevada, and has a maximum height of about twenty feet. Where this height is attained there is a companion fault scarp ten feet high facing in the opposite direction, so that the net displacement is about ten feet. At other points the main scarp is associated with others running nearly parallel and facing in the same direction."[1]

Professor Whitney, in his discussion of the earthquake[2] suggests that such disturbances might have their origin in the compression exercised by an enormous weight of material raised to a vertical height of two or three miles above the surrounding country.

The extent of the tilting of the Inyo Range to the south of Waucobi Canyon is not readily determinable. The eastern face of the range, toward Saline Valley, indicates the presence of a fault line, and the steepness of the slopes near the valley that the faulting is of relatively recent date. On the Owens Valley side the slopes are also steep, but at the mouths of the canyons there are great accumulations of talus that extend far out into the valley, and the monoclinal character of the range is broken by the presence of arching masses of strata of Triassic age, dipping westward.

North of the embayment, along the high, broad mass of the White Mountain Range, no evidence of recent elevation or tilting was observed in the hurried trip through Owens Valley along the western foot of the range.

In a paper now in preparation I shall describe certain types of faulting and tilting of monoclinal blocks of strata that are characteristic of the Great Basin area of Utah, Nevada, and southeastern California. The principal illustrations will be taken from faulted slabs of limestones collected in Waucobi Canyon on the western slope of the Inyo Range, and it is anticipated that they will aid in explaining the dynamics of such a movement as has evidently taken place in that portion of the Inyo Range which is described in this paper.

CHARLES D. WALCOTT.

[1] Mon. U. S. Geol. Survey, Vol. I, 1890, p. 361.

[2] Loc. cit., p. 276.

ITALIAN PETROLOGICAL SKETCHES.

V. SUMMARY AND CONCLUSION.

THE volcanoes which have been described in the preceding papers belong to the main Italian line which extends west of the Apennines from Tuscany to Naples, and which may be called the Bolsena-Vesuvius line. In a paper already quoted on the "Extinct Volcanoes of the Northern Apennines" de Stefani[1] calls attention to the fact that these volcanoes may be referred to two distinct types, distinguished not only by their structure, but by their eruptive rocks.

One type is that of the great strato-volcanoes, represented at Bolsena, Viterbo, Bracciano, and the Alban Hills, as well as at Rocca Monfina and Vesuvius farther south. The main structural features of these have been already noticed. Petrographically these strato-volcanoes are characterized by two features. In the first place leucitic rocks are very abundant at all of them, and form indeed their dominant and most characteristic feature. These are accompanied in most cases, not always, by non-leucitic rocks—ciminites and vulsinites, with exceptionally phonolite at Viterbo and toscanite at Bracciano. True trachytes are met with in abundance in the Vesuvian region and in small amount at Rocca Monfina, but elsewhere seem to be rare. Their second characteristic is the variety of eruptive products at each center, both among the leucitic and the non-leucitic rocks, as well as the abundance of tuffs. Though the variety be great, yet the rocks of each bear a great resemblance to those of the other centers, so much so that the whole line (including the centers of the second type) form an excellent example of a "petrographical province," and it is clear that the products of all the centers are related to each other genetically.

[1] DE STEFANI, Boll. Soc. Geol. Ital., X, 449–555, 1891.

To the northwest of Bolsena and between the line of volcanoes just noticed and the coast are the eruptive centers forming de Stefani's other type. The most noteworthy are those at Campiglia, Rocca Strada, Monte Catini, Monte Amiata, Radicofani, Tolfa, and Cerveteri. These are all of relatively small extent, and are in general higher in proportion to their breadth than the strato-volcanoes. Some of them, as Tolfa and Cerveteri, were superfusive and apparently formed by domal eruptions of a pasty magma. Monte Amiata was probably a true strato-volcano.[1] According to Lotti[2] the Campiglic mass was laccolitic in character, being covered by arching Eocene beds. It is noteworthy that dikes, which are practically unknown elsewhere, are quite numerous here.

As de Stefani points out, these smaller eruptions differ from the large volcanoes in two important petrographical particulars. First, each individual mass is made up substantially of one kind of eruptive rock, the rock type at each being practically persistent throughout the mass. This persistency of type at each is in marked contrast with the great variety of products found at each of the strato-volcanoes. In the second place these smaller eruptions seem never to have produced leucitic rocks—at least none are known with certainty to occur as their products. They are uniformly non-leucitic and trachydoleritic, and extreme in type—either acid or basic. The rocks of Campiglia, Rocca Strada, Monte Amiata, Tolfa, and Cerveteri belong to the toscanites—acid trachydolerites with over 65 per cent. of silica with or without free quartz; while those of Radicofani, and probably also those of Monte Catini, are basic in character, with SiO_2 about or below 55 per cent., and belong either to the ciminites or the basalts.

TRACHYDOLERITES.

The intermediate potash-rich rocks which are found along the Bolsena-Vesuvius line carry *basic* plagioclase-labradorite to

[1] De Stefani, Boll. Com. Geol. Ital., 1888, 223.

[2] Lotti, cf. Dalmer, Neu. Jahrb., 1887, II, 207.

anorthite—along with orthoclase, and such rocks will be called collectively in this paper by the name of *trachydolerite*, a name proposed by Abich[1] as far back as 1841. This term seems the more appropriate since one of his type rocks is that of Monte Santa Croce at Rocca Monfina, which has the mineralogical characters of one of the subgroups with the chemical composition of another. For those intermediate effusive rocks in which the plagioclase occurring along with orthoclase is *acid*—andesine to oligoclase—the name *trachyandesite*,[2] which is in use in France, will be reserved.

Ciminite.—The rocks belonging to this group are porphyritic in structure, the phenocrysts being of augite, olivine, and sometimes feldspar, and the rather light to dark groundmass being seen under the microscope to be generally a holocrystalline paste of feldspar with augite and magnetite grains, glass base being rare. The lamprophyric habit of some of the specimens has been remarked on. The ciminites are characterized mineralogically by the presence of *alkali feldspar* and a *basic plagioclase*, *augite* and *olivine*, with accessory *magnetite* and *apatite*. Biotite and hornblende (especially the latter) are either entirely absent or only present in small amount. Chemically they are rather basic, silica varying from 54 to 57 per cent.; alumina is moderately high, as are the iron oxides; magnesia and lime quite high, respectively 3 to 6 and 5 to 9 per cent. Alkalis are low for the rocks of the region, but potash is uniformly higher than soda. These rocks do not seem to be very abundant, except at the Monti Cimini, where they apparently occur in large quantities.

In Table I are given all the reliable analyses of these Italian rocks which are known to the writer, together with those of the rocks of Radicofani. Of these No. 1 of the flow at Fontana di Fiesole, near Viterbo, may be regarded as typical. Vom Rath's analysis (No. 2) of a similar rock from the same region closely agrees with this, the chief discrepancy being found in the alkalies,

[1] Abich, Vulk. Erscheinungen, Brunswick, 1841, 100.

[2] This term has been used in a more general sense in the preceding papers.

TABLE I.

ITALIAN CIMINITES.

	1	2	3	4	5	6	7	8	9	10	11
SiO_2	55.44	58.67	56.32	56.76	56.42	57.95	57.73	54.83	55.00	53.63	55.23
Al_2O_3	18.60	15.07	18.17	16.79	16.81	12.52	17.85	20.17	14.38	14.17	14.06
Fe_2O_3	2.09	.....	2.23	2.07	3.26	.....	4.44	4.77	.....	1.46	5.06
FeO	4.48	8.35	6.47	6.95	6.92	5.44	3.90	3.86	9.29	8.07	4.12
MnO	.....	.....	.....	.....	0.23	1.70	.....	.....	.....	Trace	0.57
MgO	4.75	2.97	2.84	1.63	3.50	5.27	1.77	1.93	7.72	7.05	4.00
CaO	6.76	8.07	5.33	6.01	5.64	3.80	3.65	4.12	8.51	8.52	9.34
Na_2O.......	1.79	3.36	1.80	2.43	1.21	3.27	3.77	3.04	2.25	1.80	2.07
K_2O	6.63	3.50	4.18	4.67	3.07	4.78	7.65	7.38	2.52	2.03	2.43
H_2O	0.25	0.82	2.15	2.44	2.25	5.49	0.09	0.46	0.48	2.01	1.07
TiO_2	0.16	.....	.....	.....	.....	.....	.....	.....	.....	SO_3 0.62	SO_3 0.84
P_2O_5	Trace	.....	0.34	0.47	1.08	.....	Trace	.....	.....	0.93	1.33
	100.95	100.81	99.83	100.22	100.39	100.22	100.85	100.56	100.15	100.29	100.12
Sp. gr.	2.700	2.765	2.52	2.47	2.625	2.668	2.61	.....	2.808	2.79	2.683

NOTES TO TABLE I.

1. Fontana Fiesole, Viterbo, H. S. Washington anal., JOUR. GEOL., IV, 849, 1896.
2. West slope of Monte Cimino, vom Rath, Zeit. d. d. geol. Ges., XX, 304, 1868.
3. Mont' Alfina, Bolsena Region, Ricciardi anal., Klein, Neu. Jahrb. B. B., VI, 7, 1889.
4. Sassara, Bolsena Region, Ricciardi anal., Klein, *loc. cit.*, 7.
5. Monte Rado, Bolsena Region, Ricciardi anal., Klein., *loc. cit.*, 33.
6. Above Ortaccio, Campiglia, Tuscany, vom Rath, *loc. cit.*, 331.
7. L'Arso, Ischia, Fuchs, Tscher. Min. Mitth., 1872, 230.
8. Scoria, Le Cremate, Ischia, Fuchs, *loc. cit.*, 231.
9. Radicofani, vom Rath, Zeit. d. d. geol. Ges., XVII, 405, 1865.
10. Radicofani, doleritic variety, Ricciardi anal., Mercalli, *op. cit. post.*
11. Radicofani, andesitic variety, Ricciardi anal., Mercalli, *op. cit. post.*

which sum up about the same, but whose relative proportions are quite different. Ricciardi's two analyses of "olivine-bearing andesitic trachyte," Nos. 3 and 4, are quite typical, though the alkalies are rather low, as is generally the case in his analyses. These rocks evidently belong to the ciminites, as has been noted on a previous page.[1] It seems proper also to class with the ciminites the so-called augite-andesite of Monte Rado in the Bolsena region[2] on the strength of Ricciardi's analysis (No. 5), though it shows rather more iron and less alkalies than the first four. While Klein does not definitely speak of orthoclase as present, he refers the high potash either to the glass or to the presence of orthoclase or anorthoclase among the feldspar laths. No. 6 is of an "augite-porphyry" forming a dike at Campiglia, described by vom Rath, who says that "it does not agree with any rock heretofore described in petrography." It is porphyritic in structure, showing phenocrysts of orthoclase, plagioclase, augite, a little biotite and quartz, and quite abundant, generally serpentinized, olivines, which lie in a light to dark greenish gray groundmass. The rock examined was evidently much decomposed, but the analysis resembles in general those of the ciminites, though alumina is decidedly low.

Analysis No. 1 yields the following approximate composition:

[1] JOUR. GEOL., IV, 554, 1896.

[2] JOUR. GEOL., IV, 554, 1896.

Orthoclase,	39.4
Albite,	15.2
Anorthite,	22.8
Olivine,	10.2
Diopside,	8.7
Magnetite,	3.0
Accessory,	0.7
	100.0

I have also included among the ciminites, both on mineralogical and chemical grounds, the well-known "trachyte" of L'Arso on Ischia. This has long been known as an instance of the exceptional occurrence of olivine in trachyte, and has been taken by Rosenbusch[1] as the type of one subgroup of his "andesitic trachytes." Judging from an examination of a number of sections from specimens collected on the spot, plagioclase is not as abundant as in the Viterbo or Bolsena rocks. There are, however, some phenocrysts with multiple twinning lamellæ whose extinctions show them to be labradorite, Ab_1 An_1 or more basic; and a certain portion of the groundmass feldspar laths are of a similar plagioclase. Olivine, while present in my specimens, is not as abundant as at Viterbo, but a colorless diopside or augite is the prominent and abundant ferromagnesian constituent.[2] These observations agree with the analyses by Doelter of the main flow (No. 7) and of the scoria of the crater at Le Cremate (No. 8), which show less magnesia and lime and more alkali than in the typical ciminites.

Though we possess no reliable analysis of it, the so-called "biotite-trachyte" of Monte Catini in Tuscany may perhaps be regarded as closely related to the ciminites. Both orthoclase and a (basic ?) plagioclase are present and some pilite pseudomorphs after olivine are noted by Rosenbusch,[3] who also remarks upon its lamprophyric character. The rock is very remarkable for the abundance of olivine along with biotite.

[1] ROSENBUSCH, Mikr. Phys., II, 773, 1896.

[2] I could find no traces of the leucite mentioned by vom Rath.

[3] ROSENBUSCH, Neu. Jahrb., 1880, 206, and Mikr. Phys., II, 764, 1896.

Closely related to the ciminites, if not to be classed with them, are the interesting rocks of Radicofani. This is a small hill a few kilometers east of Monte Amiata. The rock has been studied microscopically by Weiss,[1] Bucca,[2] and Mercalli.[3] Two varieties are to be distinguished—a doleritic and an andesitic. The former is dark gray to black, very compact and of specific gravity 2.79 (Mercalli). Augite, olivine, and feldspar phenocrysts are visible. Microscopically they resemble the dolerites, numerous large crystals of pale augite, olivine, and plagioclase (with a few of orthoclase, according to Mercalli), lying in a groundmass composed of microlites of plagioclase, magnetite, and apatite in a dark glassy base. The olivines in this rock are generally altered to fibrous green serpentine. The andesitic variety is light gray, of a trachytic aspect and specific gravity 2.683 (Mercalli). It shows phenocrysts of olivine. In thin sections are seen phenocrysts of plagioclase, orthoclase, augite, and olivine (the last altered to a reddish substance on the borders) lying in a groundmass of abundant feldspar microlites and magnetite grains, with a rather scanty yellowish glass base. It is seen that while the first variety is mineralogically a basalt, the second is a ciminite.

Three analyses of these rocks are given in Table I. Vom Rath's (No. 9) is of a specimen of the andesitic variety and is similar to those of Ricciardi. Ricciardi's (Nos. 10 and 11) differ from each other notably only in the silica, which is quite low in the doleritic variety though still higher than in normal basalts, and in the magnesia, which is extremely high in the more basic variety. Thus while the silica percentage is about that of the ciminites, alumina is decidedly lower (about that of the toscanites), iron higher, magnesia and lime very high, and alkalies low, but still higher than in normal basalts, and with potash above soda. From these analyses it seems probable that some of Bucca's and Mercalli's plagioclase is to be referred to alkali

[1] Cf. vom Rath, Zeit. d. d. geol. Gesell., XVII, 405, 1865.

[2] Bucca, Boll. Com. Geol. Ital., 274, 1887.

[3] Mercalli, Atti. Soc. Ital. Sci. Nat., XXX, 1887.

feldspar—perhaps triclinic, and also that the plagioclase must be either a basic labradorite or anorthite. These rocks may then be regarded as among the more basic members of the ciminites.

We may finally allude briefly to the fact that at Rocca Monfina so-called basalts occur as products of the last phase of activity, and that there is reason for thinking that these rocks much resemble those of Radicofani and may be regarded as basic ciminites.[1]

Vulsinite.—The rocks belonging to this group are porphyritic in structure and megascopically look much like typical trachytes. Feldspar phenocrysts are especially prominent and with them are seen smaller crystals of augite and rare tables of biotite. The groundmass is light gray and in most cases is holocrystalline, or nearly so, glass being present in only small amount in the specimens examined. The feldspars comprise *orthoclase and soda orthoclase* and a *basic plagioclase*—labradorite to anorthite—in quite large amount. The ferromagnesian minerals are typically represented by *augite* or *diopside*, though *biotite* is accessory and is very abundant in some of the basic varieties. Hornblende is lacking at all the Italian localities examined, except for the occasional presence of sporadic crystals of barkevikite. *Magnetite* is generally present, but not in large amount. Both quartz and olivine are wanting, or only present sporadically.

The chemical composition of these rocks is shown in Table II.

They are rocks of medium acidity, the silica varying from 55 to 60 per cent., or perhaps somewhat over. Alumina and iron oxides are in about the same amounts as in the trachytes, magnesia somewhat higher, lime quite high (3 to 6 per cent.), and alkalies in the most representative rocks very high, with potash largely preponderating over soda. No. 1 may be regarded as the type analysis of a specimen from Bolsena. With this the analyses of vom Rath (No. 2) and Ricciardi (No. 3) agree fairly well, the greatest difference being in the alkalies. In No. 1 these are high, with potash greatly in excess of soda, while in

[1] JOUR. GEOL., V, 1897.

vom Rath's their total amount is about the same but the relative quantities quite different, and in Ricciardi's they are both much lower than in No. 1, but with potash in excess. It may be remarked that these mutual differences are fairly constant elsewhere and point to differences in analytical methods rather than to differences in composition.

Another typical vulsinite was found near Vetralla in the Viterbo region, and its analysis (No. 4) closely agrees with that of the Bolsena rock. The San Magno vulsinite (No. 5) is quite similar, though the silica is a little higher and the alkalies low. In regard to the rocks from Torre Alfina and San Lorenzo (Nos. 6 and 7) I must confess to some hesitation. Klein mentions olivine as occurring in notable quantity, though both analyses show small amounts of magnesia and high silica. The analyses resemble, indeed, much more those of the acid toscanites, and it seems probable that they were not made on the specimens examined by Klein. No. 8 is by Ricciardi of a specimen from the Piano delle Macinaje at Monte Amiata sent him by Verri.[1] The analysis is essentially that of a vulsinite. This view is confirmed by the description of Artini,[2] who states that it is gray, porphyritic, and composed of large phenocrysts of sanidine, smaller but more numerous phenocrysts of plagioclase, showing a core of bytownite, a border of andesine, with augite and biotite, lying in a groundmass of feldspar, augite, and glass.

Analyses 1 and 4 yield the following approximate compositions, though the results are uncertain, owing to our ignorance of the composition of the biotite and augite:

	1	4
Orthoclase,	49.5	44.3
Albite,	21.7	27.0
Anorthite,	14.4	14.1
Diopside,	6.4	3.2
Biotite,	3.4	4.8
Accessories,	4.6	6.6
	100.0	100.0

[1] RICCIARDI speaks of it as labeled "the main mass of Monte Amiata." VERRI corrects this error later (Boll. Soc. Geol. Ital., VIII, 1889).

[2] ARTINI, Giorn. Miner., IV, 7, 1893.

TABLE II.

ITALIAN VULSINITES.

	1	2	3	4	5	6	7	8	9	10
SiO_2	58.21	59.22	57.97	57.32	60.03	63.22	63.26	59.73	55.69	55.08
Al_2O_3	19.90	18.56	17.65	19.85	17.05	16.26	16.05	16.79	19.08	17.25
Fe_2O_3	4.11	....	0.63	2.21	1.83	1.41	1.04	1.44	4.07	....
FeO	0.87	6.06	7.50	2.35	4.15	3.84	6.13	3.21	3.26	9.33
MnO	....	....	0.09	....	0.09	Trace	0.14	....	Trace	....
MgO	0.98	1.12	1.71	1.60	1.12	1.25	1.29	1.47	3.41	2.77
CaO	3.58	2.96	5.53	3.82	6.58	4.75	5.50	3.27	6.87	7.34
Na_2O	2.57	4.87	1.50	3.22	2.31	2.42	1.62	4.31	2.89	1.86
K_2O	9.18	6.66	5.31	9.15	5.12	4.18	3.18	6.09	4.41	5.32
H_2O	0.74	1.14	1.82	0.57	1.42	1.87	1.57	3.93	0.17	0.17
TiO_2	Trace	....	....	....	....	....	....	....	....	....
P_2O_5	Trace	....	0.42	....	0.42	1.07	0.51	....	....	....
	100.14	100.59	100.13	100.09	100.12	100.27	100.29	100.24	99.85	99.12
Sp. gr.	2.534	2.548	2.451	2.611	2.543	2.481	2.416		2.717	2.713

NOTES TO TABLE II.

1. Bolsena, H. S. Washington anal., JOUR. GEOL., IV, 552, 1896.
2. Bolsena, Vom Rath, Zeit. d. d. geol. Ges., XX, 291, 1868.
3. Bolsena, Ricciardi anal., Klein, Neu. Jahrb. B. B., VI, 8, 1889.
4. Vetralla, near Viterbo, H. S. Washington anal., JOUR. GEOL., IV, 849, 1896.
5. San Magno, Latera, Bolsena, Ricciardi anal., Klein, *loc. cit.*, 10.
6. Torre Alfina, Bolsena, Ricciardi anal., Klein, *loc. cit.*, 3.
7. San Lorenzo, Bolsena, Ricciardi anal., Klein, *loc. cit.*, 3.
8. Monte Amiata, Ricciardi, Gazz. Chim. Ital., XVIII, 1888.
9. Monte Santa Croce, Rocca Monfina, H. S. Washington anal., JOUR. GEOL., V, 252, 1897.
10. Monte Santa Croce, Vom Rath, Zeit. d. d. geol. Ges., XXV, 245, 1873.

In the last rock (9 and 10) we have an example of the mutual exclusion of biotite and olivine in the Italian and other trachydolerites, to which attention has already been called by Rosenbusch.[1] It is mineralogically a biotite-vulsinite, in that it is free from olivine, but chemically a ciminite, the silica being low and magnesia and lime high. The explanation of this peculiarity may be looked for in the complexity of the biotite molecule. It was pointed out by Iddings[2] that, since the biotite molecule may be regarded as made up of molecules of olivine $2(Mg, Fe)\ O, SiO_2$ and feldspathoid molecules of the form $(H, K)_2\ O. Al_2O_3. 2\ SiO_2$, under conditions where the complex biotite molecule would be unstable it would dissociate, resulting in the formation of crystals of olivine and of a potash-alumina silicate, either leucite or orthoclase, according to circumstances. This explanation has also been adopted by Bäckström[3] in the case of the leucite-basanites of Volcanello, he considering them to be the effusive forms of magmas which would appear intrusively as minettes or kersantites. The same idea has lately been alluded to by Pirsson,[4] who adds: "This process would of course find its most natural expression in magmas rich in magnesia and potash," which, it will be observed, is the character of the ciminite magma.

[1] ROSENBUSCH, Mikr. Phys., II, 773, 1896.

[2] IDDINGS, Origin Igneous Rocks, Bull. Phil. Soc. Washington, XII, 166, 172, 1892.

[3] BÄCKSTRÖM, Geol. Fören. Stockh. Förh., XVIII, 155, 1896.

[4] PIRSSON, JOUR. GEOL., IV, 687, 1896.

Applying this idea to the rocks at hand it is evident that we may regard the olivine-bearing ciminites as formed from rather basic trachydoleritic magmas, rich in magnesia, which under other conditions of solidification would have assumed the form of biotite-vulsinites—thus adding another to the number of cases of magmas of the same chemical composition forming on solidification different mineral aggregrates. In this connection and as favoring this view of the dissociation of the biotite molecule may be mentioned the great paucity in biotite of all the leucitic rocks of Italy, and, it may be added, of the purely orthoclase-trachytes of Ischia. There seems to be, indeed, as demanded by the theory, a mutual exclusion of biotite and leucite. Olivine, it is true, is not very abundant in the leucitic rocks, except at Vesuvius, the magnesia generally entering into the pyroxene molecules, perhaps owing to the richness of the magma in CaO.

Toscanite.—The rocks belonging to this group are highly porphyritic and a glassy groundmass is often met with, though holocrystalline forms occur. They are characterized by the presence, along with the *alkali feldspar*, of a *plagioclase* which is rather more acid than in the preceding groups, generally varying from andesine to labradorite, though anorthite is found at Monte Amiata and elsewhere. The most constant and prominent ferromagnesian mineral is *biotite*, which is never wholly wanting, and at some localities, as at Campiglia and Rocca Strada, is the only colored constituent. In other places (Bracciano, Cerveteri, and Tolfa) *augite* or *diopside* is abundant along with the biotite; while again, as at Monte Amiata, *hypersthene* replaces augite as companion to the biotite. *Quartz* is often present, either in well-shaped crystals or as anhedra, but olivine is never found. *Magnetite* is rare or absent. Silica is much higher than in the other groups, varying from 65 to 73 per cent., alumina and iron are low, magnesia and lime high considering the acidity, and the alkalies also high, with potash higher than soda. We may then regard the toscanites as acid *biotite-trachydolerites*, and the rocks of Bracciano, Cerveteri, and Tolfa would be *augite-toscanites*, while those of Monte Amiata would be *hypersthene-toscanite*, if such a subdivision be deemed advisable.

In Table III are given the best analyses of the representative Italian toscanites. Those from Bracciano, Cerveteri, and Tolfa (Nos. 1, 2, 3, 4, and 5) have been already described. Attention need only be called to the richness of the San Vito rock in Na_2O relative to K_2O, as shown by Dr. Röhrig's analysis, and confirmed by mine made later. In this respect it is notable among the rocks analyzed by me. The rocks of Monte Amiata, whose composition is given in No. 5, have been so fully described by J. F. Williams, that the reader is referred to his paper.[1] The rocks of Campiglia and Rocca Strada, Nos. 7, 8, 9, and 10, are purely biotite-toscanites and are all quartz-bearing. It will be observed that the pyroxene-bearing toscanites (1–6) are notably less acid than those which carry only biotite.

Trachydolerites elsewhere.—Having thus reviewed the main feature of the trachydolerites along the Bolsena-Vesuvius line, it will be of interest to see if such rocks are found elsewhere. Their geographically nearest counterparts are found in the Lipari Islands where vulsinites and ciminites occur according to the descriptions of Sabatini[2] and Mercalli.[3] It must be noted, however, that these are not very abundant and are associated with true rhyolites, andesites, and basalts, and not with leucitic rocks. Some of the rocks of Monte Ferru in Sardinia and of the Ponza Islands may also belong to this group, though there is doubt as to the character of the plagioclase, and they may be rather trachyandesites. Another example of such transition rocks is found at the Azores, where Hartung[4] in 1860 noted the presence of rocks intermediate between the trachytes and the basalts, which he called by Abich's name of trachydolerite. The later investigations of Mügge[5] have established the presence of such rocks, though we are again left in doubt as to the char-

[1] J. F. Williams, Neu. Jahrb. B. B., V, 403 ff., 1887.

[2] Cortesee Sabatini, Isole Eolie, Rome, 1892.

[3] Mercalli, Giorn. Min., III, 97, 1892.

[4] Hartung, Die Azoren, Leipzig, 1860, 291, 319.

[5] Mügge, Neu. Jahrb., 1883, II, 201.

TABLE III.

ITALIAN TOSCANITES.

	1	2	3	4	5	6	7	8	9	10[1]
SiO_2	64.57	64.04	66.24	65.19	67.61	65.05	70.64	69.90	71.14	73.00
Al_2O_3	16.80	14.48	15.64	16.04	14.04	16.22	14.11	14.73	11.14	14.45
Fe_2O_3	0.97	1.73	1.16	1.16	....	1.01	....	....	....	....
FeO	3.02	4.35	2.19	2.48	5.40	2.48	2.86	2.90	2.73	3.12
MnO	Trace	....	....	....	....	Trace	....	....	Trace	Trace
MgO	1.69	1.03	0.89	0.99	0.65	1.46	0.72	0.72	1.62	0.82
CaO	3.53	4.00	2.17	2.92	3.71	3.19	2.02	1.91	3.17	3.30
Na_2O	3.81	4.14	2.05	2.26	5.50	2.62	4.67	4.30	1.40	1.70
K_2O	4.01	3.65	6.60	6.11	2.41	5.52	2.95	3.01	4.13	3.18
H_2O	1.28	2.06	3.25	1.85	2.28	1.60	2.30	2.10	1.77	0.70
TiO_2	....	0.28	....	....	....	0.44	....	....	0.00	Trace
P_2O_5	....	....	....	....	....	Trace	....	....	Trace	Trace
SO_3	....	....	....	....	....	0.11	....	....	1.78	Trace
Cl	....	....	....	....	....	0.04	....	....	Trace	Trace
X	....	....	....	....	....	0.59	....	....	1.05	Trace
	99.68	99.76	99.00	100.33	101.60	100.33	100.27	99.57	99.83	100.27
Sp. gr.	2.542	2.542	2.455	2.509	2.537	....	2.478	....	2.480	2.76

[1] Contains also traces of Li_2O, B_2O_3, and CO_2.

NOTES TO TABLE III.

1. Monte San Vito, Bracciano, H. S. Washington anal.
2. Monte San Vito, Bracciano, A. Röhrig anal., JOUR. GEOL., V, 49, 1897.
3. Monte Cucco, Cerveteri, H. S. Washington anal., JOUR. GEOL., V, 49, 1897.
4. Castle Hill, Tolfa, H. S. Washington anal., JOUR. GEOL., V, 49, 1897.
5. Tolfa, vom Rath., Zeit. d. d. geol. Ges., XVIII, 596, 1866.
6. Monte Amiata, mean of 7 analyses, J. F. Williams, Neu. Jahrb. B. B., V. 446, 1887.
7. Campiglia, Tuscany, vom Rath, *loc. cit.*, 640.
8. Campiglia, Dalmer, Neu. Jahrb., 1887, II, 213.
9. Sassoforte, Rocca Strada, Matteucci, Boll. com. geol. ital., 285, 1890.
10. Torniella, Rocca Strada, Matteucci, Boll. soc. geol. ital., X, 677, 1891.

acter of the plagioclase. Some of the analyses by Bunsen which Hartung gives are very similar to those of Tables I and II and indicate that it is basic. It is probable that similar rocks occur on Madeira,[1] and Renard[2] describes andesitic trachytes from Teneriffe and Ascension which may also belong here.

A group of rocks apparently resembling the Italian trachydolerites from near Buda-Pesth is described by A. Koch[3] as "labradorite-trachytes." They are composed of augite, hornblende, and biotite, and occasionally garnet, with labradorite (analyzed) as phenocrysts, and orthoclase only in the groundmass. The analyses much resemble those of the Italian trachydolerites, silica ranging from 52 to 67 per cent. and lime from 7 to 2, though magnesia is very low. Alkalies are much lower on the whole, but still higher than in normal andesites, and with potash predominating over soda.

The most interesting group, however, to compare with the Italian rocks is that of the absarokite-banakite series from the Yellowstone Park recently described by Iddings,[4] the rocks of which closely resemble those of the ciminite-toscanite series. The American rocks are similarly characterized by the presence of orthoclase and labradorite, with augite as the most prominent ferromagnesian mineral. The frequent occurrence of borders of

[1] HARTUNG, Madeira und Porto Santo, Leipzig, 1864.

[2] RENARD, Petrology of Oceanic Islands, London, 1890, 7, 23.

[3] KOCH, Zeit. d. d. geol. Gesell., XXVIII, 293, 1876.

[4] IDDINGS, JOUR. GEOL., III, 935, 1895.

orthoclase around labradorite cores is also noteworthy; a feature which we have met with so often in the Italian rocks. The most basic of them — the absarokites with silica from 47 to 52 and very high magnesia and lime — carry olivine, as do the more acid shoshonites with silica from 50 to 56; these latter correspond to the Italian ciminites. The last of the series — the banakites with silica from 51.5 to 61 — carry no olivine, and more biotite than augite, and are rather poor in ferromagnesian minerals; these would correspond to some of the vulsinites. It is especially worthy of note that in these last rocks "augite and olivine are more or less completely replaced by biotite" — the same mutual exclusion being observed here that we find in Italy. Chemically the absarokites are much more basic, while the analyses of the shoshonites and banakites closely approximate to those of the ciminites and vulsinites, except in the alkalies.

The similarity is indeed so great that the ciminites might with propriety be called shoshonites, and the vulsinites banakites. But there are certain considerations which seem to render such a course inadvisable. The difference in the alkalies has been already mentioned. While in the Italian rocks they are high and with potash very largely preponderating over soda, in the American rocks they are rather lower, and soda, while always lower in percentage, is much closer to the potash and molecularly often surpasses it. In Italy again we find the acid toscanites which are not represented at the Yellowstone Park, while at the latter we have the absarokites and nothing corresponding to them in acidity among the trachydolerites of Italy. The center of acidity, so to speak, at the Yellowstone Park seems to lie quite low, while in Italy it is much higher. Furthermore the great abundance of leucite at the Italian volcanoes is unparalleled in the American district, where the absarokite-banakites are genetically related to normal andesites and basalts, though leucite occurs to a small extent.[1] From these

[1] ROSENBUSCH, in the last edition of his Mikroscopische Physiographie (II, 1216, 1896), describes these rocks in connection with the leucite-tephrites.

facts we are led to believe that the parent magma of the Italian rocks was not only more acid than at the Yellowstone, but was preëminently a potash magma, which is certainly not true of the other. It may be added that the occurrence of two such well-marked and generally similar series of orthoclase-plagioclase rocks at widely distant localities forms a strong argument for the recognition of such types in accordance with Brögger's views.

Correlation of the trachydolerites.— Before passing on to the leucitic rocks it will be as well to examine the relationships of the trachydolerites and see what their position is in regard to other rocks of our classification. Brögger has so ably presented the arguments for the recognition of intermediate types that nothing need be added on that score, since all the arguments advanced by him for the recognition of the monzonites as an independent group of the same rank as the syenites and diorites apply with equal force to the trachydolerites and trachyandesites. The chief objection which may be brought against such ideas is that their acceptance would tend to "overburden petrological literature with new names." This is undoubtedly true to some extent, and many, perhaps most, of these names might be but temporary in their use, but they would yet fulfill their legitimate object of enabling us to comprise a given set of characters in one word, make our ideas of the various rock types more clear and precise, and thus lead us toward the solution of that vexed question—a rational and generally accepted classification of rocks, such as is found in the organic sciences.[1] The law of the survival of the fittest would hold good here as in animate nature. The needless names and types will be gradually discarded, and on what is left we may build a nomenclature of which the terms will be concordant both with each other and with the facts of nature, whenever the broad principle underlying the relationships of rocks shall have been discovered,

[1] In these, by the way, names are far more numerous than in petrology, and it may be added that it would seem that the advantage of having well-defined types would outweigh the disadvantage of putting a little greater tax on our memories.

TABLE IV.

	Trachyte Series		Trachyandesite Series		Trachydolerite Series		Andesite Series		Basalt Series	
	Alkali-feldspar rocks		Alkali-feldspar and acid plagioclase rocks		Alkali-feldspar and basic plagioclase rocks		Acid plagioclase (andesine-oligoclase) rocks		Basic plagioclase (labradorite-anorthite) rocks	
Acid	SiO_2 *ca.* 67–80	Liparite Rhyolite Quartz-Pantellerite	SiO_2 *ca.* 65–75	Iceland Liparites Vulcanite	SiO_2 *ca.* 64–75	Toscanite Dollenite?	SiO_2 *ca.* 61–70	Dacite	SiO_2 *ca.* 60–70	Santorinite
Medium	SiO_2 *ca.* 60–66	Trachyte Pantellerite	SiO_2 *ca.* 60–65	Domite Siebengebirge and Euganean Trachytes	SiO_2 *ca.* 60–64	Acid Vulsinite and Banakite	SiO_2 *ca.* 55–61	Andesite	SiO_2 *ca.* 52–60	Labradorite (of Fouqué and Michel–Lévy)
Basic	SiO_2 *ca.* 50–60	? ?	SiO_2 *ca.* 50–60	Basic Auvergne Trachytes	SiO_2 *ca.* 50–60	Vulsinite Banakite Ciminite Shoshonite Absarokite	SiO_2 *ca.* 45–55	Basic Andesite	SiO_2 *ca.* 43–52	Basalt Olivine-Basalt

as the doctrine of evolution now underlies the classifications of zoölogy and botany.

It is through considerations of this sort that I have felt justified in proposing the new names in the preceding pages, and that I sketched the following brief outline of a grouping of the feldspathic effusive rocks. In Table IV Brögger's idea is carried out, and furthermore the two main divisions of the lime-soda feldspars —the basic and the acid—are recognized. The reasons for the rehabilitation of an earlier system of classification[1] need not be gone into here, since the scheme represented is not proposed for general adoption, but only for the purpose of showing the relationship to well-established types of such rocks as those of the absarokite-banakite series and the ciminite-toscanite series.

In Table IV, then, the rocks included are classified by their dominant feldspars and by their silica content. In the first column we find the *trachytic series*, which includes only the purely or predominantly alkali feldspar rocks. These include the rhyolites (both of the potash and soda series) and the quartz-pantellerites; the trachytes proper, such as those of Ischia, Berkum, and Algersdorf, and the pantellerites; while the most basic members of this series are unknown at present, or perhaps incapable of existence, their place being taken by certain leucitites.[2] The *trachyandesitic series* would embrace those containing alkali feldspar and acid plagioclase (oligoclase-andesine) in approximately equal amounts. Their most acid representatives would include such rocks as the Icelandic rhyolites described by Bäckström[3] and the vulcanite of Hobbs;[4] those of medium acidity include what are called oligoclase-trachytes, and are typically represented by the *domite*[5] of the Auvergne and many trachytes of the Siebengebirge; while their more basic members

[1] Cf. J. Roth, Gesteinsanalysen, Berlin, 1861.

[2] They would represent chemically and mineralogically in an effusive form the basic augite-orthoclase *shonkinite* of Weed and Pirsson. (Bull. Geol. Soc., VI, 415, 1895.)

[3] Bäckström, Geol. Fören. Stockh. Förh., XIII, 637, 1891.

[4] Hobbs, Bull. Geol. Soc., V, 598, and Zeit. d. d. geol. Ges., XLV, 578, 1893.

[5] This might be used as the name for the group of medium acidity.

are found in many of the trachyandesites of the Auvergne described by von Lasaulx[1] and Fouqué.[2] Many of the rocks of the Euganean Hills also belong here. The series of *trachydolerites* has been already described. The *andesitic series* would include the dacites and andesites, with their definitions narrowed to their original limits,[3] so as to include only the rocks whose feldspars are acid plagioclase — oligoclase to andesine. In the *basaltic series*, carrying only labradorite and anorthite, we find the most acid members well represented by the "pyroxene-andesites" of Santorini, the greater part of whose feldspars have been shown by the researches of Fouqué[4] to be basic plagioclase. These have a high percentage of silica (65 to 69), and for convenience such rocks might be called *santorinites*. In the moderately acid part of the series would be found rocks corresponding to many of the labradorites of French petrographers, as well as many rocks classed as basalts, but which are more acid than the normal, such as those of the Löwenburg, Meissner, and the Vogelsberg. These may or may not carry olivine, as is also the case with the intermediate and basic trachydolerites and andesites. Toward the basic end we would have the basalts proper, chiefly anorthite-bearing and with or without olivine; while below these would come such rocks as the limburgites and augitites.

It will be seen from the above that the trachytes are rich in alkalies and poor in lime; the trachyandesites rather rich in potash and also in soda and lime; the trachydolerites rich in potash and lime, but poor in soda; the andesites rich in soda and lime, but poor in potash and the basalts very rich in lime and poor in alkalies, especially potash.

A somewhat similar table is given by Fouqué and Michel Lévy on page 155 of their Minéralogie Micrographique (Paris, 1879). The effusive rocks are divided according as they con-

[1] Von Lasaulx, Neu. Jahrb., 1870, 1871, 1872.

[2] Fouqué, Étude des Feldspaths, Paris, 1894, 254–270.

[3] Roth, Gesteinsanalysen, Berlin, 1861, p. XLV. Von Hauer und Stache, Geologie Siebenbürgens, 1863, 70, 79.

[4] Fouqué, Santorini et ses Eruptions, Paris, 1879; also Étude des Feldspaths, 317–320. The smaller groundmass microlites are more acid.

tain alkali feldspar, oligoclase, labradorite or anorthite, and these groups are subdivided according to their ferromagnesian minerals, biotite, hornblende, or pyroxene. Neither trachyandesites nor trachydolerites are mentioned.

It must also be noted that a somewhat similar scheme was proposed by H. O. Lang[1] in 1891 and carried out by him in great detail. He bases his purely chemical classification entirely on the relative proportions of the percentages of lime, soda, and potash, neglecting the other components and the mineralogical composition, so that the present grouping and his differ distinctly from each other.

LEUCITIC ROCKS.

Comparatively little can be said of these rocks here, since detailed descriptions of many of them have been already given, and since a proper treatment calls for more space than is available. As regards classification, while they are on the whole sharply separated from the trachydolerites, yet *inter se* they grade into each other to such an extent that the discrimination of definite types is more than usually difficult and subjective in character.

It will also have been evident from the descriptions given that many of the varieties described differ from the types generally accepted. Thus those rocks which have been called leucite-phonolite for want of a better name contain only a small amount of nepheline and are quite distinct from the typical German leucite-phonolites. The unfortunate difference of opinion as to the use of the terms leucite-trachyte and leucite-phonolite has been noticed, and in other ways the need is made evident of some general revision of all this group of important rocks. At present, however, the material is not at hand for such an attempt, which it is hoped will be undertaken later; and the names used are to be regarded as provisional only, and the whole group of leucitic rocks as the subject of future investigation. In Table V, only a few of the many analyses are given,

[1] H. O. Lang, Min. Petr. Mitth., XII, 199, 1891.

TABLE V.

ITALIAN LEUCITIC ROCKS.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
SiO_2..	45.93	47.89	48.89	49.03	47.82	47.40	49.73	50.24	52.16	55.11	55.87	55.85	55.10	55.17	55.21	55.26	58.48	59.51
TiO_2..	.....	0.77	.....	.....	.....	0.30	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.36	.....	.....
Al_2O_3	18.72	18.25	16.05	15.18	18.85	19.84	19.20	20.09	15.03	16.07	21.82	19.31	19.20	20.49	19.81	16.36	19.56	18.89
Fe_2O_3	.....	4.93	1.80	2.07	5.24	2.72	5.50	2.54	3.17	3.04	2.34	3.77	.....	3.27	2.69	5.76	.....	.....
FeO ..	10.68	3.64	10.09	6.32	5.12	4.40	2.41	5.65	8.42	8.46	1.10	1.88	6.86	2.74	2.86	2.90	4.99	5.26
MnO..	.....	Trace	0.43	0.19	.....	.....	Trace	Trace	0.24	.....	Trace	Trace	.....	Trace	.....	.....	.....	Trace
MgO..	5.67	3.68	3.98	6.05	4.40	4.23	2.63[2]	3.65	4.69	3.10	0.48	1.73	1.18	1.58	1.68	1.14	0.53	1.50
CaO..	10.57	8.70	11.88	12.58	9.51	9.88	7.96	7.83	10.07	6.46	3.07	3.84	3.75	3.73	4.61	3.90	2.60	1.90
Na_2O.	1.68	2.60	1.81	1.49	2.65	2.93	1.99	2.97	2.38	1.58	4 81	3.39	2.68	2.27	3.13	4.08	3.14	4.99
K_2O..	6.83	8.23	3.00	4.07	6.41	5.91	9.39	7.45	2.47	5.07	10.49	8.77	10.78	9.58	8.45	8.82	10.47	7.25
H_2O..	0.59	0.65	1.39	2.09	.....	1.66	1.19	0.36	0.72	0.89	0.34	1.14	1.22	0.99	0.99	1.20	0.24	0.56
P_2O_5.	.....	.....	0.29	0.86	.....	.....	.....	.....	1.15	0.75	.....	.....	.....	.....	.....	.....	.....	.....
	100.67	99.34	100.19[1]	99.93	100.00	99.27	100.00	100.78	100.50	100.53	100.32	99.68	100.77	99.82	99.43	99.78	100.01	100.05[3]
Sp.gr.	.....	2.781	2.811	2.743	.....	.....	2.655	.....	2.749	2.546	2.557	2.648	2.501	.....	2.609	.....	2.572	2.603

[1] Also 0.59 SO_3. [2] By difference. [3] Also 0.19 Cl.

NOTES TO TABLE V.

1. Leucitite, Capo di Bove, Bunsen anal.
2. Leucitite, Crocicchie, Bracciano, Washington anal.
3. Leucitite, Sassi Lanciati, Bolsena, mean of 2, Ricciardi.
4. Leucite-basanite, Toscanella, Bolsena, Ricciardi.
5. Leucite lavas, Vesuvius, mean of 49 anals., Roth, Geologie, II, 268.
6. Leucite-tephrite, Rocca Monfina, Röhrig.
7. Leucite-tephrite, Bracciano, Washington.
8. Leucite-tephrite, Monte Cavallo, Bolsena, Washington.[1]
9. Leucite-tephrite, Monte Bisenzio, Bolsena, Ricciardi.
10. Leucite-tephrite, Montalto, Bolsena, Ricciardi.
11. Leucite-phonolite, Lake Bracciano, Washington.
12. Leucite-phonolite, Bagnorea, Bolsena, Washington.[1]
13. Leucite-phonolite (?) Bolsena, Vom Rath.
14. Leucite-trachyte. San Rocco, Mte. Vico, Washington.[1]
15. Leucite-trachyte, Monte Venere, Viterbo, Washington.
16. Leucite-trachyte, Madonna di Lauro, Viterbo, Röhrig.
17. Leucite-trachyte (?), Monte. S. Antonio, R. Monfina vom Rath.
18. Leucite-trachyte, Viterbo, vom Rath.

the most representative being selected. Many more must be made before these rocks can be adequately treated from a chemical standpoint.

By far the best defined type is that of the so-called *leucitites*, which are quite constant in structure and mineralogical composition, as already described. The chemical composition of typical leucitites is given in Table V, Nos. 1, 2, and 3. They are very basic rocks, with high iron and lime, quite high magnesia, and high alkalies. *Leucite-basalts* seem to be quite unknown in the Italian localities—perhaps owing to the richness of the magma in lime, which makes a basic plagioclase-free rock almost an impossibility if any of the MgO is withdrawn from a possible diopside molecule to form olivine. Outside of the Vesuvian region, where they occur in abundance, *leucite-basanites* are only met with in small amounts. Their analyses (Nos. 4 and 5) resemble those of the leucitites except that they are higher in magnesia and iron as well as in lime, and those of Bolsena low in alumina. The *leucite-tephrites* form a group which is one of the most difficult to classify satisfactorily owing to the

[1] Made since publication of their respective papers.

large number of transition forms toward the leucitites on the one hand and the leucite-trachytes on the other. In general they are characterized by a rather doleritic micro-structure and the plagioclase is basic; chemically they are very basic in character, their silica content scarcely running above 50 per cent. Leucite-tephrites of this type abound at Bolsena, Rocca Monfina, and Vesuvius, and typical analyses are represented by Nos. 6, 7, and 8. Other leucite-tephrites occur whose silica content is higher. Examples are the rocks of Montalto (No. 10), in which Klein reports the feldspar as anorthite, and that of Monte Bisenzio (No. 9). Such acid leucite-tephrites, however, have not come under my own observation, and the high silica is to be explained by the presence of considerable orthoclase. Indeed my observations and such analyses as I have been able to make lead me to think that a typical Italian leucite-tephrite (which is poor in orthoclase) has a silica percentage of 50 or less, and that the plagioclase is generally, if not normally, a basic one.

When we reach the *leucite-trachytes* and *leucite-phonolites* we find a decidedly more acid group of rocks with silica ranging from 55 to 59. These shade off into the leucite-tephrites to some extent, but on the whole are distinctly separated from them. Of leucite-trachyte we have few analyses, Nos. 14–18 being the only reliable ones known to me. They show high alumina, low magnesia and lime, and high alkalies—especially potash, though this last feature is perhaps not as marked as we might expect. The analyses of leucite-phonolite (Nos. 11, 12, 13) resemble these very closely, though soda is somewhat higher, and are quite different from those of leucite-phonolites from Germany,[1] which are much more basic and with soda much higher than potash. Indeed, so great is the resemblance to analyses of leucite-trachyte that these Italian leucite-phonolites ought properly to be called nepheline-bearing leucite-trachytes. They all carry orthoclase in large amount, especially in the groundmass, and nepheline occurs as the last product of crystallization. Only one case of a purely leucite-nepheline

[1] ZIRKEL, Lehrbuch, II, 465, 1894.

rock was observed, that at the Asteria di Biagio, near Orvieto.[1] It may be noted here that in all these leucitic rocks the dominant feldspars are orthoclase and a basic plagioclase, that augite and diopside are the prevailing ferromagnesian minerals, that both biotite and hornblende are rare, and that they are rich in potash and also in lime. They thus resemble in their broad features the non-leucitic rocks—apart from the presence of leucite.

Turning to Table V it will be observed that there is a break in the silica percentages between 50 and 55. Below the former are the leucitites, leucite-basanites, and most of the leucite-tephrites; between the two very few analyses are seen, while between 55 and 56 there is a large number of analyses, and above this last a much smaller number, with silica running up to nearly 60, which is the extreme figure for leucitic rocks. This feature is best seen when all the analyses available are tabulated. Space considerations prevent this being done here, but the break between 50 and 55 is very evident. The number of analyses represented is so large, and covers so many varieties of rock, that this clustering of the silica about 49 and 56 may be reasonably assumed to exist in fact and not to be due to chance in the selection of analyzed material, as might well be the case with few analyses. We may note also in the analyses of Table V that, while alumina is somewhat variable, it is in general higher in the basic group than in the more acid, as is also true of iron oxides Lime and magnesia show the greatest differences, there being more than double the amount of them in the basic than in the acid group. There is less difference to be observed in the alkalies, they being very high in both groups, but perhaps more so in the acid one.

Comparison of the trachydolerites and leucitic rocks.—The general similarity of the two groups has already been noticed, and it is further of great interest to observe, on referring to Tables I, II, and III, that a clustering of the analyses about definite points is to be found in the analyses of the trachydolerites as well as

[1] Jour. Geol., IV, 558, 1896.

in those of the leucitic rocks. The ciminites and vulsinites reach no higher than 60 per cent. of silica, and lie in general between 55 and 58 per cent., while the toscanites are no lower than 64 per cent., and are in general much higher. Corresponding differences may also be noted in the other constituents, especially Fe_2O_3, FeO, MgO and CaO. It is also seen that transitional chemical forms are of limited occurrence, though the analyses are not as numerous as in the leucitic group. The analyses, then, of both groups are clustered about certain points and do not form a gradual series from the most basic to the most acid, as Brögger understands a series to be constituted. A similar clustering of the analyses may be seen at such volcanic localities as the Yellowstone Park, Montana, Cape Verde Islands, and Ægina and Methana; and the study of complete series of analyses would probably reveal the same state of affairs elsewhere. Indeed the fact may be said to be generally known, though perhaps not definitely formulated. An explanation which may be suggested is that this clustering of analyses is due to a quite complete course of differentiation, assuming the correctness of the differentiation hypothesis.

Each main group of rocks, therefore, may be subdivided chemically, and mineralogically to a certain extent, into two subgroups (classing the ciminites and vulsinites together), a basic and an acid. Further, while the leucitic subgroup is more basic in each case than the corresponding trachydoleritic one, yet the variations in each are similar. These are best seen on tabulating the means of the best of the various preceding analyses. It is scarcely worth while to do so in this place, but the main features may be briefly pointed out. There is a difference in each case of 8 to 10 per cent. of silica; and iron, magnesia, lime, and to a less extent alumina, are higher in the basic group, while alkalies show less regularity. The molecular ratio of soda to potash varies in my separate analyses from .3 to 1.2, being fairly constant (.5 to .6) in the leucitic groups, and with higher soda at the extremes of the trachydolerites. It is probable that with more numerous analyses the resemblances would be even greater since there are indications of a division of the basic leucitic subgroup into two divisions corresponding to the ciminites and vulsinites. These would include on the one hand the leucitites and leucite-basanites, and on the other the leucite-tephrites. There exist then along the Bolsena-Vesuvius line at least two well-defined series with correlated members in each, the Ciminite-Vulsinite-Toscanite Series and the Leucitite-Leucite-tephrite-Leucite-trachyte Series. These two resemble each other very closely, except for the presence of leucite in the latter and the uniformly greater basicity of the correlated members of this series as compared with those of the former. There also occurs a typically trachytic group in the Vesuvian region, while the phonolites of Viterbo mineralogically stand apart, but chemically are related to the leucite-trachytes. These series are, however, not gradual in Brögger's sense of the term,[1] but form related but separated groups of rocks.

Differentiation of the magma.—The question of the process or processes of differentiation and the composition of the parent magma is of great interest, but needs far more detailed and extensive knowledge of the regions involved and of the rocks than is yet available. The question is somewhat complicated by the presence of leucite in such large amounts, and by the fact already noted, that it is possibly derived from a potential biotite molecule, or at least that some connection seems to exist between the two minerals. It is pretty generally believed that leucite is essentially an effusive mineral, though some cases of intrusive leucitic rocks are known. Therefore, although the first impulse is to consider the leucitic rocks as distinct differentiation products from the trachydolerites, yet caution must be used, since it seems possible that their differences are due rather to differing conditions of extrusion than to differing secondary magmas. This, of course, would not be true in all cases, since leucite would be formed in a potash-rich magma poor in silica, while orthoclase would take its place in one more acid. This is seen clearly in the rocks with silica below 55 which are almost

[1] Brögger, Grorudite—Tinguait Serie, Kristiania, 1895, 169.

uniformly leucitic, while those with silica above 60 are as uniformly leucite free and orthoclase bearing. It is in the intermediate group with silica from 55 to 60 that we must look for evidences of the connection of leucite with extrusive conditions. These magmas are apparently in a nicely balanced chemical condition, which needs only a comparatively slight change of conditions to throw them into the one mineralogical group or the other. It is known that the leucitic rocks are almost invariably met with as flows, while the trachydolerites more frequently take the form of domal extrusions; that the leucitic rocks are the products of later eruptions, on the whole, than the trachydolerites except at Rocca Monfina; and that they have been ejected at central vents while the trachydolerites are more generally peripheral. This is suggestive of the idea that leucite has been formed in place of orthoclase during the simmering of the magma in the throat of the volcano under low pressure,[1] while the peripheral orthoclase magmas were partially crystallized under greater pressure.

In view of the above facts and those given in the preceding section I am inclined to think that the two main groups of rocks which are found along the Bolsena-Vesuvius line do not represent two distinct primary differentiation products, but that their differences are due to diverse conditions of extrusion, solidification, and the like, these conditions being, of course, secondary to the chemical character of the differentiation products, as has just been explained.

In regard to the character of the parent magma we may feel confident that it was very rich in potash and lime,[2] basing our judgment on the preceding descriptions and analyses. More than this we cannot postulate with any degree of certainty, but its general composition is perhaps shown by the mean of

[1] Cf. BÄCKSTRÖM, op. cit., p. 163; also LACROIX, op. cit., 637 ff.

[2] The hypothesis advanced by LAVIS (Natural Science, IV, 138, 1894) that the large amount of lime is due to absorption (osmosis) from the subjacent limestone traversed by the magma must be mentioned, though the writer can only admit its influence in a most limited way, if at all. The researches of Brögger and Pirsson have shown conclusively that it does not hold good elsewhere, and various considerations, which need not be gone into here, lead me to minimize its effect in Italy also.

the extreme differentiation products—the toscanites and basic leucitic rocks—or by the mean of the ciminites, vulsinites, and acid leucitic rocks, which closely resemble each other. On such a basis we could suppose it to have approximately a composition as follows: $SiO_2=57-58$, $Al_2O_3=17-18$, total iron oxides as $FeO=6-7$, $MgO=2-3$, $CaO=5-6.5$, $Na_2O=2-2.5$, $K_2O=7-8$, $H_2O=1-1.5$ per cent.

Whether the original magma differentiated horizontally from north to south we are not yet in a position to discuss, but at each center we may suppose the body of magma to have been quite completely differentiated. We would thus have the toscanites and the basic leucitic rocks (leucitites and leucite-basanites) representing the extreme products—the oxyphyric[1] and lamprophyric types, respectively. Apart from questions of conditions of solidification, the absence of leucite in the vulsinites may be explained by their higher silica,[2] while in the ciminites and biotite-vulsinites the high magnesia conditioned the formation of olivine, leaving the remaining part of the magma sufficiently acid for the formation of orthoclase rather than leucite. That these suppositions are possible may be seen on comparing analyses 1, 4, and 9 of Table I and 1 of Table II, with 11, 12, 14, and 15 of Table V, which are practically identical except for the silica in the first two, and the magnesia in the second two of the trachydolerites.

All this is, however, admittedly speculative to a large extent, and these views are advanced in a provisional way to be tested, and perhaps greatly modified, by future investigations. Finally, it has perhaps have been noticed that little or no reference is made to the succession of the rocks. The omission is intentional, because it does not seem to the writer, even granting that the order of eruptions is of the importance often attributed to it, that our knowledge of the subject along the Bolsena-Vesuvius line is sufficient to be of much value.

HENRY S. WASHINGTON.

[1] PIRSSON, Am. Jour. Sci., L, 118, 1895.

[2] The anomalous acid leucite-tephrites observed by vom Rath and Ricciardi are against this view, and some of them need confirmation.

VARIATIONS OF GLACIERS.[1] II.[2]

The first annual report of the *International Committee on Glaciers* has been published,[3] and gives the state of glaciers in various regions of the world so far as reports have been received, with references to some of the original sources of information. This committee was appointed to stimulate and record observations on glaciers. The following is a summary of the report.

No glaciers, except those of the Alps, have been under observations long enough to yield very definite results; but these have shown a decided periodicity of about thirty-five years in their size; it is not improbable that glaciers in other regions may have a similar periodicity.

A *period* is the time during which a glacier goes through all its changes; it begins at a *minimum*, continues through the *phase of increase*, the *maximum*, and the *phase of decrease*, and ends at the following minimum.

The Alps.—The glaciers of this chain were for the most part in the phase of decrease from 1855 to 1875; since then a number of glaciers have entered the phase of increase, namely: all those of the Mont Blanc group, about a half of those of the Valais, not more than a quarter of those of the Bernese Oberland, a few in the eastern Alps, and none east of the Brenner pass; so that the phase of increase at the end of the nineteenth century has been limited and not general; and observations from 1893 to 1895 show that many of the glaciers which have recently been advancing are again in retreat.

Of the glaciers observed in the Eastern Alps in 1895 there were about fourteen increasing, twenty decreasing, and five stationary.

[1] Read before the Geological Society of America at the Washington meeting, 1896.

[2] See this JOURNAL, Vol. III, pp. 278–288.

[3] Archives des Sciences, Vol. II, pp. 129–147, Geneva, 1896.

In the Swiss Alps where observations have been more general and have extended over a longer period, we find, in 1895, twelve glaciers increasing, forty-eight decreasing, seven stationary, and ten doubtful; in addition, several glaciers were measured for the first time in 1895, so that we may expect results from a still larger number in the future.

The great majority of the glaciers of the French Alps are decreasing in size.

The Pyrenees.—The eleven glaciers of this chain for which we have results, show five increasing, five decreasing and one stationary. Considerably over 200 French glaciers are now under observation.

The Caucasus.—A number of glaciers in this chain have been observed, showing a fairly general retreat; in 1894 some of the névé fields were growing larger.

Central Asia.—The glaciers are mostly in the Pamir, the Tian-schan, and the Alai mountains. They are of considerable size, and appear to be pretty generally in retreat.

Nova Zembla.—Glaciation is increasing.

The Scandinavian Alps.—The Norwegian glaciers do not show evidence of having participated in the great retreat of 1850–1880. The state of the vegetation in the immediate neighborhood of the glaciers shows that in many cases they have either kept or reattained the dimensions they had a century or so ago. There have been some advances and some slight recent retreats; there are no indications of any present advance.[1]

The Swedish glaciers are too little known to yield any definite results as yet.

The Himalaya.—Sir W. M. Conway reports the glaciers of this range in retreat, so far as observed, with the exception of the Bagrot glacier, which is beginning to advance.

The New Zealand Alps.—Considerable attention has of late been given the fine glaciers of this region. They seem to be either stationary or decreasing.

[1] See especially Beobachtungen üb Gletscherschwankungen in Norwegen, by E. RICHTER. Petermann's Mitth. Vol. XLII, p. 107.

United States of America.[1]—The glaciers of the United States have for the most part been so infrequently visited that the information regarding them is very meager. Professor Russell, in 1892, collected the evidence showing that in general they are retreating.[2] A few glaciers, however, give evidence of being in a state of advance.

The Malaspina glacier occupies a large plateau on the southern side of the St. Elias Mountain range. Though in general receding, a part of it near the Yahtse River was advancing and destroying trees in 1886.[3] Professor Russell states that the southeastern portion of the same glacier near Point Manby has recently advanced a distance of 500 meters and again retreated.[4]

The Frederika glacier, in the interior of Alaska (long. 142° 35′ N., lat. 61° 40′ W.) was the only glacier in its neighborhood advancing in 1891.[5]

Mr. John Muir writes me that a glacier at the southern end of the Fairweather range was advancing and destroying trees when he visited it in 1880.

Muir glacier, Alaska, which has in general been receding for the last hundred years or more, made a temporary advance between 1890 and 1892 of nearly 300 meters, but in 1894 it had again retreated to its limit of 1890. This glacier reaches tide water and ends in a vertical cliff of ice, 2.75 kilometers (9000 feet) long and 50 to 65 meters (150–215 feet) high; on each side of this cliff the glacier rests on the land and ends like an ordinary alpine glacier. The oscillation mentioned applies only

[1] This paper gives a more detailed description of the variations of the glaciers of this country than is contained in the Rep. of the Intern. Com. An excellent account of our present knowledge of these glaciers has been given by Professor Israel C. Russell in his recently published book, "The Glaciers of North America."

[2] Climatic Changes Indicated by the Glaciers of North America, by I. C. RUSSELL. Am. Geol., Vol. IX, 322–336.

[3] Shores and Alps of Alaska, by H. W. STETSON KARR, p. 77.

[4] Am. Geol., Vol. IX, 329. The best map of this region is in Russell's Second Expedition to Mt. St. Elias, 13th Ann. Rep. U. S. Geol. Sur., p. 6, or his Malaspina Glacier, this JOURNAL, Vol. I, p. 221.

[5] An Expedition to the Yukon District, by WILLARD HAYES, Nat. Geog. Mag., Washington, 1892, Vol. IV, p. 153.

to the part facing the water; the sides have been steadily receding.[1]

Mount Rainier is a volcanic cone, 4400 meters high, in the state of Washington, bearing on its steep slopes about a dozen glaciers from five to ten kilometers long. Information has reached me concerning the Carbon glacier on the northern, the Willis on the northwestern, and the Nisqually on the southern face of the mountain. All three of these glaciers are steadily receding.

Mr. Otto J. Klotz made a photographic study of the end of Baird glacier, Alaska (long. 132° 50′ N., lat. 57° 8′ W.) in 1894.[2] This will be the beginning of a careful record of the variations of this glacier.

In conclusion, the very incomplete data indicate that, with few exceptions, the glaciers of the United States are shrinking at the present time.

REPORT ON THE GLACIERS OF THE UNITED STATES FOR 1896.[3]

Cook's Inlet.—A glacier on the Kenai Peninsular has receded about 250 feet between 1880 and 1895.[4] Mr. Dall writes that he thinks all the glaciers on the Pacific coast which he has personally visited are retreating.

Chilcat Pass.—The glaciers on the southern side of this pass are receding. (*J. E. Spur.*)

Glacier Bay region.—Mr. John Muir reports that he found Rendu and Carroll glaciers, at the head of the bay, from three to seven kilometers (two to four miles) shorter in 1896 than they were in 1879. Muir glacier also continues to recede.

[1] Studies of Muir Glacier, Alaska, by HARRY FIELDING REID, Nat. Geog. Mag. 1892, Vol. IV, pp. 33–42; and Glacier Bay and its Glaciers, 16th Ann. Rep. U. S. Geol Sur., pp. 440–442.

[2] This JOURNAL, 1895, Vol. III, pp. 512–518. I recommend this article to observers as an example of how much of permanent value can be done in a short time by the photographic method.

[3] A synopsis of this report will appear in the Second Annual Report of the International Committee.

[4] W. H. DALL, Bull. Am. Soc., 1896, XXXVII, 15,

Mt. Rainier.—Professor I. C. Russell writes me:

In company with Bailey Willis and George Otis Smith of the United States Geological Survey, I visited Mount Rainier, Washington, and spent two weeks, from July 15 to August 1, in examining the glaciers on its sides.

The Willis, Carbon, Winthrop, Emmons, Nisqually, and Cowlitz glaciers were visited. Each of these furnishes clear evidence of having recently been lowered by melting, especially in the lower courses. The extremities of the three first named were examined and in each case a recent and marked recession was manifest.

The extremity of Carbon glacier, as judged by Willis, has receded about 100 meters since his former visit in 1881. The extremity of the glacier at the date mentioned was a vertical precipice of nearly clear ice, but now has a slope of 55° to 60° and is débris covered.

Willis glacier is divided at its terminus by a rugged boss of rock, for which I suggest the name Division rock, the down-stream face of which is a rugged precipice by estimate 120 or 150 meters high. I am informed by Willis, who saw it from below, that in 1883 the glacier broke off not far behind the summit of this precipice and formed walls of ice descending on each side of it. The ice did not cover the highest peak on Division rock at the date mentioned, and there are about ten small spruce trees growing on the apex. These trees are certainly more than fifteen years old. The upstream side of the rock, below the trees, is strewn with stones and dirt and has evidently been recently occupied by the glacier. At the time of my visit the ice in the central part of the glacier had receded 175 meters from the edges of the precipice. Fresh lateral moraines elevated from thirty to forty meters above the level of the glacier in 1896, and extending fully three kilometers (two miles) above Division rock, agree approximately with the 1883 level of the ice as reported by Willis.

Willis glacier now divides on reaching Division rock into two sharp-pointed tongues of débris-covered ice which end with low frontal slopes The extremities of these tongues are about abreast of the summit of Division rock. Where the glacier divides a pyramidal monument of angular stones about one and one-third meters high is built. This monument records the limit of the ice at the place where it divides, on July 31, 1896.

Up stream from Division rock there is another similar eminence which might possibly be mistaken for it, if the glacier continues to recede. The rocky knob referred to is now a part of the right or northern wall of the glacier.

Eight hundred and forty meters, as measured by pacing, above the monument described above, there is an ice-fall in the glacier 130 to 135 meters high. The descent of the surface of the glacier from the base of the ice-fall to the monument is 280 meters, by aneroid. The gradient becomes progressively steeper as one descends from the base of the ice-fall.

No marks were made to record the extent of the other glaciers visited.

Mount Hood, Oregon.—There are eight glaciers on this volcanic cone; all of them are steadily diminishing in size. The Eliot glacier on the north side of the mountain is about four kilometers (two and one-half miles) long and about 0.8 kilometer (one-half mile) wide; and shows a marked recession in the last three years. Before that the face was much steeper.[1] In the central part of the glacier near the end the velocity of movement has averaged about fifteen meters (fifty feet) a year since 1890. Coe glacier, which lies next to the Eliot on the west, is about four kilometers (two and one-half miles) long and 0.4 kilometer (one-quarter mile) wide. (*W. A. Langille.*)

Illecellewaet Glacier, Selkirk Mountains, Canada.—As there is at present no one on the committee representing the British colonies, I give what information I have concerning this glacier.[2]

Professor Charles E. Fay wrote me in 1895 that the glacier had receded since 1890, and markedly since 1894. Photographs taken by Messrs. Parker B. Field and Philip S. Abbot in 1895 and 1896, respectively, show that the recession continued last year.

There are prospects that more systematic observations of some of the glaciers of the Pacific slope may be begun next summer.

Harry Fielding Reid.

Geological Laboratory,
Johns Hopkins University,
April 8, 1897.

[1] Probably due to an advance.— H. F. R.

[2] Captain Marshall Hall, to whose interest and energy the international committee owes its existence, represented the British colonies until his sudden death in April 1896.

A SKETCH OF THE GEOLOGY OF MEXICO.

MEXICO is a country whose geology is very little known even by its nearest neighbors. It nevertheless offers a wide range of interesting problems. Its geology has been much misunderstood and this must be the excuse for presenting here a résumé of a portion of the very interesting report[1] recently published by the Geological Institution of Mexico. Aside from the itineraries with detailed observations, the report includes a synopsis of the geology of Mexico by the Director Sr. Jose G. Aguilera. In the following pages is a very much abridged translation, or abstract of Professor Aguilera's paper. The original is accompanied by a small scale map on which the geology is spread over the areas left blank on the older map of Castillo[2] and the whole forms a notable contribution to the geology of the region as well as being perhaps the best general summary of the present state of our knowledge of the subject.

Geographically Mexico may be considered as consisting of a central tableland sloping to the north and northeast, and inclosed between two ranges of mountains which are separated from the oceans by strips of lowland narrowing to the south. The two mountain ranges unite in the central portion of the country, rising above the lower land in the form of a colossal V, the arms of which continue into the United States as the Rocky Mountains and Sierra Nevada. The united range continues south into Central America with the low tableland of Yucatan, to the east rising thirty to forty meters above the sea.

The central tableland or Mesa de Anáhuac with an area of about 666,000 kilometers and an average altitude of about 1700

[1] Bosquejo geológico de México, Bol. del Inst. Geol. de México, Nums. 4, 5 y 6. 270 pp., 5 pl., map. Mexico, 1897.

[2] Bosquejo de una Carta Geológica de la Republica Mexico formada par disposicion del Secretario de Fomento, 1889.

meters, continues without interruption from the high plains of Texas and New Mexico to the valley of Toluca, which rises against the flanks of the Nevada de Toluca, reaching an altitude of about 2630 meters. This great meseta forms a geographic unit of the first order. Breaks in the bounding mountains afford easy communication with the coastal region and furnish outlets for the drainage. It is a continuation of the Great Basin region and has all the characteristics of that area. To the north it widens and decreases in altitude; to the south it narrows and rises. At its vertex are situated the City of Mexico and the two great volcanoes of the country.

In Archæan time the southern, and a part of the western coast of Mexico, rose above the waters and formed a series of islands or perhaps a single strip of land which, as with the northern portion of the continent, served as a point of initial deposition, and around which has been laid down in successive geologic times the beds which now make up North America. The rocks of this period are numerous and present many variations between different types. In the southern portion of Puebla, in Guerrero and Oaxaca where the greater number of exposures occur, their order of deposition was as follows: (*a*) Porphyritic gneiss similar to augen-gneiss, losing its schistosity below and passing into a species of granite; (*b*) Phyllite gneisses resting upon and grading into the preceding beds; (*c*) Mica schists somewhat abundant, at certain points garnetiferous and comformable with the rock below; (*d*) Phyllites, very argillaceous in their upper portion, but with the clay gradually diminishing toward the base and with concordant structural variation from stratiform to schistose. These beds rest upon chlorite, sericite and amphibole schists, which in turn cover the phyllite gneisses.

Later than the deposition of the argillaceous phyllites and before the end of the Palæozoic, there were numerous eruptions in the following order: (1) Gnėissic granite, passing into a porphyritic granite which cuts the mica schists without penetrating the phyllites. These rocks are shown in the northwestern portion of the republic in the City of Caborca, Sonora. (2)

Granite proper, cutting the mica schists and the phyllites and shown at most of the Archæan exposures as well in the northwest as the southern portion of the country. (3) Granulite, cutting all the rocks of the Archæan. (4) Hornblende-granite in frequent dikes and occasional stocks, cutting all the Archæan rocks. (5) Pegmatite, passing into graphic granite and occurring as dikes cutting the gneissic and true granites. There seem to have been two distinct periods of eruption of the pegmatite. The older, seen in Sonora, cuts only the gneissic granites, the mica and the amphibole schists. The later and more common type cuts all the Archæan rocks. (6) Greisen, associated with the granites, forming segregation veins. (7) Diorite dikes, later than the preceding rocks but earlier than the end of the Palæozoic. These are very abundant in the southern portion of Puebla and the northern part of Oxaca and Guerrero.

The Archæan forms considerable areas, and in addition to the points mentioned is found in Zacatecas near Fresnilo, in Guanajuato in the vicinity of the capital, in Sinaloa, near the crest of the Sierra Madre, and near Vera Cruz. The rocks also form the axis of the peninsula of Lower California.

The Palæozoic has few representatives in Mexico. The rocks of this system whose age is definitely fixed belong to the Carboniferous. Although considerable areas have been referred heretofore to the Silurian, and fossils characteristic of this terrane and said to be from Mexico, may be found in collections, we know of no exposures proven to be of that age. In the collection of the Institution is a piece of limestone holding beautiful specimens of *Orthis testudinaria* Dalman, and sent to Professor Castillo from the Cuesta de Santa Teresa near Cachuamilpa in Guerrero. Careful search in the locality by Professor Castillo failed, however, to reveal the source of the specimen. Many geologists have assigned to the Silurian the slates found at Guanajuato, Catorce and Zacatecas. Those at Catorce are Jurassic, and while at the other localities there are beds older than the Jurassic, there is no good reason for assigning to them so great an age as the Silurian. With regard to the Devonian Professor

Aguilera has succeeded no better than in searching for the Silurian. A careful study of localities said to have furnished Devonian fossils has only resulted in showing the presence of certain pre-Jurassic rocks whose age, because of the absence of fossils, and the metamorphism which the rocks have suffered, cannot be definitely fixed.

Carboniferous rocks of undoubted authenticity occur along the Guatemala border directly below the Cretaceous. The rocks are compact ash-gray limestones, containing *Productus semireticulatus*. Large areas of rocks in the central and northern portion of the country, assigned by Frazer, Hall and others to Silurian, Devonian and Carboniferous, are now known to be either Cretaceous or of unknown age.

In the absence of rocks belonging to the first two periods of the Palæozoic, it seems probable that Mexico, which during the Archæan was reduced to a group of islands, or perhaps to a single narrow peninsula stretching from California to Tehuantepec and Chiapas, suffered during the Silurian and Devonian a continuation of the ascendant movement which began at the end of the Huronian. The complete absence of stratigraphic and palæontologic data relative to the first subdivision of the Permo-Carboniferous authorizes the belief that during this time the elevation continued, and makes acceptable the hypothesis that it was during this time that the various islands became united and formed the skeleton of the country.

The Mesozoic is represented in Mexico by beds of the Upper Triassic and Jurassic, as well as the whole of the Cretaceous. The Triassic beds indicate a period of depression. The sediments accumulated in marshes and estuaries along the western coast to a thickness probably of 1000 meters; sediments 600 meters in thickness being now found in Sonora. The deposition was interrupted by minor elevations as is shown by lithological variations and the presence of basal conglomerates. The deposits cover a considerable area and are composed mainly of gray, red and yellow sandstones and gray to black slates. In general the rocks outcrop on the crests of low hills and ridges, being uncovered and resting upon crystalline schists, granites and similar rocks, or are intercalated between the Huronian rocks and the arenaceous marls and slates of the Upper Jurassic. The latter is especially true south of Acatlán and about Tezoatlán. In some instances the Triassic is covered only by the Cretaceous or the Tertiary.

The position of the rocks along the Gulf of California and in the territory of Puebla and Oaxaca indicates that after their deposition they were subjected to an elevation which, continuing to the present time, has placed them more than a thousand meters above sea level in Puebla and more than two thousand in Oaxaca. In spite of the evidence of the invasion of the sea in the Triassic, the absence of marine sediments makes it impossible to trace the old shore lines, but the same absence indicates that the land then extended notably more to the west than at present and that the deposits then made along the coast have since been buried.

While the deposits of the Triassic were made in marshes and lagoons, some of which perhaps communicated with the sea, those of the Jurassic are in general such as denote continental seas and deep water. Certain of the Jurassic rocks, however, seem to have been deposited in an interior sea of slight depth. At the close of the Triassic the northwestern and southern parts of the country were elevated, draining the marshes. At the same time the southeast sank beneath the Lower, and later the Middle Jurassic seas. At the close of the Middle Jurassic there was a further land movement and the Upper Jurassic sea crept in over large portions of Coahuila and Oaxaca. The Jurassic rocks are conformable with the Cretaceous and are intimately folded with them.

The Cretaceous rocks cover much the greatest portion of Mexican territory. They include three well-marked series of beds, the Lower, Middle, and Upper Cretaceous. These correspond respectively the Lower to the Neocomian, the Middle to the Cenomanian, Turonian and a portion of the Senonian, and the Upper to the Danian, and a part of the Senonian of Europe.

The beds of the lower division are largely shales, clays, marls, and greensands. The middle formation is mainly made up of compact ash-gray limestones frequently magnesian, though not in general constituting true dolomite. The limestones are rich in fossils, though they have been much metamorphosed. The upper member occurs only in the northeastern portion of the country and is represented by fine to medium grained, gray to red and yellow sandstones, alternating with clay shales of gray to black colors.

The advance of the sea begun in the Jurassic, continued until the country was converted into an archipelago at the end of the Middle Cretaceous. There was then a general elevation, carrying all but the northeastern portion of the country along the Rio Grande, above the sea. This elevation was accompanied by folding and mountain-making, continuing into the Upper Cretaceous. It was at this time that the main masses of the Sierra Madre of the east and west coasts were ridged up.

The Upper Cretaceous was laid down by a retreating sea and by the close of the Mesozoic, Mexico had its present general outline. There were, however, certain differences. Although the country then as now formed a great triangle with the apex in Central America, the width of the landmass was much less than at present. The Pacific coast line was farther west and Lower California was not yet separated from the mainland. The Gulf of Mexico had a more irregular coast line and extended to the west and southwest, probably uniting with the Pacific south of Guatemala. Yucatan and Florida were as yet covered by the ocean.

During the Eocene there was a series of vertical oscillations, but the total result was an increase of territory. In the Miocene there was along the east coast an invasion of the sea, though not so as to cover the whole of the Eocene area. At the same time the Pacific advanced inland and the first peninsula of the Republic was cut off, forming Lower California. Toward the close of the Miocene a new movement of elevation in the Atlantic region caused the sea to abandon most of its former dominion, the elevation terminating at the beginning of the Pliocene with the emergence of the peninsula of Yucatan and all of the southern part of the country which at the beginning of the Cenozoic had been buried beneath the waters of the two oceans. Upon the Pacific coast the depression seems to have continued in the Pliocene, so that Lower California was for a time cut off from Upper California by a canal and thus formed an island. On the Atlantic coast the Pliocene included a period of elevation succeeded by one of depression and in turn followed by an elevation, the latter continuing into the Quaternary.

It is not possible to fix absolutely the age of all the Tertiary beds. Those west of Laredo in the Rio Grande valley seem to belong to the Timber Belt beds of the Lower Claiborne of Harris. East of the same place are beds in part Eocene, and in part Miocene, possibly Lafayette. In the peninsula of Lower California, particularly along the Pacific coast, is a series of shallow water deposits resting upon the trachytes, andesites and dacites of the Eocene and containing pebbles of rocks erupted in the Miocene with fossils of Pliocene character. Along the Gulf of Mexico are Tertiary marine sediments made up of incoherent shell conglomerates and compact limestones. In the upper portion these contain fossils which in other parts of the continent are Miocene, mixed with recent and Pliocene forms. In the lower part the Miocene forms dominate.

The Tertiary in Mexico, as in the western portion of the United States, was a period of great eruptive activity. The wide variety of rocks and the large masses extruded are equally astonishing. Syenites, hornblende-diorites, quartz-diorites, diabases, porphyritic andesites, mica-andesites, dacites, and basalts are all present. With the andesites are trachytes, rhyolites and obsidians, and many transition varieties are present throughout the series. The eruptions begun in the Tertiary have continued to the present and have had much to do in shaping the topography of the country. The whole of the eruptive rocks are treated separately by Sr. Ezequiel Ordoñez.

H. Foster Bain.

EDITORIAL.

THE George Huntington Williams Memorial Lectures were fittingly inaugurated last month by the course of six lectures delivered by Sir Archibald Geikie at the Johns Hopkins University. The establishment of this memorial is due to the generosity of Mrs. George Huntington Williams, who provides in this way for a series of lectures to be given by geologists from various parts of the world on topics of interest to advanced workers in geology. No more appropriate introduction to what we hope may become a permanent source of inspiration to living geologists, while it will be a perpetual memorial of Professor Williams, could have been chosen than the subjects selected by Sir Archibald Geikie for his lectures — The Founders of Geology. Reviewing the beginnings of the science and the ideas and conceptions of those early workers, he not only presented a worthy introduction to a course which will deal largely with modern views and advanced theories, but he placed within easy reach of many a knowledge of ideas which may have appeared as new to us, but which in reality presented themselves to the earliest investigators. And in selecting an historical subject he followed a line which would have been most attractive to Professor Williams himself, and one in which he was peculiarly successful. Those of us who were prevented from hearing the lectures look forward to their publication with great interest.

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THROUGH the courtesy of the Governor of Maryland and of other state officials, and through that of the presidents of the railroads in the state, Professor Wm. B. Clark, the state geologist, was able to conduct several excursions into various parts of

Maryland, which were attended by Sir Archibald Geikie and the visiting geologists. They included an examination of the Cretaceous and Tertiary deposits along the Chesapeake Bay, the coalfields of Alleghany county, the Silurian and Devonian formations of the Appalachian district of the state, as well as the Cambrian strata of the Blue Ridge, and the pre-Cambrian volcanic rocks of South Mountain. Opportunity was thus given to become acquainted with the geological features of the state, which were first brought into prominence by the investigations of Professor Williams and his associates, and are now being further developed by the workers on the state survey under the direction of Professor Clark.

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SIR ARCHIBALD GEIKIE, as Director General of the Geological Surveys of Great Britain and Ireland, was prevented by the urgency of his duties at home from spending as long a time in this country as his friends here would have wished. The heartiness of his reception at those places he was able to visit may be taken as a guarantee of the high esteem in which he is held throughout the country. The hospitality shown him in Baltimore was repeated in Washington, Philadelphia, New York, and Brooklyn, in several of which places he delivered addresses. The lectures at the Johns Hopkins University attracted geologists from widely distant parts of the country and were well attended, and Mrs. Williams is to be congratulated upon so successful an inauguration of the memorial lectureship.

J. P. I.

Reviews.

Some Queries on Rock Differentiation. By G. F. Becker. Amer. Jour. Sci. (4), Vol. III, pp. 21–40, January 1897.

In this discussion Dr. Becker views his subjects from the physico-chemical side. He attempts to apply some of the results of Van t'Hoff, Oswald, Nernst, and other investigators to the question, "How may rock segregate into portions of distinctly different, yet of allied composition?" He thinks that differentiation, or segregation, as he prefers to call it, can occur only in two ways: (1) By the increasing or decreasing the concentration of certain components, caused by variations in temperature or pressure, which exist in different portions of the magma. These components are thought to be dissolved in the remainder of the liquid rock, and to obey the laws of dilute solutions. (2) By separation into two immiscible liquids due to changes in temperature and pressure. These take place by means of molecular flow, or diffusion, and he thinks convection would hinder this segregative process. He gives as instances of molecular flow the diffusion of salts in water, and explains the relation of osmotic pressure and diffusion to gas pressure and diffusion, and mentions that the three fundamental laws of gases, viz., Boyle's, Gay-Lussac's and Avagadro's have their parallels in three similar laws of solution.

Two cases of diffusion are next considered: (1) The diffusion caused by heating a solution at the top. (If the solution is heated at the bottom, convection commences and segregation is prevented.) (2) By a difference of pressure at the bottom from that at the top. Any diffusion caused by differential pressure would be too slight to have any appreciable effect. As to (1) it will appear from arguments yet to be presented that the diffusion will be so slow that in entire geological periods no effective change of composition would be possible. In his paragraph on the character of diffusion he states the units by which diffusion is measured, and that the rate of diffusion is expressed by the same mathematical formula as is the conduction of heat.

However this law only holds for dilute solutions, and he attempts to show that magmas are such dilute solutions.

Applying the foregoing to the rate of diffusion under the assumption that the solvent fluid is kept at constant composition and the dissolved substance is diffusing through it, he calculates the speed of the diffusion of various salts in water. He finds that common salt will diffuse fast enough to semi-saturate water at a distance of 1^{cm} in one day and 100 meters in 270,000 years. From certain observations he infers that lavas are at least fifty times as viscous as water, and therefore diffusion in such a substance would be fifty times as slow as that in water. Taking copper sulphate as the salt whose speed of diffusion should be multipled by fifty to represent the rate of diffusion in an average magma, he finds that in a million years there would take place a diffusion sufficient to impregnate the magma for forty-nine meters, and semi-saturate it to a distance of twelve meters. Finally he dismisses the hypothesis of the diffusion of miscible liquids because (1) diffusion is too slow a process; (2) a higher temperature is postulated at the top than at the bottom, and (3) because more or less convection is unavoidable, and he proceeds to consider diffusion of immiscible liquids.

He gives some examples of liquids which, above certain temperatures peculiar to each, are perfectly miscible, and below these definite temperatures separate into two immiscible liquids. This separation is accompanied by a sudden contraction of volume, and therefore all such separation is aided by increase of pressure. His points against such separation appear to be as follows: (1) The temperature of separation is first reached along the walls containing the magma, and therefore the separating component will condense on the containing walls much as frost and dew on good conductors of heat. Such a separation, however, involves molecular flow from the interior of the fluid to the walls, and therefore no large portion of even a moderately viscous magma could thus separate. (2) If the fluid does not condense on the sides, it must aggregate as a fog in the center of the fluid. This fog cannot condense farther, as a fog does in the atmosphere, on account of the great viscosity that he assumes the lava to have. (3) Magmas are not heated much above the melting point, and therefore the range in their temperature is not great enough to present much likelihood of their crossing the critical temperature of separation. This follows from the law of fusion that if a melted magma receives an increase of temperature, this increment will be expended in melting more of the surrounding rock rather than in raising the temperature of the already molten mass.

Concluding, therefore, that his theoretical inspection proves that differentiation can at most play only a minor part in the explanation of consanguineous rocks, he advances his theory of the original heterogeneity of the earth.

The points advanced for such a heterogeneity are as follows:

1. The land and water hemispheres.
2. Anomalies in gravity.
3. Distribution of feldspars in the west.
4. Distribution of metallic ores.
5. The seeming permanence of continental plateaus show this heterogeneity to be original.
6. Condensation from nebulous ring would forbid perfect homogeneity.
7. The viscosity of the fluid earth would permit only a rude approximation to uniformity of composition.
8. Hypogeal refusion results in a re-formation of a heterogeneous liquid.
9. The transitional series of erupted lavas may be explained by chance mixing of unlike magmas.

No attempts will be made to criticise Dr. Becker's views on the heterogeneous composition of the earth. Many of his points are strong, and have been advanced by others against the conception of a primitive homogeneous earth. Yet his application of physico-chemical principles is open to investigation.

Dr. Becker is doubtless correct in his conclusion that any change in relative concentration of *miscible liquids* by means of differential pressure or temperature is inadequate to explain any considerable diffusion of a magma. Prior to Dr. Becker, Dr. Bäckström pointed this out very clearly. Nevertheless we may be permitted to examine some of the facts he cites and inferences he draws to prove this point.

He says there are only two conceivable ways in which differentiation may occur; either by segregation into miscible or into immiscible liquids, caused by differential pressure, or temperature or both. May not these two operations be assisted by the crystallizing of different double salts at different temperatures and pressures peculiar to each?

The brilliant investigations of Van t' Hoff along this line do not seem to have been applied as yet to the problems of petrology.

After showing that the law from which he calculates the rate of molecular diffusion is good only for dilute solution, Dr. Becker says: "Magmas must be regarded as solutions of a series of very similar substances, and it is known that in such cases the solubility of each is diminished by the presence of the others."

This law holds only for salts dissolved in a dielectric, and is due to equilibrium relations between free ions and the undissociated portion of the salts. By "a series of very similar substances" is evidently meant a series of salts the members of which have some common ion or ions. If the data in the paper on the change of electric conductivity observed in rocks of different composition, while passing from liquid to solid, by Carl Barnes and J. P. Iddings,[1] are sufficient to prove that there is electrolytic dissociation in igneous magmas, then Dr. Becker's method is correct, and we need only to examine his assumptions on the viscosity, etc., of the lavas. If these data are insufficient to close the subject then Dr. Becker is reasoning from premises not yet proved.

Admitting, however, that the weight of evidence is with Dr. Becker on this point we may examine his views on the viscosity of lavas, for although of importance to his conclusions regarding segregation of *miscible* liquids, the value of his objections to segregation of *immiscible* liquids, depends upon the correctness of his assumptions on this point. He states that "There is some reason to think that the viscosity of even the most fluid lavas is more than fifty times as great as that of water." This is drawn (1) from a comparison of the speed of the flow of lava from Kilauea, with that of a stream of water of the same cross section and flowing down a slope of the same grade. (2) Since banded rhyolites show no diffusion of their layers into each other, it follows that if they had viscosity fifty times that of water they would show appreciable diffusion.

It does not seem probable that the viscosity of an extruded lava would be the same as that of one highly treated and supercharged with vapors. The erupted lava has crusts forming on both outer and inner surfaces. It has lost much of its superheated steam and other vapors, and more or less crystallization has already started throughout its mass. The unerupted lava is permeated with superheated gases, and is at a very high temperature. Of course pressure increases the viscosity and

[1] Amer. Jour. Sci. (3), XLIV, 242–249. 1892.

we do not know where the increasing pressure overtakes the effect of increasing temperature and superheated gases, and therefore we may expect some lavas to be very liquid, and to permit considerable molecular flow, while in others the viscosity might be so great as to prevent all such diffusion. Therefore is the assumption that the viscosity of unerupted lavas is the same as that of an erupted and cooling sheet warranted, and is there not a possibility of both far greater and far less viscosity than that assumed by Dr. Becker ?

We have, moreover, positive evidence that lavas may be very fluid if the pegmatitic structure in the rocks of Christiania described by Brögger as igneous be so, as he affirms for his region at least. Also the intrusion of erupted matter for long distances along planes of fissibility, in the Archean rocks of the Lake Superior region, demands more or less fluidity. If the alternate layers of banded rhyolites have a different amount of absorbed water vapor, as Professor Iddings suggests, this phenomenon might better be considered, as the result of impregnation of the magma by vapor shortly before its eruption. Moreover the fact that in the banded rhyolites we do not have diffusion between the layers is no proof that under other conditions we should not have such diffusion. Some magmas have been erupted under such conditions that they are perfectly homogeneous, while others show marked differentiation.

We reiterate that Dr. Becker is correct in concluding that differentiation into miscible liquids could play only a subordinate part in rock segregation. His attack on the theory of differentiation into immiscible liquids seems open to question; for the separation must instantly begin throughout the portion that has reached the critical temperature. This separation will start at many different centers, as in crystallization, and since molecular flow is rapid for short distances, and very slow for longer distances, this operation would be rapid. When these immiscible liquids are once formed, flow, stirring, gravity, etc., will help aggregate like to like. This segregation may be still farther assisted by the temperature sequence of crystallization of double salts.

His point, that lavas are too viscous to permit such separation and aggregation, has been already answered. His third point, that we cannot have wide enough range of temperature for this mode of separation, following from "the law of fusion," may have force in some instances, but where we have considerable mass of magma there could be a large increment of heat as we approach the center. To sum up the whole matter, his objections to the segregation of *miscible* liquids are qualitatively correct, but the quantitative accuracy is impaired by the nature of the assumptions on which the estimate is based. These assumptions are thought to be incorrect in some instances, and in all cases to lack the positive proof necessary for a scientific demonstration.

It seems unnecessary to assume that when *immiscible* liquids are formed segregation can only take place along the walls, and therefore involve extended molecular flow.

Instead of this we conceive that the process may resemble crystallization and take place at many centers, and therefore involves molecular flow through short distances. All stirring, currents, etc., instead of hindering, would aid in this case.

Finally, we have the fact of a regular rock gradiation established; a gradiation which is too widespread and uniform to be explained by an original heterogeneity of earth, and a chance mixing of the lavas. Our present knowledge, and the data at hand, are probably too meager to exactly explain the processes by which such gradation was accomplished. Yet, we may not affirm, with Dr. Becker, that rock differentiation is impossible under the known laws of physico-chemistry.

The problem will doubtless yield when attacked by the methods of modern physics and chemistry, and for this reason Dr. Becker's paper is most timely. CYRUS FISHER TOLMAN, JR.

An Introduction to Geology. By W. B. SCOTT. The Macmillan Company. 1897. 573 pp. $1.90.

The preparation of a satisfactory text-book on any subject so large as geology must always be a difficult matter. There is so much difference of opinion as to where emphasis should be laid, as to what should be said and what omitted, and as to the order in which the topics should be treated, that no book is likely to command universal approval in all respects. Yet in spite of all the difficulties Professor Scott has succeeded in preparing a book which will command respect and probably very general approval. He has shown in its preparation a sense of proportion which the makers of text-books sometimes fail to exhibit. When to this is added that he has made use of the newer literature throughout, so that the book is up to date, it will readily be inferred that the book is likely to prove a useful one in institutions where brief courses in geology are taken by somewhat mature students.

The book perhaps departs as much and as satisfactorily from the text-books heretofore in use, in its treatment of the later parts of historical geology, as at any point. In his treatment of the Mesozoic and later periods, the author has brought together much data not heretofore incorporated in a text-book, and his handling of that difficult part of the subject is much more satisfactory than that found in most text-books of corresponding scope.

The illustrations in the volume are mainly new and attractive, many of them being reproductions from photographs direct. The illustrations of fossils seem to have been selected with great care, but are, on the whole, fewer in number than could have been wished.

The publishers have done their usual excellent work in the preparation of the volume. R. D. S.

Missouri Geological Survey, Vol. XI; Clay Deposits. By H. A. Wheeler. 622 pp., 39 pl. Jefferson City, 1896.

The eleventh volume issued by the Missouri Survey is well up to the standard of the previous work. It is a report of much more than local interest, and will doubtless become the standard book of reference for clay workers, filling a position analagous to that of the Manganese Report of the Arkansas Survey. The Missouri clay report is the most comprehensive work treating this subject issued by any American state since the New Jersey report of 1878. It monographs the subject of clays and clay working as exemplified in the wide range of deposits and processes in Missouri. It is written from the point of view of the engineer and treats of the different clays as adapted to various uses. Nevertheless there are many geological problems whose solution will be the easier for it. The large number of new analyses, as well as the careful tabulation of a wide range of older ones is alone a feature of great value. The physical tests, the studies of fusibility, plasticity, and shrinkage, aside from their immediate practical importance, may be used to advantage in studies of the origin of mountains and of mountain-making forces. Probably few portions of geology are less understood or more complex than that which relates to metamorphism, and in order to understand the nature of metamorphic rocks it is necessary to have something more than a general notion of the nature of the metamorphosed material. This has been recognized so far as the petrology of igneous rocks is concerned but the petrology of the sedimentaries, being less inviting, has been largely neglected. It seems probable however that the field will eventually yield important results and certainly until it is better understood dicta regarding the metamorphism of sedimentary rocks must rest largely on assumption. Professor Wheeler's report was not undertaken with this point in view, and yet his results often have considerable bearing on the subject. His work will also, it is believed, prove helpful because of the methods of study and measurement which he has formulated.

To one not already familiar with the trade, the wide variety of products and the extent of the clay industry in Missouri, will doubtless come as a surprise, and yet among the most valuable portions of the report are the suggestions with regard to the expansion of the industry. If these be followed the state will soon receive returns many times in excess of the cost of the work. H. FOSTER BAIN.

The University Geological Survey of Kansas. By ERASMUS HAWORTH and Assistants. Vol. II, 318 pp. 25 plates. Topeka, 1897.

Under the direction of Professor Erasmus Haworth the University Geological Survey of Kansas has published a second volume upon the geology of that state. It is a companion and supplement to volume one, and covers the western half of the state as the former covered the eastern portion. It deals chiefly with the stratigraphy of the Upper Permian, Cretaceous and Tertiary formations, and while it affords much valuable information to the geologist it is written primarily for the citizens of the state. In the preparation of the volume Professor Haworth has enlisted the coöperation of Professor C. S. Prosser of Union College, Schenectady, N. Y., with his two assistants Mr. J. W. Beede and Mr. C. N. Gould, Professor S. Williston of the State University, and Mr. W. N. Logan. The report is illustrated with numerous half-tone reproductions from photographs, geologic sections and maps.

The first paper is on the "Physiography of Western Kansas" by E. Haworth. The drainage of the region as a whole is considered and the present drainage is compared with that of Tertiary time. Following this general treatment each of the individual streams is discussed in greater detail.

The next paper is by Professor C. S. Prosser upon "The Upper Permian and the Lower Cretaceous." Professor Prosser's work upon the Permian of Kansas is well known, and that portion of the present paper devoted to the Permian is but a supplement to what he has previously published. The "Red Beds', or Cimarron Series come in for consideration here. These beds have been placed by different workers in the Permian, Jura-Trias and Cretaceous. The entire absence of fossils in the series in Kansas makes their correlation at best uncertain. The presence of Permian fossils in the "Red Beds" of Texas, however, which have a similar position but differ lithologically, the seeming conformity with the true Permian below and the marked unconformity with the Cretaceous above, point to the Permian or Triassic age of the series, but Professor Prosser states that the correlation of the beds with either the Permian or the Triassic is as yet a matter of uncertainty. The second part of Professor Prosser's report is upon the Lower Cretaceous, which is represented in Kansas by the Washita division of the Comanche Series. The stratigraphy of the formation is discussed in detail, many sections and lists of fossils being given.

A chapter on "The Upper Cretaceous of Kansas" is contributed by W. N. Logan. The series is well represented in western Kansas by the Dakota, Benton, Niobrara, and Fort Pierre groups. Each of these formations is discussed in more or less detail.

The next paper is by Professor S. W. Williston upon "The Kansas Niobrara Cretaceous. This is followed by the "Physical Properties of the Tertiary" by Professor E. Haworth, in which the stratigraphy, lithology, origin and mode of formation of the Tertiary is considered. "The McPherson Equus Beds" are described by Professor Haworth and J. W. Beede. These beds have been considered as of glacial origin. This explanation of their origin is disputed by the authors and they state that no satisfactory interpretation of them can as yet be advanced. The last chapter in the volume is by Professor Williston upon "The Pleistocene of Kansas." The deposits of this age are treated briefly and mention is made of the various vertebrate remains which have been found in them.

S. W.

Preliminary Report on the Marquette Iron-Bearing District of Michigan. By CHARLES RICHARD VAN HISE and WILLIAM SHIRLEY BAYLEY. *With a Chapter on the Republic Trough.* By HENRY LLOYD SMYTH. U. S. Geological Survey, 15th Ann. Rept., pp. 477–650, pls. 13–26, figs. 9–20; 1895.

The Marquette district, the oldest important iron district in the Lake Superior region, is well known to students of pre-Cambrian geology, and while it has been studied in detail before, the present report represents the first systematic and successful attempt to unravel the structure of the region and to determine the sequence and relations of the various rock bodies. The key to the structure of this district, which is in general the key to the structure of much of the Lake Superior region, has been known for several years; it is that below the Keweenawan are three unconformable rock series, frequently so closely folded together that their separation is very difficult. These three series are the Archean, the Lower Huronian, and the Upper Huronian, or, as termed in this report, the Basement Complex, the Lower Marquette, and the Upper Marquette.

The district studied extends from the Lake Superior shore just south of Marquette westward to Michigamme, a distance of over thirty-five miles; it is nine miles in width, but in places much more than half of this distance is occupied by rocks of the Basement Complex, and has not been studied in detail. The Lower and Upper Marquette rocks occur in a basin flanked on either side (north and south) by the Basement Complex, which is composed of an intricate mixture of granites, gneisses, schists, and surface volcanics, all thoroughly crystalline, and cut by basic and acid dikes.

The Lower Marquette is separated into six conformable formations as follows, in ascending order: Mesnard quartzite, Kona dolomite, Wewe slate, Ajibik quartzite, Siamo slate, and Negaunee formation. During Lower Marquette time the transgression of the ocean was from the east, so that the lower formations are represented only in the eastern part of the district, and on going westward higher and higher strata are found, resting directly on the underlying Basement Complex, between which and the Lower Marquette there is a marked unconformity. The Negaunee is the Lower Marquette iron-bearing formation, and is composed of sideritic slates, grünerite-magnetite schists, ferruginous slates, ferruginous cherts and jaspilite, all of which are genetically related. With the Negaunee are masses of basic igneous rock, both extrusive and intrusive, the latter being the more common. There are three classes of ore deposits, one at the bottom, one within, and one at the top of the iron-bearing formation. The first two are generally of soft hematite, while the third, which is associated with the uppermost part (jaspilite) of the iron-bearing formation and passes up into the lower part of the Upper Marquette, is of hard hematite. In origin the ore is the same as in the Penokee-Gogebic range, *i. e.*, it is derived from an original sideritic chert, and has been concentrated in certain positions by percolating waters, and the silicious portions of the rock have been removed from these areas of ore concentration. The ore bodies lie in pitching troughs formed of comparatively impervious rock, as slate or basic dike rock, or both.

The Upper Marquette, resting unconformably on the Lower Marquette, is divided into the Ishpeming, the Michigamme and the Clarksburg formations. The first is composed of the Goodrich quartzite and the Bijiki schist, the latter of which is a grünerite-magnetite schist. Small ore bodies occur near the top of the schist and also in the Michigamme formation. The Clarksburg is composed of volcanic material, and the volcanic activity is thought to have begun during the time of deposition of the Ishpeming formation, and this igneous material is regarded as replacing, where it occurs, the upper part of that formation and the lower part of the Michigamme.

The Republic trough is a syncline with the axis nearly horizontal and running in a northwest-southeast direction. The three unconformable series described in the Marquette area are here represented, but of the Lower Marquette only two upper members are present, and the Clarksburg formation of the Upper Marquette is lacking. The iron ore deposits, which are of magnetite and hematite, are in the upper part of the Lower and the lower part of the Upper Marquette.

In structure the Marquette district is complicated, the rocks having been subjected to severe folding. The general structure is a broad complex synclinorium, in which the folds have an east and west direction. At the edges the folds are sharply overturned, and on going toward the center higher and higher beds are encountered. The structure is similar to the composed fan folds of the Alps, except that the whole has sagged down, forming a synclinorium rather than an anticlinorium; to this the name of Marquette type of fold is applied. In addition the rocks have been compressed more or less closely by a force acting in an east-west direction.

This report represents a vast mass of most detailed examination in the field and in the laboratory, the completed form of which is to be expected as a monograph of the U. S. Geological Survey. With this will be issued maps, on the scale of four inches to the mile, showing all outcrops and other details of structure and of topography. As already stated, this report is the first successful attempt to present the structure of the Marquette iron-bearing district, an area which has been much studied before, but most of whose problems have remained unsolved. While there are a few minor points yet unsettled, the major questions have been answered. The whole is a practical and successful application of the advanced methods and principles of structural geology applied to nonfossiliferous rocks, which methods and principles have been so masterfully presented by the senior author.

U. S. GRANT.

Abstracts.

Geological Atlas of the United States. Folio 30, Yellowstone National Park, Wyoming, 1896.

The Yellowstone Park folio, recently issued, consists of six pages of descriptive text, three pages of illustrations, four topographic sheets (scale 1 : 125,000) and four sheets delineating the areal geology of the region.

The general descriptive text, giving a succinct narrative of the geological history and development of the park country from the time of the earliest continental land surfaces up to and including the hydrothermal phenomena as seen today, was written by Arnold Hague, geologist in charge. It is followed by an account of the sedimentary rocks, from the earliest Cambrian deposits to the Tertiary conglomerates, by Walter Harvey Weed, and a brief petrographical description of the igneous rocks, by Joseph Paxson Iddings. The area of country covered by the Yellowstone National Park folio lies between parallels 44° and 45° and meridians 110° and 111°. It is situated in the extreme northwest corner of Wyoming. By far the greater part of the park is included within the area of the four atlas sheets, but a narrow strip lies to the northward in Montana, and a still narrower strip extends westward into Idaho and Montana. In the organic act establishing the park, Congress declared that the reservation was "dedicated and set apart as a public park and pleasure ground for the benefit and enjoyment of the people." Owing to the marvelous display of geysers and hot springs, and such remarkable physical features as the Grand Canyon and Yellowstone Lake, this folio possesses more than ordinary interest to geologists.

The central portion of the Yellowstone Park is a broad volcanic plateau, with an average elevation of 8000 feet, surrounded on nearly all sides by mountains rising from 2000 to 4000 feet above its general level. The continental watershed crosses the park, separating the waters of the Atlantic from those of the Pacific, the Missouri and the Columbia, by the way of the Yellowstone, and the Snake, finding their sources on this plateau.

The oldest rocks of this region are granites, gneisses, and schists regarded as of Archæan age. They occur in all the mountain uplifts that encircle the park, but are unknown in the central portion. Around these ancient continental land masses there was deposited a conformable series of sandstones, limestones, and shales extending from the time of the Middle Cambrian, the lowest beds exposed, through the Upper Cambrian, Silurian, Devonian, Carboniferous, Juratrias, and Cretaceous, including the Laramie sandstone. Nearly all these great divisions of Palæozoic and Mesozoic times are characterized by a typical fauna.

With the close of the deposition of the Laramie sandstone the conformable series of sediments came to an end. The entire region was elevated above the sea, the movement being accompanied with plication and folding of strata. This primary orographic uplift which blocked out the main ranges of the northern Rocky Mountains, has been designated the post-Laramie movement.

Tertiary sedimentary rocks occupy only small areas in the park, the greater part of the region being covered by extensive flows of lava. A heavy mass of coarse conglomerate, designated the Pinyon conglomerate, has been referred to the Eocene; and Pliocene conglomerate and coarse sands are well exposed in the escarpments of the Grand Canyon.

Volcanic energy, which has played so great a part in the geological development of the country, was connected with the post-Laramie movement and followed closely upon the elevation of the mountains, and the accompanying dislocation and compression of strata. The eruptive masses, in forcing their way upward, sought egress along lines of least resistance, or wherever strain has been greatest in the crumpled sediments. Volcanic outbursts continued on a grand scale throughout Tertiary time.

During the Eocene and Miocene periods enormous volumes of fragmental ejectamenta, largely composed of andesitic and basaltic breccias, were thrown out. The Absaroka Range was almost wholly built up of volcanic material. Evidence of this long-continued action is shown in the well-preserved fossil floras of Eocene and both Lower and Upper Miocene age. The famous fossil forests of the Yellowstone are of Miocene age. After a period of great erosion the depressed basin lying between the encircling ranges was transformed into the present Park plateau by the extravasation of immense flows of rhyolite of Pliocene age. Still later the recent basalts, the last of the igneous extrusions, poured out over the rhyolite along the ridges of the plateau. A generalized vertical section accompanies the text, showing the order of succession of the extrusive flows, from the earliest outbursts to the final dying out of eruptive energy. It is shown that long-continued currents of heated waters and acid vapors have acted as powerful agents in decomposing the igneous rocks of the plateau, and date back to Pliocene time; at least they were active before glacial ice covered the country. Hot springs, geysers, and solfataras are closely associated with the rhyolite, and in fact thermal activity is confined almost exclusively to areas of this rock.

The illustrations relate mainly to the occurrence of both active and dormant geysers and hot springs or some phase of volcanic geology. The Grand Canyon, well shown in the illustration, is a profound gorge cut in the Pliocene rhyolite, the brilliant coloring being due to the action of thermal waters.

Geologic Atlas of the United States. Folio 24, Three Forks, Montana, 1896.

This folio, by Dr. A. C. Peale, consists of five pages of text, a topographic sheet (scale 1 : 250,000), a sheet of areal geology, one of economic geology, one of structure sections, and one giving a generalized columnar section for the district.

The area covered comprises the square degree which lies between the meridians 111° and 112° and the parallels 45° and 46°, in the southwestern, mountainous portion of Montana, and includes 3354 square miles. In the extreme southeast corner the Yellowstone National Park barely falls within the area. The folio derives its name from the valley in which the Jefferson, Gallatin, and Madison rivers unite to form the Missouri. The "Three Forks" valley is important from an historic standpoint, as being the point which Lewis and Clark reached in July, 1805, when they named the three confluent branches of the Missouri.

The text begins with a general description of the geography and topography of the region, and then takes up the general geology. The oldest rocks in the region are the crystalline schists and gneisses, designated as of Archæan age, which in pre-Cambrian time formed a land mass comprising nearly all the area included in the map. While the Algonkian beds were being deposited to the extent of from 6000 to 12,000 feet, there was a gradual subsidence of the whole region, and shallow seas for the most part prevailed. During the Palæozoic age there were many minor oscillations of the surface, which were more frequent during Cambrian time than during the deposition of the Devonian and Carboniferous limestones. Toward the close of the Cretaceous period a general elevation began, which was accelerated after the deposition of the Laramie formation. The formation of the mountain ranges, together with the subsequent erosion, resulted in many valleys, which eventually were occupied by fresh-water lakes. These lakes attained their greatest extent in the Neocene period, lasting in all probability until the Pleistocene period was well advanced, and during their earlier stages immense bodies of wind-carried volcanic dust were deposited in their waters, and are now seen as beds of pure white. At the same time the dust fell upon the surrounding country, from which it was afterward washed into the lakes, forming an upper series of yellowish and rusty colored beds. These dust showers destroyed both animal and vegetable life, and the remains carried into the lakes were buried in their deposits, where they are now found as fossil bones and opalized and silicified wood.

Under the "Description of Rock Formations" are outlined all the formations from the Archean gneisses up through the Algonkian, Cambrian, Devonian, Carboniferous, Juratrias, Cretaceous, Eocene, Neocene, and Pleistocene. The rocks of more than half of the area are of sedimentary origin, while the crystalline rocks occupy approximately 1000 square miles, the remaining third of the area being covered with igneous materials. Prominent among the latter are the andesitic breccias which form the main part of the Gallatin range, the great porphyritic laccolite occupying the center of the Madison range, and the basaltic plateau which lies west of the Madison valley.

Under the heading "Structural Geology," after a general consideration, the vertical and horizontal movements are discussed, and the development of the lake basins is described. The arrangement of the rock-mass is complex, the structure being complicated by laccolites, dikes, and surface flows of igneous material. Unconformities exist, showing that areas previously raised to land surfaces and worn down have subsided, have been crossed by an advancing shore, and later have passed beneath the sea. The great series of conformable strata is closely folded, and has been pushed up in arches, many of which have been overturned from the effect of horizontal thrusts. The simple as well as the overturned synclines are marked by areas of Laramie Cretaceous beds, which, at the time of the folding, were the latest and highest of the formations. The arches between the troughs having been broken and exposed by the elevation, excessive erosion has worn them down to the older rocks, exposing the Archæan, which usually forms the axes of the uplifts. Unlike the Appalachian folds, which are strikingly parallel and continuous, these folds lie in various directions, due to several independent centers of uplift. Three great faults cross the Gallatin range, two of them extending across the Madison range to the extreme western part of the area. Following or accompanying the folding of the Cretaceous and pre-Cretaceous strata the detritus resulting from the greatly facilitated erosion, together with volcanic material erupted during this epoch, was deposited unconformably on the eroded upturned edges of the earlier-formed strata.

The lake basins are now the floors of extensive valleys separating the detached mountain ranges, which rise about 6000 feet above their bases. As the lake deposits are at least 2000 feet in thickness, the difference of elevation between the bottoms of the lake basins and the summits of the peaks must be at least 8000 feet. The region was a mountainous one before the development of the lakes, but in the evolution of the existing relief, movements and erosion have both operated to accent the topographic differences.

The principal economic resources of this region are gold, silver, iron ore, copper, limestone, and coal. The occurrence of coal in Devonian rocks on the north side of the Jefferson canyon is of geologic interest, although not of any great economic importance. The fine pumiceous volcanic dust found in the old lake basins has been utilized to a very limited extent as a polishing material. Brick clays occur, and are used to a small extent in a few localities, especially near Bozeman. In addition to the economic resources just referred to, the sheet of economic geology has indicated upon it the localities of building stone and mineral springs.

Geologic Atlas of the United States. Folio 29, Nevada City, special folio, California, 1896.

This folio, by Waldemar Lindgren, consists of seven pages of text, three special topographic maps (scale 1 : 14,400), the Grass Valley, Nevada City, and Banner Hill; three corresponding maps showing the economic geology, and three others giving structure sections.

These maps, on a scale of about four inches to the mile, have been prepared to illustrate the detailed structure of the gold-mining regions in the vicinity of Nevada City and Grass Valley. Each of them comprises an area three miles wide by four miles long, the total area being nearly thirty-six square miles. The Nevada City and Grass Valley areas fall within the boundaries of the Smartsville atlas sheet, while the larger part of the Banner Hill area falls within those of the Colfax atlas sheet. The relief is that common to the middle foothill region of the Sierra Nevada—that is, the surface is a very irregular and undulating plateau deeply trenched by the canyons of the recent river systems.

Sedimentary rocks, chiefly referred to the Calaveras formation, occupy small, usually long, narrow areas imbedded in the predominating igneous masses. Granodiorite occupies a large part of the Nevada City and Banner Hill districts, while a small *massif* of the same rock is found in the Grass Valley district. Large areas of diabase, porphyrite, and brecciated forms of these rocks surround and separate the granodiorite areas. In the southwestern part of the Nevada City district and the northeastern part of the Grass Valley, a large and complicated *massif* is found, consisting in part of diorite, in part of gabbro, pyroxenite, and serpentine.

The slates of the Calaveras formation are the oldest rocks. Next younger are the diorites, gabbros, and serpentines. Still later are the diabases and porphyrites; and the intrusion of granodiorite closed the succession of igneous rocks. The bed-rock series is, as usual, in part covered by several hundred feet of Neocene gravels, and rhyolitic and andesitic tuffs, the gently sloping top of the andesitic ridges forming a principal feature of the landscape.

The Neocene auriferous gravels have been extensively worked in the Nevada City and Banner Hill districts, both by the drifting and the hydraulic processes, and considerable ground still remains which probably can be profitably worked. The gold-quartz veins are numerous and belong to several distinct systems. They are found in all of the formations represented on the sheet, and generally cross the contacts without change. In the Banner Hill district the veins are narrow but rich, and have a general east-west direction and a northerly or southerly dip. In the Nevada City district the quartz veins have a general north-south direction and an easterly dip of about 45°. Large dislocations producing overthrust faults have occurred along several of the veins. In the Grass Valley district there is one system with a west-northwesterly direction and a steep northerly or southerly dip. On this system the celebrated Idaho mine is located. Most of the veins in the central and southerly part of the district have a northerly direction and a flat easterly or westerly dip. The veins are often accompanied by strongly developed sheeting of the country rock.

United States Geologic Atlas, Folio 28, Piedmont, West Virginia–Maryland, 1896.

This folio consists of six pages of text, signed by N. H. Darton and Joseph A. Taff, geologists, and closing with a series of vertical sections showing the positions and thickness of the coal beds; a topographic map; a sheet showing the areal geology of the district; another showing the economic geology; a third exhibiting structure sections; and a fourth containing a columnar section and a key to the synonymy of the various formation names. The maps are on a scale of 1:125,000.

The area represented is about 925 square miles. In Maryland it comprises the southern portion of Garret county and a small area in the southwestern corner of Alleghany county. In West Virginia it includes nearly all of Grant county, the western portions of Hardy and Mineral counties, the northeastern portion of Tucker county, and a narrow area of Preston county adjacent to the Maryland boundary line. Its southeastern corner is in a region of Appalachian ridges, and it extends northwestward over the Alleghany Mountains and the Upper Potomac coal basin to the headwaters of the Youghiogheny River, a branch of the Monongahela River.

The geologic formations comprise members ranging from the sandstones in the middle of the Silurian to the Upper Coal Measures of the Carboniferous. In the southeastern portion of the area there are two sharp anticlinal uplifts which bring up the Silurian rocks in two prominent mountains, New Creek Mountain and Patterson Creek Mountain. To the westward lies the coal basin which extends from the Alleghany front to the Backbone Mountain. Along its center is cut the deep gorge of the north branch of the Potomac River. The basin is a relatively shallow one, but it contains about 3000 feet of Carboniferous deposits. To the westward is the anticlinal region of

Devonian rocks which underlie the characteristic glade country about Oakland, Mountain Lake Park, and Deer Park. West of Oakland is another synclinal basin containing about 2500 feet of Carboniferous beds.

The geologic classification does not differ materially from that outlined by W. B. Rogers and others, but geographic names have been applied to all of the formations. The lowest members are a series of sandstones and quartzites, which have been referred to as "No. IV" and "Medina." This series has been subdivided into the Juniata formation, consisting of brownish red sandstones and shales; the Tuscarora quartzite; and the Cacapon sandstones, consisting of thin-bedded red sandstones. Next there is the representative Clinton formation, which has been designated the Rockwood formation, as in other folios; the Lewiston limestones, including representatives of the Helderberg and associated limestones, and the Monterey sandstones, Romney shales, Jennings formation and Hampshire formation, representing the Devonian deposits. As the last three formations are not sharply separated from each other, the patterns by which they are represented on the map are merged in a narrow zone along their boundaries. The Carboniferous period is represented by the Pocono sandstone; the Greenbrier limestone; the Canaan formation, which in a general way is a representative of the Mauch Chunk shales; the Blackwater formation, which represents the Pottsville conglomerate in greater or less part; the Savage formation and Bayard formation, which are the Lower Coal Measures; the Fairfax formation, or Lower Barren Measures, and the Elk Garden formation, a part of the Upper Coal Measures.

The principal coal beds are in the Savage formation, containing the "six-foot" or Davis coal bed; the Bayard formation, containing the coal bed known as the "four-foot" or "three-foot," or "Bayard" or "Thomas" coal; and the Elk Garden formation, containing the "fourteen-foot" coal bed.

On the economic sheet of this folio, the coal-bearing formations are strongly emphasized, and underground contours are introduced to show the lay of the "six-foot" coal bed in the Savage formation for each 100 feet. Other economic resources of the area are red hematite iron ores in thin beds in Rockwood shales and limestones at several horizons, of which the lower member in the Lewiston is locally available for cement.

United States Geologic Atlas, Folio 23, Nomini, Maryland-Virginia, 1896.

This folio consists of four pages of text signed by N. H. Darton, geologist, a topographic map of the district, a map showing the areal geology, and a map showing the distribution of underground waters and artesian wells. The scale of these maps is 1:125,000.

The area represented in this folio is about 938 square miles, which lies partly in Virginia and partly in Maryland. In Virginia it comprises nearly all of Westmoreland county, with parts of Essex, Northumberland, and Richmond, and in Maryland it includes portions of St. Mary, Charles, and Calvert counties. It lies entirely within the Coastal Plain area. The Potomac River extends northwest and southeast across the middle of the area, the Patuxent River crosses its northeastern corner, and the Rappahannock River crosses its southwestern corner. To the extreme northeastward it extends to the shore of Chesapeake Bay. These waters are all tidal estuaries. Along the river valleys there are wide, low terraces capped by the Columbia formation, of Pleistocene age. The intervening areas are plateau remnants capped by Lafayette deposits, of supposed Pliocene age. The underlying formations are the Chesapeake and Pamunkey, the latter extending from the westward only a few miles into the area, along the north side of the Potomac River.

The Pamunkey formation, of which only the uppermost beds are exposed, consist in greater part of glauconitic marls of Eocene age. It is overlain unconformably by the Chesapeake formation, which is characterized by fine sands, marls, and clays, portions of which consist largely of diatomaceous remains. The formation is very fossiliferous at some localities. Its age is Miocene. The greatest thickness which it presents in the Nomini area is about 270 feet, but it continues to thicken gradually to the eastward.

The Lafayette formation, which ranges from 25 to 40 feet in thickness, consists of sandy loams of orange, brown and buff tints often variegated, containing irregularly disposed bands and sprinklings of small quartzite pebbles and coarse sands. The pebbles and larger sand grains are orange tinted, mainly by superficial staining. The plateau surface, capped by this formation and deeply incised and dissected by the larger drainage depressions, inclines gently southeastward at an altitude ranging from about 190 feet along the northern and western border of the area to about 90 feet along its eastern border. Its greatest altitude is 200 feet in a portion of Nomini cliffs. It has also in most cases a slight slope into each of the river valleys.

The Columbia formation is a deposit of loam merging downward into coarser materials containing beds of quartzite, gravel, and bowlders. Its thickness averages 20 feet. Its surface extends from altitudes of 5 to 60 feet above tide level.

The principal economic features are underground waters, which on the lower lands furnish flows for artesian wells. Three water-bearing horizons are known, one at the base of the Pamunkey, another 100 feet higher in the same formation, and a third in the lower sandy members of the Chesapeake formation. They all dip to the eastward at a very moderate rate. There are many artesian wells which obtain water supplies from 160 to 305 feet. On the artesian well sheet of the folio distinctive underground contours are given to show the depths below tide level of all of the water-bearing horizons.

Other economic resources of the area are marls in the Pamunkey and Chesapeake formations, diatomaceous deposits in the Chesapeake formation which are often sufficiently pure for commercial use, brick clays, potter's clays, sand and gravel.

Geologic Atlas of the United States. Folio 26, Pocahontas, Virginia-West Virginia, 1896.

This folio, by Marius R. Campbell, consists of five pages of text, a topographic sheet (scale 1 : 125,000), a sheet of areal geology, one of economic geology, another of structure sections, and, finally, a sheet giving a generalized columnar section of the district.

The territory mapped and described embraces an area of 950 square miles, the southern portion of which is in Virginia and the northern portion in West Virginia. It is located west of New (Kanawha) River at the place where the state line leaves East River Mountain, the last of the valley ridges toward the northwest, and follows the irregular crests of the ridges within the coal field. The southern portion of this territory is within the limits of the Appalachian valley, and its surface is marked by linear mountains and narrow valleys, which are the characteristic forms of this central division of the Appalachian province. The northern portion is within the Cumberland plateau region, and its surface is that of a tableland deeply dissected, so that it now presents a confused mass of irregular ridges and hills, only the summits of which reach the original level of the plateau.

The geologic structure of this region varies as the topography varies. In the northern portion the rocks are nearly horizontal, their northwestward slope being rarely more than 200 feet per mile, whereas in the southern portion the rocks have been highly compressed in a horizontal direction, forming huge folds, which in many places have broken, allowing one portion of the fold to slip over the other. It is this tilted condition of the strata which gives rise to the regular topographic forms of the Appalachian valley. The attitude of the rocks is shown on the structure-section sheet by four sections which cross various portions of the territory.

The geologic history of this region is recorded in the rocks, which tell of prevailingly marine conditions from early Cambrian to late Carboniferous time. There were deposited during that time sediments to the extent of 17,000 or 18,000 feet in thickness, which have since been hardened into limestone, shale, and sandstone. Of this great mass the limestones form about 6700 feet; the shales 9500 feet; and the sandstones, about 1400 feet. On lithologic grounds these have been divided into twenty-three separate and distinct formations, which are shown on the general geologic map by various colors and patterns.

There is little variety in the mineral resources of this region. Coal, iron ore, and marble constitute about all of the mineral wealth of the territory. A limited area of coarse gray marble occurs along the northern front of Big Walker Mountain, but no development has been undertaken.

Iron ore occurs in two formations of the Upper Silurian rocks. It is of good quality, and probably in sufficient quantity to be of commercial importance, but its inaccessibility has prevented development.

Coal is by far the most important mineral resource of this region. The territory represented by this sheet embraces almost the entire Flat Top or Pocahontas coal field at present developed. All operations are confined to the great No. III or Pocahontas seam of coal, which is semi-bituminous and ranges in thickness from four to ten feet. It is exposed along the valley of Bluestone River from Pocahontas to the edge of the territory; along Tug Fork; in the valley of Elkhorn Creek from Coaldale to Kimball, near the edge of the area; and at several places on the head streams of Guyandotte River. Mining is restricted to the Bluestone region and the valley of Elkhorn Creek. In these two areas there are at present in operation thirty-seven distinct mines, which in 1894 produced 3,096,867 long tons of coal.

Geologic Atlas of the United States. Folio 25, Loudon, Tennessee, 1896.

The Loudon folio represents that portion of the Appalachian province which is situated beween the parallels 35° 30′ and 36° and the meridians 84° and 84° 30′. This area contains 968 square miles, divided among Blount, Monroe, Loudon, Knox, Roane and Morgan counties, Tennessee. The folio consists of a topographic map, a geologic map, structure sections, stratigraphic sections, a map of the economic resources, and descriptive text. The author is Arthur Keith.

The text begins with a general description of the Appalachian province, and points out the relations of this area to the general region, with regard to its surface features. The local features of the drainage by the Tennesse River and its tributaries, Emory, Clinch, Tellico, and Little Tennessee, follow next in description. The various forms of surface, such as the great valley of Tennessee and the portions of the mountain district and the Cumberland plateau by which it is bounded, are pointed out, and the relation between these forms and the underlying rocks is made clear.

Under the heading "Stratigraphy," the geologic history of the Appalachian province is presented in outline, and the local rock groups are fully described in regard to composition, thickness, location, varieties, and mode of deposition. The formations, thirty-three in number, range in age from Cambrian, to Carboniferous; being, for the greater part, Cambrian and Silurian. The mountain district is chiefly underlain by the Ocoee series, whose age is doubtful. Rocks of Carboniferous and Devonian age occupy two small belts on either side of the great valley, and Silurian and Cambrian strata are repeated in narrow belts along it. Limestones, shales, and interbedded sandstones make up the Silurian and Cambrian strata; sandstones and shales with coal seams and a limestone near the base constitute the Carboniferous; and the Ocoee rocks are conglomerates, sandstone, slate, and limestone.

The details of the strata are graphically represented in the columnar section. The different manners in which the formations decay is discussed, and the dependence of the residual soils and surface forms on the nature of the underlying rock is brought out. Great lithologic changes occur in the formations of this region, and the Knox dolomite is the only one which is uniform throughout. The direction of change was exactly reversed between Cambrian and Silurian times.

In the discussion of "Structure," after a general statement of the broader features of the province, two processes by which the strata of this quadrangle were deformed are noted. Of these the extreme Appalachian folding accompanied by faulting and metamorphism is by far the more prominent and is about equally developed throughout the quadrangle. Faults, especially, are most strikingly exhibited here. Deformation by vertical uplift is also exhibited, but it is only noticeable in comparison with broad surrounding areas. In this quadrangle the great valley is at its narrowest, on account of the extreme shortening in deformation. The structure sections illustrate the sharp folds and frequent faults into which the strata were forced. Economic products of this region are coal, variegated marble, red hematite, building stone, lime, clays, slate and timber. The outcrops of the formations containing these are indicated on the economic sheet, together with the locations of the mines and quarries. The iron ore and slate are at present of minor importance. The coal district is a part of the great coal basin of Tennessee, and the marble belts are a part of the principal productive region for that stone. Various conditions affecting the value of these deposits are pointed out, and the associations and availability of the building materials and timbers are discussed.

Geologic Atlas of the United States. Folio 27, Morristown, Tennessee, 1896.

The Morristown folio by Arthur Keith, deals with that portion of the Appalachian province which is situated between the parallels 36° and 36° 30′ and the meridians 83° and 83° 30′. This area contains 963 square miles, divided among the counties of Green, Cocke, Jefferson, Hamblen, Grainger, Claiborne, Hancock, and Hawkins, all in Tennessee. Included in the folio are topographic, economic, and geologic maps, structure and stratigraphic sections, and five pages of descriptive text.

After a description of the broader features of the Appalachian province, the local geography is analyzed. The various types of surface features are pointed out, and their relations to the underlying rocks are shown. Local phenomena such as elevations and the details of the drainage which is effected by the Nolichucky, French, Broad, Holston, and Clinch rivers, tributaries of the Tennessee, are detailed.

Under the heading "Stratigraphy" the geologic history of the Appalachians is presented in outline. This is followed by a detailed account of the local rock groups, in regard to their location, composition, thickness, variations, and mode of deposition. The soils and forms of surface produced by each formation are discussed with the formations. Twenty formations ranging from Cambrian to Carboniferous, are distinguished in this quadrangle; the greater portion being Cambrian and Silurian. The rocks of Carboniferous and Devonian age are found only in two narrow belts in the ridge district, and are represented by only four formations. Over the rest of the area Cambrian and Silurian strata are about equally represented. A great variety of limestones, shales, and sandstones compose the Cambrian and Silurian rocks. Shales and sandstones make up the Devonian, while only the limestone appears in the Carboniferous. Great changes take place in the Silurian strata; limestones on the northwest being represented by shales and sandstones at the southeast. The general character of the formations is graphically represented in the columnar sections, one being drawn for each of the two chief geologic districts.

In the discussion of structure, after a general statement of the broader features of Appalachian structure, the two types of deformation shown in this region are described, and illustrations are pointed out in the structure sections. In the ridge district the most prominent feature is the faulting, which has cut the strata into long narrow blocks and produced the characteristic ridge topography. Southeast of Holston River the rocks were deformed by close folds. Deformation by vertical uplift is also present, but it can only be observed in comparison with other and larger areas. In the structure sections, most of the details of the different structures are shown.

Economic products of this region are marble, building stone, lead, zinc, cement, clays, and timber. The outcrops of the formations containing these are represented on the economic sheet as far as possible, together with the locations of mines and quarries. The principle industries are the production of zinc and marble; the timbers and water powers are also of general importance. The various conditions which affect the development of these resources are discussed.

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