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THE AUTHORS OF THE SEVERAL PAPERS ARE INDIVIDUALLY RESPONSIBLE FOR THE SOUNDNESS OF THE OPINIONS GIVEN AND FOR THE ACCURACY OF THE STATEMENTS MADE THEREIN.

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Art. I.—*Anatomy of Australian Coniferous Timbers.*

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(With Plates I.-V.)

[Read 10th March, 1927.]

Introduction.

The conifers of Australia are unique in many respects, as has often been remarked, and are on the whole widely different from those of the Northern Hemisphere. The large and well-known tribe, Abietineae, is entirely absent from Australia, and associated with this is the entire absence of such characters as the fusiform ray, the ray tracheide, and the resin canal. On the other hand, the resin tracheide, which is entirely absent from the above mentioned tribe, appears in two of our genera, *Agathis* and *Araucaria,* belonging to the tribe Araucarineae, which is almost exclusively southern.

Owing to the difficulty in obtaining some of our isolated species a long time has elapsed since this work was begun. Specimens of all the genera have been obtained, but the following species have not been received: *Callitris Roei* Endl., *C. Morrisoni,* R.T.B., *C. Drummondii* Benth. et Hook., *Actinostrobus acuminatus* Parlat., and *Podocarpus Drouyniana* F.v.M.

Although the work is not complete, it has been decided to publish what has been done owing to many requests for information regarding the structure of our conifers. The structure of the commercial coniferous timbers of Australia has been studied by Baker and Smith (1), but these authors did not investigate the non-commercial species. These latter are of interest, however, from a palaeontological point of view. Moreover, these authors have used well recognised terms in somewhat unusual ways. The present work, therefore, has covered all the species obtainable.

For the accompanying photomicrographs I am indebted to Mr. H. Marriott, of the Anatomy Department, University of Melbourne.

Pherosphaera.

This genus is endemic to Australia and Tasmania. One species, *P. Fitzgeraldi* F.v.M., is found in New South Wales, and the other, *P. Hookeriana* Arch., in Tasmania. Both are small shrubs growing in restricted habitats.

Transverse.—Rings fairly well defined, walls thick, lumen of cells of summer wood almost obliterated. Width of cells about 15 μ. Resin cells moderately abundant or absent.

Radial.—Bordered pits uniseriate, occasionally partly biseriate. Pits on the lateral walls of the medullary rays one per tracheide, large, elliptical and oblique.

Tangential.—Medullary rays 1-5 cells high. Pits present on the tangential walls of the tracheides.

Tracheides from 0·7 to 1·3 mm. long.

In *P. Hookeriana* the cells walls are not nearly so thickened as in *P. Fitzgeraldi*. In the former the cells are squarish, with walls 3-5 μ in thickness, but in the latter they are rounded and the walls are 6-8 μ thick. In both species the thickness of the wall throughout the ring is fairly constant. In *P. Fitzgeraldi* pits on the tangential walls are very abundant, but infrequent in *P. Hookeriana*.

Material of both species authenticated by Professor Lawson; material of *P. Hookeriana* from Government Botanist, Tasmania, and from G. Weindorfer, Esq.

Microcachrys.

A monotypic genus endemic to Tasmania, *M. tetragona* Hook. is a small shrub, rare.

Transverse.—Rings rather indefinite; tracheides not very regularly arranged in radial rows; walls thin, squarish. Resin cells absent.

Radial.—Bordered pits uniseriate, indistinct. Lateral walls of medullary rays 1-2 pits per tracheide. These pits are very irregular as regards size and shape; some are large and open without any border, while some are narrow, elongated and bordered. Medullary rays frequently irregular in outline. No parenchyma.

Tangential.—Medullary rays 1-4 cells high, maximum 7. Cells elongated, thin walled.

Material authenticated by Government Botanist, Tasmania, and by G. Weindorfer, Esq., Cradle Mt., Tasmania.

Dacrydium.

There is only one species, *D. Franklinii* Hook. It is an average-sized tree, and is endemic to Tasmania. The genus is also found in the Malay area, New Zealand, and Chile.

Transverse.—Rings narrow, well defined. Summer wood 2-4 cells wide. Spring wood very open, cells usually somewhat hexagonal or rounded. Thickness of walls of spring wood about 8 μ. Tracheides not in regular radial rows. Resin cells absent.

Radial.—Bordered pits uniseriate, not crowded. Medullary rays have the marginal walls somewhat sinuous. Lateral pits on medullary rays one, rarely two, per tracheide, large, elliptical, oblique, narrow or broad. Parenchyma absent.

Tangential.—Medullary rays 3-7 cells high, maximum 13. Cells thick walled. Parenchyma absent.

Material from trade sources and from the Sydney Technological Museum.

In regard to this species Baker and Smith (1) state that one of "the most distinguishing characters of the wood is the fineness of the wall structure." This is by no means the case as their photograph shows. This statement could well be used in regard to *Athrotaxis.* As a matter of fact the walls are thick and there is very little difference between the thickness of the spring and summer cell walls.

In microscopic section *Dacrydium Franklinii* cannot be satisfactorily distinguished from *Phyllocladus rhomboidalis.* In the latter the pits on the medullary rays are usually larger than in the former, and in the latter also two pits per tracheide are common.

In *Phyllocladus rhomboidalis* the tracheides are more rectangular, seen in cross section, than in *Dacrydium Franklinii.*

Podocarpus.

This genus is represented in Australia by six species, five of which have been studied. The genus is very widespread in the Pacific regions, extending from New Zealand to Japan. In habit they range from dwarf shrubs, as *P. alpina,* to large trees, as *P. elata.*

Transverse.—Growth rings more or less indefinite, the spring wood gradually passing into summer wood, the latter consisting of one to few rows of very narrow cells. Walls thick, cells subrectangular to round, arranged in fairly definite radial rows. Medullary rays resinous or non-resinous. Resin cells present or absent; when present, widely scattering or zoned. This character is widely variable both in Australian and extra-Australian species. Kanehira (4), speaking of *P. philippinensis* Foxworthy says, "Resin cells numerous, often connected tangentially"; while of *P. macrophyllus* Don (5) he says, "Resin cells present rather scarce." Again, speaking of *P. Nagi* Zoll et Moritz, he says, "Resin cells evenly distributed in both early and late wood." The character is not generic.

Radial.—Rays resinous, uniform in character. The outer upper and lower walls somewhat irregular in outline and thicker walled. Inner horizontal walls not strictly parallel. End walls more or less vertical, unpitted, frequently curved. Lateral walls bearing 1-3 bordered pits per tracheide; pit aperture narrow or broad, oblique. Bordered pits uniseriate or incompletely biseriate, and then opposed, not alternate. Pits scattered, generally, but when crowded, indistinct Bars of Sanio are visible. Resin cells conspicuous when present.

Tangential.—Rays uniseriate, moderate in height; cells elliptical to round, thin to thick-walled, sometimes resinous.

This genus with its somewhat rounded cells, scattering resin cells, and single rows of bordered pits, is very similar to *Callitris.* No species of *Podocarpus* has, however, the peculiar plate of thickening across the bordered pits as seen in some species of *Callitris.* The cells of *Callitris,* as seen in transverse section, are always more rounded. In *Podocarpus* the medullary rays never have more than three pits per tracheide.

PODOCARPUS ELATA R.Br.

Transverse.—Rings of growth broad, summer wood few cells thick, not very distinct; the cells being about half the width of the spring wood cells. Resin cells abundant, widely scattered.

Radial.—Resin cells conspicuous; rays resinous.

Tangential.—Ray cells resinous, elliptical.

Specimen authenticated by the Sydney Technological Museum.

P. PEDUNCULATA Bail.

Transverse.—Rings very indefinite, thin walled. Resin cells absent.

Radial.—Ray cells devoid of resin; resin cells absent. Pits on medullary rays moderately large, widely open.

Tangential.—Medullary rays devoid of resin; cells varying greatly in size; thin walled.

Specimen authenticated by the Technological Museum, Sydney.

P. SPINULOSA R.Br.

Cells rounded, thick walled; resin cells absent. Rings of growth not determinable. Rays devoid of resin.

Specimen authenticated by the Technological Museum, Sydney.

P. LADEI Bail.

Similar to *P. spinulosa.*

Specimen authenticated by Government Botanist, Queensland.

P. ALPINA R.Br.

Transverse.—Rings very narrow, only a few cells wide, very irregular in width, fairly distinct. Resin cells abundant.

Radial.—Resin parenchyma present. Pits on lateral walls of medullary rays usually two, large, elliptical.

Tangential.—Rays very short, one cell high common, maximum four.

Specimens authenticated by Government Botanist, Tasmania; G. Weindorfer, Esq.; and by the author.

Phyllocladus.

This genus is not found on the mainland of Australia, and our only species, *P. rhomboidalis* Rich., is endemic to Tasmania. The genus is also found in New Zealand and the East Indies. The timber of *P. rhomboidalis* is known commercially as Celery Top Pine.

Transverse.—Rings comparatively narrow, well defined. Summer wood 2-4 cells broad, lumen almost obliterated. Spring wood open, thick walled, rectangular; cells up to 40 μ in length, radially arranged. Resin cells absent.

Radial.—Bordered pits uniseriate, not crowded, often scattered; no Bars of Sanio present. Resin cells absent. Upper and lower walls of the medullary rays straight or slightly sinuous, outer walls thinner than the inner. Pits on the lateral walls 1-2 per tracheide, large, oblique, elliptical, faintly bordered. Occasionally the aperture is narrow and then it is distinct.

Tangential.—Medullary rays generally 4-12 cells high, maximum 20. Cells elliptical, thin walled. Bordered pits on the tangential walls.

Authenticated material from the Sydney Technological Museum, and from trade sources.

In regard to this species Baker and Smith (1) say, " Similar anatomical characters " to those of *Dacrydium Franklinii.* This is so. These authors would separate the two species by the presence of bordered pits on the tangential walls of *Phyllocladus rhomboidalis*, and their absence from *Dacrydium Franklinii*. This does not hold absolutely.

Agathis and Araucaria.

Agathis is represented in Australia by three species, only one of which, *A. robusta* C. Moore, Queensland Kauri, is well known. The other two, *A. Palmerstoni* F.v.M., and *A. microstachys* Bail. et White, are also restricted to Queensland, but are confined to the far north of that State.

Araucaria is represented by two species. One, *A. Cunninghamii* Sweet, which extends down from Queensland into the north-eastern part of New South Wales, gives the well known Hoop Pine of commerce. The other, *A. Bidwilli* Hook., is confined to Queensland. It may be noted that all these five species are restricted to the coastal regions of North-Eastern Australia.

Botanically these two genera are very definite, but microscopically the timbers are very similar Penhallow (2) sought to distinguish the two genera by the distinctness of the annual rings and for *Araucaria* he states, " Growth rings not determinable," and for *Agathis* he says, " Growth rings obvious but poorly defined." The definiteness of the growth rings is not a generic character, and Penhallow himself, under *Araucaria Bidwilli*, states, " Growth rings broad, poorly defined," almost the same words as for the genus *Agathis*. Baker and Smith would separate the two genera by means of the presence or absence of resin in the medullary rays. They say (1, p. 329) that this " is an important generic, specific and phylogenetic character." An examination of Baker and Smith's own material, however, shows that this substance is present in all species. Baker and Smith themselves, under *A. Bidwillii*, say, *loc. cit.*, " The medullary rays have their cells filled with the brown or dark substance." It is true that resin is far more plentiful in *Agathis* than in *Araucaria* as a general rule, but *Araucaria Bidwillii* contains more resin than *Agathis Palmerstoni*. Baker and Smith also attempt to separate these two genera by the absence of bordered pits from the tangential walls of species of *Agathis.* This latter genus, however, has pits on the tangential walls just as has *Araucaria.* Kanehira (4) notes pitting on the tangential walls of *A. alba.* Pitting on the tangential walls is a character easily overlooked.

It has been found impossible by the author to find a single character that will separate the two genera. In the hand specimen, kauri timbers are somewhat denser, and usually darker, due to a greater amount of resin present, than Araucarian timbers. The darkness of the timbers is shown by *A. australis* Steud (New Zealand), *A. robusta* (C. Moore) F.v.M. (Queensland), *A. microstachys* Bailey et White (Queensland), and *A. lanceolata* Panch. et Sebert (New Caledonia). In all these the rays are dark coloured, but in *Agathis Palmerstoni* they are light coloured. The timber of the various species of *Araucaria* is usually light coloured. The rays are slightly darker, due to the presence of some resin. The timber of *A. Bidwilli,* however, is very dark, and in this respect approaches a kauri.

Transverse.—The tracheides are thick walled and vary from hexagonal to circular in shape. The tracheides are arranged in fairly definite rows. The annual rings are not conspicuous, and the summer wood may be reduced to a single row. Alongside the medullary rays resinous tracheides are more or less common. They are much more frequent in *Agathis* than in *Araucaria.* However, Kanehira (4) notes that in *Agathis alba* (Lamarck) Foxworthy, "Resin cells normally absent." In the only specimen of *Agathis Palmerstoni* obtainable, the resin tracheides were also absent. In *Agathis microstachys* they are scattered, not radially arranged along the medullary rays. Medullary rays usually resinous, particularly in *Agathis.*

Radial.—As is common in other Australian genera, the ray cells are all of one kind. The conspicuous feature of the rays is their irregular shape. They are more or less conspicuously contracted at the ends, and at times the end wall is obliterated. This character was observed by Penhallow (2) in the species of both genera which he studied. The character is, apparently, common to all species. It is not commented on by either Jeffry (6) or Baker and Smith (1). It was noted by Jones (3). The walls of the ray cells are thin, and do not show any local thickening. The lateral walls bear a varying number of bordered pits, where in contact with a tracheide. They range from 2 to 12 in number.

A conspicuous feature of the resin tracheides is the presence of resin plates across the cells. These are more abundant near the medullary rays. These plates are fully discussed by Penhallow (2), and they give a pseudo-parenchymatous appearance to the tissue. They vary in thickness, some are uniformly thin, others are very thick where in contact with the cell wall and narrow towards the centre. Usually the plate is entire, but it may have a small perforation at the centre. These plates were also noted by Jones (3), but they are not mentioned by Jeffry (6), who, however, does mention parenchyma. In no species studied has any parenchyma been found. The bordered pits on the radial walls range from one to four rows, the pits in each row alternating, and when crowded have an hexagonal outline. In *Agathis robusta* and *Agathis Palmerstoni*, where extra broad tracheides occur, there is an irregularity of the four rows, and a fifth row is possible. The opening of the pit is usually oblique.

Tangential.—Medullary uniseriate, rather low, averaging from three to twelve cells high. Cells oval, resinous. Resin plates conspicuous, when present. Pitting on the tangential walls common to all species. The pits may be either large or small.

Agathis robusta (C. Moore) F.v.M.

Transverse.—Rings poorly defined, summer wood 2-4 cells wide. Resin tracheides bordering the medullary rays plentiful, a few scattered. Rays resinous.

Radial.—Bordered pits 2-4 seriate, four rows abundant; aperture circular. Medullary rays resinous; 2-8 pits per tracheide; aperture oblique, narrow. Resin plates abundant.

Tangential.—Rays uniseriate, 3-15 cells high, maximum 25. Pits present on the tangential walls.

The two conspicuous features of this timber are the presence of four rows of bordered pits, and the abundance of resinous tracheides. Baker and Smith (1) state in regard to this timber, "... xlyem tracheides are also devoid of this substance (i.e., resin) ... one that differentiates the timber from *Araucaria*." The resinous tracheides are, however, abundantly present. Again (p. 377) they state, "The large number (up to twelve) of simple cells between the walls of the lumina is also a good diagnostic character of the genus." Note the curious use of the word "cell," where evidently pit is intended. The large number of pits is also found in *A. microstachys*.

Authenticated material from Sydney Technological Museum and from trade sources.

Agathis microstachys Bailey et White.

Transverse.—Rings poorly defined, 2-4 rows of summer tracheides. Resin tracheides common, scattered, not occurring along the rays. Medullary rays resinous.

Radial.—Bordered pits 1-2 seriate, occasionally three, aperture narrow, oblique. Ray cells conspicuously contracted, very resinous. Pits on the medullary rays 2-5 per tracheide, rarely more; bordered, aperture oblique.

Tangential.—Rays uniseriate, 4-12 cells high, maximum 19. Cells thin walled, round. Resin plates plentiful. Pits on tangential walls. Authenticated material from Government Botanist, Queensland.

Agathis palmerstoni F.v.M.

Transverse.—Medullary rays only slightly resinous. Resinous tracheides absent.

Radial.—Bordered pits 1-4 rows, 3-4 rows frequent, aperture circular. Resin in the medullary rays very infrequent; pits on lateral walls of rays 3-12 per tracheide, aperture oblique. Resin plates absent.

Tangential.—Rays uniseriate, 3-12 cells high, maximum 25. Bordered pits on the tangential walls.

Authenticated material from Queensland Forest Service.

Araucaria cunninghami Sweet.

This timber has been described by Penhallow (2), and there is nothing to add to his description. Baker and Smith (1) state in respect to the resin in the medullary rays, " . . . almost entire absence," but Penhallow remarks, on the other hand, "somewhat resinous." The resin in the rays is a very variable quantity. Timber grown in the grounds of the University of Melbourne shows no resin in the rays at all. Resin tracheides are also very variable in their occurrence. Some specimens show large numbers, others none. In the timber grown at the University, the resin tracheides are zoned, and none occurs adjacent to and parallel to the rays In regard to the numbers of rows of bordered pits on the radial walls of the tracheides, Baker and Smith say 2-3, but Penhallow says 1-2. There is very occasionally a third row. A single row is common. Penhallow says that pits on the tangential walls are wanting, but they do occur as noted by Baker and Smith. Penhallow remarks that the rays may be two seriate, but the author has not noted this, and apparently neither did Baker and Smith.

Authenticated material from Queensland Forest Service, Technological Museum, Sydney, Trade Sources, and from known trees.

Araucaria Bidwilli Hook.

This has been described by Penhallow, who separates this timber microscopically from *A. Cunninghamii* by the bordered pits being uniseriate. Both species have biseriate rows of pits. Baker and Smith, speaking of the end walls of the ray cells, state that they are right angled, while Penhallow remarks that the cells are "conspicuously contracted at the ends." The latter character frequently interferes with the direction of the end walls. Baker and Smith give the number of pits on the ray cells per tracheide as 4, while Penhallow gives 3-7. The latter number is correct.

Specimens of this timber grown locally show no resin tracheides at all and there is very little resin in the ray cells. It is apparent that the presence or absence of resin from either the tracheides or the rays is very variable, and that its absence from any particular specimen cannot be taken as a definite character.

Authenticated material from Sydney Technological Museum and from known trees.

Athrotaxis.

This genus is endemic to Tasmania. Of the three species, the only well-known one is *A. selaginoides* Don, which provides the King William Pine of commerce. This is one of the lightest of timbers. The other two are small, and are very restricted in distribution. All three have reddish timber, and in structure they resemble the genus *Sequoia*.

Transverse.—Rings very definite, the summer wood having very thick walls, and very narrow lumen, which is very often less than the thickness of the walls. Spring cells more or less definitely rectangular, several times longer than those of the summer wood. Resin cells present or absent, when present scattered.

Radial.—Border pits uniseriate or biseriate; when biseriate, then opposed, not alternate. Bars of Sanio present. Medullary rays narrow, irregular hastate cells often present when the rays are only one cell high. End walls vertical or oblique, often curved. Lateral walls of rays 1-6 pits per tracheide, bordered. Parenchyma present. Resin in parenchyma present or absent.

Tangential.—Medullary rays variable, in height, short rays common. Cells elliptical, thick walled. Pits on tangential walls of spring wood, common, very small.

A. SELAGINOIDES, Don.

Transverse.—Rings very narrow, up to 60 rings to an inch, usually less than 10 cells wide. Summer wood 2-4 cells, springwood up to 8 cells. Resin cells abundant.

Radial.—Bordered pits frequently two seriate. Bars of Sanio conspicuous. Pits on the medullary rays 2-5 per tracheide. Resin cells prominent.

Tangential.—Medullary rays short, commonly 2-4 cells high, maximum 9, resin cells prominent.

Authenticated material from G. Weindorfer, Esq., and from trade sources.

A. CUPRESSOIDES Don.

Transverse.—Ring broad, comparable to *Sequoia sempervirens*. Cells not as rectangular as in *A. selaginoides*. Resin cells abundant, either in or towards the summer wood.

Radial.—Bordered pits mostly uniseriate. Medullary rays 1-2 pits per tracheide. Resin cells abundant.

Tangential.—Medullary slightly higher than in *A. selaginoides*.

Authenticated material from G. Weindorfer, Esq.

A. LAXIFOLIA Hook.

Transverse.—As in *A. cupressoides*, but resin cells wanting. In young specimens isolated unthickened cells occur as in *Diselma Archeri*.

Radial.—Bordered pits uniseriate. Parenchyma abundant, but no resin present. Traumatic resin parenchyma present in some specimens.

Tangential.—As in *A. cupressoides*.

Authenticated material from G. Weindorfer, Esq., and Government Botanist, Tasmania.

Callitris.

This is the most widespread genus of the Coniferae in Australia, being found in every State, and it has also the greatest number of species. If we exclude the related African forms, which are placed under *Tetraclinis* and *Widdringtonia*, *Callitris* is purely an Australian genus. The species range from shrubs to moderately large trees. The number of species is at present a matter of dispute. Bentham (7) recognised nine species under the synonym *Frenela*, but Baker and Smith (1) recognise at least 17. The respective lists are as follows:—

Baker and Smith.	Bentham.
Callitris robusta R.Br.	Frenela robusta A. Cunn.
C. tuberculata R.Br.	F. .. var. verrucosa
C. verrucosa R.Br.	F. .. .. ..
C. propinqua R.Br.	F. .. .. ..
C. glauca R.Br.	F. .. .. ..
C. arenosa A. Cunn.	F. .. var. microcarpa
C. intratropica Benth. et Hook.	F. .. .. ..
C. gracilis R.T.B.	
C. calcarata R.Br.	F. Endlicheri Parlat.
C. rhomboidea R.Br.	F. rhomboidea Endl.
C. Tasmanica Baker et Smith	F. .. var. Tasmanica
C. Drummondii Benth. et Hook.	F. Drummondii Parlat.
C. Roei Endl.	F. Roei Endl.
C. Morrisoni R.T.B.	
C. Muelleri Benth. et Hook.	F. Muelleri Parlat.
C. oblonga Rich.	F. australis R.Br.
C. Macleayana Benth. et Hook.	F. Macleayana Parlat.
	F. Parlatorei F.v.M.

Baker and Smith suppressed one of Bentham's species, *F. Parlatorei*, and created three new ones. It will be noted that Bentham's *F. robusta* was a very comprehensive one, and included no less than seven otherwise recognised species. Undoubtedly these are all closely related. *C. gracilis* R.T.B. is a doubtful species, and is regarded by some as a synonym for *C. propinqua*. Of the remaining nine species given by Baker and Smith, seven are agreed upon by both Baker and Smith on the one hand, and by Bentham on the other. The other two are new. To the above list must be added *C. Baileyi* C. T. White, which is a Queensland species.

Transverse.—Growth rings more or less distinct, but never strongly marked; spring wood passes gradually into the summer wood. Cells thick-walled, almost circular, arranged in radial rows. Resin cells more or less abundant, but never so plentiful as in *Podocarpus,* scattered or somewhat zoned. Medullary rays resinous.

Radial.—Bordered pits uniseriate, at times incompletely biseriate, scattered. Medullary rays strongly resinous, horizontal walls parallel, end walls vertical or oblique or slightly curved. Lateral walls of the rays 2-4 pits per tracheide, aperture oblique. Resin cells present.

Tangential.—Rays uniseriate, height variable. Cells elliptical, resinous.

Callitris robusta.

Under this species, Bentham grouped among others the five species of R. Brown, *C. robusta, C. verrucosa, C. propinqua, C. glauca, C. tuberculata,* Much confusion at present exists as to nomenclature. As originally understood by Brown, *C. robusta* was a West Australian species, but Victorian trees with large cones have been placed under it. Timber specimens of all the foregoing, except *C. tuberculata*, have been obtained, and numerous specimens from commercial sources have also been received. These all show without exception, structures which are very definite and characteristic. In radial section, each bordered pit is associated with a more or less rectangular plate of thickening, extending across the tracheide, beyond the margins of the pit, but not reaching to the upper or lower margin, as seen in Fig. 1*a,* These bands are connected to the tracheidal walls. The aperture of the pit lies within the band. In tangential section these bands appear as projecting awns as seen in Fig. 1*b*. The awns arise at the top and bottom of the aperture of the pit. Another feature seen in radial section is the peculiar compound pit (Fig. 1*c*) connecting the medullary rays with the tracheides. The pit is sub-

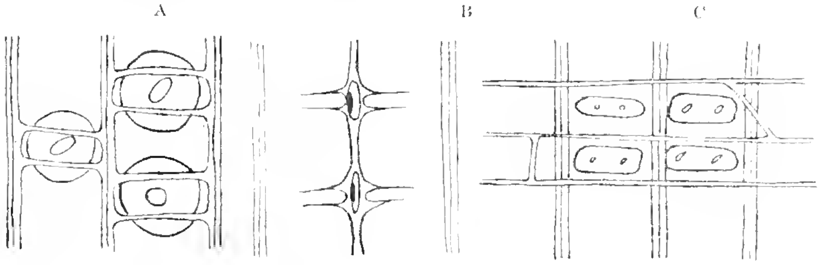

Fig. 1.

rectangular, the length being in the radial direction. The pit is not always parallel to the length of the ray cell, but may be slightly oblique. There are from one to four apertures connecting a tracheide with a ray cell, but there are never more than two apertures in these peculiar compound pits. Whenever in the four species mentioned above, the bands of thickening are found on the bordered pits of the tracheides, the compound pits are found on the ray cells.

In *C. arenosa* A. Cunn. and *C. intratropica* Benth. et Hook., as understood by Baker and Smith, and which were placed under *C. robusta* as var. *microcarpa* by Bentham, the bands across the bordered pits on the radial tracheidal walls are sparsely present, but the double pits on the medullary ray cells are absent. Although Bentham reduced these two species to varieties of *C. robusta*, some botanists to-day regard *C. intratropica* as a valid species, but would suppress *C. arenosa*, making it a synonym of the former. In both of these, the resin cells as seen in cross section, are congregated in the autumn wood; so that here the resin cells may be regarded as zoned as distinct from the scattering cells of the preceding group. The two species, *C. arenosa* and *C. intratropica*, differ from one another in the height of the medullary rays. In *C. arenosa* the rays are shorter than in the former group, rays of 2, 3 and 4 cell high being common. On the other hand, the rays of *C. intratropica* are very elongated, a fact noted by Baker and Smith. The rays generally range from 7 to 25 cells high, but the maximum is 33. In the first group the rays are usually from 4 to 10 cells high.

C. gracilis was not seen, but a tangential microphotograph (rather imperfect), Fig. 127, given in Baker and Smith's work, suggests that the awns are present. This species is regarded by some as a synonym of *C. propinqua*, and in this the awns do occur. *C. calcarata* was recognised as a distinct species by Bentham, and by Baker and Smith. The rays are slightly longer than in the first five species discussed, although Baker and Smith state that the reverse is the case. The rays generally range from 5 to 14 cells high.

C. Baileyi, the most recent species to be described, does not differ in any material way from the robusta group.

The thickening band is absent from *C. Muelleri*, *C. oblonga*, *C. Macleayana*, *C. rhomboidea* and *C. Tasmanica*. This character, therefore, serves as a useful guide in the classification of the genus.

C. Muelleri has very short medullary rays, a fact noted by Baker and Smith. The rays are usually from 2 to 4 cells high, the maximum being 10.

C. oblonga also shows short medullary rays. In this case they are shorter than those of *C. Muelleri*, being from 1 to 4 cells high.

C. rhomboidea has also short medullary rays. Its structure does not in any way differ from the preceding. *C. Tasmanica*, which some regard as a synonym for *C. rhomboidea*, has longer medullary rays. They are usually from 3 to 7 cells high, maximum 13.

C. Macleayana is a most distinctive tree, but its timber does not show any marked character.

The three West Australian species, *C. Drummondii*, *C. Roei* and *C. Morrisoni*, were not studied by Baker and Smith, and no material has been available for this study.

Material of *C. robusta*, *C. verrucosa*, *C. propinqua*, and *C. glauca* from Sydney Technological Museum, and from the author's collection. *C. arenosa*, *C. intratropica*, *C. gracilis*, *C. calcarata*, *C. rhomboidea*, *C. Tasmanica* and *C. Macleayana*, from Sydney Technological Museum. *C. Muelleri* from the Government Botanist, N.S.W., *C. Baileyi* from the Government Botanist, Queensland, *C. oblonga* from Tasmania, but not authenticated.

Actinostrobus.

This genus is very closely allied to *Callitris*, and Mueller suppressed it, and placed its two species under that genus. The two species are confined to West Australia, and both are shrubs. Specimens of *A. pyramidalis* Miq. have been authenticated by the Forestry Department, W.A., but no material of *A. acuminatus* Parlat. has been available. In structure the timber is indistinguishable from *Callitris*. Resin cells are plentiful in the transverse section, and are generally zoned. They are usually in the summer wood. In radial section the medullary rays shows a strong tendency to be contracted at the ends. There is a strong indication of this in some species of *Callitris*, but it is never marked. End walls frequently oblique, often curved. There are from 2 to 4 pits per tracheide on the medullary rays. There is no indication of the plate of thickening on the bordered pits.

Diselma.

This genus was established by Hooker in 1859. It is monotypic, and is confined to Tasmania. Bentham (7) followed Hooker in his determination, but subsequently in 1880 Bentham and Hooker in their Genera Plantarum suppressed this genus, and placed the solitary species under *Fitzroya*. *Diselma Archeri* Hook. is a shrub.

Transverse.—Rings narrow, well defined. Cells in the spring wood rounded, thick-walled; in the summer wood almost closed; radially arranged. Some cells which are conspicuously rectangular, appear to be larger than the others. Their apparent large size is due to the fact that no secondary thickening has taken place. Rays more or less resinous.

Radial.—Bordered pits uniseriate, aperture oblique. Medullary rays often irregular, cells sometimes arrow shaped (Fig. 2*a*), directed towards the exterior. Cells similar to this are figured by Jones (3) for *Sequoia sempervirens*. Lateral pits 2-4 per tracheide. End walls at times very strongly pitted. Lateral walls simply pitted. Parenchyma present, devoid of resin; transverse walls often strongly thickened at the centre, vertical walls, simply pitted when parenchyma cells are next to one another.

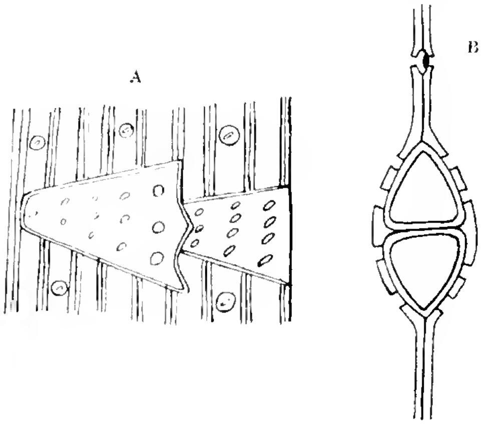

FIG. 2.

Tangential.—Medullary rays uniseriate, 1-4 cells high, one and two cells predominating. Cells elliptical, thick-walled, conspicuously pitted (Fig. 2*b*). Pits present on the tangential walls.

Tracheides.—Very short, 0·5 to 0·8 mm. long.

Material authenticated by G. Weindorfer, Esq., and Government Botanist, Tasmania.

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ADDENDUM.

Since the above was written another work from the hand of R. Kanehira has been received entitled, "Anatomical Characters and Identification of the Important Woods of the Japanese Empire." In this appear figures of radial sections, from the medullary ray region, of the following endemic Australian species, *Pherosphaera Hookeriana, Dacrydium Franklinii, Microcachrys tetragona, Phyllocladus rhomboidalis, Araucaria Cunninghamii, Athrotaxis selaginoides, Fitzroya Archeri, Callitris rhomboidea* and *Callitris* *glauca.* There are also photomicrographs of *Callitris glauca* (radial sections), and *Agathis robusta* (tangential and transverse sections). As the text is in Japanese characters the author is unable to say how far these species have been described. The figures of the two Tasmanian species, *Pherosphaera Hookeriana* and *Fitzroya Archeri* do not agree with the material I have worked with. Since receiving the above publication I have received from Tasmania more material of *Fitzroya Archeri,* and it agrees with the specimens previously obtained. The figure of *Pherosphaera Hookeriana* given by Kanehira is that of *Fitzroya Archeri.* The figure given for *Fitzroya Archeri* is probably that of *Pherosphaera Hookeriana.* The radial sections of *Dacrydium Franklinii* and *Phyllocladus rhomboidalis* are very similar, a fact which has been discussed in the preceding pages.

In the figure of *Callitris glauca* the compound pit on the medullary ray has been shown, and the plates of thickening on the bordered pits of the tracheides are also shown. Neither transverse nor tangential sections are given of any of the species.

EXPLANATION OF PLATES.

Plate I.

Podocarpus elata.—A, Transverse section showing the scattering resin cells and the indistinct boundary of an annual ring. × 80.

B, Radial section, showing the boundary of an annual ring, and resin in the medullary rays. × 80.

C, Tangential section showing the resin cells. × 80.

Plate II.

A, *Athrotaxis cupressoides.* Transverse section showing the resin cells zoned in the autumn wood, and the very strongly marked boundary of the annual ring. × 70

B, *Athrotaxis selaginoides.* Radial section showing the bordered pits arranged in pairs and also Bars of Sanio. × 190.

C, *A. cupressoides.* Tangential section showing the resin cells. × 70.

Plate III.

Diselma Archeri.—A, Transverse section showing the large, unthickened cells, squarish in outline. × 230.

B, Radial section showing parenchyma and arrow-shaped cells of the medullary rays. × 155.

C, Tangential section showing simple and bordered pits and the short medullary rays. × 170

Plate IV.

Agathis microstachys.—A, Transverse section showing the indefinite boundary of an annual ring and an isolated resin tracheide. × 100.

B, Radial section, showing the irregular nature of the cells of the medullary rays. × 68.

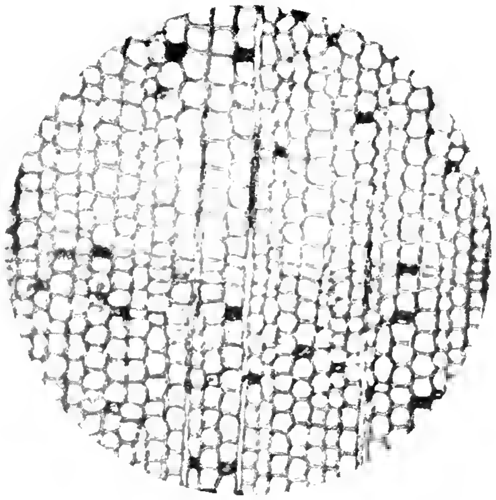
C, Tangential section, showing the alternating hexagonal bordered pits. × 100.

PLATE V.

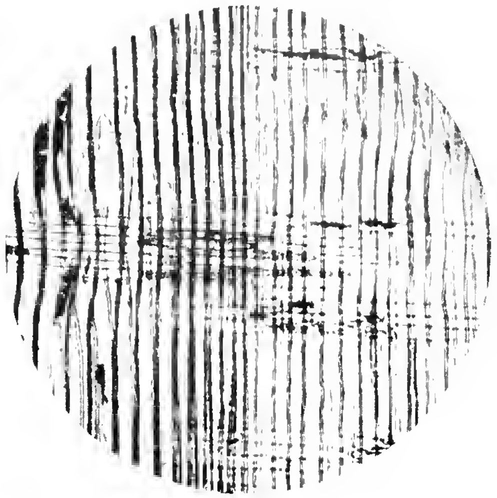
Callitris calcarata.—A, Transverse section showing scattering resin cells and the rounded nature of the tracheides. × 70.

B, Radial section, showing the plates of thickening lying across the bordered pits. × 156.

C, Tangential section, showing the awns arising from the bordered pits projecting into the cavities of the cells. × 110.



A

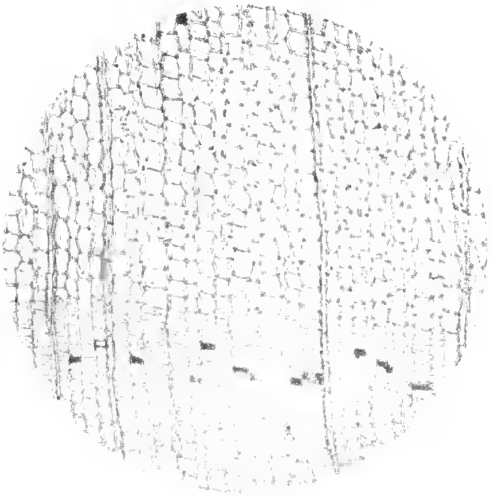


B

C

H. Marriott, photo.

Podocarpus elata.



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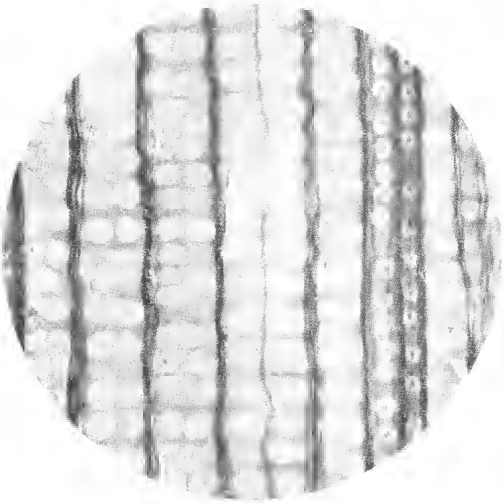
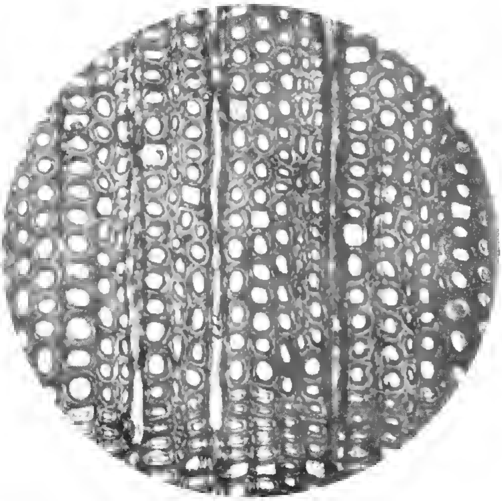


B

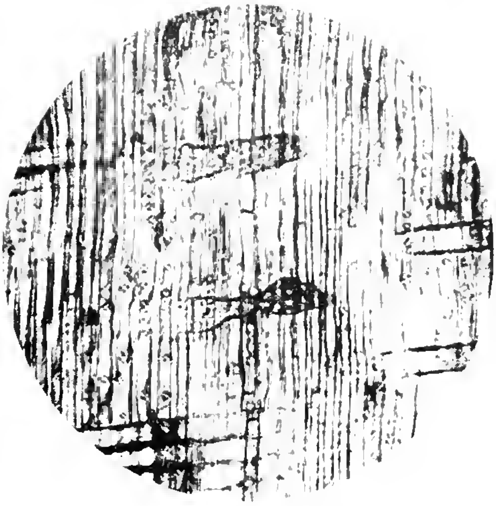
C

H. Marriott, photo.

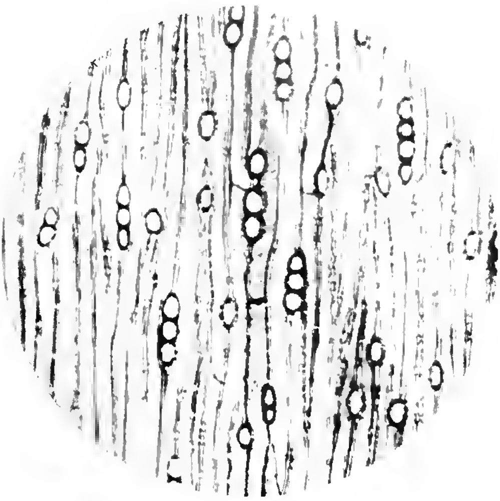
A and C, Athrotaxis cupressoides.
B, A. selaginoides.



A



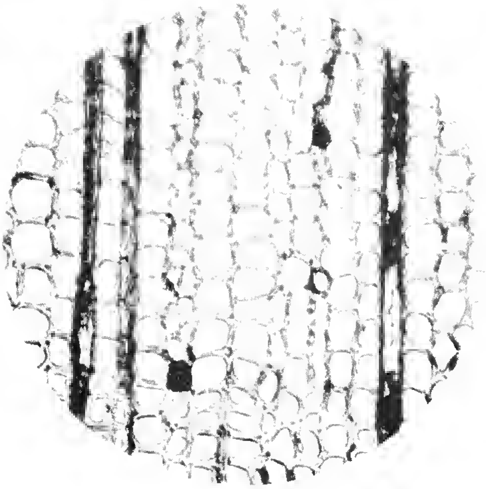
B



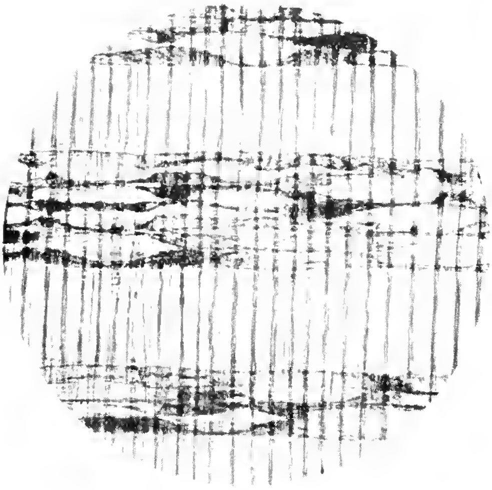
C

H. Marriott, photo.

Diselma Archeri.



A

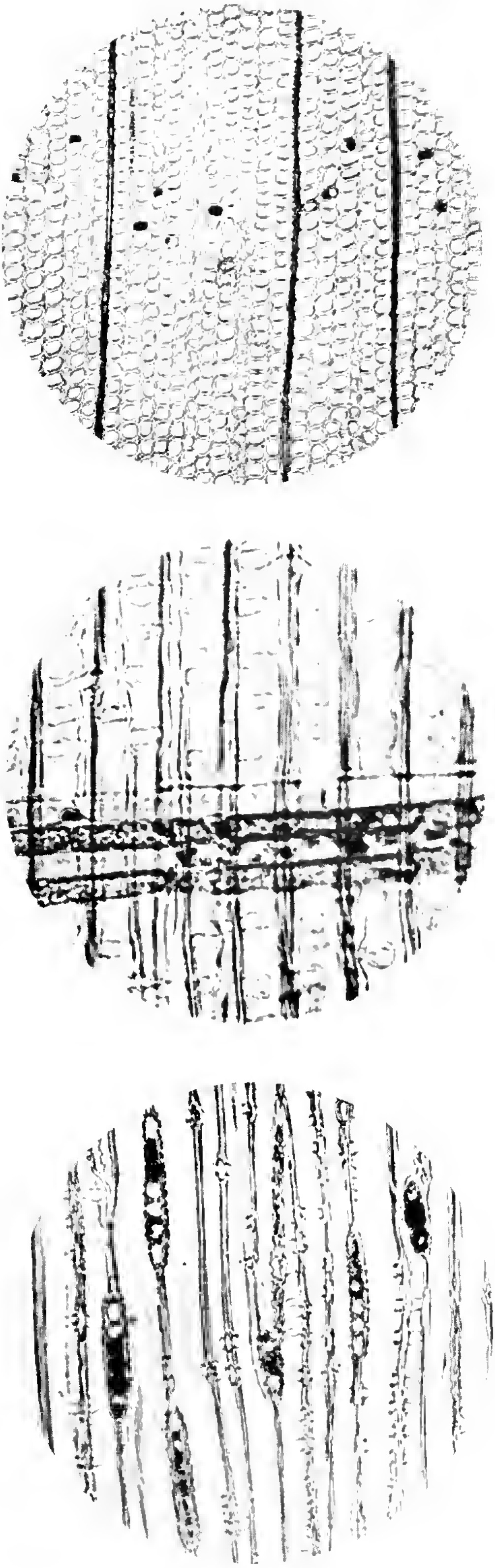


B

C

H. Marriott, photo.

Agathis microstachys.



A

B

C

H Marriott, photo.

Callitris calcarata.

[PROC. ROY. SOC. VICTORIA, 40 (N.S.), PT. I., 1927.]

ART. II.—*Vitality of White Races in Low Latitudes.*

By C. H. WICKENS.

[Read 7th April, 1927.]

One of the visitors to the Pan-Pacific Science Congress held in Australia in 1923 was Professor Ellsworth Huntington, Research Associate in Geography in Yale University. On his return to America he published an account of his journey under the title "West of the Pacific," in which he dealt with various aspects of Chosen, Japan, China, Java, and Australia, and this paper is concerned with that part of his book in which he uses Australian statistical data, and especially data concerning Queensland, to support a theory of his that persons of white race born in low latitudes have less physical vitality than similar persons born in temperate climates. Whether his theory is true or false, the author will not undertake to say; all he wishes to do is to call attention to the nature and extent of the evidence available in respect of Queensland, and to suggest that this evidence does not appear to support the theory.

Professor Huntington points out that during the eight years immediately preceding the War, the crude death rate was lower in Australia than in any country in the world, except New Zealand, and that the Queensland rate was as low as that of any State in Australia. He also shows that even when allowance is made for difference in age distribution, Queensland has still a lower death rate than the healthiest country in Europe. He says that when the low death rate of Queensland was first brought to his attention, he thought there must be some mistake, but that careful inquiry had convinced him that the records are essentially reliable. He also refers to the evidence of good health in Queensland furnished by the investigations of the Institute of Tropical Medicine at Townsville, and by the Bulletin on Tropical Australia issued by the Commonwealth Bureau of Census and Statistics.

Having thus examined and found satisfactory the evidence of vitality furnished in respect of persons *living* in Queensland, he next investigates data concerning those born in that State, and comes to the conclusion that "although the people who go to Queensland are so healthy that they reduce the general death rate to a very low level, their children for some reason or other are less healthy than are those born in the more southerly parts of Australia or in the Old Country." On the question of fertility in Queensland, he notices the relatively high birth rate of that State as compared with the rest of Australia, and says that "as in the case of deaths, the favourable condition is not due to the people who are born in Queensland, but to those who come hither from other regions." He thus considers it as established that birth in Queensland of persons of white race increases the rate of mortality and decreases the fertility of the race. The evidence which he adduces to prove this twofold conclusion are two statistical tables, the one on page 364, the other on page 366 of the book under review, both based on data obtained from the Commonwealth Statistician.

The first of these is an interesting table in which he shows, from calculations that he has made on the basis of figures supplied at his request, that for ages last birthday 15 to 49 inclusive, the rate of mortality for each sex of persons born in Queensland was sensibly higher than for Australian residents born in Victoria, New South Wales, England or Scotland, and that such is the case whether the State of residence is Victoria, New South Wales or Queensland. The figures supplied to the author gave death rates for quinqennial ages which he has summarised for the range 15-49, by using a "standard population." Exactly what standard he has used he does not indicate. His published results, however, appear to be in reasonable accord with the data supplied to him. Covering as they do deaths during the three years 1920, 1921, and 1922, of persons aged last birthday 15 to 49 inclusive, they are derived from births which occurred in the period from 1870 to 1907 inclusive, and consequently take no account of the remarkable improvement in infant and child mortality which has taken place in Queensland during the past fifteen years. In only one year in that period of fifteen has the rate of infant mortality—the number of deaths under one year per 1000 births—been higher in Queensland than the Australian average. That was in 1919, a year in which Queensland experienced a drought much severer than that experienced in other States. For the whole period of 15 years the Australian average rate was 7% higher than that for Queensland, and the Queensland rate for 1925 of 45 per 1000 births is the lowest ever recorded for an Australian State, and not much in excess of the remarkable rate of 40 per 1000 births recorded by New Zealand for the same year. These figures show that for the first year of life at all events it cannot be said that under modern conditions the Queensland born are less healthy than those born in the more southerly parts of Australia.

Fortunately, it is not necessary to stop here, for it is possible to analyse the death rates to age 9 last birthday, inclusive of persons born in the several States. This investigation was based on the deaths which occurred at these ages during the three years 1920, 1921, and 1922. The mortality for these three years indicated that for Australia as a whole out of every 1000 males born, 106 would fail to reach the age of 10, the corresponding number for females being 87 out of every 1000 born. The figures for Queensland for the same period were 102 failures out of every 1000 males born, and 84 failures out of every 1000 females born, about $3\frac{1}{2}\%$ better than the average Australian rate in both cases.

The only State showing a better result than that for Queensland is Tasmania, which out of 1000 male births had only 101 failures to reach the age of 10 compared with 102 for Queensland. For females, however, the Tasmanian failures numbered 86, compared with only 84 in Queensland.

For the purposes of this paper a series of triennial results for Queensland, covering the five triennia ending with the year 1925 have been taken out. These give the failures to reach age 10 out of 1000 males born as 116 for 1911-13, 112 for 1914-16, 106 for 1917-19, 102 for 1920-22, as already quoted, and only 87 for 1923-25. In the case of females, the results are even more striking, the failures to reach age 10 out of 1000 females born being 101 for 1911-13, 96 for 1914-16, 88 for 1917-19, 84 as already mentioned for 1920-22, and only 70 for 1923-25. The author is at present engaged in taking out a similar series of triennial rates for the other States, but these are not yet completed. The heavy part of the mortality under age 10 is, however, that under age 1, and data in respect of this are available, indicating for Queensland for the triennium 1923-25 an average for the sexes combined of 50 failures to reach age 1 per 1000 births, compared with 57 for Australia as a whole; that is, the Queensland rate was more than 12% better than that for all Australia.

While on this subject of progressive improvement in mortality rates, reference may be made here to the marked improvement in rates of mortality at all ages that has taken place in Queensland since the 'eighties, when that State was quoted as the shocking example in the matter of high mortality in Australia. An examination of the crude rates of mortality for that decade discloses the fact that in each year the male crude rate for Queensland was consistently higher than the Australian rate for the same year, and in one year (1884) there was an excess of as much as 50%. An examination of the Queensland migration records shows that in that decade there was a larger net immigration of males into Queensland than in any similar period in the history of the State. This suggests that the process of acclimatisation was expensive in terms of human lives, and does not bear out Professor Huntington's view that the new arrival was the select of the select. In fact, many of the deaths which he quotes in his table would represent first generation Australians, the offspring of these immigrants of the 'eighties, whereas the progressively improving results that have been given for recent years are increasingly second or third generation Queenslanders. Concerning the population resident in Queensland, it may be mentioned that the expectation of life at date of birth for 1881-90 was 41·3 years for males, and 49·8 years for females; for 1891-1900 it was 49·5 years for males and 55·8 for females, for 1901-1910 it was 54·2 years for males and 59·3 years for females. For the three years 1920-22 complete life tables for Queensland have not yet been compiled, but there is evidence of a corresponding improvement in both sexes.

This consistent and rapid increase in the expectation of life at date of birth was of course associated with an increasing proportion of Queensland born in the population. A comparison of these expectations of life with those for Australia as a whole indicates that whereas for 1881-90 the Queensland male expectation at date of birth fell short of that for Australia by more than 12%, for 1901-10 the excess was less than 2%, and the indications for 1920-22 are that the Queensland expectation will exceed that for Australia. There has been a marked improvement in mortality rates throughout Australia, but the improvement has been more marked in Queensland than in the rest of Australia, although Queensland has been the only part of Australia that has had any serious addition of Queensland-born persons to its numbers. In all the circumstances it may be claimed that the weight of evidence is against Professor Huntington's verdict concerning the vitality of the Queensland born.

We now come to the question of fertility, which Professor Huntington claims decreases with birth in Queensland. The only evidence on this point which he gives in his book is the table mentioned as being on page 366, and the conclusion which he draws from the figures there quoted is palpably fallacious. He has there a statement showing the total issue at time of death of persons of various birthplaces, who died in Australia during the year 1921, and because those born in Queensland who died in that year had smaller average issue than any of the others which he records, he draws the conclusion that the Queensland-born were less fertile than the others. What he has failed to remember is that the issue of a person at date of death is a function of age, and that in the case of deaths in Australia of persons who had been born in Germany or Ireland or Scotland or England, the proportion of advanced age and, consequently, with maximum families will be much larger than in the case of those born in Australia, and that in consequence of the rapid comparatively recent growth in the number of Queensland born the proportion of deceased Queensland born with maximum issue will be smaller than in some of the older States.

The case for the fertility of the Queensland-born, however, does not depend solely on the negative process of proving the invalidity of Professor Huntington's evidence. There is ample positive evidence that the fertility of the Queensland-born females if not high, is as least as high as that of the females of corresponding age born elsewhere than in Queensland, and resident in Australia at the Census of 1921. The following table, which deals with place of residence, not place of birth, is of interest, and is included partly because the data in respect of the issue of males according to birthplace is not available, and partly because it furnishes some interesting comparisons with birthplace data deduced later.

Average Issue at Census of 1921.

Age	Husbands resident in		Wives resident in	
	Queensland	Australia	Queensland	Australia
25 - 29	1·38	1·32	1·94	1·78
30 - 34	2·17	2·06	2·82	2·59
35 - 39	2·95	2·77	3·63	3·32
40 - 44	3·67	3·40	4·29	3·84
45 - 49	4·35	3·91	4·70	4·19
50 - 54	4·89	4·34	5·28	4·57
55 - 59	5·45	4·86	5·79	5·12
60 - 64	5·95	5·42	6·32	5·74
65 - 69	6·55	6·04	6·58	6·25

These figures indicate that the average issue at every age was markedly higher in Queensland than in the rest of Australia at the Census of 1921. There are, however, interesting supplementary figures relating to average issue of wives according to age and birthplace. These are as follows:—

Average Issue of Wives Resident in Australia at Census of 1921.

Age	Wives born in				
	Queensland	Australia	British Isles	Europe	All Birth Places
25 - 29	1·98	1·84	1·32	1·36	1·78
30 - 34	2·86	2·66	2·04	2·09	2·59
35 - 39	3·69	3·44	2·70	2·76	3·32
40 - 44	4·36	3·97	3·30	3·36	3·84
45 - 49	4·74	4·30	3·75	3·84	4·19
50 - 54	5·30	4·64	4·28	4·36	4·57
55 - 59	5·92	5·21	4·79	4·88	5·12
60 - 64	6·71	5·93	5·28	5·37	5·74
65 - 69	7·38	6·61	5·80	5·88	6·25

We have here all the important ages, and at every one of them there is a larger issue for the Queensland-born wife than for the wife born from any other of the quoted birthplaces. A comparison of the issue of Queensland-born wives shown in the last table with the issue of wives of all birthplaces resident in Queensland, as shown in the table before that indicates that *birth* in Queensland connotes in respect of a wife a somewhat higher issue than mere *residence* in Queensland, which appears to be contrary to Professor Huntington's theory.

It will be convenient here to call attention again to Professor Huntington's evidence in respect of Queensland's fertility. He has there committed that statistical fallacy sometimes known as the "fallacy of aggregates," an error by no means uncommon, and not always immediately evident. It may be illustrated by an example mentioned by an English Registrar-General, who said that statistics showed that the occupation of farmer had a death rate, over all, higher than that for the general population, but that when death rates for successive age groups were compared, the farmer's rate in each age group was less than that of the general population. The reason for the farmer's higher death-rate when age was not considered, was that there were so many more farmers at the advanced ages at which the death rates were high. In other words, the farmer's apparently high death rate was due to his really low death rate. In the case of fertility, the results of the 1921 Census indicate that, although the issue of Queensland-born wives is high in each age group, yet, if the results are taken irrespective of age, Queensland-born wives have an average issue over all of 3·18; Australian-born wives, 3·30; wives born in the British Isles, 3·46; wives born in Europe, including the British Isles, 3·53; and wives of all birthplaces, 3·34. As already explained, this is due to the larger proportion of Queensland-born wives in the lower age groups, where the families are in all cases smaller.

The data so far dealt with concern the whole of Queensland, but not more than 25% of the population of Queensland is actually within the tropics. The southern boundary of Queensland is approximately 29° South latitude, so that the whole State can be classed as being in low latitudes, if not altogether within the tropics. A special Census Bulletin dealing with Tropical Australia was issued in connection with the Census of 1921, and this was supplemented later by the issue of a special Part of the Census Report (Part XXVI.) on the same subject as well as by tropical sections of Part XXVIII., Families. It is unnecessary to refer to the details contained therein, but some figures comparing the issue of Queensland-born wives resident in *tropical* Australia with the corresponding issue of wives born elsewhere, but also resident in tropical Australia, may be quoted.

Average Issue of Wives resident in Tropical Australia at Census of 1921.

Age	Wives born in				
	Queensland	Australia	British Isles	Europe	All Birth Places
25 - 29	2·19	2·14	1·62	1·75	2·09
30 - 34	3·16	3·08	2·62	2·79	3·04
35 - 39	4·01	3·87	3·61	3·64	3·81
40 - 44	4·79	4·62	4·13	4·21	4·45
45 - 49	5·11	4·89	4·68	4·71	4·79
50 - 54	5·38	5·26	5·23	5·27	5·24
55 - 59	5·98	5·82	5·69	5·73	5·75
60 - 64	5·76	5·92	6·09	6·20	6·11
65 - 69	6·77	7·05	5·71	5·90	6·01

Owing to the relative smallness of the numbers involved, the rates here are somewhat less regular than those previously quoted, but up to age 60 the total issue of Queensland born wives predominates, and for all birthplaces the total issue is in general up to age 65 higher for tropical Australia than for all Australia. Data concerning wives *born* in tropical Australia are, unfortunately, not available.

There is a further small point in Professor Huntington's criticism of Queensland to which reference may be made. This is a statement by him that there is a tendency for numbers of Queesland females of adult age to get out of Queensland, with the view apparently of so avoiding the climatic disabilities of that State. This statement appears to be based mainly on the fact that when the Census data for the Queensland population according to sex and age are examined, it is seen that for early ages the numbers in each sex are fairly equal, but that at later ages there tends to be a preponderance of males. His conclusion, however, is quite wide of the mark. Like all new and progressive countries, Queensland has an excess of males, an excess which with an increasing number of births per annum is rapidly disappearing. This disappearance is of course most marked in the younger ages, which are mainly recruited from the local births in which there is little difference in the proportion of the sexes. With the lapse of time the ages having a marked male preponderance become higher and higher, and in the absence of heavy immigration eventually disappear. The statistical peculiarity to which he refers is thus due, in the main, not to a marked exit of adult females, but to the influx by birth of infant females and their subsequent retention in the State. This is indicated by the following table, which shows at the Census of 1921 the numbers of each sex of Queensland-born persons who were resident in Queensland at the date of the Census. At all ages the numbers approximate equality, the excess of males being most marked at the younger ages —not, as suggested by Professor Huntington, at the older.

The total number of Queensland-born residents of Queensland at the Census of 1921 was thus almost equally divided as regards sex, and approximate equality was in evidence in each age group, the most marked deviation being the excess of males under 5 years, due mainly to the normal excess of males at birth. Data concerning the birthplaces of residents of other parts of Australia at the Census of 1921 indicate, however, that there is a slightly higher migration of Queensland-born females than of Queensland-born males to the other States. The number of Queensland-born persons recorded at the Census of 1921 in States other than Queensland was 42,953, of which 20,142 were males and 22,811 females. In other words, at the Census of 1921 about $9\frac{1}{4}\%$ of the Queensland-born females resident in Australia were living outside their State of birth, and about $8\frac{1}{4}\%$ of Queensland-born males. These proportions for residence outside the State of birth are less than for any State of birth except New South Wales, *Queensland-born Population Recorded in Queensland at Census of 4th April,* 1921

Age Group		Queensland born population recorded in Queensland.		
		Males		Females
0 - 4	-	40,106	-	38,162
5 - 9	-	36,972	-	36,175
10 - 14	-	29,755	-	28,695
15 - 19	-	24,430	-	24,370
20 - 24	-	22,703	-	24,407
25 - 29	-	21,201	-	22,719
30 - 34	-	19,092	-	19,835
35 - 39	-	13,229	-	13,478
40 - 44	-	9,887	-	9,751
45 - 49	-	7,292	-	7,262
50 - 54	-	5,424	-	5,140
55 - 59	-	2,645	-	2,554
60 - 64	-	1,086	-	1,103
65 and over	-	491	-	577
Not stated	-	325	-	319
TOTAL	-	234,638	-	234,547

the average for all Australia being $11\frac{1}{2}$% for males and $10\frac{3}{4}$% for females. That is to say, there is a smaller rate of migration from the State of birth among the Queensland-born of either sex than is the case with those born in any other State of Australia, except New South Wales. These are the figures for 1921. In 1911 the position was very similar, Queensland's figures being 8% for males and 9% for females, and ranking still second to New South Wales, whereas the figures for all Australia were $12\frac{1}{2}$% for males and $10\frac{3}{4}$% for females. A slight female preponderance in the migration of the native-born is not peculiar to Queensland, but is also in evidence in Western Australia, and, to a larger extent, in Tasmania.

Summing up the position, it would appear that in depending on Queensland to help in the establishment of his theory, Professor Huntington has put his money on the wrong horse. If his theory is true, there would appear to be some remarkable counterbalancing advantages, geographical, climatic or other, in the case of Queensland, which must be counted to that State as a most valuable asset. As stated earlier, the immediate object of this paper is not that of proving either the truth or the falsity of Professor Huntington's general theory, but of showing that available Queensland data really furnish no evidence in its favour under modern conditions. Whether the further extension of white population into the tropical portions of the State will give equally favourable results has yet to be ascertained, but the data available in this connection are of such a nature as to warrant expectations of satisfactory progress.

[PROC. ROY. SOC. VICTORIA, 40 (N.S.), PT. I., 1927.]

ART. III.—*The Stony Creek Basin and the Corinella Dyke.*

By D. ORR, B.Sc.

[Read 4th June, 1927.]

Contents.

I.—Introduction.

The subject of this paper is a curious, amphitheatrical depression about 50 acres in area lying immediately south of Jubilee Park, 1¼ miles south of the Daylesford Post Office. The Stony Creek enters it in the south-west corner by a narrow gorge, flows along the western side, and leaves by a similar gorge in the north-west corner. Exposed by sluicing channels in the basin are ligneous shales with numerous fossil Eucalypt leaves, remains of diatoms, and abundant fresh water sponge spicules. The deposits have been penetrated in a shaft for over 100 feet.

The map showing the relation of the Stony Creek basin to the Corinella dyke is compiled from Quarter-Sheet No. 16 SE. of the Geological Survey. A correction due to Mr. Whitelaw (1) is made to the boundaries of the basalt and Ordovician in the neighbourhood of the basin.

Much of the information about the shafts and deep leads in the Eganstown district was obtained from Mr. Rehir, of the Victoria Hotel, Daylesford, who was digging there in the '90's.

II.—Previous Literature.

In his notes on Quarter-Sheet No. 16 SE., Mr. Hunter (2) refers to the basin as "a deep hole without an outlet," and considers it a point of Pliocene volcanic eruption. In a recent conversation Mr. Hunter informed me that he is now inclined to regard the basin as a faulted block.

T. S. Hart (3) has discussed the origin of the basin in some detail. His view of the sequence of events is summarised as follows:—The black clays were deposited prior to volcanic activity, or as a result of the first modifications of the drainage systems by the volcanic action. A portion of these was preserved by subsidence on a well defined line of weakness, namely, a line through the Corinella dyke, the zone of fracture in Sailor's Creek, and Wheeler's Hill. The streams flowing on the west and north sides of the basin may have flooded it. The lava flows from Leonard's Hill then buried the old river valleys and at least part of the basin. The drainage towards the pre-basaltic stream resulted in the formation of Sailor's Creek on the western, and Stony Creek on the eastern, side. The basaltic barrier across the exit from the basin formed a bar, which was only cut through slowly. While the bar was being cut through, the stream cut out a plain in the easily eroded black shales. A considerable amount of basalt could have been removed at the same time by undercutting.

While these latter conclusions are most probably correct, the earlier sequence leading to the deposition of the ligneous shales seems to be capable of a more satisfactory explanation.

Mr. Whitelaw (1) states that "the area is a foundered block at the intersection of the Ajax group of thrust faults, and a younger cross fault."

III.—Nature of Basin.

The floor of this crateriform depression lies about 100 feet lower than the rim. It is surrounded on the west and the northern sides by a basaltic plateau, in which is entrenched the Stony Creek Gorge. Deep leads occur under the basalt, but about 50 feet higher than the level of the basin. The southern and eastern banks are formed of Ordovician slates and shales, which rise to somewhat higher levels than the basaltic plateau. In the north-east corner, Pliocene alluvial gravels outcrop at the surface. The floor of the basin, which consists of recent alluvium, is fairly level, rising to the north and the east. It is dissected by numerous sluicing channels. In the most easterly of these, black ligneous shales are exposed at several places. When dry, they change to a drab colour. They are very fine grained, and contain numerous wood fragments and fossil Eucalypt leaves. Diatoms and fresh water sponge spicules have been also recorded (1) from them. These deposits have evidently accumulated in the still waters of a lake, or some allied formation. Mr. Hart claims that the shales dip from 45° to vertical, and that they therefore have been much disturbed since their deposition. In the sections examined in the basin the bedding was generally obscure, but no evidence of a steep dip was obtainable. In 1864 a shaft was sunk near the southern wall through these ligneous shales for over 100 feet. Alluvial wash was struck at 111 feet. It is doubtful whether the shaft ever reached bedrock.

Thin seams of similar black ligneous clays occur under the basalt at Sailor's and Stony Creek Falls. These contain a fair proportion of coarse grit, and no traces of either diatoms or sponge spicules, as would be expected from the nature of their occurrence.

Similar deposits have been recorded (4) from the Exchequer Co.'s shaft on the Royal Oak lead from Wombat Hill, where a thickness of 85 feet was passed through. The deposit contained wood in all stages of transformation into lignite, intermixed with leaves in all stages of preservation, identical with those of the present day. The wood was frequently replaced by pyrite. At Eganstown the shafts of the Great Extended, whose claim adjoins the eastern boundary of the Corinella pre-emptive right, and the shaft of the New National, whose claim joins the eastern boundary of the Great Extended claim, both passed through 100 feet of tripoli (diatomaceous earth).

Conditions at the time of the Newer Volcanic activity were evidently favourable to the development of diatomaceous life, as the deposits formed by the accumulation of their remains are associated with the Newer Basalt in many Victorian localities (5).

As previously stated, Mr. Hart considers that the black ligneous shales and clays of the Stony Creek basin are remnants of a much more extensive deposit preserved by faulting. He suggests their correlation with the deposits met with in the Exchequer shaft, and in the Great Extended and New National shafts at Eganstown. This would imply the existence, immediately prior to the Newer Basaltic eruptions, of lake conditions necessary for the accumulation of a deposit 100 feet in thickness over the greater part of the Daylesford area. If such conditions had existed, one would expect to find many other remnants of the deposit. These are absent, and it is more probable that these three areas of ligneous clays are of quite local and restricted occurrence, and that the Stony Creek Basin deposits have accumulated there, filling in an originally much deeper basin.

The most probable direction of the deep leads is shown in the map. At the places where the lead is shown to enter and leave the basin, the basalt extends down to a lower level than elsewhere. On the western side it is difficult to determine how much the relations have been interfered with by landslips. The steep slopes are covered with a dense growth of blackberries, which adds to the difficulty of locating the rock boundaries. Landslips have also obscured relations where the lead is shown to cross on the east bank of the Stony Creek gorge. It is however fairly certain that the basalt reached a much lower level here. River gravels which outcrop beneath the basalt in this neighbourhood also indicate that the lead crosses in that region. The exit of the lead exposed in the cutting of the Ballarat Road can be readily and definitely located.

Prior to entering the basin, the bed of the Stony Creek, downstream from the falls, consists of Ordovician slates and sandstones. Immediately it enters the basin all signs of Ordovician in the bed of the creek disappear. The stream then flows over basaltic boulders until the north-west corner is reached, where Ordovician reappears and, from there down-stream, continues to form the bedrock of the creek. Besides forming the high east and south banks, the Ordovician slates and sandstones outcrop beneath the basalt on the north and west sides. The shaft near the south bank, previously mentioned as passing through more than 100 feet of black ligneous clays, shows that the junction between clays and Ordovician must continue very steeply below the surface here.

IV.—Origin of the Basin.

To account for such a formation in which a floor of Ordovician slates and sandstones is enclosed by walls of Ordovician and Ordovician capped by basalt, which rise to a height of 200 feet above the Ordovician floor, two modes of origin may be suggested. These are (*a*) volcanic explosive activity, and (*b*) subsidence by faulting.

The first method was suggested by Mr. Hunter (1). The evidence rather indicates that such was not the case, for although the basin is surrounded on the north and west sides by basalt, this had its source at Leonard's Hill, some six miles to the south. Nor is there any sign of volcanic fragmental rocks or accumulations of broken Ordovician material around the basin, as would be the case if it were due to a volcanic explosion.

This leaves the second method of origin, namely, faulting. As will be seen in the next section, the basin lies at the extremity of a well defined line of weakness and fissuring, at the time of the Newer Basaltic eruptions. It is, nevertheless, rather difficult to picture the cause and manner by which a cylindrical block could be depressed vertically 200 feet, by faulting.

Consequent on the formation of the basin by faulting, the sequence of events was probably as follows:—It was flooded by the pre-basaltic stream whose valley was later filled by the basalt flow from Leonard's Hill. The course taken by this stream is indicated in the map showing the direction of the present deep leads in the neighbourhood of the basin. In the lake thus formed, especially in the still backwaters, conditions would be favourable to the accumulation of the black ligneous shales. That the material brought into the basin by the stream was of a suitable nature to form such a deposit is proved by the presence of similar black ligneous clays beneath the basalt at Stony Creek falls, and further south at Sailor's Creek falls. It is probable that the basin was entirely filled by these ligneous clays, as there is no indication that much of the area occupied by the present basin was covered by basalt, and certainly not by any great thickness of basalt. Next came the pouring out of lava from Leonard's Hill, filling the old creek valley, its channel through the basin, and covering possibly part of the present basin. The concentration of the drainage down the old river slopes towards the basalt flow gave rise to the present Stony Creek on the east side and Sailor's Creek on the west side of this flow. While cutting through the basalt bar at the north-west end of the basin, the Stony Creek cut a plain in the easily eroded black shales, undermining any basalt that might have overlain these. Since the extrusion of the Newer Basalt, the streams in the Daylesford area have been rejuvenated, and the present stream level is now generally some 50 feet below the level of the old deep leads. Once the bar was cut through, the basin was drained, and deepened as the Stony Creek deepened its bed, so that the floor is now well below the level of the old deep leads. Recent alluvium derived from the slopes has covered the ligneous clays, which are at present only exposed in the sluicing channels.

V.—The Corinella Dyke and its relation to the Stony Creek Basin.

The boundaries of the feature marked in the map as the Corinella Dyke are largely hypothetical. They have been taken from Quarter-Sheet No. 16 SE. of the Geological Survey. In the Corinella pre-emptive right paddock, where it is shown with a width of 14 chains, it is questionable how much of the basalt between these boundaries can be regarded as actual dyke and how much as surface rock. The basaltic hill shown on the dyke in the Corinella paddock is characterised by the vesicular nature of the basalt there as a point of eruption. Burnt Hill immediately to the SW. is very curious in structure. It is marked on the survey map as Ordovician, and a note is appended to the effect that it is a "made hill of deposit." It seems to consist on the upper slopes of a mixture of Ordovician and basaltic boulders, mostly scoriaceous in nature. One, when broken, was found to be holocrystalline, probably a type allied to essexite. It was too incoherent to permit a thin section being made for microscopical examination. This hill is probably the result of explosive volcanic activity.

A microscopical examination of sections cut from samples taken at various places along the dykes, shows the material to be a rather fine grained olivine basalt. Much of it is, on a small scale, of a spheroidal character, which gives outcrops of the unweathered rock a characteristic appearance.

Much of the surface rock in the Corinella paddock is extrusive basalt that has filled in pre-basaltic river valleys. The deep leads have been worked and found to be very rich. At a point on the S. margin of the Corinella dyke (opposite the letter "D" in "Dyke" on the map) a lead, which was being worked in 1895, ran against a a wall of basalt and was lost. It had proved to be very rich at this locality, and its disappearance gave rise to considerable discussion. On the advice of Mr. Hunter, who was surveying the area at the time, it was sought on the north side of the dyke, where it was subsequently picked up. To try and locate the lead a shaft was sunk between these two points to a depth of 120 feet. It was abandoned still in basalt.

Further east two other shafts have been sunk in the dyke. The Great Extended shaft (4) bottomed at 240 feet with a "dip of 16

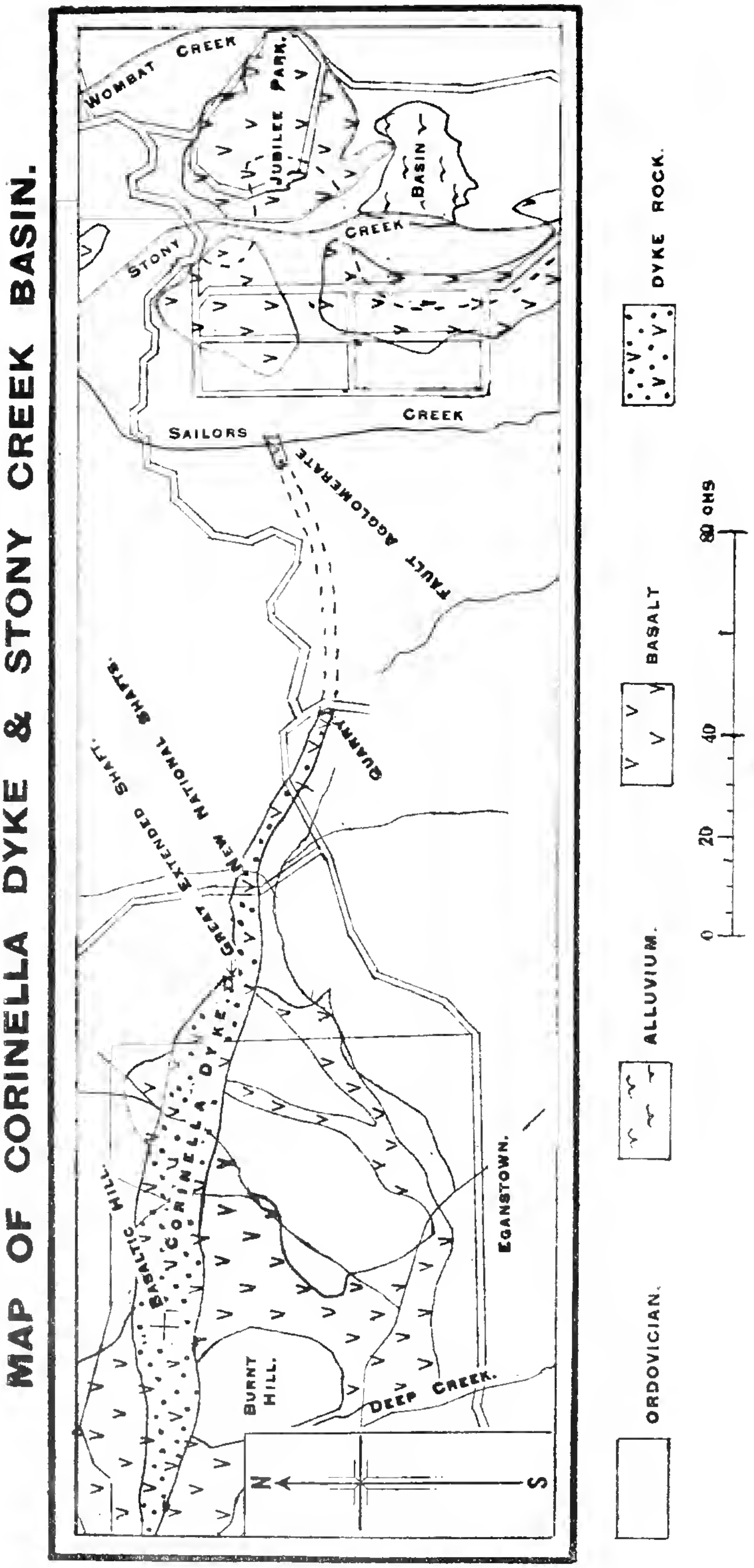

MAP OF CORINELLA DYKE & STONY CREEK BASIN.
WOMBAT CREEK
JUBILEE PARK.
BASIN
STONY CREEK
SAILORS CREEK
FAULT AGGLOMERATE
QUARRY
NEW NATIONAL SHAFTS.
GREAT EXTENDED SHAFT.
CORINELLA DYKE
BASALTIC HILL.
BURNT HILL.
DEEP CREEK.
EGANSTOWN.
N
S
ORDOVICIAN.
ALLUVIUM.
BASALT
DYKE ROCK.
0
20
40
80 CHS
SCALE

FIG. 1.

feet" in the shaft. It is supposed to have passed through infusorial (diatomaceous) earth. The shaft is on the northern margin of the dyke, and only passed through several feet of basalt. Levels opened towards the south met a wall of basalt. No sign of diatomaceous earth was found in the dump heap around the shaft. This was found to consist largely of a volcanic agglomerate composed of fragments of Ordovician slate and sandstone, and fragments of volcanic rock set in a fine greyish matrix that is possibly largely volcanic. Professor Skeats (6) has recorded a somewhat similar occurrence of a monchiquite agglomerate from Kangaroo Gully near Bendigo. He concludes that it had originated through explosive volcanic activity. It is possible that it was this material that was mistaken for the diatomaceous earth through which the shaft was supposed to have passed. It is suggested that this agglomerate fills a fractured zone in the Ordovician bedrock, and owing to a southerly dip in this zone the shaft passed into normal Ordovician at a depth of 246 feet.

Further east the dyke narrows to a width of 2 to 3 chains. In 1865 the New National Co. sank two shafts here. The first, which reached a depth of 250 feet, is recorded (4) as passing through 50 feet of clay, 100 feet of infusorial remains, and 100 feet of basaltic boulders and drift. It was abandoned at 250 feet in drift. The other shaft bottomed at 273 feet in the north-east corner with a "dip of 10 feet" to the south-east in the shaft. Ordovician bedrock is proved by shafts to extend up to the dyke on both sides at this part. As the dyke is only 2 to 3 chains in width the accumulation of over 200 feet of drift and diatomaceous earth beneath it is a remarkable occurrence, especially since the lower 100 feet consists of "basaltic boulders and drift." As the deposit is sub-basaltic and older than the basaltic dyke, no source for these basaltic boulders suggests itself. It is most probable that here again, as in the Extended shaft, the "tripoli" is really a volcanic agglomerate, a large proportion being a very fine volcanic paste decomposed to a greyish clay. Lower down, the pieces of undecomposed volcanic material may be more numerous and larger in size, and the agglomerate was then mistaken for "basaltic boulders and drift."

From these shafts, the course of the dyke eastwards is marked by a red basaltic soil. The most easterly outcrop is in a quarry. Here the dyke has split into two walls separated by Ordovician. It evidently ends at this point, for it does not outcrop further east. But between the quarry and the Stony Creek basin, a wide fractured zone in the Ordovician rocks is exposed in the bed of Sailor's Creek. The rocks here have been shattered and twisted. Forming a matrix of this broken material is a greyish white paste which has no perceptible gritty feel. It is probably decomposed volcanic matter. According to Mr. Whitelaw (1) this fault displaces the country to the north side 5 chains to the right. There is no trace of this fractured zone between Sailor's Creek and the

Basin, though it undoubtedly extends further eastward. The nature of the country here makes it very unlikely that any surface outcrops could be detected.

To account for this Corinella Dyke two hypotheses are available. The first is not very satisfactory, but would account for the presence of diatomaceous earth in the Great Extended and the New National shafts. According to this hypothesis, the first event to take place was the fracturing and fissuring of the Ordovician rocks, developing a depressed trough-faulted block in the Corinella paddock, and narrowing into a deep fissure towards the Great Extended and New National Co.'s shafts. Further east it is represented by the fractured zone in the bed of Sailor's Creek and terminates in the foundering of the Stony Creek basin block. The later development of this basin has already been traced. The Corinella downfaulted area was probably flooded by the streams in the area and partly filled by drift. The presence of the basaltic boulders in this drift cannot be explained, and remains an important argument against this mode of origin. The amount of alluvial material washed into this lake decreased, and in the clearer waters, diatoms flourished and the accumulation of their remains, mixed with finer sediment, formed a deposit about 100 feet in thickness. In Newer Volcanic times activity was renewed along this zone of fracturing, and basalt was intruded in places as a dyke, and extruded from a localised centre of eruption, filling in the trough fault and fissure, and covering over the diatomaceous deposits. In the quarry the basalt is probably intruded as a dyke. The volcanic hill in the Corinella paddock is the centre of the effusive type of eruption. In the neighbourhood of the Great Extended shaft, volcanic material was explosively injected into the Ordovician along the old fault zone, forming the volcanic agglomerate.

The second hypothesis pictures a much more probable series of events. It assumes that the term "tripoli" has been mistakenly applied to a fine volcanic agglomerate while a coarser agglomerate has been mistaken for a drift containing basaltic boulders. Along the Corinella fault line a shattered zone was developed in the Ordovician, and into it was explosively injected volcanic material, forming a dyke of volcanic agglomerate. In places, as at the upper parts of the Extended and New National shafts, a fine volcanic matrix forms the predominant part of the agglomerate, while at the Sailor's Creek zone it is mainly composed of shattered blocks of Ordovician. In the eastern extremity the sagging of the beds formed the Stony Creek basin. Contemporaneously with the formation of this volcanic agglomerate, or at a slightly later date, came the injection of basalt along this line of weakness. The intrusion in the eastern part was confined to a dyke, but in the west became effusive, culminating in the central type of eruption denoted by the volcanic hill in the Corinella paddock.

VI.—Summary.

A peculiar depressed basin of about 50 acres in area occurs immediately south of Jubilee Park, Daylesford. It is surrounded on all sides by Ordovician slates and shales, which rise to a height of 100 feet above the floor of the basin. The north and west sides are capped by basalt, under which are deep leads about 50 feet higher than the floor. It is open to the Stony Creek, which flows along the west side. Exposed in sluicing channels, are ligneous shales and clays containing diatoms and fresh water sponge spicules. These have been penetrated by a shaft for over 100 feet.

This basin is considered to have originated by the depression of a block of Ordovician, and to have been flooded by a pre-basaltic stream. It was filled by ligneous clays. The stream entering the basin was carrying similar material. In the quiet back-waters, conditions would be favourable for the growth of diatoms and fresh water sponges. The pre-basaltic stream, and perhaps part of the basin, was then filled by basalt. The twin streams, Sailor's Creek and Stony Creek, developed. While cutting through the basalt bar at the north side of the basin, Stony Creek cut out a wide plain in the easily eroded black shales, undermining any basalt that covered them. The basin was subsequently deepened as the stream entrenched itself deeper into bedrock.

The basin lies at the east extremity of a line of fracture and intrusion in late Kainozoic times. At Eganstown this is known as the Corinella dyke. Shafts through this dyke are supposed to have passed through diatomaceous earth. No trace of this is found around the dump heaps, but one consists largely of a volcanic agglomerate with a large proportion of fine greyish matrix. This was possibly mistaken for diatomaceous earth. Two alternative explanations are considered to account for the known facts. The more probable is that a fractured and shattered zone was developed in the Ordovician rocks. Accompanying this was the explosive injection of volcanic material forming a volcanic agglomerate. The proportion of volcanic material to shattered Ordovician varies at different parts. Contemporaneously, or at a slightly later date, came the intrusion of basalt along the same line of fracture as a dyke, culminating in the west in extrusive volcanic action.

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ART. IV.—*An Olivine Anorthoclase Basalt from Daylesford.*

By D. ORR, B.Sc.

[Read 9th June, 1927.]

Contents.

I.—Introduction.

This paper is mainly concerned with the chemical and petrological character of an alkaline basalt that has been recorded from the Daylesford district (1). It is shown to be an olivine anorthoclase basalt. The recent dissection characteristic of the area is also briefly discussed.

The area covered by the anorthoclase basalt is contained in Quarter-Sheets No. 16 NE. and No. 16 SE., of the Geological Survey of Victoria. Notes on these quarter-sheets appear in Progress Reports No. 8 and No. 9 of the survey. The central portion of the area was later surveyed and mapped on the larger scale of 1 inch to 16 chains by H. S. Whitelaw (2). In all these publications of the survey no distinction is made between the olivine anorthoclase basalt and the normal newer basalts of the area. Its special nature was first noticed during a geological excursion from the University. It was described by Professor Skeats (1) as an olivine anorthoclase trachyte.

II.—General Geology.

The rock formations outcropping in the area are in decreasing order of age:—Ordovician, Older Pliocene, Newer Volcanic, Newer Pliocene and Recent. All have been fully described in the publications of the Mines Department already referred to.

The newer volcanic series which forms a large part of the surface rock of the district is part of the northern outskirts of the great basaltic plain of south-west Victoria. The lava is in the form of separate flows, which have filled up pre-basaltic river valleys, sealing up valuable auriferous gravels. These flows originated from numerous volcanic vents, the volcanic hills built up around which form one of the characteristic topographical features of the district. The mode of eruption in this area differs from that of the main plain, which is considered to have originated by the fissure type of eruption.

III.—Physiography.

The area dealt with in this paper lies on the northern slopes of the Main Divide. The Divide crosses the south-east corner of Quarter-Sheet 16 SE. of the Geological Survey. Leonard's Hill, near the southern extremity of the anorthoclase basalt flow, lies about 20 chains north of the Divide.

The area is one of great diversity of surface, being very deeply dissected by numerous streams which ultimately find their way to the Loddon River. The slopes of the valleys and the Ordovician hills are generally densely timbered, while the elevated basaltic plains have been cleared for agricultural purposes. The numerous volcanic flows have been largely instrumental in the development of the present topography. The volcanic hills around the points of eruption rise well above the general level, and form prominent landmarks. The most prominent of these are Mount Franklin, Bald Hill, Fern Hill, Wombat Hill, Wheeler's Hill, and Leonard's Hill. Whereas the basalt formerly occupied the valleys of the pre-basaltic streams, it is now found on the higher ridges and plains. Frequently twin streams have deeply entrenched themselves on either side of a basaltic flow, which now forms a high flat-topped ridge between the two streams. Sailor's Creek and Stony Creek are twin streams that have entrenched themselves on either side of the anorthoclase basalt flow. The head-waters of both these streams occupy only small surface gutters, which suddenly develop into deep gorges by steep falls over the basalt. Sailor's Falls has a vertical drop of about 100 feet, Stony Creek Falls one of about 50 feet.

All the streams of the area occupy recent deeply dissected valleys. The level of the pre-basaltic streams, as denoted by the present level of the deep leads, is generally 50 feet or more above the present stream level. The most recent flow from Mount Franklin is an exception. It was evidently extruded when present stream level was reached, since the Jim Crow Creek, which flows along the eastern edge of the flow, has much of its bed in basalt. If, as is generally considered to be the case, these pre-basaltic streams had reached base level, the area must have been relatively uplifted in post-basaltic times. To form any reliable opinion as to the manner by which these streams had their erosive power increased an intimate knowledge of the country to the north of Daylesford would be required. The time necessary to acquire this information was not available.

A trip was made along the Jim Crow Creek as far as its junction with the Loddon River at Newstead, about 16 miles north of Daylesford. This creek is formed by the junction of Sailor's and Wombat Creeks. As far as Franklinford, six miles north of Daylesford, it occupies a very steep and deeply dissected valley. Past Franklinford to the junction with the Loddon, the character of the valley changes. The stream flows in an open mature valley, rising on the west and east to low rounded Ordovician hills. The floor is occupied by the most recent basalt flow from Mount Franklin. It was first thought that the cause of this recent dissection, most probably faulting, might be located in the neighbourhood where the change in the nature of this valley took place. An excellent panoramic view over this part of the country to the Loddon is obtained from the summit of Mount Franklin. No indication of any fault escarpment could be noticed.

It is most probable that this open character of the valley of Jim Crow Creek past Franklinford is due to the greater ease of weathering of the Ordovician sediments compared with the basalts, which have confined the streams in the Daylesford district to narrower and steeper valleys. The fact that auriferous gravels, of apparently the same age as the deep lead gravels, outcrop above the present stream level towards Newstead indicates that the cause of the dissection is to be sought still further downstream.

IV.—Olivine Anorthoclase Basalt.

(*a*) *Distribution and General Character.*

The source of this basalt is Leonard's Hill, a big volcanic hill about 20 chains east of Leonard's Hill station, six miles south of Daylesford on the Daylesford-Ballarat railway line. The upper part of this hill shows all the characteristics of a point of eruption, consisting of very vesicular, scoriaceous basalt mixed with finer volcanic material. From this hill the lava flowed north, filling an old pre-basaltic river valley and sealing up the river gravels. These have proved auriferous in the northern part of the area, where the Llewellyn lead has been extensively worked.

The basalt is continuous until the Stony Creek Basin is reached, past which, due to the deep dissection of the Stony and Wombat Creeks, it has been isolated as cappings to flat topped hills; namely, Table Hill, Hard Hill, and the Jubilee Park Hill. On the Quarter-Sheet (No. 16 SE.) the basalt is shown as continuous on the west bank of Stony Creek as far as the Ballarat Road, thus differing from Mr. Whitelaw's map, which shows a ridge of Ordovician, of the same level as the basaltic plateau, breaking the continuity immediately north of the outlet from the basin. Examination showed the latter mapping to be correct. The pre-basaltic stream evidently meandered at this locality.

South of Leonard's Hill, but not connected with it, two parallel basaltic flows extend in a south-easterly direction for a distance of about four miles, where they junction at the Werribee River. From here basalt outcrops intermittently on either side of this stream as it is followed southwards On the northern extremity of each of these flows is a volcanic hill. The hill in the northern extremity of the westerly flow has been isolated from the main flow by stream dissection. Except in places on the surface of the basalt flows, where the land has been cleared, the country here is extremely rugged and thickly timbered. Time did not permit of any detailed examination of these flows or of their relation to the anorthoclase basalt flow. Specimens collected from the two hills at the northern end of each flow, and from an outcrop on the Werribee River, about a mile below their junction, were sectioned. The first two (2200, 2201)[1] were very similar, and resembled a fine grained variety found at the base of Leonard's Hill, though they differed in the absence of anorthoclase. The third specimen was a typical olivine basalt, the phenocrysts of olivine being altered to brown iddingsite. It is therefore probable that these flows are distinct from the anorthoclase basalt flow, and were extruded from the hills at their northern extremities. If this is so, the flows would be older than the anorthoclase basalt flow, as all traces of scoria and ash have been removed from these hills by the processes of weathering, and now only basaltic plugs remain standing above the general level of the flow. Leonard's Hill, however, is in a much better state of preservation, and is therefore younger.

On the surface, the anorthoclase basalt has weathered to a rich red soil similar to that derived from the other basalt of the area. Exposed in a rock face at Table Hill Quarry there is a large lenticular patch, surrounded by unweathered basalt, that has been weathered to a whitish clay. The junction between the two types is quite abrupt. It is rather difficult to picture this as due to the concentration of ordinary meteoric weathering processes; more probably it is due to chemical action of enclosed magmatic waters and gases. That there were abundant is suggested by the common occurrence of calcite filling the vesicles in the rock.

Excellent sections showing the junction between basalt and Ordovician bedrock occur at Stony Creek and Sailor's Creek falls. On the under surface, for a thickness of about 6 inches, the basalt is very vesicular in character.

A number of specific gravity determinations were made on specimens collected from different parts of the flow. They varied from 2·881 to 2·791, with an average of 2·838.

(*b*) *Chemical Character.*

The specimen selected for analysis was collected at Sailor's Creek Falls. At this locality there are numerous large blocks of basalt which split fairly readily, allowing access to fresh rock.

1.—The numbers refer to rock sections in the collection of the Geological Department, University of Melbourne.

Microscopical examination of a rock section of the specimen analysed showed it to be a typical specimen.

The analysis shows a silica percentage of 47·71%. This places the rock in the basalt group. Chemically it is distinctly higher in alkalies and lower in lime and magnesia than the normal basaltic type, typified by R. A. Daly's average of 161 basalts. It therefore belongs to the alkaline suite of rocks.

The high percentage of CO_2 would seem to indicate that the sample taken for analysis was not fresh. Microscopical examination, however, showed that this was not the case. None of the minerals, including the felspars, was decomposed to any extent. Some aragonite occurred in the vesicles. This would indicate a primary origin for the carbon dioxide in the magmatic gases.

According to the Quantitative Classification, the rock would be classed as —Class 1, Dosalane; Order 5, Germanare; Rang 3, Andase; Sub-Rang 4, Andose.

(*c*) *Petrological Character.*

Megascopically it is a dark bluish grey rock, in which small phenocrysts of augite, olivine, and shiny felspar may be distinguished. In appearance it is very similar to the anorthoclase basalts of the Macedon district. Large clear phenocrysts of felspar, some over 1 cm. in length, showing a well-developed cleavage and a lenticular outline through reaction with the molten magmatic liquid, are occasionally found. They are most numerous at Sailor's Creek and Stony Creek Falls, where an abundance of broken material is available for examination. Vesicles lined with zeolites and aragonite are fairly numerous.

The vesicular blocks at Leonard's Hill contain, though not plentifully, large phenocrysts of a clear felspar. Similar crystals are found in the scoriaceous material at Mount Franklin, where they have been identified as anorthoclase. Near the foot of Leonard's Hill is found a very dense, fine-grained type of basalt, in which few, if any, phenocrysts can be recognised with a lens. It occurs in boulders which under the hammer break up into concentric shells.

The microscopical character of the rock has been determined by the examination of a large number of rock sections made from specimens gathered from different parts of the flow. There is a marked uniformity in all these sections, with the exception of those of material from the point of eruption.

Microscopically it consists of phenocrysts of idiomorphic plagioclase, showing distinct though rather fine lamellar twinning, allotriomorphic anorthoclase, granular olivine and hypidiomorphic augite and hypersthene. The ground mass is composed mainly of lath-shaped plagioclase, showing a well marked trachytic arrangement of crystals, with grains of olivine, augite and magnetite. A clear felspar sometimes occurs as an interstitial allotriomorphic mineral in the ground mass. Its refractive index, found by the

Becke method, is less than that of the felspar laths. This is probably sanidine or untwinned anorthoclase. Interstitial glass is sometimes present in small amounts. Aragonite is frequently found in the vesicles [2192, 2202, 2208].

The reaction border surrounding the allotriomorphic crystals of anorthoclase and the corroded outline of the crystals show that they were not in equilibrium with the molten liquid. Their distribution is rather irregular, as, though usually present, they do not occur in all the sections. Twinning cannot be distinguished, but they have the characteristic wavy extinction of anorthoclase. The refractive index is lower than that of the plagioclase felspar, whose refractive index, determined by the Becke method, is distinctly higher than, while that of the anorthoclase is practically the same as that of the balsam. The size varies from large phenocrysts [2204, 2205, 2206, 2207] to small corroded remnants [2191, 2193, 2195]. The smaller crystals are crowded with inclusions, but the interior of the large ones, although surrounded by altered reaction border with inclusions, is quite clear and free from inclusions.

The predominant pyroxene is a violet-grey titaniferous variety of augite. Hypersthene occurs in a subordinate amount [2191, 2193, 2203, 2195], being distinguished by its straight extinction and faint pleochroism.

The felspar laths were determined, wherever possible, by the Michel Levy statistical method, and were found to vary from an acid labradorite to a basic andesine.

Generally the rock is fairly fresh. Calcite is developed at the expense of the plagioclase [2191, 2194, 2206], frequently forming central inclusions in the larger phenocrysts. The olivine is generally altered to brown iddingsite [2195, 2199, 2206], and more rarely to serpentine [2192]. Serpentine, not directly associated with olivine, is frequently present [2203, 2208, 2195].

This microscopical examination shows the rock to be an olivine anorthoclase basalt.

Sections of the scoriaceous type from the summit of Leonard's Hill show a few porphyritic crystals of magnetite, olivine, augite and, in one case [2197] hornblende, set in a decomposed glassy ground mass. Two sections were prepared containing the large felspar phenocrysts. In one case [2196] the phenocryst had a well-developed cleavage and a wavy extinction inclined at 3-7° to the cleavage. The refractive index was practically the same as that of the balsam. It is therefore anorthoclase. In the other section [2198] the felspar showed broad lamellar twinning and a higher refractive index characteristic of the plagioclase felspars.

In the dense fine-grained variety found at the foot of Leonard's Hill [2199], the trachytic structure, so characteristic of the felspar laths in the ground mass of the other sections, is absent. The phenocrysts are smaller and less numerous, anorthoclase being represented by one small corroded remnant.

(d) *Age.*

The anorthoclase basalt flow covers auriferous drifts of the same age as those preserved beneath the normal basalt flows of the district. Leonard's Hill, compared with other hills, such as Fern Hill, Bald Hill, Wombat Hill, points of eruption of normal basalt types, is of the same order of preservation. The deep lead, like the other deep leads, lies about 50 feet above present stream level, and therefore was formed before the rejuvenation of the streams, causing the present deep dissection, took place. The flow therefore belongs to the newer basaltic period of volcanic action, and is late Kainozoic in age.

The anorthoclase basalts of the Macedon district are considered (3) to have been extruded immediately prior to the normal newer basalts. In this area, however, if the age assigned to the basalt flows immediately south of Leonard's Hill is correct, the extrusion of the normal types had already commenced when the anorthoclase basalt was poured out.

(e) *Comparison with Newer Basalts and with other Alkaline Rocks in Victoria.*

An average of six analyses of newer basalt from the Camperdown district is given with the chemical analyses. This may be taken as typical of the newer basalts of Victoria. Compared with R. A. Daly's average, it shows a marked similarity throughout. The normal newer basalts are therefore typical olivine basalts from which the anorthoclase basalt differs both chemically and mineralogically.

CHEMICAL ANALYSES.

	1.	2.	3.	4.	5.
SiO_2	47·71	48·83	51·52	48·78	48·00
Al_2O_3	15·66	16·69	16·58	15·85	14·11
Fe_2O_3	2·47	2·66	2·35	5·37	5·61
FeO	8·43	8·40	7·68	6·34	6·11
MgO	4·45	5·56	4·03	6·03	8·81
CaO	7·53	7·95	6·10	8·91	8·68
Na_2O	3·69	2·92	4·11	3·18	3·01
K_2O	2·23	2·10	2·99	1·63	1·25
H_2O +	1·93	0·66	0·22	1·03	0·73
H_2O −	0·48	1·34	1·39	0·73	0·80
CO_2	2·67	tr.	tr.	—	—
TiO_2	1·96	2·85	2·15	1·39	2·20
P_2O_5	0·89	0·74	0·82	0·47	0·50
MnO	tr.	0·25	0·13	0·29	0·13
Li_2O	n.d.	—	—	—	—
Cl_2	n.d.	0·04	0·05	—	—
SO_3	n.d.	—	—	—	—
CoO,NiO	n.d.	—	0·06	—	0·03
SrO	n.d.	—	tr.	—	—
Total	100·10	100·99	100·18	100·00	99·97

NORMS AND CLASSIFICATION.

	1.	2.	3.
Orthoclase	12·79	12·23	17·79
Albite	28·82	24·63	34·58
Anorthite	19·74	26·41	18·07
Nepheline	1·42	—	—
Diopside	10·46	7·23	5·94
Hypersthene	—	13·12	4·18
Olivine	11·89	4·32	8·59
Magnetite	3·71	3·94	3·48
Ilmenite	3·65	5·47	4·10
Apatite	1·86	1·68	2·02
Class	2	2	2
Order	5	5	5
Rang	3	3	3
Sub-rang	4	4	4
Magmatic Name	Andose	Andose	Andose

1. Anorthoclase Olivine Basalt, Stony Ck. Falls, Daylesford. Analyst, D. Orr.
2. Anorthoclase Basalt, Sugarloaf Hill, N.N.E. of Woodend. Bull. Geol. Surv. Vic. No. 24, p. 33.
3. Olivine Anorthoclase Trachyte, allot. iv., Parish of Cobaw. Bull. Geol. Surv. Vic. No. 24, p. 25.
4. Average of 161 typical basalts, mostly olivine-bearing. R. A. Daly, Journ. Geol. xvi., p. 409, 1908.
5. Average of 6 basalts, Camperdown district. Mem. Geol. Surv. Vic. No. 9, p. 22, 1910.

In Victoria there are three Kainozoic centres of alkaline volcanic activity, viz.: N.E. Victoria, in the Omeo, St. Bernard Hospice and Mt. Leinster districts; Central Victoria at Macedon; and Western Victoria around Coleraine. Besides the main Macedon area in the central Victoria province, there are two other volcanic foci of alkaline nature recorded by Professor Skeats (1). These are Mount Wilson, about six miles south east of Leonard's Hill, which is composed of trachy-phonolite, and Blue Mountain, four miles north of Blackwood township, which is tentatively described as anorthoclase-olivine-trachyte. In the same paper Professor Skeats describes the Daylesford anorthoclase basalt as an olivine-anorthoclase-trachyte from which it cannot be distinguished either megascopically or microscopically. It is therefore probable that the Blue Mountain occurrence is very similar to the Daylesford type.

The alkaline rocks of the Macedon district (3) include solvsbergites, anorthoclase trachytes, anorthoclase basalts, limburgites, Macedonite, and Woodendite. Analyses of an anorthoclase basalt from Sugarloaf Hill and an olivine anorthoclase trachyte from the Parish of Cobaw are recorded with that of the Daylesford type. The Daylesford rock shows marked chemical affinities with both types. This is reflected in the similar positions which the three rocks occupy in the Quantitative Classification. Though the chemical similarity in the case of the Sugarloaf type and the Daylesford type is very marked, the comparison then ceases. Structurally the Sugarloaf type is of the basalt variety, while the Daylesford type has a well marked characteristic trachytic structure, and might be called an anorthoclase trachy-basalt. Although the Daylesford rock has a distinctly lower SiO_2 content than the olivine anorthoclase trachyte from the Parish of Cobaw, the similarity in the chemical analyses of the two types is very marked, and as both types structurally belong to the trachyte type they are therefore more closely related than the Daylesford type and the Sugarloaf type. The silica content (51·52%) of the latter rock would, according to Hatch's classification, place it in the basalt group with the Daylesford rock.

(*f*) *Origin.*

The origin of the Kainozoic alkaline rocks of Victoria has been discussed by E. W. Skeats and H. S. Summers (3). They consider that at the beginning of the Kainozoic period, Victoria was invaded by a basaltic magma and formed a basic sub-alkaline province. In early Kainozoic times "came the separation and pouring out of the older basalts of the eastern and central portions of Victoria. This left a magma moderately rich in alkalies, and by some process of differentiation alkali magmas separated out into at least three lesser magma basins, viz.: at Omeo, Macedon and Coleraine. On the exhaustion of these lesser magma basins, extrusion once more took place from the main reservoir, giving the newer basalt series." The alkaline lavas of Blue Mountain and Mount Wilson together with the Daylesford anorthoclase basalt may be considered as offshoots from this lesser alkaline magma basin of central Victoria.

In all these other Victorian occurrences of alkaline lavas, whenever evidence of age is obtainable, it points to a slightly earlier period of eruption than the newer basalt. As previously indicated, however, it seems probable that the extrusion of newer basalt types had already commenced in the Daylesford locality when the anorthoclase basalt was extruded. Considering the close intimacy, both in space and time, of the anorthoclase basalt and the newer basalts, it cannot be doubted that both have been derived from a common magma, and are therefore genetically related.

Mineralogically the anorthoclase basalts differ from the normal basalt only in the presence of anorthoclase. This mineral accounts for the higher alkali percentage, and if absent would bring the rock chemically into line with the normal newer basalts, with which it is so intimately associated. Anorthoclase has been recorded in several instances from the newer basalts, and careful microscopical work would no doubt increase the number of occurrences. H. J. Grayson and D. J. Mahony have recorded anorthoclase from the ejected material from Mount Noorat (4), and it is fairly plentiful in the vesicular blocks of scoria at Mount Franklin. Dr. Stillwell has shown it to be present in both the newer and older basalts of Broadmeadows (5). Professor Skeats and Dr. Summers have recorded it in the newer basalt of Ballarat and Macedon (3). These latter two occurrences were as intensely corroded phenocrysts. It is therefore evident that the anorthoclase molecule is present in very minute amounts in the newer basalt magma, and that it separated out at an early stage in the crystallization to be later wholly or partially re-absorbed by the magma.

It is possible that the portion of the magma from which the anorthoclase basalt was derived had been enriched in these anorthoclase crystals. Concentration of the alkalies by resurgent gases has been suggested by R. A. Daly and C. H. Smith. The former (6) regards the source of these gases to be assimilated basic sediment, the most efficient being limestone. The latter (7) regards magmatic or "juvenile" gases to be the more likely effective concentrating agent.

In the rock under discussion, aragonite and zeolites are found in the vesicles, and would indicate the association of magmatic gases with the lava. None of the minerals associated with the more active "mineralisers," however, was detected. In this area the evidence is not sufficient to support one or other of the views as to the source of the magmatic gases. Seepages of carbon dioxide, and the fact that the mineral springs of the district are highly charged with this gas, show that the Ordovician sediments would be competent to supply this gas if assimilated on a sufficiently large scale.

Summary.

Among the newer basalts of the Daylesford district is an alkaline lava which was extruded from Leonard's Hill, six miles south of Daylesford. The area is one of great diversity of surface due to the recent rejuvenation and consequent dissection by the streams. This dissection is discussed, but no conclusive evidence as to its cause could be advanced. A chemical analysis shows that the rock has alkaline affinities. This is borne out by microscopical examination which shows it to be an olivine anorthoclase basalt. The age of the rock is discussed, it being considered to have been extruded subsequently to the commencement of newer basaltic activity. It is compared with normal newer basalt types, and its relation to other Kainozoic alkaline basalts is discussed. It is considered to be genetically related to the newer basalts, and a possible method of concentration of anorthoclase crystals or molecules by resurgent gases, either magmatic or consequent on assimilation, is suggested.

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[PROC. ROY. SOC. VICTORIA, 40 (N.S.), PT. I., 1927.]

ART. V.—*Notes on the Coastal Physiography of Port Campbell, Victoria.*

By J. T. JUTSON, B.Sc., LL.B.

(With Plates VI., VII.)

[Read 14th July, 1927.]

Introduction.

The Port Campbell area lies between Cape Otway and Warrnambool, and its coast is justly famed for its magnificent scenery. Inland, the country forms a gently undulating plain of sedimentation, rising at the coast in places to a height above sea-level of over 200 feet, and being destitute of timber near the ocean. The rocks composing this plain are Tertiary sediments, which have been so slightly disturbed that they lie very close to the horizontal. The country has been comparatively little eroded. There are no large streams, the most prominent being the Port Campbell Creek (at the mouth of which the small township of Port Campbell is situated) and the Sherbrooke River, a few miles to the east of Port Campbell. Both these streams, and some smaller ones, enter the ocean at sea-level; but numerous small watercourses and other channels that are mere gulches in the cliffs, occupy hanging valleys. By reason of the non-resistant character of most of the rocks, the valleys are fairly wide, open ones, with rather gently-sloping sides. In some valleys, as in parts of that of the Port Campbell Creek, the valley-sides tend to be steep, owing to the intercalation, high up, of bands of indurated limestone. The Port Campbell Creek, in its lower portion, is sluggish, and its valley flat-floored and marshy, features no doubt at least partly due to the formation of the small bar to be referred to immediately.

The coast-line consists of rugged cliffs, and its general outline is so simple that there are practically no harbours, with the exception of the tiny one of Port Campbell, which lies at the mouth of the creek of the same name, and is about 150 yards wide by about 250 yards long. The head of that "harbour" has been determined by the formation of a crescentic sand bar, capped by a low sand dune across the valley, which it almost closes, the exit of the stream being by a narrow channel on the western side. The bar provides an excellent bathing beach. The western and eastern sides of the "harbour" are formed of steep cliffs in process of marine abrasion.

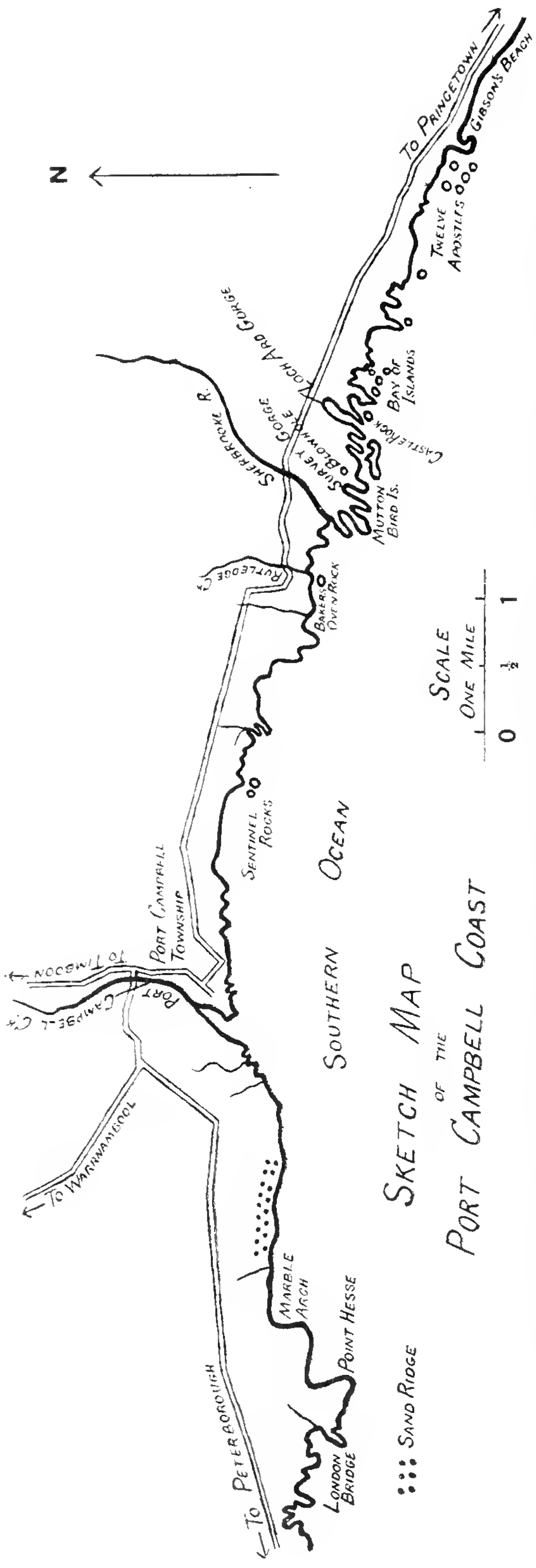

FIG. 1.—Sketch map of the Port Campbell coast, comprising the area referred to in the paper. The map was copied from one available at Port Campbell and appears to be approximately correct. Its authorship is unknown to the writer.

The site of the township on the left bank of the stream has been determined by the fact that there the left side of the valley possesses a long gentle slope, whilst the right side rises precipitously from the valley floor.

The impure limestone, referred to below, is used for road-making in the district.

Previous Literature.

The only previous physiographic references that the writer is aware of are those of J. W. Gregory (1, p. 40) and A. V. G. James (2, pp. 144 and 194) by each of whom Port Campbell (i.e. the "harbour") is referred to as a drowned river valley, and by Gregory also as an example of a ria (1, p. 56).

Physiographic Features of the Coast-Line.

In its general features, the coast-line may be described as consisting of a series of high cliffs, practically vertical, and in places overhanging, which frequently follow a sinuous line (which may be described as "crenulate," although here not necessarily indicating a youthful submerged shoreline (3, p. 278)), owing to the occurrence of numerous small bays and narrow gorges, the latter of which in some instances are continued some distance underground as sea caves, as shown by the "Thunder Cave" at the Survey Gorge; by "the Blowhole" at a point perhaps 200 yards inland, where the roof of the long horizontal cave has fallen in; and by Tom Pierce's and Miss Carmichael's caves in the Loch Ard Gorge. Tom Pierce's cave is about 40 or 50 feet long, 15 to 20 feet wide, and 10 to 15 feet high at the entrance, but becoming so low that one cannot stand erect in it; whilst Miss Carmichael's cave is about 50 feet or more long, 15 to 20 feet wide, and in places 20 feet high. Many of the bays, however, are slight open indentations. The gorges themselves are but a few yards wide and, as a rule, would be about 100 yards in length.

Arches also are formed by marine erosion of opposite faces of small peninsulas or islands. Examples of such arches occur at the peninsula known as "London Bridge," about five miles west of Port Campbell; at a small projecting tongue of land to the north-east of Point Hesse, where it is known as the "Marble Arch"; and in an island in the small "bay" immediately to the east of the Loch Ard Gorge.

Islets, usually with vertical cliffs, are fairly common—a rather unusual feature of the Victorian coast-line.

The rocks forming the cliffs are chiefly Tertiary shales, fine-grained sandstones, and impure limestones. The lower beds largely consist of easily eroded shales, with an occasional harder band, whilst those towards the top of the cliff have been made more resistant to erosion by the deposition of ferruginous or calcareous material in the form of thin bands along the bedding planes, and also as nodules and irregular masses.[1] These features, therefore, by aiding marine abrasion, and by retarding atmospheric erosion, facilitate the formation and maintenance of practically vertical cliffs, without (under the present stage of development) materially checking the rapid recession of the cliffs. The attack of the waves on a soft band of rock is greatly aided by its horizontal character. This is shown by the undermining along such a stratum, both when the direction of attack is approximately at right angles, and when, in consequence of a projecting strip of land, the direction of attack is parallel to the trend of the coast. In the latter case, it is very instructive to watch the end of a wave working along the stratum, and to note the even groove made by such action.

The hanging valleys indicate that the cliffs are receding faster than these valleys can deepen themselves, and so the latter do not reach the sea-coast at sea-level.

Cliff erosion is also assisted by the presence of pronounced, usually vertical joints, fairly widely spaced, often forming two sets, more or less at right angles to each other, sometimes very curving and sometimes dipping into the cliff. The undermining of the cliffs, their steep character, and the percolation and evaporation of water along these joints, bring about the fall of huge masses usually rectangular in cross-section; and the new face of the cliff consequently presents a somewhat buttressed appearance.

A striking feature of the coast-line is the number of taluses formed as a result of the processes just described, many of the component blocks of which are of great size. These masses, being particularly exposed to the action of the sea and of the weather, must be removed relatively rapidly.

Broad well-developed beaches and water-worn pebbles and boulders are scarce. Beaches at the foot of the cliffs in the bays do occur; but usually they are narrow and the sand scanty. Many are accessible at low tide only, and in some parts they are probably always inaccessible. One of the best beaches is that in the bay immediately to the west of London Bridge. The waterworn boulders, when naturally occurring, may have been largely removed for the purpose of roadmaking, as several heaps, gathered together for this purpose, of the fairly hard, impure limestone were noticed at the time of the writer's visit in January, 1925.[2] If, however, boulders and shingle are generally absent from the beaches, it is a matter of some surprise, considering the quantity of resistant rocks in the cliff beds.

1.—One result of the occurrence and irregular distribution of these harder bands is the formation by differential weathering of pillars of comparatively soft rock with projecting hard caps. Where a considerable area of the rocks has been exposed, as at the tops of the cliffs just to the west of Point Hesse and near the "Blowhole," close to the Loch Ard Gorge, the surface becomes honeycombed and extremely uneven and ragged, with varied and often grotesque forms.

2.—These collected waterworn rocks may possibly be due to stream action; but if so, whence they came is unknown to the writer.

The comparatively short and few streams entering the sea in this area cause little fluviatile detritus to be carried into the sea; hence the waves are freed from the task of removing the material that would otherwise be deposited near the shore, and are thus enabled to make a more continuous attack on the coast.

Wave-cut rock platforms lie at the base of the cliffs and around the stacks, which are comparatively close to the shore; but whether or not these platforms stretch seaward to any extent was not observable, although waves frequently break far out, thus suggesting the continuance of the platforms to those areas.

One obstacle to marine abrasion is the occurrence of the great seaweed commonly known as "kelp," which in many places is so firmly attached to the rocks at sea-level, and is so abundant, that rock removal must be considerably checked.

As a result of the powerful marine abrasion, a coast-line has been produced which in certain parts is very broken on a small scale. These features are observable in the vicinity of London Bridge, and especially at and adjacent to the Loch Ard Gorge. Diminutive bays and gorges succeed one another, and a moderate number of islets fringe the shore in places. A physiographer without personal knowledge of the area, looking at a map of the coast-line drawn on a fairly large scale, would probably infer that the physiographic features referred to are due to a recent submergence of the land. This question is subsequently discussed, but here it may be pointed out that although slight submergence may have taken place, and although the "harbour" of Port Campbell[3] may possibly be due to submergence, yet practically no traces of submergence remain; and the small bays and gorges are clearly due to erosion, as they certainly are not the drowned ends of normal valleys. Moreover, their actual formation can be seen now going on.

Reflection might suggest that the gorges occur only at the mouths of valleys, and that consequently, even though they are not drowned valleys, their erosion by the waves has been hastened, owing to the formation of the valley above, and the action of waterfalls (where the valleys are "hanging" ones) in bringing about a recession of the cliffs upstream. But although gorges do occur as indicated, yet there are others quite as long, which have been formed without these aids, and therefore the ocean is responsible for the whole gorge in certain cases. Doubtless where strong seas—as at Port Campbell—are available, they gather force by concentration in a narrow area, despite the increased friction they suffer. Hence if breaches are made in a cliff face, the concentrated power of the water will tend to erode gorges—at least in soft rocks—at the head of which extensive sea-caves may be formed, as for example, in the Lord Ard and Survey Gorges.

3.—The mouth of the Sherbrooke River was not examined by the writer, so that no expression of opinion can be given as to whether or not it represents a drowned river valley.

One would imagine, however, that there must at least be a temporary limit to the extension of the gorges, owing to the continually increasing friction and consequently reduced power of the waves as the gorges lengthen; but the activity of the sea may be revived as the outer cliffs are cut back.

The formation of such gorges might be expected if there were much variation in the power of resistance to marine abrasion of the rocks of the coast, but such variation at Port Campbell is not apparent on a general inspection; hence some surprise is excited by their occurrence. There must, however, be differences in resisting-power among the rocks, although difficult to detect; and perhaps wave-attack varies in strength from point to point.

The gorges, however, may be primarily or largely determined by structural features, such as strong joints or small faults highly developed in certain areas; since erosion would advance more rapidly along these lines of weakness than in areas where they were absent, other things being equal. This aspect was suggested to the writer by Professor Skeats, but it must be reserved for future investigation.

The numerous islets are due to marine abrasion, and not to submergence of the land; their shape and distribution, and their standing, as far as can be seen, upon a wave-cut platform negativing the latter idea. In a mainland so little dissected, such islets could not result from subsidence. They are, therefore, undoubtedly stacks. None of these stacks is joined to the mainland or to another stack by a sand bar, this fact being no doubt due to the rapid removal by the waves of most of the detritus from the cliffs.

The scarcity of beaches is apparently due to the tremendous scour of the waves, and to the fineness of the constituents of the rocks attacked. Such rocks yield little sand, and the fine materials are carried well out to sea. Moreover, the absence of much river-borne detritus must tend to restrict the formation of beaches. This limitation of beaches hastens in turn the wearing away of the cliffs owing to their lack of protection by the beaches. Two localities are of interest as minor examples of the prevention of wave attack. In the western arm of the Loch Ard Gorge a high bank of blown sand is preventing—but probably only temporarily—further marine abrasion of the cliffs around this arm. In the small bay just west of "London Bridge," where there is a well-developed beach, a small dune at one point acts in the same way. In each case, rough thick stalactites have formed on the inwardly-inclined cliff, so that the cessation of wave attack is not quite recent. Incidentally, it may be noticed that if man removes sand and gravel from the shore, such action will hasten the wearing away of the cliffs by the sea.

A little to the west of the large sand ridge described below, there is on the beach a large bed of rounded pebbles and boulders, covered with vegetation, in front of a talus, which thus at present protects the cliffs from marine abrasion.

A striking feature observable in some localities is the small serrations in the Tertiary rocks at the top of the cliffs. The serrations have been filled with red soil containing ironstone fragments, which deposit in many places forms a thin surface cover on the marine Tertiary sediments. The origin and age of this deposit are not obvious, although it appears to be of quite recent age, and to have been laid down subaerially.

Reclamation of Land from the Sea.

The physiographic features noted above are so characteristic of the coast that much surprise is felt when a long sand ridge is found abutting the coast. It commences a few hundred yards west of

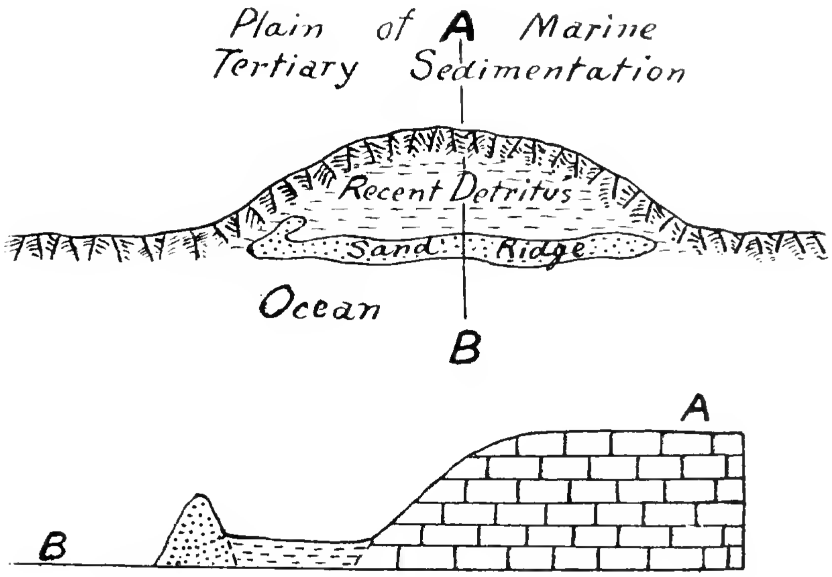

FIG. 2.—Diagrammatic plan and section of the sand ridge area west of Port Campbell.

Port Campbell "harbour" and extends in a gently curving line westerly for perhaps three-quarters of a mile. It follows the coast-line so closely that at high tide the water reaches to its base. The ridge varies in height, the highest point being about 80 feet above sea-level. Its crest usually is not more than a few feet wide, and its width at the base varies from a few yards to about 25 yards. It is clothed, but not densely, with vegetation, mostly small shrubs, but there is ample opportunity for movement of the sand by the wind. The sand is fine-grained, and, so far as cursorily examined, consists chiefly of quartz. At its western end, the sand ridge throws off inland a short minor ridge, which divides into two, but reunites. Near the eastern end, the sand rests for a short distance on a rock platform six to eight feet above the beach.

At each end of the main ridge the coast-line consists of precipitous cliffs up to 200 feet or more high, of the kind already described as characteristic of the coast as a whole. These sea cliffs are being abraded strongly by the ocean. Although they give place to the sand ridge along the coast, yet they are connected behind the ridge by a line of cliffs (which for convenience may be referred to as the " inland cliffs ") which forms an arc of which the sand ridge is the chord.

The inland cliffs present a striking contrast with the present sea cliffs in that they are clothed with vegetation; show the double curve of atmospheric denudation in profile; are not vertical, although steep; are not undermined; and have alluvial fans at the mouths of the small creeks or gullies that dissect them. These features are absent in the sea cliffs, as will be seen from the description given above of the coast generally. What are apparently old taluses occur at the foot of the inland cliffs, but these may have been formed either under marine or atmospheric conditions. Another contrast is that the gullies and short creeks which cut the inland cliffs are not hanging like those of the sea cliffs. This points to rapid recession of the latter, but to very slow backward cutting of the former.

Between the inland cliffs and the sand ridge is a narrow belt of low-lying land possessing a somewhat uneven floor, owing to the formation of the alluvial fans mentioned above, to the probable drifting of sand from the sand ridge, and to some slight stream action. The greatest width of this belt is about 70 or 80 yards, and in its higher portions its surface is probably 25 feet or more above sea-level.

The obvious interpretation of the phenomena described is that the line of inland cliffs was originally bounded by the sea; that the sand ridge was thrown up by the waves and wind, forming a typical bay dune-covered bar, which either altogether or almost entirely cut off the sea behind it from the ocean; that silting (or perhaps silting combined with uplift) has taken place until the water has given place to land; that subsequently thereto, by the accumulation of wind-driven sand from the ridge and of detritus from the gullies and face of the inland cliffs, the land surface of this reclaimed area has been raised to its present height; and that by atmospheric erosion the face of the inland cliffs has been changed from their typical sea-front form in this locality to the equally typical double curve of atmospheric denudation.

This interpretation appears to meet the facts of the case best, although others are possible. It is, however, uncertain, on the facts known to the writer, whether uplift has played any part in bringing about the present conditions.

It may be contended that the bay which has been cut off penetrated far enough into the coast-line for the water to become relatively quiet, and silting to occur—resulting in the formation of land—without necessarily the formation of a bar, and that the land gradually encroached on the sea, until the present coast-line was approximately fixed, after which the sand ridge was formed by wind action. Against this idea is the fact that the coast-line in the neighbourhood is much indented on a small scale by the abrasive action of the waves, and in several instances the indentations are quite as pronounced and some are more sheltered than the bay referred to, and yet in almost all these localities wave abrasion is still actively proceeding.

Another point requiring consideration is that at the eastern end of the sand ridge, the rock platform already referred to, stands six to eight feet above the present beach. This fact suggests that if that platform were originally continuous across the bay to the inland cliffs, and had been formed as a platform of marine abrasion, it could hardly have been formed at its present height, and hence a recent uplift of the land relative to the sea may have occurred; and in that event the change from sea to land would be effected merely by the uplift and not by silting. No direct evidence of such an uplift in the immediate neighbourhood of the bay was noticed (except possibly just to the west of the sand ridge, where some waterworn pebbles and boulders fill some hollows in the cliffs at a height of about eight feet above the beach, but these might also be regarded as the remains of a storm beach) although such evidence, if it originally existed, would no doubt usually be rapidly destroyed, except that, in other indentations, remnants of similar platforms should be observable. Whether or no such a platform exists in the old bay behind the sand ridge cannot at present be stated, as its surface, if it exist, is covered with recent debris—the wash from the inland cliffs and the sand from the sand ridge. On the whole, however, doubt is thrown on the existence of a wide platform by reason of the fact that no evidence of its occurrence is found along the greater part of the sea margin of the ridge, and on account of the absence of such platforms in neighbouring indentations. Moreover, the rock platform under the sand ridge can be explained on the assumption that it is an old low stack.

A short bore or some shallow excavations in the low-lying ground might yield some interesting results.

The sand ridge cannot be regarded as quite fixed, as the vegetation is sufficiently scattered to allow the sand to be carried by the wind over the crest landward. In this way, if there be no erosion of the sand ridge, the ridge must be increasing in width. There is evidence however, in some places, of the erosion by the sea (which would be expected, seeing that the cliffs at each end of the ridge are being cut back) with the result that the vegetation has in places been destroyed, and the loose sand is partly being removed by the sea and partly being carried by the wind over the ridge landward. As the strength of the marine abrasion on this coast is not likely to abate for some time to come, the sand ridge must either be removed or migrate. The fact that the reclamation of the old bay and the modification noticed above of the forms of the inland cliffs have apparently taken place since the formation of the sand ridge, indicates some degree of antiquity for the sand ridge; and the most feasible explanation of why the ridge has been able to maintain its identity for so long a period, despite marine abrasion, is that the latter process is counter-balanced by the deposition of wind-blown sand on the landward face of the ridge. Consequently the ridge may be migrating towards the inland cliffs. If this be so, an interesting point is, assuming these conditions to continue, whether or no the ridge will reach the inland cliffs, and be banked against, and temporarily protect from erosion the latter. This in turn will depend on the rate of migration of the sand ridge and the rate of erosion of the inland cliffs, points about which at present we know nothing.

The Stage of Development of the Coast.

D. W. Johnson (3, p. 249) distinguishes between the shore profile and shoreline development. They may be in the same or in different stages, so that if one be young or mature, the other is not necessarily in that particular stage.

In the Port Campbell district, the vertical high cliffs, their rapid erosion, the stacks and the scanty beaches indicate that the shore profile is in the youthful stage; whilst on the other hand the simply curved coast-line (apart from the minute irregularities caused by the small bays and gorges) the absence of spits, bay-bars (with the exception of that referred to in detail above), tombolos and offshore bars, indicate that the stage of shoreline development is mature.

Whether the coast-line was originally one of submergence or of emergence, or is due primarily to faulting, is difficult at present to say. The existing forms of the shore profile and of the shoreline could result from any of the types mentioned. If it were one of submergence, then the drowned valleys (except the "harbour" of Port Campbell and possibly the mouth of Sherbrooke River, assuming them for the moment to be such) together with any associated phenomena, such as spits and bay-bars, have been removed by marine abrasion. Similarly, if it were one of emergence, the offshore bar, the lagoon and possible marsh (if these features or any of them occurred) and the low-lying land of the uplifted coastal plain have been removed. In the same way, a fault-coast would have been retrograded.

The absence of any direct evidence of recent uplift has been referred to in the immediately preceding section of this paper. It may here, however, be pointed out that if a small uplift could be proved to have taken place, such would almost certainly establish the fact of a prior submergence, since the bed of the Port Campbell Creek is now so close to sea-level that, if it has recently been raised several feet, it must have been an estuary prior thereto for some distance from its mouth.

As regards direct evidence of submergence, there is none with the possible exception of Port Campbell "harbour" and the mouth (not seen by the writer) of the Sherbrooke River. But so far as concerns the "harbour," in view of the evidence adduced above as to the power of the ocean to excavate small bays and gorges; of the fact that the stream has provided a well-defined opening in the cliffs which the sea could easily further widen; of the fact that wave-cut platforms and cliffs do exist inside the "harbour"; and of the short distance the sea penetrates, it cannot be assumed from the mere form of the "harbour" that it represents a drowned portion of a valley. Of course the shortness of the "harbour" could be accounted for either by the building, in the old estuary, of the dune-covered bar already described, owing to which—above the bar—siltation has taken place and marshes have resulted[4], or by the retrogradation of the shoreline, or by both these operations, the second of which we may be sure has been in force.

The writer has been permitted, by the courtesy of Captain J. K. Davis, Director of Navigation, to inspect the charts of the ocean in the vicinity of Port Campbell, but no definite conclusions regarding the questions discussed in this paper can be drawn from them, although such might be possible, were greater detail shown.

Judgment on the original character of the shoreline must therefore be suspended pending an examination of a wider area.

It may be noted that G. S. Griffiths (5, pp. 76-79) states there is evidence of late submergence and of subsequent emergence at the Portland Promontory. Similar observations have been made in so many places around Australia that one naturally leans towards those ideas at any similar spot under examination. Each locality must, however, be independently judged.

Summary.

The Port Campbell area lies between Cape Otway and Warrnambool. Inland, the country forms a plain of Tertiary marine sedimentation, not much dissected. The coast consists of rugged high vertical cliffs of the same class of rocks.

The coast in places follows a sinuous line owing to the occurrence of small bays and narrow gorges. Arches and long sea-caves are prominent features, and numerous islets occur. These features are due to marine erosion, and not (as regards the bays, gorges and islets) to submergence of pre-existing valleys.

4.—T. S. Hall (4, p. 31) refers to the blocking of the mouths of various streams east of Warrnambool, of which Curdie's and the Gellibrand Rivers are examples, by sand dunes, without apparently believing that their estuaries are drowned valleys. The "harbour" of Port Campbell may be of similar origin.

The upper beds of the coastal cliffs, being somewhat more resistant to erosion than the lower, facilitate the formation and maintenance of practically vertical cliffs. A series of vertical joints also tends to the same result.

Hanging valleys occur in the shorter watercourses, indicating that the sea-cliffs are retreating faster than these valleys can deepen themselves.

Taluses are abundant; but well-developed beaches and water-worn pebbles and boulders are scarce.

Wave-cut platforms occur at the base of the cliffs, but their seaward extent is unknown to the writer.

A prominent sand-ridge runs along the coast to the west of Port Campbell. Behind it lies a belt of low-lying ground which is bounded by a line of old sea-cliffs, which have lost their typical marine form, and have taken on the double curve of atmospheric denudation. The sand ridge is regarded as having been formed as a bar across the mouth of the old bay, and then built up by wind-blown sand. The bay became practically closed to the ocean. Silting occurred, and the low-lying belt at the rear was formed, thus reclaiming a moderate area of land. The question of uplift is considered in this connection, and the conclusion is arrived at that as there is no definite evidence of recent uplift, the probabilities are that the low-lying belt was formed entirely by silting and subsequent atmospheric accumulation. If that be so, the sand ridge must be of some antiquity.

The sand ridge is not fixed. It is being eroded on the seaward side by the ocean, and is widening on the landward side by the deposition of sand blown over it from the seaward face. Consequently the ridge may be migrating landward.

The shore profile is youthful, whilst the stage of shoreline development is mature.

Whether the shoreline was originally one of submergence or emergence, or is due primarily to faulting, has not been determined, although some slight submergence has perhaps taken place.

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5. G. S. Griffiths. The Geology of the Portland Promontory. *Trans. Roy. Soc. Vic.*, xxiv. (1), pp. 61-80, 3 pls., 1887.

Fig. 1

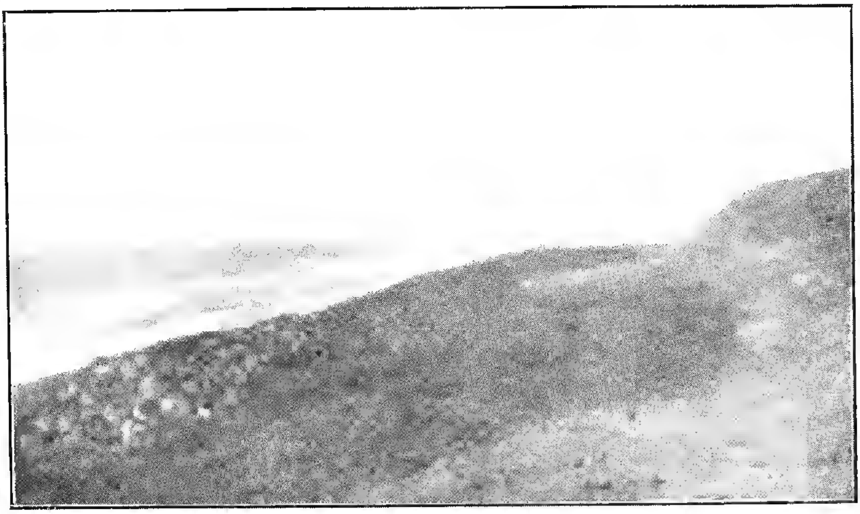

Fig. 2.

A B C

Fig. 3.

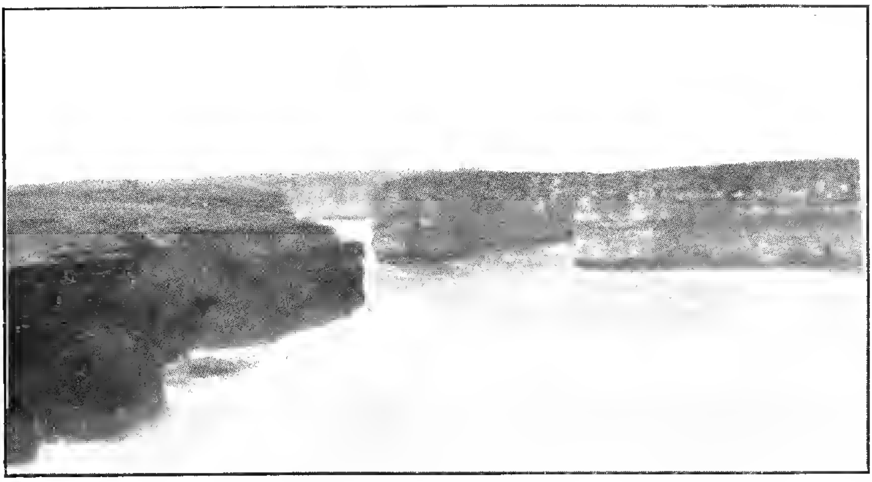

Fig. 1.

Fig. 2.

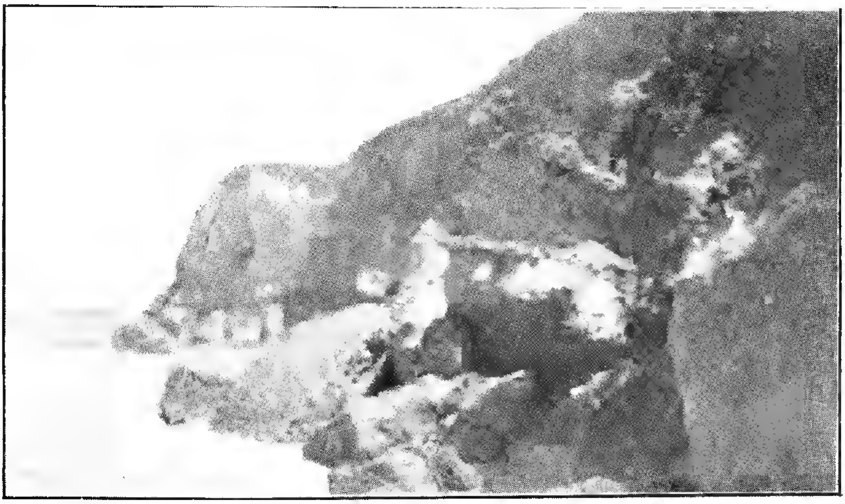

Fig. 3.

EXPLANATION OF PLATES.

Plate VI.

Fig. 1.—The old sea-cliffs, and the low-lying ground between these cliffs and the sand ridge. A small portion of the latter is shown in the foreground at the left-hand corner.

Fig 2.—The sand ridge bounding the ocean, and the low-lying ground between the ridge and the old sea-cliffs. A part of these cliffs is shown at the right hand side of the photograph.

Fig. 3.—The present and the old sea-cliffs at the western end of the sand ridge, which is shown tapering out in the foreground. The existing cliffs are shown between the letters A and B, and the old cliffs between the letters B and C.

Plate VII.

Fig. 1.—Near the Survey Gorge, illustrating the formation of vertical cliffs, and of small bays and gorges, by marine abrasion.

Fig. 2.—Stacks at the Bay of Islands. Note the rectangular forms due to two sets of master joints at right angles to each other, and also the cones of red soil, with ironstone fragments, capping the ordinary Tertiary rocks in the foreground. Victorian Railways photo.

Fig. 3.—Sea-cliffs west of the sand ridge showing great taluses, composed of huge vegetation-covered blocks.

END OF VOLUME XL., PART I.

[Published December, 1927].

[Proc. Roy. Soc. Victoria, 40 (N.S.), Pt. II., 1928.]

Art. VI.—*A Revision of the Genus Pultenaea. Part V.*

By H. B. WILLIAMSON, F.L.S.

[Read 13th October, 1927; issued separately 21st April, 1928.]

Pultenaea mollis Lindley.

An attempt is here made to clear up the difficulty involved in this species, a difficulty which seems to have arisen from an error in the determination of Robertson's Mt. Sturgeon specimens as *P. viscosa* R.Br., Fl. Aust., II., 127. Referring to Revision, Part III., *Proc. Roy. Soc. Vic.*, p. 107, it may be taken as certain that the specimens collected (*a*) by Robertson, Fl. Aust., II., 127; (*b*) by Mueller about 1855; and (*c*) by the author were the same species. The leaves are scarcely to be distinguished from those of the Clyde Mt. and Parramatta specimens of *P. viscosa* R.Br., and Mueller determined (*a*) and (*c*) as *viscosa*. Specimens (*b*) and (*c*) have been determined at Kew as *P. mollis* Lindl., as they agree with those distributed by Lindley, and which are considered at Kew as portions of the plant gathered by Mitchell and given to Cunningham. Mueller determined his own specimens as *P. mollis*, and they agree exactly with those of the author, who in conversation with the distinguished botanist in 1895 learned that 40 years before the locality had been the site of his camp on the Wannon.

It seems, therefore, that *P. viscosa* has been wrongly recorded for Victoria. In view of the fact that Bentham's description was framed to include the Mount Macedon specimens of Mueller, which now must be kept distinct, and the true *mollis* of Lindley, which is so close to the more recently described *P. viscosa*, it must for a time be doubtful whether this species should have been set up at all. The plant which has been accepted by Victorian collectors as *P. mollis* (Grampians, Mt. Macedon, Gembrook, and recently Bairnsdale, T. S. Hart), differs materially from the type which appears to be confined to the southern Grampians, the Wannon River and Portland, and as all these specimens agree on the whole with the Mount Macedon specimen collected by Mueller, it had better be kept distinct as *P. angustifolia*, Mueller's MS. name on the label. A description is here given.

Pultenaea angustifolia (F.v.M. Herb.), sp. nov.

Frutex circiter 2 m. altus, ramulis pubescentibus, foliis tenuibus fere teretibus 10-20 mm. longis glabris vel pubescentibus, floribus breves ramos terminantibus in capitula (5-7 fl.) congregatis pedicellis 2-3 mm. longis, stipulis minimis nigris recurvatis, bracteis latis pedicellis brevioribus plerumque bifidis, bracteolis latis saepe viscosis nonnumquam carinatis arcte appressis tubo *calycis aequilongis, calyce fere glabra lobis subaequalibus obtusis vel subacutis superioribus paulo latioribus quam inferiora, ovario villoso.*

Mt. Macedon, Mueller; Gembrook Ranges; Grampians; Bairnsdale (T. S. Hart, Sept., 1927).

Var. VISCOSA, var. nov.

Calyce bracteis et bracteolis viscosis.

The form from the Grampians, Vic., with its calyx, bracts and bracteoles viscous and its leaves rather longer.

The relation of the foregoing species to each other is shown thus:—

A. Leaves almost flat.

B. Leaves incurved, flowers densely crowded in a head (7 to 10) on very short pedicels, bracteoles half the length of the calyx. *P. mollis.*

B. Leaves almost straight, flowers in heads (5-6) not crowded, on pedicels 2-3 mm. long, bracteoles nearly as long as the calyx. *P. viscosa.*

A. Leaves thin, terete, channelled above, flowers not densely crowded, on pedicels 2mm. long, bracteoles short and broad. *P. angustifolia.*

Calyx viscous. var. *viscosa.*

PULTENAEA HIBBERTIOIDES Hk. f.

var. PROSTRATA, var. nov.

Frutex prostratus, foliis et floribus valde confertis.

A prostrate form with much crowded leaves and flowers. Waterloo Bay, Wilson's Prom., Nat. Park, J. W. Audas, Nov., 1908. The flowers of var. *conferta* Bth., Cobden, S.W. Vic., are much crowded, but its leaves are not distinctly so as in this form. This is evidently the plant that has been recorded from Georgetown, North Coast of Tasmania.

PULTENAEA KENNYI H.B.W.

=*P. microphylla* Sieber var. *cuneata* Bth.

This agrees with the var. *cuneata* Bth. in *Ann. Wien. Mus.*, ii., 83 (Fl. Aust., II., 117). As from this form to the normal *P. microphylla* a series of intermediates as regards width of leaves has been examined, the plant should still retain varietal rank only.

PULTENAEA FOLIOLOSA Cunn.

Benth. in *Ann Wien. Mus.*, ii., 83.

This plant has very small leaves, often only 1 mm. long, almost orbicular, crowded on short branchlets of 1-2 cm. long, at the ends of which are a few flowers in the axils. Stipules are hairlike, nearly as long as the leaves, and the bracteoles are similar to the leaves, and provided with hair-like stipules. The calyx is about 4 mm. long, with lobes not longer than the tube; the two upper ones much falcate and united to the middle. The ovary is glabrous except for a tuft of white hairs.

The type of this species came from westward of the Wellington Valley, N.S.W., A. Cunn. There are specimens from Lachlan River, Fraser; Darling Downs, Q., Mrs. Ford; Texas, Q., Boorman; Eastern Downs, H. Law. The form from Chiltern, "Mayday Hills," "Between Meadow Creek and King River," N.E. Victoria, differs from the normal in size of flowers and leaves, the latter reaching 4 mm. in some specimens. It shows a transition towards *P. styphelioides* Cunn. through its intermediate var. *mutica* F.v.M., having often lanceolate bracteoles fixed high upon the calyx. From New England, N.S.W., there is a plant which so much resembles *P. foliolosa* in general appearance that it is little wonder that it has been placed under that species. Its remarkable calyx, however, renders it quite distinct, and with the concurrence of the authorities at Kew it is now described, the species name being in honour of the collector of the Tenterfield specimen.

Pultenaea Stuartiana, sp. nov.

Frutex parvus, ramulis numerosis brevibus, foliis minimis raro 2 mm. longis ovato-orbicularibus supra concavis infra scabridis apice recurvatis, stipulis parvis, floribus fere sessilibus in axillis superioribus, bracteolis foliaceis quasi stipulatis, calyce 4 mm. longo villoso lobis latis tubo longioribus oblongis inter se aequilongis et formâ similibus superioribus non falcatis, ovario glabro apice comam gerente.

New South Wales: Tenterfield, C. Stuart; Torrington, J. L. Boorman.

This differs from *P. foliolosa* Cunn. in having the long lobes of the calyx similar in size and shape.

Pultenaea accrosa R.Br.

A record for this species in Victoria has been made, the plant having been gathered near Mt. William in the Grampians, J. W. Audas, Nov., 1923.

Pultenaea graveolens Tate.

This plant has apparently not been gathered in Victoria since Mr S. Johnson sent it to Mueller from Meredith many years ago, until with Mr. E. Cooper, senr., the author found it at Steiglitz in October, 1925.

Addendum.

[Read 8th December, 1927.]

Pultenaea patellifolia, sp. nov.

Frutex fere glaber 0·5—1 m. altus, ramulis pubescentibus, foliis fere sessilibus alternatis late obovatis vel orbicularibus circiter 3 mm. longis latisque margine paululum incurvatis ad apicem recurvo-mucronatis supra glabris infra sparsim pubescentibus, stipulis parvis, floribus subumbellatis 3-6 ramulos terminantibus, pedicellis pilosis 5-6 mm. longis, bracteis parvis, bracteolis viscosis orbicularibus appressis vix 2 mm. longis subter tubum calycis affixis, calyce circiter 5 mm. longo fere glabro lobis fere aequalibus tubo brevioribus, vexillo luteo lineis atro-rubris instructo, alis luteis, carina atro-rubra, ovario villoso in stylum subulatum extenuato, legumine ovato-oblongo breviter acuminato, seminibus 2 distincte strophiolatis.

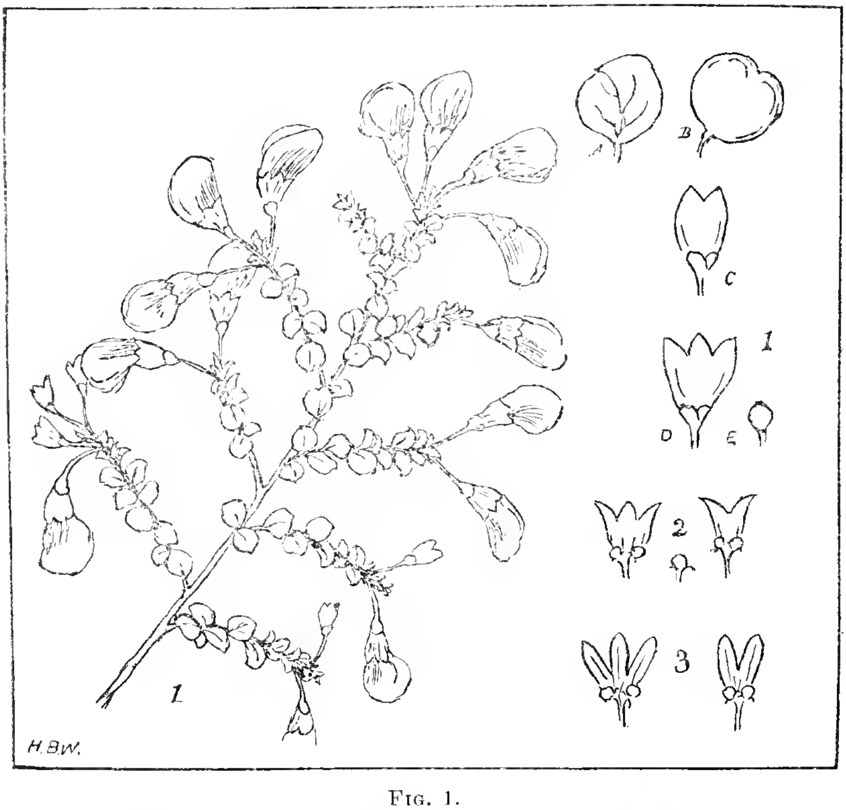

Fig. 1.

1. *P. patellifolia*—A, leaf, under side; B, leaf, upper side; C, upper calyx lobes; D, lower calyx lobes; E, bracteole.
2. *P. foliolosa*, calyx and bracteoles.
3. *P. Stuartiana*, calyx and bracteoles.

Mt. Byron, Black Range, Western Grampians, Vic., Mr. Harold Smith, October, 1927.

An almost glabrous shrub, ½ to 1 m. high, with pubescent branchlets. Leaves almost sessile, alternate, broadly ovate to orbicular, many dish-shaped, about 3 mm. in diameter, with slightly incurved margins, and ending in a recurved mucrone, glabrous above, slightly hairy below. Stipules small. Flowers almost umbellate, 3 to 6, terminating the short branchlets, with hairy pedicels 5 to 6 mm. long. Bracts small. Bracteoles viscid, orbicular, appressed, scarcely 2 mm. long, and fixed below the tube of the calyx. Calyx about 5 mm. long, almost glabrous, with nearly equal lobes shorter than the tube. Standard yellow with dark-red lines. Wings yellow. Keel dark red. Ovary villous tapering into a subulate style. Pod ovate-oblong, shortly acuminate. Seeds two, with a distinct strophiole.

This graceful and very distinct species has some resemblance to *Bossiaea cordigera*, although it is not a scrambling shrub, but distinctly erect. It belongs to the Section *Coelophyllum*, and its nearest ally is *P. Vrolandii* Maiden, which it resembles in having viscid bracteoles forming a complete cup fixed just under the calyx; but in the case of *P. Vrolandii* this cup is inflated, and almost conceals the calyx, while in the new species it is very small, and tightly appressed to the calyx. The leaves are quite unlike those of any other *Pultenaea*, their dish-like appearance suggesting the specific name, and the umbel-like inflorescence with flowers on long pedicels is unusual in the genus. It may be remarked that although the flowers are at first terminal, the ends of the branchlets are somewhat produced after flowering, so that the flowers are not then strictly terminal.

The discoverer, Mr. Smith, handed the plant in at the National Herbarium, and the Government Botanist, Mr. Rae, noting that it was worthy of further investigation, instructed his senior assistant, Mr. Audas, to proceed to Horsham to obtain additional material. The author was invited to accompany him, and through the good offices of Mr. Smith a visit was paid to the locality, 38 miles S.W. of Horsham, where the plant was found in abundance both in the sandy soil at the foot and among the rocks at the summit of Mt. Byron. As a vernacular name " Mt. Byron Bush-pea " is suggested.

Pultenaea D'Altonii H.B.W.

New Locality: Mt. Talbot, towards Mt. Byron, J. W. Audas, October 30th, 1927. Previously recorded only from the Little Desert near Nhill (type locality), and from near Steiglitz.

[Proc. Roy. Soc. Victoria, 40 (N.S.), Pt. II., 1928.]

Art. VII.—*Some Tertiary Volcanic Minerals and their Parent Magma.*

By D. J. MAHONY, M.Sc., F.G.S.

[Read 13th October, 1927; issued separately 21st April, 1928.]

In many Victorian scoria cones and bedded tuffs of Tertiary age, minerals much larger than the normal constituents of the associated volcanic rocks are found. These minerals may be free from other matter or embedded in vesicular basalt or may form the nuclei of volcanic bombs. Those examined are felspars, hornblende, augite and olivine.

Felspars.

Analyses of Felspars.

	1	2	3	4	5	6	7	8
SiO_2	65·09	66·20	65·64	65·14	64·62	65·37	61·93	66·23
Al_2O_3	21·86	22·60	21·18	20·92	22·90	21·56	22·08	19·97
Fe_2O_3	0.30	tr.	0·05	0·31	0·40	—	tr.	0·49
FeO	0·08	—	nil.	—	nil.	—	—	—
MgO	0·05	0·38	0·21	0·18	0·14	—	tr.	0·17
CaO	1·93	1·92	1·55	1·42	1·30	1·67	nil.	0·50
Na_2O	8·66	8·05	7·45	7·43	7·29	7·35	8·84	8·07
K_2O	1·68	1·05	3·66	3·93	3·07	3·74	6·34	3 36
H_2O+	0·12	0·60	nil.	0·07	0·05	0·25	—	—
H_2O-	0·06	—	0·06	0·07	—	0·07	—	0·02
CO_2	nil.	—	—	—	nil.	—	—	—
TiO_2	0·04	—	nil.	0·03	tr.	—	—	nil.
P_2O_5	nil.	—	nil.	—	nil.	—	—	—
MnO	0·02	—	—	nil.	tr.	—	—	—
Li_2O	strong tr.	—	present	tr.	nil.	—	—	nil.
SO_3	nil.	—	—	—	0·32	—	—	—
Cl	tr.	—	—	—	nil.	—	—	—
NiO,CoO	nil.	—	—	—	nil.	—	—	—
BaO	0·02	—	—	—	nil.	—	—	—
SrO	0·16	—	—	—	nil.	—	—	—
ZrO	—	—	—	—	tr.	—	—	—
	100·07	100·80	99·80	99·50	100·09	100·01	99·19	98·81
Rating	A1.I	A2.II	A1.I	A1.I	A1.I	A2.II	B3.V	B3.V

FELSPARS: NORMS BY PERCENTAGE WEIGHT.

	1	2	3	4	5	6	7	8
Or	9·99	6·20	21·71	23·34	18·19	22·16	37·57	19·93
Ab	73·48	68·27	63·22	63·06	61·86	62·33	75·00	68·43
An	10·10	9·55	7·72	7·03	6·46	8·31	8·30	2·48
SiO_2	3·67	10·53	4·42	3·32	7·27	4·54	—	4·50
Al_2O_3	2·08	4·71	2·08	1·81	5·18	2·35	—	2·12
Enst.	0·12	0·94	0·52	0·45	0·35	—	—	0·42
Hy	—	—	—	—	—	—	—	0·90
Il	0·08	—	—	0·10	—	—	—	—
Mt	0·21	—	—	0·24	0·40	—	—	—
Hm	0·16	—	0·08	—	—	—	—	—
H_2O, etc.	0·18	0·60	0·06	0·14	0·37	0·32	—	0·02
	100·07	100·80	99.81	99·49	100·08	100·01	120·87	98·80

FELSPARS: MOLECULAR PERCENTAGES.

	1	2	3	4	5	6	7	8
Or	10·24	7·03	22·49	23·98	20·15	22·80	22·94	20·97
Ab	79·94	82·16	69·50	68·77	72·68	68·64	68·46	76·42
An	9·81	10·82	8·01	7·25	7·17	8·56	8·61	2·61
	99·99	100·01	100·00	100·00	100·00	100·00	100·01	100·00

1. Mount Lookout, Aberfeldy, Gippsland. Large crystal from vesicular basalt. Sp.gr. 2·618. Analyst, A. G. Hall.
2. Mount Lookout, Aberfeldy, Gippsland. Only about one gramme available for analysis. A duplicate determination gave alkalis 9·18%. Analyst, P. G. W. Bayly.
3. Mount Anakie, about 16 miles NNW. of Geelong. Sp.gr. 2·62. Analyst, F. F. Field.
4. Mount Franklin, near Daylesford. Sp.gr. 2·613. Analyst, A. G. Hall.
5. Mount Franklin, near Daylesford. Fine, cross-hatched twin lamellae. Analysts, Miss J. M. Robertson and C. E. Eales.
6. Mount Franklin, near Daylesford. Fine cross-hatched twin lamellae. Analyst, F. W. J. Clendinnen.
7. Magorra, near Jumbunna, S. Gippsland. Glassy tabular crystals from dense basalt. Alkalis evidently too high. Analysis, Geol. Surv. Vic. Lab. (1901).
8. Mount Noorat, near Terang. Alkalis unsatisfactory on account of fusion and insufficient material for duplicate determinations in their case; duplicate determinations of the other oxides agreed closely. Sp.gr. 2·608. Analyst, A. G. Hall.

I am indebted to Professor H. S. Summers for analyses Nos. 5 and 6. The relative values of the analyses are indicated by using Washington's method of rating (1), the degree of accuracy being expressed by the letters A, B, C and D, and the degree of completeness by the figures, 1, 2, 3 and 4. Analyses rated as A1 are excellent; A2 or B1, good; A3, B2 or C1, fair; and the others poor.

Felspar is abundant at Mt. Franklin and at Mt. Anakie in loose basalt scoria, and is also found at many other points of eruption of the New Volcanic basalts. On the shores of Lake Purrumbete and other lakes of the Western District it is fairly common, and has been derived from bedded tuffs. It also occurs at Mt. Lookout (Aberfeldy) and other volcanic centres in Gippsland associated with the Older Volcanic basalt. It is found as colourless and transparent cleavage fragments, generally small but ranging up to about two inches long, as rounded lumps evidently partly absorbed by molten igneous rock, and occasionally as crystals more or less rounded. Howitt (2) described some specimens from Mt. Anakie as having albite and pericline twin lamellae, and he measured extinction angles as follows:—

P.	M.	Perpendicular to P & M.
+3°7′	+12° 30′	+10°0′
+3°3′	+12° 19′	+11°5′

Other examples since examined often resemble microcline in having twin lamellae in two directions, but extinction angles vary

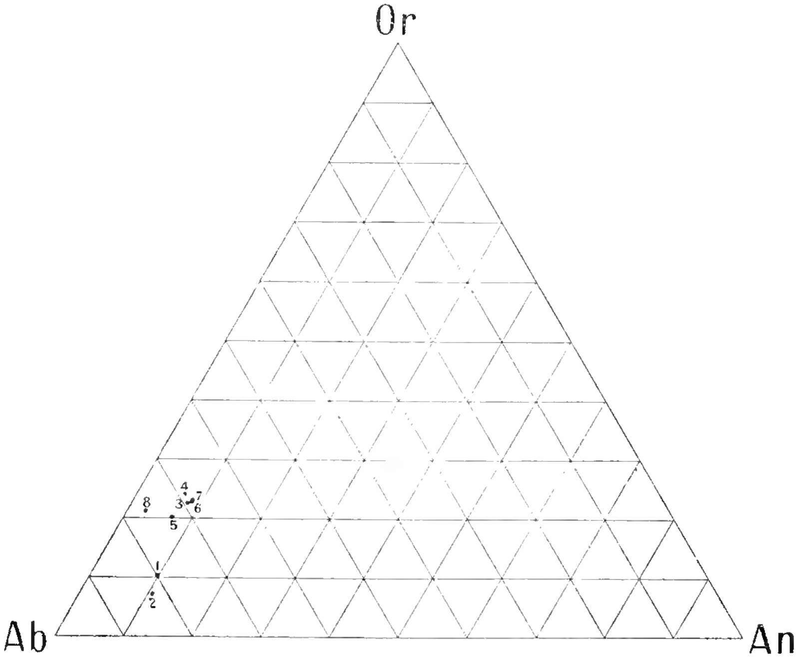

Fig. 1.—Diagram shewing composition of Felspars. Numbers correspond with Analyses.

somewhat in different parts of the same specimen. A section parallel to (001) from an Aberfeldy specimen extinguished at 6°; this felspar is twinned on the albite law. It contains a few minute vermiform intergrowths, probably quartz, and some minute specks too small for determination. It is quite clear and undecomposed.

The analyses and the triangular diagram show that all these felspars are anorthoclases ranging from potash albite to potash oligoclase, and that they are very different from the felspars entering into the composition of the associated basaltic rocks. Every analysis (except one which is rated as poor) gives an excess of SiO_2 and Al_2O_3 above the calculated amount required to combine with the alkalis. These substances may be in solid solution with the felspar, or the quartz may be intergrown as indicated in the Aberfeldy felspar mentioned above.

ANALYSES OF FERRO-MAGNESIAN MINERALS.

	9		10		11	
	%	mol. propn.	%	mol. propn.	%	mol. propn.
SiO_2	49·00	0·8127	39·09	0·6483	41·53	0·6889
Al_2O_3	8·66	0·0847	15·34	0·1500	0·95	0·0093
Fe_2O_3	2.78	0·0174	12·43	0·0778	nil.	—
FeO	6·52	0·0908	6·79	0·0945	9·02	0·1256
MgO	14·53	0·3604	7·67	0·1902	48·02	1·1909
CaO	15·64	0·2790	9·35	0·1668	0·31	0·0055
Na_2O	1·12	0·0181	2·32	0·0374	0·14	0·0020
K_2O	0·05	0·0005	1·51	0·0160	0·03	0·0003
H_2O+	0·06	0·0028	0·91	0·0506	0·38	0·0211
H_2O-	0·14	—	0·09	—	0·10	—
CO_2	nil.	—	nil.	—	nil.	—
TiO_2	1·27	0·0158	4·76	0·0593	tr.	—
P_2O_5	nil.	—	strong tr.	—	nil.	—
MnO	0·24	0·0034	tr.	—	—	—
Li_2O	nil.	—	nil.	—	—	—
SO_3	tr.	—	tr.	—	nil.	—
NiO	0·04	0·0005	—	—	—	—
CoO	tr.	—	—	—	—	—
BaO	nil.	—	—	—	—	—
S	0·13	0·0041	—	—	—	—
Cr_2O_3	0·03	0·0002	—	—	nil.	—
	100·21		100·26		100·48	
Rating	A1.I		A1.I		A1.I	

9. Augite, Mount Noorat, near Terang. Sp.gr. 3·342. Analyst, A. G. Hall.

10. Hornblende, Mount Anakie. Sp.gr. 3·32. Analyst, F. F. Field.
11. Olivine, Mount Anakie. Granular material from an "olivine-bomb." Analyst, F. F. Field.

Augite.

Only one analysis of augite has been made, and unfortunately none of the material (which consisted of a black cleavage fragment from Mt. Noorat) was kept for microscopical investigation. It is a type rich in alumina and alkalis and poor in lime. This is best shown by taking the maximum, minimum and average figures from the analyses of augites quoted by Iddings (3) and comparing them with those for the Noorat specimen.

	Al_2O_3 (36 anal.)	CaO (36 anal.)	Na_2O (18 anal.)
Maximum	9·15	23·46	1·47
Minimum	2·82	15·98	tr.
Average	5·86	20·89	0·81
Noorat augite	8·66	15·64	1·12

Augites are considered to consist of various proportions of the molecules $RO.RO_2$, $RO.R_2O_3.RO_2$ and sometimes $R_2O.R_2O_3.(RO_2)_4$. On this basis the composition of the Noorat specimen works out as follows:—

Radicle	RO_2	R_2O_3	RO	R_2O
Mol. propn.	8285	1023	7341	214
$R_2O.R_2O_3.4RO_2$	856	214	—	214
$RO.R_2O_3.RO_2$	809	809	809	—
$RO.RO_2$	6532	—	6532	—
Surplus	88	—	—	—

The molecular formula is therefore

$$65RO.RO_2+8RO.R_2O_3.RO_2+2R_2O.R_2O_3.(RO_2)_4$$

and there is an excess by weight of 0·53% SiO_2 or 0·70% TiO_2.

Hornblende.

One good analysis of hornblende is also available. The material consisted of black cleavage fragments from Mt. Anakie. Examined microscopically the crushed mineral is a monoclinic amphibole, brown (burnt umber) in colour in very small fragments, the large being opaque. It is moderately pleochroic (brown to buff) and the extinction angle measured from the *c*-axis on cleavage fragments parallel to the *a*-axis is 9°. The analysis shows that it is rich in Al_2O_3 and alkalis, and poor in lime for this type of mineral, as indicated by comparison with figures taken from Iddings's quoted analyses of hornblendes from igneous rocks.

	Al_2O_3 (30 anal.)	CaO (30 anal.)	Na_2O (26 anal.)
Maximum	17·36	13·03	3·18
Minimum	1·50	9·25	0·37
Average	10·69	11·62	1·67
Anakie hornblende	15·34	9·35	2·32

The calculation of the formula offers some difficulties. The hornblendes consist of some or all of the molecules $RO.RO_2$, $R_2O.RO.2RO_2$, $R_2O.R_2O_3.2RO_2$ and $RO.R_2O_3.RO_2$. The simple method used above in the case of augite is not applicable since no radicle is confined to a single molceule. Let w, x, y and z be the amounts of the above molecules, and a the amount of RO_2 in the whole of them. Then

$$w+2x+2y+z=a \quad \text{(total } RO_2 \text{ required)}$$
$$x+y=1040 \quad \text{(total } R_2O\text{)}$$
$$y+z=2278 \quad \text{(total } R_2O_3\text{)}$$
$$w+x+z=4575 \quad \text{(total } RO\text{)}$$

and from these equations

$$w=2a-9973$$
$$x=6655-a$$
$$y=a-5615$$
$$z=7893-a$$

The maximum value of a is therefore 6655 and the minimum 5616. It is reasonable to choose the maximum since this figure will give the least excess of RO_2. Then $x=0$. The composition now works out as follows:—

Radicle	RO_2	R_2O_3	RO	RO_2
Mol. propn.	7076	2278	4575	1040
w $RO.RO_2$	3337	—	3337	—
y $R_2O.R_2O_3.2RO_2$	2080	1040	—	1040
z $RO.R_2O_3.RO_2$	1238	1238	1238	—
Surplus	421	—	—	—

The molecular formula is therefore

$$33RO.RO_2+12RO.R_2O_3.RO_2+10R_2O.R_2O_3.(RO_2)_2$$

and there is an excess by weight of 2·54% SiO_2 or 3·37% TiO_2.

The ejected felspar, augite and hornblende are, therefore, all types rich in alkalis, alumina, and silica, and poor in lime.

Olivine.

Olivine from points of eruption either forms small, well-defined crystals, or more commonly granular masses up to a foot or more in diameter containing an admixture of other minerals. Greenish-yellow crystals about an eighth of an inch long, sp. gr. 3·486, were collected from the scoria on top of Mt. Terang. The crystal forms developed are (010), (001), (110), (120), (101), (011) and (021). The mineral was found to contain 15·80% FeO, from which its composition is estimated to be

Forsterite (Mg_2SiO_4) 77·57% by weight
Fayalite (Fe_2SiO_4) 22·43%.

The analysed olivine from Mt. Anakie was picked out from the crushed granular nucleus of a volcanic bomb, and is yellowish-green in colour. Its calculated composition is

Forsterite, 86·76% by weight.
Fayalite, 13·24%.

How the other oxides in this analysis are combined is difficult to picture, but possibly they form a basic felspar.

Both olivines are rich in magnesia, and contain only about 10% of the fayalite molecule.

Magma.

Bowen (4) has shown experimentally that minerals rich in magnesia are the first to crystallise from a cooling magma containing the elements of diopside and the plagioclases, and that alkaline minerals appear at a late stage of cooling; also that in systems involving such mix-crystals as the olivines, the earlier crystals are enriched in magnesia. It therefore seems highly probable that the olivine was formed at an earlier stage in the history of the magma than the other minerals considered above and that its association with them is more or less fortuitous. The inference is that the original magma during the progress of cooling separated by some process of differentiation into two types, one a normal basalt and the other an alkali-gabbro; and that the felspar, augite and hornblende discussed above come from the alkali-gabbro differentiate. This inference is supported by the facts that ejected blocks of essexite type occur in the basaltic tuffs of Lake Bullenmerri (5); that alkaline volcanic rocks of Tertiary age are found at Macedon (6 and 7); and that analcite basalts are plentiful in Gippsland.

If the alkaline magma be admitted, the distribution in Victoria of the minerals here considered indicates that it is widespread, and is at least as old as the Older Basalt. In contrast is the fact that typical alkaline volcanic rocks are comparatively rare. The explanation may be that the alkaline magma was relatively too viscous to flow to the surface with the same ease as the basalt. The fine-grained texture of the basalt, the infrequency of porphyritic crystals in it and the glassy nature of its quickly cooled portions show that it arrived at the surface in a completely fluid state; and the extent and thinness of the flows show that it was very mobile. On the other hand, the comparatively large size of the minerals considered in this paper indicates long continued crystallization of the magma in which they originated; the alkaline volcanic rocks of Macedon are typically porphyritic; and it is known that alumina increases the viscosity of a "melt." It would therefore appear that the original magma separated into more and less alkaline portions before Tertiary volcanic action began. The basaltic portion remained highly mobile, and rose to the surface more easily than the alkaline, partly crystallized, more viscid portion, which in consequence seldom formed lava flows, though some of its constituents together with molten basalt were hurled by explosions from points of eruption. The anorthoclase basalts of the Macedon district and the analcite basalts of Gippsland may represent a less advanced stage of differentiation or the mixing of the two types of magma.

The magmatic differentiation suggested by the study of the ejected minerals agrees in general with the deductions made by Professors Skeats and Summers (*7*) as a result of their exhaustive study of the Macedon area; but it appears that the process began before the ejection of the Older Basalts of Gippsland and continued or was repeated until the end of the volcanic period.

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Art. VIII.—*Experimental Error of Field Trials in Australia.*

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Introduction.

The question of the "Probable Error" in field trials is one which has in recent years come to the fore in connection with the work of experimental stations in Europe and America. It has sometimes been suggested that in Australia the water supply available in the soil for the crop is often the limiting factor to growth and seed production. This might lead to a more uniform growth, and thus the experimental error of plot observations might be thereby diminished. It seemed, therefore, worth while to investigate the matter fully, and with this end in view the classic experiment of Hall and Mercer was repeated at the State Research Farm, Werribee, Victoria, it being felt that such an investigation should lead to valuable results which would be a guide for the future in the "lay out" of the trial plots.

The experiment was undertaken to determine—

(1) the variation in an apparently uniform acre of wheat as measured by the "Standard Deviation," and the "Probable Error" of 1/160th acre plots,

(2) the optimum
- (*a*) size,
- (*b*) shape,
- (*c*) number of plots necessary to reduce this error to a minimum.

Method.

During the season 1926-27, the North Railway Field at Werribee was planted with "Free Gallipoli" wheat, and it produced a fair average crop, which was, before harvest, expected to yield about 24 bushels to the acre. An acre of this was selected for the experiment, and many casual observers were agreed that as far as the eye could judge, it was an even area of wheat.

A preliminary survey was made on the 29th November, 1926, when it was observed that the drilling was somewhat irregular. There was one double-sown row in every stroke of the drill, and therefore it was decided to include two of these double-sown rows in each plot. Accordingly each plot was made 30 x 20 links, and the dimensions of the whole acre, 300 x 320 links, excluding paths. Further it was found that near the western boundary of the acre, a strip a few yards wide had been damaged by cart-tracks. This was consequently excluded.

A straight row on the western side of the acre was taken as a base-line, and from this all measurements were set off. These allowed for the division of the acre into four quarters by means of two intersecting paths.

On account of the danger of shaking-out by storms before the harvesting of the whole area had been completed, an occurrence which would have wrecked the whole experiment, it was deemed advisable to mark out only one quarter-acre at a time. This was then harvested immediately. Owing to extremely favourable weather conditions during the harvesting period, such precautions proved unnecessary.

Along the boundaries of each quarter-acre pegs were put in corresponding to the corners of the outside plots. The boundaries of each 1/160th acre plot were then defined by stakes whose positions were obtained by sighting from the outside pegs. Paths were then cut in a N.-S. direction, dividing the quarter-acre into 5 strips of 8 plots each. These paths were 4 drill-rows wide, and were made by hand-cutting 2 rows on each side of the actual boundaries of the plot as defined by line and plumb-bob. As the bags for the reception of the produce from each plot had previously been marked, the crop cut in the formation of the paths was transferred immediately to the corresponding sack.

Cutting was commenced on the 22nd December with a single-horse mower fitted with a carrier-arrangement. The mower was driven in an E.-W. direction across the paths, thus cutting five plots. It was stopped in each pathway—specially cut for this purpose—to enable the crop cut from each plot to be bagged straight from the carrier. After four swathes of the mower, a strip of about one foot was left along the northern boundary of each plot. This was cut by hand, the exact boundary being defined by line and plumb-bob as before. Plots were then thoroughly gleaned for any heads that had been broken off, as well as any loose straws.

Before cutting, the plots were examined for the number of rows they contained, and for the presence of any disturbing factors. There were very few weeds. In a similar manner the other three quarter-acres were harvested, the bagged produce of the plots being carted and stored as the harvesting of each quarter-acre was completed. Field work was finished on the 7th January, 1927.

Thrashing was commenced on the 18th January. This was performed by means of a motor-stripper, which consisted of the drum and beaters of a typical Australian harvester, driven by a stationery engine mounted on the same under-carriage. After thrashing the wheat fed into the beaters, both straw and grain were delivered into a bin at the rear. Here the straw was collected, and later re-thrashed separately from the grain. The grain was winnowed to an even sample, and weighed to the nearest ounce, which was considered the limit of the overall accuracy of the experiment. Thrashing was completed on the 27th January.

Results and Discussion.

TABLE 1.—*Plan and weights in ounces of grain harvested from 160 wheat plots.*

S

125	117	125	135	159	139	150	164	143		157
121	135	123	147	147	130	141	154	144		161
124	137	126	135	142	142	138	135	139		136
125	134	127	130	144	133	141	147	142		147
128	135	121	136	138	140	135	149	139		139
132	127	118	134	135	137	137	138	127		145
137	133	122	131	120	137	139	142	133		148
141	128	130	126	119	149	143	132	133	Cart tracks	144
E										W
123	123	119	120	111	139	152	142	140		143
115	125	135	121	125	143	143	135	143		146
121	120	133	132	128	144	133	127	137		137
137	123	141	124	128	135	139	139	137		142
127	131	136	121	135	135	133	135	133		131
122	124	144	132	128	136	143	145	143		142
122	108	141	143	125	139	148	150	152		154
130	135	161	154	154	153	141	130	152		161

N

Table 1 shows the yields of plots together with their position in the field. The yields varied from 108 to 164 ozs., the variation being 20·6% on either side of the mean. The frequency curve as shown in Figure 1 was obtained by grouping the yields into periods of 5 ounces each.

With the curve from the actual results is shown the normal curve of error calculated to fit the results. Owing to the small number of observations, the approximation of the actual curve (*vide* Figure 1) to the above is considered close enough to justify the conclusion that the material was homogeneous, and that the formulae applicable to such, may be used in this case.

A study of Table 1 shows that there is a definite rise in yield from East to West, while the variations from North to South are apparently irregular. The graph (Fig. 2) of the sum totals of the rows of plots, as set out in Table 2, verifies these conclusions.

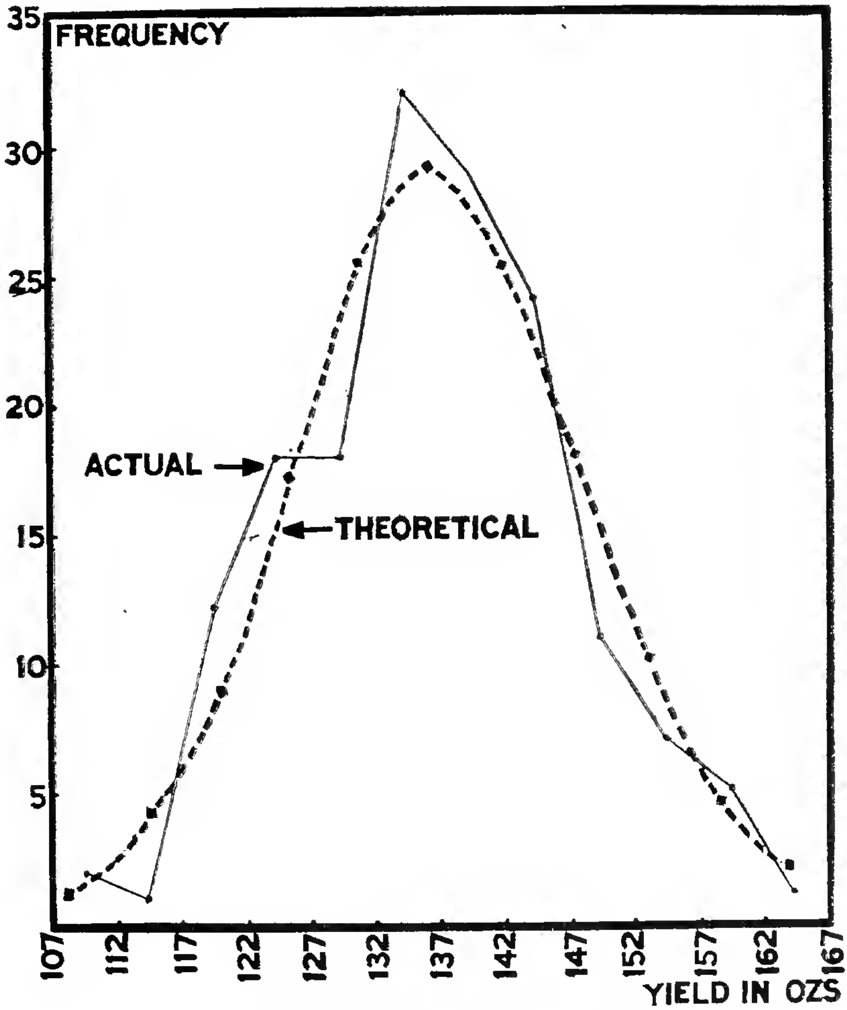

FIG. 1.—*Frequency curves for* 130 *wheat plots.*
(Actual and Theoretical).

It is necessary to consider briefly these disturbing elements before proceeding to the main discussion and conclusions.

The presence of such a regular rise in the field under observation is a factor which has appeared in most investigations of this character. In their Mangold experiment, Hall and Mercer had a similar experience in a variation from North to South of 7·3%, which, after being observed and noted, was subsequently disregarded in the calculation of results. In this case, there is a variation from E.-W. of 6·9% on either side of the mean. The irregular variation from South to North is similarly 5·9%. Since

TABLE 2.—*Varying weight of rows of plot yields.*

South-North	East-West
1414 ozs.	2030 ozs.
1403 ,,	2035 ,,
1354 ,,	2102 ,,
1370 ,,	2121 ,,
1360 ,,	2138 ,,
1330 ,,	2231 ,,
1342 ,,	2256 ,,
1345 ,,	2264 ,,
1312 ,,	2237 ,,
1331 ,,	2333 ,,
1312 ,,	
1345 ,,	
1317 ,,	
1359 ,,	
1382 ,,	
1471 ,,	

these variations, viz. 6·9% from E.-W., and 5·9% from S.-N., are of approximately the same order, it is possible in a similar manner to disregard this regular variation from side to side.

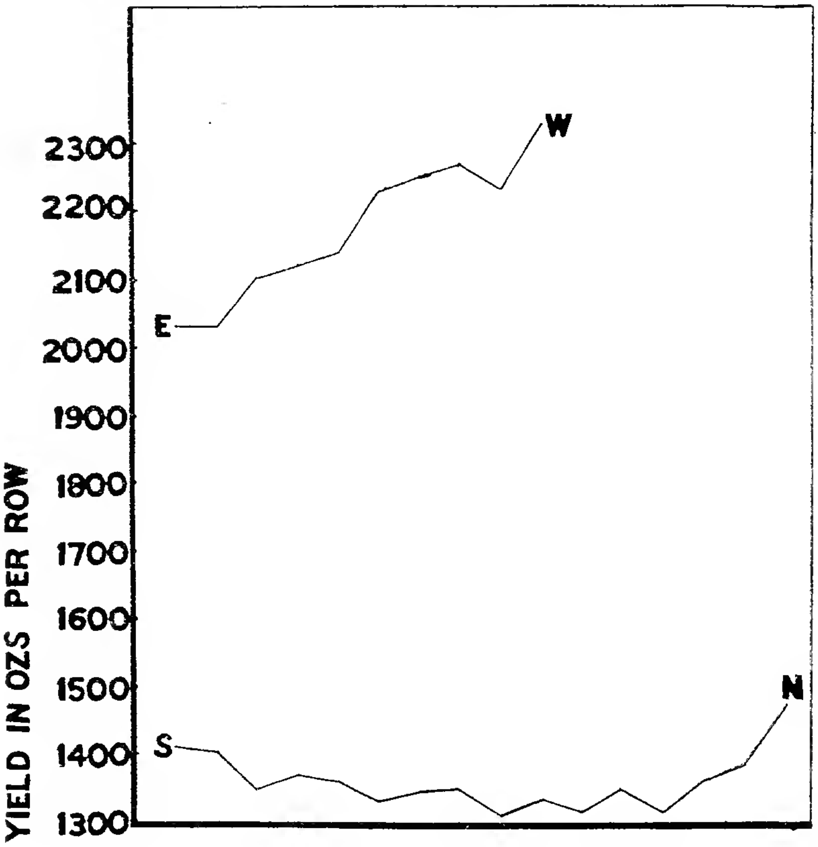

FIG. 2.—*Varying weights of rows of plot yields.*

Hall and Mercer in their experiment measured each plot as a definite distance along a certain number of rows, thus taking area of crop as their unit. On account of the irregular drilling, it was impossible in this experiment to include a definite number of rows in each plot; therefore area of land was taken as the unit.

The examination of the number of drill rows showed a variation of from 33 to 35 rows per plot. This variation, 34±1, is of the order of 3%. On taking only those plots containing 34 rows, the yields varied from 115 to 164 ounces, a range of approximately 18% on either side of the mean. Thus the normal variation due to chance is far greater than the difference that could be produced by such variation in the number of rows, and this may therefore be grouped with these chance errors. A more accurate comparison may be drawn between the Standard Deviation of all the plots (S.D.=10·9±0·41 ozs.), and that from those containing the same number of rows (34), S.D.=11·9±0·58 ozs.). These two figures are of the same order. Now, since this S.D. is a measure of the variance of the plot yields, the above assumption is confirmed.

The Variation in an Apparently Uniform Acre of Wheat as measured by the Standard Deviation and the Probable Error of 1/160th acre plots.

TABLE 3.—*Calculation of the Standard Deviation.*

Group	Frequency	Deviation from Arbitrary Mean			
	f	x	x^2	fx	fx^2
107-111	2	−5	25	−10	50
112-116	1	−4	16	−4	16
117-121	12	−3	9	−36	108
122-126	18	−2	4	−36	72
127-131	18	−1	1	−18	18
132-136	32	0	0	0	0
137-141	29	1	1	29	29
142-146	24	2	4	48	96
147-151	11	3	9	33	99
152-156	7	4	16	28	112
157-161	5	5	25	25	125
162-166	1	6	36	6	36
Totals	160	—	—	65	761

It may be calculated by the usual formulae that the mean yield of the 1/160th acre plots is 136·5 ± 7·3 ozs., i.e., there is an even chance that the yield from any one plot will be between 143·8 ozs.

and 129·2 ozs. Further that if a comparison were made between a pair of 1/160th acre plots of two different varieties of wheat on similar land to that found here, any differences between yields of less than 23·3 ozs. (17·7% of the mean), would not be significant.

Optimum Size of Plot.

In order to determine the optimum size of plot for purposes of yield trials, i.e. that size of plot which will give the least variation from the mean, it was necessary to compare the S.D. of different sizes of plots. By the grouping of adjacent plots, the yields from areas of different sizes have been obtained. The method of grouping is indicated by the accompanying dimensions in Table 3.

TABLE 4.—*The Standard Deviation (%) of Plots of Various Sizes.*

Size of Plot	No. of Plots	Dimensions	Standard (%) Deviation
1/160th	160	30 × 20 lks.	8·0%
1/80th	80	30 × 40 ,,	7·0
1/40th	40	60 × 40 ,,	5·8
1/20th	20	80 × 60 ,,	5·2
1/10th	10	80 × 120 ,,	4·6

N.B.—The small number of results in the two latter cases detracts somewhat from the reliability of the figures 5·2 and 4·6% respectively.

From the above table and the following graph, it will be noted that the S.D. (%) falls rapidly from 8·0% in the case of the 1/160th acre plots to 5·8% at the 1/40th acre plots. Further increase in size up to 1/10th acre only reduces this quantity to 4·6%. Now, since the larger the area, the greater the difficulty in obtaining an "apparently uniform" area of soil, it follows that little is to be gained by increasing the size of plot for yield trials above 1/40th of an acre.

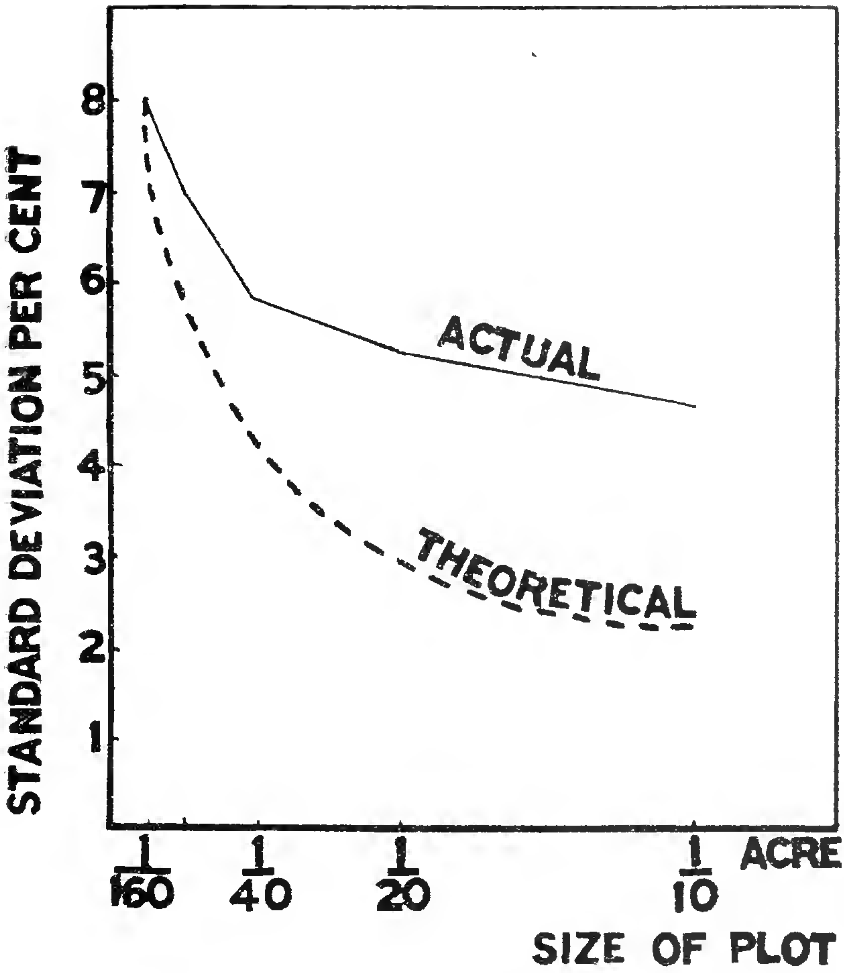

FIG. 3.—*Actual and Theoretical Curves of the Standard Deviation of Plots of Various Sizes.*

N.B.—The theoretical curve is obtained by the division of the S.D. of the 1/160th acre plots by the square root of the number of the original number of small plots combined in each grouping.

Optimum Shape of Plot.

It is generally considered that a long narrow plot is more desirable for field-scale work than a short square plot, and the following table tends to establish this belief.

TABLE 5.—*Standard Deviation of Plots of Various Shapes.*

Size of Plot	No. of Plots	Dimensions	Standard % Deviation
1/40th ac.	40	60 × 40 lks.	5·8%
1/40th ,,	32	20 × 120 ,,	5·0
1/20th ,,	20	80 × 60 ,,	5·2
1/20th ,,	16	20 × 120 ,,	3·7

It is important to note that on account of the gradual increase in yield from east to west, plots with their axis in a north to south direction cannot be used in the above comparison.

Optimum Number of Replications desirable.

Having determined the size and shape most desirable from a practical standpoint, it was necessary to find the number of replications required for a working minimum of error. The S.D. was then calculated for two scattered 1/20th acre plots, four scattered 1/40th acre plots, etc. Maximum scattering was obtained by entering the yields of the various sized plots on slips of paper, which were later drawn from a bowl, and thus the various sets of pairs, fours, eights, etc., were made up.

TABLE 6.—*Standard Deviation of 1/10th acre plots obtained by random grouping of various numbers of units.*

No. of Units in 1/10 ac. plot	No. of observations	Standard Deviation %
1	1	4·6%
2	2	4·0
4	4	3·18
8	8	2·46
16	16	2·3

N.B.—Only a low reliability can be placed on the figure 4·6, due to the small number of results.

From this it would appear that a greater number of replications than four or five is not warranted, as the small increase in accuracy so obtained would entail a great amount of extra work.

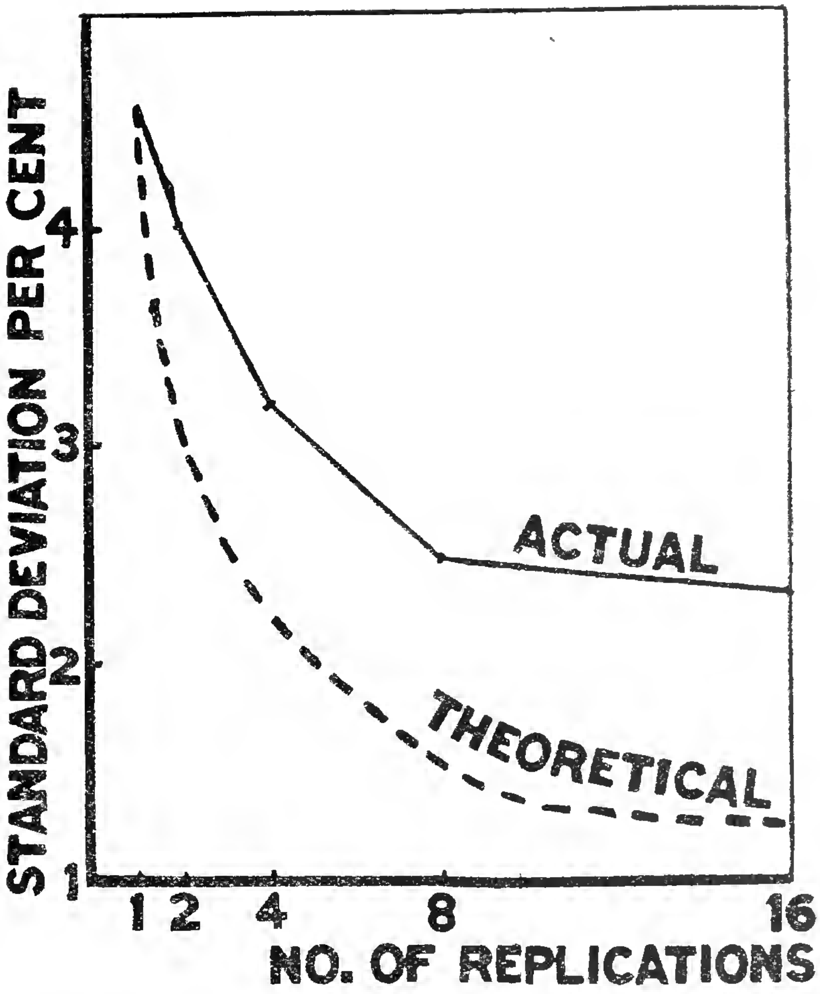

FIG. 4.—*Relation between the Standard Deviation and the Number of Replications.*
(Actual and Theoretical).

N.B.—The theoretical value is obtained by the division of the S.D. of 1/10th acre plots by the square root of the number of units into which it was divided.

Conclusions.

While the small number of observations necessarily detracts from the accuracy of some of the results, the following conclusions seem to be justified, supporting, as they do, most of the previous work overseas.

(1) That in this field experiment, there are two types of error—
   (a) casual, due to small chance errors in harvesting technique, uneven seeding, manuring, hare-tracks, etc. These may be so gradual as to be inappreciable to the eye.
   (b) more regular errors, due to marked soil variations, climate, etc.

(2) That the casual error attaching to a single plot decreases with the increasing size of plot, but the more systematic error of soil variation becomes more important as the plot increases in size.

(3) The optimum size for field trials for cereals under conditions such as these, is 1/40th acre.

(4) That there would appear to be grounds for the belief that a long narrow plot is the more desirable for field trials.

(5) That the error attaching to a 1/40th acre plot is diminished to a working minimum by a replication of five times in any one series.

It is absolutely essential that these results be applied with caution. They are only of value for the conditions which prevailed during the period of the experiment, on the particular soil on which the experiment was conducted. Thus in the first place they will apply only to areas of crop in which *the eye is unable to detect any serious lack of uniformity.* If a field, used for yield trials, contained areas in which the crop was locally affected owing to disease, extra-heavy rain or some other exceptional circumstance, there would be no reason for expecting that the statistical results obtained in the Werribee work would hold good in such an area.

In the second place, with different climatic conditions the results might be different, but the marked similarity between the results at Werribee and at Rothamsted suggests that this is not likely to be a very serious source of trouble.

Finally, the authors wish gratefully to acknowledge all assistance received. The experiment itself was undertaken under the direction of the Department of Agriculture, Melbourne, at the suggestion of Mr. H. A. Mullett, Superintendent of Agriculture.

They are also greatly indebted to Professor S. M. Wadham for his many suggestions and helpful criticism of this report.

The facility and accuracy obtained in the field work would have been impossible but for the assistance of Mr. A. Morgan, B.Ag.Sc., and Messrs. Pescott and Skene, students in Agriculture in the University of Melbourne.

[Proc. Roy. Soc. Victoria, 40 (N.S.), Pt. II., 1928.]

Art. IX.—*Contributions to the Flora of Australia, No. 34.** *Additions to the Flora of the Northern Territory and Locality Records.*

By

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and

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[Read 8th December, 1927; issued separately 28th April, 1928.]

The records made in this paper are mainly the result of a revision of the collection of Northern Territory plants made by the Horn Expedition in 1894. This collection is housed in the Tate Herbarium at the University of Adelaide, and we have here to acknowledge our gratitude to Professor Osborn for making this material available to us.

Many of the species have not been previously recorded either in the report of the Horn Expedition or in the Flora of the Northern Territory, and other records add considerably to the range of species already known without definite locality from Northern Australia, and recorded in the Melbourne National Herbarium Census.

This paper is a further step in the collection of material for a complete Flora of the Northern Territory.

GRAMINEAE.

Eriochloa punctata Hamilton.
Swallow Creek, Gidia Creek, and Opossum Waterhole, R. Tate, May, 1894, (labelled *E. polystachya* H. B. et K).

Panicum effusum R.Br.
Tennant's Creek, R. Tate, 1894.

P. reversum F.v.M.
Finke River, R. Tate, 1894.

Setaria glauca (L.) Beauv.
Palmerston, Arnheim's Land, M. Holtze, 1882.

S. verticillata (L.) Beauv.
Opossum Waterhole, R. Tate, 1894.

Alopecurus geniculatus L.
Barrow Creek, R. Tate, 1894.

*No. 33 in *Proc. Roy. Soc. Vic.*, n.s., xxxix. (2), p. 154.

Eriachne ovata Nees var. *pallida* Benth.
MacDonnell Ranges, R. Tate, 1894.

Triraphis danthonioides F.v.M.
Gill's Range, R. Tate, 1894.
This is the first definite locality recorded for this species in the Northern Territory.

Chloris divaricata R.Br.
Finke River, R. Tate, 1894 (labelled *C. acicularis*).

Fimbristylis Neilsonii F.v.M.
MacDonnell Ranges, Rev. Kempe, 1883.

Scirpus americanus Pers.
Illara Water, R. Tate, 1894 (labelled *S. pungens*).
This species had not been previously recorded for the Northern Territory.

CENTROLEPIDACEAE.

Centrolepis polygyna (R.Br.) Hieron.
South of the MacDonnell Ranges, R. Tate, 1894.

POLYGONACEAE.

Polygonum serrulatum Lag.
Finke River, R. Tate, 1894.

CHENOPODIACEAE.

Chenopodium cristatum F.v.M.
Ilpilla Gorge, R. Tate, 1894.

Atriplex campanulatum Benth.
On the sandhills south of the MacDonnell Ranges, R. Tate, 1894. This species has not been previously recorded for the Northern Territory.

A. fissivalve F.v.M.
Near Elizabeth Creek, — Giles.
This species has not been previously recorded for the Northern Territory.

A. limbatum Benth.
Finke River, R. Tate, 1894.

Bassia convexula R. H. Anders. (=*B. echinopsila* F.v.M.).
The Goyder and Ilpilla Gorge. R. Tate, 1894.

B. eriacantha (F.v.M.) R. H. Anders.
This species has not been previously recorded for the Northern Territory.

Kochia Georgei Diels.
Mt. Olga, W. H. Tietkens, 1899.

K. villosa L. var. *enchylaenoides* J. M. Black.
Charlotte Waters, R. Tate, 1894.

Threlkeldia inchoata J. M. Black.
Adminga Creek, R. Tate, 1894.
Arthrocnemum halocnemoides Nees.
Finke River, R. Tate, 1894.

AMARANTACEAE.

Trichinum arthrolasium F.v.M.
MacDonnell Ranges, R. Tate, 1894.
T. helipteroides F.v.M.
Ilpilla, Barrow Creek, R. Tate, 1894.
T. helipteroides F.v.M. var. *minor* J. M. Black.
Finke River, R. Tatc, 1894.
T. nobile L. (=*Ptilotus nobilis* (L.) F.v.M.).
Mt. Sonder, MacDonnell Ranges, R. Tate, 1894.
T. parvifolium F.v.M. (=*Ptilotus parvifolius* F.v.M.).
Crown Point, Finke River, R. Tate, 1894.
This is the first definite locality recorded for this species in the Northern Territory.
Amarantus Mitchelli Benth.
On the sandhills south of thc MacDonnell Ranges, R. Tate, 1894.
This species has not been previously recorded for the Northern Territory.
Gomphrema affinis F.v.M.
Crokcr Island, R. Tate (No. 60), March, 1883; Pine Creek, MacDonnell Ranges, R. Tate, 1894.
G. Brownii Moq.
Finke River, Rev. Kempe, 1882; Mt. Sonder, R. Tate, 1894.
G. parvifolia Benth.
Mt. Norris Bay, R. Tate (No. 79), March, 1883; Pine Creek and Barrow Creek, R. Tate, 1894.

AIZOACEAE.

Trianthema crystallina Vahl. var. *clavata* J. M. Black.
Throughout the MacDonnell Ranges, R. Tate, 1894.

PORTULACEAE.

Portulaca filifolia F.v.M.
Stuart's Pass, MacDonnell Ranges, R. Tate, 1894.
P. oleracea L. var. *grandifolia* Benth.
On the sandhills of the MacDonnell Ranges, R. Tate, 1894.
Calandrinia polyandra (Hook.) Benth.
Finke River, R. Tate, 1894.
This is the first definite locality recorded for this species in the Northern Territory.

C. pusilla L. (=*C. volubilis* Benth.).
MacDonnell Ranges, Rev. Kempe, 1883.
This species has not been previously recorded for the Northern Territory.

C. remota J. M. Black.
Charlotte Waters, Baron von Mueller.

CRUCIFERAE.

Menkea australis Lehm.
South of the MacDonnell Ranges, R. Tate, 1894.

M. sphaerocarpa, F.v.M.
Mt. Olga, Rev. Kempe, 1883.

CRASSULACEAE.

Crassula bonariensis (D.C.) Cambess.
Finke River, Rev. Kempe, 1883; (labelled *Tillaea purpurata* Hook.).

C. colorata (Nees) Ostenf.
MacDonnell Ranges, R. Tate, 1894.

LEGUMINOSAE.

Acacia Bynoeana Benth. (=*A. Wilhelmiana* F.v.M.).
Along the west end of Lake Amadeus, W. H. Tietkens, 1889.

A. Cambagei Baker.
The Goyder, Swallow Creek, and on the slopes of Mt. Daniel, R. Tate 1894 (labelled *A. homalophylla* Cunn.).

A. coriacea D.C.
MacDonnell Ranges, R. Tate, 1894.

A. ligulata A. Cunn.
West of the MacDonnell Ranges, W. H. Tietkens, 1889.

Cassia Sturtii R.Br. var. *involucrata* J. M. Black.
Stuart's Pass, MacDonnell Ranges, R. Tate, 1894.

Bauhinia Leichardtii F.v.M. var. *cinerascens.*
MacDonnell Ranges, C. A. Winnecke, 1883.

Isotropis Winneckiana F.v.M.
MacDonnell Ranges, C. A. Winnecke, 1883.

Crotalaria unifoliata Benth.
Cameron's Well, Central Australia, R. Tate, 1894.

Indigofera saxicola F.v.M.
Yam Creek, R. Tate (No. 7), 1883.

Swainsona Burkei F.v.M. var. *parviflora.*
Near Mt. Sonder, R. Tate, 1894.

S. canescens F.v.M. var. *Horniana* Tate.
Glen Helen Gorge, R. Tate, 1894 (labelled *S. Horniana*).

S. stipularis F.v.M.
Common in the scrub near the Goyder, W. H. Tietkens, 1889.

ZYGOPHYLLACEAE.

Zygophyllum Billardierii D.C. (=*Z. ammophyllum* F.v.M.).
Finke River at Idracowrie, R. Tate, 1894.
Z. compressum J. M. Black.
Sonder's Range, R. Tate, 1894.
Tribulus minutus Leich.
Ayer's Rock, MacDonnell Ranges, W. H. Tietkens, 1889.

POLYGALACEAE.

Polygala orbicularis Benth.
Port Darwin, R. Tate (No. 95), 1883.

STACKHOUSIACEAE.

Macgregoria racimigera F.v.M.
MacDonnell Ranges, C. A. Winnecke, 1883; Mt. Gillen and North of Alice Springs, R. Tate, 1894.
This is the first definite locality recorded for this species in the Northern Territory.

TILIACEAE.

Corchorus vermicularis F.v.M. (=*Scorpia simplicifolia* Ewart and Petrie, 1926).
Wycliffe, A. J. Ewart, 1924.
This curious plant is only recorded from one locality in Bentham's Flora, and it is sparsely distributed in the Northern Territory, usually near to river banks or on flood-plains. In North-West Australia it has recently appeared in many localities from Derby to Fitzroy Crossing and Leopold, mostly on grazed river areas after floods, in some cases being now the dominant vegetation over acres of ground. Apparently it is a native plant whose spread is favoured by grazing; sheep, cattle and horses usually avoid it, and even goats appear to eat it only sparingly.

STERCULIACEAE.

Melhania incana Heyne (=*Sideria reverta* Ewart and Petrie, 1926).
Taylor's Well, A. J. Ewart, 1924. This is the first record of this plant in the interior of Northern Australia. The suppressed genus "Sideria" was placed under the Malvaceae.
Ruelingia hermanniaefolia Steetz.
Near the Finke River, Rev. Kempe, 1882; Watson Hills, W. H. Tietkens, 1889. (Labelled *Commersonia Kempeana* F.v.M.).

DILLENIACEAE.

Pachynema sphenandrum F.v.M.
Near Yam Creek, R. Tate, 1894.
This is the first definite locality recorded for this species in the Northern Territory.

LYTHRACEAE.

Rotala occultifolia Koch var. *Leichardtii* Koch.
West of the MacDonnell Ranges, W. H. Tietkens, 1889; Deering Creek, R. Tate, 1894.
This is the first definite locality recorded for this species in the Northern Territory.

MYRTACEAE.

Micromyrtus ciliata J. M. Black (=*Thryptomene flavifolia* F.v.M.).
Along the south side of Gill's Range, R. Tate, 1894.

HALORRHAGIDACEAE.

Loudonia Roei Schlechtd.
On the sandhills south of Gill's Range, R. Tate, 1894.

BORAGINACEAE.

Heliotropium heteranthum F.v.M.
Near Lake MacDonald, Central Australia, W. H. Tietkens, June, 1889.
H. tenuifolium R.Br.
MacDonnell Ranges, R. Tate, 1894.

CONVOLVULACEAE.

Ipomoea heterophylla Schrank.
Port Darwin, R. Tate, (No. 50), 1883.
I. lonchophylla J. M. Black.
Swallow Creek, R. Tate, 1894 (labelled *I. heterophylla*).

SCROPHULARIACEAE.

Striga curviflora Benth.
MacDonnell Ranges, W. H. Tietkens, 1889.
S. hirsuta, Benth.
Port Darwin, R. Tate (No. 99), 1883.
This species has not been previously recorded for the Northern Territory.

ACANTHACEAE.

Ruellia bracteata R.Br.
Yam Creek, R. Tate (No. 29), 1883.

MYOPORACEAE.

Myoporum deserti A. Cunn.
South of the MacDonnell Ranges, W. H. Tietkens, 1889.

M. montanum R.Br.
MacDonnell Ranges, R. Tate, 1894 (labelled *M. Dampieri*).

Eremophila Elderi F.v.M.
James's Range, R. Tate, 1894.

E. Latrobei F.v.M. var. *Tietkensii* (=*E. Tietkensii* F.v.M.).
On the south side of Gill's Range, R. Tate, 1894.

E. neglecta J. M. Black.
At Yellow Cliffs, near Charlotte Waters, R. Tate, 1894.

VERBENACEAE.

Newcastlia cephalantha F.v.M.
Finke River, R. Tate, 1894.

RUBIACEAE.

Oldenlandia elatinoides F.v.M.
Deering Creek and Haast's Bluff, MacDonnell Ranges, R. Tate, 1894.

This species has not been previously recorded for the Northern Territory.

GOODENIACEAE.

Scaveola ovalifolia R.Br. var. *parviflora*.
Mt. Sonder, Illawarta and Idracowra, R. Tate, 1894. This is the first record of this variety in the Northern Territory.

COMPOSITAE.

Vittadinia brachycomoides F.v.M.
Throughout the MacDonnell Ranges, R. Tate, 1894.

Calotis cuneifolia R.Br.
In the mulga scrub at Glen Edith, R. Tate, 1894 (labelled *C. dentrix*).

This species has not been previously recorded for the Northern Territory.

C. scabiosifolia F.v.M.
Finke River, R. Tate, 1894.

Helichrysum bracteatum Willd.
Finke River, Rev. Kempe, 1883 (labelled *H. lucidum* Henck.).

REFERENCE.

EWART and PETRIE, 1926. Contributions to the Flora of Australia, No. 31. *Proc. Roy. Soc. Vic.*, n.s., xxxviii.

[PROC. ROY. SOC. VICTORIA, 40 (N.S.), PT. II., 1928.]

ART. X.—*Fossil Plants of the Stony Creek Basin.*

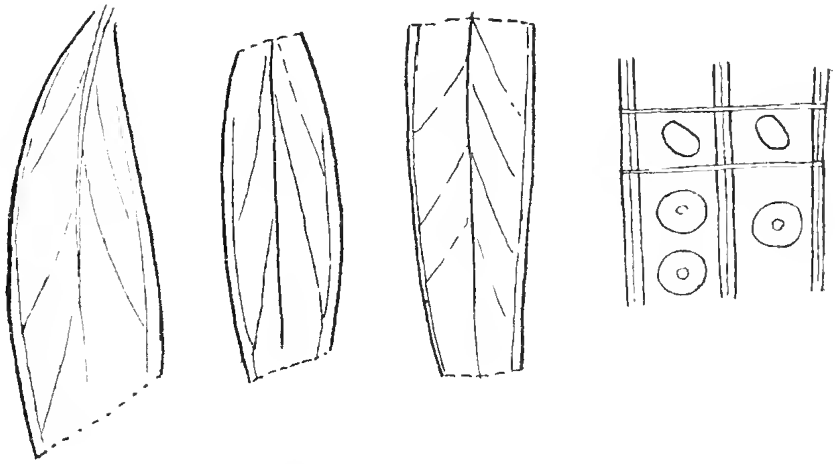
By REUBEN T. PATTON, B.Sc., M.F.

(With Plate VIII.)

[Read 8th December, 1927; issued separately 7th June, 1928].

The geology of the Stony Creek Basin, Daylesford, has been the subject of many papers, the last of which being that by Orr (1). In this basin is a thick deposit of black ligneous clay, the origin of which is a matter of doubt. Although in places the deposit contains a large amount of plant material, yet owing to its lack of any definite lamination it is very difficult to secure unbroken specimens. This applies particularly to the leaves of the genus *Eucalyptus*, which occur abundantly. Small fragments of what is apparently fern material are present, but the identification is difficult. One fern appears to be *Pteridium aquilinum*, which is at present world wide. Another specimen has large broad frond segments with large orbicular sori, characters which are identical with the living species *Polypodium pustulatum*. The veining of the leaves of the Eucalypt leaves can be very distinctly made out in fresh material. No complete leaves were obtained. The veining is of two distinct types: one has the veins very oblique and the other has the veins set at an angle of about 45°. The oblique veining occurs among others in the living species *E. amygdalina*, and the other type is seen in the living species *E. viminalis*. Both these species occur living in the area under discussion. The veining of *E. amygdalina* is very variable, so that it is quite possible that the leaves all belong to the same species. The leaves are all comparatively narrow and falcate, and about 4 to 6 inches long. It is quite probable that the fossil leaves belong to the existing species. Besides the leaves, however, there are woody masses which are very soft and cheesy in consistency. The material is very soft and, therefore, difficult to section, but when dry it is very brittle and fractures like coal.

Microscopically it is seen that the cell walls have been enormously swollen, so much so that in most parts the cell cavity has been obliterated. This swelling of the walls has also caused the bordered pits to a very large extent to disappear, and other characters are also very much affected. This makes the identification very difficult. However, it is easily seen that the wood is of gymnospermous origin. The annual rings are very distinct, and are also very broad. Approximately the spring and the autumn wood are about equal in breadth. The summer wood is very dense, and owing to the swelling of the walls the lumen is completely obliterated. The spring wood is very open, and comparatively thin walled. This portion of the ring is very much distorted. At first sight it would appear that the wood had been subject to strong pressure in a radial direction, but the nature of the deposit in which it occurs does not favour this suggestion. The distortion is entirely due to the swelling of the walls. In cross section no resin canals nor resin cells can be observed, but it is quite possible that even if the latter were present in the summer wood they would not be observed. In longitudinal radial section it is seen that the bordered pits, which are but rarely preserved, were arranged in single rows. The medullary rays are homogenous. The pits connecting the medullary rays with the tracheides are large, broad, elliptical and simple. These, too, have been largely obliterated by the swelling of the walls. This character had been observed in some fossil wood sent by Baron von Mueller to Schenk (2, pp. 872-4), and named by the latter *Phyllocladus Muelleri.* These large pits had already been noted in the living species *Phyllocladus trichomanoides,* which is endemic to New Zealand. These pits also occur in the Tasmanian species, *P. rhomboidalis.* This is also an endemic species. These pits are,



A B C D

Fig. 1.—A, B and C leaves of *Eucalyptus* spp.
D Radial section of woody material shewing uniseriate bordered pits of the medullary rays.

however, not confined to the genus *Phyllocladus,* for they also occur in the two endemic Tasmanian species, *Dacrydium Franklini* and *Microcachrys tetragona.* The last genus is endemic to Tasmania, and is monotypic. The other two genera in which the large elliptical pits occur, are, however, very widely distributed. *Phyllocladus* occurs in Tasmania, New Zealand, New Guinea, Borneo and the Philippine Islands. *Dacrydium* occurs in Tasmania, New Zealand, Fiji Is., New Caledonia, New Guinea, Borneo, Philippine Is., Malay and Chile. From the distribution of the existing species it is seen that these two genera range over a very wide area, and it is therefore very surprising that, while these two genera are found on the south, east and north of Australia, they are nowhere found at present on the mainland itself. The two genera, *Phyllocladus* and *Dacrydium*, as far as their Tasmanian species are concerned, are so very similar as regards their wood anatomy that it is impossible to separate them. It is therefore impossible to say in which genus this fossil wood should be placed. The longitudinal tangential section does not show any definite characters, and this is also a feature of the Tasmanian species mentioned above. Similar fossil wood has been obtained from the Malakoff Reef at Ballarat, and also from the Langi Logan Mine at Ararat. From the distribution of the fossil wood, therefore, it is apparent that somewhere about the Newer Basaltic period at least one of the above genera was present in Australia itself. The disappearance of the genus from the mainland has been probably due to secular changes of climate since basaltic times. The three genera mentioned are found in the wetter areas of Tasmania, and therefore it is most probable that similar conditions previously existed in those parts of Victoria where the fossils have been found. The presence of *Polypodium* sp. also indicates a wet habitat. *Polypodium* to-day exists as an epiphyte on tree-ferns, and other arboreal vegetation in the moist gullies of the State. This further supports the suggestion that the climate was formerly moister than it is to-day. The distribution of the species *Eucalyptus amygdalina*, *E. viminalis* and *Pteridium aquilinum* is not controlled by climatic but by soil conditions. All these three are found in the wettest areas as well as in the comparatively dry regions. The area where the fossils have been found has, therefore, apparently become progressively drier, and therefore moisture loving species have, so to speak, been driven out.

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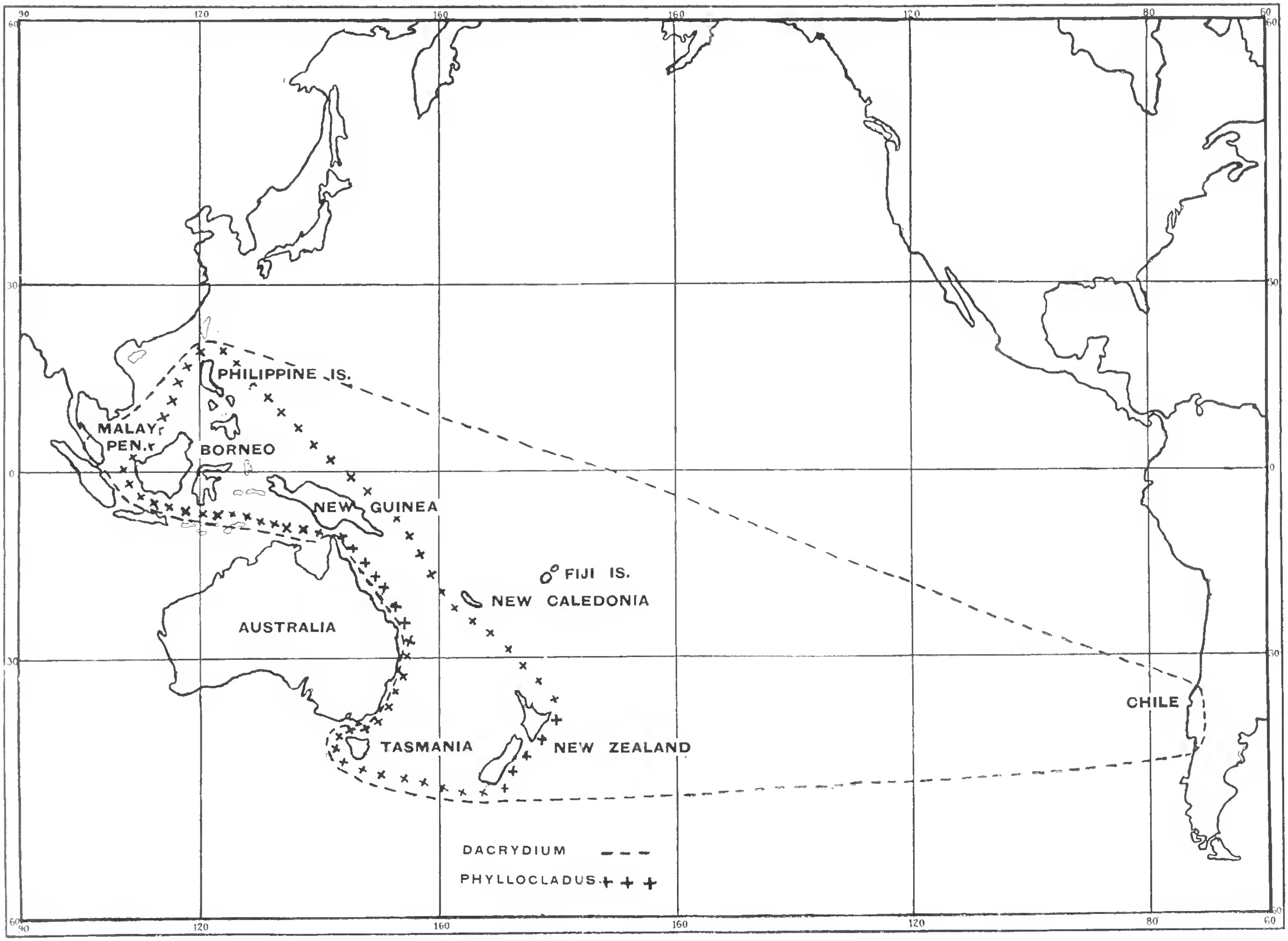
EXPLANATION OF PLATE VIII.

Distribution of the genera *Phyllocladus* and *Dacrydium*.



Distribution of Phyllocladus and Dacrydium.

[PROC. ROY. SOC. VICTORIA, 40 (N.S.), PT. II., 1928.]

ART. XI.—*The Staurograptus Bed of Victoria.*

By W. J. HARRIS, M.A., and R. A. KEBLE.

(With Plate IX.)

[Read 8th December, 1927; issued separately 7th June, 1928.]

Messrs. W. J. Harris and W. Crawford recently found some dendroid graptolites of considerable importance to Victorian Ordovician stratigraphy, in a band of slate on the bank of a creek 3 miles north east of Romsey. The band contains the genus *Staurograptus,* and we regard it as being very near the base of the Lower Ordovician. The band (approximately 27 chains, N.18°W. from the south-west corner of Allot. 26, Parish of Springfield, on a water reserve), is of hard, black slate intercalated with bands of chert, quartzite, and altered sandstone. A note on Quarter Sheet 5 SE. refers to the outcrop as "black shales." The strike is almost north and south and dip 86° west. Easterly up the creek is an outcrop of quartz-porphyry.[1] Still further east shales, mudstones and sandstones occur, lithologically similar to those outcropping in typical Silurian areas.[2]

Only two graptolite genera, viz. *Staurograptus* and *Dictyonema,* have been recognised, in both cases preserved as films on the bedding planes of the slate, but in profusion. *Staurograptus* is a new record for Victoria; *Dictyonema* has been found at several localities, more particularly at Taylor's Quarry, 5 miles to the north. There *D. macgillivrayi* T. S. Hall, *D. pulchellum* T. S. Hall, and *D. grande* T. S. Hall, occur with *Bryograptus, Clonograptus, Tetragraptus,* etc.

Genus **Staurograptus** Emmons.

STAUROGRAPTUS DIFFISSUS, sp. nov.

(Plate IX., Figs. 1-5.)

Polypary broadly conical to saucer shaped; usually vertically compressed. Sicula long, conical, suspended by a long nema; no primary disc observed.

The primary theca grows beyond the aperture of the sicula; the polypary begins with four or more branches.

Polypary small, in cyathiform aspect less than 1·5 cm. wide distally, in vertically compressed aspect (apparently less mature forms) not exceeding 1 cm. It develops by dichotomy to approxi-

1.—This is shown on the Quarter Sheet as "greenstone," and was probably presumed to belong to the diabases of which the hills to the north are largely composed. It is an acid dyke similar to those found further south.

2.—Professor Skeats, however, has described these as Heathcotian eastwards up to the Basalt junction. Pan-Pacific Sci. Congress, Australia, Melb. Handbook, p. 134, 1923; reprinted in Proc. Pan-Pac. Sci. Cong., Aust. 1923, ii., p. 1667, 1925.

mately 16 branches of the fourth order; none of our forms seems to have developed further.

Branches slender, about 0·25 mm. wide, all the branches slightly flexuous, branching at irregular intervals. In the horizontally compressed polypary the branches of the third order diverge at an average angle of 45°.

Thecae number from 20 to 25 in 10 mm., in contact for one-third of their length, outer wall straight or slightly concave, apertural margin slightly concave. Ventral margin makes, with the axis of branch, an angle of about 40°.

Remarks.—The nema of the mature forms is about 7·0 mm. in length, and is often split, giving the appearance of a double nema, bifurcating at different distances from the sicula. In one instance the strands of the nema are twisted around each other below the sicula, but reunite and apparently form a single tube at a still lower level. Except as regards size, the vertically compressed polypary bears a considerable resemblance to *S. dichotomous* Emmons It differs, however, from that species in the angles of bifurcation and the details of its thecae. In the cyathiform aspect the typical nema is readily recognised.

Associates.—*Dictyonema scitulum*, sp. nov., *D. campanulatum*, sp. nov., and Crustaceae.

Genus **Dictyonema** Eichwald.

Dictyonema campanulatum, sp. nov.

(Plate X., Figs. 6-13.)

Polypary cyathiform, flabelliformly compressed in mature specimens, attaining a length of approximately 1·2 cm. and a width of 1·5 cm. Branches irregularly disposed, somewhat flexuous; outside branches convex to the axis of the polypary proximally, approximately straight distally, inside branches flexuous throughout. Bifurcations fairly frequent. Branches from 0·3 to 0·4 mm. wide of increasing width, 10 with interspaces in a width of 10 mm., space between the branches more than the width of the branches. Stout transverse dissepiments 1·0 mm. to 2·0 mm. apart, which, with the adjacent branches enclose an irregularly shaped interspace.

Thecae 12-14 in 10 mm., acutely dentiform.

Sicula about 0·7 mm. long with long attenuated nema.

Remarks.—The material on which this description is based cannot be regarded as ideal. Nevertheless there is little doubt regarding the distinctness of *D. campanulatum* from any other form known to us.

Some specimens (Pl. IX., Figs. 7, 8, 10, 12, 13) show curious double or triple nemas, hair-like filaments, one of which occasionally ends in a small triangular body suggestive of a peduncular attachment.

Associates.—*Staurograptus diffissus*, sp. nov., and *D. scitulum*, sp. nov. Crustaceae.

Dictyonema scitulum, sp. nov.

(Plate IX., Figs. 14-19.)

Polypary cyathiform, flabelliformly compressed, in mature specimens attaining a length of 2 cm., a width distally of about 2 cm. (included in an angle of 85°).

Branches nearly parallel, regularly disposed, outer ones slightly concave to axis of polypary proximally, and straight distally, inner ones straight throughout. Bifurcations infrequent. Branches 0·4 mm. (0·4-0·5 mm.) wide, of constant width, 13-14 occupying (with interspaces) a width of 10 mm. The spaces between the branches is somewhat less than the width of the branches. Comparatively stout transverse dissepiments, from 0·7 mm. to 1·5 mm. wide, connect the branches and these with the branches enclose a subrectangular interspace. Thecae 14-17 in 10 mm. distally. Thecal apertures thickened and acutely dentiform.

Sicula 1 mm. long.

Remarks.—The type specimen, although preserved as a film, exhibits some of the characteristics revealed by Wiman (1), Bulman (2) and others in their work of isolation of specimens in relief from matrices with dilute acids.

Two types of thecae may be recognised, the thecae and "gonangia" of Wiman (1). The latter arise from opposite sides of the former and throughout their short length appear to be disposed in alternately right and left hand spirals, their apertures being opposed. The apertures are visibly thickened. An attempt was made to trace some plan of arrangement of the cell groups about the branches, but, other than that indicated, unsuccessfully.

The dissepiments are straight bars connecting adjacent branches and show no evidence of fusion midway. An apertural process, very similar to that described by Ruedemann in regard to the thecae of *D. furciferum* (3, p. 607), extends from the flattened aperture of the "gonangium" and impinges on the dorsal part of the adjoining branch.

There is little doubt that *D. scitulum*, sp. nov. is closely related to *D. furciferum*, but unfortunately the thecae of the type specimen are not clearly enough shown to ascertain whether the difference is varietal or specific. On the other hand, Ruedemann (3, pl. iii., f. 11) has only figured a portion of a polypary, and until better material is forthcoming, it has been thought desirable, on account of its stratigraphical importance in Victoria, to give *D. scitulum* specific rank.

Associates.—*Staurograptus diffissus*, sp. nov. and *D. campanulatum*, sp. nov. Crustaceae.

Correlation of Fauna.

The importance of the Springfield association to the Victorian Ordovician sequence lies in the facts that it is the oldest graptolite fauna yet discovered in Australia, and is comparable with the oldest but one of the graptolite associations of America and Europe. The graptolite succession is generally alike in all parts of the world and the forms described in this contribution are so closely related to those found in similar associations elsewhere that there is little doubt that the Springfield slates are very near to the base of the Ordovician. Making world-wide comparisons, stratigraphically above them should occur a fauna equivalent to that of the American Deep Kill Zone III, containing *Clonograptus flexilis* and *Tetragraptus* (4, p. 130); such a position and association is held by the Taylor's Quarry slates east of Lancefield (5, p. 175).

If conditions were suitable to its preservation and it is accessible, a bed containing exclusively a *Dictyonema* allied to *D. flabelliforme* Eich. should yet be found in Victoria stratigraphically below the Springfield slates. This bed in other parts was formerly regarded as marking the closing stage of the Cambrian, but latterly both in American and Europe, it has been recognised as introducing the extensive Ordovician transgression. Such is probably the case in Victoria, for stratigraphically above the Springfield slates we have a very comprehensive suite of Lower Ordovician graptolites which have been zoned and subzoned, while, apparently, stratigraphically below them a little east of their strike some distance north we have the Cambrian *Dinesus* trilobite fauna. It is probably in this direction that the missing bed will be found.

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EXPLANATION OF PLATE IX.

All Figures × 2·6.

Figs. 1-5.—*Staurograptus diffissus*, sp. nov.

1. Young polypary showing sicula and nema. Paratype.
2. Polypary vertically compressed. Paratype.
3. Polypary laterally compressed. Paratype.
4. Polypary vertically compressed. Paratype.
5. Polypary vertically compressed. Holotype.


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Figs. 6-13.—*Dictyonema campanulatum,* sp. nov.

6. Young polypary, with single nema. Paratype.
7. Young polypary with divided nema. Holotype.
8. Proximal portion of polypary, showing divided nema. Paratype.
9. Polypary showing typical form of polypary. Paratype.
10. Polypary, distorted, showing divided and attachment suggestive of peduncular appendage. Paratype.
11. Portion of polypary showing dissepiments. Paratype.
12. Proximal portion of polypary showing divided nema. Paratype.
13. Complete polypary with tripartite nema. Paratype.

Figs. 14-19.—*D. scitulum,* sp. nov.

14. Portion of polypary showing interspaces and dissepiments. Paratype.
15. Imperfect polypary showing interspaces. Paratype.
16. Portion of mature polypary showing transverse dissepiments. Paratype.
17. Distorted polypary. Paratype.
18. Polypary. Paratype.
19. Complete polypary. Holotype.

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The names of new genera and species are printed in italics.

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CONTENTS OF VOLUME XLI.

PART I.

PART II.

[Proc. Roy. Soc. Victoria, 41 (N.S.), Pt. I., 1928.]

Art. I.—*Notes on New Zealand Hydroida.*

By R. E. TREBILCOCK.

(With Plates I.-VII.)

[Read 8th March, 1928: issued separately 27th September, 1928]

During a visit to New Zealand in April and May, 1923, I spent a few days collecting Hydroids at Auckland, Island Bay (Wellington), New Brighton (Christchurch), St. Clair (Dunedin), and Bluff. The collecting was done solely in rock pools at low tide, and among algae washed ashore, but it resulted in several new species, a number of species not hitherto recorded from New Zealand, and numerous other and interesting forms.

The present paper deals with this collection, and also includes references to a few specimens collected by my late colleague, Mr. J. F. Mulder, from Stewart Island "oyster" shells many years ago, and to some specimens kindly sent to me by Mr. W. M. Bale, F.R.M.S., for examination and comparison.

I have to thank Mr. W. M. Bale for the very great assistance he has rendered me by identifying species in respect of which I had doubts, by sending me literature and specimens from his own extensive collection for examination, and by valuable advice throughout the preparation of this paper.

Fam. CLAVIDAE.

Endocrypta huntsmani (Fraser).

Crypta huntsmani Fraser, 1911, p. 19.

Endocrypta huntsmani Fraser, 1912, p. 216; 1913, p. 149; 1914, p. 109.

Ascidioclava parasitica Kirk, 1915, p. 146.

I have compared a specimen of *Ascidioclava parasitica* from New Zealand (kindly sent to me for examination by Mr. Bale) with specimens of *Endocrypta huntsmani* from Departure Bay, west coast of Canada (received from Dr. C. McLean Fraser), and there is not the slightest doubt that not only do they belong to the same genus, but also that they are not specifically distinct.

Mr. Bale's specimen is from the peripharyngeal groove of a *Polycarpa*, and was collected at Wellington, N.Z.

Fam. PENNARIIDAE.

Pennaria australis Bale.

Numerous specimens, growing in a shallow rock-pool at the entrance to Auckland Harbour.

This species has not hitherto been recorded from New Zealand.

INCERTAE SEDIS.

Saaba (?) scandens, n. sp.

(Plate I., Figs. 1, 1*a*.)

Specimens from Island Bay no doubt belong to the same genus as *Saaba arenosa* (Bale).

The hydrocaulus is fascicled in its proximal part, unjointed, and consists of string-like stems, with a few ascending branches. The perisarc has a tough and cartilaginous appearance. The polyp-tubes are few, and spring irregularly from all sides. Near the end of the polyp-tubes there is an annular thickening, and often another just below it, probably due to regeneration. Beyond the distal thickening the edge of the polyp-tube is sometimes quite sharp, sometimes rather ragged. Inside the annular thickening is often a narrow septum. Unfortunately no hydranths are present.

Unlike Bale's species, the present form is climbing in habit, the hydrocaulus adhering loosely to other hydroids.

The height of the largest specimen, which is incomplete, is about 35 mm.

Springing from several of the polyp-tubes are large sac-like bodies, which are possibly gonangia. As in *Saaba arenosa* they are formed of very thin colourless perisarc which does not stain readily, and have the whole exterior surface coated with closely adhering grains of sand, calcareous particles and Foraminifera.

In the absence of hydranths the position of this genus is very uncertain, and it can only provisionally be referred to the Hydroida.

Fam. CAMPANULARIIDAE.

Obelia geniculata (Linn.).

Loc.—Island Bay, and New Brighton (Christchurch).

Obelia australis v. Lendenfeld.

I found this species, with numerous gonothecae, growing in tide-pools below the swimming pool at St. Clair (Dunedin).

Orthopyxis formosa, n. sp.

(Plate I., Figs. 2-2*e*.)

Hydrorhiza broad, flattened, with flanged margin, forming an irregular network.

Hydrosoma varying from 1·2 mm. to 2·3 mm. in height.

Peduncles somewhat flattened, usually strongly and spirally undulated; a single spherule below each hydrotheca.

Hydrothecae large, compressed; in broad aspect with wide base and only slightly expanding upwards, and with thickening of walls mostly extending from the base up to just below the rim, where there is an additional thickening on the outside forming a stout band which completely surrounds the upper part of the hydrotheca; in narrow aspect narrower at the base and with little thickening except at the base and near the rim.

Margin rising slightly above the thickened rim, very thin, furnished with about 12 rounded teeth.

Gonothecae not present.

Hab.—At entrance to Auckland Harbour, on floating seaweed.

Occasionally hydrothecae are found without any thickening, but such have the walls more or less wrinkled, and are obviously abnormal. The hydrothecae vary considerably in size, as may be seen by reference to my figures which are all drawn to the same scale.

ORTHOPYXIS DELICATA, n. sp.

(Plate II., Figs. 1-1*f*.)

Hydrorhiza broad, only slightly flattened, with a slightly flanged margin.

Hydrosoma varying from 0·75 mm. to 1·5 mm. in height; peduncles somewhat flattened, strongly and spirally undulated throughout their entire length; a single spherule below each hydrotheca.

Hydrothecae large, slightly compressed; in broad aspect with a wide base, but expanding considerably upwards; in narrow aspect narrow at the base and expanding still more upwards so as to make the aperture more nearly circular; walls in broad aspect thickened near the base and becoming only slightly thinner towards the rim, in narrow aspect much thinner throughout; no annular thickening around the rim.

Margin of hydrothecae rather thin, furnished with from about 10 to 15 rounded teeth.

Gonothecae about 1·2 mm. in length, springing from short expanding peduncles, somewhat pear-shaped, more rotund on one side than the other, thus making them curved, with a large, circular, terminal opening.

Loc.—St. Clair (Dunedin), growing over the surface of delicate algae and polyzoa. In the latter case the hydrorhiza forms an anastomosing network roughly corresponding with the cells of the polyzoa.

The hydrothecae vary considerably in size, as will be seen by reference to my figures, which are all drawn to the same scale.

ORTHOPYXIS CRENATA (Hartlaub).

Numerous specimens with gonothecae, from Island Bay.

SILICULARIA BILABIATA (Coughtrey).

I found this species growing profusely over *Laminaria* washed ashore at Island Bay.

Silicularia campanularia (v. Lend.).

I found this species in large numbers at St. Clair (Dunedin) and Bluff.

Fam. LAFOEIDAE.

Hebella calcarata (L. Agassiz).

I found numerous examples of this widely spread species growing over *Sertularella subarticulata* from Stewart Island.

Hebella corrugata (Thornely).

I found specimens of this widely spread species growing on *Thecocarpus formosus* var. *inarmatus,* n. var., at Island Bay.

In my specimens the aperture of the hydrothecae is not as oblique as figured by most authors.

Measurements.—Length of pedicel 0·20—0·45 mm.; length of hydrotheca 0·72—0·90 mm.; diameter of hydrotheca 0·37—0·55 mm.

Not previously recorded from New Zealand.

Filellum serratum (Clarke).

Specimens of this species occur on several other hydroids from Bluff, Stewart Island, and Island Bay. Not previously recorded from New Zealand.

Perisiphonia quadriseriata, n. sp.

(Plate II., Figs. 2-2*d*.)

Hydrorhiza consisting of a dense mass of tubes forming a parchment-like disc.

Hydrocaulus stout, straight, attaining a height of 14 cm., fascicled, consisting of a single axial tube, bearing hydrothecae, surrounded by a large number of peripheral tubes bearing sarcothecae only.

Hydrocladia sub-opposite, forming an angle of about 60° with the hydrocaulus, attaining a length of about 22 mm., stout, flattened, oval in section, about 0·5 mm. in broader (vertical) diameter, and about 0·4 mm. in narrower; fascicled, consisting of a single axial tube bearing hydrothecae, surrounded by a large number of peripheral tubes, none of which spring from the axial tubes of the hydrocladia; hydrocladia not of smaller diameter at base than elsewhere.

Hydrothecae borne on axial tubes of hydrocaulus and hydrocladia, close-set, each usually overlapping the proximal portion of its successor in the same series, cylindrical, with a slightly bulging profile, lying closely adpressed to the axial tube for a considerable part of their length, the terminal portion curving away from the axial tube and projecting for a short distance (about 0·1 mm. in the longest example) through the fascicle of peripheral tubes. Aperture of hydrothecae circular, margin smooth.

Base of hydrothecae passing into a projection of the axial tube corresponding to a hydrothecal peduncle, and containing a strong diaphragm which slants from the outside inwards and slightly downwards.

Hydrothecae on hydrocaulus in two series on opposite sides of the peripheral tube, both series lying in the same plane, alternate though not always regularly spaced, varying in length with the thickness of the mass of peripheral tubes through which they project.

Hydrothecae on the hydrocladia in four series, two series close together on the abcauline side, and two series close together on the adcauline side, the two abcauline series being widely separated from the two adcauline. Hydrothecae, in each series, regularly alternating with those of adjacent series on both sides of it. but opposite to those of the series diagonally opposite.

Sarcothecae numerous, scattered on hydrorhiza, hydrocaulus and hydrocladia, short, cylindrical, diameter wide compared with their length, borne on slight projections from the peripheral tubes, and separated from the projections by a constriction.

Gonosome, not present.

Locality.—Island Bay, washed ashore.

The hydrocladia would appear from casual examination to be opposite, but, on dissecting away the mass of the peripheral tubes, it is found that the axial tubes of the hydrocladia spring from the axial tube of the hydrocaulus at points that would otherwise be occupied by alternate hydrothecae. The hydrocladia are thus subopposite.

The peripheral tubes communicate freely with each other, and with the axial tube of the hydrocaulus by numerous circular or oval apertures. They do not however directly communicate with the axial tubes of the hydrocladia except by one or two apertures near the base of each hydrocladium and within the bundle of peripheral tubes of the hydrocaulus.

The axial tubes of the hydrocladia are not thickened to any great extent, but that of the hydrocaulus has a massive wall, built up of numerous layers.

In the axil of each hydrocladium is a hydrotheca which differs from the others. It springs from the hydrocladium immediately above the point of origin of the latter, but lies within the peripheral tubes of the hydrocaulus through which it projects. It curves in the same direction as the hydrothecae of the hydrocaulus, and in the opposite direction to the other hydrothecae on the adcauline side of the hydrocladium. Perhaps it would be more correct to say that the axial tube of the hydrocladium springs from the base of this hydrotheca, for the latter certainly belongs more to the hydrocaulus than to the hydrocladium. The wall of the lower part of this axial hydrotheca is much thickened, and from an aperture just below the diaphragm springs a peripheral tube. This tube immediately divides, one branch running up the hydrocaulus and the other along the hydrocladium.

Other peripheral tubes running up the hydrocaulus from below also divide near the point of origin of the hydrocladium, one branch continuing upwards and the other going along the hydrocladium.

The proximal hydrotheca on each hydrocladium on the abcauline side is separated from the others by a short distance, the first hydrotheca of the adjoining series being missing.

The present species is represented in my collection by a single specimen.

Fam. HALECIIDAE.

Halecium flexile Allman.

I found a few small colonies of this species growing in a rock pool at St. Clair (Dunedin), also at Bluff.

Halecium lenticulare, n. sp.

(Plate III., Figs. 3-3*d*; Plate IV., Figs. 1-1*b*.)

Colonies small, attaining a height of a little more than 1 cm., not fascicled, regularly and markedly sympodial (an example of cincinnal monopodia), the stems usually having a marked zig-zag appearance, sparingly bipinnate.

Primary hydrothecae low. Secondary hydrothecae with a large basal cavity, somewhat symmetrically developed. Hydrothecae usually with very thin walls, open margin curved outwards and usually everted, particularly on the adcauline side. Diaphragm well developed, but extremely thin; aperture narrow, often terminating in a very delicate membranous tube, which stretches a considerable distance into the basal cavity. Below the diaphragm a well developed adcauline thickening of the wall ("pseudo-diaphragm") often extending completely round the hydrotheca but always thicker on the adcauline side. Sometimes another thickening, similar, but not so pronounced, near the base of the basal cavity.

Regenerations of hydrothecae markedly active, unregenerated examples being an exception to the general rule.

Gonothecae borne on the apophyse immediately below the primary hydrothecae. Male gonothecae borne mainly on the distal parts of the colony, small, ovate, much flattened. Female gonothecae usually confined to the proximal parts of the colony, large, lenticular, with a circular opening in the distal part of the abcauline side; margin of opening thickened.

Localities.—St. Clair (Dunedin), Bluff, Island Bay (Wellington).

The type specimen is from Bluff Harbour.

The specimens from St. Clair differ from the type in that most of the perisarc is enormously strengthened by internal annular thickenings, arranged more or less diagonally around stem and branches.

The specimens from Island Bay resemble those from St. Clair in the above respect, but differ from those from the other two localities. In the latter the hydrothecae, primary and secondary, are usually almost, if not quite, in a straight line with the internode from the apophyse of which they spring, thus giving the colony a distinct zig-zag appearance. In the Island Bay specimens, however, the apophyse and hydrothecae curve away from the line of the internode, and the succeeding internode is in a straight line with its predecessor, the whole stem thus being straight. (Pl. IV., Fig. 1.) Specimens from all three localities bear gonothecae.

Halecium corrugatissimum, n. sp.

(Plate III., Figs. 1-1*f*.)

Colonies small, attaining a height of about 5 cm. Stem not fascicled, strongly annulated, and divided into very short internodes. Growth irregularly sympodial, the main axis not being produced beyond the primary hydrotheca, immediately below the diaphragm of which spring one, two or three branches, the branching thus being sometimes falsely dichotomous or falsely trichotomous.

The branches do not lie in one plane, but are quite irregular in this respect.

Pedicels expanding upwards, much and deeply corrugated. Hydrothecae large, margins broadly expanded and slightly everted, with a well marked row of dots. Margins or the whole hydrotheca sometimes reduplicated.

Diaphragm fairly well developed, but thin; aperture wide.

Gonothecae borne on short pedicels below the hydrothecae, mainly on the upper part of the colony, ovoid, with from 5 to 7 deep and even annulations; upper part usually devoid of annulations, and more or less hemispherical.

Locality.—St. Clair (Dunedin).

The young hydranth is enclosed by an almost spherical, thin, chitinous ball, which eventually splits away from the hydrophore. Fig. 1*d* shows an example with the splitting process just commenced.

This species is closely allied to *H. speciosum* Nutting (1901, p. 181, pl. xxii., figs. 1, 2).

Halecium expansum, n. sp.

(Plate III., Figs. 2-2*c*; Plate IV., Figs 2-2*b*.)

Colonies small, attaining a height of about 6 mm., main stem either not fascicled or sometimes strengthened by one or two irregular peripheral tubes, irregularly sympodial, the prolongation of the axis often developing quite as strongly as the branch, false dichotomy occasionally met with.

Primary hydrothecae sessile. Secondary hydrothecae with a large basal cavity. Hydrothecae wide, shallow and expanding, with very thick walls, margin never curved outwards. Diaphragm well developed and massive, aperture large. Walls of basal cavity without any marked thickening. Between each hydrotheca and the basal cavity of the hydrotheca above it, a more or less spherical internode, the base of which springs from the inner edge of the diaphragm.

Regenerations of hydrothecae fairly active.

Gonothecae not present.

Locality.—Growing on roots of algae in rock-pools at St. Clair (Dunedin).

The branches are not confined to any particular plane, but are quite irregular in this respect. In the distal parts of some of the colonies the branching is very active, resulting in a bushy mass.

The ring of chitinous "dots" around the hydrothecae are not conspicuous; in fact, I could find them only in a few young hydrothecae that happened to be empty.

Campanulina humilis Bale.

(Plate IV., Figs. 3-3*d*.)

I found numerous specimens of the creeping form of this species growing on other hydroids, polyzoa, and the roots of algae, at St. Clair (Dunedin). After a long search among the material with a view to finding a gonosome, I discovered several branched specimens. These in their mode of branching agree with *Campanulina turrita* Hincks, except that the branching is more active and the hydrothecae consequently more crowded. My specimens are all small, the largest being only 1·35 mm. in height. The stems and branches are all closely annulated, or, sometimes, spirally constricted, throughout.

The specimens are in excellent state of preservation, with many of the polyps fully expanded. There is a web between the tentacles (see Fig. 3*c*), but it extends only a very short distance up.

Unfortunately, no gonothecae were present, so the assignment of the species to the genus *Campanulina* is provisional. Hitherto the species has been known by its creeping form only.

Thyroscyphus simplex (Lamouroux).

Specimens, with gonothecae, from Island Bay. The gonothecae are as described by Bale (1915), except that they are somewhat shorter and broader, their length being from 1·1 mm. to 1·2 mm., and their diameter at the widest part 0·7 mm.

Fam. LINEOLARIIDAE.

Lineolaria flexuosa Bale.

There is a specimen of this small and little known species in the collection of the late Mr. Mulder. It has not hitherto been recorded from New Zealand.

Locality.—Stewart Island.

Fam. SYNTHECIIDAE.

SYNTHECIUM PATULUM (Busk.)

Billard (1925) has united *S. patulum* Busk and *S. orthogonium* Busk under the name *S. patulum*, concluding from his examination of specimens collected by the "Siboga" Expedition that the distinctions pointed out by Bale (1914), namely, the arrangement of hydrothecae, pinnae, and nodes on the hydrocaulus, cannot be relied on to separate the two specifically.

In the absence of gonothecae, I am assigning to this species specimens collected by me at Auckland Harbour and from Stewart Island.

They both differ from Billard's figures in that the orifice of the hydrothecae is very little, if at all, everted. Reduplication of the margin is not common. The measurements of the hydrothecae, however, generally agree with those given by Billard.

	Auckland Specimens.	Stewart Is. Specimens.
Length adnate - - - - -	0·46—0·60 mm.	0·50—0·69 mm.
Length free - - - - -	0·16—0·35 mm.	0·20—0·43 mm.
Diameter at mouth - - - -	0·19—0·21 mm.	0·25—0·32 mm.
Interval between pairs of hydrothecae (measured from adnate part of one to the base of the next above it) - -	0·18—0·50 mm.	0·11—0·34 mm.

Fam. SERTULARIIDAE.

SELAGINOPSIS MONILIFERA (Hutton).

(Plate IV., Figs. 4, 4*a*.)

Bale (1915, p. 266) in his description of this species, under the name of *Selaginopsis dichotoma*, states that the hydrophyton is monosiphonic. All my New Zealand specimens are fascicled.

There is considerable variation in the distance between hydrothecae even in a single specimen; the space occupied by four hydrothecae in the four series (measured from the base of the first to the base of the fifth) varies in my specimens from 0·6 mm. to 1·45 mm. Occasionally, when widely separated, the hydrothecae lose their quadriserial arrangement and all lie in the same plane.

Localities.—St. Clair (Dunedin), Bluff, and Stewart Island.

This species has not hitherto been correctly figured.

Genus **Sertularella.**

Characters.—Hydrothecae with operculum of three or four valves; hydranths with abcaulinary caecum; hydrothecae alternate, opposite, verticillate, or spirally arranged.

The addition of the last three words to the above is rendered necessary by the discovery of *Sertularella irregularis*, n. sp.

One of the characteristics of the genus *Sertularella* is the presence of a more or less developed abcaulinary caecum, or blindsac. From the circumference of this, most markedly at the abcauline side, spring a number of threads a split external ectodermal lamella, according to Kühn which stretch to the wall of the hydrotheca, and hold the caecum in position. In many species, especially, curiously enough, in those in which the caecum is well developed, these threads have no definite points of attachment to the chitin, but appear to be attached only to the layer of ectoderm cells which is left adhering to the inside of the hydrotheca when the young hydranth shrinks away from it. This layer often breaks away, and lies loosely within the hydrotheca, but attached by the threads to the caecum.

In other species these threads have definite points of attachment to the chitin itself, the points of attachment being marked by a number of scars, or, sometimes, chitinous denticles which are usually minute. Occasionally, however, there is a comparatively large denticle at the abcauline side, and sometimes this is the only one that can be detected.

This line of denticles stretches obliquely backwards and downwards around the lower part of the hydrotheca. This line of attachment is the " apparent oblique septum " referred to by Bale (1914, p. 21) in his description of *S. divaricata*.

I have found that the angle at which this ring encircles the hydrotheca is fairly constant in each of the species I have examined, but often differs in closely allied species, and thus gives considerable assistance when in doubt as to which of two species a specimen belongs. For example, in *S. johnstoni* the highest point reached by the ring is about half way up the abcauline side of the hydrotheca; in *S. pygmaea*, which is so closely allied as to be considered by some authorities to belong to the same species, without doubt erroneously, the ring reaches to about one-third of the way up; while in *S. rentoni* it is quite close to the base, and only slightly diagonal.

Sertularella pygmaea Bale.

Specimens, growing on other hydroids, from Bluff.

Sertularella rentoni Bartlett.

(Plate I., Fig. 3.)

I found this species growing in a rock-pool at St. Clair (Dunedin). No gonothecae were present. It has not hitherto been recorded from any other locality than Victoria.

In *S. pygmaea* the line of points of attachment of the caecum is less conspicuous than in *S. rentoni*, and at the front of the hydrotheca is usually much higher up, and runs around it in a more diagonal position. This enables the two species to be separated with ease, even when no gonothecae are present.

Usually the walls of the hydrothecae are thin, but the margin is sometimes slightly thickened, but never to the extent found in the species next described.

SERTULARELLA MACROGONA, n. sp.

(Plate I., Figs. 4-4*d*.)

Hydrocaulus attaining a height of about 1 cm., simple or irregularly branched, branches usually springing from inside a hydrotheca. Hydrocaulus and branches divided by slightly oblique joints into short internodes, each (with an occasional exception) bearing a hydrotheca.

Hydrothecae adnate for about one-third of their height, both series springing from the front, the two planes in which they lie being at about right angles to each other; hydrothecae tubular, smooth, slightly concave in outline on the abcauline side, the adcauline side being ventricose; the margin slightly thickened, especially at the adcauline side; aperture with three broad rounded marginal teeth, one superior, short and comparatively inconspicuous, and two lateral, much longer; no internal submarginal denticles. Operculum of three triangular pieces.

The hydrothecae lie at, approximately, an angle of 45° with the stem, and the aperture is, approximately, at an angle of 45° with the length of the hydrotheca, thus making the aperture at about right angles with the stem.

Gonothecae large, about 4 times as long and 2½ times as broad as the length of a hydrotheca, usually springing from inside hydrothecae, but sometimes borne on the front of the stem just below a hydrotheca, obovate, flattened and slightly depressed just above its widest part, and from the centre of the depression rises a narrow, converging tube with a circular orifice.

Locality.—St. Clair (Dunedin).

Though the branches usually spring from inside a hydrotheca, generally broken, they sometimes arise from the front of the hydrocaulus, just beneath a hydrotheca. One specimen shows a branch springing from inside a broken gonotheca.

The lower part of the hydrocaulus, below the proximal hydrotheca, is deeply and closely annulated or spirally thickened.

This species is allied to *S. rentoni* Bartlett, but differs in many important respects, as will be seen by a comparison of the description of the two species.

The points of attachment of the caecum of the hydranth are in the same position as in *S. rentoni,* and marked in the same way by a faint ridge with minute chitinous processes.

SERTULARELLA PROCERA, n. sp.

(Plate I., Figs. 5-5*d*.)

Colony tall and slender, attaining a height of 22 cm., tapering very gradually towards the apex. Main stem giving rise to a few principal branches of the same structure as itself. Main stem and principal branches fascicled, except in distal parts. Main stem and branches giving rise on all sides to irregularly placed pinnae (the longest of which attain a length of about 1·3 cm.), except at the distal part where the pinnae all lie in the same plane and are more or less regularly alternate.

Pinnae sometimes strengthened in their proximal part by a tube running out from the fascicled stem or branch, but otherwise not fascicled, themselves pinnate or bipinnate, or with somewhat irregular sub-dichotomous ramification; the more regular forms with the sub-pinnae alternate; usually three hydrothecae (including one in the axil) between every two sub-pinnae or sub-dichotomous branches.

Internodes of stem and main branches usually bearing three hydrothecae; those of the pinnae and sub-pinnae bearing only one each. Pinnae not terminating in stolons.

Hydrothecae tubular or sub-conical, both series directed strongly to the front, curved outwards, sometimes somewhat abruptly; margin with three conspicuous teeth, one superior and two lateral, and an operculum of three pieces; no internal submarginal denticles. Points of attachment of caecum of hydranths extending very obliquely across the hydrothecae, reaching to nearly half way up in the front.

Gonothecae borne on the pinnae, large, obovate, surrounded by a number of prominent annular ridges, except on the proximal part of back which is smooth and adpressed to the pinna; distal portion of gonotheca not projecting forward; rising from the centre of the flattened end surrounded by the distal ridge a narrow, long, expanding tube; aperture usually central, rarely slightly eccentric.

The annular ridges on the gonothecae are similar to those of *S. johnstoni* and *S. pygmaea* except that they are somewhat more pronounced and the flange rather wider.

A fenestra is sometimes present at the base of the hydrothecae but more often absent. Similar fenestrae are numerous on the axillary tubes of the stem and branches, often on the abcauline side. Inter-communication between the tubes is frequent. Occasionally bridges like the letter H are met with between tubes not in contact with one another, though how they originate is not clear.

This species is closely allied to *S. divaricata* var. *subdichotoma*. A single pinna or two could not be distinguished from that species, but the manner of growth is altogether different.

Localities.—Bluff, several fine specimens; Stewart Island (J. F. Mulder), fragments.

Sertularella subarticulata (Coughtrey).

(Plate VII., Figs. 7-7*b*.)

Locality.—Bluff, numerous specimens; Stewart Island, growing on "oyster" shells. This species has not hitherto been correctly figured.

SERTULARELLA IRREGULARIS, n. sp.

(Plate V., Figs. 1-1*b*.)

Hydrorhiza somewhat flattened, giving rise to shoots at close intervals.

Hydrocaulus unbranched or sparingly branched, attaining a height of about 5 mm., divided into short internodes each of which bears a hydrotheca.

Hydrothecae not arranged in two series, but in an irregular spiral, every fourth one approximately completing one turn, so that there are three irregular, longitudinal series. Hydrothecae adnate for about one-third of their height, tubular, slightly converging towards the mouth, slightly curved, the adcauline side being convex and the abcauline concave; aperture with three pointed, prominent teeth, one superior and two lateral, and an operculum of three triangular flaps. No internal sub-marginal denticles. Hydranth with about 16 to 20 tentacles, abcaulinary caecum weakly developed.

Gonothecae usually springing from the interior of a hydrotheca, but sometimes from the stem, ovate, marked with about 8 to 10 conspicuous transverse annulations which are not provided with a flange, terminating at the summit in a short tube which is sometimes slightly expanded at the orifice.

Locality.—St. Clair (Dunedin), growing on roots and stems of algae in rock-pools below the swimming pool.

SERTULARELLA CRASSIUSCULA Bale.

I collected specimens of this species, with gonothecae, at Bluff and New Brighton. In most of the hydrothecae in my specimens the marginal teeth are very shallow indeed, and the margin practically entire. Only in a comparatively few cases can I make out the four teeth, which are little more than undulations of the margin.

SERTULARELLA FUSCA, n. sp.

(Plate V., Figs. 2-2*b*.)

Hydrocaulus pinnate, or, occasionally, slightly bipinnate, attaining a height of about 15 mm., divided by oblique joints into internodes each bearing a hydrotheca.

Pinnae alternate, often crowded, one springing immediately below almost every hydrotheca of the hydrocaulus, both series directed in a marked degree to the front, the angle between them usually being 45° or less.

Hydrothecae alternate, both series directed in a marked degree to the distal side, the angle between the two series being usually a little less than 90°, adnate for a third, or less, of their height, constricted and somewhat thickened immediately below the mouth, especially on the adcauline side, where the margin is slightly everted; abcauline side almost straight, adcauline side ventricose; margin with three prominent, rounded teeth, and an operculum of three pieces; three small and often inconspicuous internal submarginal denticles.

Gonothecae not present.

Locality.—St. Clair (Dunedin), in rock-pools below the swimming pool.

In several of the specimens there spring, from immediately below the base of one or more of the proximal hydrothecae,

	S. simplex St. Clair Dunedin	*S. simplex* Auckland Harbour	*S. robusta* var. *quasiplana*
Hydrotheca			
length - - -	0·40 - 0·52	0·42 - 0·54	0·50 - 0·55
greatest diameter -	0·20 - 0·25	0·25 - 0·32	0·29 - 0·33
diameter at mouth (*c*) -	0·14 - 0·20	0·17 - 0·20	0·15 - 0·20
proportion adnate -	⅓ - ½	about ½	about ½
Internode			
length - - -	0·36 - 0·62	0·45 - 0·94	0·55 - 0·82
diameter (*d*) - -	0·15 - 0·20	0·13 - 0·16	0·15 - 0·16
Gonotheca			
length - - -	1·24 - 1·70	?	1·36 - 1·72
diameter - - -	0·60 - 0·83	?	0·77 - 0·90

	S. robusta forma typica (*a*)	*S. angulosa* Bale (*b*)	*S. robusta* var. *flucticulata*
Hydrotheca			
length - - -	0·45 - 0·60	0·57 - 0·60	0·65 - 0·75
greatest diameter -	0·23 - 0·37	0·29	0·34 - 0·37
diameter at mouth (*c*) -	0·16 - 0·22	0·16 - 0·19	0·22 - 0·25
proportion adnate -	⅓	⅓ - ½	about ⅓
Internode			
length - - -	0·45 - 1·00	0·50 - 0·60	0·45 - 0·65 (*e*)
diameter (*d*) - -	0·15 - 0·21	0·17	0·18 - 0·30
Gonotheca			
length - - -	1·95	?	1·60 - 1·92 (*f*)
diameter - - -	1·00	?	1·20 - 1·35 (*f*)

(*a*) Measurements taken from specimens from Bluff and Stewart Island.
(*b*) Measurements taken from Bale's figure.
(*c*) Measured across the narrowest part.
(*d*) Half way between base of hydrotheca and proximal end of internode.
(*e*) Proximal internode of branch often attains 1·10 mm.
(*f*) From robust specimen from Bluff. Other specimens vary from 1·30 mm. × 0·85 mm. to 1·80 mm. × 1·0 mm.

stolons which turn downwards, but not in contact with the stem. In one example one of these reaches the hydrorhiza, and anastomoses with it.

Sertularella simplex-robusta Group.

The New Zealand forms belonging to this group are very difficult to separate from one another. Though *S. simplex* (Hutton), at the one end of the group, and *S. robusta* var. *flucticulata,* n. var., at the other, are so different even to the naked eye that no one could have any difficulty in separating them, there are numerous intermediate forms connecting them, which merge gradually into one another.

One great difference between the two above named is in the size of the hydrothecae, but the table of measurements on the opposite page shows how completely the gaps between them are filled up by other forms. The measurements are in millimetres.

Sertularella simplex (Hutton).

(Plate VI., Figs. 1-1*d,* 2-2*e.*)

Hutton's description (1872) of this species under the name of *Sertularia simplex* is not very full, and could easily include several forms which undoubtedly belong to a distinct species, though where to draw the line between them is not easy to decide. Coughtrey (1874) adds to Hutton's description sufficient further details to fix the typical form more satisfactorily. He, however, includes under this name two other forms, which he figures (1874, pl. xx., figs. 9 and 10), the latter of which he afterwards (1875) describes as a distinct species under the name of *Sertularella robusta.* The second form he describes as having faint, shallow grooves, generally three in number, that cross the hydrotheca.

It is very difficult indeed to decide to which species some of the forms in my collection belong, as there are so many intermediate forms, differing from one another in small details, but all of them having the general characteristics of the typical form.

The figure and description given by Bale (1924) may be taken as illustrating the typical form of the species. The hydrothecae of the specimens collected by me at the entrance to Auckland Harbour agree with his figure and description, but, though it was the most common species on the beach, I failed to find a gonotheca.

Hutton (1872) says "Hydrothecae distant," and many of my specimens agree with this. There is, however, considerable variation in this respect even in a single colony. Figs 1 and 1*a* are drawn from two shoots springing from the same hydrorhiza, and illustrate how considerable the variation may be.

The hydrorhiza anastomoses very freely; and my Auckland specimens show a considerable number of single hydrothecae growing from the hydrorhiza. No doubt they are the beginnings of new shoots which would ultimately develop, but in their present form they remind one forcibly of Allman's untenable genus

Calamphora. The hydrorhiza in these specimens is not flattened to any appreciable extent.

Specimens growing in tide pools at St. Clair (Dunedin) differ somewhat from the former, the hydrothecae being smaller, and usually directed more to the front, and slightly less of it being adnate. The gonothecae are also different from the typical form as figured by Bale, inasmuch as the tubular neck is absent. They have four conical projections at the summit, but these are not well developed. (See Fig. 2*c*.) The difference between the two forms is not sufficient to warrant the constitution of a new species in the case of such a variable hydroid as the present.

Stechow (1923) has figured quite a number of species belonging to this group, all of which have four external teeth and three internal submarginal denticles, as having one superior, one inferior, and one lateral internal denticle. I feel sure, however, that he has done this inadvertently. Bale describes the denticles as being "two within the two upper emarginations of border, and the third below inferior marginal tooth," and, in all probability, this is the arrangement of the internal denticles in all species having four teeth and three internal denticles. Plate VI., Fig. 1*d*, shows the appearance, when looking straight into the aperture, of the hydrotheca. The external teeth are not apparent in this figure, as they face directly towards the observer, but their position is indicated by the angles at the bases of the triangular flaps of the operculum, *a* and *b* representing the positions of the superior and inferior marginal teeth respectively, and *c* and *d* those of the lateral.

Hutton says in his original description that this species is "simple or rarely branched." I have a small branched specimen from St. Clair that I consider belongs to this species. It shows considerable variation both in the length of the internodes and in the manner in which the hydrothecae lie. In some shoots both series project to the front in a marked degree; in others the two series lie almost in the same plane. In this specimen the gonothecae differ somewhat from those already described, being, as a rule, narrower. None of them possesses more than three projections at the summit. (See Figs. 2*b*-2*d*.)

All the above described forms have the hydrothecae entirely destitute of any transverse undulations, and I consider that the forms with undulated hydrothecae should not be assigned to this species.

Sertularella robusta Coughtrey.

(Plate VI., Figs. 3-3*c*.)

Of the three forms originally assigned by Coughtrey to *Sertularia simplex* I include under the present species those figured by him (1874, pl. xx., figs. 9, 10). He included only Fig. 10 under the name *Sertularia robusta,* apparently leaving Fig. 9 as *Sertularia simplex*. These are what he refers to as the "several pigmy varieties in which the hydrothecae are transversely wrinkled." I take it that the word 'pigmy' here refers to the height of the colony, and not to the size of the hydrothecae, because reference to his figures shows that the hydrothecae of Fig. 9 do not differ appreciably in size from those he figures as the typical form (Fig. 8). In his Description of Plate he says, "All objects magnified 50 diameters except where otherwise specified." This, as Mr. Bale has pointed out to me, is obviously incorrect. The length of a hydrotheca of the typical form, in my collection, of *S. simplex*, which varies very little from that figured by Bale, is about 0·5 mm. Assuming that the hydrothecae of the typical form of *S. simplex* as figured by Coughtrey are about the same length, his figures of *S. simplex* and its variety *S. robusta* cannot be magnified more than about 18 diameters.

I have endeavoured to separate the forms with undulated hydrothecae into more than one species, but, although the large and small forms differ very considerably from one another in size and general appearance, I have so many intermediate forms that I am unable to do so satisfactorily, and must be content for the present in describing as varieties certain forms that differ somewhat from the typical form. At first it seemed that there was a decided gap between the largest of the small forms and the smallest of the large, but this is filled by *Sertularella angulosa* Bale (1893, p. 102, pl. iv., fig. 6), which, I think, must be regarded as a variety of *S. robusta* (*Sertularella robusta* var. *angulosa*). In the smaller forms the hydrothecae are about 0·5 mm. in length, and differ from *S. simplex* in having transverse ridges. In *S. angulosa* the hydrothecae are about 0·6 mm. in length. In this form the stem is zig-zag. In many of my New Zealand specimens also the stem is zig-zag (though most of them are almost, if not quite, straight), and one specimen so closely resembles Bale's figure as to leave no doubt whatever in my mind concerning the identity of the species.

As it is quite impossible to say definitely which form Coughtrey had before him and used as his type of *S. robusta*, I am assuming that it was the more common form, and not either of the varieties I am describing under the names of var. *quasiplana* and var. *flucticulata*. Both of these are comparatively rare, while the common form is so plentiful that Coughtrey could not possibly have missed it.

The full description of a typical specimen of *Sertularella robusta* is as follows:—Shoots simple, attaining a height of 10 mm., divided by slightly oblique joints into internodes which vary considerably in length, each bearing a hydrotheca on its upper part. Hydrothecae adnate for about one-third of their height, large, divergent, barrel-shaped, but smaller towards the summit, usually more ventricose on the adcauline than the abcauline side, with about six distinct sharp, transverse ridges, completely surrounding them, but usually becoming less distinct on the abcauline side; aperture expanding, with four well-defined teeth, aperture sometimes at about right angles to the length of the hydrotheca but often with the inferior tooth projecting further than the others; three internal, compressed, vertical, submarginal denticles, two of which are within the two upper emarginations of the border, and the third opposite the inferior marginal tooth.

Gonothecae large, borne sometimes on the hydrocaulus and sometimes on the hydrorhiza, ovate, with several distinct cross undulations, upper part sometimes in the form of a tubular neck, which, however, is not always distinctly present; summit usually with about four conical projections.

Locality.—Bluff, and on "oyster" shells from Stewart Island. I have already referred to the single hydrothecae that are found on the hydrorhiza of *S. simplex*. In the present species single hydrothecae are also met with quite commonly, and remind one even more forcibly of Allman's genus *Calamphora*.

Sertularella robusta var. quasiplana, n. var.

(Plate VI., Figs. 4, 4*a*.)

I have separated *S. robusta* from *S. simplex* on account of the presence in the latter and the absence in the former of transverse undulations on the hydrothecae. The present form seems to be on the border line. At first sight it looks like a rather robust form of *S. simplex*, but closer examination reveals the presence of three or four transverse rugae completely surrounding the hydrotheca. It is true they are often rather faint; in fact, in some hydrothecae, such as the one figured, they would be likely to be overlooked but for the presence of minute diatoms which grow thickly along the shallow depressions between the ridges. This variety differs from the others not only in the above respect, but also in having the hydrothecae usually broader at the base, in proportion to their height, than the others. They are often adnate for as much as one-half of their height. In some specimens I have found the superior tooth projecting slightly more than the others, but usually the mouth is at right angles to the length of the hydrotheca. The teeth are, as in the typical form, well defined. My specimens attain a height of 13 mm.

The gonothecae do not differ from the typical form in any important particular. They are, however, somewhat larger.

Locality.—Island Bay.

Sertularella robusta var. flucticulata, n. var.

(Plate VI., Figs. 5, 5*a*.)

This variety differs from the others mainly in its much greater size in all its parts, and only for the existence of *S. angulosa* Bale (1893, p. 102, pl. iv., fig. 6), I would have no hesitation in ranking it as a distinct species. The rugae appear like little waves on the adcauline side (hence the proposed name of the variety), but rarely extend more than half way round the hydrotheca, the abcauline side being almost, if not altogether, free from undulations. The internal submarginal denticles are very large and well developed, but form very thin vertical plates. Usually the mouth of the hydrotheca is not at right angles to its length, the inferior tooth projecting considerably more than the others. The teeth are rarely well developed, and are often no more than a slight wave in the otherwise entire but oblique peristome.

The gonothecae are broader than those found on the other varieties, and are borne on stem and branches.

Unlike the other forms belonging to this species the hydrophyton branches rather freely, but the branching is quite irregular. There is considerable variation in the length of the internodes, even in the same colony. In one specimen they vary from 0·45 mm. to 0·85 mm.

Locality.—Bluff.

Thuiaria farquhari Bale.

(Plate VII., Fig. 4.)

A fine specimen of this species collected at Bluff densely clothes the stem of an ascidian for several inches.

Thuiaria buski Allman.

(Plate VII., Figs 1-1*c*.)

Hydrocaulus not fascicled, attaining a height of about 3 inches (*fide* Allman), straight or almost so, unbranched, pinnate. Stem usually thick, divided by slightly oblique nodes into internodes of variable length, each bearing from 1 to 5 pairs of hydrothecae. Pinnae irregular, usually with a tendency to alternate disposition, rarely opposite, stout, divergent at nearly right angles, borne on slender apophyses from which they are separated by a rather oblique, conspicuous node; usually divided into 2 or 3 long internodes each bearing from 4 to 8 (sometimes up to 11) pairs of hydrothecae; nodes oblique, very rarely transverse.

Hydrothecae in pairs, strictly opposite both on hydrocaulus and pinnae, adnate in front, widely separated behind, most of their length vertical, upper portion turned outward and narrowed, aperture vertical, widened laterally, with two lateral lobes, facing outward and forward; edge of peristome thin, especially on the adcauline side, where the sinus between the lateral lobes is filled up by a very thin prolongation of the wall of the hydrotheca; sometimes a slight broad internal thickening of the perisarc just inside the peristome on the abcauline side, but no well developed internal denticle.

Pairs of hydrothecae usually closely approximated, sometimes actually touching, on the pinnae; more separated on the hydrocaulus.

Gonothecae borne on the front of the pinnae, near the base of same, ovoid, about 2·5 mm. in length, aperture round, entire, on a very short neck.

Colour of perisarc, dark brown.

Locality.—Island Bay and Bluff.

Allman's (1876) description and figures of this species are faulty. He describes and figures the pinnae as being divided into short internodes, each of which bears a single pair of hydrothecae only, and his figure shows the joints as being transverse. At Mr. Bale's request Captain A. K. Totton, M.C., of the British Museum (Natural History), has examined Allman's type, and in a letter, which the former has kindly placed at my disposal, writes as follows:—" The successive pairs of hydrothecae on the type of *D. buskii* are closely approximated though not quite touching, but there is *not* a node between each pair. It would be unwise to say more about the nodes than this, because the type specimen is a poor one, very imperfect and much overgrown."

In my experience nodes in the pinnae of Sertulariidae are never found in the position shown in Allman's figure, immediately above the base of the hydrothecae. The explanation of his mistake is doubtless that he examined a pinna lying approximately in the position shown in my Fig. 1*c*, and mistook for a node the base of the hydrotheca on the further side of the pinna. In his Fig. 4 an oblique view of the pinna is shown. His Fig. 7 is a lateral view, not " oblique," as he calls it. This is borne out by the relative distances between the hydrothecae and the back of the pinnae. The importance of this is that if his Fig. 4 showed a true lateral view of the pinna, the distance by which the hydrothecae are separated at the back would be greater than it really is. I have searched my material for a transverse node such as he shows, but find that transverse nodes in this species are very rare, and when present occur, as one would expect, above the adnate part of the hydrothecae. Allman's figure would make them occur behind the adnate part.

In all my specimens the colour of the perisarc is very pale horn.

This species is allied to *T. bicalycula*, but differs from it in several respects, the most striking of which are that in the latter the hydrocaulus is much stouter and consequently the hydrothecae on it are far more widely separated at the back, these hydrothecae are not spaced regularly and not always in pairs, the apophyses are much stouter and are not separated from the pinnae by a conspicuous node, and on the pinnae of the latter species the pairs of hydrothecae are not placed so closely together.

Thuiaria buski var. tenuissima, n. var.

(Plate VII., Fig. 2.)

Specimens from Island Bay and Bluff, attaining a height of 35 mm., differ sufficiently from the typical form to be ranked as a distinct variety. The whole hydrophyton is more slender, the hydrocaulus being little, if at all, thicker than the pinnae and scarcely distinguishable from it in arrangement of the hydrothecae. The hydrothecae are somewhat smaller and the pairs are not so closely approximated. The hydrocaulus and pinnae being narrower, the hydrothecae are not so widely separated at the back. The pinnae are much shorter than those of the average specimen of the typical form, and the node between pinna and apophyse is more oblique. The apophyses are much longer and more slender. To the eye this variety closely resembles Allman's natural size figure of *T. buski* (Allman, 1876, pl. xiv., fig. 3).

Gonothecae not present.

Thuiaria spiralis, n. sp.

(Plate VII., Figs. 3-3*e*.)

Hydrocaulus attaining a height of 16 cm., arranged in a loose but fairly regular spiral, sparingly branched, pinnate. Stem thick, fistulous, divided by slightly oblique joints into internodes, each bearing from 1 to 5 pairs of hydrothecae. Pinnae quite irregular, occasionally opposite, stout, divergent usually at an angle of 60° or more, borne on short stout apophyses from which they are separated by a conspicuous oblique node; pinnae themselves giving rise to secondary pinnae borne on similar but somewhat more slender apophyses; pinnae and secondary pinnae stout, usually divided by slightly oblique nodes into internodes, each bearing from 1 to 7 (sometimes up to 11) pairs of hydrothecae, but sometimes undivided.

Hydrothecae in pairs, strictly opposite, in contact in front, widely separated at the back, especially those on the hydrocaulus, most of their length vertical, upper portion turned outward and forward, and narrowed; aperture vertical, widened laterally, with two lateral lobes; edge of peristome thin, especially on the adcauline side in the sinus between the lateral lobes, slightly thickened just inside the abcauline side, but with no well developed internal denticle.

Pairs of hydrothecae fairly closely approximated on the pinnae, but widely separated on the hydrocaulus.

Colour of perisarc, dark brown.

Gonothecae borne on the front of the pinnae, near the base of same, large, ovoid, about 2·5 to 2·7 mm. in length, and 1·1 to 1·3 mm. in diameter; aperture round, entire, on a very short neck, scattered, vertically flattened, irregular denticles sometimes projecting into the interior round the neck, but not always present.

The spiral habit and dark colour of this species at once makes it easily distinguished from *T. buski* and *T. bicalycula*, to which it is allied. It also differs from the latter in the regular arrangement of the hydrothecae on the hydrocaulus, and the oblique joints between the pinnae and the apophyses. The hydrothecae on the pinnae are not so closely approximated as in *T. buski*.

The pinnae, following the twisting of the hydrocaulus, are given off in all directions, and do not lie in a single plane. The cauline hydrothecae also spirally follow the twisting of the hydrocaulus.

Sertularia episcopus (Allman).

I found specimens of this species growing profusely over algae washed ashore at Island Bay.

Sertularia fasciculata (Kirchenpauer).

I collected a specimen of this species at Island Bay, and another at Bluff.

Sertularia bispinosa (Gray).

A specimen of this species is in the collection of the late Mr. J. F. Mulder, but the locality is not stated. The gonothecae contain a ring of tiny internal denticles. One of the gonothecae is totally destitute of "shoulders."

Sertularia trispinosa Coughtrey.

(Plate V., Fig. 3.)

I found numerous specimens, with gonothecae, at St. Clair (Dunedin), and Bluff.

Attention has been drawn (Mulder and Trebilcock, 1914, p. 38) to the presence of a tiny aperture, from which sometimes protrudes a short and delicate tube, in the perisarc of the infrathecal chamber of *S. minima*, *S. minuta*, and allied species. This aperture is also found in a similar position in *S. trispinosa*, but in no case can I find any trace of a tube. In this species I have noticed protruding from the aperture a small mass of (?) protoplasm, but whether it is a sarcostyle or not I am unable to determine, as the soft parts of my specimens of this species are not in sufficiently good state of preservation.

In most cases in *S. trispinosa* these apertures are missing, and, when present, I have not found them paired.

Stechow treats these structures as nematophores, and creates a new genus *Nemella* for the reception of the species possessing them.

Sertularia trispinosa var. inarmata, nov.

(Plate V., Fig. 4.)

A specimen, collected by me at Island Bay, having a large number of shoots, differs from the typical form in its gonothecae which are totally destitute of "horns" or even "shoulders." At first I felt disposed to treat it as merely an accidental variation, especially as in some instances there is a slight irregularity in outline of the gonothecae at the spot usually occupied by the "horns."

However, after examining the whole of the gonothecae, of whieh there are a considerable number, and among which I find no exception, I have come to the conclusion that the difference is sufficient to warrant this form being named as a distinct variety.

In the trophosome the variety does not differ in any respect from the typical form.

SERTULARIA MINIMA Bale.

(Plate VII., Figs. 5, 5*a*.)

I have specimens of this speeics from Island Bay (Wellington), St. Clair (Dunedin), and Bluff. In specimens from all three localities the tiny apertures and tubes are found springing from the infrathecal chambers. In many of the specimens from St. Clair two apertures and tubes are found instead of onc, and similar structures are also found on the hydrorhiza, but in the latter case the tubes are much longer.

Two apertures, with tubes, are also found in some of the Bluff specimens. In the latter the gonothecae sometimes have and sometimes are without the internal submarginal denticles.

The Island Bay specimens belong to the variety *pumiloides*.

SERTULARIA DIVERGENS Busk.

A few specimens of this species were growing on an " oyster " shell from Stewart Island. " *Tridentata xantha* " Steehow (1923*a*, p. 64; 1925, p. 236, fig.) does not belong to this species, but is probably a young form of *Sertularia unguiculata* Busk.

SERTULARIA UNGUICULATA Busk.

I collected specimens of this species at St. Clair and Bluff, those from the latter locality having gonothecae. They do not differ in any respect from the average Victoria speeimen.

DYNAMENA QUADRIDENTATA (Ellis and Solander).

A few fragmentary specimens of this speeies from " oyster " shells from Stewart Island are in the colleetion of the late Mr. J. F. Mulder. Not hitherto recorded from New Zealand.

STEREOTHECA ELONGATA (Lamouroux).

Bale (1924) states that " specimens from Lyttelton, in Professor Chilton's collection, do not differ in any respect from the small form abundant on the southern Australian eoast." My New Zealand specimens, on the contrary, whieh I collected at Island Bay, St. Clair (Dunedin) and Bluff, belong to the larger variety, and most of them are more robust than the average large southern Australian specimens, and usually branch more freely.

Fam. PLUMULARIIDAE.

Plumularia pulchella Bale.

I collected a single specimen of this small species, with gonothecae, growing on *Stereotheca elongata*, at Bluff. It differs in no respect from the form usually found on the Victorian coast. As in the Victorian specimens, the gonothecae are of two sizes, one about twice the length of the other. Possibly they are of different sexes, but in the absence of gonangial contents I am unable definitely to decide that point. This species has not hitherto been recorded from New Zealand.

Plumularia setacea (Linn.).

I collected numerous specimens of this species at St. Clair and Island Bay.

Plumularia setaceoides Bale.

I collected numerous specimens of this species, with gonothecae, at Island Bay, St. Clair (Dunedin), and Bluff. It has not hitherto been recorded from New Zealand. The specimens do not differ materially from the average specimen from Victoria.

I have considerable doubt whether *Plumularia wilsoni* Bale (1926), (=*P. delicatula* Bale, not Busk, not Quelch) is specifically distinct from *P. setaceoides*, but must examine further specimens of *P. wilsoni* in a well preserved condition before coming to a definite conclusion. Some of my specimens from Island Bay, which had been washed ashore and dried, cannot be distinguished from the last named species, though others were undoubtedly *P. setaceoides*.

Plumularia hyalina Bale.

(Plate VI., Fig. 6.)

I collected specimens of this species at St. Clair, Island Bay, and Bluff. It has not hitherto been recorded from New Zealand.

This species has always been looked upon as possessing pinnae each bearing essentially a single hydrotheca only, and would thus be placed in Nutting's genus *Monotheca*. The better opinion seems to be that the retention of this genus is not warranted. In specimens collected at St. Clair and Island Bay I find an additional argument in favour of this view. Several of the pinnae bear two hydrothecae each, and are divided, like a typical *Plumularia*, into alternate long and short internodes, the former each bearing a hydrotheca, one median inferior and two lateral superior sarcothecae, and the latter each bearing a single median sarcotheca only.

The retention of the genus *Monotheca* would doubtless be very convenient, but the existence of forms such as the above is a strong argument against it.

THECOCAULUS MINUTUS, n. sp.

(Plate VII., Figs. 6, 6*a*.)

Hydrocaulus attaining a height of about 5 mm., not fascicled, unbranched, lower part usually destitute of appendages, remainder divided into alternate hydrothecate and non-hydrothecate internodes, the latter usually short. Pinnae, the proximal two usually opposite, the remainder alternate, bearing from one to three hydrothecae, divided into alternately long and short internodes of which only the former bear hydrothecae.

Hydrothecae free for two-thirds of their length, campanulate, longer than broad, broad at base, slightly constricted at the rear near the margin; margin smooth, circular slightly everted at the rear.

Sarcothecae bithalmic, canaliculate, narrow at base, one median below each hydrotheca, and a pair of laterals above it, one median on each intermediate internode of stem and pinnae, and sometimes one median above the caulinary hydrothecae, on the upper part of the hydrothecate internodes.

The pinnae are each borne on a prominent apophyse, which springs from beside each caulinary hydrotheca.

The first internode, and somtimes the second, are short, and bear no appendages. The intermediate internodes, both on the stem and pinnae, vary in length, but are usually short. Sometimes on the stem two intermediate internodes are found in succession.

The joint above each intermediate internode, both on stem and pinnae, is oblique.

The lateral sarcothecae rise to about the level of the margin of the hydrotheca. Gonosome, not present.

Locality.—St. Clair (Dunedin).

THECOCAULUS HETEROGONA Bale.

Mr. Bale has kindly sent me a specimen of this interesting species. In the axil at the back of each hydrotheca there is a sarcostyle protected by an extremely delicate, monothalmic, rudimentary, bract-like sarcotheca, shaped something like the terminal half of the bowl of a spoon. These sarcothecae are difficult to detect anywhere, but particularly so on the pinnae; in fact, I could distinguish them there in only a few instances.

AGLAOPHENIA ACANTHOSTOMA Allman.

I collected several specimens of this species at Bluff and St. Clair (Dunedin).

AGLAOPHENIA LAXA Allman.

(Plate V., Figs. 5-5*b*.)

I collected numerous specimens of this species with corbulae at Island Bay. The largest specimen attains a height of nearly 60 mm. In my specimens the teeth of the hydrothecae are more rounded than shown by Bale (1924, p. 260, fig. 15).

There are two forms of this species represented in my collection, one with the hydrocladia lax, there being about 26 to the cm., the other with close-set hydrocladia, as many as 46 to the cm. In general appearance these two forms are so different as to lead one at first to the conclusion that they belong to different species, but, apart from the distance between hydrocladia I can detect no difference between them, and, as the length of the hydrocladial internodes varies in some specimens, there is little doubt that examination of a large number of specimens would reveal intermediate forms connecting these two extremes.

Bale's conjecture that the gonosome, when found, would prove to be of the same character as in *A. acanthocarpa* and *A. divaricata* I find to be correct.

THECOCARPUS FORMOSUS (Busk) var. INARMATUS, nov.

(Plate V., Figs. 6, 6*a*.)

I was fortunate in collecting a number of specimens of this apparently rare species at Island Bay. M. Billard, to whom I submitted specimens, has kindly compared them with his specimens from Madagascar, and writes me as follows:—

> "Malgré des différences, je crois qu'il s'agit de la même espèce. Dans vos échantillons, seule la dent latérale adcaulinaire est bifurquée à tel point même qu'elle apparaît comme en formant deux; les deux autres situées du côté de la médiane ne le sont pas du tout. Je dois dire que mon dessin représente un cas extrême et que dans toutes les hydrothèques les dents latérales voisines de la médiane ne sont pas toujours aussi franchement bifurquées; le dessin de Marktanner donne un cas intermédiaire entre ce qui existe chez mes exemplaires africains et vos exemplaires néo-zélandais. Dans ceux-ci j'ai noté le plus faible développment du repli intrathécal et du processus spiniforme médian. Dans les échantillons que vous possédez, les hydroclades sont-ils terminés par une épine ayant à sa base une dactylothèque? Je n'ai pas observé ce détail dans les spécimens que j'ai reçus. Il-y-aurait lieu je crois de faire de la forme néo-zélandaise une variété distincte."

Billard's letter leaves little for me to add in the description of this variety. In none of my New Zealand specimens are the hydrocladia terminated in a spine.

The median spiniform processes of the hydrothecae are hollow, and vary considerably in size.

Gonosome, not present.

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EXPLANATION OF PLATES.

PLATE I.

Fig. 1.—*Saaba* (?) *scandens*, n. sp. ×15.
 1*a*. Gonangium (?) of same. ×15.

Fig. 2.—*Orthopyxis formosa*, n. sp.
 2. Showing flanged hydrorhiza, renovation of stem, and broad view of hydrotheca. ×20.
 2*a*. Another hydrotheca, broad view. ×20.

- 2*b*. The same, narrow view. ×20.
- 2*c*. A large hydrotheca, with renovated margin. ×20.
- 2*d*. A thin walled specimen, showing hydranth. ×20.
- 2*e*. Transverse section through perisarc of stem, showing flattening and thickening. ×20.

Fig. 3.—*Sertularella rentoni* Bartlett. ×70.

Fig. 4.—*Sertularella macrogona*, n. sp.

- 4. Typical specimen. ×20.
- 4*a*. Front view. ×70.
- 4*b*. Side view. ×70.
- 4*c*. Hydrotheca, showing operculum. ×70.
- 4*d*. Gonotheca. ×15.

Fig. 5.—*Sertularella procera*, n. sp.

- 5. Part of typical colony. ×½.
- 5*a*. Part of pinna. ×35.
- 5*b*. The same showing fenestrae. ×35.
- 5*c*. A hydrotheca from the hydrocaulus. ×35.
- 5*d*. Gonotheca. ×15.

Plate II.

Fig. 1.—*Orthopyxis delicata*, n. sp.

- 1-1*d*. Hydrothecae, showing variation in size. ×50.
- 1*a*. Showing renovation of margin. ×50.
- 1*e*. Gonangium. ×15.
- 1*f*. Hydrotheca, viewed from above. ×50.

Fig. 2.—*Perisiphonia quadriseriata*, n. sp.

- 2. Complete specimen. ×½.
- 2*a*. Part of hydrocaulus and of one hydrocladium and the base of another, dissected after maceration in liquor potassi, showing part of three peripheral tubes. ×35.
- 2*b*. Part of hydrocladium, broad view. ×35.
- 2*c*. The same, narrow view. ×35.
- 2*d*. Three sarcothecae. ×110.

Plate III.

Fig. 1.—*Halecium corrugatissimum*, n. sp.

- 1. Complete colony, showing method of branching. ×15.
- 1*a*. Two hydrothecae. ×70.
- 1*b, c*. Hydrothecae, showing reduplication of hydrothecae. ×70.
- 1*d*. Young hydrotheca. ×70.
- 1*e*. Hydrotheca and gonotheca. ×70.
- 1*f*. Hydrotheca, ×110, to show thinness of perisarc.

Fig. 2.—*Halecium expansum*, n. sp.

- 2. Complete colony, showing method of branching, with hydranths, one of them young. ×15.

2*a*. The same species, showing normal method of branching. ×50.
2*b, c*. Hydrothecae. ×110.

Fig. 3.—*Halecium lenticulare*, n. sp.
3. Complete colony, showing method of branching and position of gonothecae, the proximal one of which has been twisted on its stalk to show broad aspect. ×15.
3*a*. An example of vigorous reduplication of hydrotheca. ×15.
3*b, c*. Examples of irregular branching. ×35.
3*d*. Male gonotheca. ×15.

Plate IV.

Fig. 1.—*Halecium lenticulare*, n. sp.
1. Specimen from Island Bay. ×35.
1*a*. Specimen from St. Clair. ×50.
1*b*. Specimen from Bluff, showing delicate diaphragm, and reduplication of margin of hydrotheca. ×110.

Fig. 2.—*Halecium expansum*, n. sp.
2. Distal part of a colony, with hydranths, showing crowded state of hydrothecae. ×50.
2*a*. Another example of active branching. ×50.
2*b*. An example of unusually active renovation of hydrothecae. ×50.

Fig. 3.—*Campanulina humilis* Bale.
3. Simple form. ×50.
3*a, b*. Branched form, showing hydranths. ×50.
3*c*. Base of four tentacles, showing web. ×360.
3*d*. Tip of tentacle, showing nematocysts. ×360.

Fig. 4.—*Selaginopsis monilifera* (Hutton). ×15.
4*a*. A young hydrotheca of same, showing three-toothed margin. ×35.

Plate V.

Fig. 1.—*Sertularella irregularis*, n. sp. ×50.
1*a, b*. Gonothecae of same. ×35.

Fig. 2.—*Sertularella fusca*, n. sp. × 35.
2*a*. Another view of same. ×35.
2*b*. Hydrotheca. ×50.

Fig. 3.—*Sertularia trispinosa* Coughtrey, showing pore (*a*) in infrathecal chamber. ×50.

Fig. 4.—*Sertularia trispinosa* var. *inarmata*, n. var. Gonotheca. ×15.

Fig. 5.—*Aglaophenia laxa*. Allman. ×110.
5*a*. Hydrotheca, viewed from the front. ×110.
5*b*. Adcauline part of top of hydrotheca. ×200.

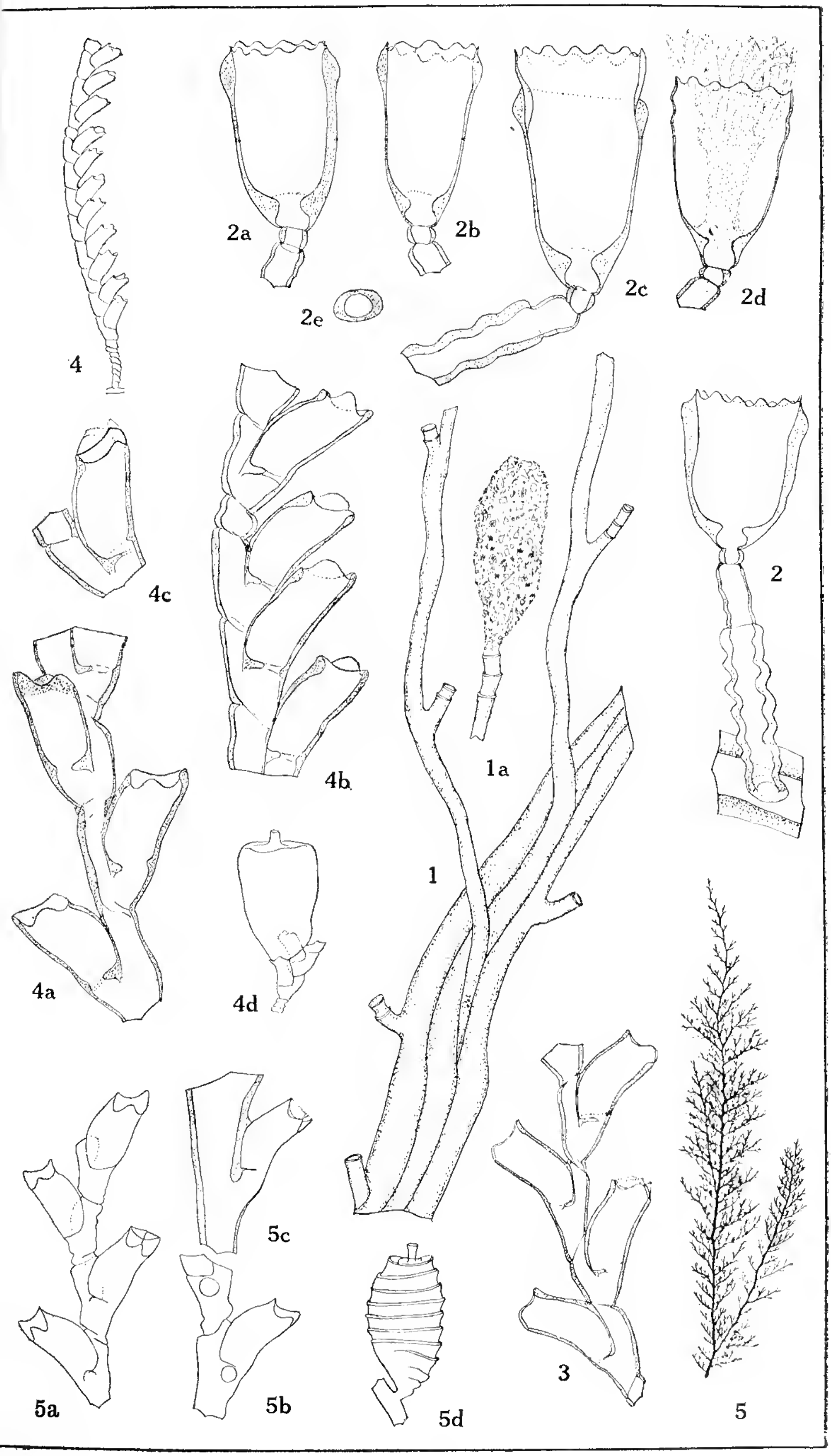
Fig. 6.—*Thecocarpus formosus* (Busk) var. *inarmatus,* nov. ×110.
6*a*. Front view of hydrotheca. ×110.

PLATE VI.

Fig 1.—*Sertularella simplex* Hutton. (Loc. Auckland.)
1, 1*a*. Specimens taken from same hydrorhiza. ×15.
1*b*. Typical hydrotheca. ×35.
1*c*. Single hydrotheca growing from hydrorhiza. ×35.
1*d*. Mouth of hydrotheca viewed from above, showing operculum, internal denticles, and position of (*a*) superior, (*b*) inferior, and (*c* and *d*) lateral teeth. ×50.
Fig. 2.—*Sertularella simplex* Hutton. (Loc. Dunedin.)
2. Part of hydrocaulus, showing unusual anastomosis. ×35.
2*a*. Hydrotheca from specimen with unusually massive walls. ×35.
2*b-e*. Gonothecae, showing extent of variation. ×35.
Fig. 3.—*Sertularella robusta* Coughtrey.
3. Typical hydrotheca from Island Bay. ×35.
3*a*. Typical hydrotheca from Bluff. ×35.
3*b*. Single hydrotheca growing from hydrorhiza, front view. (Loc. Bluff.) ×35.
3*c*. Gonotheca. (Loc. Island Bay.) ×15.
Fig. 4.—*Sertularella robusta* var. *quasiplana,* n. var. (Loc. Island Bay.) ×15.
4. Typical hydrotheca. ×35.
4*a*. Gonotheca. ×15.
Fig. 5.—*Sertularella robusta* var. *flucticulata,* n. var.
5. Branched form with gonothecae. ×20.
5*a*. Typical hydrothecae. ×42.
Fig. 6.—*Plumularia hyalina* Bale, showing hydrocladium bearing more than one hydrotheca. ×50.

PLATE VII.

Fig. 1.—*Thuiaria buski* (Allman). (Loc. Island Bay.)
1. Part of average pinna. ×15.
1*a*. Pinna without joints, side view. ×15.
1*b*. Part of pinna with two kinds of nodes, side view. ×15.
1*c*. Part of pinna showing both series of hydrothecae. ×15.
Fig. 2.—*Thuiaria buski* var. *tenuissima,* n. var. ×15.
Fig. 3.—*Thuiaria spiralis,* n. sp.
3. Distal half of type specimen. Nat. size.
3*a*. Part of hydrocaulus showing spiral arrangement of hydrothecae. (The hydrocaulus has been straightened in the drawing to economize space.) ×15.



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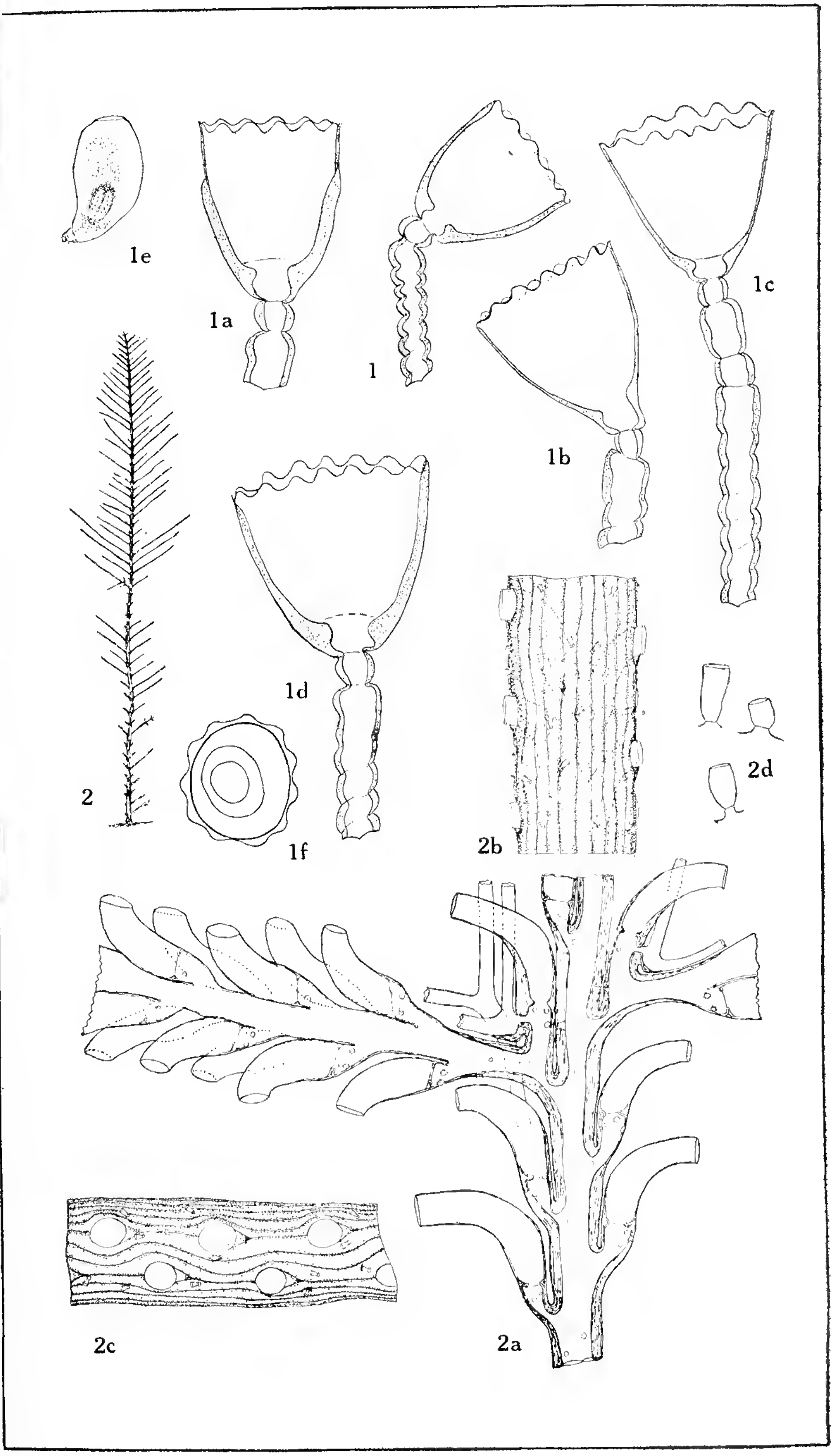

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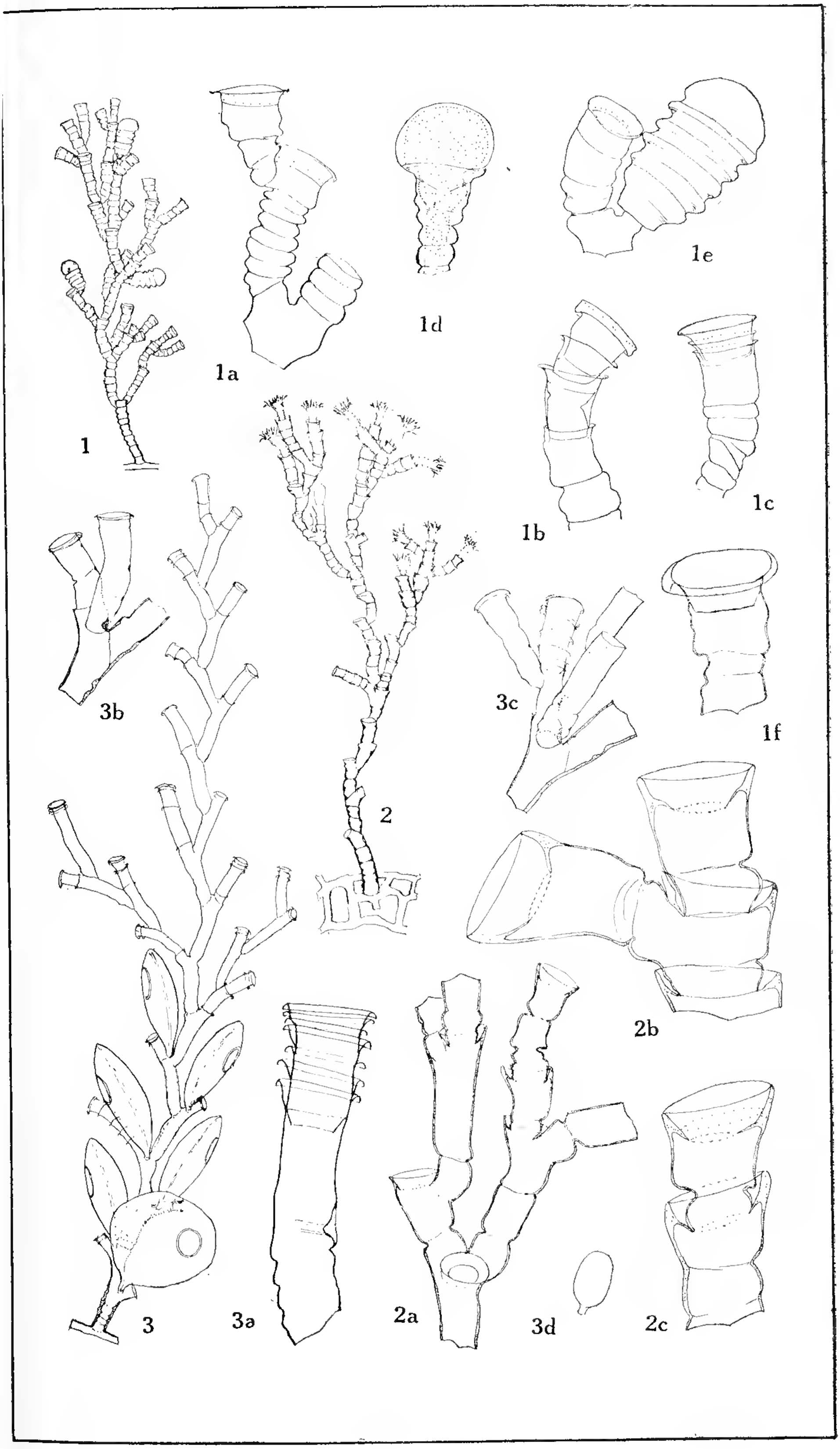

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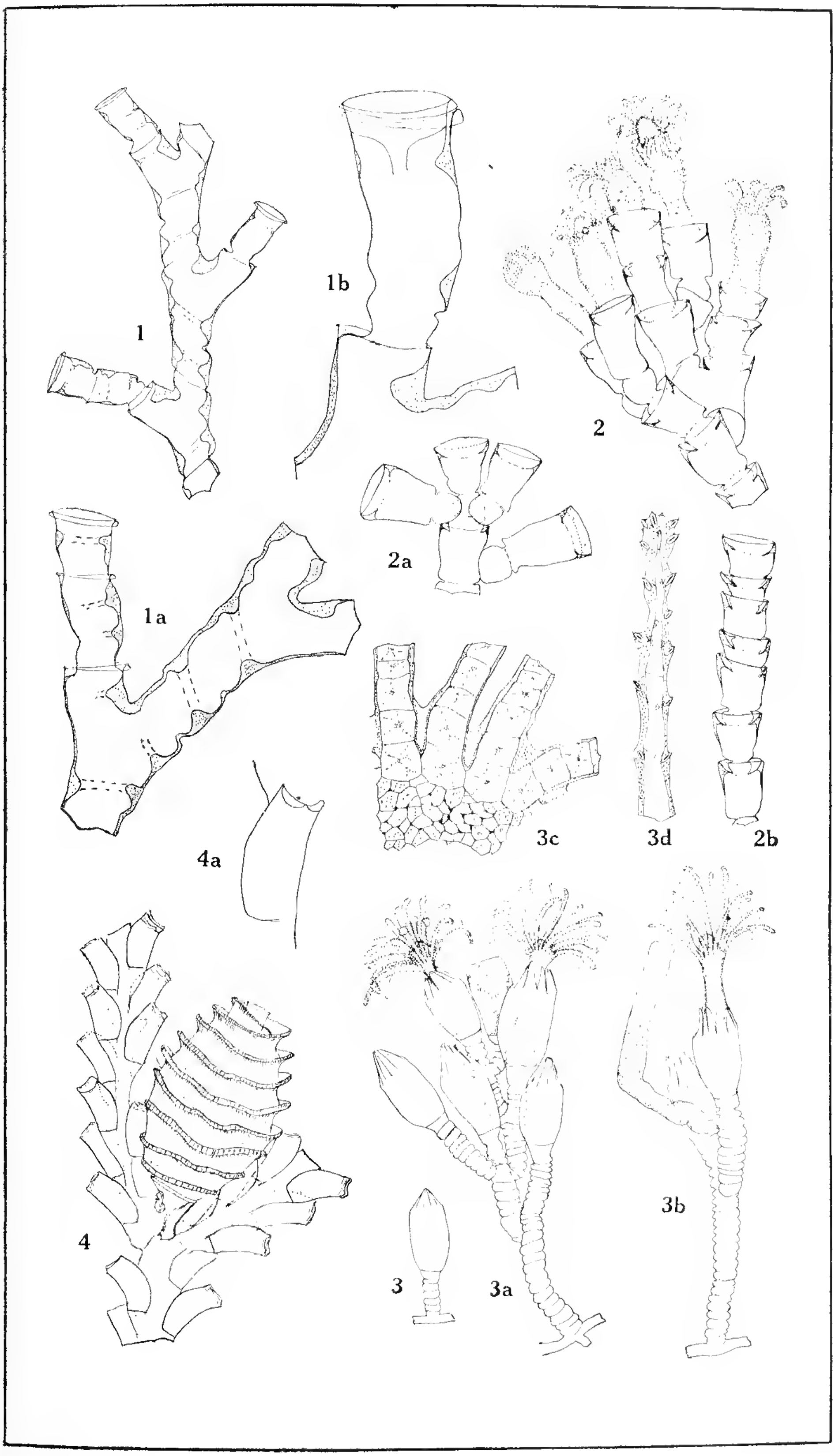

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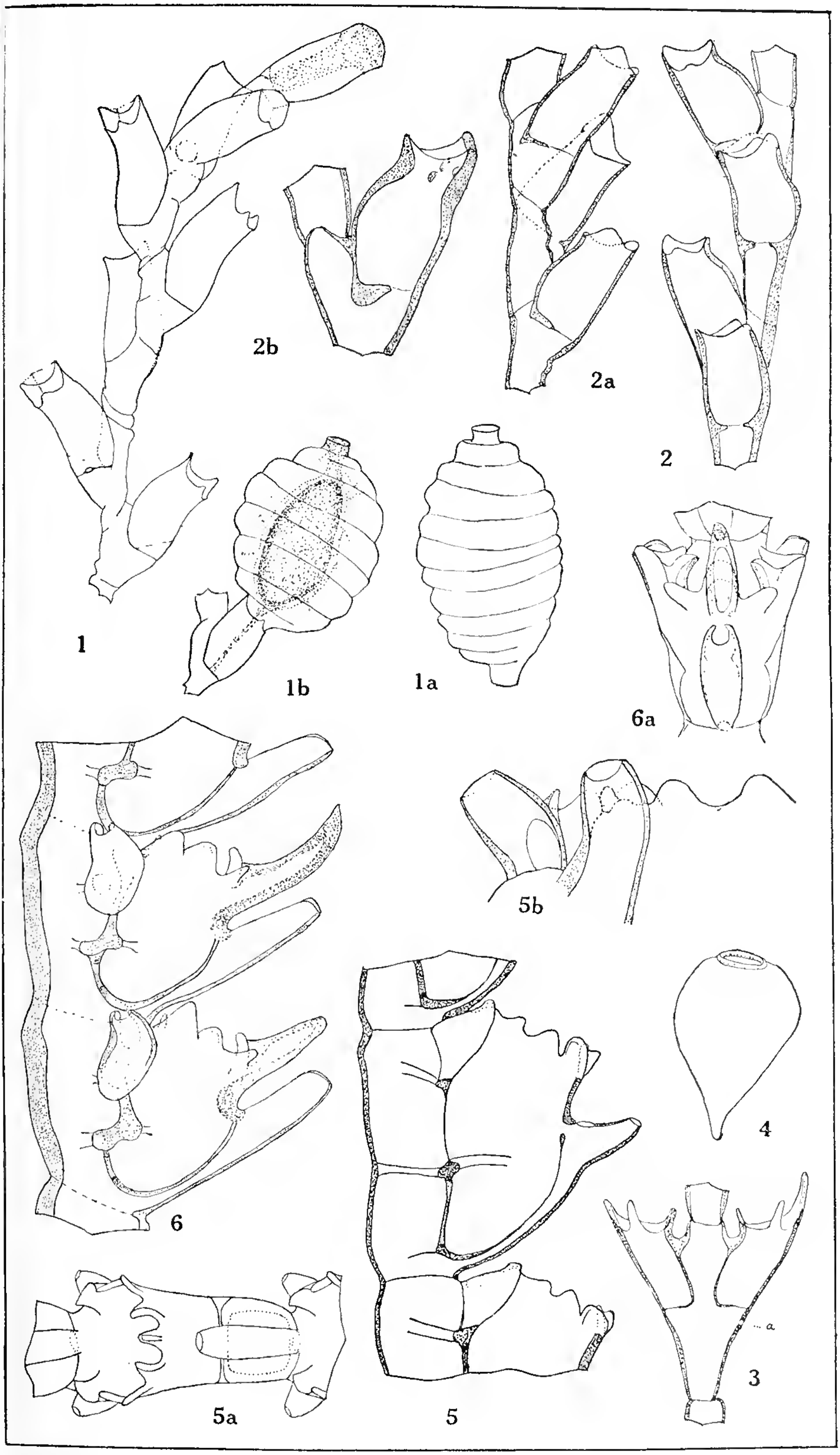

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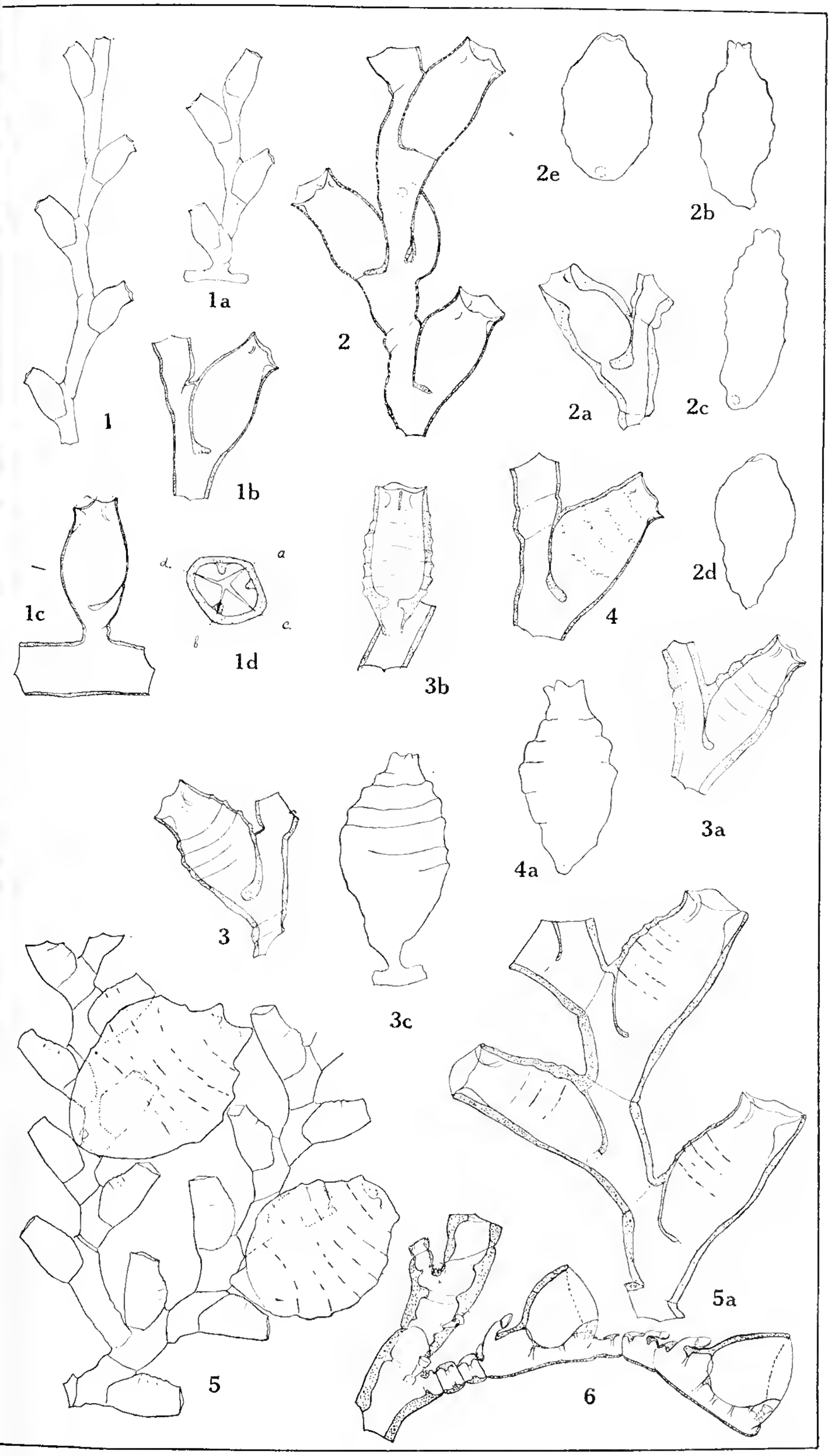

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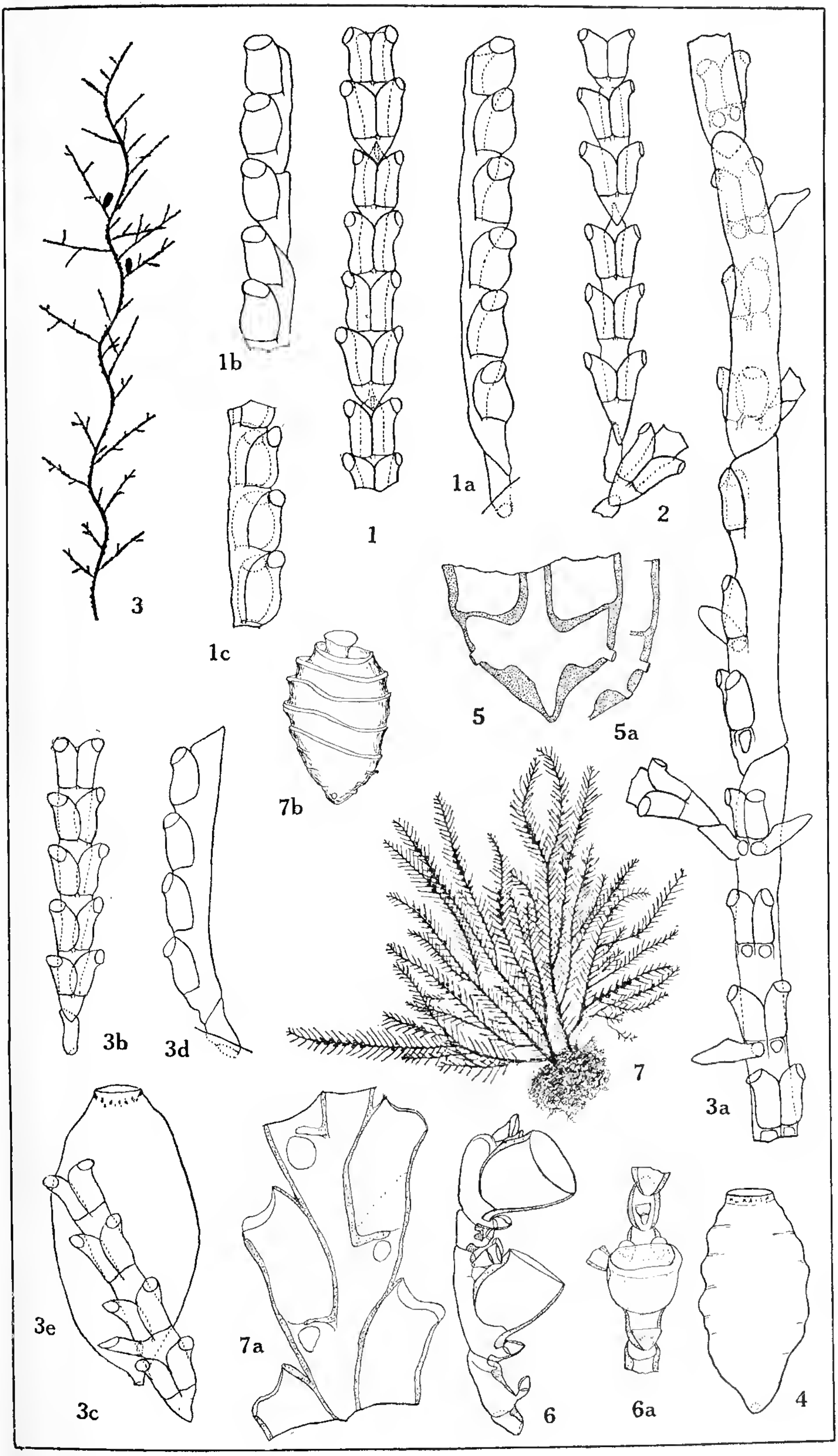

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Fig. 4.—*Thuiaria farquhari* Bale, gonotheca. ×15.

Fig. 5.—*Sertularia minima* Bale.

5. Infrathecal chamber, showing a pair of pores, with tubes. ×110.

5*a*. Side of another specimen, showing two pores on one side. ×110.

Fig. 6.—*Thecocaulus minutus*, n. sp.

6. Hydrocladium. ×50.

6*a*. Front view of part of hydrocladium. ×50.

Fig. 7.—*Sertularella subarticulata* (Coughtrey).

7. Small complete colony. ×½.

7*a*. Hydrothecae. ×50.

7*b*. Gonotheca. ×15.

[PROC. ROY. SOC. VICTORIA, 41 (N.S.), PT. I., 1928.]

ART. II.—*The Diurnal and Annual Fluctuations of Temperature in the Interior of a large Tree.*

By A. O. BARRETT.

(Read 12th April, 1928; issued separately 27th September, 1928.)

In the autumn of 1926 it became necessary for me to find out the temperature of the earth in basements of stone, concrete, asphaltum, wood, and the like.

It occurred to me as to whether the trunk of a living tree has a temperature different from that of the surrounding air. Is the temperature of the heart wood different from that of the half-formed surface timber where growth and respiration are active? Does the translocation of food-materials produce heat? Is this heat (if any is found) neutralised by the ascending soil water?

The changes in the internal temperature of an inanimate object always lag behind those of the air outside, but if one continues recording the daily rise and fall long enough—for twelve months —the temperature of a column of iron or stone will average that of its surrounding air.

The choice of a tree fell on a specimen of *Pinus canariensis* in my garden at "Lalbert," Armadale, Victoria, which grew on a lawn amidst other trees, but whose trunk was surrounded by a dense hedge of Coprosma 6 ft. high and 3 ft. thick, which left inside a space 3 ft. wide where one could walk. The shade of the other trees, the branches above, and this hedge, constituted an effective screen between the sun and the trunk; therefore the sun's rays could not shine directly on to the trunk at any time, and only air of shade temperature could ever reach the trunk, conditions which one usually finds in a forest or wood. The girth of the trunk was 12 feet 6 inches at three feet from the ground on 10/7/26, and a year later had increased by an inch. The old dead corrugated bark is about three inches thick. The spread of the branches above is about 70 feet, and its height is 50 feet.

On 10th July, 1926, I took an auger 5/8 in. diameter and 2 ft. long, and having cut a circular cavity in the dead bark 3 in. diameter just down to the living wood, bored a hole 23 in. long to the centre of the trunk, parallel to the earth, from north to south, at a height of 3 ft. from the soil; also another similar hole at a tangent to the circumference of the living sap wood, so that the thermometer would be totally enclosed, and so that its bulb would be some 4 in. inside from the surface of the dead corky bark, and about 1 in. into the living outside ring. This hole ended 3 in. from the beginning of the core hole, and was at the same level, and was bored from the S.E. to the N.W.

Now when one bores a hole into a living tree, heat is engendered by the act; also the cells of wood around the hole begin to flow with sap, consequently the temperature of the first few days recorded by a thermometer is not normal, until the effects of the friction and injury have faded away.

The holes being prepared, thermometers (fitted with rubber corks) which recorded exactly similar temperatures as did my maximum and minimum thermometer at 53°F., at 60° and at 72°, were inserted—one in each hole. The thermometer for the core hole was wired to a skewer of hard wood, whose outer end protruded 1 in. from the rubber cork, in order to facilitate removal for observation; both corks exactly fitted the holes, and by cutting a niche in the corks one could always pull them out so that the column of mercury was uppermost, and put them back the same way. This enables one to see the position of the column instantly on withdrawal, and to read the temperature accurately, even if the column moves. The whole operation of withdrawal, reading and replacement takes only four to five seconds, after one becomes accustomed to it. The maximum and minimum thermometer was hung 1 in. away from the bark at the spot where the bulb of the bark thermometer was, and over the hole of the core thermometer. It is useless to take the temperature of a tree trunk in one part of a forest unless one records the temperature of the air at the same spot.

The temperatures were taken at sundown, but in the warm weather the minimum was read in the morning, and the maximum in the evening of the same day. In the winter the temperatures in my garden were very similar to those issued daily in the *Argus*, but in the summer the temperatures in the garden were much lower than those of the bureau. Having proceeded thus for about one month, and shown the idea to Professor Ewart, he encouraged me to continue for at least twelve months. With few exceptions, due to absence, the recording of temperatures proceeded daily for twelve months, and to facilitate the summarising of the results they are presented in graph form. From perusal of the results it will be seen that:—

(*a*) The mean annual temperature of the heart wood was 1°F. lower than that of the air.

(*b*) The mean annual temperature of the alburnum was 1·1°F. higher than that of the air.

(*c*) The mean annual temperature of the duramen and alburnum combined was the same as the mean temperature of the air.

Further observations showed that although the trunk was shaded, the average temperature of the alburnum on the north side was one degree higher than that on the south side, and hence the average temperature of the centre of the tree was not more than half a degree lower than the mean of the two sides. This difference I suggest is due to the fact that the average temperature of the air on the south side of this tree was 1° lower than that on the north side. The flow of heated air in Australia is from the north and the flow of cold air is from the south, though it has also been suggested that the ascending water stream cuts off a small fraction of the external heat of the air from the duramen, which otherwise

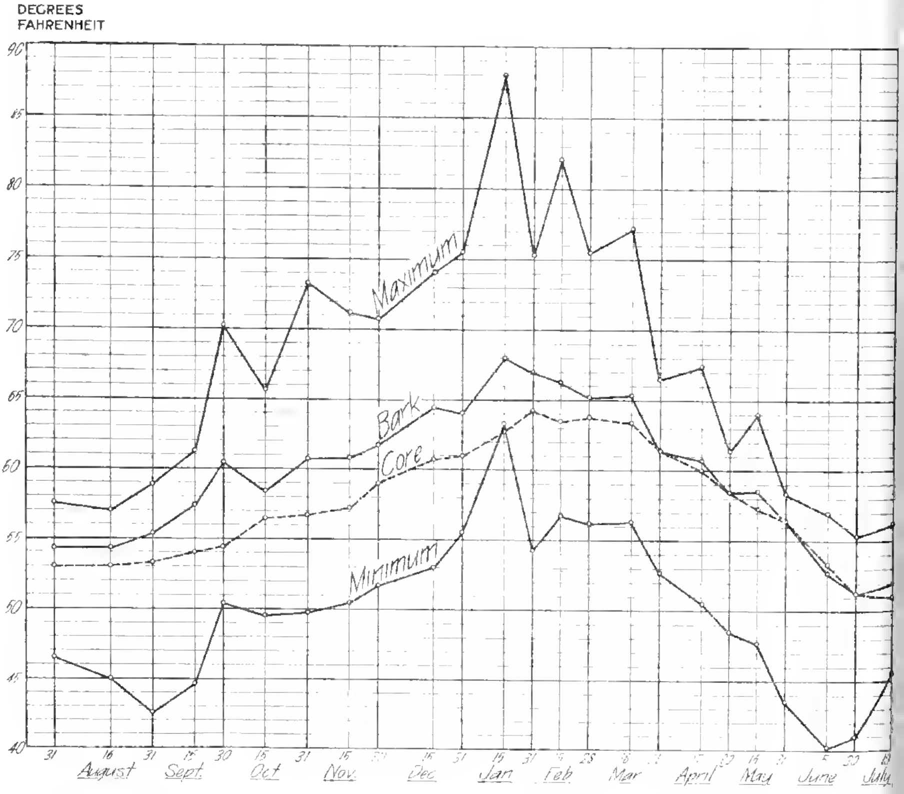

Fig. 1.—Temperature of Air and of a *Pinus canariensis* throughout year 1916-17.
Average mean temperature of air for year = 58·7 Fahr.
Average mean temperature of bark and core = 58·7 Fahr.
Trunk 12′–6″ girth at 3′ from ground, completely shaded by dense hedge of Coprosma.

behaves in regard to external temperature variations as an inert mass having no appreciable production of heat of its own.

During the whole period of observation there did not occur at any time any positive indication of any alteration in temperature due to pollination, or the sudden bursting into growth of the needle buds or the growth of branches, nor did sudden drenching with rain produce the fall of temperature one would expect. On March 18th, 1927, the bark on the trunk became soaked with rain, and the temperatures rose 0·5°. This happened again on April 12th, 1927. I suggest this is due to the rushing of the water by capillarity into the vesicular tissue of dry, dead bark, developing heat by friction and chemical action. The rain was colder than the bark.

As a rule the difference between the maximum and minimum temperatures did not result in much variation in the heat of the alburnum at the time of occurrence in this tree. In June, 1927, owing to a succession of frosts followed by warm afternoons, I took the opportunity of recording the temperature of the alburnum frequently, and from this it will be seen that there was only a difference of 0·5°F. between the temperature at about 6-8 a.m., when the ground was white with frost, and the temperature about 4-6 p.m., when by contrast the air was warm and the afternoon delightfully sunny. I suggest this is due in this tree to the fact that the alburnum is insulated from the air on the outside by a thick layer of dead bark, which is a bad conductor of heat. The slowness of the change in temperature in the core of this tree trunk is illustrated by noting the fact that by the 12th June, 1927, the average daily mean temperature of the air had fallen 7 degrees owing to frost, whereas two feet inside the tree it required four days to reduce the temperature by 2°F.

At the same time I became possessed of the idea that the temperature of this tree was more subject to change from atmospheric causes in the first half of this year than it was in the last half of last year. I suggest it is due to the fact that the tree is drained of water due to its spring growth, and that consequently its specific heat is lower than in the spring.

I have noticed that dead, dry timber seasoned, fluctuates more than timber of the same dimensions does in a living tree, and consider this is due to its low specific heat, owing to the absence of "free" water.[1]

On one occasion the temperature of the core fell faster than that of the alburnum. This was on and about the 21st to the 26th May, 1927, when the temperature of the core was reduced by the falling temperature of the air, would have been the temperature of the alburnum, but for the fact that again rain drenched the bark, and either its condensation in the dead bark or the fact that it was warmer than the air, caused a rise in temperature, which warmed the alburnum. As soon as the rain stopped the bark dried and the temperature of the outside of the tree suffered a quick fall, and on the 26th became lower than the core.

While taking these temperatures daily, I began to take the temperature of many other varieties of trees and their parts, and noticed many curious happenings which may be of interest. This has resulted in the conviction in my mind—

(1) That all dicotyledonous trees average (over long periods) almost the same temperature as the air of the forest or

1 It has been suggested by Professor Ewart, however, that it is due to the effect of the transpiration current.

locality where they live, although small trees have a greater daily variation of temperature than large trees, as they have more bark surface per unit of mass than the latter.

(2) That trees with smooth bark have a greater daily variation in temperature than those with thick, corky, or stringy bark.

(3) That the parts of trees upon which the sun shines have a greater variation than those in permanent shade, and that the thinner branches have a greater daily variation than the trunk.

(4) That the twigs from which the leaves grow vary in temperature hourly.

(5) That the temperature of the smooth barked part of a branch on eucalypts varies more than that of the part which—although the same thickness—is nearer the trunk, and which is covered with stringy or hairy or corrugated bark.

(6) That the average temperature of any part of the trunk of a large tree shows no evidence of any material average difference in temperature from that of the atmosphere. There is always the " lag," but the temperature average is practically the same over long periods.

(7) That all leaves in my garden, whether of Australian or other origin, which admit of the bulb of a thermometer being wrapped up in them, are of the same temperature as that of the air with which they are surrounded.

(8) That the ascending water current can only influence the temperature of the trunk in the alburnum or water-conducting wood.

In conclusion I wish to thank Dr. Ewart for his assistance and for codifying my results; also Messrs. Lang and Mitchell, consulting engineers, for the preparation of the graph.

Temperature of Core and living sap cells of Pinus Canariensis.

NOTE—All tree temperatures were taken at sundown.

1926		Tree Temperatures		Air Shade Temperatures		
		Core	*Bark*	*Max.*	*Min.*	*Remarks.*
July	10	54 °F	54 °	58 °	43 °	Auger heat
	11	53	54	61	50	
	12	53	54	61	49	
	13	53	54	58	44	
	14	53	54	58	48	
	15	54	54	53	45	
	16	53	54	54	42	
	17	53	54	55	45	
	18	53	54	56	43	
	19	53	54	55	40	
	20	53	54	59	48	
	22	53	54.5	69	56	
	23	53	54.5	57	47	
	24	53	54	53	44	Rain
	25	53	54	53	43	Rain
	26	53	54	56	47	
	27	53	54	59	48	
	28	53	54	58	50	
	29	53	54	59	49	
	30	53	54	57	48	
	31	53	54.5	60	50	
Av. 21 days		53	54.1	57.5	46.6	Mean air temp. 52 °
August	1	53	54	55	45	
	2	53	54	59	42	
	3	53	54	53	46	
	4	53	54	55	40	Rain
	5	53	54	56	42	
	6	53	54	55	44	
	7	53	54	55	45	
	8	53	54	56	44	
	9	53	54	54	44	
	10	53	54	65	53	
	11	53	54	60	52	
	12	53	54	58	52	
	13	53	54	56	41	
	14	53	54.5	59	41	
	15	53	54.5	59	48	
	16	53	54.5	57	41	
Av. 16 days		53	54.1	57	45	Mean=51 °
	17	53	54.5	59	48	Buds loosening
	18	53	54.5	66	44	
	19	53	55	65	53	
	20	53	55	53	42	
	21	53	55	52	36	Pollen cones forming
	22	53	55	57	32	Frosty
	23	53	55	61	34	
	24	53.5	55	62	42	
	25	53.5	55	55	53	
	26	53.5	55	54	40	
	27	53.5	55	53	41	
	28	54	55.5	65	34	
	29	54	56	64	49	
	30	54	56	57	47	
	31	54	56	58	42	
Av. 15 days		53.4	55.2	58.7	42.5	Mean=50.6 °

1926		*Core*	*Bark*	*Max.*	*Min.*	*Remarks.*
September	1	54	56	63	44	
	2	54	56	63	42	
	3	54	56.5	61	50	Buds bursting
	4	54	56.5	59	42	freely
	5	54	57	56	45	
	6	54	57	57	39	
	7	54	57	60	45	
	8	54	57	67	37	
	9	54	57	72	47	
	10	54	58	59	50	
	11	54	58	59	43	Pollen cones ripe
	12	54	58	63	50	Fruit cones ap-
	13	54	58.5	64	52	pear
	14	54	59	55	45	
	15	54	59	61	40	
Av. 15 days		54	57.3	61.2	44.7	Mean=52.9°
	16	54	59	70	40	
	17	54	59.5	67	41	
	18	54	60	70	43	
	19	54	61	78	45	
	20	54	61	76	53	
	21	54	61	73	56	
	22	54	62	85	57	Hot
	23	54	63.5	81	63	wind
	24	54	62.5	57	52	
	25	54.5	61	70	52	Pollen cones
	26	55	60	74	54	empty
	27	55.5	59.5	73	55	
	28	56	58.5	58	51	Rain
	29	56.5	59.5	60	51	
	30	56.5	59	64	42	
Av. 15 days		54.6	60.5	70.4	50.3	Mean=60.3°
October	1	57	59	74	44	
	2	57	60	74	54	
	3	57	61	68	58	Re-bored hole
	4	57	59	67	44	centre
	5	56.5	58.5	61	54	Very wet and
	6	57	58	62	50	windy
	7	56.5	57	59	49	Wet and
	8	56.5	56	58	48	windy
	9	57	57	60	49	
	10	57	58	70	50	
	11	57	59	68	48	Fine, S. W. wind
	12	57	57	60	45	Gales, rain
	13	57	57	65	52	
	14	56	57	75	48	Rain
Av. 14 days		56.8	58.1	65.8	49.5	Mean=57.6°
	16	56	60	80	47	
	17	56	58.5	77	50	Hot
	18	56	60	75	48	,,
	19	56	60.5	74	52	
	20	56	59	70	45	,,
	21	56.5	62	77	52	
	22	56.5	62	76	55	,,
	23	56.5	61	70	55	,,

1926		*Core*	*Bark*	*Max.*	*Min.*	*Remarks.*
October	24	56.5	60.5	70	48	,,
	25					,,
	26	57.5	59.5	66	48	Cool
	27	57.5	62.5	79	50	Hot
	28	57.5	63	82	49	
	29	57.5	62.5	75	59	Gales N.W.
	30	57.5	62	63	49	Bleak (rain)
	31	58	60	68	40	,, ,,
Av. 15 days		56.8	60.9	73.4	49.8	Mean=61.6°
November	1	57.5	59	68	55	
	2	57.5	59.5	68	47.5	
	3	57.5	58.5	61	50	Cold, Gale
	4	57.5	57.5	58	45	,, ,, hail
	5	57	56.5	57	48	,, ,, ,,
	6	57	56.5	66	45	,, ,, ,,
	7	57	60	80	47	
	8	57	65	93	55	N.W. gale
	9	57	65.5	89	55	6 p.m.
	10	57	63	70	51	
	11	57	60	66	47	
	12	57.5	65	86	46	Very dry
	13	57.5	63	74	54	
	14	57.5	63	68	54	
	15	58	62	68	55	
Av. 15 days		57.3	60.9	71.4	50.3	Mean=60.8°
	16	58	62	77	49	
	17	58	61	65	45	Gales rainy W.
	18	58.5	59	63	48	Showers passed
	19	59	61	79	47	Dry conditions
	20	59	62.5	84	52	
	21	59	64	76	59	
	22	59	63	69	55	
	23	59	61	63	54	Cold wind S.W
	24	58.5	59.5	62	51	Needles ex-
	25	58.5	59.5	63	53	panding
	26	59	60	65	47	
	27	59.5				
	28	60	67	97	52	Hot, very dry
	29	60	64	66	60	
	30	60	61	63	53	
Av. 15 days		59	61.7	70.8	51.8	Mean=61.3
December	1	60	62	70	54	
	2	60	62	74	48	
	3	60	70	94	53	
	4	60.5	67	78	62	
	5	61	65	70	60	15 points rain
	6	60.5	63	67	51	W. Gale
	7	61	63	74	47	
	8	61	64	78	57	
	9	61.5	66.5	91	56	Leaves small
	10	61	68	64	58	and scanty,
	11	61.5	64	69	48	too dry
	12	61	62	64	52	Fine and cool
	13	61	61.5	61	51	
	14					
	15	61	66	80	45	
Av. 14 days		60.8	64.5	73.8	53	Mean=63.4°

1926	*Core*	*Bark*	*Max.*	*Min.*	*Remarks.*
16	61	65	81	62	16 points rain
17	61	63	75	57	Rain
18	61	62	63	56	
19	61	61	63	53	
20	61	63	72	52	
21	61	64	85	54	} 40 points
22	61	63	64	55	}
23	60.5	62	67	55	
24	60.5	65	87	45	
25	61	66	92	60	Hot
26	61	68	82	62	
27	61	66	71	59	
28	61	64	75	55	
29	61.5	64	79	56	No dew
30	61.5	64.5	78	53	
31					
Av. 15 days	61	64	75.6	55.6	Mean=65.6°

1927	*Core*	*Bark*	*Max.*	*Min.*	*Remarks.*
January 1—5	absent		85	49	For period of 6 days Rain, drizzle
6	62	64.5			
7	62	64	68	60	
8	62	63	72	57	
9	62	65	90	56	
10	62.5	68	94	67	Hot and dry
11	63	71	96	70	
12	63	72	92	67	
13	63.5	71	90	61	Old needles
14	64	74	102	69	dropping freely
Av. 9 days	62.7	68	88	63.4	Mean=75.7°
15	64.5	73.5	80	63	Cool change
16			70	57	
17	65	73	79	55	25 points rain
18	65	69	75	59	
19	65	66	68	51	
20	65	72	88	50	
21	65	62	83	60	
22	64.5	66	80	50	
23					
24	64	67	83	60	
25	63.5	66	77	55	
26	63.5	65	74	40	
27	63.5	64	64	57	
28	63.5	64	67	53	
29	63.5	63	67	49	
30					
31					
Av. 13 days	64.3	67	75.4	54.2	Mean=64.8°
February 1	64	66	82	52	
2	64	69	89	61	
3	64	66	82	54	60 mile gale
4	64	66	78	60	
5	63.5	63	70	55	
6	63	64.5	74	55	
7	63	65	78	57	Premature Autumn

1927		Core	Bark	Max.	Min.	Remarks.
	8	63	64	67	53	No moisture or
	9	63	65	82	48	dew
	10	63	69	93	56	No sap flow,
	11	63.5	70	98	61	heat now felt
	12	63.5	69	91	73	at once thro'
	13					the bark, no
	14	63.5	68	98	55	evaporation
	15	64	66	68	57	to resist heat
Av. 14 days		63.5	66.4	82.1	56.9	Mean = 69.5°
	16	63.5	65.5	70	60	
	17	64	66	77	56	
	18	64	66.5	80	62	
	19	63.5	64	75	57	
	20					
	21	63.5	66	77	55	
	22	64	67	80	53	
	23	64	68	82	61	
	24	64	65	77	54	A little rain
	25	64	64	68	52	
	26	63.5	63	65	55	
	27	63.5	64	74	56	
	28	64	64	82	55	
Av. 12 days		63.7	65.2	75.5	56.3	Mean = 65.9°
March	1	64	68	97	59	Very hot
	2	64	70	93	71	
	3	63.5	69	83	80	Sudden cold
	4	63.5	66	67	49	change at
	5	63.5	64	65	52	noon
	6	63.5	62	58	51	
	7	63.5	63	76	48	
	8	63.5	63.5	75	50	
	9	63.5	65	77	48	
	10	63.5	66	84	50	
	11	63.5	68	92	63	
	12	63.5	66	84	58	Lawns nearly
	13	63.5	65	80	51	dead, 160
	14	63.5	64	69	58	points since
	15	63	64	67	58	January 1
	16	63	63	68	57	
Av. 16 days		63.5	65.4	77.2	56.4	Mean = 66.8°
	17	63	63.5	72	57	
	18	63	64	62	56	Rain at last
	19	63	63	63	54	Trunk of tree soaking, yet temp. of outer
	20	63	62	63	52	rings rose 0.5°
	21	62.5	61	65	56	F. 70 pts. rain
	22	62	60.5	56	51	Drizzle
	23	62	60	57	54	
	24	61.5	60	57	54	
	25	61.5	60.5	69	57	
	26	61	60.5	65	52	
	27	60.5	60	60	54	
	28	60	60	70	53	
	29	60	61	77	41	
	30	60	62	83	47	
	31	60	61.5	77	55	
Av. 15 days		61.5	61.3	66.4	52.8	Mean = 59.6°

1927		Core	Bark	Max.	Min.	Remarks.
April	1	59.5	61.5	69	57	
	2	59.5	60.5	65	56	
	3			} 85	49	Max. and min. for two days
	4					
	5	60	63	75	52	
	6	60	62	62	46	
	7	60	62	65	53	
	8	60	61	65	55	
	9	60	60	66	44	
	10	60	60	64	51	
	11	60	59	61	44	
	12	60	62	69	49	A little rain
	13	60	60	65	53	
	14	60	59.5	64	51	
	15	60	59.5			
Av. 13 days		60	60.8	67.3	50.7	Mean = 59.0°
	16	59.5	59			
	17	59.5	59	} 68	43	Max. and min. for two days
	18	59.5	59			
	19	59	59.5	63	50	
	20	59	59	60	45	Hole in bark closing up, re-bored
	21	59	58	58	51	
	22	59	57	59	47	
	23	58.5	57.5	61	52	
	24	58.5	58	62	54	
	25	58	58	60	53	
	26	58	57	58	50	
	27	58	57.5	63	48	
	28	58	60	68	43	
	29	58	60.5	70	47	Many trees dying, leaves falling
	30	58	59	63	48	
Av. 15 days		58.7	58.5	62.5	48.5	Mean = 55.5°
May	1	58	58	57	42	
	2	58	59.5	63	44	
	3	58	59	61	46	Nice rain 30 points. Copious condensation of moisture on thermometer in core lately. This has not occurred before. None on the thermometer in bark
	4	58	58	58	47	
	5	57.5	57.5	62	46	
	6	57.5	57	63	43	
	7	57	58	67	41	
	8	57	60	73	50	
	9	57	59.5	73	48	
	10	57	60.5	67	58	Rain
	11	57	58.5	60	48	Rain, 50 points
	12	57	58.5	57	45	Dull
	13	57	58.5	62	48	
	14	57	58.5	66	49	
	15	57	59	67	54	
	16	57	58.5	68	54	
Av. 16 days		57.4	58.6	64	47.7	Mean = 55.8°
	17	57	59	66	49	
	18	57	57	58	44	
	19					
	20					
	21	57	58	63	44	

1927		*Core*	*Bark*	*Max.*	*Min.*	*Remarks.*
	22	57	58	64	46	Rain, 25 points
	23	57	58	60	48	
	24	57	57.5	59	46	Rain
	25	56.5	57.5	58	47	Fall of temp. in core not al-
	26	56.5	56	56	44	ways preced-
	27	56	56.5	55	46	ed by fall of
	28	56	55	51	44	temp. in bark
	29	55.5	54	56	41	Rain
	30	55.5	53.5	56	34	Fine, 26° on grass, frost
	31	55	53	58	34	Fine, frost
Av. 13 days		56.4	56.4	58.5	43.6	Mean = 51.0°
June	1	54.5	53	57	33	Fine, frost
	2	54	53	59	37	,, ,,
	3	54	53	59	33	,, ,,
	4	53.5	54	60	48	Rain
	5	53.5	55	64	55	
	6	53.5	54.5	58	45	
	7	53.5	54	56	44	
	8	53	54	57	47	
	9	53	52.5	50	40	
	10	53	51.5	51	43	Drizzle & rain
	11	53	52	53	45	
	12	53	51.5	56	33	Frost, fine
	13	52.5	52	55	32	,, ,,
	14	52	51.5	58	33	
	15	51.5	51.5	61	35	
Av. 15 days		53.1	52.8	57	40.2	Mean = 48.6°
	16	51.5	51	53	33	
	17	51	50.5	55	32	
	18	51	51	57	46	
	19	51.5	51.5	63	50	
	20	51.25	52.5	60	48	
	21	51.5	52	52	44	Record num-
	22	51.5	52.5	56	46	ber of frosts
	23	51.5	53	57	49	
	24	51.5	53	57	46	
	25	51.5	52.5	54	47	
	26	51.5	51.5	54	42	Fine
	27	51.5	51	53	37	,,
	28	51.5	48.5	47	31	Fine, very cold fog at 8 a.m.
	29	51.5	49.5	55	32	Fine, warmer
	30	51.5	50.5	57	32	
Av. 15 days		51.4	51.4	55.3	41	Mean = 48.1°
July	1	51	52	57	47	It took 4 days for the succes-
	2	51	52	56	45	sive waves of
	3	51	52	57	48	cold to affect
	4	51	52	56	46	the core
	5	51	52	57	49	Rain all over
	6	51	53	59	50	Vic. 50 to 100
	7	51	53	54	44	points
	8	51	52	53	41	
	9	51	51.5	53	42	
	10	51	51.5	58	44	
	11	51	52	58	47	
Av. 11 days		51	52	56.2	45.7	Mean = 50.9°

Summary of Average Temperatures.

		Tree Core	Tree Bark	Air Max.	Air Min.	Tree Mean	Air Mean
July	10-31	53	54.1	57.5	46.6	53.5	52
August	1-16	53	54.1	57	45	53.5	51
	17-31	53.4	55.2	58.7	42.5	54.3	50.6
Sept.	1-15	54	57.3	61.2	44.7	55.6	52.9
	16-30	54.6	60.5	70.4	50.3	57.5	60.3
October	1-15	56.8	58.1	65.8	49.5	57.4	57.6
	16-31	56.8	60.9	73.4	49.8	58.8	61.6
Nov.	1-15	57.3	60.9	71.4	50.3	59.1	60.8
	16-30	59	61.7	70.8	51.8	60.3	61.3
Dec.	1-15	60.8	64.5	73.8	53	62.6	63.4
	16-31	61	64	75.6	55.6	62.5	65.6
Jan.	1-14	62.7	68	88	63.4	65.3	75.7
	15-31	64.3	67	75.4	54.2	65.6	64.8
Feb.	1-15	63.5	66.4	82.1	56.9	64.9	69.5
	16-28	63.7	65.2	75.5	56.3	64.4	65.9
Mar.	1-16	63.5	65.4	77.2	56.4	64.4	66.8
	17-31	61.5	61.3	66.4	52.8	61.4	59.6
Apl.	1-15	60	60.8	67.3	50.7	60.4	59
	16-30	58.7	58.5	62.5	48.5	58.6	55.5
May	1-16	57.4	58.6	64	47.7	58	55.8
	17-31	56.4	56.4	58.5	43.6	56.4	51
June	1-15	53.1	52.8	57	40.2	52.9	48.6
	16-30	51.4	51.4	55.3	41	51.4	48.1
July	1-11	51	52	56.2	45.7	51.5	50.9
Average		57.7	59.8	67.5	49.8	58.7	58.7
		58.7		58.6		58.7	

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Art. III.—*Some Trematode Parasites on the Gills of Victorian Fishes.*

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(With Plates VIII.-XI.)

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This work was carried out under the guidance of Dr. O. W. Tiegs, and my thanks are due to him for his assistance and interest.

Methods.—The material was fixed in 1% formalin. Bouin, Zenker, and corrosive sublimate were also tried, but the formalin proved most satisfactory. Iron haematoxylin was used for all sections, and Erhlich's haematoxylin for whole specimens. In cases where the iron haematoxylin overstained the vitellaria in sections, Erhlich was used as an alternative.

Genus Anchylodiscus Johnston and Tiegs, 1922.

Anchylodiscus gadopsis, n. sp.

(Plate VIII., Fig. 1; Pl. X., Fig. 6.)

Found in great numbers on the gills of *Gadopsis* sp. (River Black Fish).

Locality.—Campaspe River, Vic.

Formalinised animal measures about 0·36 mm. in length, breadth 0·08 mm.

External Features.—Small body, slightly oval in section, with indication of head at anterior end; at posterior end is a well-marked hooked disc. The hooks are arranged in nine pairs, two consisting of large hooks, the bases of which are slightly bifurcated, and are connected by a single crossbar, while seven consist of minor hooks, one pair of which lies across one of the crossbars. The large hooks are supported by a ring of chitinous material (Pl. VIII., Fig. 1). Immediately in front of the pharynx there are two pairs of eyes, of which the anterior pair is the smaller.

Three pairs of "head organs" are present (Pl. VIII., Fig. 1); the cephalic glands are situated slightly anterior to the eyes.

The "brain" lies between the eyes, and is the only indication of the nervous system.

Alimentary Canal.—The mouth is situated ventrally, and is anterior to the eyes. The pharynx is large, intestine is bilobed and devoid of caeca and ends blindly towards the posterior end of the body.

Reproductive System.—The testis is slightly elongated, lies dorsal to the ovary (Pl. X., Fig. 6), and extends posterior to it. The vas deferens passes forwards dorsally as a very wide tube, and opens posterior to the pharynx by a chitinous penis, which is a straight-pointed structure (Pl. VIII., Fig. 1).

The ovary is a large median structure, situated about half-way along the length of the animal. The oviduct passes forwards and opens to exterior close to the male opening. There is no vagina. The vitelline system is very large, and occupies the larger part of the body. The transverse yolk duct passes across anterior to the ovary and opens into the oviduct.

The egg is enormous, the ripe egg in the oviduct displacing the organs of the body.

Points by which *A. gadopsis* is distinguished from *A. tandani* T. H. Johnston and O. W. Tiegs (8):—

1. One pair of minor hooks lies across one of the crossbars in a median position (Pl. VIII., Figs. 1, 2).
2. No vesicula seminalis could be determined. The time of the season may account for this.
3. The penis is straight instead of curved.

Genus **Squalonchocotyle** Cerfontaine, 1898.

Squalonchocotyle antarctica, n. sp.

(Plate IX., Figs, 4, 5; Text-Fig. 1.)

This marine parasite belongs to the sub-family Onchocotylinae Cerfontaine (7), of the family Octocotylidae van Ben et Hesse (3). It is very similar to *S. vulgaris* Cerfontaine (7), and *S. grisca* Cerfontaine (7). Found on the gills of *Mustelus antarcticus.*

Locality.—Port Phillip Bay.

Average length of formalinised animal 10 mm., breadth 1 mm.

External Features (Pl. IX., Fig 4).—Body elongated and flattened dorso-ventrally. At the posterior end is a fixing organ which is composed of a fixing disc with a caudal appendage. On the former are three pairs of large suckers arranged in two parallel rows and each provided with a single large hook. Two smaller, unarmed suckers are present at the extremity of the caudal appendage, and a pair of small minor hooks is situated between them. The body is attached to this organ at the level of the middle pair of large suckers.

Each large hook ends in a small pointed structure which is recurved at right angles, and sharply defined from the main body of the hook by its smaller diameter. The minor hooks are Y-shaped, the three arms being more or less equal, and the base of the Y ends in a small hook which is recurved so as to point in a direction parallel to the long axis of the hook (Text-fig. 1*a*, 1*b*).

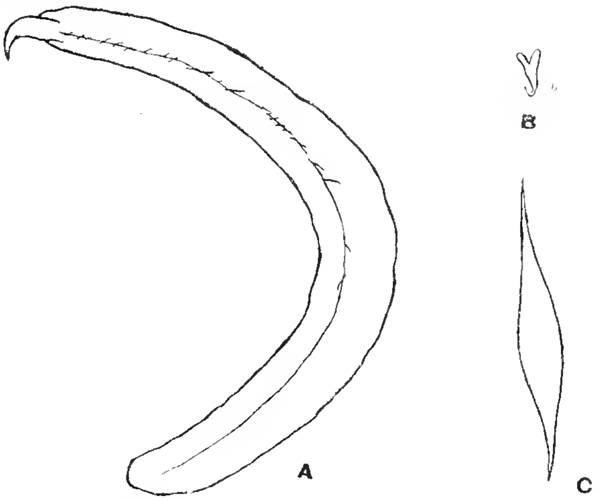

Fig. 1.—*Squalonchocotyle antarctica*, n. sp., drawn with camera lucida. A, major hook: B, minor hook: C, egg.

Alimentary Canal.—The mouth is situated ventrally, and is surrounded by a large circular sucker; a short muscular pharynx opens into the oesophagus, which divides immediately into the two main branches of the intestine. These unite at the posterior end of the body, and pass into the fixing organ. Here the intestine divides again into two single branches passing anteriorly and posteriorly along the disc and caudal appendage respectively. Small unbranched caeca are given off both medially and laterally along the length of the intestine.

Reproductive System (Pl. IX., Fig. 5).—The reproductive organs are typical of the sub-family. The common genital opening is median, and is situated just posterior to the pharynx. The two vaginal openings are lateral, and on nearly the same level as the genital opening.

The eggs are oval and narrow, with two short polar filaments. The length of the egg is approximately 150 μ, which is roughly twice the length of the filaments (Text-fig. 1*c*.).

S. antarctica is distinguished from *S. vulgaris* by the following points:—

1. Shape of buccal sucker.
2. Shape of minor hooks.
3. Length of polar filaments of egg.

S. antarctica is distinguished from *S. grisea* by the following points:—

1. Structure and shape of large hooks.
2. Position of vaginal openings.

Macrophylla, n. gen.

MACROPHYLLA ANTARCTICA, n. gen. et sp.

(Plate X., Figs. 7-9.)

Marine form from the gills of *Mustelus antarcticus.* Found on only two specimens of about a hundred examined.

Locality.—Port Phillip Bay.

Length of formalinised animal 13·15 mm., breadth 1·3-2·5 mm.

External Features (Pl. X., Fig. 7).—At the anterior end on either side is a single pair of large flat expansions, ridged on their ventral surface. Sections of these structures, examined under high magnifications, seem to reveal them as glandular in nature. At the hinder end is a large disc, attached by its middle to the body of the worm (Pl. X., Fig. 7). This disc is provided with a very large sucker, divided by radii into five secondary suckers, of which the largest is incompletely divided into three compartments.

Body Wall (Pl. X., Fig. 9).—This consists, so far as could be made out on the material available, of an epidermis with a marked cuticle. The musculature consists of a circular layer divided into three secondary layers, a well defined longitudinal layer, and vertically running fibres.

Alimentary Canal.—The crescent-shaped mouth opens into an enormous pharynx, which extends well over half the breadth of the animal. The pharynx is extremely muscular, and is provided with large unicellular glands. The intestine is bifurcated, long and narrow, and extends almost to the posterior end of the worm. Along its length numerous branching caeca are developed.

Reproductive System (Pl. X., Fig. 7, 8).—There are two compact testes situated behind the ovary, about a third of the length of the animal from the anterior end. The left testis is situated a little in front of the right. The two vasa deferentia lead into a common tube which travels to the left of and dorsal to the ovary. It then passes forwards almost to the level of the reproductive openings, crosses under the vagina, turns back upon itself and enters the penis. This is a pear-shaped muscular organ, which passes to the exterior along a narrow duct whose opening is situated on the side of the animal just behind the left glandular expansion, and immediately anterior to the uterus.

The ovary is a well-marked, median, round body, considerably larger than the testes. The oviduct passes forwards as a straight tube and continues as the uterus to open just behind the male opening. The vitelline glands extend along either side from the anterior to almost the posterior end of the body. The two longitudinal yolk ducts open into a transverse duct, which runs anterior to the ovary, and opens into a dilated short median yolk-duct, which in turn opens into the oviduct. The vagina has a common opening to the exterior with the male duct. It passes behind into a curious muscular organ (Pl. X., Fig. 8), which in turn opens into a slightly convoluted tube, leading backwards and emptying into the transverse yolk duct. The muscular organ above referred to, and the proximal part of the convoluted tube which leads away from it, lie suspended in a cavity, indicating that they are distensible structures. It is probable that the tube is a receptaculum seminis, though I have never observed spermatozoa within it.

In two specimens an egg was present in the uterus; it is oval in shape, and measured about 220 μ in length, 107 μ in breadth. The genus *Macrophylla* is distinguished from its nearest ally *Tristomum* by the following points:—

1. Two compact testes as contrasted with numerous testicles.
2. Only five instead of seven distinct radii in posterior sucker.
3. Glandular membranes at anterior end in the place of suckers.

Genus **Octobothrium** Leuckart, 1827.

Octobothrium thyrites, n. sp.

(Plate XI., Figs. 10-12; Text-Fig. 2.)

Marine form found on gills of *Thyrites atun* (Barracouta).

Locality.—San Remo, Vic.

Length of formalinised animal 7-8 mm., breadth 2-2·5 mm.

External Features (Pl. XI., Figs. 10, 11).—Body elongated and flattened dorso-ventrally, tapering forwards each end; it is more pointed anteriorly. A distinct "head" region is marked off anteriorly by the two lateral openings of the vagina which are surrounded by tumid lips. Posterior end terminates in a fixing disc which is not sharply defined from the body. Disc is provided with eight suckers arranged in two rows converging posteriorly, and each sucker has a complex armature (Pl. XI., Fig. 11, and Text-fig. 2*a*). Two pairs of small hooks are situated at the extreme posterior end, the more anterior pair being the larger (Text-fig. 2*c*). In the "neck" region the body wall is so folded as to give a false appearance of segmentation. (Pl. XI., Fig. 10).

Body Wall.—This consists of a syncytium with a marked cuticle. The musculature consists of a thick layer of well developed longitudinal fibres, the circular fibres being only poorly developed.

Alimentary Canal.—The mouth is situated on the ventral side of the extreme anterior end. On each side of the mouth is a pair of small oral suckers, which is characteristic of the group. The mouth leads into a wide, but not muscular pharynx, opening into the intestine, which forks immediately posterior to the transverse vaginal duct. Numerous diverticula are given off along the whole length of the intestine, both medially and laterally.

Reproductive System (Pl. XI., Fig. 12).—The male organ is represented by numerous testicles occupying the middle of the posterior 3/5ths of the body. The single vas deferens passes up medially and dorsally as a coiled tube, and opens to the exterior on the ventral surface of the "head" by a sucker which is surrounded by small hooks (Pl. XI., Fig. 12, and Text-fig. 2*b*).

The ovary is lobed and single, situated on the right side about 2/5ths of the total length from the anterior end. In stained specimens a lobed structure (Pl. XI., Fig. 10, *y.o*), which takes up the stain very readily, appears in sections to be composed of young ova. There is some doubt about this, as similar stained cells extend from this structure to the posterior end of the body.

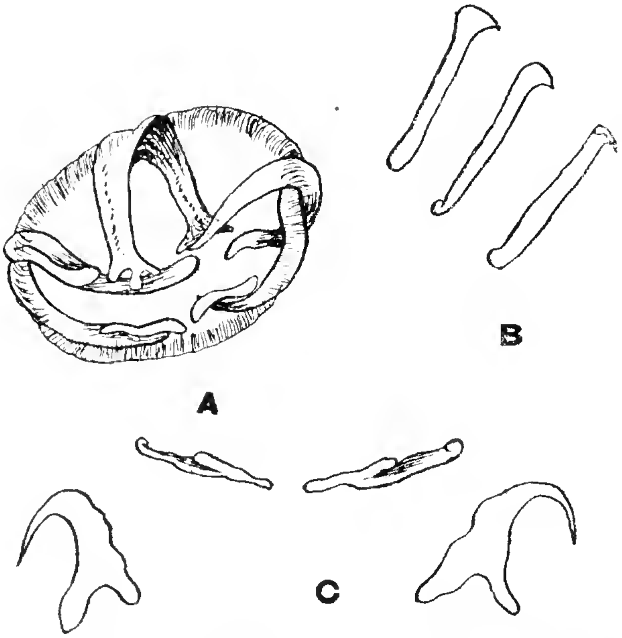

Fig. 2.—*Octobothrium thyrites*, n. sp., drawn with camera lucida. A, armature of posterior sucker; B, hooks of genital apparatus; C, hooks at posterior extremity.

The ovary, however, appears to be continuous with the lobed portion. The oviduct passes forwards dorsally, the shell gland opens into it immediately posterior and dorsal to the yolk reservoir. It continues forwards ventrally as the uterus to open posteriorly to the male genital opening. The vitelline glands extend along either side from the "neck" to the posterior end of the body. The longitudinal ducts open into a large transverse yolk duct which opens medially into the yolk reservoir, to the right of which lies the ovary. A single yolk duct passes down and opens into the oviduct. Laurer's canal is clearly seen as a narrow tube running from the junction of the oviduct and vitelline duct to the intestine. The two vaginal openings are connected by a single transverse duct, from the centre of which a single duct passes down on the right hand side to open into the double receptaculum seminis (Fig. 12). From this a narrow duct passes down and opens into the transverse yolk duct on the right. By this arrangement, sperm not used in fertilisation may be passed into the intestine. In fact, I have observed in sections structures which closely resemble sperm together with yolk granules in Laurer's canal.

History.—Hermann in 1782 was the first to describe a worm of this group. Then in 1828, Leuckart, and later Kuhn, described the same species. At first the posterior end was taken for the anterior end, and vice-versa.

I have followed Bronn's classification, which gives the following synonyms for *Octobothrium*:—*Dactylocotyle, Choriocotyle, Pterocotyle, Glossoctyle, Octocotyle, Ophiocotyle* and *Octosoma*.

Of the previously described species I have not been able to obtain the literature describing—*O. lanceolatum, O. sagittatum,* and *O. arcuatum*.

O. thyrites is distinguished from *O. thunninae* by the following points:—

1. The arrangement of the suckers on the posterior disc.
2. The posterior disc is not divided from the body by a constriction.
3. The intestine is forked below, not above, the sexual openings.
4. The genital armature is distinctive in both species.

Genus Ancyrocephalus Creplin, 1839.

(Syn. *Diplectanum* Diesing, 1858). (MacCallum 9.)

Ancyrocephalus bassensis, n. sp.

(Plate VIII., Fig. 3.)

Marine form found in great numbers on the gills of *Platycephalus bassensis* (Flathead).

Locality.—Port Phillip Bay.

Length varies considerably; formalinised animal, measuring 0 49 mm. to 0·95 mm.; average breadth 0·09 mm.

External Features.—Body elongate and circular in section. At the anterior end there is a slight indication of a "head" region; at the posterior end is a fixing disc which is not sharply marked off from the body. The disc is armed with nine pairs of hooks, consisting of two large pairs, the bases of which are bifurcated and connected by two cross bars, and seven minor pairs (Pl. VIII., Fig. 3).

Musculature.—This consists of an inner and outer longitudinal layer, with a circular layer between them. The longitudinal layer at the posterior end is strongly developed to supply the disc. Three pairs of head organs and numerous cephalic organs are present, the latter being arranged laterally and extending from the anterior pair of eyes to the region posterior to the pharynx.

Alimentary Canal.—The mouth is situated on the ventral surface in the "head" region, and opens into a very muscular pharynx. This opens into a short oesophagus, passing into the simple forked intestine which ends blindly at the posterior end of the body, and is devoid of caeca.

Reproductive System.—The position of the testis and ovary varies according to the degree of contraction of the animal. The testis is a single large rounded structure taking up the whole of the diameter of the body and lies immediately posterior to the ovary. A single vas deferens is given off anteriorly on the left, and passes forwards ventrally to a large vesicula seminalis, opening to the exterior by a chitinous penis. A well marked prostate gland lies to the left of the penis, into the base of which it opens (Pl. VIII., Fig. 3).

The ovary is much smaller, and lies dorsally and anteriorly to the testis. The oviduct is short, and passes forwards as the uterus to open to the exterior with the vas deferens at the common genital opening which is median and ventral in position. The vagina is very short, and opens on the left just anterior to the ovary; it connects with the receptaculum seminis which is globular in shape, before passing immediately into the genital junction. The vitellaria are well developed, extending along the lateral margins, and the transverse yolk duct passes across anterior to the ovary.

I have found no reference to any other description of this genus occurring on Australian fishes.

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EXPLANATION OF PLATES.

PLATE VIII.

Fig. 1.—*Anchylodiscus gadopsis*, n. sp. Entire animal, ventral view.
Fig. 2.—*A. tandani* Johnston and Tiegs. Disc in ventral view (from T. H. Johnston and O. W. Tiegs (8)).
Fig. 3.—*Ancyrocephalus bassensis*, n. sp. Entire animal, ventral view.

PLATE IX.

Fig. 4.—*Squalonchocotyle antarctica*, n. sp. Entire animal, ventral view.
Fig. 5.—*S. antarctica*, n. sp. Longitudinal section.

PLATE X.

Fig. 6.—*Anchylodiscus gadopsis*, n. sp. Transverse section, showing the relative position of ovary and testis.
Fig. 7.—*Macrophylla antarctica*, n. gen. et sp. Entire animal.
Fig. 8.—*M. antarctica*, n. gen. et sp. Reproductive organs, slightly diagrammatic.
Fig. 9.—*M. antarctica*, n. gen. et sp. Section through body wall, highly magnified.

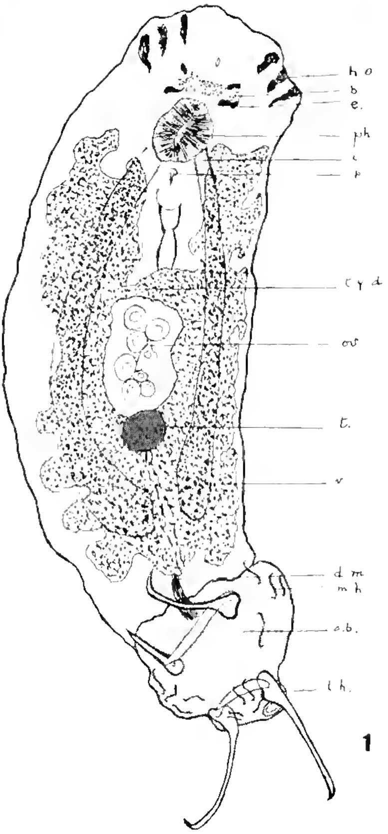
PLATE XI.

Fig. 10.—*Octobothrium thyrites*, n. sp. Entire animal with alimentary canal drawn on the right side only, and vitellaria on the left side.

Fig. 11.—*O. thyrites*, n. sp. Posterior end, highly magnified.
Fig. 12.—*O. thyrites*, n. sp. Reproductive organs, slightly diagrammatic.

Explanation of Lettering.

a.s. Sucker with chitinous armature; *b.* "brain"; *b.c.* Buccal sucker; *c.* cuticle; *c.a.* caudal appendage; *c.b.* cross-bar; *c.g.* cephalic glands; *c.g.o.* common genital opening; *c.m.* circular muscle layer; *d.m.* disc muscle; *d.s.* double sucker; *e.* eye; *eg.* egg; *ep.* epidermis; *g.o.* genital openings; *h.o.* "head organ"; *i.* intestine; *i.c.* intestinal caecum; *l.c.* Laurer's Canal; *l.h.* major hook; *l.m.* longitudinal muscle layer; *m.* mouth; *o.* oviduct; *oe.* oesophagus; *o.s.* oral sucker; *ov.* ovary; *p.* penis; *p.g.* prostate gland; *ph.* pharynx; *p.i.* part of intestine; *p.s.* posterior sucker; *r.* radius; *r.s.* receptaculum seminis; *s.* sucker; *s.g.* shell gland; *t.* testis; *t.s.* testicles; *t.y.d.* transverse yolk duct; *u.* uterus; *v.* vitellaria; *v.d.* vas deferens; *vg.* vagina; *vg.o.* vaginal opening; *v.s.* vesicula seminalis; *y.g.* yolk glands; *y.o.* young ova; *y.r.* yolk reservoir.



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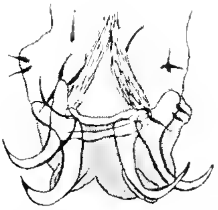

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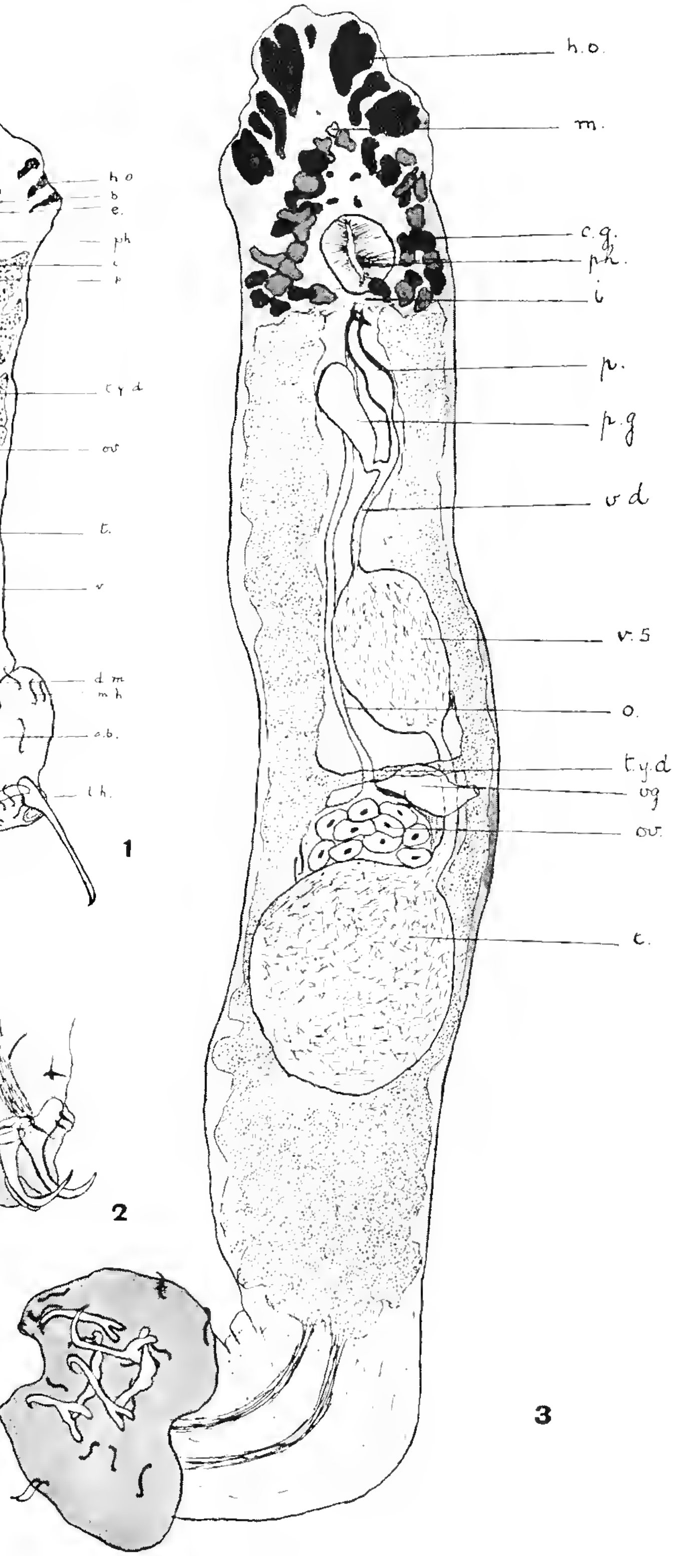

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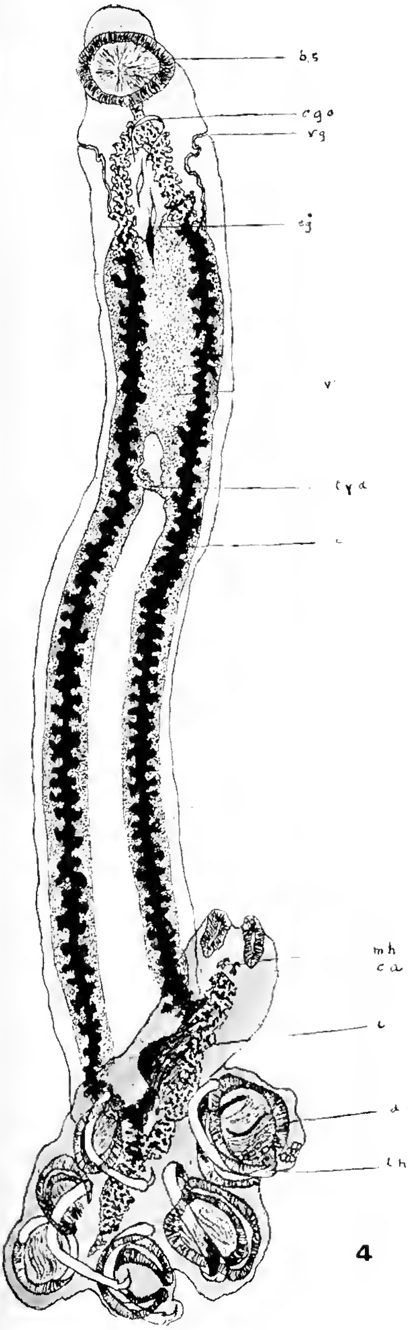

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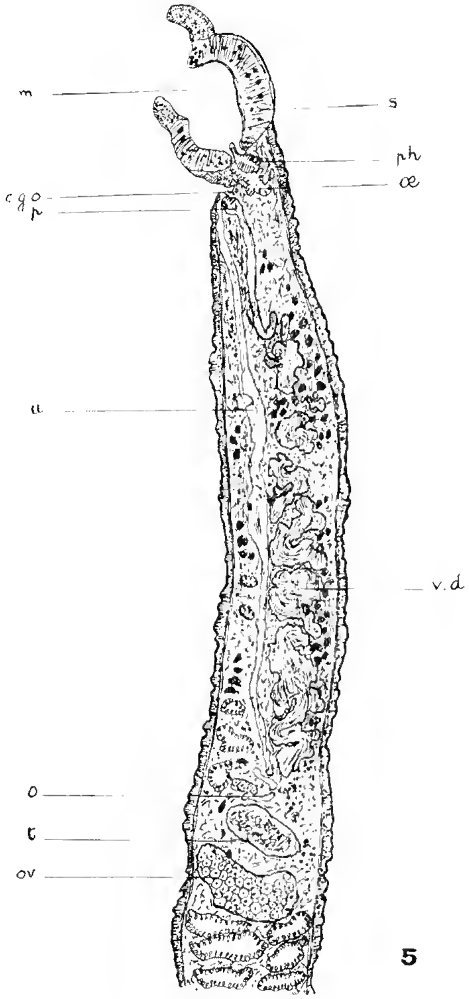

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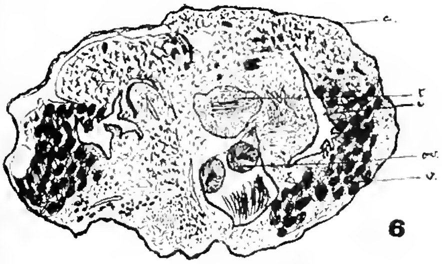
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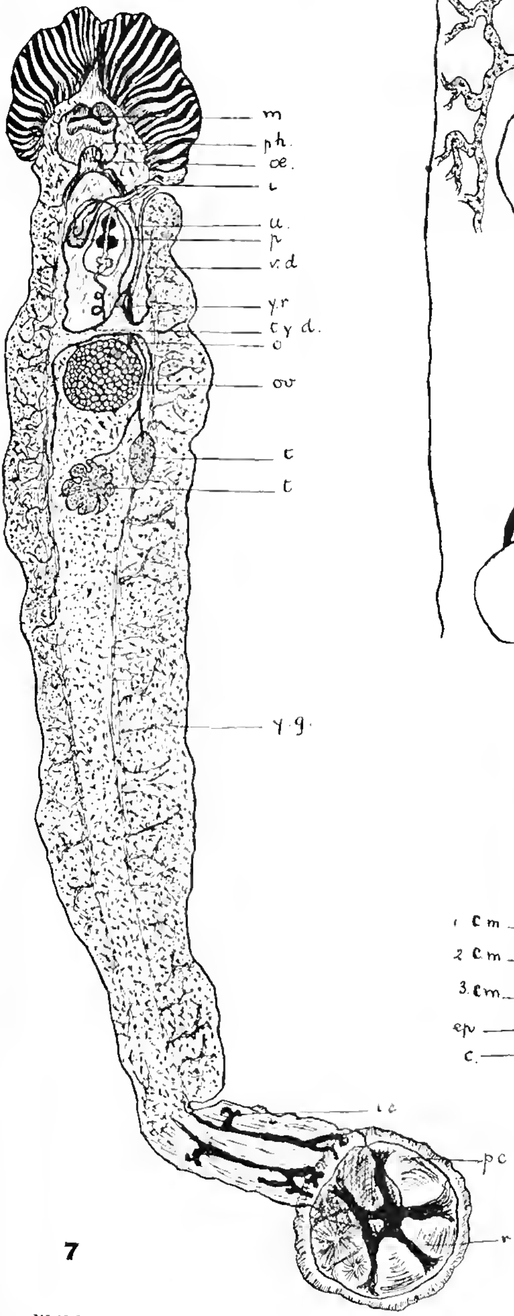
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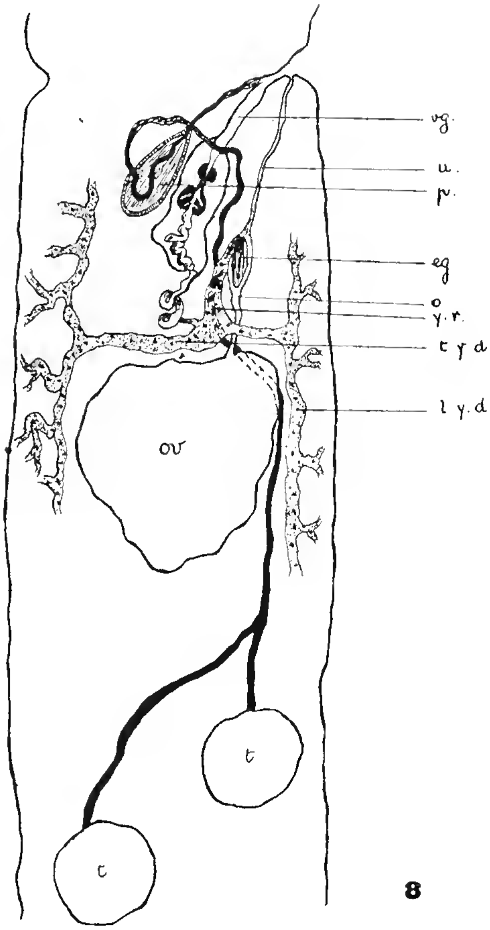
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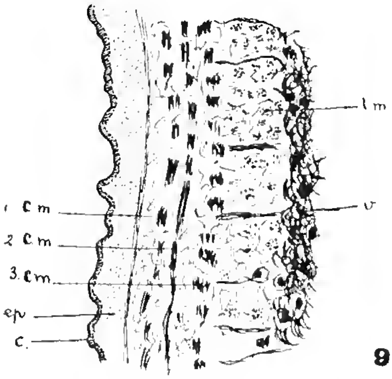
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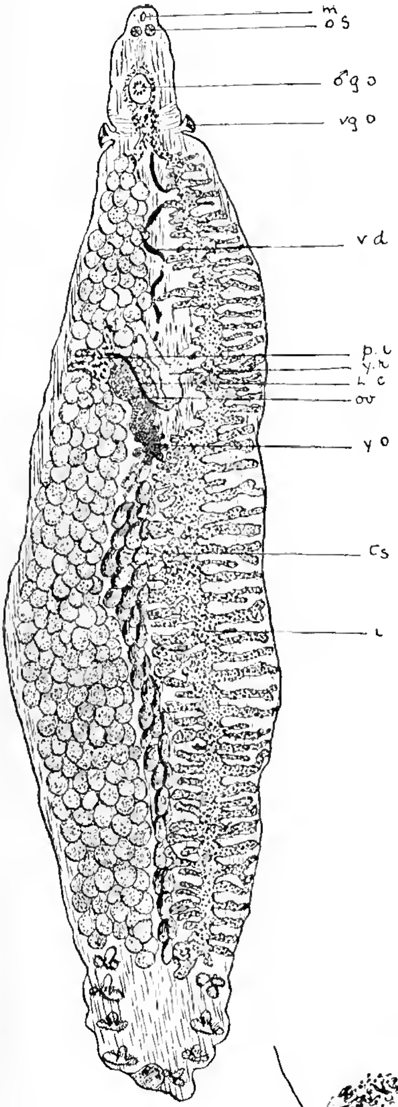

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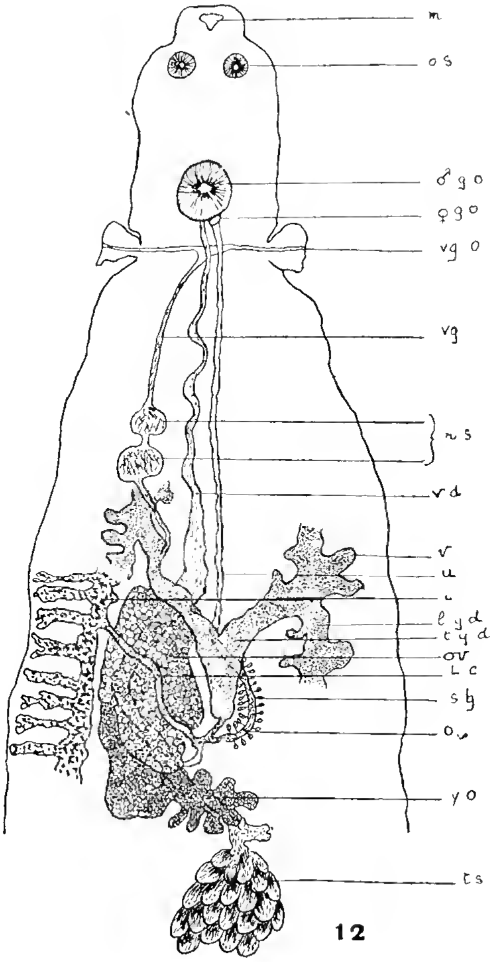

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[Proc. Roy. Soc. Victoria, 41 (N.S.), Pt. I., 1928.]

Art. IV.—*Note on the Reflection of X-rays from Glass and Quartz.*

By

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(Read 12th April, 1928; issued separately 27th September, 1928.)

The reflection of X-rays has been observed by the authors for glancing[1] angles up to 45° from glass and 40° from quartz, the critical or limiting angle not having been observed. The X-rays incident on the glass or quartz are, it is believed, heterogeneous X-rays of wave-length in the region of about 50 Å.U. The most intense wave-length in the incident radiation is probably the $K\alpha$ line of carbon of 45 Å.U. wave-length.

That X-rays incident at angles of less than 1° are reflected by glass and by metals is now a well-known phenomenon (1), but that a wave-length of about 50 Å.U. would be reflected when incident at about 40° is not to be expected from the observations already made. Holweck claims to have observed the reflection of long X-rays from polished bronze at 11·7° and 16·2° (2). Dauvillier (3) remarks that he observed in this region (50 Å.U.) optical reflection from glass and from a thin film of melissic acid on lead.

Assuming that we have correctly interpreted the preliminary observations which we have made, it can be concluded that X-rays can be reflected from spherical surfaces and brought to a focus, which will make new methods for the study of long X-rays possible.

Experiments.

The apparatus used in our experiments is a vacuum spectrograph in which the crystal has been replaced by a piece of optically flat plate glass or quartz which acts as the reflector of the X-rays. The target, Wehnelt cathode, the reflector, the camera and photographic film are in the same vaccum.[2] The X-rays

1.—All angles of incidence and reflection stated are glancing angles.
2.—The spectrograph in the use of a common vacuum for the "X-ray tube" and spectrograph is similar to that described by Shearer, *Phil. Mag.*, Oct., 1927.

emitted by the target pass through a circular hole in a shield and then fall on the reflector. The reflected rays pass through a slit into a camera and fall on a Schumann film. Copper and carbon targets have been used. The difference of potential between the cathode and the copper target was at first up to 10,000 volt rectified A.C. In later experiments, the P.D. between the carbon target and the Wehnelt cathode has been about 375 volt given by a battery.

The photographic film on development shows a slit image of the focal spot on the target. This slit image is the same whether it is taken direct, without the glass or quartz reflector, or with the reflector, except that in the latter case there is lateral inversion of the image. The angle of incidence is accurately equal to the angle of reflection. Using the copper target reflection up to an angle of 29° from glass was observed, and with the carbon target rays reflected at 45° from glass and 40° from quartz have been photographed. In each case, this angle is the largest attainable with the spectrometer. An exposure of 1200 milliampere second and a potential difference of 375 volt gives a well-defined image of the focal spot on Schumann film.

Estimates of intensity with the Schumann film are difficult to make. The ratio of intensity of the reflected beam to that of the incident beam in the case of the graphite target is of the order of ½ up to 30° glancing angle. At 40° incidence this ratio had considerably diminished.

The evidence that the radiation is optically reflected appears to be conclusive.

What is the nature of the radiation which is reflected?

As the photographic film is enclosed and placed opposite the slit (0·05 mm. wide) in a metal box which is at the potential of the negative end of the filament of the cathode, the rays cannot be cathode rays.

The radiation—

(*a*) is emitted, as shown by the slit images, from the same focal spot as that from which short wave X-rays[3] were proved to be emitted in other experiments;

(*b*) penetrates aluminium foil[4] 0·0006 mm. thick, about 1% of the incident radiation being transmitted (this foil was tested and found to absorb visible light);

(*c*) is absorbed by glass and by fluorite;

(*d*) is emitted by a carbon target on which 375 volt electrons are incident;

3.—That these rays were X-rays was fully verified by wave-length measurement.

4.—In a previous paper by one of the authors (Shearer, *P. M.* Vol. IV., p. 747, 1927), two thicknesses of aluminium foil were not found to be transparent to X-rays in this region. It should be noted that only one thickness of foil is penetrated in the observation recorded above, and all the conditions in these experiments tend to give an incident beam of increased intensity.

(*e*) is not emitted when the filament is hot, and no potential is applied between it and the anode;

(*f*) is in its action on Schumann film approximately proportional to the exposure measured in milliampere second at constant voltage.

If the radiation is not X-rays emitted according to the usual laws[5] connecting wave-length with applied potential, it can be longer in wave-length than is given by those laws; but it would appear to be very improbable that it is shorter. The observation (*c*) above excludes the assumption that the radiation is in the range of about 8000 down to 1200 Å.U. Observation (*b*) excludes the region longer than 8000 Å.U. It remains to consider the region from about 100 to 1200 Å.U. All the evidence from the observations of Schumann, Lyman, Millikan and Holweck[6] show that radiation in this region is highly absorbed by all forms of matter, and thus (*b*) above excludes the Millikan and Lyman regions of the spectrum. Observation (*e*) confirms that the radiation is not one emitted by a hot body at a temperature up to 1200°C., the highest temperature of the filament. The absorption measurement in (*b*) is consistent with the radiation being of wave-length from 50 to 80 Å.U., assuming the λ^3 law of absorption. Observation (*f*) implies that the radiation is produced by the incidence of electrons on the target.

Taken as a whole, the evidence strongly supports the view that X-rays of wave-length about 45 Å.U. can be reflected at angles up to 40° from glass and quartz.

The Lorentz dispersion formula in the form

$$\delta = 1 - \mu = \frac{e^2}{2\pi m} \sum \left(\frac{n_s}{\nu^2 - \nu_s^2} \right) = 4{\cdot}478.10^{-14} \sum \left(\frac{n_s}{\nu'^2 - \nu_s'^2} \right)$$

where e and m are the charge and mass of the electron, n_s is the number of electrons per unit volume of natural frequency ν_s (wave-number ν'_s) and ν is the frequency of the incident radiation (wave-number ν'), has been shown to give, in the case of X-rays, positive values of δ which are confirmed by experiment (1). Total reflection is therefore to be expected for radiation incident on substances for which μ is less than unity at a glancing angle less than a certain critical value. This was first observed by Compton (1) from surfaces of glass, silver, lacquer and calcite.

5.—These laws have been assumed by Holweck for the range 44 to 300 A.U. "De la Lumière aux Rayons X", Chap. III.

6.—Holweck finds that μ/ρ for celluloid increases rapidly up to about 300 A.U., becomes a maximum at about 320 A.U., and then rapidly decreases toward 1200 A.U.

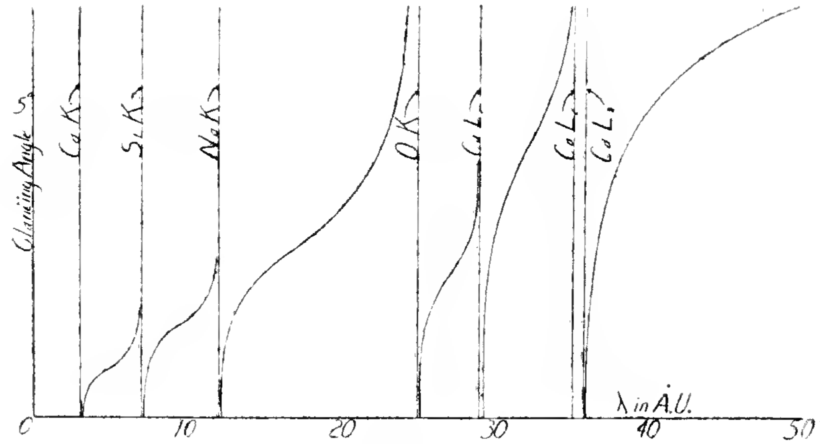

FIG. 1.

In the figure the critical glancing angle for glass θ_c is plotted against wave-length in Å.U. of the incident radiation, where θ_c is obtained from the relation $\cos \theta_c = \mu$ and μ is calculated from the Lorentz formula. n_s is obtained from the following data (assumed) :—

Density of glass:	3 gm./cc.
Composition:	71% SiO_2
	15% CaO
	14% Na_2O.

Number of electrons per atom:

	K	L	M	N
Si(14)	2	8	4	—
Na(11)	2	8	1	—
Ca(20)	2	8	8	2
O(8)	2	6	—	—

The following values of $\lambda_s \left(=\frac{1}{\nu'_s}\right)$ in Å.U. were adopted:

	K	L
Si(14)	7	112
Ca(20)	3	33
Na(11)	12	322
O(8)	25	717

The results obtained in this paper do not appear to be reconcilable with this curve.

We have to thank Messrs. H. Massey and C. Mohr for computing the data shown in Fig. 1.

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(1) A. H. COMPTON. X-rays and Electrons, Chap. VII.
(2) HOLWECK. De la Lumiere aux Rayons X, p. 85, Paris, 1927.
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[Proc. Roy. Soc. Victoria, 41 (N.S.), Pt. I., 1928.]

Art. V.—*Contributions to the Flora of Australia, No. 35.** *The Naturalized Aliens of Victoria.*

By

ALFRED J. EWART, D.Sc., Ph.D., F.L.S., F.R.S.

[Read 12th July, 1928; issued separately 27th September. 1928.]

These now form a prominent part of the Flora of Victoria, and they are steadily increasing both in numbers of species and of individuals. In 1909 the number of aliens recorded was 363, and in 1928 it had risen to 461. This rate of increase represents approximately one every two months, or slightly more than five a year, and this rate of increase has been maintained with remarkable uniformity during the past sixty years. The alien plants are also more numerous in individuals than the native flora, although the latter represents a much larger number of species, about 3000, and the aliens occupy a greater area of the soil than does the native flora outside of the forest areas.

Nevertheless, all the aliens are not obnoxious, since they include all the clovers, trefoils and medicks, most of the more valuable pasture grasses, and some garden plants that have run wild. Less than a hundred of the aliens are serious weeds, and few of them represent as serious a menace as does our native bracken on newly cleared forest land. In addition, two native plants, the Chinese Scrub (*Cassinia arcuata*) and the Nut Grass (*Cyperus rotundus*), have proved so troublesome as to be proclaimed for the whole State, while the native Prickly Acacia (*A. armata*) has been proclaimed for eleven shires, and the Three-cornered Jack (*Emex australis*) for two.

The sources of origin of the aliens show several points of interest. Naturally most are derived from plants with a wide general distribution. Thus 140 are native to Europe, Asia and Africa, and 66 to Europe and Asia. Of plants native to single continents, Europe has contributed 57 aliens, America 30, North America 18, South America 12, North and Central Africa 11, South Africa 29, and Asia 2. From the Mediterranean region 31 aliens are derived, whereas only 11 are native to Europe, Asia and America, 7 to Europe and Africa, 4 to Europe and America, and 2 to Asia and Africa. Only 8 of our aliens are general cosmopolitans exclusive of Australia, 13 are cosmopolitan to the temperate regions, 7 to the warmer zones, and 2 come from the N. Temperate and Arctic zones.

Not included in the above are the following single cases:—*Avelina Micheli* is derived from Italy, *Calycotome spinosa* from Spain, *Centaurea Picris* from the Caspian region, *Chloris abys-*

*No. 34 in *Proc. Roy. Soc. Vic.*, n.s., xl. (2), p. 81.

sinica from Abyssinia, *Leycesteria formosa* from the Himalayas, *Lychnis divaricata* from Sicily, *Lycium chinense* from China, *Rubus phoenicolasius* from Japan, and *Verbena venosa* from the Argentine. Only one alien, *Eleusine coracana,* has its home in Asia, Africa and America, but several are native to other parts of Australia. *Albizzia lophantha* is native to West Australia and *Andropogon erianthoides* to New South Wales and Queensland, but both have become naturalised in Victoria. *Hibiscus Trionum*, which is native to Europe, Africa, Asia and Australia (with the exception of Victoria and Tasmania), has reached Victoria as an alien with the advent of civilisation, and in the same way *Setaria macrostachya*, which is native to Asia and Tropical Australia, has established itself in the South, aided by man. The activities of man, particularly through the transport of fodder, are probably responsible for the relatively high proportion of aliens contributed by South Africa, and these include some of our worst weeds both here and still more in West Australia (Cape weed, Onion grass, Stinking Roger, etc.).

The native flora of Victoria, exposed as it is to the competition of imported aliens and to the pressure of settlement, is in a condition of rapid flux. It is probable that less than half of the original flora will survive within 50 years, and that many plants originally widely spread will be confined to special localities. Were it not for the disturbing factors introduced by man the spread of the introduced aliens might have been used as a test of Willis's age and area hypothesis. As it is, although in a very general way the older weeds are more widely spread than the more recent introductions, the rule does not apply to hardly any comparable pair of individual cases. Thus the Evening Primrose, *Oenothera biennis* (1887), has covered less ground than the Foxglove, *Digitalis purpurea* (1917). The Musk Weed, *Myagrum perfoliatum* (1916) has become more abundant than the Horehound, *Marrubium vulgare* (1870), and Onion grass, *Romulea Bulbocodium* (recorded in 1873, but abundant in Melbourne in 1860), with twenty years' start has hardly covered more ground than St. John's Wort, *Hypericum perforatum* (recorded in 1893), but introduced in 1880. A still more striking case is that of the Stinkwort, *Inula graveolens* (1893), which rapidly overtook the Stinkweed, *Gilia squarrosa* (1887), both in area and in abundance.

One would expect the largest number of the naturalised aliens to belong to the Compositae (70), and the disproportionately high number derived from the Leguminosae (50), and from the Gramineae (102) is an aftermath of the pastoral phase when the world was searched for fodder plants to improve our pastures. The native Gramineae comprise 125 species, and many of these are dying out, so that in the near future the grass flora will be mainly foreign. Another curious disproportion is shown among the Monocotyledons. There are 13 alien Irids and only four of the Liliaceae, while no Orchid or Amaryllid has become naturalized, and only one alien sedge has crept in among the 111 native species of the Cyperaceae. As the native Irideae are only 8 in number, this is the first native order in which the aliens have widely outnumbered the natives. Of the total of 461 naturalized aliens all but twelve belong to natural orders already represented in the flora. The new orders added are Aroidaceae (1), Cactaceae (2), Dipsacaceae (2), Fumariaceae (1), Polemoniaceae (1), Pontederiaceae (1), Resedaceae (2), Salicaceae (1), Valerianaceae (1), but no member of the Myrtaccae, Sapindaceae or Rhamnaceae has become naturalized. Aliens are relatively high in the Labiatae, Solanaceae and Scrophulariaceae, nearly half the latter order being now represented in Victoria by naturalized aliens (24 native species to 18 aliens).

Strictly speaking, the age and area hypothesis is held to apply to closely related plants or to species of the same genus, although if true at all there seems no reason why it should not apply generally or why, if it does not apply generally, it should be true in a restricted form. Even taking species of the same genus, it appears that the time factor is of far less importance in determining the area covered by a species than its suitability to new habitats, its means of distribution, its aggressiveness and its resistance to foes and injurious agencies. In the case of the genus *Poa*, *P. annua*, *P. pratensis* and *P. trivialis* were recorded as naturalized in 1878, 1888 and 1888 respectively, but *P. pratensis* has taken the lead because it is better suited generally to the local conditions, and *P. compressa* (1908) is rapidly overtaking some of the earlier introductions. Similarly, in the case of the clovers, taking those which spread by natural means, *Trifolium glomeratum* (1892), is more widely spread than *T. arvense* (1887), and of the red (*T. pratense*), yellow (*T. procumbens*), and white clovers (all 1864), white clover (*T. repens*) has taken the lead mainly because of its superior means of natural distribution and its greater staying power.

According to Willis, however, comparisons cannot be made between single pairs of species, but only between groups of not less than 10 closely related species. As a matter of fact, if the age and area hypothesis has any general value, any average of any 10 pairs selected at random should be as good as two groups of ten each of related species. Even using 10 pairs of related species it is easy to construct natural cases in which the "law" could not apply. Thus, suppose a genus of five species is diverging through subgenera B, C and D, each of five species, and that in groups B and C, the size of the seed diminishes, and in group D that of the pappus, so that groups B and C have twice the rate of dispersal of A and D.

Then, taking any descending order of age for the species groups B and C will occupy double the area relatively to a given age as compared to groups A and D. Beneath the areas are set out proportionately to the ages and rate of spread in each group.

The ages selected are immaterial if they are set out in descending order.

Genus A.	Age in years.	Area in 10,000 acres.	Sub-Genus C.	Age in years.	Area in 10,000 acres.
1	6.000	60	1	2,500	50
2	5,500	55	2	2,000	40
3	5,500	55	3	2,000	40
4	4.500	45	4	1,500	30
5	4.500	45	5	1,000	20
Sub-Genus B.			Sub-Genus D.		
1	3.500	70	1	800	8
2	3.000	60	2	600	6
3	3,000	60	3	600	6
4	2.500	50	4	500	5
5	2.000	40	5	500	5
	Proportion total age to total area	1 : 135		1 : 175	

Hence the proportion between age and area may vary widely even in comparisons between groups of ten, each containing equal numbers of plants with the same rate of dispersal. If groups A and C are compared with groups B and D, the relative proportions between age and area are as 1 : 126 and as 1 : 61.

If groups B, C and D had all twice the rate of dispersal of A, then a simple arithmetical calculation shows that in 6000 years the area of group C and D would become equal to that of group A and B, whereas the average group ages would be as 57 : 100. Suppose that the dispersal of a plant is uniform, so that it spreads at the rate of a mile a year; then the area covered is proportional to the square of the distance of linear dispersal, i.e., to the square of the time, so that in one, two and three years the areas are respectively one, four and nine.

Hence if the groups A, B, C and D all had the same rate of spread and their average ages were 10,000, 5,000, 2,500, and 1,000 years, then the areas covered would be proportional to the squares of the ages, i.e., as (A) 100 : (B) 25 : (C) 9 : (D) 1. Thus the accidental inclusion of a single A plant in a D series because of an apparent close affinity would vitiate subsequent calculations, and to avoid such inclusions it is necessary to assume the age and area hypothesis, i.e., the very thing set out to be proved. It seems probable that the age of a species is one of the least important of the factors governing its distribution, and that in only few cases can a relation be traced between the age of species and the area they cover at the present day. The area of a cosmopolitan is limited by that of the surface of the earth, and during its existence a species like the common bracken or any other cosmopolitan may have travelled several times round the earth. Bracken certainly, and other cosmopolitans probably also, have had sufficient time to cover the surface of a planet far larger than Jupiter, and in such cases the present area of distribution cannot bear any definite relation to the age of the species.

END OF VOLUME XLI., PART I.

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Art. VI.—*On Grooved, Pitted and Miniature Pedestal Rocks at Lake Goongarrie, Western Australia.*

By J. T. JUTSON, B.Sc., LL.B.

(With Plates XII., XIII.)

[Read 13th September, 1928; issued separately 30th January, 1929.]

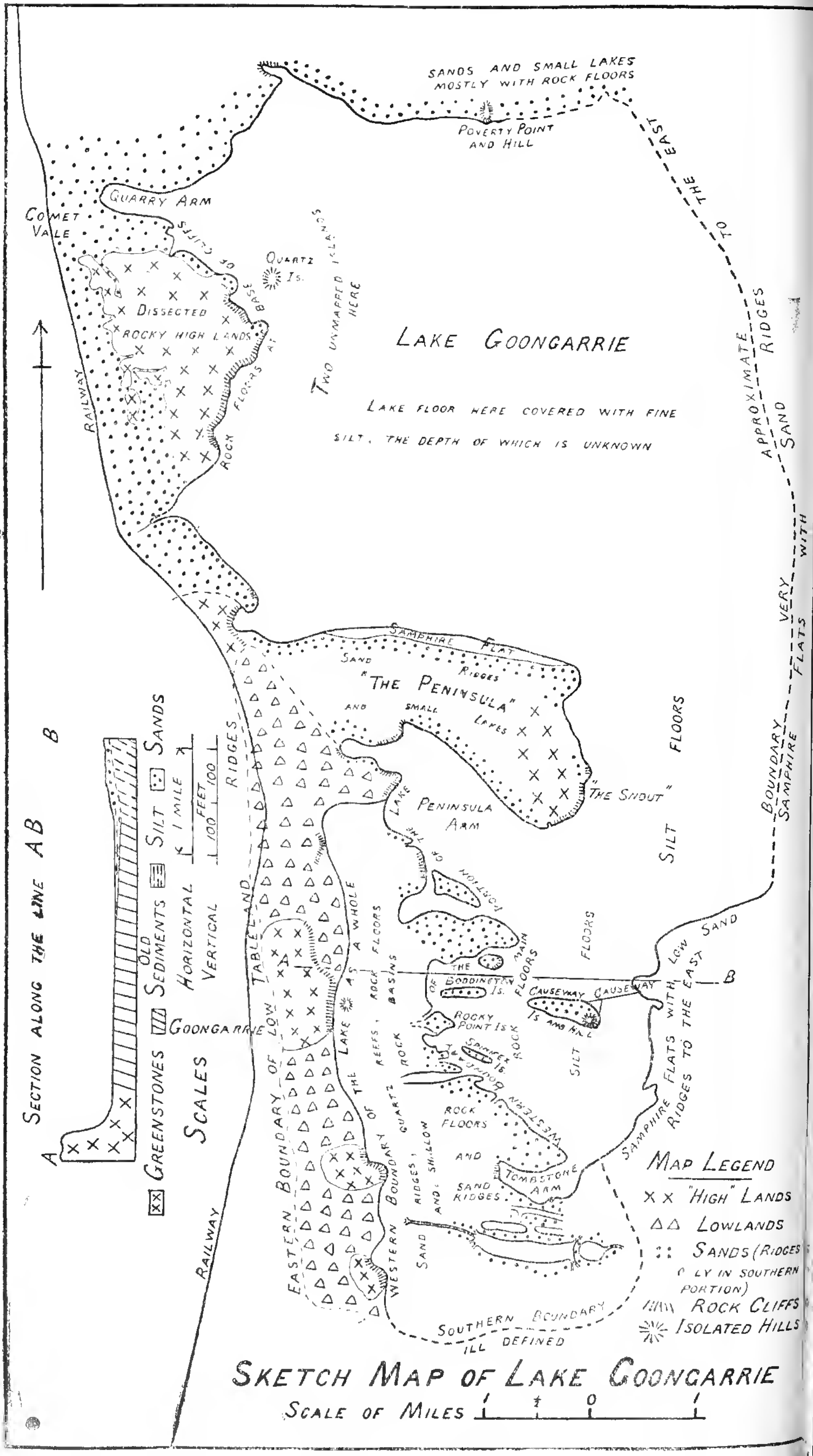
Contents.

I. Introduction.

Lake Goongarrie is a "dry" lake or playa in sub-arid south-central Western Australia. It lies north of Kalgoorlie and just to the east of the railway line from Kalgoorlie to Leonora, and extends northwards from Goongarrie to Comet Vale. It is situated on the Great Plateau of Western Australia, which in the district referred to is about 1200 feet above sea-level.

In the course of geological work some years ago at the mining centres of Goongarrie and Comet Vale, the writer made a sketch survey of the lake, the map of which has been published on a reduced scale in this journal in connection with a paper (1) by the writer on various physiographic phenomena observed during the course of the survey and is here reproduced. The same map, but on a larger scale, appears in an official report (2, Plate I.) by the writer, published by the Geological Survey of Western Australia.

In addition to the phenomena described in the paper (1) just referred to, certain rocks, some *in situ* and some fragmentary, were observed to be pitted, grooved or undermined in a remarkable manner, and under conditions with regard to adjacent rocks


SANDS AND SMALL LAKES MOSTLY WITH ROCK FLOORS
POVERTY POINT AND HILL
TO THE EAST
QUARRY ARM
COMET VALE
CLIFFS OF
QUARTZ Is.
TWO UNMAPPED ISLANDS HERE
DISSECTED ROCKY HIGH LANDS
ROCK FLOORS AT BASE
LAKE GOONGARRIE
LAKE FLOOR HERE COVERED WITH FINE SILT, THE DEPTH OF WHICH IS UNKNOWN
APPROXIMATE BOUNDARY
RIDGES SAND WITH VERY FLATS SAMPHIRE
RAILWAY
SAMPHIRE FLAT
SAND RIDGES AND SMALL LAKES
"THE PENINSULA"
"THE SNOUT"
PENINSULA ARM
SILT FLOORS
LOW TABLELAND RIDGES
EASTERN BOUNDARY OF LOW TABLELAND
THE LAKE AS A WHOLE
REEFS, ROCK FLOORS
ROCK BASINS
LOW SAND
CAUSEWAY
THE EAST
THE BODDINGTON Is.
MAIN FLOORS
CAUSEWAY IS AND HILL
ROCKY POINT Is.
SPINIFEX Is.
ROCK FLOORS
WESTERN BOUNDARY OF THE QUARTZ
SAND RIDGES AND SHALLOW
SAMPHIRE FLATS WITH RIDGES TO THE EAST
ROCK FLOORS AND SAND RIDGES
TOMBSTONE ARM
SOUTHERN BOUNDARY ILL DEFINED
SECTION ALONG THE LINE AB
A
B
GREENSTONES
GOONGARRIE
OLD SEDIMENTS
SILT
SANDS
SCALES
HORIZONTAL 1 MILE
VERTICAL 100 FEET 100
MAP LEGEND
"HIGH" LANDS
LOWLANDS
SANDS (RIDGES ONLY IN SOUTHERN PORTION)
ROCK CLIFFS
ISOLATED HILLS
SKETCH MAP OF LAKE GOONGARRIE
SCALE OF MILES 1 ½ 0 1

that indicated that the forces responsible for the production of such features were working in a peculiarly restricted way. A description of such occurrences, together with a discussion as to the origin of such features, is therefore of interest; but this interest is heightened by the possibility that light may thereby be thrown upon the origin of the surface features of the interior of Western Australia, concerning which—especially in regard to the "dry" lakes or playas—no unanimity has yet been reached. This paper is therefore submitted.

II. Previous Literature.

The writer is not aware of any similar phenomena in Western Australia having been described, and he consequently believes that this paper contains the first description of such phenomena occurring in that State, or indeed in any other part of Australia; but the literature of the other States, which may bear on the matter, has not been searched.

Extra-Australian literature treats of some related occurrences, and such will be referred to below.

III. Climatic Conditions.

In order that the facts and arguments submitted may be better appreciated, a brief statement of the climatic conditions of the area is advisable.

The Comet Vale-Goongarrie district has an average rainfall of about ten inches per annum, most of which falls in fairly steady rain during the winter months. In summer, the individual falls are frequently heavier than those of winter, and consequently are probably responsible for more erosion than the winter rains, notwithstanding the greater abundance of the latter. There is great variation in the annual quantity of rain, some years being as low as four or five inches, whilst a wet year may have up to 19 or 20 inches, which, however, is exceptional.

The range of temperature is considerable. In the summer the temperature may frequently rise above 100°F., and in the winter it may fall below 50°F. in the daytime and may reach freezing point at night. In the summer there is great radiation of heat at night, which thus often brings about a pronounced fall in the temperature during that time. The nights are therefore almost always cool.

The humidity is low, but the evaporation of water is enormous, as is shown by the records from Coolgardie, farther south, where the amount reaches 87 inches annually.

Frosts occur in the winter, and hence are responsible for a certain amount of rock splitting. The variation in day and night temperatures also brings about exfoliation of the rocks.

From the writer's observations, the winds, taken as a whole, are not very strong, except the westerlies, which at times blow with great force, and are apparently the dominant winds.

The lake floor is almost always free from water; hence the name "dry" lake. When rain falls it spreads as a sheet a few inches thick over the lake floor, but it rapidly evaporates. This floor is destitute of vegetation, but at its margin, in those places where the ground is but slightly higher, samphire and other salt-loving vegetation grow, whilst the rest of the country carries small trees and shrubs, forming a scrub, with much bare ground between the plants.

IV. Description of the Occurrences.

(A) Grooved Rocks.

(*a*) "*Greenstones.*"—The western side of Lake Goongarrie at Comet Vale consists, in places, of moderately high and steep cliffs of tough, fine-grained basic rocks ("greenstones"), of which amphibolites are probably predominant. At the immediate foot of the cliffs there is a rock floor of similar rocks.

Just south of a large "natural quarry," almost due east of the old Sand Prince Lease,[1] a remarkable set of grooves may be observed in the lowest rocks of the cliff face. These grooves are closely spaced, are usually in straight lines, and run in all directions in a horizontal plane, in that plane in some cases being roughly parallel to and in other cases intersecting one another; but their inclination to that plane is generally vertical or close to the vertical. They may vary from an inch or two to about ten inches in length, with a depth varying from a few lines to about four inches, and a maximum width of an inch. In length, depth and width, the grooves tend to taper into the solid rock.

On careful examination, these rectilinear grooves are found to follow the small irregular divisional planes (due to jointing and earth movements) which abundantly traverse the rocks, but the grooves are not mere openings in the rocks caused by the two sides of a divisional plane becoming forced apart. The rock material has been actually removed by some natural agent so as to leave a distinct groove of the kind indicated. The grooving agent has merely selected the divisional planes as convenient lines for the commencement of operations. Possibly, without such planes the action would not take place, at least not in such a rectilinear fashion. The grooved surfaces are mostly fairly smooth, but they are not polished.

The grooved rocks extend from three to four feet upwards from the lake floor. Above this height grooves are absent, although the rocks form part of the same rock mass as the grooved ones and have the same divisional planes.

1.—This and other leases referred to below are marked on the geological maps accompanying the writer's geological report on the district (2).

Apart from the grooving, the rocks of the cliff face are breaking down under the influence of the weather in the usual way.

The accompanying photograph (Pl. XII., Fig. 1) illustrates the features described.

Grooves in greenstones have also been noted at the following localities, among others:—

(i.) At the large "natural quarry" already referred to, there is a talus of fallen blocks of the fine-grained greenstone, which are grooved for a few feet in height at the base of the talus; whilst the higher blocks are free from grooves.

(ii.) On the western shore of the lake, about four miles north of Goongarrie, at the north-western side of a small "inlet," close to the railway line, grooving occurs in a rock cliff of greenstone, and is there limited to a height of about two feet from the base, where there is also an abundance of fine sand.

(iii.) Grooves occur in fragments of greenstone lying on the surface of the ground at the foot of the cliffs of the same rock to the west of the lake and about a quarter of a mile north of the old Beelzebub Lease, which is situated about one and a half miles to the east of the Goongarrie railway station. The ground here is well above the level of the lake floor. Fine quartz sand occurs in the grooves.

(iv.) A few chains north of the Lady of the Lake Lease, Goongarrie, there are two small greenstone knobs, not exceeding eight feet in height, the surfaces of which largely consist of fragments of the rock, the result of breaking down by the weather. These fragments for a height of not more than two feet from the floor of the knobs are grooved and also pitted. Above this height grooving and pitting do not occur. There is an abundance of fine-grained quartz sand at the bases of the knobs, and also associated with the grooved and pitted rock fragments.

(v.) On the western shore of the lake at Comet Vale, near a small "inlet" just to the north of the old Planet Lease, there is a greenstone knob a few feet in diameter and about eight feet high. The rocks of the knob are grooved to a height of about four feet from the floor of the knob, being higher than usually noticed elsewhere. On the western side of the knob there is a sand dune higher than the knob, which had wind-blown sand scattered around its base and over its flanks to a height of about five feet. At the time of observation the fine sand at the foot of the knob was being rapidly removed by the wind, and blown against the hard rocks of the knob.

(vi.) In the Black Diamond Lease at the southern end of the Goongarrie mining field, a short watercourse, commencing at a high quartz "blow," ends in a small alluvial fan, on the surface of which are many greenstone fragments, mostly a few inches only in length and breadth. On the alluvial fan there is scarcely any vegetation, and the ground is consequently exposed to the full force of the wind. The rock fragments on the fan are grooved and also pitted. The country rises from the fan, and concurrently the vegetation increases, but as it does so, the rock fragments cease to be grooved and pitted. In the actual channel of the watercourse the rock fragments have neither grooves nor pits.

(vii.) On the western shore of the lake, probably at Comet Vale, but the exact locality cannot now be indicated, grooving at the base of the greenstone rocks occurs, and some of the grooves are in parallel lines, being evidently along planes of schistosity in the rocks.

In none of the above instances have the rocks been polished.

In addition to the general grooving of rock masses and irregularly shaped fragments noticed above, an interesting occurrence of grooved rocks may now be described. The phenomena have been observed in one locality only, which is on the western side of the lake at Comet Vale near the grooved rocks first described in this paper.

At this point, on the floor of the lake close to the greenstone cliffs, a number of pebbles of the fine-grained greenstone, possessing distinct horizontal grooves, were observed. The pebbles are numerous, but are confined to a small area. They rest on the lake floor by a fairly flat bottom, but otherwise are generally rounded and usually from one to two inches in diameter. The grooving, practically in all pebbles, commences about a quarter of an inch above the bottom of the pebble, and extends, as a rule, completely around each pebble. The grooves are about half an inch in width, and penetrate the rock to a depth of usually less than a quarter of an inch. The surface of the grooved portions of the rock is even, but only slightly smoother than the surrounding parts of the pebble, and there is no indication of polishing. The pebbles have apparently been quite undisturbed for a considerable time.

(*b*) *Quartz and Jasperoid Rocks.*—At the northern end of Lake Goongarrie there is a prominent hill bordering the lake known as "Poverty Hill" (see text-fig. 1). On account of the toughness of the rocks (quartz in the form of reefs and jasperoid banded rocks, the origin of which has not been investigated) composing this hill, the latter projects somewhat into the lake as a distinct point, and hence this feature is known as "Poverty Point." At the foot of the steep cliff forming Poverty Point there is a flat cone of detritus derived from the rocks of Poverty Hill. This cone rises not more than two feet above the lake floor and in length is about one chain from north to south and two chains from east to west.

Boulders and pebbles of the quartz and jasperoid rocks (of many sizes from an inch to 12 inches approximately) are strewn upon the surface of the cone, and many of them are thin flat-lying fragments. All are more or less rounded and smoothed (but not polished) on their sides and upper surfaces, especially in the case of the larger fragments. These boulders and pebbles are remarkable for the grooving they have sustained. Some of them have pronounced horizontal grooves completely around them; in others the grooves do not extend so far. Generally speaking, the grooving is much stronger in or entirely limited to those portions which have apparently been particularly exposed to the eroding agents. In the jasperoids, when the bands are not parallel to the surface of the ground, the grooves often follow the bands, and therefore may be at any angle.[2] Two horizontal grooves, one above the other, may occur.

The width and depth of the grooves rarely exceed half an inch and are frequently less. The grooves commence usually about a quarter of an inch from the base of the pebbles, but in some cases they were as high as an inch above the base.

In addition to the rounding and grooving, the rocks were also markedly pitted. The pits may be round, elliptical or oval at their mouths and may be drilled at almost any angle from the vertical to the horizontal. In size the pits vary from about two inches to a quarter of an inch or less in diameter. The pits in places unite to form a groove, and, in some instances, the pit has extended into a hole bored right through the pebble.

The grooves and pits and the rounded faces occur, not only in the loose rocks on the small alluvial cone, but also in the rocks forming the base of the cliff. Above a height of about three feet from the floor of the cone, the rocks are almost invariably quite angular, not grooved and not pitted, although some grooving and pitting can be traced to a height of about 25 feet. But where such occurs the cliff is exposed to the action of strong south-westerly, southerly and south-easterly winds.

Similar quartz and jasperoid rocks occur at the Causeway Hill (see text-fig. 1), and there the same phenomena of rounding, grooving and pitting occur as at Poverty Point, to a height, as a rule, of about three feet from the floor of the lake.

At "The Snout" (see text-fig. 1) similar jasperoid rocks are grooved and pitted at the base of the cliff, and also on a shoulder perhaps 20 feet or more above the lake floor, but no details are available.

(B) Pitted Rocks.

(*a*) *Greenstones.*—In various places on the flats, which in part border the western shore of the lake at Goongarrie, there are a number of small, roughly circular knobs of resistant, fairly coarse-grained greenstones, in which felspar and fibrous hornblende are quite prominent. These knobs are usually from about 6 to 15 feet in height, and from about 5 to 12 feet in diameter. The flats on which they rest are usually open spaces,

2.—In the same rocks the evident difference in texture in the component bands brings about differential grooving.

with only a few scattered, low, shrubby plants. The ground may be covered with much white quartz rubble or by sandy or clayey soils.

The rocks of some of the knobs are pitted to a height of about three feet above the surface of the ground. The pits at their openings mostly are circular, with a diameter of usually less than half an inch, and with varying depths, which probably as a rule do not exceed half an inch. The pits penetrate the rocks at different angles, and in places are numerous. They pass alike through the hornblende and felspar, but the hornblende is slightly more resistant to this mode of erosion than the felspar, since in places the hornblende projects as unreduced fragments into the pit, a fact which was not observed in the felspar.

Above the limit in height mentioned, pits are absent, although the upper portions of the rocks are as much exposed to the action of the weather as the lower.[3]

Where pitting occurs, there is generally some fine quartz sand about the base of the knob and in the pits.

It may be noted that in a hornblende felspar porphyry (the precise locality of which cannot now be given) the hornblende was in small spherical nests of about equal size. In the lower portion of the outcrop, the hornblende weathers out more rapidly than the felspar phenocrysts, and hence a number of small pits of uniform size have developed.

The pitting of the greenstones in manner described above may be observed at the following localities:—Towards the northern end of the Bushman Lease, south-east from Goongarrie township; in or near the Lady of the Lake Lease, at the southern end of the Goongarrie field; in the Lord Nelson Lease, just to the west of the Lady of the Lake Lease; and north of the Overlander Lease, which is to the north of the township of Goongarrie.

In addition to the small knobs just referred to, small fragments of greenstone lying on the surface of the ground in certain areas, are also extensively pitted.

The surface of portions of the low-lying, gently-sloping ground, bordering the western shore of the lake at Goongarrie has an abundance of rock fragments of various sizes. The vegetation is sparse, and the fragments, which consist of white quartz and fine and coarse-grained greenstones, are consequently much exposed to wind, sun and rain. It is in the coarse-grained greenstones that pitting, in association with grooving, occurs. Many of the fragments are thin in proportion to their length and breadth, and lie flat. This fact, combined with the gentle slope of the ground, makes the gravitational travelling of the rock fragments very slow; hence many may remain in the same positions for long periods, thus giving erosion an opportunity to make its mark in any particular manner.

3.—A few small pits may be observed on the tops of some greenstone ridges and knobs, but these are clearly due to the action of rain, and they have no relation to the pits of which this paper specially treats.

The pits usually are circular, and may occur on both the top and sides of the rock. On the top, the pits vary in diameter from about one-eighth of an inch to half an inch or more, with similar depths, whilst in some thin fragments the holes have been drilled through from top to bottom. On the sides, the holes do not exceed half an inch in diameter and depth, and are usually much less. Frequently the pits coalesce, and so a more or less continuous horizontal groove may be formed. Fine sand occurs in some of the pits, the surfaces of which are usually fairly smooth.

Localities where the phenomena described may be seen are on the western side of the Golden Sun Lease, Goongarrie; at the small alluvial fan in the Black Diamond Lease, at the southern end of the Goongarrie mining field, referred to under the grooving of greenstones; and generally in various places on the low-lying exposed ground immediately to the west of the lake at both Goongarrie and (more rarely) Comet Vale.

The rocks are nowhere polished.

(*b*) *Quartz and Jasperoid Rocks.*—The pitting of these rocks at Poverty Point and Causeway Hill has been described above when giving details of their grooving.

(*c*) *Other Rocks.*—At the western end of one of the southern arms of the lake, which the writer has named the "Tombstone Arm," a cliff a few feet high occurs, surmounted by a number of projecting but discontinuous rocks of approximately even size. They resemble a number of tombstones, somewhat tilted from the vertical; hence the name, "The Tombstones," given to the locality. These slab-like rocks have had their shape determined by their vertical planes, and by the removal of intervening slabs, but it is not apparent why such a peculiarly selective mode of erosion has taken place.

The component rocks are believed to be fine-grained quartz-porphyries, but the writer's records on this point are incomplete.

The surface of a "tombstone" is coated with a film of iron oxide, and is free from pits and grooves.

The rocks which form the low cliff referred to are dark grey shales and slates from which masses several feet in length have been detached. The upper surfaces and sides of these detached blocks often have pits varying in diameter from a quarter of an inch to about one foot, and in depth from a quarter of an inch to three inches. They are usually roughly circular in surface outline, except where two or more pits have coalesced into one elongated one. The pits may be large shallow saucer-like hollows or relatively deep narrow ones, or they may have about the same surface diameter and depth.

At a tiny gully close to "The Tombstones," there is a short, sharp drop to a lower level, down which rain water occasionally falls. The rocks at this point are much pitted, and of especial interest is a concretionary structure which has facilitated the hollowing out of the rocks on vertical faces in a remarkable manner.

The writer's records unfortunately are insufficient to state what these concretionary rocks are.

The shales and slates at "The Tombstones" are mostly free from the iron oxide film mentioned above.

(C) Miniature Pedestal[4] Rocks.

On the western shore of the lake at Comet Vale, and quite close to the rocky cliffs, several examples of miniature pedestal rocks occur. The lake floor at the edge of the lake is a "billiard-table" rock floor. The pedestal rocks are part of the same rock mass as the floor, and consist of fine-grained greenstones of the type already referred to. They are so tough that examples of the pedestal rocks could only be obtained by the writer by wedging them out from the floor along the close-set and irregular joint planes of the rocks.

Kirk Bryan (4, p. 123) describes a pedestal rock as an isolated rock consisting of a larger mass above, supported on a more slender pedestal.

These miniature pedestal rocks attain a height of two to three inches above the rock floor. In horizontal section, the portions above the pedestals are roughly circular or oval, with diameters up to about two inches; and they project about half an inch or more beyond the pedestals, but the extent of the projection varies in the same pedestal rock and in different rocks. The pedestals themselves form short columns about one inch, and less, in height. The result is the well-known mushroom appearance. The surface of the pedestals and of the rock floor overhung by the upper masses is smoothed by abrasion, but is not polished.

At Poverty Point, some of the quartz or jasperoid rock fragments on the surface of the alluvial cone mentioned above, have been undermined so as to form miniature pedestal rocks with a pedestal about an inch in height, and a top that may be six or seven inches in diameter, and which may project one to two inches beyond the pedestal. The rock fragments are smoothed and rounded.

The pedestal rocks described are in miniature only, but nevertheless they are of interest, inasmuch as they indicate, to some extent, the nature of the erosion processes operating in the district.

V. The Origin of the described Phenomena.

For the sake of clearness and convenience of reference, the various types of erosion dealt with in this paper have been separately described. In considering, however, the possible origin of

4.—The word "pedestal" has been suggested by Kirk Bryan (3, 4, and 5) as a descriptive term for the kind of rocks now described, and is preferable, in the writer's opinion, to the old term "mushroom."

the described features, it is convenient to treat the subject as a whole, touching on the various aspects as they arise.

In the following discussion the semi-arid nature of the country, with the resulting scarcity or absence of vegetation, and the abundance of blown sand available must be borne in mind. The mode of occurrence of the sand is described in publications (1) and (6).

As regards the agents of erosion which have brought about the effects noted, the abrasive action of streams, lakes and seas, and of the wind; the action of rain in its mechanical and chemical aspects; the effect of the crystallization of salts at the surface of the rocks; and differential atmospheric weathering generally, must be considered. There may, of course, be a combination of forces.

No satisfactory evidence has yet been adduced to show that the sea has had any influence in moulding the rock cliffs and rock floors of the lake. The former occurrence of large freshwater lakes in the interior of Western Australia has been postulated, but definite evidence is as yet wanting. Even if the sea had recently occupied large areas of the country, or if lakes of the type just mentioned had previously existed, all the effects noted could not be ascribed to such agencies, which may therefore be disregarded.

Again, the erosive power of the very shallow waters that occasionally cover the lake surface is too weak to produce the various kinds of grooving and pitting, or the pedestal rocks described above. Moreover, some of the features observed occur beyond, although close to the lake, so that there must be some agent more general in its action than sea or lake waters.

Rain, chiefly by its chemical action, may form pits in rocks containing much soluble material, such as arenaceous limestones; but such pitting, so far as the writer is aware, is rare in igneous and most sedimentary rocks. Rain, no doubt, in its combined chemical and mechanical action, can groove and pit rocks, but such action would not be limited to a definite height above the surface of the ground. In the examples described in this paper (omitting the rocks at "The Tombstones"), there is such a limitation on the cliff faces, except in occasional special cases, which can be accounted for. Similarly, pitting and grooving are only found among surface rock fragments where the ground is open and largely destitute of vegetation, and therefore exposed to the action of the wind.

Rain, therefore, does not appear to be the primary cause of the pits and grooves, although, once erosion had commenced, it would doubtless be hastened by the rain; but this would hardly or only slightly apply to horizontal pits and grooves.

The effects of the crystallization of salts must be considered. The water beneath the floor of the lake is heavily charged with common salt, and much of the underground water at some distance from the western shore of the lake also contains the same substance in abundance. Other salts also occur.

If crystallization takes place when the water rises by capillary attraction to the surface and there evaporates, the rocks may be disintegrated to some extent, as the writer in an earlier paper (7) has indicated.

Where pronounced divisional planes occur in the face of a cliff (as in the fine-grained greenstone cliffs containing at their base the rectilinear grooves described above) these planes may possibly facilitate the ascension of the salt-charged water through the immediately adjacent areas of the rock; and at the surface, as a result of the crystallization of the salt, slight disintegration or internal strain may occur. If wind-driven sand be the chief cause of the grooves, it would be aided by such disintegration or strain.

The crystallization of salt at Lake Goongarrie cliffs, however, seems to cause an irregular undermining by a flaking of the rock rather than disruption or strain along the divisional planes. Where grooves are several inches deep, it is improbable that they are caused wholly or largely by salt crystallization, as it is difficult to imagine the process working in this regular way. Moreover, the grooved rocks forming the actual cliff face have mostly been broken away from the main mass—apparently before the grooves were formed—and consequently evaporation of the water and precipitation of the included salts would doubtless take place at the surface of the rocks *in situ*.

So far as the writer's observations and recollections go, no disruption or weakening along the division planes occurs. The surface of the grooved rocks is firm, and free from signs of disintegration by flaking or crumbling.

With regard to the pits in the small coarse-grained greenstone knobs, the crystallization of salt may perhaps loosen or detach a mineral fragment, and so be the means of starting a pit; but it is inconceivable that the process should so continue as to form the spherical fairly smooth pits already described. Rather there would be a disintegration over practically the whole of the surface of the area affected. Furthermore, these pitted rocks consist in part of blocks detached from the main mass, and it is a fair assumption that the pits have developed since the detachment—at least in some of the rocks. If so, the crystallization of salts is not likely to occur on the surface of the fragmentary rocks.

With reference to the horizontal grooving of the fragments of quartz, greenstone and other rocks lying loose upon the surface of and, consequently, not in continuous contact with the ground, the same difficulty as to the passage of the capillary water into the fragments again occurs. If, however, this difficulty were overcome, the crystallization of salts at an even height above the surface of the ground seems improbable. Crystallization is more likely to occur over the whole exposed surface. Apart, however, from theoretical considerations, the rock fragments show no evidence of decay through crystallization of salts.

Other chemical action will tend to weaken the coherence of the the rocks, and so make them more easily eroded by any eroding agent.

There is no indication that temperature variation is the cause of the pits and grooves or that it has aided in their formation.

The abrasive action of the wind being the remaining possible factor, is therefore apparently the prime cause of the pits and grooves. Its action is discussed below.

At "The Tombstones" the majority of the pits clearly appear to be due chiefly to the solvent action of rain. This conclusion is suggested by the fact that there is no definite limitation of the height at which they occur, and by the large, shallow, saucer-shaped character of many of the pits. The process appears to start with the formation of small irregular hollows (due to differential atmospheric erosion) on the surfaces of the rocks. Rain water collects in these hollows and acts as a slight solvent, thus further disintegrating the rocks. Further rain will wash out the separated material, and, the processes being repeated, the cavities become enlarged. Some of the smaller pits, and especially the more or less horizontal ones, may be due to the action of the wind. The hollowing out of the rocks at the small waterfall is due mainly to the fall and splash of the water.

Kirk Bryan in various publications (3, 4 and 5) has given instances of pedestal rocks formed otherwise than by wind action. He considers (3, p. 11) their formation to be due to the work of rain, of mechanical disruption, of stream action and of chemical weathering; and he has shown (3 and 5) in lucid and convincing fashion that in arid areas, in some instances, such rocks are moulded into their present shapes by the action of a "drip curtain" during rain, and by the spreading of a film of water on the under surface of the overhanging rock. Pedestal rock formation takes place in this way, especially when a less resistant rock, e.g., a shale, underlies a more resistant one, e.g., a conglomerate. In the case, however, of the miniature pedestal rocks on the floor of Lake Goongarrie, the homogeneous character of the rocks, the smoothness of the face of the pedestal and of the floor forming its base, the absence of the grooves caused by the drip curtain, and the weakness as an eroding agent of such a tiny drip curtain, if formed, suggest strongly that rain action must be eliminated.

The mode of occurrence of the miniature pedestal rocks, where those rocks are *in situ*, should be favourable to erosion by salt crystallization, as it is in undermined areas that one would expect such crystallization to take place. No such effects, however, are visible megascopically. The surface of the pedestal is smooth and free from any indication of crumbling or flaking; and apparently the pedestal is as tough as the rock above and below. If crystallization is taking place, then its action appears to be very slight, or even negligible.

Microscopical examination of the miniature pedestal rocks—as well as of the pitted and grooved rocks—might throw some light on the question whether salt crystallization has directly or indirectly aided in the formation of the pits, grooves and pedestal rocks.

The remarks made above in connection with the pits and grooves as to further chemical action and the effect of temperature variation apply to the miniature pedestal rocks.

The wind in its abrasive capacity therefore appears to be the principal agent in the formation of the pedestal rocks.

By a process of elimination of other possible factors the writer has arrived at the conclusion that the wind in its direct abrasive capacity is the chief agent in the production of most of the unique features described in this paper; and the general conditions prevailing favour this view. These conditions are limitation in height of erosion, which is especially characteristic of wind action; the dry climate; the sparse vegetation; and the abundance of quartz sand. In the case of the pits in the coarse-grained greenstones, Harger's suggestion (7, p. xxxv) with regard to the honeycombing of "augen" gneiss, that the holes were probably started by the weathering out of a particular mineral, would probably apply.

The actual mode in which wind-driven sand brings about the results stated may now be considered, although the subject is a difficult one on account of want of direct observation of the process.

The restriction of the grooves in the cliffs and of the pits in the small coarse-grained greenstone knobs to a height of about three feet above the surface of the ground is probably due—at least in part—to the wind being unable, as a rule, to lift above this height particles of sand of a size or in numbers sufficient to erode a rock surface. This limitation is apparently of wide application. Kirk Bryan (5, p. 12) states that all authorities are agreed that two to three feet above the ground surface is the limit of effective wind scour; and he refers to the paper by W. H. Hobbs, who shows (9, p. 33), among other examples, that in the Great Oasis of the Libyan Desert the cast-iron telegraph poles lining the railway were well burnished by the flying sand to a height above the ground of only about a yard (see also p. 35). Hobbs's observations are strikingly confirmed by the records given in this paper, if wind-driven sand has caused the grooves and pits.

The actual process is difficult to visualize, but the following suggestions are made. The more or less vertical grooves will be first discussed. The sand must be lifted and driven against and perhaps up or down the face of the rocks to the height mentioned. Erosion may take place by this means, but so comparatively evenly—except in specially favourable places—that there is no definite record of the work of the sand blast. The "frosting" evenly over the surface of glass by the sand blast in Nature is an illustration of this widespread erosion. It is easily recognized on the glass on account of the smooth surface of the glass at the commencement of the bombardment of the sand grains, and the resulting roughening of such surface. In rocks, however, such as greenstones, the surface would show little recognizable change, unless the action were very strong, and except, as already noted, in specially favourable places, such as joint or division planes. These provide lines of weakness along which the wind-driven grains may erode faster than the adjacent portions of the rock. In this way a slight groove may be made, which then supplies a definite passage along which the rasping sand grains may be pushed up or down by the wind, which must be assumed, when it approaches the rock face, to be deflected in various ways. So the grooves may deepen, widen and lengthen, and are probably most pronounced close to the ground.

The typical pits on the faces of masses of rock rising well above the surface of the ground are in the coarse-grained greenstone knobs. The formation of the pits in these rocks is no doubt favoured by the comparatively large crystals of felspar and hornblende, of which the rocks are chiefly composed. Bombardment by wind-driven quartz grains, to a height of about three feet above the surface of the ground, takes place, and if, owing to ordinary atmospheric weathering or crystallization of salt, a piece of felspar or hornblende has been detached, a small hollow or incipient pit in the rock face will result. Sand grains are thrown against the rock face to the height mentioned, and some must enter the pit. Centrifugal action as suggested by Harger (8, p. xxxv), may be set up, whereby the sand grains are whirled round the walls of the cavity, thereby increasing its size.

Regarding the horizontal grooving of loose fragments of rocks and to the undermining that takes place in the formation of the miniature pedestal rocks, the grooves usually commence about one-quarter to one-half of an inch above the base of the fragment, although it has been shown in this paper that where bands of varying degrees of toughness occur, and even in apparently quite homogeneous quartz, there may be two horizontal grooves, one above the other. The undermining of the pedestal rock is also just above the surface of the ground. The difficulty is to understand why the groove is formed so uniformly at the height mentioned, and not only in one kind of rock, but also in several classes.

Long and patient work would be necessary to determine this question by actual observation; but if it be accepted, owing to the elimination of all other possible agents as prime factors, that wind-driven sand is the cause, then it must be assumed that such sand, owing to the quantity available, or to its coarseness of grain, or to the strength of the wind itself at the height mentioned, or all or some of these combined, acts most powerfully at that height. The sand must act above this height, but apparently so evenly that it shows no striking effects.

Harger (8, p. xxxiv) states that in late German South-West Africa the cutting or eroding action of the sand-laden blast is the most severe just above the ground level, the heavier grains of sand acting like a rasp and in time cutting upstanding pillars of rock right through, an example in granite being given. Another result is the formation of "mushroom-topped" tors. Harger's observations are thus in accord with those recorded in this paper.

The writer's observations do not show that pits and grooves occur more frequently on one side of an outcrop than on another, except in one or two instances where they are more numerous on the eastern than on the western side.

The dominant winds appear to be westerly, but these may not be the prevailing winds. The wind, however, probably forms eddies in the vicinity of rock masses. See Hobbs (9, pp. 35 et seq.) and Harger (8, p. xxxv), who states that the best and deepest honeycombing is seen on the lee side of the rock masses.

In support of the wind theory, reference may be made to the outcrops of a vertically banded siliceous ironstone about 10 to 12 inches thick, occurring at Goongarrie to the west of the lake. These outcrops form a band at the junction of two other rocks, and they may be traced in a north-north-westerly direction intermittently for some miles. This band projects, on the average, for about 12 inches above the surface of the surrounding ground. Its surface is grooved, pitted, smoothed and rounded, and presents a striking contrast with the sharp contours of similar rocks elsewhere in the district, but situated under different conditions. The bare surrounding ground and the abundance of fine quartz sand in the vicinity leave little doubt that the wind is responsible for the features described.

If the conclusions set out in this paper as to wind erosion, and particularly with regard to the miniature pedestal rocks, be well founded, they are important in that they support the idea that the rock floor of the lake on its western shore is due to wind planation.

The writer has in another publication (10) pointed out that the mode of rounding described in that paper of fine-grained greenstone pebbles does not take place until the iron oxide crust, which is very widespread, has been broken. In the same group of rocks, pitting and grooving do not occur, usually, unless this iron crust is absent. The facts that the fine-grained greenstones from which the crust has always been absent or from which it has been removed after its formation, and that the pitting and grooving of these greenstones occur generally at the base of cliffs, are coincidences merely, since the coarse-grained greenstones and the quartz and jasperoid rocks may be without a distinctive iron crust at any height, but the pitting and grooving are restricted as shown in this paper.

At "The Tombstones," the sedimentary rocks are free from the iron crust, and pits abound in them, but as shown above, they are, in the main, essentially solution hollows. In the adjacent rocks (probably porphyries), which project well above the surface of the ground as "tombstones," an iron crust is well developed, and pitting is absent. Thus in those two groups of rocks we have striking examples of how erosion may be retarded or hastened according to the occurrence or non-occurrence of the protective iron crust.

The relations between the crust-bearing and the crustless rocks, especially those of the same kind, would probably repay close investigation.

VI. Records of Grooving and Pitting elsewhere by Wind Action.

That pitting and grooving of rock surfaces have in some instances has been caused by the action of the wind has been stated by various writers. The following remarks summarize practically all records that have come under the writer's notice. He is indebted to Mr. Kirk Bryan, of the United States Geological Survey, for several of the references.

T. O. Bosworth (11) describes small corrugations and pits in granite, due to erosion by wind blown sand, on the coast of Mull, Scotland. The quartz and felspar in the rock have been highly polished by this action.

W. P. Blake (12) describes the cutting by the sand blast of a granite surface into "long and perfectly parallel grooves and little furrows" on a mountain pass in California. The rocks were also smoothed and polished by the action of the wind.

R. F. Rand (13) states that at Angra Pequena, on the south-west African coast, biotite schist and granite have suffered great pitting and honeycombing by the action of the wind, which is very powerful and blows from the coast.

A. Wade (14) points out that the softer limestones of the Eastern Desert of Egypt are sometimes regularly grooved by the wind in such a manner as often to simulate bedding planes. Andesites and porphyries are also grooved all over in a peculiar manner by the action of wind-blown sand.

R. D. Oldham (15) describes grooves of varying size in quartzites and sandstones caused by wind erosion.

R. W. G. Hingston (16) records the erosive action of the wind in a gorge in Tibet. Granite boulders on their windward side were polished, and were cut into by deep pits and grooves, some of the latter an inch in depth.

E. de Martonne (17, pp. 663, 664) briefly refers to the disintegration of heterogeneous rocks, such as sandstones, conglomerates and granites. Grains become detached and are swept away by the wind. This results in the formation of a honeycombed surface. The pits may be enlarged by wind corrasion until potholes result, such potholes being common in granites (17, p. 668).

Johannes Walther (18, p. 168 and fig. 132, p. 169) describes the well-known "stone lattice" of the desert.

H. S. Harger (8, p. xxxv and fig. 7) describes the occurrence of "augen" gneiss in the late German south-west Africa, where the rock has been extensively honeycombed by the corrasive action of wind and weather. He points out that the best and deepest honeycombing is seen on the lee side of the rock masses, and that the holes, which were probably started by the weathering away or falling out of a particular mineral, have been rounded and enlarged by loose grit being whirled by the wind around the walls of the cavities.

VII. Summary.

At Lake Goongarrie, a playa in sub-arid Western Australia, the conditions are described under which certain rocks are being grooved and pitted, and others undermined so as to form miniature pedestal rocks.

The rocks concerned are "greenstones," quartz, certain jasperoid rocks, and shales. They occur as rocky cliffs of the lake; as small isolated rocky knobs; and as fragments scattered over portions of the surface of the lake floor on the western shore, and over the adjacent wind-exposed, low-lying ground, which has but scanty vegetation.

These rocks are pitted and grooved. The grooves may run at all angles in a horizontal plane, although in their inclination to that plane tending generally towards the vertical, and, where this occurs, the irregularities are due to the numerous small joints and other division planes by which the rocks are traversed. Other grooves are horizontal. The pits are mostly small, but they are in some cases of moderate size.

Where the rocks occur as cliffs or knobs, the grooving and pitting (except the pits at the locality known as "The Tombstones") are restricted to a height of about three feet from the base of the cliff or of the knob, as the case may be; and where they occur as surface fragments, the grooving and pitting are restricted to those fragments which lie on nearly flat wind-exposed areas with scanty vegetation.

The miniature pedestal rocks are of the fine-grained greenstone class, and occur on the western shore of the lake close to the cliffs of the same rocks, which there bound the lake.

From a consideration of the mode of occurrence of the grooves and pits and of the tiny pedestal rocks, water, both in its mechanical and solvent action, is eliminated as the chief agent in the production of the phenomena described. The disruptive power of salts brought by capillary attraction to the surface, and there crystallizing, is also practically eliminated; and the wind, acting in its abrasive capacity, is regarded as the predominant factor. This, however, does not apply to the pits at "The Tombstones," where water, in its solvent action, is considered to be the chief cause of those pits.

A brief account of extra-Australian records of pitting and grooving of rocks is given.

The writer is indebted to Professor Skeats for criticism of this paper.

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EXPLANATION OF PLATES.

Plate XII.

Fig. 1.—Rectilinear grooving in the fine-grained greenstone. Cliff face south of the large "natural quarry" on the western shore of Lake Goongarrie at Comet Vale. Note the absence of grooving towards the top of the figure.

Fig. 2.—Miniature pedestal rock of fine-grained greenstone on the floor of the western shore of Lake Goongarrie at Comet Vale, near the large "natural quarry." Slightly less than natural size.

Fig. 3.—Pebbles of the fine-grained greenstone, showing the horizontal groove above the base. From the rock floor of the western shore of Lake Goongarrie at Comet Vale, near the large "natural quarry." Natural size.

Plate XIII.

Fig. 1.—A fragment of the coarse-grained greenstone, showing the almost continuous horizontal groove slightly above the base. Some of the pits on the top can be observed. From west of the Golden Sun Lease, Goongarrie. Natural size.

Fig. 2.—A fragment of quartz with a horizontal groove slightly above the base, particularly shown in profile at each end. From flat cone at the foot of Poverty Point, northern end of Lake Goongarrie, Comet Vale. Natural size.

Fig. 3.—A fragment of jasperoid rock, showing its rounded surface and the deep notch at one end. From near the Lady of the Lake Lease, Goongarrie. Natural size.

ADDENDUM.

A series of papers by the writer treating of various phases of physiography in sub-arid Western Australia appeared in earlier volumes of this Journal. The proofs of most of those papers

Fig. 1

Fig. 2

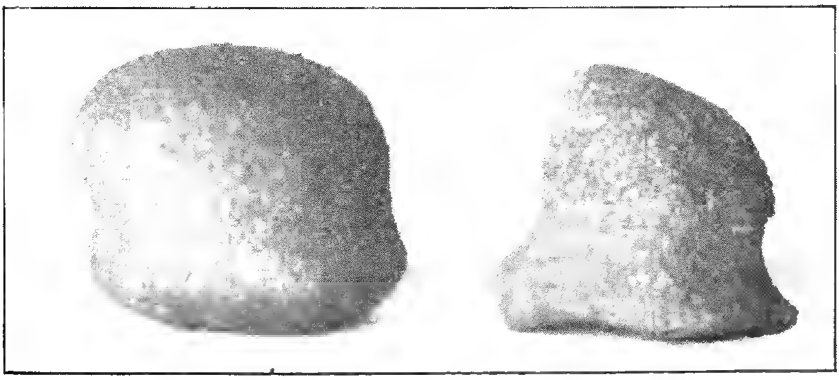


Fig. 3

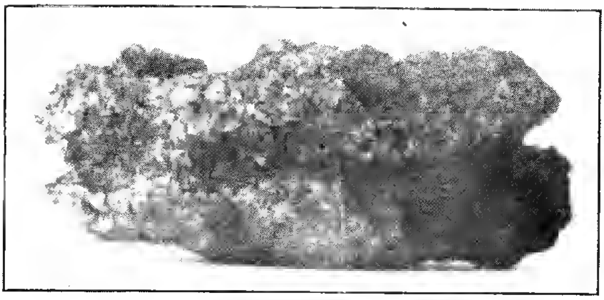


Fig. 1

Fig. 2

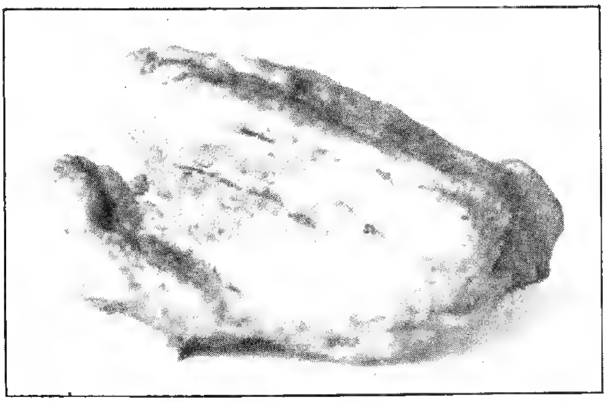


Fig. 3

were not corrected by the writer, with the result that various typographical errors have crept in, which it is now desired to correct, without including all minor palpable errors.

CORRIGENDA.

Proc. Roy. Soc. Vic.

N.S., XXX. (2), 1918.

Page 163, 2nd line: For "water" read "matter."

Page 171, 25th line: For "corrosive" read "corrasive."

N.S., XXXI. (1), 1918.

Page 119, 19th line: For "gravitional" read "gravitational."
26th line: Delete "upon."

Page 121, 3rd line: For "corrosion" read "corrasion."

Page 124, 4th last line of main text: For "corrosion" read "corrasion."

Page 125, 10th line: For "erosinal" read "erosional."
14th line: For "solutions" read "solution."
22nd line: For "corrosive" read "corrasive."

Page 126, 10th last line: For "one" read "once."

Page 128: Add at the end the following:—

EXPANATION OF FIGURES.

Fig. 1.—Locality map of the southern portion of Western Australia.

Fig. 2.—Diagrammatic section showing a piedmont plain truncated at the lake floor. See pp. 117 and 123.

Fig. 3.—Diagrammatic section across an arm (with a sand ridge on either side) of the lake, showing the bare rock floor of the lake and the detritus beneath the sands of the ridges. See pp. 119 and 125-128.

Fig. 4.—Diagrammatic section (after Hobbs) from high land to a playa surface.

Fig. 5.—Diagrammatic section across the lake, showing the lake floor abutting the "high" lands. See page 123.

Fig. 6.—Diagrammatic section across the lake, showing a narrow piedmont plain intervening between the rock floor and the "high" lands. See p. 123.

Pages 113-128: Throughout for "lowlands," read "'low' lands."

N.S., XXXII. (2), 1920.

Page 314, 5th last line: For "38" read "83."

Page 315, 19th line: For "willy-willy," read "willy-willys."

Page 317: The first two sentences under "General Remarks" apply to the first eight records.

Page 319, 3rd last line: For "could" read "would"; and last line, for "hemispheres" read "hemisphere."

Page 320, 20th and 21st lines: The words, "but the rate of motion could not be determined" should be in parentheses.

27th line: Delete the comma after "dull."

Page 321, 12th line: For "columns" read "column."

14th line: For "over" read "ones."

24th line: For "whirls" read "whirl."

Page 322, 2nd last line: For "525" read "52."

[Proc. Roy. Soc. Victoria, 41 (N.S.), Pt. II., 1928.]

Art. VII.—*Notes on Australian Termites (Isoptera). Descriptions of new species.*

By GERALD F. HILL.

(With Plate XIV.)

[Read 13th September, 1928; issued separately 30th January, 1929.]

In this paper the following termites are described as new, namely, two species of *Hamitermes* from Western Australia, and one species of *Mirotermes* from each N.W. Australia, N. Queensland and Victoria. The hitherto undescribed alate form of *Eutermes mareebensis* from N. Queensland is described.

The genus *Hamitermes* is widely distributed in Australia, where it is represented by 16 described and numerous undescribed species. Included in the latter are several very striking examples of the sub-genus *Drepanotermes*, which it is considered are best held over until the alate forms have been discovered.

The genus *Mirotermes* is represented by 18 previously described species, which are listed in a recent paper (Hill, 1927). It is of interest to note that one of the species described in the following pages is the first of the genus to be recorded from Victoria.

Eutermes, the third genus referred to in this paper, is represented in Australia by 32 described and probably as many undescribed species, many of which are so closely similar in the soldier caste that the group can be satisfactorily dealt with only in a review of the whole of the available material. The inclusion here of a description of an undescribed caste of a hitherto incompletely known form, however, appears to be justified in view of the fact that the remainder of the writer's collection contains only completely described or wholly undescribed species.

Hamitermes westraliensis, n. sp.

(Plate XIV., Figs. 1, 2.)

Imago.

Colour.—Head very dark brown, slightly darker than pronotum; postclypeus and antennae distinctly lighter; anteclypeus hyaline; legs, labrum and palpi yellow-ochre to ochraceous-tawny; pleurites and sternites mostly yellow-ochre, the former suffused with brown, the latter brown around spiracles; meso- and metathorax and tergites somewhat paler than pronotum; wings dark brown, veins very distinct.

Head.—Hemispherical behind the eyes, depressed angularly in front of fontanelle, a little wider than pronotum, very setaceous, the setae long and short, as on pronotum. Eyes small, prominent (0·192 diam.) surrounded by a pale ring. Ocelli oval (0·096 × 0·144) widely separated (0·128) from eyes. Antennae 16-jointed; 1st joint more than twice as long as 2nd and markedly wider; 2nd a little longer than wide; 3rd very short and closely fused with 4th, which is scarcely longer; 5th about as long as 3rd and 4th together, longer than 6th. Postclypeus markedly setaceous like labrum, with brown median suture, truncate in front, markedly convex behind, strongly arched above, 0·48 long × 0·65 wide. Fontanelle large, about as large as ocelli, oval, with linear extension anteriorly, anterior margin of ovate portion on line with posterior margin of eyes. Anteclypeus hyaline, nearly straight on sides, strongly produced in front.

Thorax.—Pronotum large, nearly straight in front, antero-lateral corners somewhat rounded, sides sloping rather sharply to the slightly sinuate hind margin. Meso- and metanotum narrowed sharply to the deeply notched posterior margin.

Wings (Pl. XIV., Fig. 1).—Large, dark coloured, with distinctly darker veins, the latter distinct to their extremities, the proximal half of the two anteriormost veins markedly setaceous; microtrichia moderately numerous.

Legs.—Moderately long and setaceous.

Abdomen.—Markedly setaceous; cerci with large basal segment, as long as apical segment.

Measurements.

	mm.
Length, with wings - - - -	14·25 — 14·50
Length, without wings - - -	7·50 — 8·00
Head, from base to apex of labrum, long -	1·60 — 1·67
Head, from base to clypeofrontal suture, long	0·74 — 0·80
Head, at and including eyes, wide - -	1·30
Antennae, long - - - - -	2·04
Pronotum, long, 0·68; wide - -	1·24
Wings, forewings, long, 12·50; wide -	3·28
Wings, hindwings, long, 12·00; wide -	3·40
Tibia iii, long - - - -	1·36

Soldier.

Colour.—Head yellow-ochre; thorax, mouth parts (excepting mandibles) and legs light buff; mandibles yellow-ochre at base, shading to dark chestnut towards apex; labrum and clypeus yellow-ochre, margined anteriorly with hyaline, a dark chestnut spot at articulation of mandibles.

Head (Pl. XIV., Fig 2).—Long and very little widened on sides, wide and only slightly rounded behind, strongly arched above; clothed very scantily with reddish setae, these most numerous on the frons. Mandibles relatively short, little more than half as long as head capsule, stout, strongly curved in at the tips, each with a short tooth a little nearer base than apex. Labrum moderately large, conical, with several stout reddish setae, a little more than half as long as mandibles. Clypeus shorter than labrum, anterior margin strongly bilobed and broadly margined with hyaline. Antennae 15-jointed; 3rd joint very short, much shorter than 1st and 2nd; 4th longer than 5th, about equal to 2nd; gula about one-fourth as wide as head.

Thorax.—Pronotum short and wide, with few long reddish setae, mostly near margins, anterior half narrowed and bent up, with slight emargination, anterolateral angles markedly produced, sides narrowed sharply to obscurely sinuate posterior margin; mesonotum narrower than pronotum, with wide but not deep emargination, fringed with reddish setae; metanotum wider than mesonotum, similarly fringed, posterior margin not so strongly emarginate.

Legs.—Moderately long and slender, with very scanty setae.

Abdomen.—With scanty reddish setae.

Measurements.

	mm.
Total length - - - -	5·50 — 6·00
Head, to apex of mandibles, long - -	2·35 — 2·41
Head, to apex of labrum, long - -	2·04
Head, to labral suture - - -	1·62
Head, wide - - - - - -	1·36 — 1·42
Head, greatest depth, including gula - -	1·17
Gula, long - - - - -	0·32
Pronotum, long 0·50; wide - - -	0·93
Tibia iii, long - - - - -	1·24

Worker.

Colour.—Warm buff, frons whitish, antennae a little darker than head, mandibles chestnut.

Head.—Posteriorly from the insertion of the antennae hemispherical, with very few setae; postclypeus about one-third wider than long, strongly arched above, anterior margin truncate, posterior margin markedly convex, with scattered reddish setae, a dark ferruginous spot at each end; antennae 16-jointed.

Thorax.—Pronotum as in soldier.

Measurements.

	mm.
Total length - - - - -	4·50 — 4·90
Head, to apex of labrum, long - -	1·55
Head, to clypeofrontal suture, long - -	1·05
Head, wide - - - - -	1·30
Pronotum, long 0·43; wide - - -	0·86

Locality.—Western Australia; Darlot (Charles Biddle, 6.12.27).

Types (imago, soldier, worker) in the author's collection.

Hamitermes (Drepanotermes) tamminensis, n. sp.

(Plate XIV., Figs. 3-6.)

Imago.

Colour.—Head, pronotum and principal veins of wings dark brown; antennae and legs light yellowish-brown; pleural sclerites and tergites brown, lighter than head; sternites yellowish, suffused with dark brown at spiracles; postclypeus yellowish-brown suffused with dark brown on sides.

Head (Pl. XIV., Fig. 3).—Clothed with many small setae, widest in front, narrowed slightly posteriorly. Eyes very small and prominent. Ocelli widely separated from eyes. Fontanelle very large, broadly oval. Antennae with 16-17 segments (generally 17); 1st long and stout, cylindrical; 2nd less than half as long and much narrower than 1st, cylindrical; 3rd and 4th very small, closely fused; 5th globose.

Thorax.—Pronotum clothed similarly to head, slightly narrower than head, anterior margin nearly straight, anterolateral angles broadly rounded, the posterior margin broadly rounded with obscure indentation in middle; posterior margin of meso- and metanotum widely notched.

Wings (Pl. XIV., Figs. 4, 5).—Large, all veins very distinct; the two anteriormost veins very setaceous.

Legs.—Long and slender, with numerous small setae.

Abdomen.—Moderately setaceous; setae small.

Measurements.

	mm.
Total length - - - - -	19·00 — 20·00
Length, without wings - - -	9·00
Head, to apex of labrum, long - -	1·98
Head, to clypeofrontal suture, long - -	1·05
Head, wide - - - - - -	1·60
Antennae, long - - - - -	2·54
Eyes, diam. - - - - -	0·240×0·288
Eyes, from ocelli - - - -	0·160
Eyes, from lower margin of head - -	0·144
Ocelli, longest diam. - - - -	0·160
Pronotum, long 0·93; wide - -	1·48 — 1·55
Wings, forewings, long 16·00; wide -	4·27
Wings, hindwings, long 15·00; wide -	4·52
Tibia iii, long - - - - -	1·86

Soldier.

Colour.—Head, antennae and pronotum dark orange-yellow; legs, tergites of abdomen light clay colour; anterior margin of anteclypeus whitish; labrum lemon-yellow; mandibles mahogany-red.

Head (Pl. XIV., Fig. 6).—Elongate oval, with very few setae; frons rugose; postclypeus strongly bilobed, divided medially by a deep groove; mandibles long and slender, with broad tooth on each about the middle, tooth on left jaw larger than that on right; gula long and narrow, rather more than one-fourth wider in middle than head. Antennae with 16 (very rarely 17) segments; 1st segment long, moderately wide, twice as long as 2nd, slightly widened towards the apex; 2nd much narrower than 1st, nearly cylindrical; 3rd a little shorter than 2nd, narrow at base but as wide as 2nd at apex; 4th shortest of all; 5th as long as 3rd; 6th-11th lengthening progressively.

Thorax.—Pronotum small, with very few setae, these stout and confined to near the margin except on anterior one-third which bears scattered setae; the anterior one-third narrowed and sharply bent up and rounded on anterior margin; posterior margin rounded, very slightly sinuate in middle. Mesonotum about as wide as pronotum, with sinuate posterior margin and setae as on pronotum; metanotum markedly wider, but not longer, than mesonotum; posterior margin and setae as in the latter.

Legs.—Long and slender, with scanty setae; claws and spines small and slender.

Abdomen.—Short and wide, narrowed abruptly to bluntly pointed apex, with rather scanty, long setae; circi large, the basal segment large, nearly as long as the apical segment, which is slender.

Measurements.

	mm.
Total length - - - - -	5·90
Head, to apex of mandibles, long - -	2·66 — 2·72
Head, to external articulation of mandibles, long - - - - -	1·67 — 1·79
Head, wide - - - - -	1·36 — 1·42
Gula, at narrowest part, 0·031; long -	0·062
Antennae, long - - - - -	3·28
Pronotum, long 0·62; wide - -	0·93 — 0·99
Tibia iii, long - - - - - -	1·86 — 1·92

Worker.

Colour.—Head, upper surface as in soldier, sides and frons shading to light straw; postclypeus suffused with orange-yellow laterally.

Head.—With very few pale setae, widest in front, narrowed posterior margin; postclypeus about half as long as wide, nearly truncate in front, broadly rounded behind. Antennae with 17 segments; 3rd segment shortest.

Measurements.

	mm.
Total length - - - -	5·80 — 6·20
Head, to apex of labrum, long - -	1·86
Head, to clypeofrontal suture, long - -	1·17 — 1·24
Head, to external articulation of mandibles, long - - - - -	1·42
Head, wide - - - - -	1·61 — 1·67
Antennae, long - - - -	2·91
Pronotum, long 0·62 — 0·68; wide -	0·93 — 1·00
Tibia iii, long - - - -	1·79

Localities.—Western Australia: Tammin (type locality) all castes, Eradu, soldiers and workers, Merredin, soldiers (J. Clark). Geraldton, queen, soldiers and workers (Edwin Ashby, in January).

Allied Species.—This species is most closely allied to *Hamitermes* (*Drepanotermes*) *silvestrii* Hill from Townsville, N.Q., (*Bull. Ent. Res.*, xii. (4), p. 364, 1922), from which the imago is distinguished, *inter alia*, by its much smaller size, darker (less reddish) wings, and fewer antennal segments, and the soldier by its oval, smaller and lighter coloured head and fewer antennal segments.

Types (imago, soldier and worker) in the author's collection.

Eutermes mareebensis Hill.

Proc. Linn. Soc. N.S.W., xlvii. (2), 1922.

(Plate XIV., Figs. 7, 8.)

Imago.

Colour.—Head and thorax mummy-brown; tergites of abdomen very little paler; clypeus buckthorn-brown, mandibles (excepting teeth), antennae and trophi a little paler; coxae, trochan-

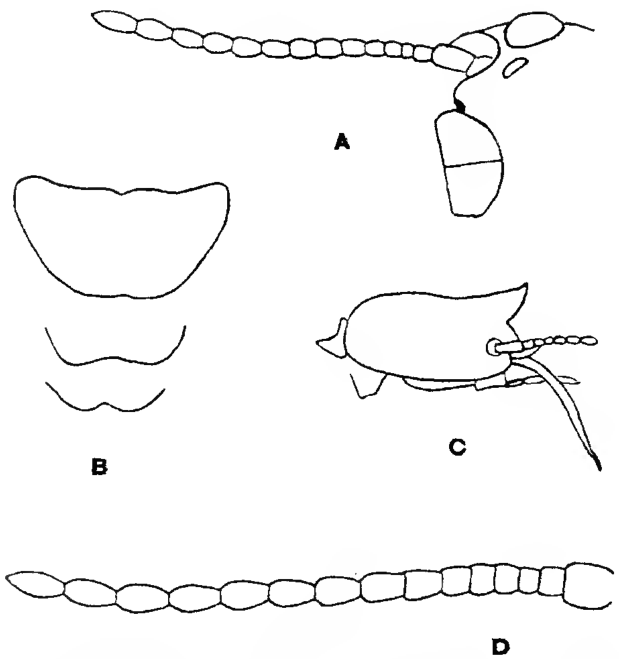


Fig. 1.—*Eutermes mareebensis*, Hill, imago, *a*, head, *b*, thorax. *Mirotermes argutus*, n.sp., *c*, soldier, head. *Mirotermes insitivus*, n.sp., *d*, imago, antennae.

ters, femora and tibiae somewhat lighter than tergites; tarsi whitish, sternites paler than legs, the first four mostly pale yellowish-brown suffused with darker colour laterally; wings smoky, with principal veins same colour as tergites.

Head (Text-fig. 1*a*).—Moderately setaceous, widest in front, almost hemispherical behind the eyes when viewed from above, frontal and transverse sutures distinct. Fontanelle large, linear, nearly as long as eyes are wide, the anterior end slightly widened. Eyes small (0·170×0·170) prominent, about as far from lower margin of head as they are from ocelli. Ocelli large (0·085 long), oval, oblique. Postclypeus large, distinctly lighter than head with a fairly distinct brownish median suture, twice as wide as long, the anterior margin truncate, with a scanty fringe of setae, these mostly longer than the few on the remainder of the postclypeus, posterior margin hemispherical; anteclypeus large, whitish, produced in the middle. Antennae 14-jointed; 1st joint large, cylindrical; 2nd a little more than half as long as 1st and a little narrower; 3rd markedly shorter and narrower than 2nd smallest of all; 4th-13th progressively longer and wider, the 13th nearly as long as 1st; 14th as long as 1st, narrower than 13th, widest at proximal third.

Thorax (Text-fig. 1*b*).—Pronotum moderately setaceous, a little narrower than head, slightly arcuate in front, anterolateral corners, narrow sides sloping sharply to the narrow and slightly sinuate posterior margin; posterior margin of meso- and metanotum more sinuate than in pronotum.

Wings (Pl. XIV., Figs. 7, 8).—Slender, the radial sector and first six or seven branches of the cubitus very distinct, the former and the margin very setaceous. Membrane with rather numerous microtrichia, and densely covered with star-like micrasters. The media passing through the wing a little above the middle, and joining the margin a little above the apex, generally with one branch about the distal fifth to the hind margin; the cubitus with about eleven branches, the first two or three very short, the others not so well-defined, but easily discernible to their extremity, mostly unbranched.

Legs.—Dark coloured, short and comparatively stout; the femora with scanty setae; tibiae with markedly stronger and more numerous setae; tibiae, spurs and claws long and slender.

Abdomen.—

Measurements.

	mm.
Length, with wings ♂ 7·50 — 8·00; ♀ -	8·00 — 8·50
Length, without wings ♂ 4·10 — 4·44; ♀ -	4·67 — 4·90
Head, to apex of labrum, long - -	0·91
Head, to clypeofrontal suture, long - -	0·46
Head, at and including eyes, wide - -	0·69
Antennae, long - - - -	1·10
Pronotum, long 0·34; wide - -	0·60
Forewing, long 6·00 wide - -	1·52
Tibia iii, long - - - - -	0·62 — 0·68

Locality.—North Queensland; Meringa (F. H. Taylor, Nov., 1924).

The identity of the above has been established by comparison of associated soldiers and workers with the types of these castes (from Mareeba, Cairns hinterland, N.Q.).

Types (imago, soldier and worker) in National Museum, Melbourne.

MIROTERMES ARGUTUS, n. sp.

Soldier.

Colour.—Head, antennae and palpi light orange-yellow, thorax and legs stramineus.

Head (Text-fig. 1*c*).—Long and narrow, parallel on sides, with scanty long setae; frontal process large, stout at base, rather bluntly pointed, the extreme tip bent upwards. Antennae 14-jointed, slender: 1st joint large, more than twice as long as 2nd and one-third wider, slightly swollen at apex; 2nd longer than wide, parallel on the sides; 3rd and 4th smallest, 4th a little smaller than 3rd; 5th-9th increasing in length progressively; 10th-14th subequal, long and narrow (about as long as 8th). Labrum narrow, parallel on the sides, truncate in front with the anterolateral corners produced into points. Mandibles very long and slender. Gula long and narrow, about one-fourth as wide as head.

Thorax.—Pronotum small, much narrower than head, saddle-shaped, anterior margin convex in the middle, the anterolateral corners narrowed, sides and posterior margin together nearly hemispherical, with scanty long setae.

Measurements.

	mm.
Total length - - - - -	4·25
Head, to apex of frontal process, long -	1·42
Head, deep - - - - -	0·62 — 0·74
Head, wide - - - - -	0·86
Gula, at narrowest part, wide - -	0·228
Antennae, long - - - -	1·70
Mandibles, long - - - -	1·14
Pronotum, long 0·27 — 0·28; wide -	0·56 — 0·57
Tibia iii, long - - - -	0·62

Worker.

Colour.—Head light orange-yellow, frons whitish, antennae, thorax and legs pale stramineus.

Head.—Glabrous, almost spherical as seen from above, widest at antennae, with scanty setae. Clypeus large, strongly convex, with obscure median suture, a pale ferrugineous mark at articulation of mandibles, with a few setae; anteclypeus large, nearly as long as postclypeus. Labrum small, markedly convex, with few setae. Antennae 14-jointed; 3rd and 4th joints smallest, closely fused, 5th shorter than 2nd, globular; 6th-14th increasing in length progressively; 14th noticeably longer than 13th, narrowed from the proximal fourth to the pointed apex.

Thorax.—Pronotum, as in soldier.

Measurements.

	mm.
Total length - - - - -	3·50
Head, to apex of labrum, long - -	0·85
Head, to clypeofrontal suture, long - -	0·60
Head, wide - - - - -	0·74 — 0·80
Pronotum, long 0·22; wide - - -	0·45
Tibia iii, long - - - - -	0·60

Locality.—Victoria, Kewell.

Described from a soldier and three workers; found under a log (February).

Allied Species.—The soldier differs from the typical form of *Mirotermes kraepelini* Silv. in having a shorter and narrower head, more angular frontal process, and much more slender mandibles. From variety "A" of the last named species (Hill, *Mem. Nat. Mus., Melb.*, No. 7, 1927, p. 95) it differs in having a more angular and straighter frontal process, longer, shallower and deeper coloured head and different labrum; from variety "C" it differs in its smaller and narrower head, more slender mandibles, narrower and otherwise different labrum; from variety "E" it differs in having a shorter and narrower head, more slender mandibles, narrower labrum and more slender frontal process.

Types (soldier and worker) and others in National Museum, Melbourne; collected and donated by Mr. Jas. A. Hill, of Murtoa.

Mirotermes jarmuranus, n. sp.

Imago.

Colour.—Head, thorax and tergites of abdomen argus-brown; legs, antennae and sternites of abdomen buckthorn-brown; clypeus ochraceous-tawny. The whole insect densely setaceous, many of the setae markedly long.

Head.—Almost hemispherical when viewed from above, the summit depressed, fontanelle obscured by setae. Eyes moderately small (0·306×0·306) and prominent. Ocelli large (0·170 long) broadly oval, a little less than their short diameter from eyes. Antennae 15-jointed, very long; 3rd joint very large, not much smaller than 1st; 2nd very small, bead-like; 4th and 5th long and narrow, shorter and narrower than 3rd; 6th longer than 4th and 5th; remaining joints very long and narrow. Mandibles each with apical tooth much larger than, and widely separated from, the next. Postclypeus small, strongly convex above, with numerous long and short setae; anteclypeus whitish, short, truncate in front. Labrum small, longer than wide, not covering apex of mandibles.

Thorax.—Pronotum very large, markedly longer than wide, strongly arched, conspicuously concave in front, sides sloping to the broadly rounded posterior margin. Posterior margin of mesoand metanotum narrowed and deeply notched, the metanotum more so than mesonotum.

Wings.—Wing stumps small, those of mesonotum not much larger than those of metanotum.

Legs.—Moderately short and stout; very setaceous.

Measurements.

	mm.
Length, without wings - - -	6·15
Head, to apex of labrum, long - -	0·96
Head, to clypeofrontal suture, long - -	0·74
Head, at and including eyes, wide - -	1·19
Head, deep - - - - -	0·51
Antennae, long - - - -	2·28
Pronotum, long 0·85; wide - -	1·19
Tibia iii, long - - - -	1·19

Locality.—North-West Australia: 130 miles south-east of Broome (July or Aug., 1924).

Described from a dealated female, collected and presented to the National Museum, Melbourne, by A. S. Cudmore.

It is possible that the specimen described above is the macropterous form of *M. broomensis* Mjöb., only the soldiers and workers of which have been described.

Mirotermes insitivus, n. sp.

(Plate XIV., Figs. 9-11.)

Imago.

Colour.—Head very dark brown, postclypeus very little lighter than head, anteclypeus whitish; labrum suffused with yellow; antennae, mouth parts and legs, light brown; pronotum nearly as dark as head; wings dark smoky.

Head (Plate XIV., Fig. 9).—Small, rounded when viewed from above, rather densely clothed with short and long setae. Eyes rather large (0·289×0·289), prominent, close (0·04) to lower margin of head, closer than to ocelli. Ocelli large (0·136), broadly oval, separated from the eyes by a space equal to their short diameter. Postclypeus moderately large, about twice as wide as long, strongly convex, hemispherical behind, truncate in front, with rather distinct median suture and clothed moderately densely with small setae; anteclypeus less than half as long as postclypeus, nearly truncate in front. Labrum small, a little widened in the middle, moderately convex, densely setaceous, broadly rounded in front. Fontanelle small, oval, laying within a small depressed area and in line with the middle of the eyes (in all cleared preparations there is to be seen a dark-coloured, broadly oval posterior extension of the fontanelle).

Antennae (Text-fig. 1*d*).—15-jointed; 1st joint short and wide, two-thirds as wide as long, as long as 14th; 2nd short and wide, as wide as long; 3rd very short, but nearly as wide as 2nd; 4th and 6th about equal to 2nd; 5th wide, but a little shorter than 4th and 6th; 8th to 13th about equal, a little longer than 7th, the latter wider at base than the following joints; 14th, a little longer than 13th, but hardly as long as 15th, which is elongate-oval, and widest in the middle. Mandibles with apical tooth on each side much larger than the next; dentition as shown in (Pl. XIV., Fig. 9).

Thorax.—Pronotum very large, as wide as head, densely setaceous, rather strongly arched, the anterior margin broadly concave, anterolateral angles rounded, sides sloping sharply to the narrow posterior border, the latter sometimes almost truncate, but generally markedly emarginate. Meso- and metanotum with the sides markedly narrowed posteriorly, the hind border of the former generally emarginate as in pronotum, that of the latter much more deeply and acutely notched, both sclerites markedly setaceous, though less setaceous than pronotum.

Wings (Pl. XIV., Figs. 10, 11).—Generally with hindwings a little longer and wider than forewings, rather wide relatively to length, of same colour as those of *M. kraepelini*, very setaceous along border and radial sector; the two anteriormost veins, especially the radial sector, very dark; all the veins distinct to their termination; the media passing through the upper third of the wing, with 4 or 5 branches, the first generally a little beyond the middle and sometimes branched, the main stem joining the margin near the apex of the wing; the cubitus with 8-14 branches, seven or eight nearest the base very dark and distinct. Membrane with few microtrichia, but densely covered with micrasters. Wing-stumps small, very setaceous, suture straight.

Legs.—Densely setaceous, femora a little less so than tibiae; claws and spurs long and slender.

Abdomen.—Very setaceous, the setae shorter and finer than those on head and thorax; circi short and very wide at base.

Measurements.

	mm.
Length, with wings - - - -	11·00 — 11·50
Length, without wings - - -	6·00 — 6·50
Head, to apex of labrum, long - -	1·14
Head, to clypeofrontal suture, long - -	0·57
Head, at and including eyes, wide - -	1·14
Antennae, long - - - - -	1·60 — 1·70
Pronotum, long 1·60 — 1·70; wide -	1·14 — 1·30
Forewings, long 9·00 — 9·50; wide -	2·70
Tibia iii, long - - - - - -	1·14

Locality.—N. Queensland: Townsville (G.F.H., 22.12.19, 6.1.20, 15.2.21).

Biology.—The association of this species with *Eutermes vernoni* Hill is referred to in an earlier paper (Hill, *P.L.S. N.S.W.*, xlvii. (2), 1922, p. 148, 2nd line).

Type in the author's collection.

A CORRECTION.

In my paper entitled "Termites (Isoptera) from South Sea and Torres Strait Islands," *Proc. Roy. Soc. Victoria*, xxxix. (1), 11th Nov., 1926, the reference to *Calotermes (Calotermes) repandus* Hill is given as "*Memoirs of the National Museum, Melbourne*, No. 7, in Press." The correct references are "*The Entomologist*," lix., Nov., 1926, p. 297, and "*Insects of Samoa*," part vii., 28th May, 1927, p. 6.

It should be noted also that owing to long delay in the Press, the description of the imago of *Calotermes (Glyptotermes) xantholabrum* Hill (*Mem. Nat. Mus.*, Melbourne, No. 7, June, 1927) is antedated by the subsequently written preliminary and full descriptions of the soldier caste in "The Entomologist," and "Insects of Samoa," of the above-mentioned dates, respectively.

ACKNOWLEDGMENTS.

Cordial thanks are extended to Mr. J. A. Kershaw, National Museum, Melbourne, to the collectors who have courteously made available the material dealt with in this paper, and to Messrs. G. McLennan, B.V.Sc., and D. Murnane, B.V.Sc., for the photomicrographic illustrations.

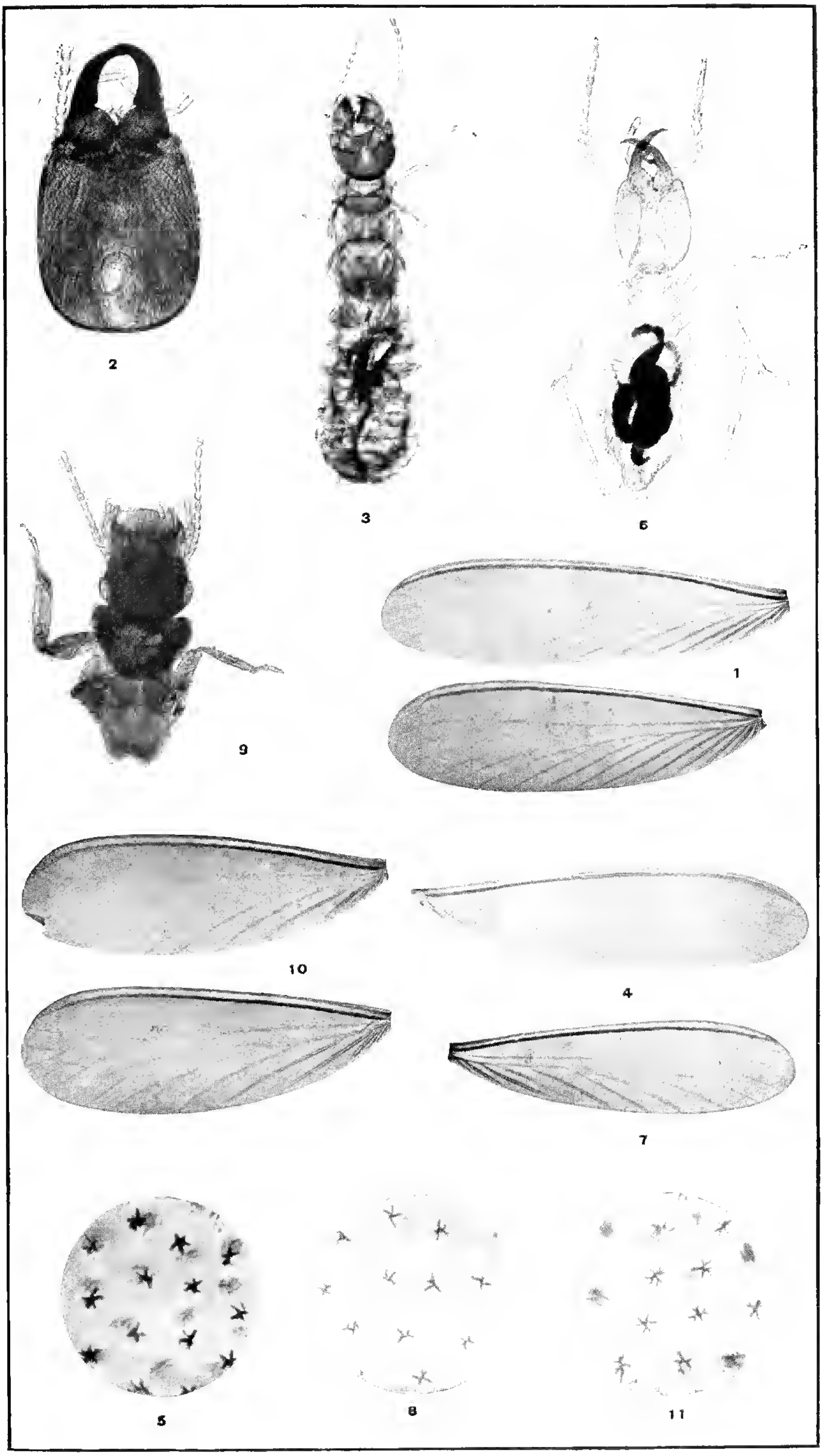
EXPLANATION OF PLATE XIV.

Figs. 1, 2.—*Hamitermes westraliensis*, n. sp.
- ,, ,, 1. Imago: wings.
- ,, ,, 2. Soldier: head.

Figs. 3, 6.—*Hamitermes tamminensis*, n. sp.
- ,, ,, 3. Imago.
- ,, ,, 4. Imago: wing.
- ,, ,, 5. Imago: micrasters.
- ,, ,, 6. Soldier.

Figs. 7, 8.—*Eutermes marcebensis* Hill.
- ,, ,, 7. Imago: wing.
- ,, ,, 8. Imago: micrasters.

Figs. 9, 11.—*Mirotermes insitivus*, n. sp.
- ,, ,, 9. Imago: head and thorax.
- ,, ,, 10. Imago: wings.
- ,, ,, 11. Imago: micrasters.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[PROC. ROY. SOC. VICTORIA, 41 (N.S.), PT. II., 1929.]

ART. VIII.—*The Devonian and Older Palaeozoic Rocks of the Tabberabbera District, North Gippsland, Victoria.*

By

PROFESSOR ERNEST W. SKEATS, D.Sc., A.R.C.S., F.G.S.
(University of Melbourne).

(With Plate XV.)

[Read 11th October, 1928; issued separately 8th January, 1929.]

Introduction.

The geology of the Tabberabbera district has long been recognised as presenting interesting problems concerning the Middle Devonian sediments, because their lithological characters, as well as the subsequent earth movements which have affected them, present a contrast with the rocks of the better-known areas of Buchan and of Bindi in Eastern Victoria. As no geological work had been done in the region under discussion for over a quarter of a century, I welcomed the opportunities which arose in January, 1924, and January, 1925, of paying visits to the area. Through the kindness of Mr. W. Baragwanath, Director of the Geological Survey of Victoria, camping facilities were made available. Mr. Baragwanath joined me for the first four or five days of field work, Mr. J. Easton, Geological Surveyor, and his assistant (Mr. Norman Winter) were with me throughout the three weeks spent in the field, and Mr. Keble, of the Geological Survey, was with us for the last five days of the first trip, and Mr. Easton was with me during three weeks of the second visit. While I am responsible for the form and substance of this communication, I owe much to help rendered in the field by the gentlemen above mentioned.

Previous Literature.

The late Dr. A. W. Howitt, whose pioneering geological work in Gippsland was so remarkable, was the first to investigate the area about 50 years ago (1). His report is not only a valuable contribution to the geology of a wide area, but includes an exceedingly interesting account of a trip in bark canoes downstream from Tabberabbera through the gorge of the Mitchell River, accompanied by two aboriginals, Turnmile, meaning "one who swaggers," and Bungil Bottle, distinguished for his capacity for the absorption of strong waters.

The peculiar nature and compressed character of the mid-Devonian Tabberabbera shales was recognised and described and their unconformable relations to the flat-lying beds of the Upper Devonian Iguana Creek series was recognised and figured.

Mr. E. J. Dunn (2) in 1890 published the account of a rapid survey of the area. His account refers to the presence of Silurian [Ordovician] rocks in Sandy's Creek, and of small areas of limestones in the Tabberabbera series. A sketch map accompanying Mr. Dunn's report shows the approximate distribution of the Silurian [Ordovician], Middle Devonian and Upper Devonian sediments.

Mr. O. A. L. Whitelaw (3) in 1899 published some sections illustrating the relations of rocks from the district, in a general account of Devonian rocks in Gippsland.

Mr. H. Herman (4), in June, 1899, published a short account of the Tabberabbera district with sketch geological map and section.

Mr. R. Etheridge (5), in 1899, gave identifications and descriptions of Silurian corals from Sandy's Creek.

Mr. T. S. Hall (6 and 7), described Upper Ordovician graptolites from Sandy's Creek.

Location of area and means of access.

The district described in this paper constitutes a roughly rectangular area of approximately 30 square miles. It lies within the Counties of Dargo and Wonnangatta, and includes parts of the parishes of Tyirra, Nungatta, Cobbannah and Morekana. The parish plans, on a scale of 2 inches to the mile, contain little topographical detail, and parts of them, in this sparsely settled region, are blank. The name of Tabberabbera does not occur on them, but is understood to refer to the scattered settlements close to the junction of the Mitchell and Wentworth Rivers. This lies about 40 miles WNW. of Bairnsdale, which is about 170 miles east of Melbourne. Tabberabbera, I understand, is an aboriginal name meaning Thunder, and in the months of January and February, during the occasional storms, the noise of thunderclaps reverberating among the hills of the district makes the naming appropriate.

The conditions of access to the district have much changed in the last forty years. Then it was difficult to reach the area, as there was no good graded road from Bairnsdale, but within the area access to various parts was readily made by good mining tracks, which were kept in repair, as alluvial and reef gold mining were then fairly active. Good grazing existed, as rabbits had not then invaded the district, so that, apart from the miners, there was a fair number of settlers running cattle, which assisted to keep the tracks open. Now there is a good graded and metalled road from Bairnsdale to Bullumwaal, and a good graded and formed road from Bullumwaal to Tabberabbera. But within the district mining has long ceased, mining tracks are overgrown, rabbits have come in, and therefore the country carries only a fraction of the cattle formerly grazed. Settlement has, in consequenee, declined, blaekberries have over-run many of the gullies, and hop vine and other secondary scrub all contribute to make the district one in whieh it is not easy to do geologieal mapping. The district is rough and hilly, in plaees with steep, precipitous gorges, and in the months of January and February, apt to be uncomfortably hot. In the circumstanees, much of the energy one would like to put into geological mapping is necessarily expended in the physical exertion of climbing, or of forcing one's way through serub.

Nature of work done.

The total period of six weeks spent in the field allowed of some attention being paid to the stratigraphical and tectonic problems of the area, but, having regard to the fairly rugged topography, was insufficient for detailed mapping. The geological map which aceompanies this paper, while it represents a considerable advance of knowledge over the earlier pioneer work, must be regarded as a sketch map. In particular, the boundaries shown for the Upper Devonian rocks are only roughly approximate, as this series was not the main object of study. The boundaries shown between Middle Devonian and Silurian rocks and between Silurian and Upper Ordovician rocks are based on more eareful work, checked by palaeontological determinations kindly made for me by Mr. Chapman, Palaeontologist to the National Museum. Even these junctions, away from the sections exposed in the rivers, are only sketched in. It is clear, therefore, that until a detailed survey is made, some of the problems of stratigraphy and of tectonics cannot be completely solved, and such conclusions as are drawn in this paper are necessarily qualified by this eonsideration.

The sketch geological sections accompanying the map, and drawn nearly to the same vertical as horizontal scale, represent an attempt to illustrate the structure of the area.

Physical Features of the Area.

On approaching the area from Bullumwaal by road over the Upper Ordovician rocks, the following aneroid heights were noted:—Bullumwaal 735′, Burnett-Merrijig divide 1475′, Merrijig River crossing 1005′, Merrijig-Sandy's Creek divide 1475′, road crossing over upper part of Sandy's Creek 695′, Sandy's-Wentworth divide (at the Gooseneck) 1105′, Camp No. 1 460′, Wentworth R. level near Camp No. 1 450′. The rough timbered country of the Upper Ordovician series in the eastern part of the area rises, therefore, to a maximum of 1000 feet above the level of the Wentworth River.

The Silurian rocks oeeupying the northern central part of the area yield fairly open undulating country in the valleys, especially near the junctions of the Wentworth and Mitehell Rivers, and the

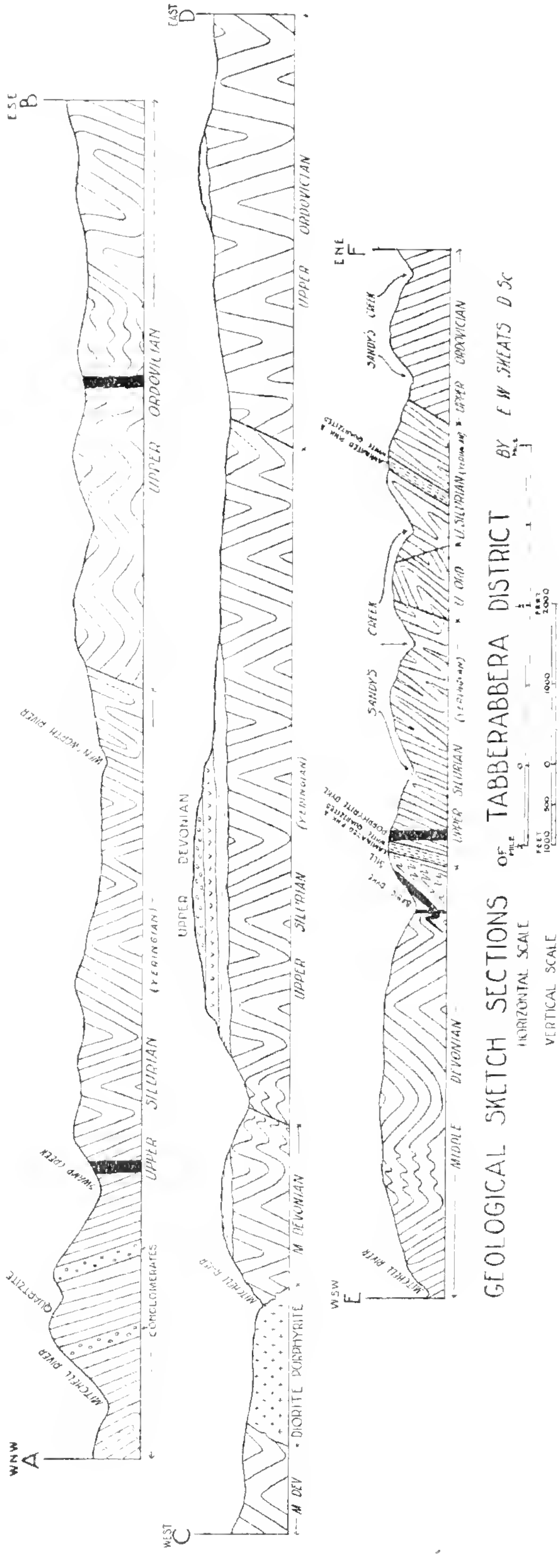
GEOLOGICAL SKETCH SECTIONS OF TABBERABBERA DISTRICT
BY E W SKEATS D Sc
HORIZONTAL SCALE
VERTICAL SCALE
WNW A
ESE B
WEST C
EAST D
WSW E
ENE F
MITCHELL RIVER
QUARTZITE
CONGLOMERATES
UPPER SILURIAN (YERINGIAN)
UPPER ORDOVICIAN
DIORITE PORPHYRITE
M DEVONIAN
M DEV
UPPER DEVONIAN
MIDDLE DEVONIAN
SANDY'S CREEK
SILL

Fig. 1.

mouth of Swamp Creek. In following up Swamp Creek to the north a prominent sandstone hill to the NNE. is seen rising to about 1450′, while to the west a very steep ridge of heavy conglomerates, rising to a height of about 1400′, about 900′ above Swamp Creek, forms a narrow divide with a steep slope to the West down to the Mitchell River. About 2½ miles up Swamp Creek its level by aneroid is 500′, and beyond this the country is unfenced and becomes very rough.

The Middle Devonian rocks form a belt, trending about NW. across the area except in the south central part, where they are overlain by the Upper Devonian rocks. They are prominent near Ostler's and Horseshoe Bend, and to the north-west, and have weathered into undulating park-like country, grassed and with few trees.

The Upper Devonian rocks developed in the central part of the area form a rough dissected tableland rising in the central part to nearly 1500′, and owing to a gentle south-west dip of about 5° descending by eroded terrace formations towards the Mitchell River. The Mitchell and Wentworth Rivers and Sandy's Creek all have well developed meanders and horseshoe bends, suggesting that the country had been formerly maturely dissected. Owing to late Tertiary uplifts all the streams were rejuvenated, and have trenched deeply into the underlying rocks. The whole course of Sandy's Creek below the Merrijig junction constitutes now a gorge-like valley, with steep cliffs of Upper Devonian on either side, overlying Ordovician, Silurian and Middle Devonian rocks, all of which slope steeply down to stream level, and in places form precipitous river cliffs. The Mitchell River, about 1½ miles below Ostler's, flows in a picturesque gorge, about 500 feet deep, cut through the Upper Devonian rocks for about a mile or so above the junction with Sandy's Creek. Just south of Camp No. 2, an abandoned course of the Wentworth River is shown by a broken line on the map, trending westerly, and then bending south to join Swamp Creek, just above its junction with the Wentworth River.

Geology.

Upper Ordovician.

Prior to my visits to the district definite Ordovician fossils had been obtained only from one locality (No. 9 on Map) on Sandy's Creek, about 25 chains above the junction with Merrijig Creek. These were obtained by Mr. Herman in 1897, and include *Glossograptus hermani, Dicranograptus ramosus* and *Didymograptus ovatus* (7). We revisited the locality and obtained similar specimens of these graptolites. Our examination of the road cuttings east of Camp No. 1, on the road going east towards Bullumwaal, yielded a number of graptolites, including *Diplograptus* sp. and *Glossograptus hermani*, from black cherty slates, interbedded with black cherts about half a mile south-east of Camp

No. 1 (No. 5 on Map). Traces of graptolites were found in similar black cherty slates for about a mile east of this locality. There can be little doubt that all these rocks in the eastern part of the area belong to the Upper Ordovician series, and as such they are shown on the map. The road section east of the Camp shows in addition to black slates and cherts, grey and brown micaceous sandstones and a considerable development of olive-coloured micaceous mudstones, some of which are finely laminated with thin beds of lighter and darker colour suggesting seasonal banding. Several lamprophyre dykes seen in road section $1\frac{1}{2}$ miles east of the camp are described later. One other small inlier of rocks older than the Silurian, and presumably Upper Ordovician in age, although no fossils were found in them, was found in Sandy's Creek. It occurs about $1\frac{1}{4}$ miles below the junction with the Merrijig Creek, as an elliptical area elongated in a north-westerly direction, and only about 200 yards broad. The rocks are black slates, similar to those containing Upper Ordovician graptolites, and quite unlike the Silurian rocks with which they are in contact. The boundaries of this inlier with the Silurian are probably determined by faults, while the main junction of the Ordovician and Silurian rocks may be determined either by faults or by an unconformity.

Silurian (Yeringian).

It is under this heading that the greatest changes are shown in the map accompanying this paper as compared with previous maps. Hitherto no Silurian rocks have been shown on any map of this area except in Sandy's Creek. As the result of my stratigraphic examination in the field and Mr. Chapman's valuable help in the determination of fossils from a number of localities, it is now known that a broad belt of country in the north-central part of the area and a limited belt in Sandy's Creek below the outcrop of Upper Ordovician rocks consist of Upper Silurian rocks, probably of Yeringian age. The large general geological map of Victoria, 1902, on the scale of 8 miles to the inch, shows as Silurian all the rocks of Sandy's Creek from the junction with the Mitchell River upstream for about 3 miles to just below the Merrijig Creek junction, where the Upper Ordovician rocks come in. Actually the occurrence of Silurian rocks in Sandy's Creek is limited in extent to a strip of country exposed on either side of Sandy's Creek, extending from about 300 yards below the Merrijig-Sandy's junction downstream for about a mile and a half. Even within this belt its continuity is interrupted by the small inlier of Upper Ordovician rocks previously referred to.

Some fossil corals from Sandy's Creek, probably collected by Mr. Herman in 1897, were described by Mr. Etheridge (5) in 1899 as Upper Silurian. The locality was probably from an outcrop of impure limestone about 200 yards upstream from the Upper Ordovician inlier, since we found at that spot similar genera to those described by Mr. Etheridge. The forms he described are

Diphyphyllum porteri var. *mitchellensis*, var. nov., U. Silurian, *Rhizophyllum interpunctatum* De Koninck, U. Silurian, *Monticulipora* (*Heterotrypa*) *australis*, sp. nov., U. Silurian.

The 1902 map, eight miles to the inch, shows a great area coloured as Middle Devonian limestone, which starts about two miles south of Tabberabbera, and continues northwards for about 18 miles. It is shown extending for two or three miles east of the Wentworth River, and has a maximum breadth of about eight miles, gradually becoming narrower in its northerly extension. The later general geological map of Victoria, 1909, on a scale of 16 miles to the inch, gives this area the colour appropriate to the Upper Devonian sandstones and shales. This is lithologically more correct, but from the point of view of age appears to be further from a correct determination than that shown in the earlier map. My own observations in the field have only extended to a point on Swamp Creek, about three miles north of Tabberabbera, but the rocks up to that point show similar lithological characters to those nearer Tabberabbera, such as localities 1, 2, 3 and 6, on the map, from which abundant fossils, determined by Mr. Chapman as Upper Silurian (Yeringian), have been obtained. It seems certain, therefore, that the southern part of this area up to three miles north of Tabberabbera, consists of Silurian and not of Middle or Upper Devonian rocks, and it is probable that the whole of this area, extending to about 18 miles north of Tabberabbera, consists of rocks of Silurian age.

The localities 1, 2, 3, and 6 from which we obtained abundant fossils occur north and south of the junction of the Mitchell and Wentworth Rivers, which Howitt named as Tabberabbera.

Loc. 1. Allot. 13, S. Websdale, Tyirra.
Fossils—*Bythotrephis* cf. *gracilis* J. Hall.
Spirifer aff. *crispus* (Hisinger).
Yeringian.

Loc. 2. Allot. 14, Tyirra.
Fossils—*Spirifer* aff. *crispus* (Hisinger).
Ctenodonta cf. *portlocki* Chapman.
Yeringian.

Loc. 3. Allot. 9A, E. Desailly, Tyirra.
Fossils—*Spirifer* aff. *crispus* (Hisinger).
Pentamerus aff. *lens* (Sowerby).
? *Glossites* or ? *Palaeoneilo*.
Actinopteria sp.
Yeringian.

Loc. 6. Allot. 6, Nungatta. E. bank of Mitchell River, about half mile south of Birch's.
Fossils—Plant remains, ind.
? *Tryplasma*.
Chollotrypa sp.
cf. *Favosites gothlandica* Lam.
Roemingeria sp.
cf. *Leptaena* sp.
Atrypa aspera (Schloth.). Gerontic forms.
Conchidium sp.
Spirifer sp., probably new.
Yeringian.

This evidence shows that the type locality for the Tabberabbera shales at the junction of the Mitchell and Wentworth Rivers actually consists of Upper Silurian rocks. Dr. Howitt (1, page 206) states: "I found a small limestone patch at Tabberabbera, situated at the junction of the Mitchell and Wentworth Rivers. No fossils have been procured from the limestone, but associated with them are black shales, yielding plentifully the *Spirifera laevicostata* [later redescribed as *Spirifer yassensis*] and a *Grammysia*. They are regarded by Professor McCoy as being of the same age as the Buchan limestones, and therefore Middle Devonian."

To reconcile these statements with the evidence I have obtained, it is necessary to interpret very loosely Howitt's word "associated" in connection with the black shales yielding the above forms. It is almost certain that Howitt did not obtain them from the junction of the Mitchell and Wentworth Rivers, and I was unable to locate such black shales at this junction. It is probable that he obtained them from a locality on the Mitchell River, about three miles below Tabberabbera.

He figures (1, p. 207) a sketch section No. 16 Tabberabbera, showing the fossiliferous black shales on the east side of the Mitchell River, and just below the junction with the Upper Devonian (Iguana Creek) beds. His statement is that the section is "below Tabberabbera." Further on (1, p. 215), when describing his canoe journey down the Mitchell, he states that they started about two miles below Tabberabbera, and after continuing some time he landed and examined a limestone which he states was "very much upon the line of section given in sketch No. 16." It is not possible to locate this place exactly from Howitt's description, but I take it to be about one mile down stream from Ostler's. If that is so, the difficulty disappears, since I have obtained Middle Devonian fossils at Horseshoe Bend and east of Ostler's and rocks of a similar character continue down stream for some distance.

Loc. 4, at the road cutting on the north side of the Wentworth River, about half a mile west of Camp No. 1, provides another fossiliferous locality in the Silurian series. The rocks are finely laminated black and brown cherts crowded with Radiolaria. Mr. Chapman has reported on microscopic sections of these rocks as follows:—

"The rock is crowded with radiolarian remains, but only very few are determinable. In some cases the ferruginous staining and replacement of the siliceous test is an aid to deciphering the form and structure."

Genera or species noted—

Distriactis sp.
Acanthosphaera cf. *etheridgei* Hinde.
Stylosphaera sp.
Spongoloncha cf. *lens* Hinde.

The assemblage closely resembles that from the Tamworth district, described by Hinde in *Quart. Journ. Geol. Soc.*, vol. lv., 1899, pp. 38-64."

Lithological types in the Silurian rocks of this district are numerous and varied. The sections exposed in the road cuttings between localities 4 and 2 on the map, are in a zone of great crushing and contortion. Olive mudstones and dark calcareous shales, some very fossiliferous, are common. In places where the calcium carbonate has been leached out the rocks are rusty brown in colour, and the fossils are only preserved as casts. Thin lenticular blue limestones were also noted. Sandstones and grits are fairly prominent. Calcareous mudstones and thin blue limestones occur also south and north of Loc. 6, South of Birch's. An impure blue limestone in Sandy's Creek about 200 yards above the Upper Ordovician inlier yields an abundant supply of Silurian corals.

Two parallel massive and thick conglomerates with intercalated grits are shown on the map, extending from east of E. Websdale's down to the Mitchell River, and a smaller conglomerate and grit higher in the Silurian series are shown east of Swamp Creek.

The pebbles in the most westerly conglomerate near E. Websdale's are up to a foot in length, and are much dimpled and sheared. Fine-grained laminated pink and white sandstones or quartzites were noted about two miles up Swamp Creek adjoining the big dyke shown on the map, and were seen again on the Mitchell River about one mile west of Sinnott's, and very similar types occur in two places in the Sandy's Creek section, one adjoining the western boundary of the Silurian and the other near the eastern boundary of the same series.

Numerous dykes intersect the Silurian rocks. Many appear to have a similar strike to that of the adjoining sediments, others cut across the strike of the sediments at various angles. They include hornblende porphyrites, some fresh and others calcareous with decomposition, quartz felspar porphyries, black dykes showing quartz, and a tinguaite. Brief petrological descriptions of some of these are included later in the paper.

Middle Devonian.

The rocks to which a Middle Devonian age can be assigned are restricted, as shown on the map, to a belt of country occupying the western part of the area.

The junctions with the Silurian rocks to the east have been definitely located only in two places. One is near Loc. 7, on the Mitchell River, east of the saddle of Horseshoe Bend. The other is in Sandy's Creek, just above Whitbourne's Hut, and just east of a prominent sill or interbedded flow near a crush zone, and just west of prominent laminated pink and white quartzites.

Below this point on Sandy's Creek, down to the junction with the Mitchell River, the whole sequence for about 1½ miles across the strike is in the Middle Devonian sediments, and characteristic

Middle Devonian fossils have been collected from several bands of blue limestone or dark calcareous shales exposed in the river cliffs.

One limestone band a few hundred yards below Whitbourne's flat yielded in microscopic sections, according to Mr. Chapman's determination—

Spirifer yassensis.
? *Coenites* or *Campophyllum?*
Carapaces of Ostracods, chiefly *Primitia.*
Syringopora?
Foraminifera including *Pulvinulina?*
Nubecularia?
Crinoid ossicles.

From Loc. 7, just east of the saddle of Horseshoe Bend, abundant fossils were obtained, chiefly as casts, which Mr. Chapman has determined as under:

From a shale band—

Spirifer yassensis de Kon.
Grammysia sp.

and from a limestone band—

Abundant specimens of *Spirifer yassensis* de Kon.

Similar fossils were also obtained at Loc. 8, south of Horseshoe Bend and east of Ostler's. The lithological types in the Middle Devonian include blue limestones, black, brown and yellow shales or slates, some silicified or flinty shales and siliceous sandstones. The rocks at Horseshoe Bend are intensely crumpled, faulted and in places vertical.

Numerous dykes penetrate these rocks, and are especially noticed in the ridge-like saddle of Horseshoe Bend and south from that locality; some striking E. and W., others conforming more or less to the strike of the sediments either W. or E. of north. They include hornblende and other types of porphyrites; at Loc. 8 a tinguaite strikes E. and W.; at Whitbourne's flat on Sandy's Creek an interbedded igneous rock occurring as a sill or lava flow is a fine-grained porphyrite; and S. of Whitbourne's flat a big black basaltic dyke cuts across the sediments. South of Ostler's, where the Mitchell bends to the west, the slopes below the Upper Devonian series consist of a large area of diorite porphyrite, probably intrusive into the Middle Devonian sediments (see Section C-D).

Upper Devonian.

The rocks of this series, provisionally described as of Upper Devonian age, occur within the central and south-western parts of the area shown on the map. They form a series about 900 ft. in thickness. They rest in turn on the heavily eroded edges of folded rocks of the Upper Ordovician, Upper Silurian and Middle Devonian series, and as they themselves are almost horizontal, their dip being not more than 5° to the SW., their relations with the older rocks, even with the Middle Devonian, constitute a very important and striking angular unconformity.

They have not in this district as yet yielded any recognisable fossils, and the validity of the reference of them to the Upper Devonian depends on questions of geological continuity and of lithological correlations with other areas. The following rough section, supplied to me by Mr. J. Easton, and trending in an approximately easterly direction from the Mitchell River above Horseshoe Bend, and just north of Loc. 7, will serve to illustrate the sequence of the rocks of this series. At the base, about 150′ above the level of the Mitchell River, and resting directly and unconformably on the eroded surface of the folded Middle Devonian mudstones and shales, are about 100 feet of purple grits and mudstones, then a few feet of purple breccia followed by about 60 feet of purple mudstone. About four feet of nodular or spherulitic rhyolite comes next, followed by 90 feet of red and grey mudstone, then 20 feet of breccia and conglomerate, 50 feet of mudstones, 3 feet of rhyolite, 70 feet of conglomerate and breccia, and continuing to the top of the series developed in this district about 500 feet of siliceous and pebbly grey sandstone beds.

The precise sequence of these rocks varies somewhat in different parts of the area shown on the map. In some places the interbedded rhyolites are much thicker, and just east of the diorite porphyrite about a quarter of a mile south of Loc. 8 the sequence appears to start with spherulitic rhyolites.

The reference of these to the Upper Devonian is not quite certain, since, as shown on the map, they have a dip of 30°, and it is just possible that they may unconformably underlie the base of the Upper Devonian, and may be a small area of Lower Devonian igneous rocks. If this were so the diorite porphyrite on which they appear to rest would be older than is shown in the sketch geological section.

On the whole, however, it is thought to be more probable that these spherulitic rhyolites are of Upper Devonian age, and that their relatively high and abnormal dip is due to restricted local movement. This view is strengthened since A. W. Howitt (18) in describing the sequence of Upper Devonian rocks in the Snowy Bluff section, refers to interbedded compact felsites (felstones), having in places a spherulitic structure, the spherules being from one to two inches in diameter.

This description corresponds closely with the nature of the spherulites just east of the diorite porphyrite, and is in accordance with their recurrence higher in the series as noted by Mr. Easton in the section described above.

In most parts of the area, however, purple mudstones form the base of the series. No interbedded basalts (melaphyres of Howitt) have been found "in situ" in these rocks, but they probably occur, since abundant pebbles of this type of rock have been found at the Mitchell River at and near Loc. 7. I have not seen any dykes penetrating these rocks, but Mr. Easton informs me of the interesting fact that he has obtained a lamprophyre and several felspar porphyrite dykes intruded into the Upper Devonian sediments.

The lithological characters of these rocks and their prevalent purple and red colours suggest that the series is a lacustrine one, rapidly accumulated in an arid climate subjected to occasional rain storms.

Tectonic Movements and Structures.

The district has clearly suffered from successive movements of compression in post-Upper Ordovician, post-Upper Silurian, and post-Middle Devonian times, and in the Silurian and Upper Ordovician rocks it is almost impossible to distinguish the effects of the earlier from those of the later movements.

The present relations expressed in dips, strikes, trends of fold axes and trend of boundaries between different formations have developed as the result of the combined effects of all the earlier and later structural movements.

The structural features in the Ordovician rocks are fairly clearly shown in the road section, starting from about half mile from Camp No. 1, and continuing for about $2\frac{1}{2}$ miles in a general easterly direction. The distribution of dips and strikes shown on the map indicates that away from the junction with the Silurian the average strike is about N.20° E. and the average dip about 65°-70°. Near the Silurian junction the strikes are much more disturbed, and trend west of north at varying angles from NNW. to W. It would seem that near the Silurian junction along this road section is a zone of special disturbance, and since it will be seen that the Silurian rocks near this junction also tend to have abnormal strikes it may be that either this junction was determined by post-Silurian fault movements or, if the junction be an unconformity, that the post-Silurian movements were only able to impress themselves on the indurated and compressed Ordovician rocks in the neighbourhood of the junction with the Silurian.

The section in Sandy's Creek above the Merrijig junction shows an abnormal strike of N.70° W. This locality is about half mile from the junction with the Silurian. About a mile below the junction the small, probably faulted, inlier of Ordovician rocks has a strike of N.30° W., and an unusually low dip of 20°. This latter may well be an effect of overfolding.

The general strike of the Ordovician east of north, away from the Silurian contact, is in harmony with the evidence given by Teale (10) from Nowa Nowa, and farther east in Croajingolong. In this part of Victoria the trend of the Palaeozoic rocks and of their junctions, as seen on a general geological map, is east of north, and continues in this direction into New South Wales. But northwards from a line through Mt. Wellington, Waterford to Mt. Baldhead, the trend of the junctions of Upper Palaeozoic and Lower Palaeozoic rocks is about N.40° W., and strikes of this nature are common in the Ordovician rocks north of the line mentioned. Both sets of trend lines must be of post-Palaeozoic development, or at any rate continued till late Palaeozoic times, since the trend of the junction of the Upper Devonian and Upper Ordovician rocks in the northern area conforms to the direction of N.40°W.

The structural features in the Silurian (Yeringian) rocks are comparatively simple in the sections seen in Sandy's Creek. The strikes are all west of north, varying from 20° to about 40° west of north. The lines of junction with Upper Ordovician and with Middle Devonian rocks appear to trend about N.40°W.

Much greater diversity of strikes and complexity of folding occur in the central and northern part of the area in sections seen on the Mitchell and Wentworth Rivers and in Swamp Creek on the bare exposed saddles within this part of the region.

West of a north and south line through Camp No. 2, the strikes are all west of north at angles varying from N.20°W., which is a common strike in the western outcrops, to N.65°W., in several places near Loc. 6. In the road sections east of Camp No. 2, and in one or two localities further north, the strikes are all east of north from 20°-50°, except in one case south-east of Camp No. 1, adjoining the junction with the Upper Ordovician. A dyke and grits strike north and south about one mile north of Camp No. 2. On either side of this there is a tendency to a convergence of strike of the beds to the south, suggesting a syncline pitching north. A prominent grit bed on the Wentworth River just north of Birch's shows an axis of a syncline. However, the prominent conglomerate beds shown on the western part of the map continue with a strike of N.20°W. in a southerly direction at least to the Mitchell River. There may be a strike fault east of these conglomerates, and the big dyke seen along Swamp Creek may have been intruded along such a fault. The average dip of the Silurian rocks is very high. The only one as low as 45° occurs near the Middle Devonian junction north-east of Loc. 7. In many cases the beds are vertical, and perhaps the average dip on either side of the fold axes is 70° to 75°. A puckered anticline and syncline with steep northerly pitch occur at Loc. 7 at the junction with the Middle Devonian rocks. While the high dips and the fold axes are the expression of compressional earth movements, the numerous dykes intersecting the Silurian rocks indicate that tensional cracks either accompanied or succeeded the compressive movements within the same geological period or at later times.

The majority of the dykes in the Silurian, especially the porphyrite dykes, appear to strike nearly or quite parallel to the adjoining sediments, but near Horseshoe Bend two dykes, one of them a tinguaite, cut right across the strike of the sediments in an east-west direction.

The structural features in the Middle Devonian rocks have been noted near Horseshoe Bend, near Localities 7 and 8, and in continuous sections along Sandy's Creek for about 1½ miles across the strike upstream from its junction with the Mitchell River.

In the first locality considerable changes in strike direction are noticeable from N.10°E. to N.20° W., while on the saddle in the neck of Horseshoe Bend a porphyrite dyke strikes east and west and farther south at Loc. 8 a tinguaite dyke strikes in the same direction. The rocks in this locality are very steeply folded and crinkled, with dips of 75° to 80°. At Ostler's and south of the Mitchell River south of Ostler's, there is a large area of intrusive rock, dark green in colour, consisting of diorite porphyrite. Howitt also noted the occurrence of a similar rock further down the Mitchell River in a locality which I have not been able to visit. The boundaries and field relations of this rock were not determined, but it is probable that it represents a hypabyssal intrusion of post-Middle Devonian age.

On Sandy's Creek the strikes of the rocks and the fold axes are uniformly west of north, usually about N.20°W. Several anticlinal and synclinal folds are seen in section in the river cliffs, and usually the dips on either side of the axes are at 45°-50°. Dips up to 80° are, however, recorded, and at one of the anticlinal folds severe local puckering and faulting complicate the relations. At the junction with the Silurian rocks just above Whitbourne's Hut, while the dip is westerly, there is a zone of puckering and overfolding with an intercalated fine-grained sill or lava seen in the cliff section. It is clear from these facts that in this region there is evidence of local severe compressive earth movements later than the Middle Devonian. Teale (10) has noted that at Hickey's Creek on the Macallister River, there occurs a local severe tectonic zone of faulting and synclinal folding, which is of post-Upper Devonian age since rocks of this age are involved.

In the Grampians in Western Victoria the author (11) has given evidence of post-Lower Carboniferous plutonic intrusions. The evidence cited from these localities shows that the long maintained view that notable compressive earth movements with accompanying plutonic intrusions ceased in the Lower Devonian period cannot now be entirely accepted.

In Central Victoria the similarity of composition of dacites and granodiorites suggests that although the granodiorites are instrusive into the dacites, they probably belong to the same period of igneous activity, which has been regarded as probably Lower Devonian, since in various places the dacite series is overlain unconformably by Upper Devonian sediments. At Bindi, the Middle Devonian limestones and shales rest possibly unconformably on the Snowy River porphyrites of Lower Devonian age, and are only gently folded. At Buchan, pyroclastic igneous rocks associated with the Snowy River porphyrites, are intercalated with the lower part of the limestones and shales. In the Buchan district the structural relations of the limestone series are seen from numerous recent road sections to have been affected in general by only gentle post-Middle Devonian compressive movements since the average dips seldom exceed 20° except in one or two places, where quite local puckers have developed small anticlinal folds with high dips. At Buchan and Bindi, therefore, the gentle folding stands in marked contrast to the more severe compression which has affected the Silurian rocks generally in Victoria and the Middle Devonian rocks of Tabberabbera.

The rocks described as Upper Devonian in this district have not suffered from any compressive earth movements. They appear in the sections exposed in the field to be almost horizontal, but a dip of about 5° to the south-west can be inferred from the fact that rhyolites and other associated rocks outcropping at river level along the Mitchell at about 400′ elevation are over 1000′ above sea-level about two miles ENE. from that locality.

Significance of the Unconformity between the Middle and Upper Devonian Rocks.

The most remarkable structural features of the district are firstly, the severe compression and folding which have affected the Middle Devonian rocks, whose age is definitely determined by their fossil content, and secondly, the profound character of the unconformity which separates these folded rocks from the flat-lying sediments and lavas which rest on their denuded edges and also unconformably overlie the Silurian and Upper Ordovician rocks. These overlying rocks are here described as Upper Devonian, but the question of their age invites some discussion. As stated above, no fossils have as yet been found in these rocks, but they appear to be geologically continuous, as stated by R. A. F. Murray (17), with the series developed further south at Iguana Creek, and south-west at the Avon River. There is continuity and similarity of sedimentation in all three areas, but McCoy (11) described the Avon River beds as Lower Carboniferous, on account of the presence in them of *Lepidodendron australe,* and the Iguana Creek Beds (12) as Upper Devonian on account of the presence in them of *Cordaites australis* and *Archaeopteris Howitti.*

A broad belt of similar sediments stretches N.40°W. from the Avon River through the Mt. Wellington district, described by Teale (10), to Mansfield. Near Mansfield, on the Broken River, Cresswell and, later, George Sweet (14) discovered plants and fossil fish partially described by McCoy (13) as showing forms of mingled affinities ranging through Lower Devonian, Upper Devonian to the base of the Carboniferous. McCoy placed the Mansfield Beds as at the top of the Upper Devonian. It should be noted that McCoy identified the plant remains as *Lepidodendron Mansfieldense,* a species quite distinct from the form met with in the Avon River section. Smith Woodward (15), however, later described the Mansfield fossil fish as typically Lower Carboniferous, and the Geological Survey of Victoria, in their latest general geological map of the State (1909), on the scale of 16 miles to the inch, have distinguished the beds round Mansfield from the rest of the belt of similar rocks, colouring them as Carboniferous, and the rest, including the Avon River beds, as Devonian. In numerous localities in New South Wales, as at Mt. Lambie and Tamworth, New South Wales geologists have shown that, in that State, *Lepidodendron australe* is interbedded with marine beds containing Devonian marine fossils, at Tamworth with radiolarian cherts described as of Middle Devonian age, and at Mt. Lambie and elsewhere interbedded with marine beds containing *Spirifer disjuncta*, a typical Upper Devonian brachiopod. Professor Benson (16) has given a full discussion on the Devonian palaeontology of Australia and discussed the stratigraphical implications.

Our Victorian problem is to reconcile the geographical continuity over a wide area of fairly flat-lying beds of similar lithological types, and apparently one series formed under similar conditions, with the palaeontological determinations which would place the Avon River Beds on plant determinations as Lower Carboniferous, the Mansfield beds as Lower Carboniferous on identification of fossil fish, and the Iguana Creek beds as Upper Devonian on the identification of fossil plants.

The reconciliation of these apparent anomalies will probably not be achieved until continuous and detailed geological surveys are made throughout the broad belt of rough mountainous country between Iguana Creek and the Avon River, and between the Avon River and Mansfield. Until this work has been accomplished the point of view expressed on the Geological Map of Victoria in 1909—the separation of the Mansfield area from the remainder—appears to have some justification.

The important evidence from various localities in New South Wales that *Lepidodendron australe* is there an Upper Devonian form may justify us in Victoria in regarding the Avon River beds as well as the Iguana Creek beds as of Upper Devonian age.

In this connection it is perhaps pertinent that the broad belt shown on the Geological Survey Map of Victoria, 1909, as Devonian, is an area throughout which there are intercalated with the conglomerates, sandstone and shales, important flows of rhyolite and thinner sheets of basic lavas (melaphyres of Howitt) and similar intercalated igneous rocks are recorded from several of the New South Wales areas in which Upper Devonian rocks are recorded. But in the Mansfield area these intercalated igneous rocks have not been found. Despite then the similarity of the sediments in the Mansfield district to the sediments farther to the south-east, the absence of contemporaneous lavas in the Mansfield area, may be regarded as negative evidence supporting the positive evidence of the fossil fish described by Smith Woodward as fixing a Lower Carboniferous age for the Mansfield beds.

The foregoing discussion then may justify us in accepting, at any rate provisionally, the flat-lying sediments with intercalated lavas of the Tabberabbera district as of Upper Devonian age.

If this view is correct the significance of the gigantic unconformity between these beds and the highly crumpled Middle

Devonian rocks beneath is remarkable and difficult to explain, for we have to picture that in this part of Victoria in the geologically short interval between Middle and Upper Devonian the sea receded, the Middle Devonian rocks were crumpled and elevated, and denuded to a low-lying area, before the lacustrine conditions of the Upper Devonian were established.

Petrographic Characters of the Igneous Rocks of the District.

In this paper, mainly concerned with structural and stratigraphical relations, only brief descriptions of the igneous rocks will be given. The reference numbers are those of the main collection of rock sections in the Geological Department of the University of Melbourne.

Dykes of varying size and petrologic character occur in the Upper Ordovician, Silurian (Yeringian), Middle Devonian and Upper Devonian (Easton's communication) rocks.

A big hypabyssal or small plutonic intrusion of diorite porphyrite occurs in the Middle Devonian rocks as well as an intercalated sill or lava flow.

Prominent nodular or spherulitic rhyolites, as well as banded flow rhyolites, occur in the Upper Devonian, and the evidence of boulders in the river-beds suggests that basic flows (melaphyres) may also be represented in the Upper Devonian, although they have not yet been found " in situ."

In the Upper Ordovician sediments, apart from spherulitic keratophyres, and a hornblende porphyrite, high up Sandy's Creek, near the Bullumwaal road, the only dykes found up to the present are somewhat decomposed mica lamprophyres. A boulder of a somewhat similar rock found about two miles up Swamp Creek suggests that mica lamprophyres may also penetrate the Silurian rocks, while a boulder of a fresh green tinguaite, No. 1726, found about three miles up Sandy's Creek, indicates that a dyke of this type probably intruded the Ordovician sediments. Within the Silurian (Yeringian) rocks, dykes of hornblende porphyrite, felspar porphyrite, quartz felspar porphyrite, oligoclase trachyte and of tinguaite, No. 1737, have been found, and a boulder of fresh tinguaite, No. 1718, was found in the Mitchell River, about half a mile below E. Websdale's house. This represents material from a dyke which may intersect either Silurian or Upper Ordovician rocks, since the Mitchell River above this point drains areas of both these series. Dykes penetrating the Middle Devonian sediments include numerous porphyrites, a basalt and a tinguaite, No. 1727. It will be noted that four felspathoid-bearing rocks are now known from this district. The author (8) has given petrographic descriptions of them recently, so that it is not necessary to refer to them further, except to point out that within recent years it has become known, by the author's contributions to recent volumes, as one of the Secretaries to the Alkaline Rocks Research Committee of the Australasian Association for the Advancement of Science, that Eastern Victoria must be regarded as an alkali-rich province. Phonolites and tinguaites have been recorded by him from the Tolmie Ranges, near Mansfield, from Pretty Boy pinch, west of Tabberabbera, from near Mt. St. Bernard, north-north-west of Tabberabbera, and from near Omeo, north of Tabberabbera. Many of these are so fresh and unaltered that they may quite likely be of Middle to Late Kainozoic age, like the alkali rocks of Mt. Macedon and the Western District of Victoria. If this is so, they may have been intruded along tension cracks associated with the successive plateau elevating movements, differential in character, which have uplifted Eastern Australia. It cannot, however, be said that their association with fault movements has yet been proved or definitely established.

Descriptions of Rock Sections of Igneous Rocks.

1608. Dyke 10′ thick, road cutting in Upper Ordovician, 1½ miles east of Camp No. 1.

A dense dark fine-grained rock in hand specimen, weathering to a rusty brown colour. Pale to pink "Schlieren" occur through it and occasional large plates of biotite are present. Under the microscope brown biotite is abundant, green and brown sub-porphyritic hornblendes, and small prismatic green to brown crystals of the same mineral are abundant. Large clear zoned crystals of plagioclase are invaded by the ferromagnesian minerals and the ground mass is partly cloudy through the alteration of the smaller felspars, while "Schlieren" are represented by clear colourless areas, partly consisting of felspar, and isotropic areas which occur suggest that a felspathoid such as sodalite may be present. The rock may be described as a mica hornblende lamprophyre.

1723. Dyke through Upper Ordovician in the upper part of Sandy's Creek, near the Bullumwaal road.

In hand specimen the rock is rather decomposed, cream-coloured, and apparently largely felspathic. Under the microscope it is seen to be practically wanting in ferromagnesian minerals, and to be composed almost entirely of felspar. A few areas of almost colourless chlorite indicate the former presence of a small amount of a ferromagnesian mineral. A number of small quadrate to lath-shaped clear felspars with fine twin lamellae and almost straight extinction consist of oligoclase, while the bulk of the rock consists of spherulitic aggregates of felspar laths. The rock may be described as a spherulitic keratophyre.

1738. Dyke penetrating Upper Ordovician high up Sandy's Creek near Bullumwaal road.

In hand specimen the rock appears to be fairly fresh, dark grey in colour, fine grained with small porphyritic crystals. Under the microscope the rock consists mainly of two minerals. Plagioclase is abundant as fair sized porphyritic fresh crystals of quadrate habit and moderate extinction angle indicating andesine. Somewhat later than the felspar is abundant pale hornblende, some of which is altered to chlorite. A little magnetite in crystals and irregular grains is also present. The rock is a rather basic hornblende porphyrite.

1730. Dyke cutting Upper Ordovician high up Sandy's Creek, about one mile below Bullumwaal road.

In hand specimen the rock is cream coloured, with porphyritic quartz. Under the microscope large corroded crystals of quartz showing crystal boundaries are common, and large abundant phenocrysts of plagioclase ranging from oligoclase to andesine are set in a fine groundmass of spherulitic aggregates of felspar. Small microscopic quartz veins penetrate the rock. The rock may be described as a porphyritic and microspherulitic quartz keratophyre.

1724. Weathered dyke cutting Silurian, 250 yards NE. of Loc. 2.

The hand specimen is a dense fine-grained brownish grey rock, with porphyritic felspars. In section its altered character is apparent. All the larger felspar phenocrysts are kaolinized. Smaller quadrate phenocrysts are oligoclase, as is most of the felspar in the felted groundmass. The ferromagnesian mineral has altered to chlorite and a small amount of secondary calcite is present. The rock may be described as an oligoclase trachyte.

1747. From big dyke cutting Silurian shown on map along Swamp Creek, from quarter mile below top fence.

In hand specimen the rock has a rather coarser texture than most of the dykes seen, and shows small phenocrysts of felspar and hornblende. Under the microscope both plagioclase and hornblende are abundant, each is in turn porphyritic, and each may be included in the other, suggesting almost simultaneous crystallization. The groundmass consists mainly of small plagioclase felspars. The felspar is mainly oligoclase, the hornblende is pale, and some amount of minute magnetite is present, and secondary calcite occurs in small amount. The rock is a hornblende porphyrite.

1743. From same dyke as 1747, but 10 chains lower down Swamp Creek.

In hand specimen its paler colour and more altered appearance than 1747 is noted. Under the microscope it is distinguished from 1747 by the absence of hornblende, and the abundance of secondary calcite and the presence of a fair amount of quartz in the groundmass. The rock is an altered felspar quartz porphyrite.

1606. Dyke penetrating Silurian, road east of Loc. 2, at north-west corner of Allot. 9, R. J. Oates.

In hand specimen the rock is dense, cream-coloured, with porphyritic quartz crystals. Under the microscope large phenocrysts of oligoclase, andesine and of corroded quartz crystals are set in a micrographic groundmass of quartz and acid plagioclase. The rock is a micrographic quartz felspar porphyrite.

1719. Dyke cutting Silurian and striking north and south from hill east of Swamp Creek. Allot. 2, K. Sinnott.

In hand specimen the rock is dense and cream-coloured, with porphyritic felspars and quartz. Under the microscope phenocrysts of untwinned felspar and of corroded quartz are set in a microcrystalline groundmass of quartz and felspar, consisting of both plagioclase and orthoclase. Some elongated biotite more or less altered to chlorite is also present. The rock is a quartz felspar porphyry.

1744. Big dyke 110′ thick, penetrating Silurian near western boundary, 250 yards above Whitbourne's Hut, Sandy's Creek.

In hand specimen the rock is dense and dark greenish in colour, with small felspar phenocrysts. Under the microscope the rock is seen to be considerably altered. The plagioclase phenocrysts are decomposed, and the hornblende replaced by chlorite and abundant calcite. The groundmass contains small crystals of magnetite, but consists mainly of a microcrystalline aggregate of felspar, with some quartz. The rock is an altered hornblende porphyrite.

1739. Black dyke cutting Silurian conglomerate on Mitchell River, west of Sinnott's.

In hand specimen the rock is black and densely crystalline. Under the microscope it is seen to be fresh with ophitic texture since lath-shaped labradorite penetrates pale brown augite, a little of which is altered to chlorite. Irregular crystals of magnetite are fairly abundant. The rock is a dolerite.

1733. Big dark dyke cutting Silurian quartzites, and striking N.10°W. near bend in Mitchell River, west of Sinnott's.

In hand specimen the rock is a black fine-grained but crystalline rock with felspar phenocrysts. Under the microscope it is seen that the rock has suffered dynamic alteration. Porphyritic plagioclase felspars are set in a finer ophitic intergrowth of felspar laths and ferromagnesian minerals, but the latter are now fibrous hornblende and the plagioclase has been mostly recrystallized to radiating or needle-shaped secondary minerals. Fine-grained irregular crystals of magnetite occur in the groundmass. The rock is a fine-grained dynamically altered dolerite.

1746. Dark dyke striking east and west, eight chains NW. of saddle of Horseshoe Bend.

In hand specimen the rock is a dark grey fine-grained crystalline rock. Under the microscope the rock is seen to consist of large lath-shaped labradorite, with prismatic to irregular pale purplish to brown augite and a fair quantity of magnetite or ilmenite. Considerable alteration of much of the augite has occurred with the development of calcite and the introduction of some chlorite. In the interstices of the rock some of the felspar is somewhat spherulitic. The rock is a fine-grained felspathic dolerite.

1729. A rather large mass probably intrusive into the Middle Devonian, south of Ostler's, on the Mitchell River.

In hand specimen the rock is of medium grain size, and dark grey green in colour. Under the microscope the texture is between the hypabyssal and the plutonic. There is a tendency for the irregularly quadrate felspars, oligoclase to andesine, to be porphyritic. The ferromagnesian mineral, originally hornblende, is now largely pale green and fibrous in habit, and is largely chlorite. A small amount of minute felspars with interstitial quartz, constitutes a second generation of crystals in which are recognised small magnetite phenocrysts and occasional irregular crystals of sphene. The rock is a diorite porphyrite.

1731. Big dyke 150′ thick, striking N.40°E., penetrating Middle Devonian, west of Loc. 7.

In hand specimen the rock is a nearly black, fine-grained rock, showing minute quartz and specks of pyrites. Under the microscope its fine-grained texture is clear, but the rock is much altered, both plagioclase and augite being largely altered. The lath-shaped plagioclase still shows twinning, but the ferromagnesian mineral is now changed to chlorite. A little interstitial quartz, and a small amount of black opaque iron ores occur; calcite is moderately abundant. The rock is a fine-grained quartz dolerite.

1732. Dyke 15′ thick, cutting Middle Devonian, south end of Whitbourne's paddock, Sandy's Creek.

In hand specimen the rock is black, fine-grained, but crystalline, with small porphyritic felspars. Under the microscope the rock is clearly porphyritic. Clear large lath-shaped labradorite felspar and pale brown augite phenocrysts are set in a finer textured ophitic aggregate of the same minerals, with the addition of granular magnetite; green chlorite and calcite, are noted as secondary products. The rock is a porphyritic dolerite.

1612. Sill or interbedded flow in Middle Devonian five chains south of south end of Whitbourne's flat, Sandy's Creek.

In hand specimen the rock is dark, fine-grained, and somewhat decomposed. Under the microscope it is seen to be considerably altered. Phenocrysts of altered plagioclase and hornblende altered to chlorite are abundant. A fair amount of granular magnetite is present and the felspathic groundmass contains a little interstitial quartz. The rock is an altered porphyrite.

1745. Acid lava at base of Upper Devonian, ridge south of Ostler's, and south of the Mitchell River.

In hand specimen the rock is compact, fine-grained, pink to grey coloured, showing fluidal banding. Under the microscope the fluxion structure is well developed. Phenocrysts of corroded quartz crystals are set in a microcrystalline to cryptocrystalline groundmass of quartz and felspar in which dark irregular bands are developed streaming past and round the phenocrysts. The rock is a banded and fluidal rhyolite.

1740. A nodular or spherulitic lava at the base of the Upper Devonian, ridge south of Ostler's, and south of the Mitchell River.

In hand specimen large nodular spherulites up to $1\frac{1}{2}$ inches diameter of dense brown material, with lighter margin, are set in a dense fine-grained matrix. Under the microscope the section passes through the margin of one of the nodules, which is brown in colour and almost completely glassy. The nodules are set in a rock which shows a remarkable flow structure of cryptocrystalline to glassy texture, in which occur small phenocrysts of corroded quartz and of felspar. The rock is a spherulitic or nodular rhyolite.

Summary and Conclusions.

The earlier work of Howitt and others in the Tabberabbera district is referred to. The conditions of access to the district have been improved by the making of good roads to the area, but within the area the diminution of settlement due to decay of mining and introduction of rabbits has led to the overgrowing of tracks, the growth of secondary scrub and the blackberry pest; and these combine with the rugged topography to make geological work difficult. Two periods of three weeks each in January and February of 1924 and 1925 were spent in the area, which lies 40 miles NNW. of Bairnsdale in Eastern Victoria. The boundaries of the geological formations are approximately located on the map published with this paper, and the structure elucidated by three sketch geological sections. The area of Upper Ordovician rocks, consisting of black shales, cherts and sandstone, previously known in Sandy's Creek has been extended.

It has been shown that at Tabberabbera itself, formerly regarded as the type area for the Tabberabbera shales of Middle Devonian age, no Middle Devonian rocks occur, but that a broad belt of Silurian rocks, consisting of impure limestones, shales, grits, sandstones and conglomerates, trends NNW. to SSE. across the area, including Tabberabbera. The Middle Devonian rocks, consisting of blue limestones, shales and sandstones, with characteristic fossils such as *Spirifer yassensis*, are restricted to the western part of the area.

The Upper Devonian rocks, red and purple sandstones, shales and conglomerates, with interbedded rhyolites, form an unconformable plaster in the central part of the area, resting in turn on the denuded edges of Middle Devonian, Silurian and Upper Ordovician rocks. The Ordovician, Silurian and Middle Devonian rocks have suffered from very severe compressive earth movements, and are in consequence highly folded, even the Middle Devonian showing dips ranging from 45° to 80° on either side of the fold axes. The boundaries between these formations are determined by unconformities or faults. The Upper Devonian rocks, with a dip of 5° to the SW., have not been compressed into folds, but were elevated and tilted with the older rocks by late Kainozoic differential earth movements. The Mitchell and Wentworth Rivers have cut steep valleys and gorges, and have given an immature topography to the district.

The outstanding structural features in the Tabberabbera district are the local character of the severe compression of the Middle Devonian sediments, contrasted with their open folding at Buchan and Bindi, and the gigantic character of the unconformity separating them from the Upper Devonian rocks. The appreciation of this has led to the discussion of the age of the rocks called Upper Devonian, from which no fossils have been obtained in this district. The comparison with areas of similar rocks at Iguana Creek, the Avon River, Mt. Wellington and Mansfield in Victoria, and Mt. Lambie and other areas in New South Wales, has led to the view that the reference of them to the Upper Devonian can be justified on the available evidence.

A brief account of the petrology of the igneous rocks of the area is appended. Lava flows of spherulitic and of banded rhyolite are interbedded with the Upper Devonian. It is shown that numerous dykes penetrate the Ordovician, Silurian and Middle Devonian rocks, and that a few have been noted by Mr. Easton penetrating the Upper Devonian. The types include mica lamprophyres, hornblende porphyrites, felspar porphyrites, keratophyres, quartz keratophyres, spherulitic quartz porphyrites, dolerites and oligoclase trachytes. In addition four examples of felspathoid-bearing rocks, tinguaites, have been recorded, two as boulders and two as dykes "*in situ.*"

It is shown that the Eastern part of Victoria constitutes an alkali-rich province, since felspathoid-bearing rocks have been previously recorded by the author from Pretty Boy Pinch, the Tolmie Ranges, Mt. St. Bernard and from Omeo, localities lying west, north-west, north and north-east of Tabberabbera.

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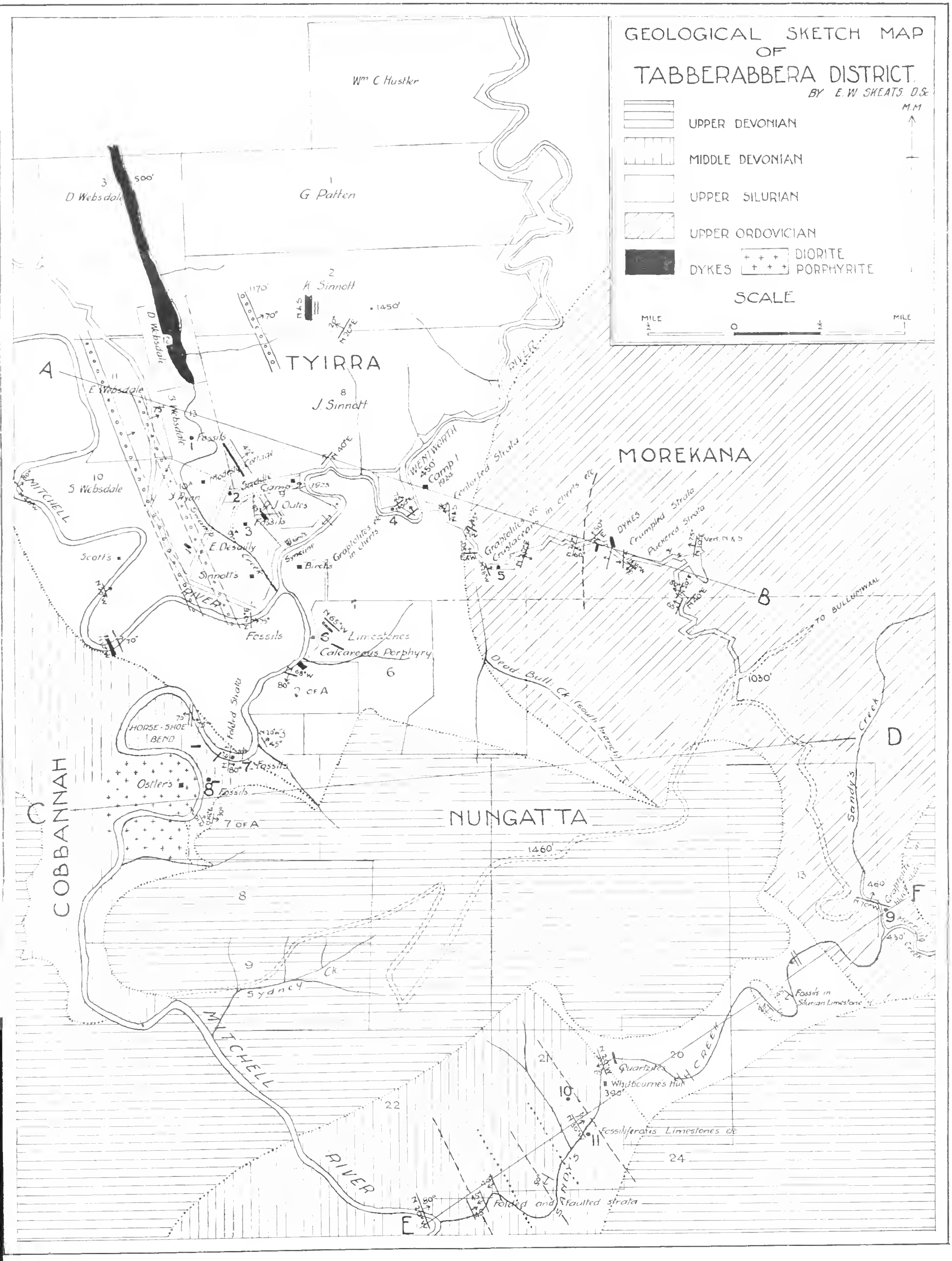
GEOLOGICAL SKETCH MAP OF TABBERABBERA DISTRICT
BY E. W. SKEATS D.Sc.
UPPER DEVONIAN
MIDDLE DEVONIAN
UPPER SILURIAN
UPPER ORDOVICIAN
DYKES
DIORITE PORPHYRITE
SCALE
MILE
MILE
TYIRRA
MOREKANA
NUNGATTA
COBBANNAH
MITCHELL
RIVER
Sandy's Creek
TO BULLUMWAAL
Dead Bull Ck (South branch)
Limestones
Calcareous Porphyry
HORSE-SHOE BEND
Ostler's
Fossils
Graptolites etc in cherts
Contorted Strata
Crumpled Strata
Puckered Strata
Folded Strata
Fossils in Silurian Limestone
Quartzite
Whitbourne's Hut
Fossiliferous Limestones etc
Folded and Faulted strata
Sydney Ck
G Patten
D Websdale
S Websdale
E Websdale
J Sinnott
K Sinnott
E Desailly
J Ryan
Sinnott's
Scott's
Birch's
Wm C Hustler
Camp 1 1924
Camp 2 1925
WENTWORTH
A
B
C
D
E
F

[Proc. Roy. Soc. Victoria, 41 (N.S.), Pt. II., 1929.]

Art. IX.—*The Building Stones of Victoria, Part II. The Igneous Rocks.*

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(With Plate XVI.)

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Introduction.

In the following paper some Victorian igneous rocks used as building stones are described. Of the fourteen rocks included here, twelve have been used for constructional or ornamental purposes as well as in monumental masons' work, and one in monumental work alone, and one, the Tynong granite, has recently been selected for use in the Victorian Shrine of Remembrance.

H. C. Richards (13) in 1909 published a description of eight Victorian sandstones used as building stones. The title of his paper was "The Building Stones of Victoria—Part I.: The Sandstones." Therefore, this paper is styled "The Building Stones of Victoria, Part II.: The Igneous Rocks."

In addition to the building stones described here, there are other igneous rocks occurring in Victoria which have been used in the past for building stones, and of course many others which may be used in the future, but so far as the writer is aware those referred to here include most of those being quarried at the present time for purposes of building.

From Victorian igneous rocks entire buildings have been erected, or they have served as basecourses, as ornamental pillars or columns, and for monumental works, and at the present time thin slabs are frequently cut for use as a veneer on concrete buildings.

Igneous rocks used as building stones are divided into three classes by stonemasons. The first is that of the "granites," which in this connection includes all coarse, even-grained types of igneous rocks, and these are usually capable of taking a polish. The second is the "porphyry" class, including all rocks with large porphyritic felspar crystals. As a rule, these are used in small polished slabs for ornamental purposes. The "bluestones" or basalts form the third class. These are sombre, blue-grey coloured fine-grained rocks, whose chief use as building stones is for basecourses, where their dark colour makes an effective contrast with a lighter coloured main structure.

The following scheme has been adopted in the description of each building stone. In an introductory paragraph the site of the quarry, the amount of stone available there, and the systems of jointing with their corollary, the size of blocks obtainable, are described. In a paragraph headed "Appearance," the colour and structure of the stone are referred to as well as any blemishes it may possess. Under "Working Qualities," the ease of sawing and polishing the stone and the quality of its polish are treated. Following this, all the tests done on each stone are grouped together, and in a final paragraph a tabulation of some of the buildings erected of the stone is given, with a summary of the principal characters which either recommend or forbid its use.

The rocks are described in the order of the classes recognised by technical workers in the trade. Within each class, where there is more than one representative, that stone most in use for building is treated first, and is followed by the rocks in descending order of their use up to the present time.

Of the quarries described here all have been visited by the writer, with the exception of those at Gabo Island and Tallangatta. All crushing strength tests except that of the Gabo Island granite have been carried out in the Melbourne University Engineering School, on test pieces, most of which have been prepared by the writer. The remaining tests have been done by the writer unless the contrary is stated.

The writer desires to acknowledge gratefully the helpful advice and criticism offered to her throughout this work by Professor Skeats, and to thank Associate-Professor Summers also for his continuous assistance.

Messrs. William Train and Co., and the owners and managers of the various quarries visited, have been always most courteous in throwing open their works for inspection, and in giving much practical advice.

Previous Literature.

In 1860 a committee of the Royal Society of Victoria published a report of building materials (1) occurring in Victoria. The report which, so far as is known, is the first record in print of such occurrences, describes rather fully the basalt or "bluestone" of the colony, without, however, specifying localities from which it was then obtained. It records various quarries for granite, indicating that stone for building in Melbourne had been obtained at that period from Gellibrand's Hill, at Broadmeadows, and from Gabo Island.

In 1864 a treatise on "Australian Building Stones," by J. G. Knight (2), was published in London. As the author was the chairman of the Committee of the Royal Society referred to above, this treatise contains in a fuller form practically the same information given in the Committee's Report.

Later reports are confined to lists of localities of quarries in granite, greenstone, basalt, serpentine, etc., until in 1915 R. T. Baker published the "Building and Ornamental Stones of Australia" (17), which includes notes on many of the igneous rocks of Victoria, referring to their use or possible use as building stones. A similar list, though a shorter one, appears in the Commonwealth Year Book for 1909 (18). Until the present time the only other references have been reports in Geological Survey Records on single quarries and a few references in reports on the building stones of other States.

Publications dealing with the use or possibilities of Victorian igneous rocks as building stones as well as other books and papers referred to here are listed in the bibliography at the end of the paper.

The Igneous Building Stones of Victoria.

Granites.

The "granite" of the worker in the stone trade has been defined above as a coarse, even-grained type of igneous rock which can usually be polished. This group of rocks is subdivided according to the predominating colour of each type into red or pink, grey, green and black granites. In a red or pink granite the felspar present is usually orthoclase or an alkali plagioclase which has become reddish brown by iron staining. This felspar being present in comparatively large proportion, imparts its reddish brown colour to the whole rock. These "red or pink granites" conform most nearly to the granite of the petrologist. In a grey granite the felspar present is a white one uncoloured by iron, which occurs with small amounts of black mica, giving a "pepper and salt" or grey colour to the stone. The petrologist's granodiorite is included here. The green granites derive their colour from the minerals hornblende and epidote. The latter of these occurs as an alteration production of plagioclase felspar. Such rocks are diorites. A black "granite" may be composed of orthoclase or plagioclase felspar, augite and biotite, with an iron oxide, when it will fall into either the syenite or diorite petrological class. With the addition of olivine and the subtraction of some of the felspar, the rock becomes a gabbro. The combined effect of these minerals approximates to a black stone. The first two classes include a far greater proportion of rocks than do the last two.

In addition to this subdivision by colour, granites are classified according to their grain size. A convenient method of classification is outlined by T. Nelson Dale (10). By it a granite containing felspars of more than 1 centimetre (2/5 inch) diameter is classed as coarse-grained, one with felspar whose diameters lie between 0·5 cm. (1/5 inch) and 1 cm. (2/5 inch), is medium grained, and all those with felspars below 0·5 cm. are fine-grained. Throughout this paper this scale is referred to when the terms coarse-grained, medium-grained, and fine-grained are used. The lower limit for the coarse-grained division seems rather a high one, but since this is the most distinctly enunciated scale of grain size, and is quoted by J. Allen Howe in the "Geology of Building Stones" (15), it has been adopted here.

In the quarrying of granite the system of joints which occur in the rock are important. In most granite quarries it is found that the rock will split most easily in one definite direction, which is known always as the "rift." In a direction at right angles to the rift a granite will also split with ease, but slightly less well than along the rift. This second direction of splitting is known as the "grain." The terms "rift" and "grain" are used throughout this paper with the same significance. In most quarries the rift and grain are vertical, and the joint system in the third dimension is usually horizontal, so that a sheet-like structure in the granite is suggested. This third joint is never so perfect as either rift or grain, the break being usually concave or convex, and the "sheets" more or less lens-shaped.

Another term of almost universal application in quarries, which needs explanation, is the word "dry." A "dry" is a direction in a rock mass along which a block of the stone tends to fracture, but may not do so until after it has been quarried and exposed for some time. The fracture does not usually take place along a plane, but along a curved direction and penetrates for but a short distance into a block. "Drys" are spaced quite irregularly, and their existence in a block of stone is often not suspected until after cutting and dressing is completed, when if a "dry" shows up the block must be rejected.

Harcourt Granite.

The granite used most widely in Victoria as a building stone outcrops over an area of some 150 square miles in the neighbourhood of Harcourt and Ravenswood, 80 miles north of Melbourne and 20 miles south of Bendigo. It is quarried on the side of Mount Alexander, three miles east of the Harcourt railway station, on the Melbourne to Bendigo line, where quarrying commenced over sixty years ago, and during this period a large quantity of stone has been removed.

The joint system in this rock mass is exceedingly favourable for the extraction of large blocks. The "rift" or easiest direction of splitting the stone runs vertically north and south, and the "grain" is also vertical, and runs east and west. Rift and grain are so spaced that very large blocks can be obtained; in 1921 a block 84 feet long, 28 feet wide and 25 feet deep, which weighed 5000 tons was moved by a single charge of powder.

Appearance.—This granite is a light grey one, containing large crystals of white felspar and glassy quartz, and a smaller quantity of biotite mica. The felspars average 1/5 inch in diameter, so that the granite just falls within the medium-grained division of the Nelson Dale scale. The grain size is very even through the rock except where "black spots" or "heathen" occur. These are patches of dark fine-grained material averaging two square inches in size, although much larger ones occur. They are rich in the mineral biotite, and form basic segregations. They show prominently on sawn and polished blocks and occur at an average distance apart of two feet. Less frequently small acid veins about half an inch wide occur, which contain quartz and felspar alone. These are not very noticeable on account of the prevailing light grey colour of this stone. Its light grey colour is this granite's most noticeable feature, and is especially marked on smooth, unpolished blocks. The polished stone has a darker colour, which becomes somewhat lighter after exposure, apparently on account of the gradual evaporation of quarry damp. The granite placed in 1926 in the additions to the State Savings Bank in Elizabeth Street was distinctly darker at first than that in the first part of the building erected in 1911, but now the junction between the two cannot be distinguished. Specimens from all parts of the quarry are very similar, and it is noticeable that the rock outcropping at Big Hill, ten miles to the north of this quarry, does not differ in grain size nor mineral composition.

Working Qualities.—Rift and grain in this granite are so well developed as to make the ease of working this stone at the quarry a standard of excellence among granite masons. Blocks of all sizes and shapes required are obtainable, and since the supply is practically inexhaustible any type of work can be undertaken in this stone. At the mason's yard this stone takes a good edge or "arris," and it polishes well, although biotite is inclined to flake off from the surface, leaving it uneven.

Resistance to Crushing.—This stone has been tested in the Melbourne University Engineering School three times for its resistance to a crushing stress. Three inch cubes were used for the tests, which were conducted on the dry stone. The cubes crushed at 11,444 lbs. per sq. in. (736 tons per sq. ft.), 11,333 lbs. per sq. in. (728 tons per sq. ft.), and 8510 lbs. per sq. in. (547 tons per sq. ft.) respectively. The stone has a somewhat lower crushing strength than most of the granites described here.

Absorption.—The percentage of water absorbed was determined by immersing a small weighed and dried block of the stone in water. The rectangular shape of the block made the conditions approximate to those experienced by the stone in a building in wet weather. After four days' immersion the block absorbed 0·11% of its weight of water, so that Harcourt granite may be called impervious for all practical purposes.

Chemical Analysis.—A chemical analysis of this rock has been made by Mr. G. Ampt, and the result published in a paper by Dr. H. S. Summers (16). It is included here under Chemical Analyses at the end of the paper.

Specific Gravity and Weight per cubic foot.—The specific gravity of this granite is 2·678, and hence the weight of a cubic foot is 167·5 lbs., which is a normal weight for a granitic rock.

Microscopic Examination.—A thin section of this rock shows idiomorphic crystals of felspars, interstitial quartz, in some cases under strain, and highly pleochroic biotite. There are a few occurrences of the accessory minerals apatite, zircon and magnetite. The relative grain size has been calculated for the three principal constituents by an adaptation of Rosiwal's method for measuring the dimensions of minerals (7). This rock is coarse-grained enough for the measurements to be made in millimetres on the polished surface of the rock itself. The result of twelve traverses gave the ratio Quartz: Felspar: Biotite, as 4:5:2.

Felspar is in the form of plagioclase and orthoclase in the proportion of 3:2. The plagioclase was determined as Ab_1An_1, or $Na_2O\,CaO\,2Al_2O_3.8SiO_2$ by measurement of its angle of extinction. Orthoclase has altered to kaolin, which has become iron-stained, and some of the plagioclase has changed to epidote. This rock belongs to the adamellite class, since more than one-third and less than two-thirds of the felspar is orthoclase. In the American Classification the rock falls into Class 1, Persalane; Order 4, Brittanare; Rang 2, Toscanase; Subrang 3, Toscanose.

A portion of a basic segregation was examined under the microscope. It is distinctly fine-grained. Plagioclase is more abundant than orthoclase and the former shows marked alteration to epidote. The section is crowded with small, stumpy biotite crystals in greater abundance than in the normal rock. Quartz is also present. This section was difficult to obtain since the basic segregations are crumbly.

Uses.—This granite is widely used in Melbourne. Some of the better known buildings in which it appears are the Colonial Mutual Life Assurance, formerly the Equitable Life Assurance, where the upper storeys have been constructed of smooth, unpolished blocks, the Commercial Travellers' Club, the State Savings Bank, the Herald Newspaper Office, the Union Bank, the Flinders Street Railway Station, and many others. The stone is seen throughout the city in polished ornamental panels, pillars, steps and basecourses.

Its very light grey colour must be regarded as a defect in this stone, because it becomes dirty rapidly in a city atmosphere. The gateway of the Fish Market in Flinders Street, and Rocke, Tompsitt's warehouse in the same street are examples of dirty Harcourt stone.

The dark basic segregations or "heathen" are a disfigurement. These may be seen in the wall of the head office of the State Savings Bank.

No other granite, either Victorian or imported, has been used to the same extent as this stone for building, ornamental and monumental purposes in Melbourne.

Wangaratta Granite.

Granite from this district has been used locally and in Melbourne. It is quarried in the Warby Ranges, about seven miles SW. of Wangaratta. The Warby Ranges consist of a granite inlier rising abruptly from a plain composed of Recent material.

The quarry for building stone has been made in an area where segregation of pyrites has occurred in the granite, giving it an appearance distinctly different from that of the pyrites-free granite found at no great distance. The quarry is on a hillside, and after the blocks are dislodged and shaped into roughly rectangular blocks they are rolled downhill and levered on to lorries. The working face slopes nearly parallel with the slope of the hillside. This quarry face is very uneven, since there is trace neither of rift nor of grain in the granite, but "drys," whose nature is defined above, are found irregularly through the stone. On account of the "drys," the size of the blocks obtainable is very uncertain, and a great deal of material has to be rejected. Blocks up to six feet in length have been got out, but there is no guarantee that blocks of this size can be secured frequently. The size more usually obtained is 2 ft. 6 in. long by 1 ft. square. This lack of regular jointing somewhat restricts the use of this granite as a building stone.

Appearance.—The granite is pink and even-grained, but its appearance varies with the amount of pyrites present, and the proportion of this mineral which has been oxidised. Three distinct types can be recognised, and are described here as A, B and C.

Type A is a pale pink, fine-grained granitic rock, containing abundant creamy felspar, averaging 1/20 inch in diameter, grains of quartz, and scattered pyrite cubes. Some of these have been lost, leaving small cavities in the rock.

Type B is a very soft friable cream-coloured rock. It contains felspar, kaolin, quartz, but no pyrites, and is very porous.

Type C is a dark, fine-grained stone, of a colour ranging from pale pink to purple. Felspar is very abundant, and there is a good deal of quartz. Pyrites is absent, though occasionally cubic cavities, which contained originally pyrites crystals, are to be seen.

Limonite resulting from the oxidation of the sulphide mineral has penetrated the felspar, colouring it dark pink and purple, and probably causing the greater hardness of this type. Type C has a warm and attractive appearance on either smooth or rock-faced surfaces due to the alternating red and cream patches, according to the varying richness of the stone in ferric oxide.

Working Qualities.—The buildings in which this stone has been used have been constructed of comparatively small blocks, averaging 2 feet 6 inches by 1 foot square. Types A, B and C have been used for slightly different purposes in building construction. Type A, rich in unaltered pyrites, is used with a rock-faced finish in the construction of walls. Men who have worked on both say that this stone may be worked with about the same ease as Melbourne basalt. When it is being chiselled a strong smell of sulphur dioxide is noticed. It will not work up to a particularly sharp arris. Type B being a soft stone is very easy to work, and is used with the axed finish required in window surrounds. Type C, the hardest stone, is selected for rock-faced work, and is used chiefly in walls and foundations.

The rock rich in pyrites (type A) was found to take a good polish; square cross-sections of pyrites, prismatic crystals of cream felspar and quartz grains showing up well against a pale pink groundmass. The only undesirable feature is the presence of some small pits on the surface. Type C, which is coloured purple-red, is much too porous to look well when polished, though the solid parts take a high polish. Holes 1/8th in. in diameter and 1/16th in. deep are commonly seen.

Resistance to Crushing.—Specimens of types A, B and C were tested for their resistance to crushing. Type A, which is the stone containing unaltered pyrites crystals, is much the strongest of the three, since it broke only under a load of 19,600 lbs. per sq. in. (1261 tons per sq. ft.). Type B, the soft stone, fractured under a load of 7,110 lbs. per sq. in. (457 tons per sq. ft.), which is a low value for the crushing strength of any igneous rock. Type C proved rather stronger, breaking beneath a load of 9,670 lbs. per sq. in. (622 tons per sq. ft.). The comparative weakness under a crushing load of the two latter stones compared with normal igneous rocks can be attributed to the changes suffered by the stone in the oxidation of its pyrites. The figures indicate, however, that even these two stones are quite strong enough for use for ordinary purposes in a building.

Absorption Percentage.—Rectangular blocks of all the stones were tested for their absorption percentages. They were immersed in distilled water until they ceased to gain in weight, when they were judged to be completely saturated. This took a different period for each stone. All their absorption percentages are above the average of normal granitic types, due to the cavities left, when pyrites cubes are lost, and the general alteration suffered by the stones.

Type A	immersed for	9 days	gained	1·45%	of its weight.
,, B	,, ,,	13 ,,	,,	3·75%	,, ,,
,, C	,, ,,	14 ,,	,,	4·08%	,, ,,

Specific Gravity and Weight per Cubic Foot.—Type A has a specific gravity of 2·512, and weighs 157 lbs. per cubic foot. Type B weighs 145 lbs. per cubic foot and its specific gravity is 2·324. The specific gravity of type C is 2·446, and its weight per cubic foot is 152·5 lbs.

These figures are all low, which is probably due to the fact that the stones are rather porous. The resulting low weight per cubic foot is a factor in favour of the use of this stone.

Microscopic Examination.—In a thin section of type A, felspar makes up two-thirds of the rock, quartz bulks largely, and there are some cubic crystals of pyrites. The felspar is allotriomorphic, much of it being clouded by formation of kaolin, which is stained by ferric oxide. Epidote and sericite have formed also, and some of the unaltered felspar shows lamellar twinning. Kaolin is formed typically from alkalic felspar, while sericite and epidote come from calcic plagioclase, and since a greater proportion of the felspar present has altered to ironstained kaolin than to epidote and sericite, this rock may be termed an altered granite.

Type B is very similar to type A, except that fresh, unaltered pyrites cubes are absent from B. Clouded felspar is the most abundant mineral. Kaolinization and limonitic staining are marked, and the development of sericite from plagioclase is more noticeable than in type A.

A thin section of type C is distinguished from types A and B by the greater abundance of hematite present. After its formation by oxidation from pyrites, the hematite penetrated along cleavage cracks of the kaolinized felspar, making a rectangular network within the mineral (Pl. XVI., Fig. 1), which has strengthened and hardened the stone. Little quartz is present, and no unaltered pyrites.

Uses.—The stone has been used in two churches in Wangaratta. The first part of the Anglican Cathedral was built about 1908 of stone from this quarry, and in 1922 the quarry was reopened to obtain stone for additions to this building. Blocks of the hard red material (type C) are used with a rock-faced finish in the main structure, while the softer type B is used for the window surrounds. Rock was extracted from this quarry 60 years ago, when blocks for the Catholic Church in Wangaratta were obtained. In Melbourne sawn blocks of Wangaratta granite have been used in Collins House, Collins Street. The stone used appears most like type C. For the keystone of the arch over the entrance a block of Sydney sandstone was introduced.

The blocks are light reddish in colour, and show patches of a darker colour due to the oxidation and leaching of iron of the pyrites crystals originally contained in the rock. Such differential staining is more usually associated with sedimentary rocks, and the rock in this building is often mistaken for such.

The warm reddish colour of this stone is very attractive, and should make it a popular one for city use, since it discolours less readily after exposure to a city atmosphere than do stones of paler tints.

Cape Woolamai Granite.

The granite outcrop of Cape Woolamai forms the south-eastern point of Phillip Island in Westernport Bay, and has provided stone for building in Melbourne. Cape Woolamai is two miles across Newhaven Strait from San Remo, a township on the mainland 80 miles by road and rail south-west of Melbourne. By another route the granite may be taken about 15 miles by water to Stony Point, which is 46 miles from the city by rail. The distance from Cape Woolamai to Melbourne directly by water is approximately 65 miles. The depth of water at the stone landing stage at the Cape is 2 fathoms. Three hundred yards out it has increased to 12 fathoms.

The Cape is formed of a granite cliff, rising out of the sea to a height of about 300 feet. At its widest, the Cape is one mile across, and the granite is nowhere covered by more than a few inches of unconsolidated sands. From the headland a jetty of granite blocks was built out into Westernport, from which boats removed the stone. At present the main quarry, which is connected to this jetty by a tramline somewhat out of repair, is under water at high tide. The perpendicular sides of this disused quarry show that large well-shaped blocks were obtained by fracture along regular joint planes, one of which strikes north and south with the face of the joint plane dipping 60° to the east, while the second strikes east and west and dips 30° south. Blocks up to 6 ft. in length by 2 ft. square are still lying at the stone landing stage, while pillars 12 ft. high by 2 ft. square, and blocks 7 ft. long by 3 ft. 6 in. wide by 2 ft. 6 in. high, were used in the base-courses and portico of the Equitable Building, now the Colonial Mutual Life Assurance Building.

The granite mass contains cream-coloured acid veins and vughs of large pink felspar crystals, which mar the evenness of grain of the rock. Segregations of basic material do not commonly occur in this stone, which is remarkably free from any dark mineral.

Appearance.—This granite has a pleasant colour varying between a light and a dark pink, according to the amount of alteration suffered by the felspar present. The felspar crystals average three-tenths of an inch in diameter, so that the grain size of the rock is medium. It is composed mainly of pink felspar and quartz. In addition a little green-stained felspar and a subordinate amount of black mica are present.

The granite when polished has a darker colour, and makes a handsome ornamental stone. Narrow veins about 2 inches wide, containing large quartz and felspar crystals from 1 inch to 2 inches in length, cut across blocks of the normal coarse-grained granite. More rarely portions of the stone are marred by dark streaks caused by the segregation of ferromagnesian minerals in narrow veins. Some of these can be seen in the base-course of the Equitable Building. One vein measures 18 inches long and 2 inches wide. These veins are not so dark-coloured as the "black spots" in Harcourt granite, because the black minerals are not so closely packed, and therefore are less of a disfigurement to the stone.

Working Qualities.—Little is known of other working qualities than the polish of this stone, because it is over 30 years since it was worked. On a test piece in the laboratory a surface was smoothed and an extremely fine polish was obtained with relatively little work.

Resistance to Crushing.—This granite has a remarkably high crushing strength for a rock of this grain size. A block measuring approximately $1\frac{1}{2}$ sq. in. by 2 in. broke under a load of 27,100 lbs. per sq. in. (1743 tons per sq. ft.).

Absorption Percentage.—A smooth block of this granite was immersed in distilled water for 12 days, during which time it absorbed only 0·18% of its weight of water.

Chemical Analysis.—The result of a chemical analysis of this rock, which has been carried out by Mr. A. G. Hall for Dr. H. S. Summers (16), appears at the end of this paper. This granite is the richest in silica of the eight granites and granodiorites, whose analyses are published in the paper cited.

Specific Gravity and Weight per Cubic Foot.—The weight per cubic foot of this stone is 165 lbs., calculated from the specific gravity of 2·643, given with the chemical analysis (16).

Microscopic Examination.—The minerals present are felspar, quartz, biotite, apatite and zircon. Felspar is in the form of microperthite altered to kaolin, and of plagioclase near oligoclase. Some microperthite crystals show a thin film of iron oxide, which is the cause of the reddish tint seen in most of the felspar in hand-specimens. The tinge of green seen in others is due to small crystals of epidote, formed from plagioclase. Large grains of quartz are abundant, while flakes of biotite in a dark-coloured, corroded form are rare. Some of these are altered to chlorite. Apatite and zircon are included in mica. The proportion of orthoclase to plagioclase is greater than 2 to 1; therefore this rock is a true granite.

Uses.—Large polished blocks (7 ft. long by 3 ft. 6 in. wide by 2 ft. 6 in. high) form the base-course of the Colonial Mutual Life Building, and pillars 12 ft. high flank the entrance. This was built for the Equitable Life Assurance Company in 1893, and the Cape Woolamai quarry was opened to supply stone for this building. So far as is known, it is used nowhere else in the city. Vertical cracks have developed across the face of some blocks. It is likely that these have arisen from "drys" in the granite, while the appearance of some blocks is marred by quartz veins. It is reported that specks of gold can be seen on some of the polished blocks.

The size of blocks obtainable, the excellent polish and colour of this granite are in its favour, and though the quarry is rather inaccessible, its position at the water's edge makes possible direct water transport to the city by boats of shallow draught.

Gabo Island Granite.

This small island is composed of granite, which has been quarried and used for building. It is close to the coast near the boundary between Victoria and New South Wales, and lies near the sea route between Sydney and Melbourne, 242 miles from the former and 333 from the latter. It is thus accessible by boat from either capital. Admiralty charts record the depth at the jetty as 5 fathoms. Blocks measuring 2 feet high by 3 feet square are in use.

Appearance.—The presence of abundant red felspar gives an attractive pink colour to this rock. It is composed of comparatively small crystals, all uniform in size. Since the felspars have an average length of one-tenth of an inch, the rock falls into the fine-grained group of building stones. In a polished block the colour is dark pink, though rectangular pale green felspars frequently occur. The dark red colour of rock-faced blocks of this stone can be seen in the Elizabeth Street Post Office, Melbourne. A vein, half an inch wide, of very fine grained quartz and pink felspar crosses one of the hand-specimens examined.

Working Qualities.—Blocks of this stone have been left exposed for 60 years in a stonemason's yard in Melbourne. They have retained a good "arris" and polish until the present time.

The granite polishes fairly well, although small pits are left on the surface where hornblende has been torn out while the stone was being ground smooth.

Resistance to Crushing.—The result of crushing strength tests on this granite is published by Baker and Nangle (12). Three 3-inch cubes were tested and their strengths in lbs. per sq. in. were 15,200, 14,900, and 17,500 respectively (979, 950, and 1128 tons per sq. ft.).

Absorption Percentage.—A small block of the stone dressed to a rectangular shape was immersed in distilled water for eight days, when it was found to have increased in weight by 0·39%.

Chemical Analysis.—The chemical analysis is recorded at the end of the paper.

Specific Gravity and Weight per Cubic Foot.—The weight per cubic foot of this granite is slightly under 165 lbs., calculated from the specific gravity (16), which is 2·635.

Fire Test.—Baker and Nangle (12) have carried out tests to discover the effect of heating and sudden cooling by streams of water on Gabo Island granite. These tests imitate the effect of fire and fire-fighting apparatus on a granite building. A cube was heated gradually to 783°C., and removed after 35 minutes, when it was found to be badly cracked. A second cube was heated gradually to 544°C. and plunged suddenly into cold water. This cube was almost unaffected.

Microscopic Examination.—This granite contains altered felspar, abundant quartz and altered hornblende. Most of the felspar is in the form of a microperthitic intergrowth beneath a film of iron-stained kaolin, while some of it shows lamellar twinning and a cloud of alteration products (epidote, sericite, etc.), in which are caught up many small flakes of chlorite, which is the cause of the green felspar noticed in the hand specimen. Ilmenite and apatite also occur. The rock is best described as a normal granite.

Uses.—Polished columns of this granite are used in the building of the Australian Travel Service, 493 Collins Street, rock-faced blocks of the stone support Tasmanian sandstone columns in the Elizabeth Street Post Office, and smooth-dressed blocks form the base-course of the Customs House, Flinders Street.

The colour of this stone readily recommends its use, and its strength is great enough to fulfil any requirement. Unfortunately, the long distance of Gabo Island from a city will operate against the frequent use of the granite from there.

Orbost Granite.

About two miles east of Orbost, on the road to Mallacoota Inlet, and 233 miles east of Melbourne, Young's Creek has exposed a large face of granite which was quarried for use in the Commonwealth Bank in Melbourne in 1923. No soil overburden covers the granite, and there is an exposure about 40 feet high by 60 feet in width. The face of stone in the quarry is remarkably irregular, and shows more or less conchoidal breaks, which prove that there is no continuity in the jointing system in the stone. The most marked joint runs on a sloping plane at right angles to the face of the quarry, but is not continuous for any distance.

Appearance.—This is a greenish-grey granite, considerably darker in colour than the Harcourt stone. Its green tint comes from stained felspar, and is an attractive colour, especially when seen on a polished block. The felspars average one-tenth of an inch in diameter, and the granite is therefore fine-grained.

The granite mass is traversed by many veins of quartz up to an inch in width, with some of which epidote and carbonate minerals are associated. Large, dark-coloured segregations of basic minerals, and narrow veins of dark-coloured minerals, also mar the appearance of the stone, and in addition blocks up to 12 inches square of fine-grained sedimentary material occur as inclusions. Some of these are surrounded by a rim of partially absorbed material. Even small hand specimens cannot be obtained free from disfiguring "black spots." One block of stone outcropping near the quarry is traversed by three narrow dark veins, one of which on examination under the microscope was found to consist of a string of chlorite crystals altered from hornblende and biotite. The minerals from which the string of chlorite has been derived have resisted weathering to a greater degree than has the remainder of the roek, with the result that the narrow dark veins are the centres of three ridges standing about one inch above the general surface of the rock.

Working Qualities.—This stone was eut into two 2-ineh cubieal blocks for testing purposes, and it was noticeably easier to saw than most other granitic types, presumably on account of decomposition suffered by the minerals present. The stone polishes rather well, though the polished surfaee is somewhat pitted. These pits are due to the loss of biotite during the grinding of the rock.

Resistanee to Crushing.—Two reetangular blocks each approximately a two inch cube of this granite were tested. One crushed beneath a load of 15,300 lbs. per sq. in. (984 tons per sq. ft.), while the other did not crush under the heaviest load of which the machine is capable, 100,000 lbs., or 25,400 lbs. per sq. in. (1633 tons per sq. ft.). It was noticed that although the specimen had not actually broken, it was just on the point of breaking. It should be pointed out that although the crushing strengths of these two cubes vary rather widely, they were prepared in a similar manner by the writer from a single block of the stone, and were crushed in the same machine by the same operator on the same day.

Absorption Percentage.—A smoothed block of Orbost granite absorbed 0·15% of its weight of distilled water after immersion for eight days.

Specific Gravity and Weight per Cubic Foot.—The specifie gravity of this stone is 2·803, hence the weight per cubic foot is 175 lbs.

Microscopic Examination.—A thin section shows quartz in allotriomorphic and interstitial grains and felspar in relatively small idiomorphic crystals, which are altered considerably, though in a few crystals the lamellar twinning of the plagioclases can be detected. The plagioclase has been saussuritized, causing the formation of grains of zoisite, a little epidote and small, brightly polarizing fibres of mica, probably the soda mica, paragonite, since it has developed from plagioclase. Biotite is present, showing very extensive alteration to chlorite, which imparts a green tint to the rock, and a small proportion of hornblende also. Magnetite, apatite and zircon are accessories. The rock may be termed a granodiorite.

A thin section was cut of one of the foreign included blocks. This consists essentially of small angular interlocking quartz-grains set in a felspathic matrix. Flakes of chloritized biotite and cubes of pyrite occur sparingly. The inclusion is an indurated sandstone or quartzite. The junction between the inclusion and the normal granodiorite is marked by a band of quartz which has recrystallized and forms a polysynthetic mosaic.

Uses.—The sole use of this granite in Melbourne has been for the base-course of the Commonwealth Bank in Collins Street.

The stone is polished here, but the polish is not good. Most of the blocks are marred by black spots or inclusions of foreign rocks.

This rock is found at such a great distance from Melbourne, and is so variable in appearance, that it will probably never be widely used. The heart of the stone would almost certainly be more uniform in appearance. The colour is distinctly attractive, and in comparison with other granites this one is more easily worked.

Trawool Granite.

Granite from this locality was quarried for building about 30 years ago. The Monthly Progress Report of the Geological Survey for 1899 (8) records the value of the granite obtained here in 1897 to be £2,100. The quarry site is 60 miles north of Melbourne, and within two miles south-west of the railway siding at Granite, on the Mansfield line. Quarrying was commenced on an outcrop beside the Trawool Creek, the water from which has now filled the quarry hole to within three or four feet of the top of its walls. The vertical walls of the quarry striking approximately north and south and east and west show that the joint system in the stone is good, which is further proved by a polished block measuring 4 ft. by 3 ft. 6 in. by 1 ft., lying near the quarry. This block was rejected because large felspar crystals 2 in. long by ½ in. wide have broken out of it, and cracks have developed in the stone.

The quarry was opened to supply stone for the Equitable Building, but early in the work it was abandoned on account of flaws such as those found in the rejected block described above. Machinery for all processes of dressing and polishing the stone was brought to the quarry. Gabo Island stone was also taken there to be dressed and polished.

Appearance.—It is a grey granite, containing white well-shaped felspar crystals in a finer-grained groundmass. The average grain-size of the felspar measured in a hand specimen is slightly over one-tenth of an inch, so that this granite is a fine-grained one. However, scattered through the rock are occasional large felspar crystals, over an inch in length, making the rock almost a porphyritic granite. These prominent felspar crystals make the stone more suitable for small pieces of ornamental work than for the construction of walls. The colour of the groundmass is darker than Harcourt stone, and consequently it does not change colour markedly after some years' exposure in city air.

Working Qualities.—On a polished surface of this stone numerous pittings occur which are due to the softness of the abundant biotite, which is torn out when the surface is being ground smooth. The stone therefore cannot be said to take a good polish. The tendency of large plagioclase phenocrysts to drop out during the working of the stone has already been noted.

Resistance to Crushing.—This has not been determined.

Absorption Percentage.—After immersion for twelve days a rectangular block of Trawool granite absorbed 0·28% of its weight of water.

Chemical Analysis and Specific Gravity.—The chemical analysis of the Trawool granite has been published (16), and the specific gravity determined as 2·666.

Weight per Cubic Foot.—The weight per cubic foot of this rock is 167 lbs.

Microscopic Examination.—Plagioclase near labradorite, quartz, perthite and biotite are found in the rock. Some of the biotite is chloritized and apatite and zircon are abundant accessory minerals. The rock is named adamellite by Dr. Summers (16). "Xenoliths" such as inclusions of micaceous hornfels and cordierite hornfels found in the Trawool stone show that the quarry is in an area close to the contact between sedimentary rock and adamellite (Tattam, 22).

Uses.—Polished blocks of this stone have been used in the base-courses of Sargood's and Griffiths' warehouses in Flinders Street, Melbourne, in pillars at 459 Little Collins Street, and in ornamental bands, and the steps of the Australian Mutual Provident Building, Collins Street.

Dromana Granite.

Granite outcrops in the hills behind Dromana township, 40 miles south of Melbourne, where a quarry has been made, which is distant about two and a half miles east of the Dromana jetty. The outcrop at this point is very extensive. Joints in the quarry, approximately east and west and north and south, are evenly spaced and are sufficiently far apart for the extraction of blocks 7 ft. long by 3 ft. square. In 1920 a private road was being made to the quarry, and in 1924 a report appeared in the press that a tramway was being constructed which would junction with the Melbourne road, not far from Red Hill station.

Appearance.—This is a green granite whose colour is derived from abundant felspar crystals altered to a bright apple-green. These felspars are rectangular, and stand out almost as phenocrysts from a finer-grained groundmass in which the felspar is creamy-yellow. Zoning in some of the green felspars can be detected by the unaided eye.

The average size of all the felspars is slightly less than one-twentieth of an inch, so that the Dromana stone ranks as a fine-grained building stone. Veins half an inch wide of honey-coloured quartz crystals cross some polished blocks of the stone. No basic segregations mar any specimens which have been examined, nor were they seen in the stone at the quarry on a visit in 1920.

Working Qualities.—The working qualities have been tested in Train's yard, South Melbourne, where large-sized slabs have been worked up. The granite is reported as comparing favourably with Harcourt granite for ease of working. It spalls off well, and works to a fine edge and polishes well and easily. It repays the work put into it better than does the Harcourt stone, since no unsightly dark patches appear upon the polished surface. The green tint is seen to better advantage on the polished stone.

Resistance to Crushing.—Two tests have been carried out on specimens of this stone obtained in 1918, when quarrying commenced first. Dry cubes measuring approximately two cubic inches were tested. The cubes crushed under loads of 17,870 and 16,300 lbs. per sq. in. respectively (1149 and 1048 tons per sq. ft.). The stone broke with the columnar fracture usual among granitic rocks. The values are high, and since the two tests gave results of approximately the same magnitude, it is safe to forecast for the stone obtained from Dromana strength sufficient for any purpose whatsoever.

Absorption Percentage.—The absorption percentage was determined on a small smooth rectangular block of the granite. After three days' immersion the block was found to have increased in weight by only 0·18%. Hence, like the Harcourt stone, it is nearly impervious to water.

Specific Gravity and Weight per Cubic Foot.—The specific gravity of this stone is 2·605; therefore, the weight per cubic foot is 163 lbs.

Microscopic Examination.—This examination shows a holocrystalline, even-grained rock which has undergone a good deal of alteration. The minerals present include felspar, quartz, hornblende, biotite and in very small quantity apatite, zircon, magnetite, pyrites and copper pyrites. Specks of gold are sometimes noticed on polished surfaces. The alteration of some of these minerals has given rise to others. Chlorite has resulted from changes in biotite and hornblende; kaolin and sericite from felspar, limonite from the iron-containing minerals. Orthoclase showing perthitic intergrowth with another alkali type, and a plagioclase, near labradorite, are both present. Minute flakes of chlorite occur throughout the felspar, which are no doubt responsible for its green colour. The proportion of orthoclase to plagioclase felspar being less than 1 : 2, this rock is classified as a granodiorite.

Uses.—This stone has been used in the steps of the entrance to and the facings for the block of shops in the Argus building, Elizabeth Street, and a Soldiers' Memorial in Daylesford contains a polished block of it.

It can be obtained in great quantity, the quarry is reasonably near Melbourne, the stone works up well, and has a handsome appearance from its bright green colour, which should give it special architectural value.

It is a stone that could be used on bigger pieces of work than has been the case in the past.

Colquhoun Granite.

Near the railway siding of Colquhoun, 28 miles east of Bairnsdale in Gippsland, and 195 miles east of Melbourne, a red granite has been quarried and worked up in Melbourne for monumental work. The quarry is one mile west of the Colquhoun railway siding and 200 yards south of the railway line. The country in this district is thickly timbered, and the side of a small gully has been chosen for the site of the quarry. There is no overburden on the patch of granite where quarrying was commenced, and though the rock mass appears lens-shaped and dips away from the surface to the north, the covering for some distance is thin, and is composed of unconsolidated sands whose removal should not represent a costly item in the quarrying operations.

A description of this quarry has been published by A. H. Sharpe (20).

The stone has been quarried over an area approximately 40 ft. long by 20 ft. wide and to a depth of 15 ft. Jointing is good in this stone. There are two systems of vertical joints which persist throughout the quarry. The "rift" trends north-north-east and the "grain" makes an angle of approximately 100° with the "rift." The joints are sufficiently far apart for the extraction of blocks of 4 ft. 6 in. long by 2 ft. square. The granite exposed at the surface is somewhat iron-stained, but on a quarried surface is free from quartz veins and basic segregations.

Appearance.—This granite has a warm pink colour, and when polished is almost a brick-red. Its grain-size is fine, since its felspar crystals average slightly less than one-tenth of an inch in diameter. It contains beside felspar and quartz only a small amount of biotite mica. Blocks lying at the quarry have a margin of 6-9 inches wide of greyish-green granite, surrounding the normal red rock. Outside this rim again, is a brown, iron-stained band a quarter of an inch thick. A faint brown stain discolours the surface of some polished red blocks. It is only visible when the stone is polished. This rust mark is attributed to the passage of iron-bearing solutions carried upwards through the rock by evaporation. As described under the paragraph "Microscopic Examination," the origin of the rim of grey-green granite surrounding the red stone is ascribed to the same cause. All the stone worked up to the present has been taken from the surface or but slightly below it, and within a zone likely to be affected by evaporation. Neither the stain nor the greyish-green rim occurring along joints is likely to be found in blocks taken from greater depths.

Working Qualities.—This granite is reported to be difficult to work, but the stone takes and keeps a good arris. It takes an excellent and uniform polish, since it is composed almost entirely of quartz and felspar, which are of nearly equal hardness.

Resistance to Crushing.—The crushing strength of this granite, which was determined by a test on a two-inch cube, is 14,750 lbs. per sq. in. (946 tons per sq. ft).

Absorption Percentage.—This granite absorbed 0·32% of its weight of water after immersion for eight days.

Specific Gravity and Weight per Cubic Foot.—The specific gravity is 2·616 and the weight of a cubic foot of this granite is 163 lbs.

Microscopic Examination. — In thin section the following minerals are found, angular grains of quartz, orthoclase felspar showing perthitic intergrowth with an alkali plagioclase, subordinate plagioclase of composition between oligoclase and andesine, and grass-green and greenish-yellow biotite which occurs very sparingly. Much of the felspar is clouded by alteration to kaolin and epidote. The former is coloured brown by a thin film of iron oxide. The large proportion of orthoclase to plagioclase present in this rock places it among the true granites.

An examination of a thin section of the greenish-grey granite found as a rim 6-9 inches thick around the margin of some of the exposed blocks of the normal red stone shows perthitic felspar, plagioclase of composition near oligoclase, quartz, and a few flakes of chloritized biotite, some of which are green, while one or two whose ferrous iron has been oxidized show a brown staining. In the amount of iron-staining in the perthitic felspar lies the difference between this grey rock and the red granite which it surrounds. In the former, iron-staining is not so marked, and it is suggested that iron has been leached out from the originally stained felspar of the now grey rock, and carried to the surface of the block, or to a joint plane channel. A narrow, very much iron-stained rim, a quarter of an inch wide, was noted around the extreme edge of the block, while the grey rock, which may be regarded as a bleached type, lies immediately inside the narrow rim to a depth of about 9 inches, and inside it again is found the normal red rock unaffected by iron-bearing solutions rising to the surface by evaporation. The original red staining of the felspar is regarded as the work of magmatic vapours. Plagioclase has undergone alteration to epidote in both types and in both is subordinate to orthoclase in amount.

Uses.—A few monumental headstones have been worked up out of the red Colquhoun stone, but otherwise it has not been used. The rock has an attractive colour, a uniform texture, takes a good polish, and is easily accessible to a railway line. The difficulty of working it up and the distance of the quarry from Melbourne, while adding to the expense, should not prevent its use in the future.

Tynong Granite.

The Victorian Shrine of Remembrance is to be constructed of granite obtained from Tynong, Gippsland. Tynong is 43 miles south-east of Melbourne, to which it is connected by rail. Several large domes of granite form the crest of a small hill one mile north of the railway station, and the quarry is situated on the north side of one of these. There is a downward grade from quarry to railway station, which facilitates transport. This dome of granite rises about 25 feet above the ground, and outcrops over an area of about 30 feet in diameter, with no overburden whatever, and with but a quarter-inch rim of weathered iron-stained material covering the fresh granite. As is usual with granite exposed to the sun's heat, thin sheets tend to exfoliate from this outcrop and split off parallel to the domed outcropping surface. The uppermost one is about 6 inches thick. Very little quarrying has yet been done, but work is proceeding to expose the stone over a larger area in order to obtain material for the Shrine. In the weathered dome two major joints trending north-west and south-east are evident about 12-15 feet apart. These are south of the present small quarry, work in which aims at reaching them. In the preliminary workings now going on the stone is reported to split best along the "board," that is to say, horizontally. When splitting the stone vertically, north and south and east and west directions are at present selected. Lines of holes are drilled in these directions by means of a jack hammer driven by compressed air. Plugs and feathers are then inserted in the holes, and on hammering them a clean break occurs. The object of this preliminary work is to cut back to the major joint or "dry" referred to above, and down to a "board" or horizontal joint. The size of blocks to be obtained is said to be limited only by the capacity of the crane, which can lift 10 tons. The blocks so far removed average 2 ft. 6 in. square by 3 to 5 ft. in length. In the faces of stone exposed by workings in the quarry, perhaps 250 square feet, only two small "black spots" each about 1 inch in diameter were observed. One light-coloured vein about 1 inch in width, composed of coarse felspar crystals, was seen passing through the stone to the surface. Around this vein occurs a good deal of a pyritic mineral. This mineral is fortunately only observed in any amount coating joint planes, and does not extend into the body of the stone, and in a thin section very little pyritic mineral was found, so that if careful selection of pyrites-free blocks is made, little trouble from discoloration by oxidation should be experienced.

Appearance.—The rock is a very light grey granite composed of large white felspar crystals, glassy quartz and a little black mica. A small quantity of an iron sulphide mineral can be seen. The axed surface of the stone is nearly white. As described in the previous paragraph "black spots" are of very infrequent occurrence. Indeed, dark minerals are only rarely found in the main body of the rock, though patches about 12 inches in diameter occur where dark minerals are more plentiful, but are not so concentrated as to constitute a "black spot."

Working Qualities.—This granite is reported to correspond to that from Harcourt in its working qualities. The hardness of the two is nearly equal. The Tynong stone will work up to a smooth axed surface, and into rounded capitals and pediments, and will take a sharp "arris." It polishes well and easily, and looks distinctly grey when polished. The small infrequent biotite flakes being so much softer than the quartz and felspar grind away more quickly than these, leaving small pits in the polished surface.

Resistance to Crushing.—A rectangular block of this granite of approximately two cubic inches volume in a compression test crushed under a load of 25,700 lbs. per sq. in. (1652 tons per sq. ft.).

This high value is comparable only with the crushing strengths of the granites from Cape Woolamai and Orbost and the dacite from Aura of the stones described here.

Absorption Percentage.—A block of this granite with smoothly ground surfaces absorbed 0·28% of its weight of water after eleven days' immersion.

Specific Gravity and Weight per Cubic Foot.—The specific gravity was determined as 2·633, and the weight per cubic foot calculated to be 165 lbs.

Microscopic Examination.—In thin section the following minerals are seen—allotriomorphic quartz in large and small grains, of which some are interstitial, while some small grains are contained within felspar crystals and collections of other small grains are suggestive of chalcedonic quartz. The greater proportion of felspar consists of large phenocrysts of albite perthitically intergrown with orthoclase, and the remainder is plagioclase of composition between $Ab_{60}An_{40}$ and $Ab_{40}An_{60}$, which occurs in zoned phenocrysts as well as in smaller interstitial crystals. The alkali felspar is somewhat kaolinized, while the core of some of the plagioclases has altered to a sericitic aggregate. In addition to these constituents there is only a small proportion of dark-coloured minerals of which the principal ferromagnesian is brown biotite, in places altered to a green chloritic product. Zircon, apatite, fluorite, pyrite and pyrrhotite are accessory minerals. The two latter occur very sparingly, and their oxidation should do no harm to the colour of the rock when present in such small proportions. Undoubtedly these minerals occur more freely along joint planes in some parts of the quarry which should be avoided in the selection of blocks for building. The texture is holocrystalline and hypidiomorphic. The rock is a granite.

Uses.—Granite was quarried in this locality some years ago and used as pitchers in the yards at Spencer Street Station. However, as it was found to be slippery for such a purpose (a quality inherent in all granites, and not confined to this particular stone), the granite pitchers were removed. Blocks of granite from this quarry have been used as pedestals for statues in the Queen Victoria Gardens. For facing the exterior of the Shrine of Remembrance this stone is being used in smoothly dressed axed blocks. The stone with this treatment appears almost dead white, which colour is desired for the Shrine.

The Tynong granite outcrops within 45 miles of the city, is near a main railway line, and there is in sight a very large quantity of stone, so that it should prove a useful stone for building purposes in Melbourne.

Dacite.

Aura, Dandenong Ranges.

A great part of the Dandenong Ranges consists of the rock dacite, which in places has been quarried for building stone and road metal. One such quarry, a quarter of a mile east of the Aura railway station, and about 30 miles east of Melbourne, which has supplied stone for building, was visited. The place chosen for quarrying was at the outcrop of a hemi-cylindrical block about 30 feet in length. The quarry is within five yards of the narrow gauge railway line, on the high or northern side, so that drainage from the quarry should be excellent. The outcrop has a semi-circular upper surface, showing traces of exfoliation, which is stained slightly by rust and lichens. The exposed block disappears into the hill-side under an overburden of about two feet of soil containing boulders.

Two vertical joints, one due north and south and the other due east and west, are excellently developed, allowing the removal of well-shaped blocks at least 2 ft. long by 2 ft. 6 in. wide, since blocks of this area have been cut into slabs 3 inches thick and used for a veneer on a concrete building. A block now lying at the quarry measures 5 feet by 2 feet by 2 feet. No horizontal joint plane is apparent. Very little material has been removed from the quarry up to the present. The cavity worked is 4 ft. high by 10 ft. long by 2 ft. 6 in. wide.

The colour of the exposed stone is uniformly dark, only one acid vein a quarter of an inch wide being observed traversing the outcrop. The stone has been quarried by drilling holes 6 to 8 inches deep, and inserting plugs and feathers in these. No machinery has been installed, and the quarrying done up to the present has been only in the nature of scratching at the surface.

Appearance.—This rock is fine-grained, and the fractured surface is coloured dark-grey to black. Though petrologically a dacite, it falls into the trade class of "black granite." A very slight tendency to parallel arrangement of the mica is apparent in freshly-broken pieces in the field. The rock when polished is darker in colour, since there are only a few sparkling crystals of felspar to break its uniform blackness. A smoothly ground, unpolished surface of the stone has a blue tint. Quartz veins a quarter of an inch wide occur so rarely that only one out of every five finished blocks of stone contains one. The colour is unpopular in the building trade, where it is condemned as "cold." For special purposes, such as monumental work, however, the distinctive almost black colour of the polished face should be an asset.

Working Qualities.—The cutting of a small cube for a test did not present greater difficulty than is to be expected with any quartz-bearing igneous rock, though the stone is said by one man who has had experience with it, to be difficult to work. This man spoke also of the existence of "drys," whose occurrence on a dressed block makes it necessary to reject the block. A sharp knife-like "arris" was obtained on the test block. The rock takes a high polish, and its surface remains smooth and without pits after grinding. However, as the individual minerals are small and dark-coloured, there is no relief on a polished surface except for some milky quartz and a few grains of a metallic mineral. On this account probably, the polished Aura stone when used for building is relieved by blocks of unpolished stone finished by patent hammering, which gives it a light grey colour.

Resistance to Crushing.—A rectangular block approximately 2 sq. in. by 1·6 in. high crushed under a load of 26,400 lbs. per sq. in. (1672 tons per sq. ft.).

Absorption Percentage.—After immersion in distilled water for 12 days a rectangular block of this stone absorbed 0·16% of its weight of water.

Specific Gravity and Weight per Cubic Foot.—The specific gravity of this stone is 2·765, and the weight per cubic foot is 172·5 lbs.

Microscopic Examination.—This rock is remarkably free from alteration products. Felspar of composition between labradorite and andesine in zoned hypidiomorphic crystals is the most abundant mineral. A few allotriomorphic crystals of quartz occur. Of ferromagnesian minerals biotite is more prominent than pyroxene, which is represented by hypersthene. A few irregular crystals of iron sulphide are present. In a dark-coloured rock such as this one, discoloration due to the oxidation of an iron sulphide mineral need not be feared. The groundmass is granular and micro-crystalline in texture, and consists of small circular, equidimensional felspar grains and some quartz. The felspar crystals are very small, and the determination of their species is difficult, but many of them being clear and untwinned suggest orthoclase. Accessory minerals are magnetite, apatite and zircon. The rock is a biotite hypersthene dacite.

Uses.—This stone was used in a branch of the English, Scottish and Australian Bank, at the corner of Swanston and Little Bourke Streets, Melbourne. This was demolished in 1927, and upon rebuilding the dacite was not used. Polished slabs of the stone were used mainly, but around the doorway relief was given to the dark Aura stone by specimens of a grey rock with an axed finish. The locality of this rock is uncertain.

The abundant supply, the proximity to a railway track, and the uniformity of colour are all points in favour of the use of this stone, though it should be noted that Aura is on a narrow gauge railway line, and any quarried material has therefore to be transferred at Upper Fern Tree Gully to wide gauge trucks.

PORPHYRY.

Tallangatta.

This district contains many igneous rocks, one of which, a porphyry, has been used in Melbourne as an ornamental stone. Details of the position of the quarry with respect to the town of Tallangatta, which is 212 miles from Melbourne in a north-east direction, or of the nature of the outcrop of the rock, are not known to the writer.

Appearance.—The stone used is light pink in colour, and has large porphyritic crystals of a cream-coloured rhombic-shaped felspar and corroded crystals of quartz set in a fine-grained pink groundmass. Its attractive colour shows well when the stone is polished. Other types from the same district have been examined, which should also serve well as ornamental stones. One of these has the greenish-brown colour and fine-grained appearance familiar in the "trachyte" of Bowral, New South Wales. On a polished surface numerous rectangular porphyritic crystals of green felspar are seen. This stone polishes excellently.

Working Qualities.—A specimen of the pink rock was ground smooth and polished in the laboratory. A very even surface was obtained, and a high polish appeared on it. Other working qualities are unknown to the writer.

Resistance to Crushing.—This has not been determined.

Specific Gravity and Weight per Cubic Foot.—The specific gravity of this porphyry is 2·565, and its weight per cubic foot is 160·5 lbs.

Microscopic Examination.—Examined in thin section the rock is found to be much altered. Large quartz crystals, some idiomorphic and some corroded by the surrounding groundmass, stand out from among the rest of the minerals, which are clouded with decomposition products. Small porphyritic crystals of felspar occur, but all traces of twinning and cleavage are masked by a thick film of secondary products, such as kaolin, sericite and iron oxide, so that the species cannot be determined. Fibrous aggregates of a ferromagnesian mineral, which is a chloritic product of the original biotite, are seen. The groundmass of the rock is crystalline, and consists mainly of small felspars. The rock is a quartz felspar porphyry.

Uses.—A large rectangular block of the pink stone has been used in the Eight Hours Day Monument, erected in 1888 near Parliament House, and moved in 1923 to its present site, at the corner of Victoria and Lygon Streets. The steps and pillar of the monument are constructed of Harcourt stone, while the central block at the base of the pillar bearing the inscription comes from Tallangatta.

Its warm pink colour, the large well-shaped, cream-coloured felspar crystals, and its good polish make this stone a very handsome one.

Basalts.

Malmsbury Basalt.

The basalt of Malmsbury and district was quarried for building stone and road metal before 1861, as notes on Quarter Sheet 9 NW. published in that year record quarries for this stone. Many of the early quarries were in the neighbourhood of Green Hill, a point of eruption three and a half miles north-east of Malmsbury. Basalt quarries are working now about two miles east of Malmsbury, and half a mile west of the railway siding of Edgecumbe, on the Redesdale branch line. Several small quarries are in operation on a low rise about twenty feet in height, which at one time formed the outer bank of a meander of the Campaspe River. The river now flows to the east of its old course, and this deserted meander is now a marsh. The quarries are working into the old river bank, which by this means has been cut back about 30 feet. Pillars of stone which are useless on account of the amount of honeycomb basalt in them are left standing in the quarries. The vertical jointing system in this stone is not particularly marked in any given direction. Those working on the stone say it may be split vertically with equal ease in any direction, and vertical joints intersecting at various angles were observed in the quarry. Some of these joints are filled with a weathered layer of clay or "reef," up to one foot in thickness, between the solid basalt. These are called "clay" or "open" joints, and those where no clay appears are known as "tight joints." The stone with "tight joints" is more difficult to quarry. The vertical joint planes meet at angles which suggest that columnar jointing, with each column of a large diameter, is prevalent in this flow as in other flows of basalt. The horizontal joints or "bed" are rather uneven, and follow more or less the upper surfaces of layers of honeycomb basalt which are found through the solid stone. A characteristic section in the quarry is seen in a face of basalt about 16 feet in height. A layer of soil 1 foot in depth covers 4 feet of solid basalt, which overlies 14 inches of honeycomb basalt. Below this, 15 inches of solid stone overlies a thin "reed" or sheet of porous stone half an inch in thickness. Below this depths of solid stone of about 18 inches width are separated by layers of honeycomb basalt perhaps 6 inches in thickness or by narrower "reeds." The thicknesses of the layers of solid stone are not uniform throughout the quarry. The "honeycomb" basalt—i.e., the extremely porous stone—since it is developed in bands 6 to 14 inches thick, may mark the quickly cooled upper surfaces of individual flows, to which a great deal of gas finds its way from the body of each flow, and so forms the "honeycomb" basalt at the surface of the flow. Later, this honeycomb layer is covered by a new flow of basalt. The ease with which horizontal jointing takes place immediately above a layer of "honeycomb" basalt is probably due to this junction between flows. The "reeds," which are thin sheets of porous basalt, are never more than half an inch thick. These often occur in a horizontal plane, but also an "up and down reed" occasionally passes through solid stone from one honeycomb layer to another. It is thought that the "reeds" represent the tracks of bubbles of gas which are carried horizontally for a certain distance and then may find their way to the surface by travelling vertically or diagonally up through the flow, making an "up and down reed." Their origin is thus pictured as similar to that of the "corks" found commonly in Footscray basalt and described later. In the "reed," however, there has been no subsequent filling of the steam cavities. A type of "reed" difficult to account for is one which follows a horizontal plane for some distance, bends at right angles to a vertical plane for about 6 inches, then back to a horizontal plane again for a foot, following this the "reed" bends down again along a vertical plane, and finishes up after another bend in the same horizontal plane in which it commenced. The bubbles appear to be surmounting an obstruction of stone already solidified, perhaps a block of foreign stone being carried along by the molten basalt.

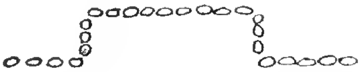

FIG. 1.—Path of "reed" in basalt, Malmsbury.

In the stone in this part of Malmsbury no "corks" are seen, but half a mile away basalt outcropping on the main road contains them. They are described and their origin is discussed in the description of the Footscray basalt. As in many other igneous rocks, "drys" occur in this basalt. They are sometimes marked by a brown iron-stained thread in the good stone as though some oxidation of iron had taken place along them.

Appearance.—The stone is fine-grained, porous and slate-grey in colour. It contains many colourless, needle-like zeolite crystals. Its uniform appearance is monotonous and unrelieved by any sparkling mineral. Two grades of stone are recognised, depending upon the porosity. First quality stone is porous, but none of the pores is larger than one-fortieth of an inch in diameter. Second quality stone is porous and contains these minute pores, but in addition some larger ones, whose diameters vary between one-eighth and one-half inch, are scattered irregularly through it.

Working Qualities.—The Malmsbury basalt is quoted by quarrymen as the standard of excellence among building stones when working qualities are considered. By means of a scavelling pick a block of stone obtained from the quarry is readily dressed to a regular shape. "Drys" in the stone, as described above, are the only flaws against which the workman has to guard when selecting blocks for dressing. The average size of the finished blocks obtained is 4 ft. long by 2 ft. by 1 ft. In a report by Lidgey published in 1894 (6), the Malmsbury basalt is described as taking "a fine polish," with which statement the writer cannot agree. A piece of first quality Malmsbury was smoothed and polished, but as was expected, the pores in the stone are so numerous that the smallest polished surface is broken by gaps where the pores intervene, and in many of them the rouge powder used for polishing lodges and is extremely difficult to remove. To overcome this disadvantage canada balsam was poured on the smooth surface of a heated block of the basalt, then baked, and allowed to cool. Grinding removed the superficial layer of balsam, and the surface was then polished. An even polish, though a poor one, resulted, since there were few pores unfilled by balsam.

Resistance to Crushing.—A two-inch cube of the stone was crushed under a load of 8,620 lbs. per sq. in. (554 tons per sq. ft.).

Absorption Percentage.—The stone absorbed 2·16% of its weight after immersion in water for five days. Absorption was complete after this period, since three weeks later no material increase in weight was found in the test block.

Specific Gravity and Weight per Cubic Foot.—The specific gravity is 2·595, and the weight per cubic foot 162 lbs.

Microscopic Examination.—The rock contains plagioclase felspar laths whose mean composition is that of labradorite, abundant squat prisms of faint green augite, corroded crystals of olivine, the larger ones completely changed to brown iddingsite, and the smaller ones colourless with a border alteration only. Magnetite is common, many crystals of it occurring in long narrow flakes. The texture is ophitic, since some of the felspar is enclosed by later crystallizing augite. On account of the extreme porosity of the rock, a thin section is rather broken. The rock is an olivine basalt.

Uses.—Malmsbury basalt was at one time used very extensively for the basecourses of large Melbourne buildings. The stone from the Green Hills quarries probably figures in many of these. Nowadays some of the stone from the quarry visited near Edgecumbe is used for basecourses, but it is generally sawn into steps and cemetery kerbing. Malmsbury basalt forms the basecourses of the following buildings in Melbourne:—English, Scottish and Australian Bank (head office), Bank of Australasia, Australian Mutual Provident, Royal Insurance, London and Lancashire Insurance, Northern Assurance, Alliance Insurance and Guardian Insurance Buildings, and many others. It is used in the gateway in the main entrance to the University. In combination with Footscray basalt it is used in the Melbourne Grammar School. Malmsbury basalt is not accepted for use on the roads, as on account of the ease with which it is worked it is regarded as too soft for this purpose. The ease with which it may be worked recommends this stone for use for building, when its dull appearance will serve as an effective contrast to a lighter-coloured stone, but it is too unattractive to be used alone in construction.

Footscray Basalt.

The quarry visited at Footscray lies north of the Footscray railway station, and is four miles west of Melbourne. Quarrying commenced here more than 25 years ago, and in that time stone has been removed over an area 150 yards square for an average depth of 20 feet. The ground here was practically horizontal originally, and the result of quarrying has been to leave a hole in the ground with the dimensions given above. Several basalt flows have occurred in this area, the later ones being superimposed on the earlier, and marked junctions occur between them. Drainage from the quarry is reported as good, since all rain water flows away through a vesicular, iron-stained basalt which forms the bottom of the main quarry. The depth below the surface at which the iron-stained band lies, varies in different parts of the quarry. At the northern end this band is 21 feet below ground level. Immediately above it lies 15 feet of solid rock, from which building stone is obtained. In the eastern part of the quarry this same vesicular band is seen 10 feet below the surface of the ground, and stone is quarried from beneath it, presumably in an earlier flow. The top of the quarry is formed by 5 feet of stone showing irregular columnar jointing. The jointing system is very irregular, even in the solid stone. In quarrying, a vertical drill-hole perhaps 26 feet deep is made with a pneumatic drill, until the iron-stained honeycomb layer is reached. A charge of powder in this hole blows out the side of the quarry, and may dislodge blocks large enough for building stone purposes. Such a block with very irregular surfaces and measuring 8 feet long by 3 feet square was seen by the writer. It was to be cut up by the use of plugs and feathers into regular-shaped kerb stones 6 or 7 feet long by 12 inches by 7 inches. Stones which spall well are cut into larger blocks suitable for basecourses. Otherwise the building stone market is not now catered for.

Horizontal layers of vesicles traverse the solid rock. They average half an inch in width, but occasionally reach two inches. They are known as "reeds," and represent the paths of bubbles of gas which have travelled through the lava along the direction of the "reed." The gas has taken a horizontal track along the level where the viscosity of the crystallising lava has prevented its further passage upward. The lava being still in motion, has drawn out the bubbles of gas into ellipses, whose long axes are arranged parallel to the direction of movement. In some "reeds" the vesicles are lined with white carbonate crystals, which penetrate into a central cavity. In such a case the quarrymen speak of a "silver reed." Elsewhere the solid stone is pierced by vertical cylindrical pipes known as "corks." These are channels whose diameters vary from one to three inches, which pass from the bottom honeycomb layer of the quarry vertically up through the stone until within 14 feet of the surface. In the uppermost 14 feet of the quarry is stone showing a great development of platy and horizontal jointing, which may represent a different flow of basalt, and through which the "corks" do not pass. The channels or "corks" show up in the normal basalt, since their margins are defined by rows of vesicles, and they are more porous than the normal stone, carrying as they do an average of 20 pores to the square inch. The pores are the shape of irregular triangles, or quadrangles, or they are circular. Some are filled with a white

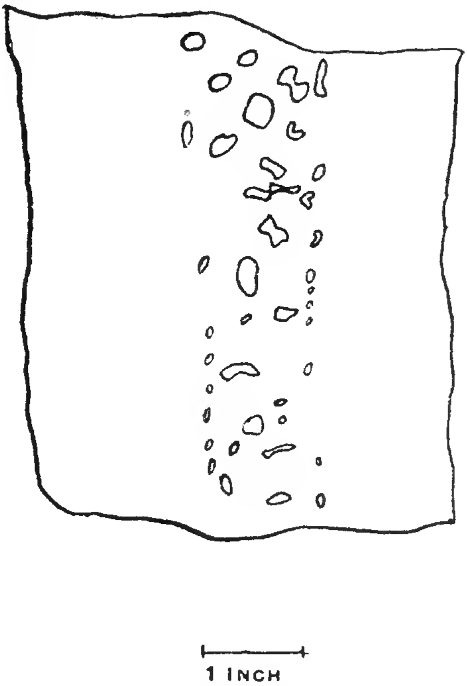

FIG. 2.—Longitudinal section through "cork." One-fourth of the larger pores are filled with carbonates. The shapes of the pores are characteristic.

carbonate mineral. The rock forming the matrix of the "cork" is finer-grained than is the normal rock. Near the bottom of the flow the "corks" are narrow, being about one inch in diameter, while towards the top they expand to about three or four inches across. At the bottom of the "cork" the white carbonate coating to the pores, which makes a "silver cork," is more commonly found than at the top of the "cork," where the vesicles remain empty, forming a "black cork." The "corks" are practically vertical, but owing to the irregularity with which a stone splits after a charge of gelignite, they appear in circular, elliptical or half-moon-shaped cross-section and look like sporadic occurrences. One "cork" was traced vertically by the writer for twelve feet

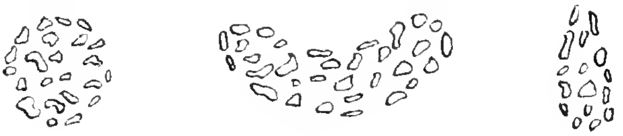

FIG. 3.—Characteristic cross-sections through "corks."

through the stone, while experienced quarrymen state that they have traced a single "cork" through the 40 feet of the stone which is worked. "Corks" are the channels by which the gases imprisoned in a lava escape to the surface. On account of the passage of gases through such a channel, the lava in its neighbourhood is rendered very porous, and is retained in the liquid state for a longer period than the surrounding lava, one result of which is the larger percentage of isotropic material seen in a thin section of a "cork," as described later under "Microscopic Examination." The "cork" expands when nearing the surface, since the overlying pressure is less.

Du Toit describes (11) in the diabasic lavas of Barkly West, South Africa, "pipe amygdales" or "bubble trains," structures very similar to "corks," which he ascribes to the "escape of steam generated in the flowing of molten rock over moist surfaces." In Victoria, since many of the basalt flows have filled old stream valleys, an analogous origin is not impossible. As described earlier, the floor of this quarry is formed by an iron-stained layer of stone which may represent the lower surface of the flow in contact with the bed of the old river.

Appearance.—This basalt is a fine-grained rock coloured dark-grey, with a slight bluish tint, which earns it the trade name of "bluestone." The whole rock is pierced by fine pores, and in addition larger circular vesicles averaging one-tenth of an inch in diameter occur about one inch apart throughout the stone. The rock is denser than the basalt from Kyneton, in which the pores and vesicles are more numerous. It contains small sparkling felspar crystals and occasionally a yellowish-green powdery mineral, probably halloysite. Blocks of otherwise solid stone contain elliptical or circular patches of varying size, which are cross-sections through the "corks" described above. In paving stones the "corks" stand up above the surface of the rocks after a certain amount of traffic over the pavements. This is seen especially on the north side of Bourke Street, between Swanston and Russell Streets. This greater resistance to wear is considered to be due to the coarser texture of the "cork," as compared with the finer-grained nature of the matrix. Another type of abnormality found in this rock is the "flint," which is a patch rich in calcium carbonate, where all pore spaces are filled with this white mineral, which has crystallized from solutions perhaps imprisoned in the rock when crystallization of the main flow prevented their escape. The "flints" are so known because it is reported that the rock in which they occur is more difficult to work than the normal basalt. They are also found in the Kyneton stone.

Working Qualities.—In spite of the irregular jointing this stone spalls remarkably well. An experienced worker easily breaks it into rectangular blocks with a hammer. However, it is not so easy to work as the more vesicular Malmsbury and Kyneton basalts. A sample was ground smooth and polished with rouge powder, which filled all the small pore spaces in the basalt, and no amount of scrubbing would remove it. The solid portions between the pores took a moderately good polish, showing a greyish-brown colour, but the general effect is far from pleasing. This result illustrates the common saying, "Basalt will not polish."

Resistance to Crushing.—A three inch cube of Footscray basalt which was crushed in 1891 fractured under a load of 10,577 lbs. per sq. in. (680 tons per sq. ft.). A two inch cube of this stone was made from material obtained in 1926 from a quarry at Footscray, and this stone proved stronger than that crushed earlier. Its crushing strength was 16,300 lbs. per sq. in. (1048 tons per sq. ft.).

Absorption Percentage.—The absorption percentage of this stone is 1·45. The absorption of water by the basalt is gradual and continuous. In five days' immersion a block measuring about one cubic inch increased in weight by 1·09%, but after thirteen days its weight had increased by 1·44%. At the end of seventeen days, when the stone had absorbed 1·45% of its weight of water, saturation was considered complete.

Chemical Analysis.—A chemical analysis of the basalt from this quarry has been made in the Victorian Mines Department Laboratory by Mr. A. G. Hall, but has not been previously published. By the courtesy of the Geological Survey permission has been given to publish it in this paper with other analyses.

Specific Gravity and Weight per Cubic Foot.—The specific gravity of the stone obtained from this quarry determined by weighing a specimen first in air and then in water is 2·570. From this value the weight per cubic foot is found to be 161 lbs. It will be noticed that the specific gravity given with the chemical analysis is 2·839. This value was obtained by weighing the powdered basalt, and since basalt is a porous rock the disagreement between the two determinations is intelligible. The first method is more useful for building stones, though it is difficult to carry out in the case of a porous rock, where some of the water is absorbed while weighing is proceeding. The result obtained is known as the "apparent specific gravity," and from it the weight per cubic foot of the stone is calculated.

Microscopic Examination.—A thin section of the normal stone of the quarry contains laths of plagioclase whose composition is between labradorite and bytownite. Many of these are set inside titaniferous augite crystals in the typical ophitic texture. Some augite shows strain polarization. Olivine is abundant, and has a brown alteration product, iddingsite, around its edges and along its cleavage planes. Occurring interstitially between some felspar laths is a colourless substance thickly studded with black globules of iron oxide and some long laths of an iron oxide mineral, magnetite or ilmenite. Since this mineral occurs in hexagonal plates, and in brown skeletal crystals, forms more characteristic of ilmenite than of magnetite, it is more likely to be the titanium-bearing iron oxide, ilmenite. Titanium is also present in the augite of this rock. The colourless matrix in which the ilmenite occurs was at first taken for volcanic glass, but Professor Skeats has pointed out that while some of this material is isotropic, much of it is not, and also the refractive index is too low for a basaltic glass, nor has it the characteristic greenish-brown colour of such a glass, and further glass in basalt is found only in a narrow tachylytic margin of a basalt flow, always less than one inch in width, while the specimen from which this section was cut comes from within a uniform mass of basalt, certainly 30 feet in thickness. In ordinary light the refractive index and colour of this material are similar to the felspar of the basalt. Where it is anisotropic its polarization colours are low in the first order, and occasionally there is a suggestion of zoning in the interstitial material. These considerations point to the interstitial material being felspar. It has been the last material to crystallize from the liquid state, and has thus filled up interstices, a role commonly taken by the quartz of quartz-bearing rocks. The iron oxide carried in this liquid has separated in the form of globules. In some cases this liquid has been supercooled below the temperature of crystallization of felspar, and has eventually solidified in the form of a felspathic glass, and hence is isotropic. In ordinary light this isotropic material is in colour and refractive index indistinguishable from that which is anisotropic, and the former also contains the iron oxide globules found in the latter. Where an augite crystal is set in this matrix the iron oxide has been drained from the latter to go to the formation of augite, and the augite crystal is surrounded by a narrow rim of clear, colourless, felspathic matrix. The rock is a porous olivine basalt.

In a thin section of a "cork" or pipe-amygdale, the materials of the normal rock are found. The interstitial felspathic glass is more abundant here, and in this case practically all of it is isotropic. In this section in addition to the globular form the iron oxide also occurs in hexagonal plates, and in brown feathery skeletal crystals (Plate XVI., Fig. 2) suggestive of incipient crystallization brought about by the mother liquor being retained in the liquid state longer than where the iron oxide is found in the globular form. When it is remembered that this material comes from the former channel for the passage of gases its less crystalline state is explicable. While passing through the "cork" the gases would tend to keep the neighbouring lava in a state of flux, with crystals of augite, olivine, felspar and iron oxide suspended in a liquor which, drained of other constituents by their crystallization and largely felspathic in composition, became supercooled below its freezing point. After the passage of most of the gases, that is to say of the fluxing agent, sudden solidification or quenching would cause the formation of felspathic glass as the matrix binding together the crystalline material. Many pores are filled with a concentrically or radially arranged calcium carbonate mineral, probably aragonite. In a thin section of a "flint" the minerals of the normal rock may be recognized. Many of the pores in the rock are filled with aragonite. Here too the felspathic matrix occurs in both isotropic and anisotropic forms, the former preponderating. Carried in it is iron oxide in both globular and skeletal-crystal forms. Hematite is noted very occasionally in the section.

Uses.—The stone from this quarry is used for screenings, for foundations in concrete roads, for gutter pitchers, paving slabs, doorsteps and staircases and, when large enough blocks are obtainable, for building stone. It is commonly used in basecourses, and can be seen in the base of the Melbourne Town Hall and of the Telephone Exchange. St. Patrick's Cathedral, Melbourne, has been constructed entirely of Footscray basalt, as have been numerous Melbourne warehouses.

The large supply, the proximity of the outcrop to Melbourne, and the comparative ease of dressing it, are to be reckoned in favour of this stone's use in Melbourne. Its dark colour considerably lessens its suitability as a building stone, and while it should make it more suitable for monumental work, the fact that it will not polish curtails its use for this purpose.

Kyneton Basalt.

Basalt in the neighbourhood of Kyneton, as well as near Malmsbury, has been quarried for building stone for many years. A quarry visited three miles south-east of Kyneton, and two miles north-west of Carlsruhe, is on the site of a very old one on a low ridge running parallel to and about one mile east of the railway line, and is 55 miles north of Melbourne.

An area 30 ft. by 40 ft. has been quarried to a depth of 25 ft. By the lease under which the stone is obtained, the quarry has to be filled as stone is taken out, so that only a small pit is left where present quarrying operations go on.

The quarry face shows a layer of overburden 2 ft. in depth, while for a further 5 ft. below the stone is broken into large boulders showing spheroidal or "onion" weathering. Below this the stone is solid though at intervals very vesicular bands about 2 in. in width occur. The stone in the upper portion of the quarry contains some sporadic vesicles or "blow-holes," which are larger than the pores of the normal vesicular basalt. The stone in the lower 15 ft. of the quarry is free from them. A series of horizontal and north-south and east-west vertical joints traverse the stone, along which weathering agents have found a track, forming a band of clay one inch in width as a result of the alteration of the basalt. Hence the joints are called "clay joints." From the "clay joints" the flaws called "drys" pass in to the good stone. The stone is liable to split along a "dry" and a block must be rejected if a "dry" appears on a dressed surface. The dry may only show after the dressing of the block is complete. The stone is found to be without "blow-holes" or "drys" about 25 feet below the surface, where flawless regular blocks 10 feet by 8 feet by 7 feet can be extracted. Vertical holes 6 inches deep are drilled 8 inches apart by means of a jumper drill along a vertical "clay joint." After the block has cracked vertically, that is, along the "cut," holes passing horizontally into the stone for 18 inches are drilled 2 feet apart on the front of the stone just above a line of honeycomb basalt if any is present. Plugs and feathers at first and, later, "lifters" are inserted in these holes, and a horizontal crack occurs which is called the "board." Along the east and west vertical joints a good face of stone is obtained. Along other vertical joints the stone is apt to break irregularly.

Appearance.—This basalt is a drab-grey vesicular one, with here and there groups of vesicles filled with an opaque white mineral which effervesces with acid, and when examined in thin section is found to be calcite. The patches which contain calcite are known as "flints," and are said to blunt tools used on the basalt. It is difficult to see why the soft mineral, calcite, in these patches should have earned them the name of "flints," though when it is remembered that elsewhere the vesicles are empty the assertion that the "flints" are harder than the normal stone is probably explained. Some vesicles are penetrated by needle-like crystals of probably a zeolite mineral, natrolite. An axed surface of this basalt is lighter grey in colour than is a rock-faced block, but both colours are monotonous and rather unattractive.

Working Qualities.—This stone is reported to be easier to work than the Footscray basalt, though it is not so easy as that from Malmsbury. In common with these other basalts it is easily broken by the hammer along plane surfaces at right angles, giving nearly smooth rectangular blocks. A great deal of quarry damp is noticed in the stone when a chip is flaked off a block just after it has been quarried.

This basalt is too vesicular to be susceptible of polishing.

Resistance to Crushing.—This porous basalt has a lower crushing strength than the denser Footscray basalt. The Kyneton stone crushed under a load of 9,220 lbs. per sq. in. (593 tons per sq. ft.).

Absorption Percentage.—Absorption percentages of both normal and "flint" types of the stone were obtained. The normal stone absorbed water slowly, and saturation was not complete until the stone had been immersed for 24 days, when it was found to have absorbed 2·92% of its weight of water. The absorption percentage of the "flint" type was 1·77, which indicates that in a "flint" nearly half the pore space of the normal basalt has been filled with secondary minerals.

Normal Footscray basalt has an absorption of 1·45%, i.e., only half that of normal Kyneton stone. The porosity of the latter makes it the easier stone to work.

Specific Gravity and Weight per Cubic Foot.—The specific gravity of the stone is 2·615, and its weight per cubic foot is 164 lbs.

Microscopic Examination.—A thin section shows fresh, unaltered labradorite felspar and augite, olivine surrounded by a rim of reddish-brown iddingsite, and some magnetite. The structure is vesicular, but many of the vesicles are coated with calcite. The mineral content and texture of this rock are typical of normal basalt.

Uses.—The main use to which the Kyneton stone is put is the construction of basecourses. Its dark colour makes an effective

Tabulated List of Tests.

Name and locality	Specific Gravity	Weight per Cubic Foot in Lbs.	Absorption Percentage	Crushing Strength Lbs. per Sq. In.	Crushing Strength Tons per Sq. Ft.
Granite, Harcourt	2·678	167·5	0·11	11,444	736
				11,333	728
				8,510	547
Granite, Wangaratta—					
Type A	2·512	157	1·45	19,600	1261
,, B	2·324	145	3·75	7,110	457
,, C	2·446	152·5	4·08	9,670	622
Granite, Cape Woolamai	2·643 (16)	165	0·18	27,100	1743
Granite, Gabo Island	2·635 (16)	165	0·39	15,200	979
				14,900	950
				17,500	1128
Granite, Orbost	2·803	175	0·15	25,400*	1633
				15,300	984
Granite, Trawool	2·666 (16)	167	0·28	not determined	
Granite, Dromana	2·605	163	0·18	17,870	1149
				16,300	1048
Granite, Colquhoun	2·616	163	0·32	14,750	946
Granite, Tynong	2·633	165	0·28	25,700	1652
Dacite, Aura	2·765	172·5	0·16	26,000	1672
Basalt, Footscray	2·570	161	1·45	10,577	680
				16,300	1048
Basalt, Kyneton	2·615	164	2·92	9,220	593
Basalt, Malmsbury	2·595	162	2·16	8,620	554

* Not actually broken, but on the point of breaking.

contrast with a lighter-coloured superstructure. The basecourses of the New Arts Block at the Melbourne University are constructed of basalt from this quarry in blocks measuring 8 ft. 9 in. by 5 ft. by 1 ft. 6 in. Waste pieces left after the shaping of larger blocks are trimmed up for gutter pitchers, etc.

The large quantity available, the ease of extraction and working, and the possibility of obtaining big blocks, are all points in favour of this stone.

Chemical Analyses.

	1	2	3	4	5
SiO_2	70·94	76·31	72·49	69·19	50·86
Al_2O_3	13·99	13·09	13·48	13·45	13·84
Fe_2O_3	0·35	0·41	1·16	2·71	4·70
FeO	3·02	1·07	2·09	2·78	6·56
MgO	0·80	0·36	0·49	1·06	8·94
CaO	2·35	0·65	1·31	2·04	8·45
Na_2O	3·94	3·00	3·38	2·89	2·59
K_2O	3·66	4·76	4·06	3·94	0·75
H_2O+	0·21	0·29	0·76	0·77	0·82
H_2O-	0·11	0·11	0·18	0·16	0·57
TiO_2	0·58	tr.	0·46	0·51	1·93
P_2O_5	tr.	—	tr.	0·18	0·23
CO_2	—	0·66	tr.	0·07	nil
MnO	—	0·11	0·13	0·14	0·20
Li_2O	—	} tr.	} tr.	tr.	tr.
Cl	—	}	}	tr.	tr.
NiO	—	0·01	}	nil	0·01
SO_3	—	nil	} nil	nil	—
CoO	—	—	}	nil	tr.
BaO	—	—	—	—	tr.
Cr_2O_3	—	—	—	—	0·05
S	—	—	—	—	0·03
Less O=S	—	—	—	—	0·01
Total	99·95	100·43	99·99	99·89	100·52
Specific Gravity		2·643	2·635	2·666	2·839

1. Adamellite, Harcourt Quarry (Analyst, G. Ampt) (16).
2. Granite, Cape Woolamai (Analyst, A. G. Hall) (16).
3. Granite, Gabo Island (Analyst, J. Watson) (16).
4. Adamellite, Trawool Quarry (Analyst, A. G. Hall) (16).
5. Basalt, Eldridge's Quarry, Footscray (Analyst, A. G. Hall).

Summary.

In this paper are described fourteen Victorian igneous rocks used as building stones. It has been found that most of these are excellently adapted for such a purpose so far as their durability is concerned, but the long distance at which some of them occur from a market must add to the expense of using them, as for example the rocks from Gabo Island, Colquhoun, Orbost and Wangaratta.

Some are considered most suitable for ornamental purposes, as they consist of large crystals included in a fine-grained ground-mass. Such are the stones from Tallangatta and Trawool. Another set, including the Aura dacite and the three basalts, being very dark and sombre in colour, needs to be combined in a building with a lighter-coloured rock to give relief.

The rock so far obtained from the quarry at Orbost is found to be too uneven in texture to be usable with success. As is pointed out in the report on that stone, probably a more even-textured stone freer from "black spots" and sedimentary inclusions will be found at depth in this quarry.

So far as working qualities are concerned, the basalts stand out as those most easily worked; next in order of ease is probably the Wangaratta stone, followed by that from Orbost. The stone from Harcourt is well known to be, for a granite, not difficult to work, while the Tynong granite is reported to approximate closely to it in ease of working.

So far as attractiveness of appearance, convenience of situation to the capital, and amount of stone available are concerned, the stone from Dromana seems to merit development; while, though its situation is somewhat remote, and the quantity perhaps limited, the working qualities and appearance of the Wangaratta stone should recommend its further use.

In the case of the granites from Wangaratta, Orbost, Dromana, Colquhoun, Tynong, the dacite from Aura, the porphyry from Tallangatta and the basalts from Footscray and Kyneton, the petrological descriptions of these rocks are here published for the first time.

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EXPLANATION OF PLATE XVI.

FIG. 1—Microphotograph—Altered Granite, Warby Ranges, Wangaratta. Ordinary light, × 26.

1. Orthoclase.
2. Hematite.
3. Hematite penetrating along cleavage crack parallel to *c* (basal pinacoid).
4. Hematite penetrating along cleavage crack parallel to *b* (clinopinacoid).

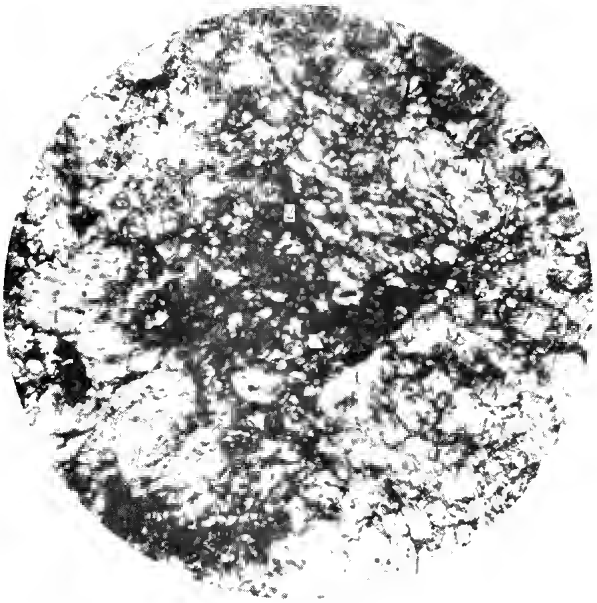

Fig. 1.

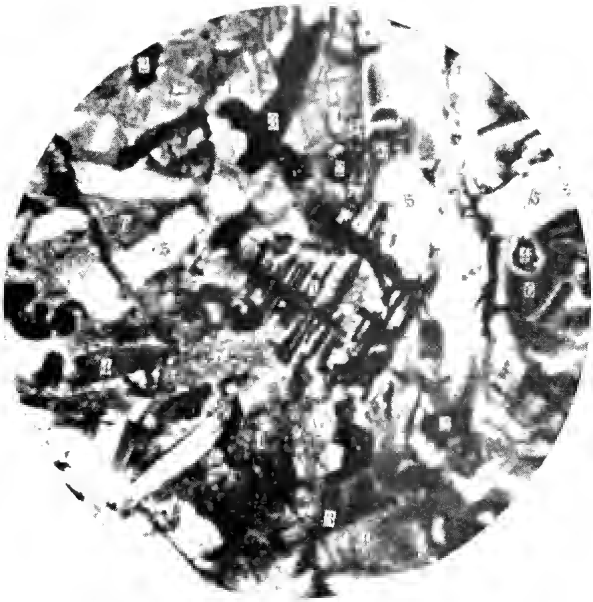

Fig. 2.

FIG. 2—Microphotograph—Basalt, Standard Quarries, Footscray, showing texture of " cork " or pipe amygdale. Ordinary light, × 115.

1. Brown skeletal crystal of ilmenite.
2. Hexagonal cross sections of ilmenite.
3. Flakes or flattened crystals of ilmenite.
4. Augite.
5. Plagioclase.
6. Isotropic felspathic matrix clouded by globules of iron oxide.
7. Anisotropic felspathic matrix clouded by globules of iron oxide.

[Proc. Roy. Soc. Victoria, 41 (N.S.), Pt. II., 1929.]

Art. X.—*Long Range Rainfall Forecasting from Tropical (Darwin) Air Pressures.*

By E. T. QUAYLE, B.A.

[Read 11th October, 1928; issued separately 3rd April, 1929.]

Darwin has come to occupy a position of singular importance in world meteorology, especially with regard to its air pressure records. These have not only proved valuable as aids to forecasting Indian weather, but show striking correlations with the meteorological phenomena of many other areas, chiefly tropical. It therefore seemed reasonable to hope that since our Southern inland rains are mainly of tropical origin, they also would show some relation to Darwin air pressures. This paper gives the results of an attempt to show whether this is such as to be of use for forecast purposes.

That tropical conditions have a large and direct control over our Southern weather I have already shown by Bulletin 15, Commonwealth Bureau of Meteorology. In this case the minimum temperatures, which give some indication of the total blanketing effect upon the earth's surface of the humidities of the air at all levels of the atmosphere, were used. From these it was deduced that even in winter vast bodies of moist tropical upper air not infrequently invade the continent, and that the rain production of storm systems generally is dependent upon their being met by these invasions. It was found, too, that the semi-permanence of tropical conditions made possible during the winter half of the year forecasts of rain probabilities as much as three weeks ahead, and for this Darwin was the station mainly relied upon.

Of the data up to the present available those provided by the surface air pressures are probably the best for tracing changes in the general atmospheric circulation due, say, to the varying output of solar heat, the interplay of ocean currents and storm systems, etc. And any change in the distribution of pressure over the globe must have its influence upon the development and paths of storm systems, and so upon the rainfall of any locality. It is in the tropical belt that such changes might be expected to reveal themselves first.

This investigation consists mainly of comparisons between the monthly means of air pressure at Darwin, and of the rainfall at ten representative stations in Northern Victoria. These are Swan Hill, Echuca, Yarrawonga, Warracknabeal, Charlton, Bendigo, Shepparton, Dookie, Horsham and St. Arnaud.

As with the minimum temperatures, so with the air pressures in tracing rainfall relations, it will be seen that the tropical control of our Southern inland rains is apparently limited to the winter half of the year. This is sufficiently well shown by the numbers of times during the 45 years, 1884-1928, in which the individual months show agreements between the departures from normal of the Southern rainfalls and of the Darwin air pressures, counting agreement when lower barometer readings go with higher rainfall, and vice versa. Expressed in percentages of the possible number (45), these are as follow:—January, 55; February, 57; March, 53; April, 45; May, 67; June, 67; July, 71; August, 72; September, 64; October, 73; November, 72; December, 50.

With a view to rainfall prediction the Darwin pressure departures for each pair of months were compared with our Southern rainfalls for the following pair. Agreements, reckoned as above, resulted as follow:—

Darwin Pressure Departures		Northern Victorian Rainfall Departures	Percentage of Agreements p.c.
January-February	with	March-April	47
February-March	,,	April-May	50
March-April	,,	May-June	67
April-May	,,	June-July	76
May-June	,,	July-August	77
June-July	,,	August-September	82
July-August	,,	September-October	70
August-September	,,	October-November	71
September-October	,,	November-December	50
October-November	,,	December-January	55
November-December	,,	January-February	59
December-January	,,	February-March	56

which are actually better than the synchronous monthly agreements.

As the foregoing suggests, the best forecast results are got by using the Darwin June-July air pressures to indicate the Southern August-September rainfall. This is of economic importance, the August-September rainfall having almost a critical value in cereal production, as well as determining the state of Spring and Summer pastures. The graph, Figure 1, in which pressure departures are reversed, shows the remarkably consistent way in which our August-September rainfall follows the June-July Darwin pressure departures. These curves give the high correlation co-efficient of $-\cdot 79 \pm \cdot 038$. The proportionality between the extreme variations is good enough to suggest possibilities of forecasting drought or flood conditions.

Correlation of the June-July Darwin air pressures with the rainfalls of the three following months taken separately, gave coefficients of $-\cdot 62$ with August, $-\cdot 58$ with September, and $-\cdot 29$ with October, which confirm the advisability of taking the months in pairs.

The following table gives the forecast relation between the successive two-monthly Darwin air pressure means and the Southern inland rains for the two months following:—

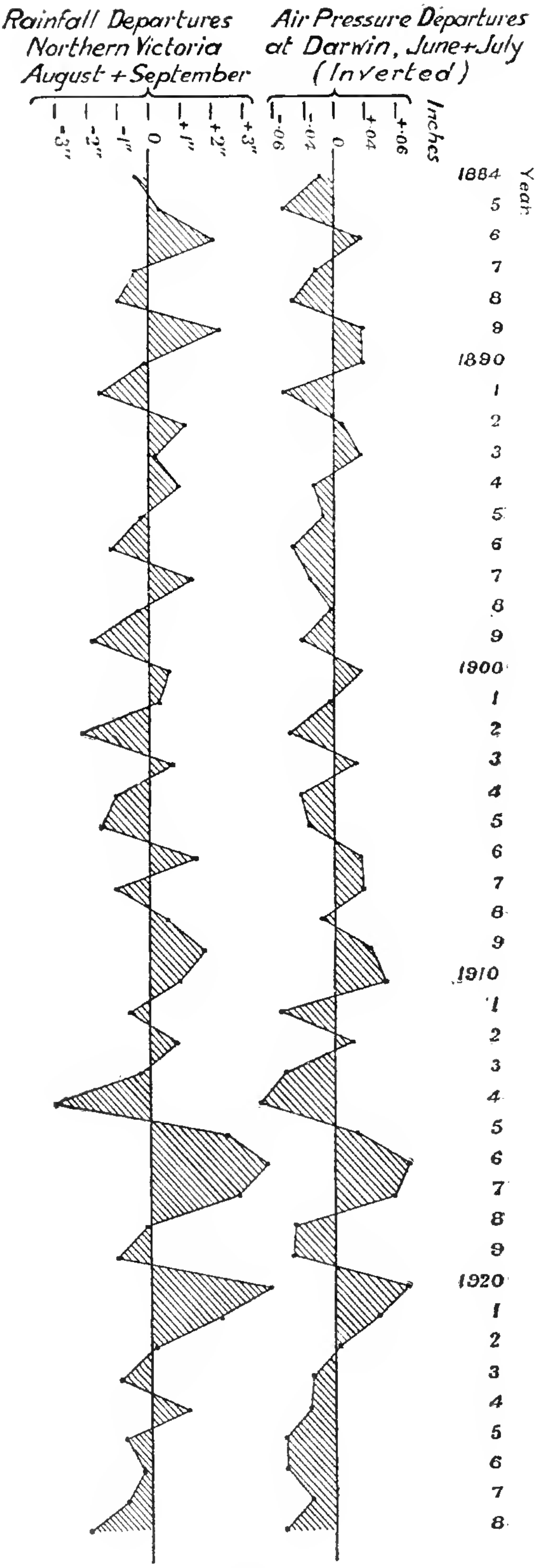
Rainfall Departures Northern Victoria August + September
Air Pressure Departures at Darwin, June+July (Inverted)
-3" -2" -1" 0 +1" +2" +3"
-·06 -·04 0 +·04 +·06
Inches
Year
1884 5 6 7 8 9 1890 1 2 3 4 5 6 7 8 9 1900 1 2 3 4 5 6 7 8 9 1910 1 2 3 4 5 6 7 8 9 1920 1 2 3 4 5 6 7 8

FIG. 1.

Pressure Departures at Darwin for		Rainfall over Northern Victoria for	Correlation Co-efficients.
March-April	with	May-June	—·15± ·098
April-May	,,	June-July	—·39± ·085
May-June	,,	July-August	—·65± ·057
June-July	,,	August-September .	—·79± ·038
July-August	,,	September-October	—·52± ·073
August-September	,,	October-November .	—·37± ·088

In Figure 2, the August-September rainfalls for Northern Victoria (ordinate) are plotted against the Darwin air pressure departures (abscissa) for June-July. Each unit represents for the former one inch, for the latter ten-thousandths of an inch.

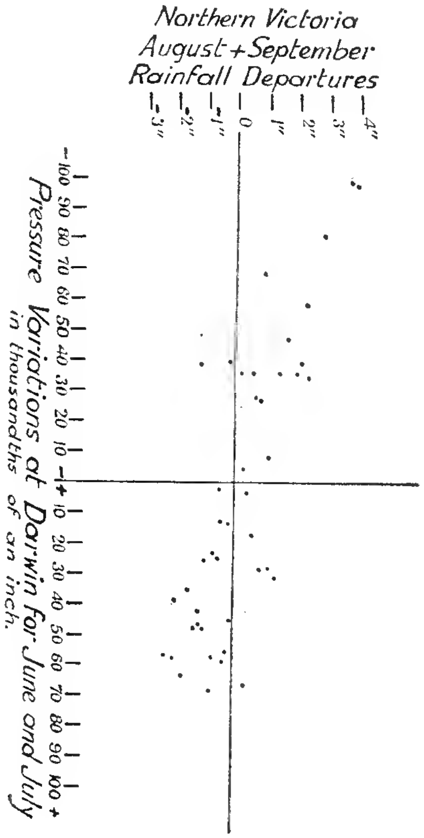

Fig. 2.

The proportionality between them is so well maintained that if we take the rainfall increase as nearly three-tenths of an inch for each one-hundredth of an inch fall in the monthly barometric mean at Darwin, we find for the 45 years under review that forecasts of the amount of rain so based upon the air pressures would have been less, or not more, than one inch in error on 35 occasions, and over two inches in error on two occasions only. If it were necessary to say only whether the rainfall would be above or below average, the percentage of forecast accuracy would have been 82.

It is to be noted that the rainfall normals used for this paper are based upon the 30-year period, 1885-1914. By using the whole 45 years the principal correlation co-efficients are slightly improved by ·01, i.e., —·79 becomes —·80.

[Proc. Roy. Soc. Victoria, 41 (N.S.), Pt. II., 1929.]

Art. XI.—*Solitary Waves at the Common Boundary of two liquids.*

By FRANCES E. ALLAN, M.A.

(Communicated by J. H. Michell).

[Read 11th October, 1928; issued separately 3rd April, 1929.]

The form and the velocity of solitary, or indefinitely long, waves in a single liquid have been examined experimentally by Scott Russell and mathematically by Boussinesq and Rayleigh. The much wider problem of the possible aperiodic wave forms at the common boundary of two superposed liquids does not seem to have received similar treatment. Those who have treated the subject of waves of finite height at the surface of separation of two liquids have dealt rather with the case of periodic waves, for which a different method is suitable. (Priestly, *Camb. Phil. Soc. Proc.*, 1910; Lamb, *ibid.*, 1922; Kolchine, *Math. Ann.*, 1927-8.)

The discussion here given follows the method used by J. H. Michell in unpublished work.

The motion is supposed two-dimensional, and will be treated as steady by choice of an origin of coordinates moving at the rate of the wave-form. The axis of x is taken horizontal and the axis of y directed upwards. The independent variables are changed from x, y to x, ψ where ψ is the stream function for the motion. This simplifies the treatment of the conditions over the boundaries, the coordinate ψ being constant over each of them. The dependent variable to be found in terms of x and ψ is now y, for which, therefore, a differential equation must be found. When y is found the form of a boundary is given in Cartesian coordinates by ascribing the corresponding constant value to ψ.

In carrying out the process of approximation we take as the general mathematical characteristic of the long-wave motion that the variation of a quantity specifying it (in particular, the gradient of the wave form), in a distance equal to the depth of either liquid, is a small fraction of the quantity itself. Thus, if we take the unit of length as of the order of magnitude of the depth of either liquid, the second derivative d^2y/dx^2 is to be a small fraction of dy/dx, and so for higher derivatives. The assumption is to include the smallness of dy/dx itself. The general discussion terminates in the expression of the gradient dy/dx of the wave form in terms of y. I have considered the conditions under which the gradient takes the factor form appropriate to either a crested or an inverted (trough) wave form. The expression of x in terms of y in general involves elliptic integrals of the third kind. Where the undisturbed depth of the lower liquid is small we may find an approximate equation involving an elliptic integral of the first kind only to determine the form of the symmetric wave. I have dealt, finally, with a case of asymmetric wave (bore) where the gradient-equation for the form can be integrated without further approximation.

The Differential Equation for y.

In terms of independent variables x, y, the corresponding components of velocity are given by

$$u = -\partial\psi/\partial y,$$
$$v = \partial\psi/\partial x,$$

and the vorticity by

$$\omega = \partial^2\psi/\partial x^2 + \partial^2\psi/\partial y^2.$$

When the independent variables x, ψ, are introduced we have

$$v = \left(\frac{\partial\psi}{\partial x}\right)_{y \text{ const.}}$$

$$= \frac{-\dfrac{\partial y}{\partial x}}{\dfrac{\partial y}{\partial\psi}}, \text{ when } y \text{ is a function of } x \text{ and } \psi,$$

and

$$u = -\left(\frac{\partial\psi}{\partial y}\right)_{x \text{ const.}}$$

$$= -\frac{1}{\dfrac{\partial y}{\partial\psi}}, \text{ when } \psi \text{ and } x \text{ are the independent variables.}$$

Also

$$\left(\frac{\partial v}{\partial x}\right)_{y \text{ const.}} = \left(\frac{\partial v}{\partial x}\right)_{\psi \text{ const.}} - \frac{\dfrac{\partial v}{\partial\psi}\,\dfrac{\partial y}{\partial x}}{\dfrac{\partial y}{\partial\psi}},$$

and

$$\left(\frac{\partial u}{\partial y}\right)_{x \text{ const.}} = \frac{\dfrac{\partial u}{\partial\psi}}{\dfrac{\partial y}{\partial\psi}}.$$

Therefore, as a function of x and ψ,

$$\omega = \frac{\partial v}{\partial x} - \frac{\dfrac{\partial v}{\partial\psi}\,\dfrac{\partial y}{\partial x}}{\dfrac{\partial y}{\partial\psi}} - \frac{\dfrac{\partial u}{\partial\psi}}{\dfrac{\partial y}{\partial\psi}}.$$

Whence, substituting for u and v,

$$\omega = \left\{-\frac{\dfrac{\partial^2 y}{\partial x^2}}{\dfrac{\partial y}{\partial\psi}} + \frac{\dfrac{\partial y}{\partial x}\,\dfrac{\partial^2 y}{\partial x\partial\psi}}{\left(\dfrac{\partial y}{\partial\psi}\right)^2}\right\} + \left\{\frac{\dfrac{\partial^2 y}{\partial x\partial\psi}\,\dfrac{\partial y}{\partial x}}{\left(\dfrac{\partial y}{\partial\psi}\right)^2} - \frac{\dfrac{\partial^2 y}{\partial\psi^2}\left(\dfrac{\partial y}{\partial x}\right)^2}{\left(\dfrac{\partial y}{\partial\psi}\right)^3}\right\} - \frac{\dfrac{\partial^2 y}{\partial\psi^2}}{\left(\dfrac{\partial y}{\partial\psi}\right)^3},$$

that is,

$$-\omega\left(\frac{\partial y}{\partial\psi}\right)^3=\frac{\partial^2 y}{\partial x^2}\left(\frac{\partial y}{\partial\psi}\right)^2-2\frac{\partial y}{\partial x}\frac{\partial y}{\partial\psi}\frac{\partial^2 y}{\partial x\partial\psi}+\left\{1+\left(\frac{\partial y}{\partial x}\right)^2\right\}\frac{\partial^2 y}{\partial\psi^2}.$$

Therefore for irrotational motion, where $\omega=0$, we have

$$\frac{\partial^2 y}{\partial x^2}\left(\frac{\partial y}{\partial\psi}\right)^2-2\frac{\partial y}{\partial x}\frac{\partial y}{\partial\psi}\frac{\partial^2 y}{\partial x\,\partial\psi}+\left\{1+\left(\frac{\partial y}{\partial x}\right)^2\right\}\frac{\partial^2 y}{\partial\psi^2}=0.(1)$$

To investigate a type of irrotational waves we must now find an approximate solution of this equation which will satisfy also the boundary conditions of the problem.

J. H. Michell has used this process as an alternative method of determining the well-known results for the infinitesimal and solitary long waves at the free upper surface of a liquid. The method applies equally well to problems on superposed liquids, and I have used it to find the equation to the form of the wave of finite height and wave length as far as the terms of the sixth order in the wave height.

The question to be considered here, however, is the form of the long wave at the boundary between two liquids in relative motion, the whole being confined between parallel planes at a distance h apart.

Let $y=0$, $y=h$ be the fixed horizontal planes between which the liquids lie. Let $\psi=0$ at $y=0$, $\psi=a$ at $y=h$ and $\psi=c$ at the interface of the liquids. Finally, let ρ, ρ' be the densities of the lower and upper liquids and U, V their respective "undisturbed" velocities.

At the first step in the approximate solution of the differential equation (1) for y, we neglect the first two terms as of the second order and the equation then reduces to

$$\frac{\partial^2 y}{\partial\psi^2}=0. \qquad \text{.................................(2)}$$

On integration, this gives, for the lower liquid,

$$y=\eta\psi, \qquad \text{.................................(3)}$$

where η is a function of x. (There is no term independent of ψ since $y=0$ when $\psi=0$.)

Substituting the value of y given by (3) in the second order terms of (1), and integrating again, we find

$$y+\tfrac{1}{6}\psi^3\left(\eta^2\frac{\partial^2\eta}{\partial x^2}-2\eta\left|\frac{\partial\eta}{\partial x}\right|^2\right)=\eta\psi, \qquad \text{.....................(4)}$$

and putting $y=\eta\psi$ in the second order terms of (4), we obtain

$$y+\tfrac{1}{6}\left(y^2\frac{\partial^2 y}{\partial x^2}-2y\left|\frac{\partial y}{\partial x}\right|^2\right)=\eta\psi. \qquad \text{.....................(5)}$$

Using the result

$$\eta=\frac{\partial y}{\partial\psi}+\tfrac{1}{2}\psi^2\left\{\eta^2\frac{\partial^2\eta}{\partial x^2}-2\eta\left(\frac{\partial\eta}{\partial x}\right)^2\right\},$$

and its consequence

$$\eta\psi = \psi\frac{\partial y}{\partial \psi} + \tfrac{1}{2}\left\{y^2\frac{\partial^2 y}{\partial x^2} - 2y\left(\frac{\partial y}{\partial x}\right)^2\right\},$$

we can write (5) in the form

$$y - \tfrac{1}{3}\left\{y^2\frac{\partial^2 y}{\partial x^2} - 2y\left(\frac{\partial y}{\partial x}\right)^2\right\} = \psi\frac{\partial y}{\partial \psi}. \quad \text{.................(6)}$$

For the upper liquid, when we integrate the equation $\partial^2 y/\partial\psi^2 = 0$ we get

$$y - h = \eta(\psi - a), \quad \text{..........................(7)}$$

since $y = h$ when $\psi = a$.

Following the same steps as in the case of the lower liquid we get the equation

$$y - h - \tfrac{1}{3}\left\{(y-h)^2\frac{\partial^2 y}{\partial x^2} - 2(y-h)\left(\frac{\partial y}{\partial x}\right)^2\right\} = (\psi - a)\frac{\partial y}{\partial \psi}. \quad \text{......(8)}$$

Since the pressure must be continuous across the interface, we deduce from Bernouilli's pressure equation the result

$$\rho q^2 - \rho' q'^2 = (A - 2gy)(\rho - \rho'), \quad \text{.... ....(9)}$$

for points on the interface, where q and q' are the velocities in the lower and upper liquids respectively at the point considered, and A is some constant.

But

$$q^2 = \frac{1 + \left(\frac{\partial y}{\partial x}\right)^2}{\left(\frac{\partial y}{\partial \psi}\right)^2},$$

and $\psi = c$, at the interface, so from (6) we find that at the interface

$$c\frac{\partial y}{\partial \psi} = y - \tfrac{1}{3}\left\{y^2\frac{\partial^2 y}{\partial x^2} - 2y\left(\frac{\partial y}{\partial x}\right)^2\right\}$$

and therefore

$$q^2 = \frac{c^2\left\{1 + \left(\frac{\partial y}{\partial x}\right)^2\right\}}{y^2\left\{1 - \frac{1}{3}\left(y\frac{\partial^2 y}{\partial x^2} - 2\left(\frac{\partial y}{\partial x}\right)^2\right)\right\}^2}$$

$$= \frac{c^2}{y^2}\left\{1 + \tfrac{2}{3}y\frac{\partial^2 y}{\partial x^2} - \tfrac{1}{3}\left(\frac{\partial y}{\partial x}\right)^2\right\}, \quad \text{.....................(10)}$$

and in a similar way we find

$$q'^2 = \frac{(c-a)^2}{(y-h)^2}\left\{1 + \tfrac{2}{3}(y-h)\frac{\partial^2 y}{\partial x^2} - \tfrac{1}{3}\left(\frac{\partial y}{\partial x}\right)^2\right\}. \quad \text{.........(11)}$$

Hence (9) becomes

$$\frac{\rho c^2}{y^2} - \frac{\rho'(c-a)^2}{(y-h)^2} + \tfrac{2}{3}\left\{\frac{\rho c^2}{y} - \frac{\rho'(c-a)^2}{(y-h)}\right\}\frac{\partial^2 y}{\partial x^2} -$$

$$-\tfrac{1}{3}\left\{\frac{\rho c^2}{y^2}-\frac{\rho'(c-a)^2}{(y-h)^2}\right\}\left(\frac{\partial y}{\partial x}\right)^2=(\mathrm{A}-2gy)(\rho-\rho'), \quad (12)$$

and this is the differential equation for the form of the interface. We may write it

$$\frac{\rho c^2}{y^2}-\frac{\rho'(c-a)^2}{(y-h)^2}+\tfrac{1}{3}\left\{\frac{\rho c^2}{y}-\frac{\rho'(c-a)^2}{y-h}\right\}\frac{d}{dy}\left(\frac{dy}{dx}\right)^2$$
$$-\tfrac{1}{3}\left\{\frac{\rho c^2}{y^2}-\frac{\rho'(c-a)^2}{(y-h)^2}\right\}\left(\frac{dy}{dx}\right)^2=(\mathrm{A}-2gy)(\rho-\rho'), \quad \text{.........(13)}$$

that is,

$$\frac{d}{dy}\left[\left\{\frac{\rho c^2}{y}-\frac{\rho'(c-a)^2}{y-h}\right\}\left(\frac{dy}{dx}\right)^2\right]=3(\mathrm{A}-2gy)(\rho-\rho')-\frac{3\rho c^2}{y^2}+3\rho'\frac{(c-a)^2}{(y-h)^2}. \quad \text{............(14)}$$

Integrating this we obtain

$$\left\{\frac{\rho c^2}{y}-\frac{\rho'(c-a)^2}{y-h}\right\}\left(\frac{dy}{dx}\right)^2=3(\mathrm{A}y-gy^2)(\rho-\rho')+\frac{3\rho c^2}{y}+\frac{3\rho'(c-a)^2}{y-h}+\mathrm{D}, \quad \text{............(15)}$$

where D is a constant of integration.

Thus

$$\left(\frac{dy}{dx}\right)^2=\frac{\{\mathrm{D}+\mathrm{B}y-3g(\rho-\rho')y^2\}y(y-h)+3\rho c^2(y-h)-3\rho'(c-a)^2y}{\rho c^2(y-h)-\rho'(c-a)^2y}, \quad \text{............(16)}$$

where $3\mathrm{A}(\rho-\rho')=\mathrm{B}$.

This is the expression found by J. H. Michell for the gradient. We now assume that this expression will factorize in such a manner as to give the desired wave form, and then consider the further conditions which will make such a form possible. That is, we suppose

$$\left(\frac{dy}{dx}\right)^2=\frac{-3g(\rho-\rho')(y-k)^2(y-k_1)(y-k_2)}{\rho c^2(y-h)-\rho'(c-a)^2y}. \quad \text{............(17)}$$

This makes $dy/dx=0$ and $d^2y/dx^2=0$ when $y=k$; and $dy/dx=0$ when $y=k_1$, and when $y=k_2$.

Thus with this form the condition that the surface may be horizontal when $y=k$, is satisfied.

Now for (16) to be equivalent to (17) we must have, by equating coefficients of y,

$$k^2k_1k_2=\frac{\rho c^2h}{g(\rho-\rho')}, \quad \text{..........................(18)}$$

$$3g(\rho-\rho')\{2kk_1k_2+k^2(k_1+k_2)\}=-\mathrm{D}h+3\{\rho c^2-\rho'(c-a)^2\}, \quad \text{..(19)}$$

$$-3g(\rho-\rho')\{k^2+2k(k_1+k_2)+k_1k_2\}=\mathrm{D}-\mathrm{B}h, \quad \text{......................(20)}$$

$$3g(\rho-\rho')\{2k+k_1+k_2\}=\mathrm{B}+3gh(\rho-\rho'), \quad \text{..........................(21)}$$

and from these equations (18)-(21) we deduce :—

$$k_1+k_2=\frac{\rho c^2}{k^2g(\rho-\rho')}-\frac{\rho'(c-a)^2}{(h-k)^2g(\rho-\rho')}+h, \quad \text{............(22)}$$

$$\text{and } k_1 k_2 = \frac{\rho c^2 h}{k^2 g(\rho - \rho')}, \qquad \text{.......................(23)}$$

so that k_1, k_2 are the roots of the equation

$$\alpha^2 - \left\{ h + \frac{\rho c^2}{k^2 g(\rho - \rho')} - \frac{\rho'(c-a)^2}{(h-k)^2 g(\rho - \rho')} \right\} \alpha + \frac{\rho c^2 h}{k^2 g(\rho - \rho')} = 0. \quad \text{...(24)}$$

We therefore have

$$2k_1 = h + \frac{\rho c^2}{k^2 g(\rho - \rho')} - \frac{\rho'(c-a)^2}{(h-k)^2 g(\rho - \rho')}$$
$$- \sqrt{\left\{ h + \frac{\rho c^2}{k^2 g(\rho - \rho')} - \frac{\rho'(c-a)^2}{(h-k)^2 g(\rho - \rho')} \right\}^2 - \frac{4\rho c^2 h}{k^2 g(\rho - \rho')}},$$

$$2k_2 = h + \frac{\rho c^2}{k^2 g(\rho - \rho')} - \frac{\rho'(c-a)^2}{(h-k)^2 g(\rho - \rho')}$$
$$+ \sqrt{\left\{ h + \frac{\rho c^2}{k^2 g(\rho - \rho')} - \frac{\rho'(c-a)^2}{(h-k)^2 g(\rho - \rho')} \right\}^2 - \frac{4\rho c^2 h}{k^2 g(\rho - \rho')}}.$$

We may write

$$\frac{c^2}{k^2} = \mathrm{U}^2 \quad \text{and} \quad \frac{(c-a)^2}{(h-k)^2} = \mathrm{V}^2,$$

since U is the velocity at infinity of the undisturbed lower liquid of depth k, and V is the velocity at infinity of the undisturbed upper liquid of depth $(h-k)$.

If we also write $\rho' = \lambda\rho$ and $\mathrm{V}^2 = \mu \mathrm{U}^2$ we have :—

$$2k_1 = h + \frac{\mathrm{U}^2}{g(1-\lambda)}(1-\lambda\mu) - \sqrt{\left\{ h + \frac{\mathrm{U}^2(1-\lambda\mu)}{g(1-\lambda)} \right\}^2 - \frac{4h\mathrm{U}^2}{g(1-\lambda)}},$$

$$2k_2 = h + \frac{\mathrm{U}^2}{g(1-\lambda)}\left\{ 1-\lambda\mu \right\} + \sqrt{\left\{ h + \frac{\mathrm{U}^2(1-\lambda\mu)}{g(1-\lambda)} \right\}^2 - \frac{4h\mathrm{U}^2}{g(1-\lambda)}}.$$

Necessary Conditions for such a Wave.

We have put the equation for the gradient into the form

$$\left(\frac{dy}{dx}\right)^2 = \frac{3g(1-\lambda)(y-k)^2(y-k_1)(y-k_2)}{\mathrm{U}^2[k^2 h - \{ k^2 - \lambda\mu(h-k)^2 \} y]}.$$

Now the denominator may be written $k^2(h-y) + \lambda\mu(h-k)^2 y$ and y is less than h at all points on the interface. Therefore the denominator is always positive. Hence, assuming $\lambda < 1$ (*i.e.*, $\rho' < \rho$), we must have $y - k_1$ and $y - k_2$ of the same sign, to make dy/dx real.

But y lies between k and either k_1 or k_2, since k, k_1, and k_2 are the turning values of y. Therefore, either

(i) $k < y < k_1 < k_2$,

or (ii) $k > y > k_2 > k_1$.

These alternatives represent

(i) a crested wave,

or (ii) an inverted wave.

There is no wave for a value of k between k_1 and k_2.

Thus, for values of k between 0 and k_1 there is a crested wave, and for values of k between k_2 and h there is an inverted wave.

Lamb has treated the infinitesimal wave at the interface between two liquids (see Lamb's Hydrodynamics, Arts. 231-234), and if in Lamb's result we make the wave length tend to infinity, we find, as we should expect, that the two heights at which infinitesimal long waves are possible are k_1 and k_2.

Now, since k_1 will be the height of the crest when a crested wave exists and k_2 will be the depth of the lower liquid at the trough in the case of an inverted wave, it will be necessary for k_1 and k_2 to be real if there is to be a wave form at all. Therefore, referring to the equation (24), we deduce the condition

$$\left\{h + \frac{U^2(1-\lambda\mu)}{g(1-\lambda)}\right\}^2 \nless \frac{4hU^2}{g(1-\lambda)}.$$

Approximation-Method for High Waves.

If we take k very small we find approximately

$$\left(\frac{dy}{dx}\right)^2 = C\frac{y(y-2k)(y-k_1)(y-k_2)}{y}$$
$$= C(y-2k)(y-k_1)(y-k_2),$$

for values of y near the crest, where C is a known constant. This makes

$$\sqrt{C}\,x = \int\frac{dy}{\sqrt{(y-2k)(y-k_1)(y-k_2)}}.$$

Hence we can find an approximate form for the wave in terms of an elliptic integral when the wave is near its greatest height.

The Asymmetric Long Wave.

There is, however, a type of long wave whose form can be determined from the differential equation without further approximation. This is the wave which we get on putting $k_1 = k_2$. Its differential equation is

$$\left(\frac{dy}{dx}\right)^2 = \frac{3g(1-\lambda)(y-k)^2(k_1-y)^2}{U^2[k^2h - \{k^2 - \lambda\mu(h-k)^2\}y]},$$

and therefore when $y = k$, or $y = k_1$, $dy/dx = 0$, and $d^2y/dx^2 = 0$.

This means that the wave has no crests but rises gradually, through an infinite horizontal distance from $y = k$ to $y = k_1$. The motion is here of the nature of a "bore."

Since k_1 and k_2 are the roots of equation (24), the condition that k_1 should be equal to k_2 is

$$\left\{\frac{\rho c^2}{h^2 g(\rho-\rho')} - \frac{\rho'(c-a)^2}{(h-k)^2 g(\rho-\rho')} + h\right\}^2 = \frac{4\rho c^2 h}{g(\rho-\rho')h^2}, \quad \text{.........(25)}$$

that is,

$$\left\{\frac{U^2}{g(1-\lambda)}-\frac{V^2\lambda}{g(1-\lambda)}+h\right\}^2=\frac{4U^2h}{g(1-\lambda)}. \quad \text{..................(26)}$$

This gives

$$h^2-\frac{2}{g(1-\lambda)}(U^2+\lambda V^2)h+\frac{(U^2-\lambda V^2)^2}{g^2(1-\lambda)^2}=0, \quad \text{...........(27)}$$

and the roots of this are always real, since $(U^2+\lambda V^2)^2 > (U^2-\lambda V^2)^2$. This means that for any given pair of values of the velocities U, V, of the currents, there are two possible values of h, the distance apart of the horizontal boundaries; they are given by

$$h=\frac{1}{g(1-\lambda)}(U \pm \sqrt{\lambda}V)^2. \quad \text{....................(28)}$$

If we regard equation (26) as an equation for V in terms of h and U we find

$$|V|=\frac{U \pm \sqrt{gh(1-\lambda)}}{\sqrt{\lambda}} \quad \text{.......................(29)}$$

When condition (26) is satisfied, we have, from (22)

$$k_1=k_2=\tfrac{1}{2}\left\{h+\frac{U^2}{g(1-\lambda)}-\frac{V^2\lambda}{g(1-\lambda)}\right\}, \quad \text{................(30)}$$

and on substituting for V from equation (29) we deduce

$$k_1=h\sqrt{\frac{U^2}{gh(1-\lambda)}}. \quad \text{.......................(31)}$$

The positive sign with the root in (29) would give

$$k_1=-h\sqrt{\frac{U^2}{gh(1-\lambda)}},$$

and we consider, therefore, only the negative sign. That is, we take

$$\lambda V^2=U^2\left\{1-\frac{\sqrt{(1-\lambda)gh}}{U}\right\}^2$$

$$=U^2\left(\frac{h}{k_1}-1\right)^2.$$

Now, returning to the equation for $(dy/dx)^2$, these results give

$$(dy/dx)^2=\frac{3g(1-\lambda)}{U^2}\frac{(y-k)^2(k_1-y)^2}{[hk^2-\{k^2-(h-k)^2(1-h/k_1)^2\}y]}$$

$$=\frac{3g(1-\lambda)k_1^2}{U^2h}\frac{(y-k)^2(k_1-y)^2}{[k^2k_1^2-\{k_1^2-(h-k)^2(h-k_1)^2\}y/h]}$$

$$=\frac{3(y-k)^2(k_1-y)^2}{[k^2k_1^2-\{k^2k_1^2-(h-k)^2(h-k_1)^2\}y/h]}.$$

Three cases now arise, depending on whether

(i) $kk_1 = (h-k)(h-k_1)$,

(ii) $kk_1 > (h-k)(h-k_1)$,

(iii) $kk_1 < (h-k)(h-k_1)$.

We shall now consider these separately.

(i) Here we have $kk_1 = (h-k)(h-k_1)$
and, therefore, $k + k_1 = h$.
This means that the highest and lowest levels of the wave are equidistant from the mean height $h/2$ of the liquids.
In this case

$$\left(\frac{dy}{dx}\right)^2 = \frac{3(y-k^2)(k_1-y^2)}{k^2 k_1^2},$$

and therefore

$$\frac{dy}{dx} = \frac{\sqrt{3}}{kk_1}(y-k)(k_1-y),$$

where y lies between k and k_1.

On integrating, if we choose the origin so that the constant of integration is zero, we find

$$\frac{\sqrt{3}}{kk_1}x = \int \frac{dy}{\left(\frac{k_1-k}{2}\right)^2 - \left(y - \frac{k+k_1}{2}\right)^2}$$

$$= \frac{2}{k_1-k} \text{ artanh } \frac{y - \frac{k+k_1}{2}}{\frac{k_1-k}{2}}.$$

Now changing over to a horizontal axis along the mean level, so that $y' = y - \frac{k+k_1}{2}$, we find the equation to the wave form is

$$\frac{k_1-k}{kk_1}\frac{\sqrt{3}}{2}x = \text{artanh}\frac{2y'}{k_1-k},$$

that is, $y' = a \tanh mx$,

where $a = \frac{k_1-k}{2}$,

$$m = \frac{\sqrt{3}}{2}\left(\frac{1}{k} - \frac{1}{k_1}\right).$$

(ii) Consider now the case $kk_1 > (h-k)(h-k_1)$.
Here

$$\left(\frac{dy}{dx}\right)^2 = \frac{3(y-k)^2(k_1-y)^2}{[k^2k_1^2 - \{k^2k_1^2 - (h-k)^2(h-k_1)^2\}y/h]}$$

$$= \frac{a^2(y-k)^2(k_1-y)^2}{\beta^2 - y},$$

where $\alpha^2 = \dfrac{3h}{k^2k_1^2 - (h-k)^2(h-k_1)^2}$ and $\beta^2 = \dfrac{k^2k_1^2}{3}\alpha^2$.

Now, since $kk_1 > (h-k)(h-k_1)$,
therefore $h < k + k_1$,
and therefore $h - k < k_1$ and $h - k_1 < k$.

But
$$\beta^2 = \frac{k^2k_1^2h}{k^2k_1^2 - (h-k)^2(h-k_1)^2}$$
$$= \frac{h}{1 - \dfrac{(h-k)^2(h-k_1)^2}{k^2k_1^2}}$$
$$= \frac{h}{1-\theta}, \text{ where } 0 < \theta < 1.$$

Therefore $\beta^2 > h$,
$> k_1$,
$> k$.

Now $\dfrac{dx}{dy} = \dfrac{1}{\alpha}\dfrac{\sqrt{\beta^2 - y}}{(y-k)(k_1-y)}$, therefore

$$(k_1 - k)\alpha x = \int \frac{\sqrt{\beta^2 - y}}{y-k}\,dy + \int \frac{\sqrt{\beta^2 - y}}{k_1 - y}\,dy$$
$$= -2\sqrt{\beta^2 - k}\ \text{artanh}\ \frac{\sqrt{\beta^2 - y}}{\sqrt{\beta^2 - k}} + 2\sqrt{\beta^2 - k_1}\ \text{arcoth}\ \frac{\sqrt{\beta^2 - y}}{\sqrt{\beta^2 - k_1}},$$

which is the equation to the wave form in this second case.

(iii) If $kk_1 < (h-k)(h-k_1)$,
$$(dy/dx)^2 = \frac{\alpha^2(y-k)^2(y-k_1)^2}{\beta^2 + y},$$

where $\alpha^2 = \dfrac{3h}{(h-k)^2(h-k_1)^2 - k^2k_1^2}$,

and $\beta^2 = \dfrac{k^2k_1^2}{3}\alpha^2$.

Therefore $\dfrac{dx}{dy} = \dfrac{1}{\alpha}\dfrac{\sqrt{\beta^2 + y}}{(y-k)(k_1-y)}$, and

$$\alpha x = \int \frac{\sqrt{\beta^2 + y}}{(y-k)(k_1 - y)}\,dy$$
$$= \int \sqrt{\beta^2 + y}\left\{\frac{1}{y-k} + \frac{1}{k_1 - y}\right\}\frac{1}{k_1 - k}\,dy\,.$$

Therefore

$$(k_1-k)\alpha x = 2\sqrt{k_1+\beta^2}\ \operatorname{artanh}\frac{\sqrt{y+\beta^2}}{\sqrt{k_1+\beta^2}} - 2\sqrt{k+\beta^2}\ \operatorname{arcoth}\frac{\sqrt{y+\beta^2}}{\sqrt{k+\beta^2}}.$$

The present paper embodies a small portion of the work done under the terms of a Research Grant for Mathematics in the University of Melbourne. The publication of the rest of the work has been postponed owing to the author's departure for England.

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Art. XII.—*The Geology and Palaeontography of the Cathedral Range and the Blue Hills, in North-Western Gippsland.*

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(With Plates XVII., XVIII.)

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Summary.

1. The Cathedral Beds, formerly believed to be of Upper Palaeozoic age, are demonstrated to be of pre-Upper Devonian, and probably of Upper Silurian age.
2. The western edge of the large area of igneous rocks which contains Mt. Torbreck and the Cerberean Ranges, is shown to consist of Upper Devonian rocks, mainly rhyolites, and these are shown to occur to an unknown extent to the east.
3. A newly discovered fish fauna from the Upper Devonian is described.
4. Silurian fossils from a new locality are listed, and a new stelleroid noticed.

Introduction.

Location.

The area studied is a roughly rectangular block of country stretching, along its western boundary, from Buxton to Taggerty, a distance of seven miles. It extends eastwards for five and a half miles from Taggerty, and three and a half miles from Buxton, and consists mainly of the southern two-thirds of the Parish of Taggerty, in the County of Anglesea.

The location was suggested in December, 1927, by Professor Skeats, as likely to reveal the relations between the Cathedral Beds (supposed Upper Devonian or Lower Carboniferous), and the dacites (supposed Lower Devonian).

The latter are, however, not present in the area, and the Cathedral Beds appear to be Silurian in age, while the supposed dacites are Upper Devonian rhyolites.

Previous Workers.

The amount of previous work done in this area is extremely small. In 1899 W. H. Ferguson reported as follows after a very rapid examination: "The rocks are layers of coarse and moderately coarse-grained sandstones, with some shales . . . the sandstones . . . contain a few well waterworn pebbles. . . . Ripple markings and filled-in desiccation cracks were noted. In some of the coarse-grained sandstones spots of very fine sedimentary rock were seen. . . . No fossils were found in the sandstones of the Cathedral Mountain, which is three or four miles in length. The rocks near this mountain are Upper Silurian porphyries, slates and sandstones. No clear contact could be found showing the relation of the Silurian rocks to the Cathedral sandstones, but the general lithological inference is that the Cathedral rocks are younger than the Silurian, and probably of Upper Palaeozoic age, Upper Devonian or Lower Carboniferous. On the east the sandstones join the fragmental porphyry formation at the Little River. These rocks, in other parts of the colony, have been referred to Upper Palaeozoic age." (Ferguson, 1899).

On this evidence, the Cathedral sandstones were coloured as Upper Palaeozoic on the Geological Map of Victoria, an inch to 8 miles, published later by the Survey.

Professor J. W. Gregory probably visited the area, and he published his idea of the structure in his handbook on the Geography of Victoria (Gregory, 1912, p. 72), showing the Cathedral sandstones as older than the volcanic rocks, which he believed to be dacites, and thought to be of Tertiary age. A rock section [400] at the Geology School is labelled "Dacite: Between Chapel Hill and the Cerbereans," and was probably collected by him. It is not, however, a dacite, but a section of the main rhyolite flow.

Professor Skeats (1910) writes, following Gregory:—"The map indicates a great mass of granitic rocks extending from near Narbethong, through Marysville, north-east to Mount Torbrech, whereas over most of this area the rock is certainly dacite." The granitic rock at Buxton is coloured as such by the Survey. The only other relevant record of geological work the author could find is a report by Dunn (1907) on gold and tin workings just outside the area here considered, and dealing with Silurian sediments only.

Physical Features.

The area is one of strong, even precipitous, relief. The Cathedral Range runs in a general SSE. direction from the Cathedral to the Sugarloaf (see map), and is a composite hogback grading to a razorback, with the dip slopes (often bare sandstone) to the east, and the escarpment on the west. There the slopes are covered with thick talus, and in profile this presents a curve of great beauty.

The crest of the range is determined by the outcrops of two beds of hard sandstone, extending the whole seven miles, and separated by soft shales. At the northern end the highest ridge, with the Cathedral Mount, is formed by the lower standstone, while in the south the highest ridge, with the Sugarloaf, is formed by the upper sandstone dipping easterly at 65°, and constituting a razor-back. The trough-shaped subsequent valley between the sandstones is called the Tableland. It is well grassed, and is used as a sheep run.

In the valley west of the Cathedral Range the Acheron River flows northwards to the Goulburn, while the valley east of that Range is occupied by the Little River, flowing north-north-west and later west to join the Acheron at Taggerty. The western boundary of the area studied is marked by the crestline of the Blue Hills, a range higher than the Cathedral Range, running generally NNE.-SSW. The slopes of this range are covered with rounded rhyolite boulders in the upper parts, but become clearer on the Silurian lower down. Chapel Hill lies in the traingle between the Little River and the Blue Hills. Immediately to the east of Buxton a resistant granodiorite-porphyrite has determined the formation of a steep and, especially at its southern end, high ridge. The river flats are swampy.

Nature of the Present Survey.

The combination of steep bouldery slopes, sometimes precipitous, dense growths of bracken, and in the gullies, tangled fern flora, made the work of surveying without a companion both arduous and difficult. The boundary of the Upper Devonian north-east of the Little River, the Buxton granodiorite, the Little River alluvium (where shown on the map), and a small but important area east of the Sugarloaf were traversed by compass, distances being paced. The Cathedral Beds were mapped approximately by radiations from fixed points on the main road, in the absence of a reliable method of measuring distances up steep slopes, and the talus from the Cathedral Range was marked in from sketches of the range. The outcrops on Chapel Hill, the talus from the Blue Hills, and the boundary of the Silurian to the east of Buxton, were sketched in from a knowledge of the country from memory, with the help of notes and sketches. The Lands Department's parish plans on a scale of 2 inches to the mile were used as the basis for all work.

Geology.

Yeringian (Upper Silurian).

1. *Typical Silurian.*

Shallow marine Silurian mudstones, sandstones and shales occur both in the north and the south. Fossils were found near the foot of the Blue Hills, in red sandstones showing miniature current bedding due to ripple-mark. The fossils are for the most part fragmental, and occur in small groups, suggesting re-sorting along a beach or on a sandbar. The following forms have been identified (the last four by Mr. Chapman):—

Anthozoa.	*Cladopora* sp.
Asterozoa.	*Taeniaster* (?), sp. nov. aff. *spinosus* Billings.
Brachiopoda.	*Orthis* (*Dalmanella*) *testudinaria* Dalman.
	Chonetes sp.
	cf. *Coelospira* sp.
Pteropoda.	*Coleolus* cf. *aciculum* J. Hall.
Cephalopoda.	*Orthoceras* sp.

The assemblage, especially *Cladopora* and *Dalmanella*, which are characteristic, indicates that the beds are Yeringian (Upper Silurian) in age. Indeterminate fragments of plants were found in several places along the Little River east of Taggerty. No fossils were found in the south near Buxton, but the Silurian rocks are apparently continuous on the west side of the Acheron from Taggerty to Buxton, as is shown on the Geological Survey's map, and in part confirmed by Dunn (1907). The beds are lithologically quite similar in the north and the south.

In the north the fossiliferous beds are overlain unconformably by the Upper Devonian, and are faulted against the Cathedral Beds along an east-west fault line. This fault is pre-Upper Devonian, beds of that age not being displaced by it. In the south the relations with the Cathedral Beds are different, the two apparently forming a conformable series. The Buxton granodiorite–porphyrite (? Lower Devonian) is intruded, perhaps as a sill, into the typical Silurian sediments, which are only slightly metamorphosed. Quartz veins, in part auriferous, are associated with the granodiorite.

On the north side of the Little River, the dip is 58° to the south-south-west, and the same dip and strike were found in a small creek just to the north of the fault, on the northern slopes of the Cathedral Range. No other outcrops were found where a definite dip could be obtained (see, however, p. 180).

2. *The Cathedral Beds.*

The rocks—hard sandstones, soft sandstones, and shales—which constitute the Cathedral Range and Chapel Hill, form a triangular outcrop between the Blue Hills and the Acheron Valley, ending abruptly in the north against a fault line. On the evidence before cited (see p. 177), they were previously regarded as of Upper Palaeozoic age.

Field Relations.

Ferguson could find ". . . no clear contact . . . showing the relation of the Silurian rocks to the Cathedral sandstones." Furthermore he says, "On the east the sandstones join the fragmental porphyry formation at the Little River."

(*a*) At their northern termination the Cathedral Beds are brought against the typical Silurian rocks by an east-west fault. Huge monoliths of crushed and shattered sandstone occur along the fault line, and the strikes are locally contorted. The evidence of faulting may be traced a short distance to the east before being covered by talus, and the further extension of the fault to the east is inferred from the abrupt termination of the Cathedral Beds along the east-west line. Evidence as to the hade is indefinite, but the general dip of the Cathedral Beds (especially on Chapel Hill away from the fault line may indicate that the downthrow is to the south. No indication of displacement of the Upper Devonian beds by this fault was seen.

(*b*) East of Buxton, the relations are different. Traversing eastwards from Buxton, we notice that

1. The typical Silurian beds are intruded by the granodiorite-porphyrite.

2. The Silurian can be traced without apparent break to the foot of the Blue Hills, and there the dip and strike are the same as those of the Cathedral sandstones which occur close by, and have the same relations to the Upper Devonian as does the typical Silurian. The following observations are significant:—

(*a*) 1½ miles W.20°N. from Buxton, the Silurian beds strike N.32°W. dip 40° westerly (Dunn, 1907). Compare

(*a'*) About a mile northwards along the Cathedral Range from the Sugarloaf, Cathedral Beds strike N.25°W. dip easterly at 60°.

(*b*) 3 miles E.10°S. of Buxton, the Silurian beds strike N.30°W. dip easterly at 70° (Dunn, 1907). Compare

(*b'*) Southern end of the Cathedral Range, Cathedral Beds strike N.35°W. dip 65° easterly. Furthermore, the Cathedral Range shows a marked parallelism with the trend lines in the Silurian in the southern part of the area, where no faulting occurs.

3. Just east of the Sugarloaf, in a small creek, the relations between the Cathedral beds and the Upper Devonian rhyolites can be clearly seen. The latter, striking N.25°E., and dipping at 30° easterly, overlie the Cathedral Beds, striking N.35°W., dipping 65° easterly, with a strong unconformity. The basal conglomerate, though developed further north, is absent here; but that we are dealing with the base of the rhyolite is shown by the well-developed prismatic jointing, which disappears higher up in the flow, the numerous linearly arranged sandstone inclusions which lessen in number and lose their linear arrangement higher up, and the slightly vesicular nature of the flow, which elsewhere is devoid of vesicles. Further, there is no contortion of strikes or brecciation in the Cathedral sandstones, such as are found where these beds are faulted in the north. Similar relations hold everywhere at the edge of the Upper Devonian series, being especially well shown south-east of Chapel Hill, where the characteristic oscillation ripple-marked sandstones are overlain by the Upper Devonian basal conglomerate.

The pre-Upper Devonian age of the Cathedral Beds is thus established, and their conformability with the Silurian strongly indicated. In the absence of palaeontological evidence as to their more precise age, the author has placed them high in the Upper Silurian series.

Lithology.

Ferguson's original description is in the main correct, though, even after extensive search, the present author could find none of the "well-waterworn pebbles" mentioned by him, the largest particles found being only a few millimetres in diameter. The sandstones are very thick-bedded, and where not cross-bedded, are even-grained. The jointing is somewhat irregular, curved cracks often forming in the thick, even beds. When not strongly weathered the sandstones are red, but leaching of the outer few millimetres of weathered blocks produces a white skin. Ripple-markings, mud-cracks, current-bedding, and hardened clay pellets were found.

Along the Cathedral Range, subaqueous current ripple-marks occur, rarely. On Chapel Hill, however, ripple-marks of symmetrical shape, and formed by wave action (oscillation ripple-marks), occur in profusion in fine sandstones of lighter colour than the Cathedral sandstones. At some horizons the successive ripple-marked layers are separated by only fractions of an inch, and the lengths of the ripples from crest to crest (wave-length) remain fairly constant, averaging a little over an inch. The direction of propagation of the water waves which produced the ripples remained fairly constant, also. Examples were found of superimposition of the ripples in parallel and slightly inclined directions. No current-ripples (asymmetric) were found on Chapel Hill.

Mud-cracks are rare, but were found at the Sugarloaf, the north end of the Cathedral Range, and on Chapel Hill. The former two examples are in very fine, indurated sediment, a thin parting between heavy sandstones. The polygons are small, about six or eight inches across. The latter example (Chapel Hill) is in a thick sandy mud bed, which is cracked to a depth of about eighteen inches, the polygons ranging up to fifteen inches across. The edges are here turned down conspicuously.

Sandstones showing current-bedding were found at the Sugarloaf, but nowhere else. The current-bedded layers are usually bounded by plane surfaces, though a very few show curved boundaries. The slopes are fairly steep, especially in the thicker beds, whose thickness is up to three feet between the bounding planes.

Inclusions of very fine sediments similar to the material of the mud-cracked layers on the Cathedral Range are common there, but are absent in the oscillation ripple-marked sandstones of Chapel Hill. They probably represent clay pellets rolled into the sands by current action.

The interbedded soft sandstones and shales are grass-covered, and the only outcrops are blocks in the roots of fallen trees. The bed separating the two sandstones of the Cathedral Range is a soft chocolate sandstone, and differs from the more yellowish shales of Chapel Hill. No fossils were found in any of the Cathedral Beds.

The Cathedral Beds differ from the Upper Palaeozoic rocks with which they were formerly included, in the absence of the conglomerates which are so characteristic of the latter, as described by Howitt (1876), Murray (1877), Kitson (1899), and Teale (1920), the absence of interbedded lavas, and the absence of fossils. They also dip at a much greater angle than the Upper Palaeozoic rocks, except where these are faulted. The author considers that much more detailed work than was possible in the time available will be necessary to elucidate the very interesting question of the conditions under which the Cathedral Beds were deposited. He would point out, however, that—

1. The Chapel Hill beds resemble somewhat the Berea sandstones of North America in the profuse development of the oscillation type of ripple-mark, with a generally constant direction of propagation, the absence of current ripples, and the lack of fossils (Hyde, 1919).

2. The Chapel Hill and the Cathedral beds were not deposited under exactly the same conditions, as is shown by their different physical characteristics (see above).

3. In the Grampians sandstones, a thick series in which no fossils were found for many years, the few remains now known indicate a marine origin for the beds in which they occur (Chapman, 1917).

4. The absence of cut-and-fill structures and coarse materials, and the scarcity of muds and sun-cracked layers, as well as the extent and thickness of the beds, are against either a flood-plain or sub-aerial deltaic origin.

(?) Lower Devonian.

Intruded into the Silurian sediments at Buxton and to the east of Taggerty is a granodiorite-porphyrite, which is placed in the Lower Devonian by analogy with the other Victorian granodiorites, which are supposed to be of this age. Such granodiorites occur near Marysville, to the south of the occurrence at Buxton. The latter is much more extensive than the outcrop at Taggerty, being a long and narrow outcrop traced for two miles in a NNW. direction, and continuing still further to the southwards. The obvious relation of its outcrop to the trend of the Silurian near by, and its long, narrow outcrop, have led the author to believe that it may be a sill. The amount of metamorphism of the adjacent sediments is but slight, being merely an induration, with some silicification and development of muscovite. Quartz veins are associated with this intrusion, and these have proved auriferous to the south of the area considered.

The occurrences at Taggerty are very small, perhaps offshoots from a larger concealed mass. Of note is the occurrence in these rocks of numerous pink garnets, sometimes showing dodecahedral outlines but more often rounded by reaction with the magma. Cognate (basic) and foreign xenoliths also occur.

Upper Devonian.

Beds of this age were discovered, forming the top of the Blue Hills and the ranges east of the Sugarloaf, and formerly believed to be Lower Devonian dacites. The main development is a series of acid lavas (rhyolites) of undetermined thickness, which outcrop along the whole of the eastern boundary of the area studied. Basalts and sediments also occur. There are numerous flows, the lower ones being interbedded with fossiliferous lacustrine and fluviatile deposits of limited areal extent; but the main rhyolite is recognisable continuously for over seven miles along its western edge, and the further extent to the south was not determined. Through the courtesy of the Director of the Victorian Geological Survey, Mr. Baragwanath, and his officers, the author had the privilege of examining some specimens collected by Mr. O. A. L. Whitelaw from the Mount Torbreck region, some nine miles to the east of the Blue Hills. The specimens proved to be of extreme interest, as they revealed the presence of exactly similar rhyolites, both in hand specimen and under the microscope, in that area, associated with typical dacites (as developed near Healesville, in the Dandenong Ranges, and at Mount Macedon) of supposed Lower Devonian age. A porphyritic granitic rock, very similar to that found at Buxton, is also in close proximity. The problems of the extent of the rhyolites and their relations to the granitic rocks are thus opened up.

A generalized sequence of the Upper Devonian is as follows:—

6. Rhyolite α (main flow, very thick).
5. Rhyolite β (small flow, in the north).
4. Basalt (in the north and south only).
3. Sediments (sandstones and shales in the north, bedded tuffs and volcanic breccias in the south).
2. Basal rhyolite.
1. Basal conglomerate (in the north).

The absence of the basal beds in places is due to their development only in the valleys of the Upper Devonian land surface.

They are overlapped by the main rhyolite flow, and where this rests on the Silurian directly, the upper Devonian land was high, so that the Sugarloaf was probably an upstanding peak then, as now (see Section E.-F., Fig. 1).

1. *The Basal Conglomerate.*

This extends uninterruptedly for nearly four miles along the Blue Hills, east of Chapel Hill. It is rather variable in thickness, reaching a maximum of about ten feet in the central part, and thinning out towards the north and south, where it is absent. The

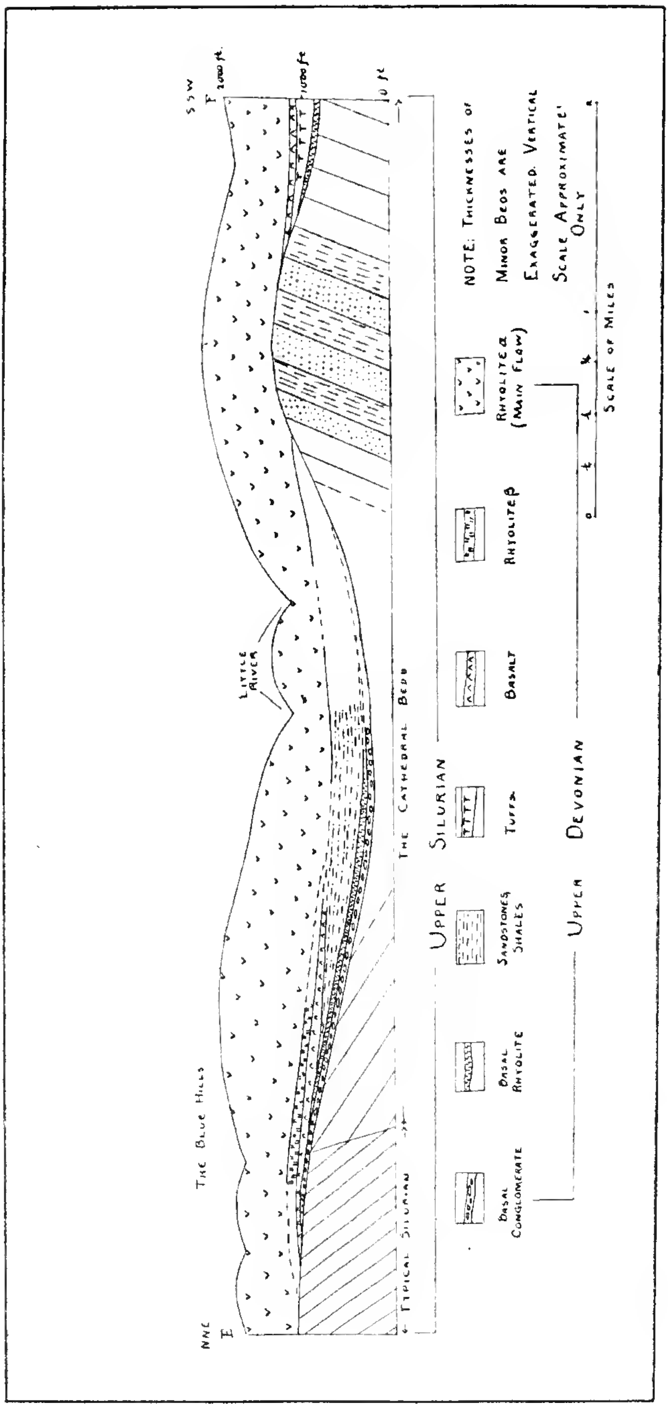

FIG. 1.—Diagrammatic section along the crest of the Blue Hills, parallel to the edge of the Upper Devonian outcrop.

coarseness varies in a like manner, the boulders in the centre being larger than elsewhere, reaching a foot or more in diameter. Some pebbles are well rounded, others flat and with the edges rounded off. They consist entirely of coarse sandstones, probably derived from the Cathedral Beds, and resemble fluviatile (valley-plain) deposits.

2. *The Basal Rhyolite.*

Locally, rhyolites of relatively small extent and thickness overlie the basal conglomerate, or rest directly on the Silurian where this is absent. These rhyolites generally show prismatic and platey jointing, and are lighter coloured and more weathered than the main flow. They are also more calcic, containing less free quartz and more plagioclase felspar (see p. 192).

3. *The Sediments.*

The basal flows of rhyolite apparently blocked the Upper Devonian streams, so that lakes were formed in which yellow and red sandstones, and red, blue and green shales were deposited. These sediments have yielded a fish fauna and remains of plants. The following forms occur:—

Ostracodermi. *Bothriolepis gippslandiensis*, sp. nov.
Dipnoi. *Eoctenodus microsoma*, gen. et sp. nov.
Holonema cf. *rugosum* Newberry, 1889.

This assemblage is a typically Upper Devonian one (see p. 198).

Numerous round impressions in the fossiliferous blue shales probably represent bubble impressions, the gas coming from the decomposition of the inclosed organisms (Twenhofel, 1921, 1926, p. 289). Round the organic remains, especially the plants, and along joint planes, the blue shales are buff in colour. The jointing, especially in the sandstones, is much less regular than in the Silurian beds which underlie the Upper Devonian.

East of Buxton, bedded tuffs and volcanic breccias overlie the basal rhyolite, and underlie the basalt and main rhyolite. The tuffs are of two kinds, one a blue-black, well-jointed, compact rock, grading with increased size of its component particles into the volcanic breccias, and the other a light, chocolate, poorly-jointed, fine-grained rock. Both are products of the basic igneous activity.

The volcanic breccias compare almost exactly in hand specimen and microscopically with Teale's "basal beds" from the Mt. Wellington area, labelled by him "basal breccia." In that area the relations of these beds were not clear, but at Buxton they are evidently part of the basal beds of the Upper Devonian series, as thought by Teale to be the case. Above them comes the basalt to which they are undoubtedly related.

4. *Basalt* (pp. 191).

Very dense, fine-grained, hard blue-grey basalts occur fairly constantly above the sediments and below the main rhyolite.

They are occasionally absent, as at the Sugarloaf and in the extreme north. At their farthest northerly occurrence they rest directly on the basal conglomerate, without any intervening sediments. There they are very amygdaloidal at the base, the amygdales being filled with chlorite and chalcedony, and there are small amygdales in most of the basalt sectioned from higher up in the flow. In other parts of Victoria the basalts are interbedded with the rhyolites, and always occur "consistently higher in the series than the Wellington rhyolites" (Teale, 1920). Although the name "melaphyre" has usually been applied to similar rocks by workers in other areas, the author feels that in view of their relatively fresh state, the term basalt is most suitable in the present case.

5. *Rhyolite β* (pp. 190).

In the north, a small flow of a black aphanitic rock with small, clear quartz crystals occurs above the basalt and beneath the main rhyolite. It is, again, less acid than the main flow.

6. *Rhyolite α* (pp. 188).

The most constant of the Upper Devonian rocks is the main rhyolite. Its thickness must be very great, though this was not determined, only the lower edge of the flow being examined. Its coarseness of grain led it to be identified as granite by the early surveyors.

The problem of the separation and distribution of the Upper Devonian and Lower Carboniferous series in South-Eastern Australia has long been a vexed one, and the discovery of the fish remains at Taggerty serves to give some definition to the data. Not only as regards structure and field relations, but also both macroscopically and microscopically, the rhyolites, "melaphyres," tuffs, conglomerates, shales and sandstones in the Cathedral district compare with similar rocks in the Upper Palaeozoic belt in Eastern Victoria, and the growing ideas as to their Upper Devonian age are strengthened. It should be noticed that the Taggerty fishes occur in beds stratigraphically beneath the main rhyolite flow, while many of the Lepidodendron sandstones in the great Upper Palaeozoic belt occur well above this flow, as at Mt. Wellington.

PLEISTOCENE (?) TO RECENT.

Deposits of greater age than the alluvium of the river valley-plains are represented in the alluvial fan from the Blue Hills, east of Taggerty, and the numerous alluvial cones and piedmont alluvial plain on the western slopes of the Cathedral Range. The creek which enters the Little River after flowing west past Andrews' house, aided by smaller streams, both tributaries of itself and of the Little River, has built an extensive alluvial fan. Owing to the removal of the lower edge of this by the Little

River, these streams are all now incised into the fan. It is composed of boulders, grading downwards in size to the individual quartz grains weathered from the rhyolites. The water-table is everywhere near the surface, as is shown by the numerous seepages which occur, both on its surface and more especially along its lower edge, where it is terraced by the Little River. The soil is rich, and the abundance of water and sheltered position make it valuable as farm land.

The talus produced by the rapid erosion of the Cathedral Range has formed extensive and very thick deposits between that range and the Acheron River. The numerous small wet weather streams which flow westwards down the escarpment face have each built a steep alluvial cone, and the coalescence of these has produced a very thick, continuous sheet of sediments. The streams which produced the sheet are now incised into it, because of the terracing of the lower edge by the Acheron. These deposits began to accumulate when the Cathedral Beds were exposed, in the process of dissection of the peneplain which was developed over Victoria in early Tertiary time. The date of the deformation of this peneplain is uncertain, but it is very probable that some of the above described deposits are at least as old as the Pleistocene.

The Acheron and Little Rivers and many of the smaller streams have alluvial flats, composed mainly of coarse boulders with interstitial fine silts. These flats are often swampy, especially in the upper reaches of the Little River. There, also, perfect small examples of alluvial cones are developing at the mouths of small streams from Chapel Hill. These cones have developed on top of the river alluvium since the last big flood, as they are unmodified by the river, the streams which formed them wandering indiscriminately over their surfaces.

Summary.

After the deposition of the Upper Silurian beds in shallow epicontinental seas (and perhaps other environments in part), they were compressed in Siluro-Devonian or Lower Devonian times, into a series of large folds. Probably in the Lower Devonian, associated with the final earth movements, a large sill or dyke of granodiorite was intruded in the south, and some smaller apophyses in the north. Before the Upper Devonian, normal faulting occurred. Owing to the acceleration of erosional processes consequent on the high relief imposed by the fold movements, Lower and Middle Devonian times are represented by an unconformity. Continental deposits accumulated in the Upper Devonian in lakes formed by the dislocation of the drainage system by small flows of rhyolite. In late Upper Devonian time basalts and huge masses of acid lavas were extruded. Subsequently, the region was subjected to pressure from ESE. and WNW., producing the present strikes and dips of the Silurian and Devonian rocks.

From the Upper Devonian to the Pleistocene, the resultant of earth processes has been erosion, and no deposits are found of an age intermediate between these two periods. In the early Tertiary a peneplain was produced, which later suffered uplift, so that it is now in process of dissection. Locally, continental deposits of Pleistocene and Recent age were produced, and these are even now being removed by the streams.

Petrography.

(The numbers in square brackets refer to slides in the collection at the Geology School, University of Melbourne.)

Rhyolite a. Cordierite Nevadite.

(Pl. XVII., Fig. 1.) [2244; 2245.]

Macroscopically and microscopically, this flow is extremely constant over the seven miles studied. It is a compact rock with dark cryptocrystalline groundmass and very numerous phenocrysts, a few millimetres in diameter, of clear quartz and cloudy felspar, usually white, but sometimes pink, and an occasional biotite. Fluxion structure is developed only along the lower edge, and even then is infrequent, though some beautiful specimens were found, coloured by weathering. Throughout the whole flow to some extent, but becoming more numerous towards the base, are xenoliths of sandstone and shale. Where the flow rests on the Cathedral sandstones the sandstone xenoliths are more numerous, and where it rests on the more shaly typical Silurian beds, the shale xenoliths, often altered to a spotted shale and always indurated, are more frequent. A few xenoliths of the basalt were found.

Chemical Composition.

	1.	2.	3.
SiO_2	74·72	74·39	78·64
Al_2O_3	13·05	14·28	9·85
Fe_2O_3	0·52	0·52	0·54
FeO	1·42	1·09	2·00
MgO	0·41	0·27	0·10
CaO	0·66	0·24	0·80
Na_2O	3·62	2·78	2·03
K_2O	4·31	5·33	5·16
H_2O+	0·61	0·22	0·40
H_2O-	0·13	0·56	0·14
CO_2	0·08	—	—
TiO_2	0·16	0·29	0·67
P_2O_5	0·38	tr.	tr.
MnO	—	n. det.	—
F	n. det.	n. det.	n. det.
Cl	tr.	n. det.	n. det.
Total	100·07	99·97	100·33

1. Rhyolite, Blue Hills, Taggerty. Analyst, E. S. Hills.
2. Rhyolite, Archer's Lookout, Narbethong, Analyst, N. R. Junner.
3. Rhyolite, Mount Wellington. Analyst, E. O. Thiele.

Norms and Classification.

	1.	2.	3.
Quartz	35·58	36·30	44·52
Orthoclase	25·58	31·69	30·58
Albite	30·39	23·63	17·29
Anorthite	0·56	1·11	2·22
Corundum	2·24	3·47	—
Hypersthene	2·85	1·76	2·68
Magnetite	0·70	0·70	0·70
Ilmenite	0·30	0·61	1·22
Apatite	0·93	—	—
Class—	Persalane	Persalane	Persalane
Order—	Quarfelic	Quarfelic	Quarfelic
Rang—	Peralkalic	Peralkalic	Domalkalic
Sub-Rang—	Sodipotassic	Sodipotassic	Do-sodipotassic
Magmatic Name—	Alaskose	Alaskose	Mihal-Tehamose

Under the microscope the quartz phenocrysts are seen to be rounded and embayed, often very deeply. The felspar is microperthitic orthoclase, the included felspar being quite abundant. It has a greater refractive index and double refraction than the orthoclase, and shows polysynthetic twinning. The high soda (and low lime) content of the rock points to the perthitic intergrowth as being albite or oligoclase-albite. The orthoclase phenocrysts are nearly as numerous as those of quartz, and about the same size; they show some rounding of the corners and edges, and are very fresh. Small plagioclase phenocrysts are of infrequent occurrence. Though the maximum extinction on the albite twinning lamellae ranges up to 26° in these, the refractive index is less than that of quartz. They may be oligoclase-andesine. A small amount of biotite is present in all sections, while in one it is more abundant as small flakes in a rather coarser groundmass than usual. Colourless cordierite, fresh in part, but often altered to muscovite (pinite) or almost isotropic chlorite, is also present. One section exhibits a trilling, but often all that remains of the original mineral is a brown micaceous or chloritic mass. Small blue tourmalines occur as single crystals and as radiating aggregates, and are often associated with the material filling the embayments in the quartz crystals. Small black specks in the groundmass are probably ilmenite.

The groundmass is micro- to cryptocrystalline, and always shows well-developed flow structure, the contorted lines curving round the phenocrysts of quartz and felspar, which are not arranged linearly. Biotite crystals curve with the flow lines, and wrap round the quartz and felspar. On solidification, the groundmass was evidently a glass, varying in composition from point to point. Some bands are coarser than others, and consist of colourless mica and material with undulose extinction and fairly high double refraction, which is probably a soda felspar. Other bands are cryptocrystalline, much of the material having a higher refractive index than quartz. Again, in some cases biotite flakes, quartz, felspar and colourless mica can be recognised, and occasional microspherulitic aggregates occur. Apatite needles are seen in the quartz and orthoclase, but the high norm of this mineral indicates that some is present in the groundmass.

Junner (1914) has described rhyolites from near Narbethong, which resemble very closely the above rock. He mentions, among other things, the occurrence of blue tourmaline, corroded quartz, and perthitic orthoclase. The analyses show an evident similarity also.

Rhyolite β [2246].

This is a black aphanite with small, clear quartz crystals and turbid felspar. Under the microscope it is seen to be crowded with angular fragments of quartz and felspar, which appear to represent broken crystals. This might be due to continuation of the process of embayment till the crystals are eaten through, or (Rosenbusch; Osann, 1923) to rapid cooling of the rock giving rise to shattering of the crystals. The felspar is both plagioclase and orthoclase, the former giving a maximum paired extinction of 22° on the albite lamellae, having a lower double refraction than that of quartz, and a high refractive index. It is thus andesine. Carlsbad twinning is sometimes shown as well as the albite, and zoning is well developed. The orthoclase is in general untwinned, and is about equal in amount to the plagioclase. A few fragments of pink garnet, and biotite flakes are present. The groundmass is cryptocrystalline, and micro-fluxion structure, due to an originally heterogeneous magma liquid, is sometimes seen. Apatite, inclosed in quartz crystals, is a common accessory, and veinlets of epidote and zoisite traverse the rock. A somewhat clastic appearance is shown under the microscope, and cherty-looking aphanites from near Narbethong have been described as silicified tuffs by Junner (1914). However, in the present case, the evidence points rather to solidification with sudden chilling of a lava flow, perhaps under water. Thus,

(*a*) Some of the shattered phenocrysts have not been separated, and the fragments as seen may be imagined as fitting together.

(*b*) The micro-fluxion structure shows that the groundmass is not clastic but igneous, representing a devitrified glass.

(*c*) The rock does not contain lapilli, and is quite distinct from the pyroclastics which occur at Buxton.

(d) The epidote and zoisite veinlets may be due to the action of caught up and heated water on the groundmass of the rock.

Small (microscopic) xenoliths of sandstone and basalt occur, but are not large enough to be seen in hand specimen.

An analysis of the rock gave the following result:—

		Norms and Classification.	
SiO_2	70·81	Quartz	33·48
Al_2O_3	15·73	Orthoclase	32·25
Fe_2O_3	0·76	Albite	14·67
FeO	1·97	Anorthite	6·95
MgO	1·30	Corundum	4·39
CaO	1·68	Hypersthene	6·47
Na_2O	1·75	Magnetite	0·70
K_2O	5·44	Ilmenite	0·15
H_2O+	0·54	Apatite	0·47
H_2O-	0·10	Class—Persalane	
CO_2	—	Order—Quarfelic: Columbare	
TiO_2	0·09	Rang—Domalkalic: Alsbachase	
P_2O_5	0·22	Sub-rang—Dopotassic: Mihalose	
Total	100·09	Analyst—E. S. Hills.	

Basalt [2250].

This is a hard, dense, fine-grained, grey rock. Under the microscope small phenocrysts of pale green augite are common, and these are sometimes glomeroporphyritic. Labradorite also occurs as phenocrysts and felted laths in the groundmass. Small rectangular crystals of black iron oxide are numerous, and carbonates are present in the groundmass. Irregularly shaped vesicles are scattered throughout, and contain mainly chalcedony, though in some concentric bands of chlorite are seen.

The rock is moderately fresh, but some chloritization of the pyroxenes has gone on, and an occasional large felspar shows complete decomposition to colourless mica, though others are quite unaltered. Local variations are mainly textural, one section showing macroscopic crystals of iron oxide, but no plagioclase or augite phenocrysts. In the north the flow is amygdaloidal, the amygdales being about a quarter of inch in diameter, and very numerous. They are filled with chalcedony and chlorite.

Volcanic breccia [2248].

This rock is dense, and contains numerous lapilli of grey-black altered basalt, set in a lighter-coloured matrix. The lapilli do not exceed an inch in length, and they grade downwards to small grains in the tuffs. Under the microscope the lapilli are seen to be of porous altered basalt, the vesicles being filled with chlorite and chalcedony, also epidote and carbonates. Numerous rhomb-shaped sections of an altered mineral occur, composed of serpentine and showing irregular cracks along which iron oxide is segregated. These are almost certainly altered olivine, and they are present in both the lapilli and the groundmass, in the latter case as fragments bounded by the curved fracture lines. The absence of olivine in the basalts above the tuffs is interesting, and indicates that the augite was produced by the reaction of the olivine with the magma. Small iron oxide crystals are numerous. In the groundmass of the rock detrital quartz occurs, with fragments of altered olivine and small fragments of the basalts.

Basalt tuffs.

The finer grained pyroclastics have weathered very strongly, giving chocolate and purple soft, light and friable material. The breccias and tuffs are both well bedded and jointed.

Basal rhyolite [2247].

The flows at the base of the series are less acid than the main rhyolite. They are light or dark grey, with a few quartz crystals and abundant tabular felspars set linearly in a fine-grained groundmass. Under the microscope, altered felspar and biotite and embayed quartz phenocrysts are seen. Acid oligoclase apparently predominates over orthoclase, though the alteration makes determination uncertain. Numerous blebs of limonite are apparently pseudomorphous after magnetite, the original parallel growth of the cubic crystals being readily made out. The groundmass is microcrystalline to cryptocrystalline.

Granodiorite-porphyrite [2249].

In hand specimen this rock shows moderate sized phenocrysts of quartz, white felspar and biotite, set in a finer groundmass. Much fissured pink garnets occur sporadically. They show dodecahedral outlines and are about half an inch in diameter. A few biotite-rich " basic segregations " were seen, and some xenoliths of country rock, altered to hornfels.

Under the microscope, the quartz is seen to be embayed. The rock weathers readily, all the specimens examined having cloudy felspars. The plagioclase gives a maximum extinction of 20° on the albite twin lamellae, and is andesine. Orthoclase is subordinate in amount to the plagioclase. The biotite is bleached and chloritized, and has numerous inclusions of zircon as elongated crystals arranged along the cleavage planes. Some zircon and apatite occur in the groundmass, which is composed of quartz, biotite and felspar. The latter is in part twinned plagioclase of lower refractive index than that of quartz, probably oligoclase, and in part untwinned felspar of low double refraction and lower refractive index than that of quartz, probably orthoclase. The cracks in the garnets are filled with chlorite and inclusions of biotite and apatite are present.

The Buxton and Taggerty granodiorites are exactly similar both macroscopically and microscopically, except that in a slide of the latter a fairly large piece of blue tourmaline showing radiate structure occurs.

Palaeontography.

Fish and Plant Remains from Taggerty.

Plantae.

The fragmental plant remains found in the blue shales which yielded the fishes described below are incapable of exact definition. Some are narrow, alternately branching stems, with indications of a relatively large central woody (?) cylinder. Miss I. Cookson, who examined these remains in the hope that they might be Psilophytales, says that they yield no indication of structure on treatment with hydrofluoric acid, and are indeterminate.

Others are unbranched and show indications of longitudinal ribbing, both coarse and fine. These resemble the "*Cordaites*" *australis* McCoy, from the Avon River beds.

Class PISCES.

Sub-class DIPNOI.

Order CTENODIPTERINI.

Family CTENODONTIDAE.

Eoctenodus, gen. nov.

Eoctenodus microsoma, gen. et sp. nov.

(Plate XVIII., Figs. 2-7; Text-fig. 2, Nos. 1, 2, 3, 5, 6.)

Type Material.—Dentaries of mature and immature individuals. Parasphenoid and median occipital bones of mature individual. Scales. Bones of the shoulder girdle.

The Palate.—Specimen JA. Impression of the lower surface of the left dentary (pterygopalatine with attached dental plate), preserved in fine blue shale, and cleaned by weathering. Dental plate elliptical, 0·55 cm. wide and 1·50 cm. long, bearing 10 denticulate sub-parallel ridges. The ridges increase in size from 1 to 10 (see Text-fig. 2, No. 1), and the denticles increase in size from inside to outside, being directed apically outwards.

Pterygopalatine. Maximum length 1·85 cm., maximum width 0·90 cm. (Text-fig. 2, No. 1, and Pl. XVIII., Fig. 7). JA shows the usual transverse crack across the alate extremity, but even so a distinct downward turn of this part is noticeable. No scar is present on the inner edge such as has been described for *Sagenodus* and *Ctenodus* (Watson and Gill, 1922-24), due to overlap of the parasphenoid. In *Eoctenodus* the latter bone apparently abutted against a ridge on the pterygopalatine. As is usual, the symphysis of the left and right pterygopalatines was weak, the three specimens found being separate. Both extremities of the alate portion are rounded and the lateral edges smoothly curved.

Specimens JE 3, JB 1. Mould of the left dentary, preserved in the same blue shale as JA, but unweathered. General description as for JA, but 9 ridges only present on the dental plate, and the whole somewhat smaller in size, indicating a younger individual. Differs also in that the ratio of breadth to length is greater than in JA. Pterygopalatine unbroken, and showing marked downward curving of the extremity. Thickness of dental plate at outer edge 1·25 mm.

Specimens C. XVII., *a,b.* Mould of left dentary of a very small form, probably the young of *Eoctenodus.* The dental plate measures only 0·4 cm. by 0·2 cm., and bears eight ridges, strongly denticulate, and all slightly concave forwards. Pterygopalatine relatively large compared with the dental plate, and of a peculiar shape (see Pl. XVIII., Fig. 2). Four denticles present on the larger ridges, directed apically outwards.

Specimens JFA, JF. Mould, in the same matrix, of a parasphenoid, the posterior shaft being incomplete. Length 3·5 cm., width 1·4 cm. JFA shows the impression of the cranial (dorsal) surface, and a plasticine squeeze reveals a ridge round the anterior part of the lozenge, which may have abutted against a similar ridge (*vide ante*) on the buccal surface of the pterygoids. Posteriorly a central ridge extends from the centre of the main lozenge into the attenuated basisphenoid. A peculiar median pit is situated on the anterior part of the lozenge. (Pl. XVIII., Fig. 5; Text-fig. 2, No. 5).

Cranial Roof Bones.—Specimens C.MO 1, 2. Mould, in the same matrix, of a median occipital, incomplete. Anterior process relatively large and sharply defined. Estimated length (of median occipital) twice the breadth. One surface smooth (outer ? surface), and bearing only slightly developed radiating ridges, the other, of which only the anterior part is preserved, bearing finely sculptured lines, radiating from the centre of the bone. Maximum thickness, 1·5 mm. Length of anterior process 8 mm., breadth of bone about 2·0 cm.

Specimen JD. Impression, in the same matrix, of a circumorbital (?) bone. 7·8 mm. by 4 mm., 1 mm. thick. It shows ridges radiating from a central rosette, and is bevelled along the two long edges, the surfaces of the bevel being roughened.

The Shoulder Girdle.—The Clavicle. Specimen C.C. Mould, in the same matrix, of the upper surface of the right clavicle. Shaft long and narrow, 2·4 cm. long, 0·6 cm. wide, tapering at the articulating end, which bears a well developed ridge and hollow. Head imperfectly preserved, but apparently not very long. The end of the shaft is cracked across and slightly displaced, and this may indicate that it has been flattened from a twisted shape.

The Cleithrum. Specimens C XVIII. *a,b.* Mould, in the same matrix, of the left cleithrum. Outer surface with a very strong, central ridge, continued into a strong articulating process. Outer edge thickened. The bone is concave inwardly (the orientation being as given by Watson and Gill, 1922-24), but has been crushed in preservation due to collapse of the thick, spongy, bony structure, so that it is probably incomplete at the expanded end. (Pl. XVIII., Fig. 4; Text-fig. 2, No. 6.)

Bones, indet.—C XV. 1. Group of small cylindrical bones, associated with a longer linear group. These may be fin-bones.

2. Fine straight bones up to 1 inch long. These may be ribs or fin rays.

C.C. Strong, curved bone with expanded end, oval in section. This may be a neural spine.

Squamation.—Scales thin, often subquadrate with rounded corners and slightly concave edges. Internal structure of fine radiating ridges and furrows. Exterior smooth, marked by concentric growth lines, the centre of growth being excentric. The largest found measured 14·25 mm. by 12·75 mm. A few subrhomboidal scales were found, and these are smaller. Some show what is thought to be remnants of the lateral line (Pl. XVIII., Fig. 3.)

Relationships.—The dipnoan above described shows relationships with *Ctenodus* in some of the characters of the dental plate, with its sub-parallel ridges and elliptical shape, the well defined anterior process of the median occipital, the relatively large, thin, sub-quadrate scales and the bones of the shoulder girdle. It is related most closely to the small or moderate sized *C. interruptus* of the Lower Carboniferous, but is distinctive in the fewer ridges on the dental plate, and is separated from all forms of *Ctenodus* by its distinctive parasphenoid, which indeed serves to separate it from all other dipnoans. In size it probably approximated to that of *Phaneropleuron* and *Scaumenacia.*

Subclass OSTRACODERMI.

Order ANTIARCHA.

Family ASTEROLEPIDAE.

Bothriolepis Eichwald, 1840.

BOTHRIOLEPIS GIPPSLANDIENSIS, sp. nov.

(Plate XVIII., Fig. 8; Text-fig. 2, No. 4.)

Type Material.—Impression of some plates of the head; impression of the external marginal of the right appendage.

Plates of the Head.—Specimen C.B. Impression, in fine, irregularly fracturing sandstone of the dorsal surface of some of the head plates of a *Bothriolepis.* Surface ornamentation of tubercles, fused more or less at their bases, producing distinctly

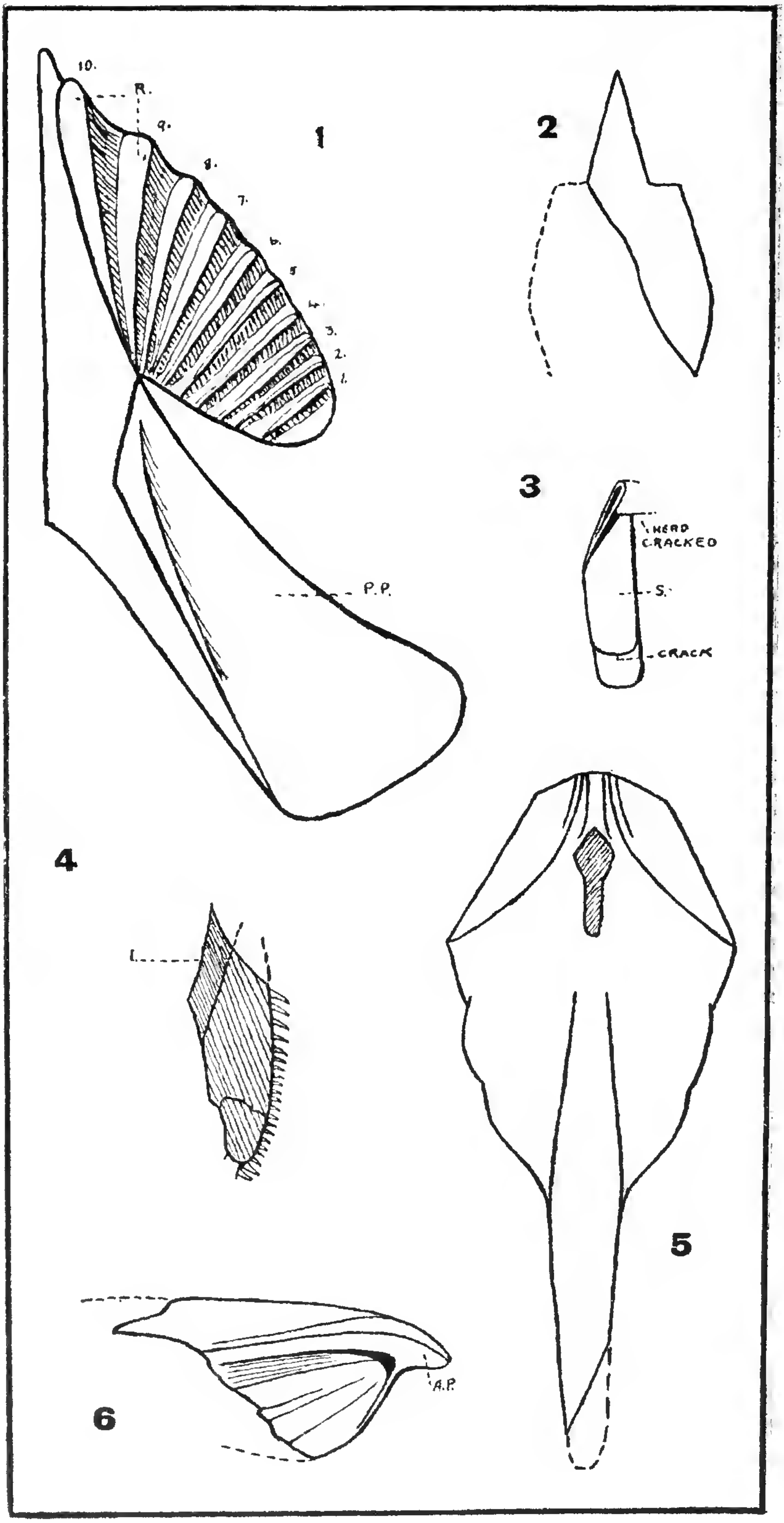

FIG. 2.

nodose ridges. The tubercles are often arranged linearly, e.g., parallel to the sensory grooves, which are united by a V-shaped commissure behind the orbits, and appear to bend round at the sides of the latter, instead of further anteriorly as in *B. canadensis* and *B. hydrophila.* (Pl. XVIII., Fig. 8.) Fracturing and displacement of the plates during preservation has, however, rendered the paths of these grooves outside the median occipital uncertain. The latter is wider than long, width 1·8 cm., length 0·9 cm. The post-median is missing, as are the orbitals.

Lateral Appendages.—Specimen C.L. Impression, in the same fine sandstone, of the external marginal plate of the right appendage. Marginal denticulations very strong. Ornament of fine parallel ridges, parallel to the line of junction with the interior marginal plate, and hence making an acute angle with the denticulate margin. Maximum width, 0·75 cm., exclusive of the denticles, length along the junction with the interior marginal 1·7 cm. The sudden constriction distally indicates that the distal end of the appendage is narrower than the proximal (Fig. 2, No. 6).

Relationships.—The above *Bothriolepis* resembles *B. canadensis* in the strongly denticulate margins of the appendages, but differs in the relatively short, compressed median occipital, in the disposition of the sensory grooves, and in size.

Sub-Class DIPNOI.

Order ARTHRODIRA.

Family PHYLLOLEPIDAE.

Holonema Newberry, 1889.

Holonema cf. rugosum Newberry, 1889.

Specimen C.H. Mould, in fine sandstone, of a plate of a placoderm fish, incomplete. Specimen measures 5 cm. by 2·5 cm. Ornament of radiating rugae, which are rounded, and in general equal in width to the separating grooves. One edge shows a slightly obtuse angulation. Maximum thickness shown 2 mm., which is near an edge, so that probably the plate was thicker in other parts. Compares almost exactly in pattern and size with the figure given by Newberry (1889, pl. xviii., fig. 4). "*Holonema rugosum.* Portion of lateral plate of carapace(?), natural size."

Fig. 2.

1. *Eoctenodus microsoma*, sp. nov. Dentary, drawn from a wax squeeze. R., Denticulate ridges (denticulations not shown), numbered from 1 to 10. P.P., pterygopalatine. ×4.
2. *Eoctenodus microsoma.* Median occipital, in part restored, showing anterior process. ×2.
3. *Eoctenodus microsoma.* Clavicle, drawn from a wax squeeze. S, shaft. ×1.
4. *Bothriolepis gippslandiensis*, sp. nov. External marginal of the right appendage. I, inserted area. ×4/3.
5. *Eoctenodus microsoma.* Parasphenoid restored. Cranial surface, from a squeeze. The shaded area is a pit. ×13/5.
6. *Eoctenodus microsoma.* The cleithrum, from a wax squeeze. A.P., articulating process. ×3/2.

Discussion.

The assemblage of fishes above described is a typically Upper Devonian one, and resembles in a remarkable way the suite of Chemung (Upper Devonian) age at Scaumenac Bay, Canada. In both localities we find a primitive small dipnoan, a coccostean form, and *Bothriolepis*, associated with plant remains (and in Canada, more fishes). This is interesting in view of the close resemblance Benson has shown to exist between the marine Upper Devonian rocks of New South Wales and the Chemung marine beds of the Eastern United States (Benson, 1922).

It is interesting to note that Dr. Smith Woodward writes (1904): "It may be said that . . . *Bothriolepis* and *Asterolepis* characterise the Upper Old Red Sandstone or Upper Devonian wherever it occurs—in Britain, Belgium, Germany, Russia, Spitzbergen, Greenland, Canada and the Catskills of New York." As the only other Upper Devonian fossils which had been found in Victoria up to the present were plant remains, some of which are of doubtful value, the present discovery serves to give some definition to our ideas of the Upper Palaeozoic succession in Victoria.

In conclusion, I wish to acknowledge my indebtedness to those who have freely given their advice and help during the progress of the research. To Professor Skeats especially, under whose direction the work was carried out, I must convey my thanks for his ready counsel on all occasions, his companionship for a few days in the field, and his criticism and encouragement. To Mr. Chapman, who has been my guide on all palaeontological questions, who determined some of the Silurian fossils, and who allowed me to use specimens in his care at the National Museum for comparison; to Miss I. Cookson, for help with the plant remains; to Mr. D. McCance, who smoothed out my paths in chemical analysis; and to Mr. J. S. Mann, who photographed the specimens figured in this paper, I must also express my thanks.

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EXPLANATION OF PLATES.

PLATE XVII.

Geological Map of the Cathedral District.

Notes on the Map.

The absence of contours renders the interpretation of this map a little difficult, because of the strong relief. The bending round of the outcrops of the Cathedral Beds at the north and south ends of the range is due to the form assumed by the beds on erosion. Between Chapel Hill and the Cathedral Range there is probably a fault, whose line is hidden under alluvium.

The wave-like edge of the talus along the Cathedral Range is meant to represent the numerous regularly developed alluvial cones descending from the escarpment.

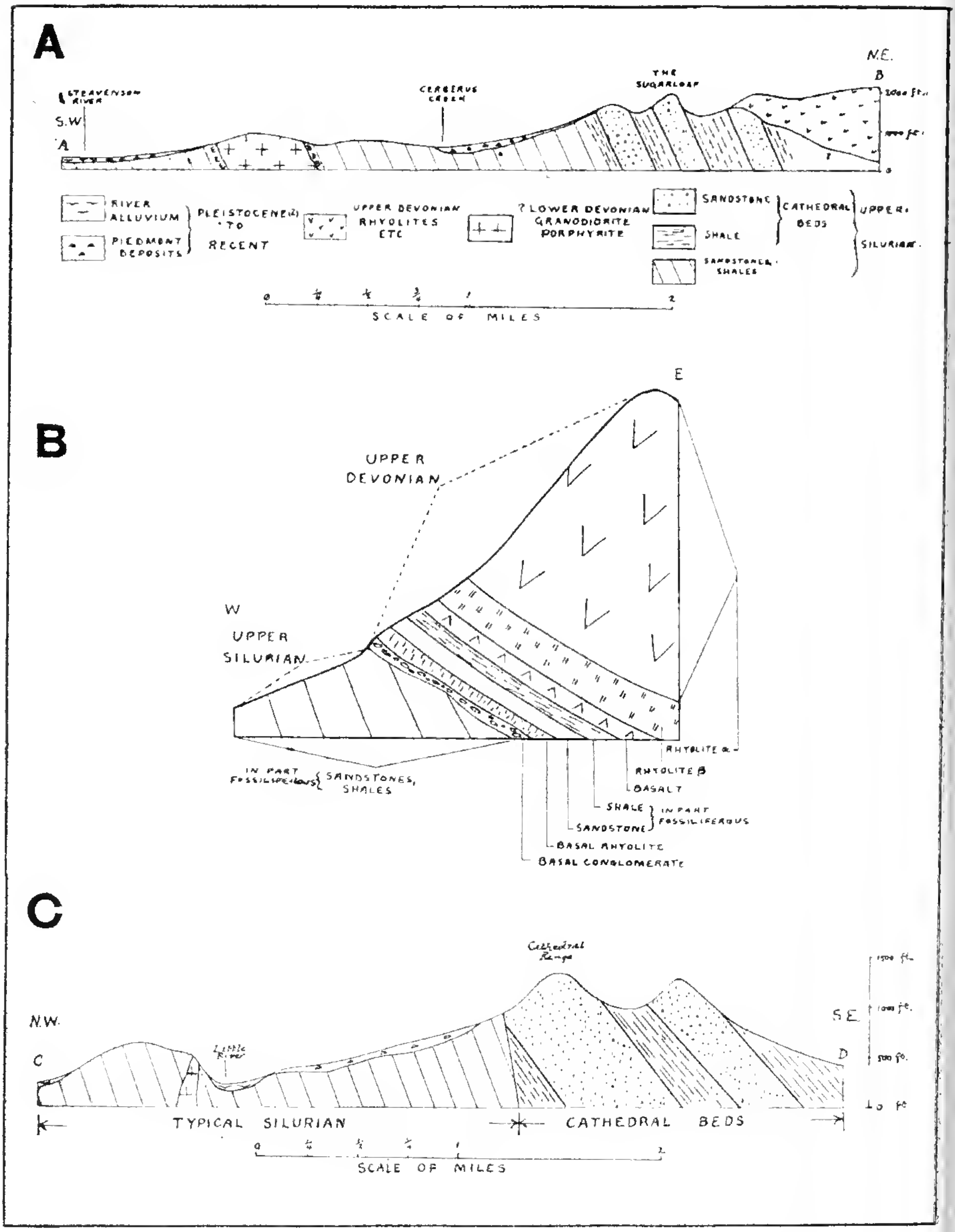
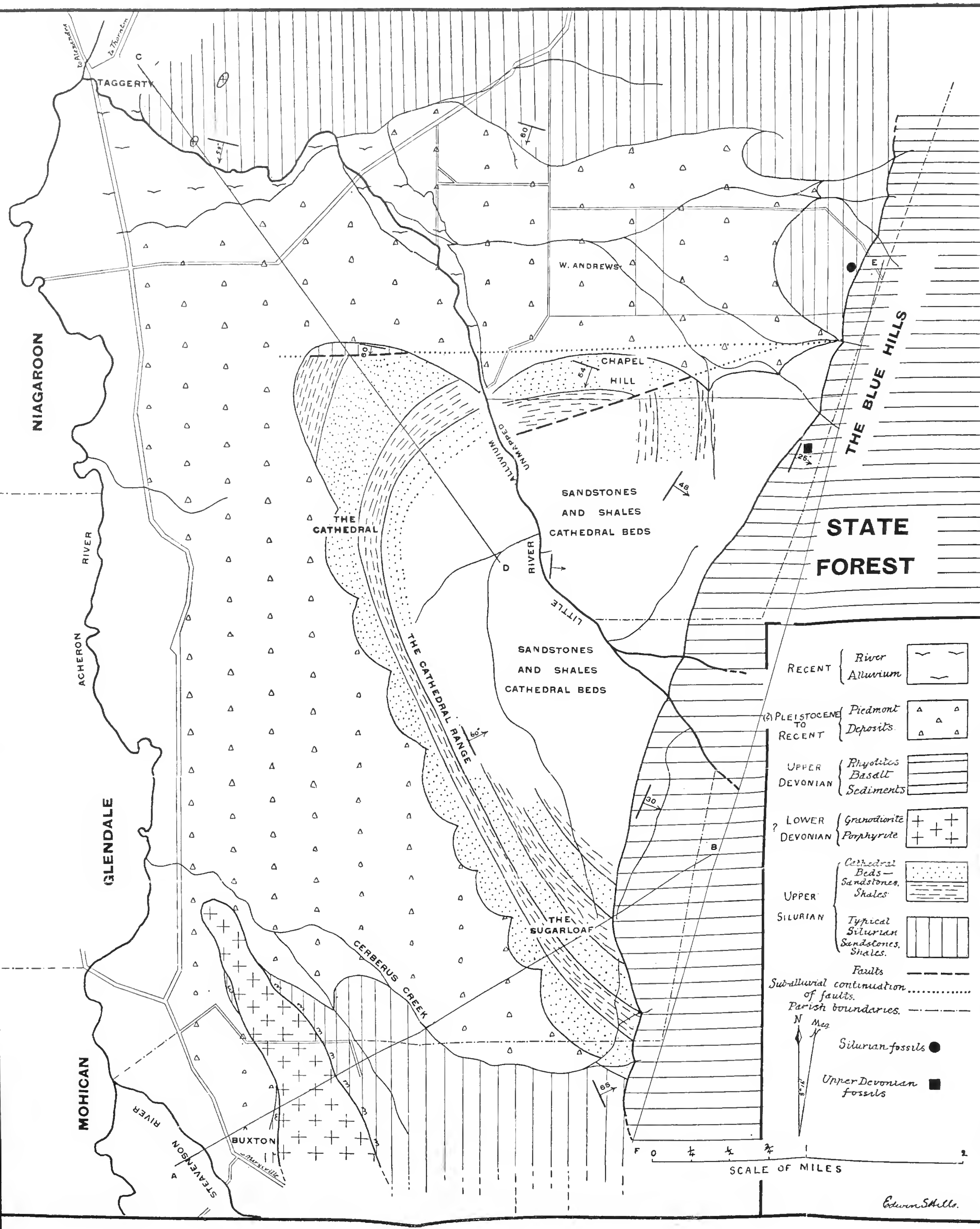


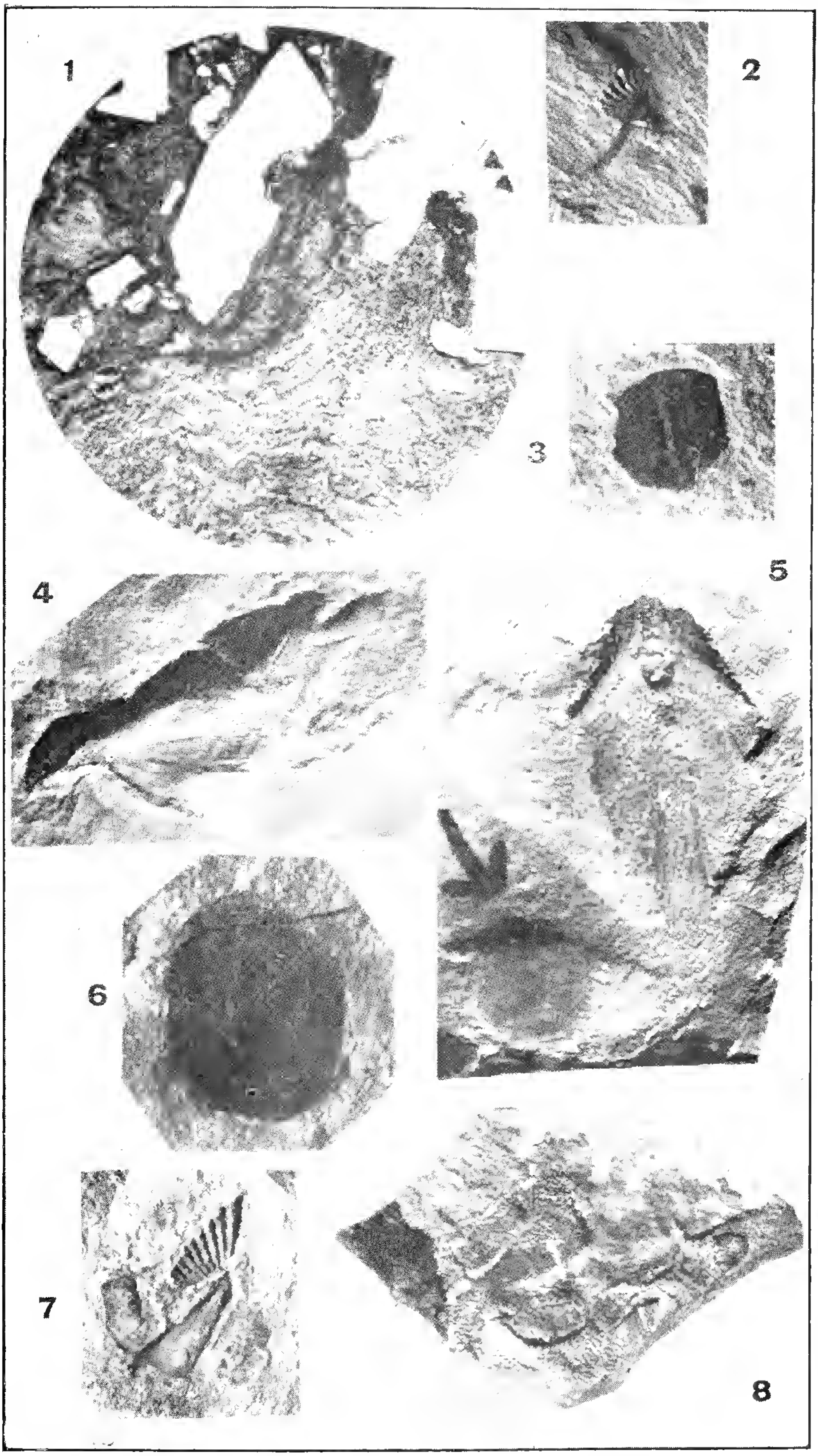
FIG. 3.—A: Sketch section along the line A B from SW. to NE. through the Sugarloaf, Buxton.

B: Diagrammatic section from west to east across the summit of the Blue Hills, showing the relations of the Upper Devonian and Silurian rocks in the north.

C: Sketch section along the line C D from NW. to SE., across the north end of the Cathedral Range, Taggerty.

GEOLOGICAL MAP OF THE CATHEDRAL DISTRICT





Devonian Fishes, Taggerty.

Plate XVIII.

Fig. 1.—Section of Rhyolite *a* (cordierite nevadite), from the Blue Ranges, Taggerty. Ordinary light, showing embayment of quartz, and flow-structure in the groundmass. × 25.

Fig. 2.—*Eoctenodus microsoma*, sp. nov. Impression of buccal surface of left dentary of young. ×2. [770].

Fig. 3.—*Eoctenodus microsoma.* Scale, showing lateral line. ×2. [771].

Fig. 4.—*Eoctenodus microsoma.* Impression of the outer surface of the left cleithrum. ×5/3. [772].

Fig. 5.—*Eoctenodus microsoma.* Impression of the cranial surface of the parasphenoid, incomplete posteriorly. ×2. [773].

Fig. 6.—*Eoctenodus microsoma.* Scale, showing internal structure. ×2. [774].

Fig. 7.—*Eoctenodus microsoma.* Impression of buccal surface of the left dentary, and another small bone, indet. ×1. [775].

Fig. 8.—*Bothriolepis gippslandiensis*, sp. nov. Impression of the exterior surface of part of the head, showing median occipital bone with V-shaped sensory canals. ×1. [776].

Note.—Owing to an optical illusion, it is possible that the impressions of the bones of *Eoctenodus* (Figs. 2, 4, 5, and 7) may appear as the actual or positive, rather than the impression.

Numbers in brackets refer to registered specimens in the collection of the Department of Geology, University of Melbourne.

[PROC. ROY. SOC. VICTORIA, 41 (N.S.), PT. II., 1929.]

ART. XIII.—*On the Flanged Cowry, Palliocypraea gastroplax.*

By FREDK. CHAPMAN, A.L.S., F.G.S., etc.

(With Plates XIX., XX.)

[Read 13th December, 1928; issued separately 3rd April, 1929.]

Occurrence of Specimen.

The remarkable cowry described by the late Professor Sir Frederick McCoy, under the name of *Cypraea gastroplax* (McCoy, 1875, p. 20, pl. xvi., fig. 1; pl. xvii.; pl. xviii., fig. 2), remained a unique specimen, so far as the National Museum collection is concerned, until the subject of this note was found by Mr. Walter Greed, of Hamilton. Mr. Greed discovered his specimen, a nearly perfect example, in the lower beds at Clifton Bank, Muddy Creek, Hamilton. He presented it to the National Museum on the 3rd March, 1924 (Reg. No. 13273). The fragility of the Muddy Creek specimen makes it surprising that the shell was obtained in so perfect a condition. As it is, however, a portion of the thin shelly flange has developed cracks more or less parallel with the periphery, and portions that came away had to be supported with paper. Other fractures seen in the shell run in zig-zag fashion across these peripheral cracks right through the flange into the dome of the shell. The prevalence of these fractures in the shell and flange seems to suggest that there was an abnormal amount of organic basis in this type of shell, which, on the extraction of the specimen from the stratum gave rise, by rapid drying, to contraction and compensatory rifting.

Detailed Description of Fossil.

The form of the body of the shell is broadly pyriform, roundly contoured anteriorly, and tapering rapidly posteriorly. The profile shows a strong humping of the body of the anterior, with the spire nearly flush with the general shape, comparable with the roundly based *Cypraea sphaerodoma* Tate. The lower surface of the shell is nearly flat, with a gently furrowed or depressed margin on the upper surface, indicating the junction of the body of the shell with the explanate flange. The aperture runs the whole length of the shell, is gently sinuous in the middle, strongly arched towards the anterior, and slightly undulose posteriorly. The usually crenate margin of the aperture is well marked, the teeth becoming obsolete at about one-fifth from either end. Both apertural openings are slightly expanded and tubular. During the examination of this fragile specimen a portion of the flange, with the surface of the body of the shell, became loose, thus revealing a stouter shell layer beneath, over which the thin enamel lay like a glaze.

The length of the shell, from the anterior edge of the flange to the posterior, measured along the apertural region, is 97 mm. The greatest width from side to side is 90 mm. The length of the body whorl, from the centre of the spire at the apex to the base of the body within the siphonal extension, is 56 mm. The greatest width of the body whorl is 52 mm. The greatest height of the shell, measured from the base, is 33 mm.

Cossmann and Vredenburg on Palliocypraea.

Cossmann, in his original descriptions of his subgenus *Palliocypraea,* makes reference to Dr. G. B. Pritchard's specimen from Mornington, which he figures (Cossmann, 1906, pl. ix., figs. 10, 11), as the genotype of "*Rhynchocypraea* (*Palliocypraea*) *gastroplax* McCoy." Pritchard's specimen is really a plesiotype, for the genotype (which can be a name only) is *Cypraea gastroplax* McCoy. This latter is represented by the holotype of the species, in the National Museum (Reg. No. 12140). Cossmann states the age of the Mornington specimens as "Eocene," but both the Mornington and Muddy Creek (Lower) beds are now usually regarded as Oligocene, and certainly not Eocene.

In an exhaustive summary of the Family Cypraeidae, E. Vredenburg (Vredenburg, 1920, pp. 126, 128), refers McCoy's *Cypraea gastroplax* to a section of *Gisortia* under Cossmann's name of *Palliocypraea.* He cites two species—*C. gastroplax* McCoy and *C. mulderi* Tate. From a consideration of the form of the latter shell, however, it appears quite incompatible to associate the two species, for *C. mulderi* has a broadly ovoid contour to the body whorl, and the only approach to a flange is in the depressed and round edged base of the shell.

Morphological Considerations.

In his original description of this cowry McCoy said: "The enormously extended circular thin flange into which the base is extended, renders this cowry totally unlike any previously known living or fossil species." This statement still seems to hold good, and the genus *Palliocypraea* is therefore monotypic. One calls to mind the families of the *Aporrhaidae* and the *Strombidae* in which the outer lip of the body whorl is extended, flattened and fingered, and which extension sometimes involves the entire length of the shell. This extension does not, however, surround the shell, and possibly only in *Cypraea* could this be effected, since in that genus or its allies there is a greatly expanded mantle which covers, or nearly so, the whole body and base of the shell.

In *Trivia* the edges of the mantle do not quite junction, as may be seen in the median dorsal furrow dividing the costate ornament.

The flange in this species has no morphological connection with an expanded lip, as in the genera mentioned, nor with the thin everted lip of an embryo cowry, which in after life becomes introverted and crenulate. The shelly flange is, therefore, an exogenous growth in continuity with the periphery of the shell and was probably the result of using up a redundancy of shell material as a secretion of the basal part of the mantle, which otherwise would have been utilised in adding to the body whorl of this extraordinarily thin cowry shell. The shell flange, moreover, would obviously be advantageous to the cowry in creeping over an even-surfaced oozy sea-bed.

Although we consider it better to regard *Palliocypraea* as worthy of separate generic rank, there is no doubt that the body form shows it to be related to the group often referred to as *Gisortia*. Thus we may cite *C. leptorhyncha*, *C. ampullacea*, *C. eximia* and *C. sphaerodoma* as representative of this type of shell, which, indeed, was already established in Lower and Middle Tertiary times, whilst in *C. umbilicata* we have a survival to the present in Austral seas.

Conditions of Deposition in the Muddy Creek and Balcombe Bay Beds.

The bed at Clifton Bank, where Mr. Greed's discovery of *Palliocypraea gastroplax* was made, is a yellowish, friable shelly sand or marl containing numerous polyzoa and the pteropod, *Vaginella*, together with some foraminifera. The finer muddy portion of the matrix seen in the Balcombe Bay specimen is wanting in the Muddy Creek deposit, but in both localities fairly deep water conditions are indicated by the occurrence of pteropod shells.

The foraminifera of the Balcombe Bay impure limestone add somewhat to the depth estimation of water in that locality in Balcombian times, and this is further substantiated by the prevalence of glauconite grains.

At a rough estimate *Palliocypraca* lived in the Balcombian sea in the Port Phillip area at between 200 and 400 fathoms, whilst in the Muddy Creek (Clifton Bank area) its probable depth would be 100 fathoms or less.

Comparison of the Present Specimen with the Balcombe Bay Holotype.

McCoy's type specimen is stated to come from " the Oligocene Tertiary limestone of the tract between Mount Eliza and Mount Martha on the shores of Hobson's Bay." In explanation we may remark that the precise locality, seeing that the shell occurred in a

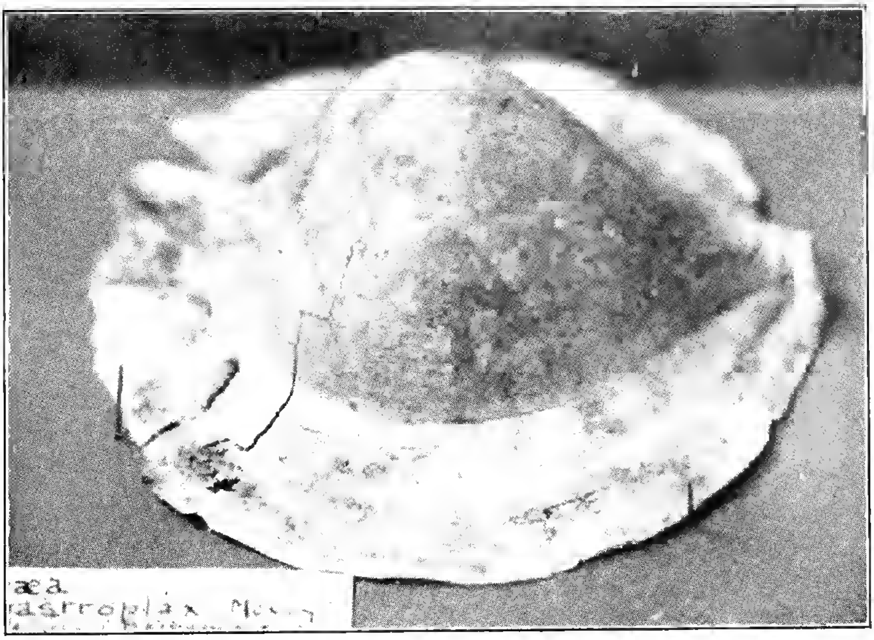
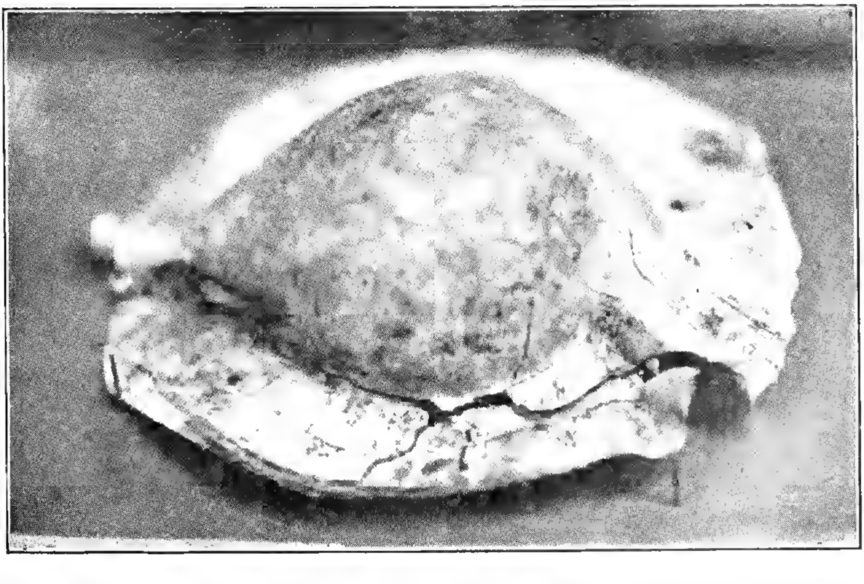
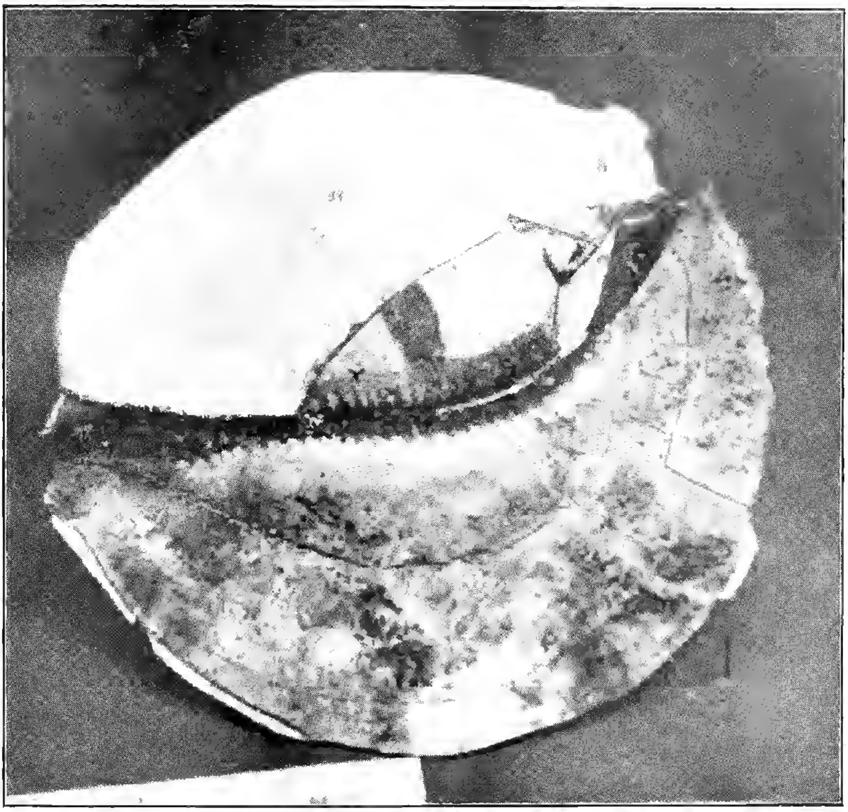


Fig. 1.



F. C. photo. Fig. 2.

Palliocypraea gastroplax.



F. C. photo.

Fig. 3.

Palliocydraea gastroplax.

septarian block, is the old Cement Works at Balcombe Bay. The locality cited by McCoy as "Hobson's Bay" is probably a misprint for Balcombe Bay or Port Phillip Bay.

The type specimen (holotype) in the National Museum (Reg. No. 12140) is undoubtedly conspecific with the beautifully preserved Muddy Creek specimen. The latter is only slightly smaller in proportion, the difference in the length of the body being about 8 mm.

The type specimen is preserved in a hardened concretionary and impure limestone, the matrix of which is foraminiferal, and besides this, contains innumerable shells of the little pelagic pteropod, *Vaginella eligmostoma* Tate. The interior of the shell has been naturally filled with this *Vaginella*-bearing mud, and where the shell of the cowry has peeled away, the glass-polished surface of the mud-cast is revealed. In this condition, of a partially-fractured shell reposing on its cast, the tenuity of this species is remarkably well brought out, showing an inner, prismatic layer and the outer, enamelled shell. The inner layer is seen on a weathered surface to show that the prismatic structure radiates across the flange, whilst the enamel layer of the flange itself has a fibrous structure concentric with the periphery.

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EXPLANATION OF PLATES.

PLATE XIX.

Fig. 1.—*Palliocypraea gastroplax* (McCoy). Aspect showing profile of body whorl. Circ. nat. size.

Fig. 2.—*P. gastroplax* (McCoy). Another view of dorsum. Circ. nat. size.

PLATE XX.

Fig. 3.—*Palliocypraea gastroplax* (McCoy). Ventral aspect, Slightly enlarged.

[PROC. ROY. SOC. VICTORIA, 41 (N.S.), PT. II., 1929.]

ART XIV.—*On some Trilobites and Brachiopods from the Mount Isa District, N.W. Queensland.*

By FREDK. CHAPMAN, A.L.S., F.G.S.

(Commonwealth Palaeontologist, National Museum, Melbourne.)

(With Plates XXI., XXII.)

[Read 13th December, 1928; issued separately 3rd April, 1929.]

The following are descriptions of a small but very interesting series of Cambrian Trilobites and Brachiopods, collected by Messrs. Campbell Miles and E. C. Saint-Smith, from the head of the Templeton River, twelve miles west of Mount Isa, and from Thornton River, NW. Queensland. These fossils were submitted to me for examination through the courtesy of Mr. B. Dunstan, F.G.S., Government Geologist of Queensland. Included in these descriptions is a specimen, viz., *Marjumia conspicabilis,* submitted later by Mr. Campbell Miles, and now incorporated in the Queensland Collection.

The specimens were received with other fossils (Ordovician), on 14/4/25, and a preliminary report was furnished, 7/5/26, which, however, was not published. Since writing this report I have been able to devote more time to the study of these fossils, and in some cases the former tentative determinations have been somewhat modified. Their generic affinities are such as to confirm the horizon in which they are found, as being of Middle to Upper Cambrian age. The genera and species herein described are as follows:—

BRACHIOPODA:—

Lingulella marcia Walcott, var. *templetonensis,* nov.
Acrothele bulboides, sp. nov.

TRILOBITA:—

Agnostus chinensis Dames.
Bathyuriscus saint-smithii, sp. nov.
Bathyuriscus nitidus, sp. nov.
Bathyuriscus olenelloides, sp. nov.
Marjumia milesi, sp. nov.
Marjumia conspicabilis, sp. nov.
Marjumia elegans, sp. nov.
Dikelocephalus dunstani, sp. nov.
Milesia templetonensis, gen. et sp. nov.

Phylum MOLLUSCOIDEA.
Class BRACHIOPODA.
Order ATREMATA.
Family OBOLIDAE.
Genus **Lingulella** Salter.

LINGULELLA MARCIA Walcott, var. TEMPLETONENSIS, nov.
(Plate XXI., Figs. 1, 2.)

Lingulella marcia Walcott, 1911, pp. 74-75, pl. xiv., figs. 3, 3*a*. Id., 1913, p. 69, pl. ii., figs. 6, 6*a*.

Observations.—This new varietal form is distinguished by its large size, compared with the type species. There are two examples in the present series. One is an internal cast of a pedicle or ventral valve, showing umbonal and lateral scars. The characteristic divergent striae of this specific form are even impressed on this cast, as was also shown in the internal shell surface figured by Walcott (*loc. cit.*) from a Chinese example. The outline of this Queensland specimen represents the internal surface of a shell of the narrower variety of *Lingulella marcia*. This agrees with the figure 6*d* of Walcott's series from the Middle Cambrian of China. The internal striae and pedicle channel are very distinctly seen, and the shell is of porcellanous whiteness on a yellow matrix.

Dimensions.—Length, 14·5 mm.; width, 11·5 mm.

The length of the typically broad form of *Lingulella marcia* from the Cambrian of China, figured by Walcott on his pl. ii., fig. 6*e*, is 3 mm. On account of the large dimensions of our specimens we are justified in regarding the Queensland form to be at least varietal to the Chinese species, and have therefore named it as a local variety.

Occurrence.—Twelve miles west of Mt. Isa, head of Templeton River; collected by Messrs. Campbell Miles and E. C. Saint-Smith, July, 1924.

Order NEOTREMATA.
Family ACROTHELIDAE.
Genus **Acrothele** Linarsson.

ACROTHELE BULBOIDES, sp. nov.
(Plate XXI., Figs. 3-5.)

Description.—Shell slightly wider than long, rounded to almost subquadrate. Ventral valve with a fairly long hinge-line; anterior border rounded and meeting the hinge-line at a decidedly sharp angle. Posterior sloping away to the anterior border. The tumid area occupied by a deep subquadrate fossette indicating the pedicle opening, whilst towards the hinge-line there is the usual

V-shaped depression common to the genus. The shell-structure is corneous and glossy and generally white, whilst the surface is concentrically marked with very fine growth lines. Dorsal valve slightly convex to flat, broadly rounded, with fine concentrically marked surface, the striae on which are seen to slightly undulate or even anastomose.

Dimensions.—Length of holotype (ventral valve), 3·5 mm.; width, 4 mm.; height, circ. 1 mm. Length of paratype (dorsal valve), 5 mm.; width, 5·5 mm.

Observations.—From the relative tumidity of the ventral valve it might appear that the relationship of the above species was with *Acrotreta* rather than *Acrothele*. The broadly expanding anterior area, however, shows it to belong to the type of *Acrothele* represented by Walcott's *A. matthewi*, var. *eryx*, from the Middle Cambrian of China (Walcott, 1913, p. 73, pl. iii., figs. 6, 6*a*-*h*). *Acrothele bulboides* differs in the greater tumidity of the pedicle area and in the practical absence of radial surface striae. From *Micromitra* the above form is distinct in the position of the pedicle opening, although at first sight the shells appear to belong to that genus, as indicated on the Field List supplied with this collection.

Occurrence.—Twelve miles west of Mount Isa, head of Templeton River; collected by Messrs. Campbell Miles and E. C. Saint-Smith, July, 1924.

Phylum ARTHROPODA.

Class TRILOBITA.

Order HYPOPARIA.

Family AGNOSTIDAE.

Genus **Agnostus** Brongniart.

Agnostus chinensis Dames.

(Plate XXI., Fig. 6.; Pl. XXII., Fig. 20.)

Agnostus chinensis Dames, 1883, p. 27, pl. ii., figs. 18, 19. Walcott, 1913, p. 99, pl. vii., figs. 4-6, 6*a*.

Observations.—Three pygidia occur on two of the chips under field No. 26 of the present collection. They agree specifically in having a semi-circular border with a sub-acuminate axial lobe; there is also a sub-central tubercle adjacent to a transverse and slightly curved ridge. On each side of the margin of the pygidial border, towards the posterior third, there is an obscure and blunt spine.

A species of the genus *Agnostus*, viz., *A. elkedraensis* Eth. fil., has already been recorded from the same area, by Dr. Whitehouse in his "Note on a Collection of Cambrian Trilobites from the South Templeton River, Queensland" (Whitehouse, 1927). *A. elkedraensis,* according to Etheridge jun., who described it from the Barkley Tableland, has no lateral pygidial spines, but differs from the present species in having a transversely divided pygidial lobe with a tubercle on the anterior portion, whilst the lateral spines are more posteriorly situated. Etheridge's comparison of *A. elkedraensis* with *A. acadicus* of Hartt, shows it to be distinct from the Thornton River form here referred to *A. chinensis*.

Dimensions.—Plesiotype, length of pygidium, 2·75 mm.; greatest width, 2·5 mm.

Occurrence.—Found in whitish porcellanised rock with iron-stains, Thornton River, NW. Queensland; collected by Mr. Campbell Miles.

Order OPISTHOPARIA.

Family BATHYURIDAE.

Genus **Bathyuriscus** Meek.

BATHYURISCUS SAINT-SMITHII, sp. nov.

Description.—(Based on type, collected by Mr. D. Smith.) Form of carapace roundly ovate. Head broadly rounded, with solid and lengthened genal spines extending to the line of the third thoracic ring. Glabella prominent, well-rounded in front, straight at sides. Fixed cheeks and palpebral lobes semicircular and strongly curved. Frontal limb finely lineate, increasing in strength towards the genal angles. Transverse furrows of the glabella well-marked. Neck-ring distinct, apparently without spine.

Thoracic segments twelve, narrow, with sillon. The segments of the lobe broad and well defined, with indications of a short basal spine. At junction with the axial furrows the surface of the pleura rise to tubercles which may have supported the short spines. Extremities of pleura terminate in short backwardly curved spines. Pygidium comparatively small, semicircular, consisting of four segments, with a terminal ovate axial lobe.

Dimensions.—Length of carapace, 48 mm. Width of cephalon measured at the genal angles, 35 mm. Length of cephalon, 17 mm. Length of thorax, 23 mm. Length of pygidium, 8 mm. Greatest width of axial lobe, 9·25 mm.

Observations.—The nearest related species to the above is perhaps *Bathyuriscus anax* Walcott, which occurs in the Middle Cambrian of Salt Lake Country, Utah. Although agreeing in general form and character, the present species differs from *B. anax* in having twelve instead of eight thoracic segments, and in having longer genal spines. The carapaces are often so abundant that one lies upon the other and they appear to have drifted into a closely packed pool. The rock in which they are found varies from a whitish tuff-like and silicified sediment to a similar hard rock much stained with iron, varying from yellowish to perhaps brown.

Occurrence.—This handsome species is by far the commonest trilobite in the Mount Isa Cambrian series. Twelve miles west of Mount Isa, at the head of the Templeton River; collected by Messrs. Campbell Miles and E. C. Saint-Smith. Also the holotype by D. Smith, per E. H. Muir (presented to the Commonwealth Collection). Named in honour of Mr. E. C. Saint-Smith.

Bathyuriscus nitidus, sp. nov.

(Plate XXI., Fig. 9.)

Description.—Carapace elongate-ovate. Cephalon rounded, paraboloid, with slender, dependent genal spines. Glabella rather narrow, long, and with four well-marked transverse furrows. Frontal limb sulcate within the margin, becoming finely grooved towards the genal spines. The fixed cheeks and the palpebral lobes wide and expanded, margined by a lunate crest. Neck-ring well developed. Thoracic segments probably eight, very narrow, the pleura terminating in sharp spines. The axial lobe is about half the width of the thoracic lobe. Pygidium unknown.

Dimensions.—Length of cephalon, 6 mm. Width at genal angles, 11 mm. Width of thorax, circ. 9·5 mm.

Observations.—This neat little species appears to find some relationship with *Bathyuriscus rotundatus* (Rom.), which is found in the middle and base of the Upper Cambrian in the Mount Stephen district, British Columbia (see Walcott, 1916, p. 346, pl. xlvii., fig. 2, 2*a*,*b*). Thus the present form has similarly sharp genal spines and thoracic margins, whilst the shape of the glabella is also identical. On the other hand our species has more widely expanded fixed cheeks.

Occurrence.—A single specimen found 12 miles west of Mount Isa, at the head of the Templeton River; collected by Messrs. Campbell Miles and E. C. Saint-Smith.

Bathyuriscus olenelloides, sp. nov.

(Plate XXI., Fig. 10.)

Description.—Form of carapace elongate-ovate. Cephalon broadly semicircular. Glabella roundly expanded in front, concave laterally; border of fixed cheeks strongly convex, with the palpebral lobes small and lunate. Genal spines long and divergent. Thorax of 10 segments, narrow, with sharply terminated pleura. Pygidium obscurely preserved and apparently small, rounded at extremity.

Dimensions.—Height of cephalon, 9 mm. Approximate width at genal angle, 20 mm. Length of thorax, 14 mm. Height of pygidium, circ. 3·5 mm.

Observations.—This is a much larger form than *B. nitidus*, which occurs on the same slab, and further differs from it in its broader carapace and strongly divergent genal spines. This latter character suggested the trivial name *olenelloides.* This type of cephalon is also seen in *Bathyuriscus primus* (Walcott, 1916, p. 352, pl. xlvi., fig. 6*d*), from the Lower Cambrian, Alberta, Canada, which otherwise differs in having a shorter carapace with fewer thoracic segments.

Occurrence.—A single individual on a slab of white porcellanous shale with *B. nitidus*, sp. nov., 12 miles west of Mount Isa, at the head of the Templeton River; collected by Messrs. Campbell Miles and E. C. Saint-Smith.

Family OLENIDAE.

Genus **Marjumia** Walcott.

Marjumia milesi, sp. nov.

(Plate XXI., Fig. 11.)

Description.—Cephalon (glabella and fixed cheeks only). Glabella elongate-ovate, broad anteriorly, and at the base with moderately well-marked transverse furrows. Border of fixed cheeks subcircular with a small palpebral lobe at the posterior lateral angle. Pygidium transversely ovate, the lateral margin curving outwardly and downwards, forming conspicuous falcate or sickle-shaped spines. Posterior lateral margins continued to basal extremity, entire but for a small blunt posterior spine on each side of the flattened concave border of the pygidial extremity. The pygidium has four segments. Pygidial axis moderately convex, flattened towards the posterior excepting at the extreme end, which is swollen. The flattened pygidial border below the extremity of the pygidial axis has the surface finely and concentrically furrowed as in both *Bathyuriscus* and *Dikelocephalus.*

Dimensions.—Height of cephalon (paratype), 13 mm. Glabella at widest part, 6·5 mm. Pygidium (holotype), length, 12·75 mm. Greatest width above principal spines, 27 mm. Length of pygidial axis, 8·5 mm. Width of axis at junction of thorax, 8·5 mm. Width of posterior extremity, 5 mm. Width of pygidial border at posterior extremity, 4·25 mm.

Observations.—Several of the species of the genus *Marjumia* which Dr. Walcott has described from the Middle Cambrian of Millard County, Utah (Walcott, 1916, p. 402, pl. lxv., fig. 3*b*), have points of agreement with the above species, but differ in some essentials. Thus the pygidia figured by that author as *Marjumia callas* have the lateral spines falcate, but the pygidial extremity is rounded and not obtusely concave. Another species, which was not determined by Walcott, but placed under *Bathyuriscus* and compared with *Marjumia callas* (Walcott, 1916, p. 348, pl. lxv., fig. 5), and in the text with *Bathyuriscus adacus,* is even closer in pygidial characters.

Occurrence.—12 miles west of Mount Isa, at the head of the Templeton River; collected by Messrs. Campbell Miles and E. C. Saint-Smith.

MARJUMIA CONSPICABILIS, sp. nov.

(Plate XXII., Fig. 13.)

Description.—Holotype, consisting of large part of thorax and pygidium, shows the carapace to be of large size, and of a long-ovate form. The thorax has the lateral margins broadly rounded, and the 14 segments of the genus are represented. The longitudinal axis is wide, and tapers only slightly towards the pygidium. It is on this depressed area that the ends of the pleura separate into salient backwardly directed spines. The last of the series belongs to the anterior segments of the pygidium, where it represents the falcate spine typical of the genus *Marjumia*. The thoracic segments are fairly narrow, and the pleura are each marked by a conspicuous diagonal sillon. The pygidial border in the specimen is not sufficiently well preserved to indicate the number of spines it carries, but there is an indication of at least one pair of spines below the anterior, falcate ones. The pygidial margin is finely, concentrically striate, as in *M. milesi.*

Dimensions.—Length of thorax, circ. 34 mm. Greatest width of carapace, 47 mm. Length of pygidium, circ. 11 mm. Greatest width, 26 mm.

Observations.—Apparently the only species comparable with *Marjumia conspicabilis* is *M. typa* Walcott. The carapace of the Shepherd Creek species, however, is more broadly ovate, and the marginal depression of the pleura and pygidium is more pronounced. The longitudinal axis in *M. typa* is much narrower, and the axial furrows are nearly straight. The spinose ends of the pleura in *M. typa* are sharper and more salient than in *M. conspicabilis*, where they curve rather suddenly towards the posterior. The axis of the pygidium in *M. typa* is proportionately longer than in *M. conspicabilis* and its marginal border has apparently a large number of spines.

Occurrence.—Shepherd Creek, near Miles Creek, north branch of the Templeton River, NW. Queensland; presented to the Geological Survey of Queensland by Mr. Campbell Miles.

MARJUMIA ELEGANS, sp. nov.

(Plate XXII., Figs. 14-16.)

Description.—Carapace rather small, broadly ovate anteriorly, tapering posteriorly; cephalon broadly semi-circular, with a pyriform and anteriorly expanded glabella. Outer limb grooved internally, and finely longitudinally, sulcate towards the genal angles. Genal spines moderately long, dependent. Thorax consisting of 14 segments. Pleura comparatively narrow, grooved diagonally, spinose at the curved extremities. Pygidium comparatively small, consisting of four segments, and bearing four pairs of lateral, somewhat hook-shaped spines. Axial furrows somewhat deeply impressed and straight.

Dimensions.—Length of carapace, 27 mm.; width of cephalon, 21 mm. Greatest width of thorax, 18 mm. Length of pygidium, 6 mm.

Observations.—This species is perhaps the commonest of the genus here described, and the holotype has been selected from a complete carapace (No. 13A, Queensland Collection). The diagnostic characters have been based on additional specimens, among which are some well preserved cephala and pygidia. In the pygidial characters the species also resembles *M. typa* Walcott, already referred to, but the carapace, as a whole, is a rather different form.

Occurrence.—12 miles west of Mount Isa, at the head of the Templeton River. Also occurring in a collection from Mr. Campbell Miles, from Shepherd Creek, near Miles Creek, north branch of Templeton River.

Family DIKELOCEPHALIDAE.

Genus **Dikelocephalus** Owen.

Dikelocephalus dunstani, sp. nov.

(Plate XXII., Figs. 17, 18.)

Description.—Based on remains of cephalon and pygidium. Cephalon, large, broad, the cranidium showing an expanded glabella, extending to the frontal margin. On either side, the frontal limb gradually expands towards the genal angle. The glabella with four transverse furrows. Palpebral lobes of the fixed cheeks wide and strongly curved. Pygidium broad, almost flabellate, with a short pygidial axis, almost triangular in outline, with four segments. Marginal border of the pygidium broad in outline and conspicuously incised with fine linear grooves. At the lateral posterior angles there are two large falcate spines which more closely approximate to one another than in *D. minnesotensis*. On the posterior segment of the pygidial axis is an indication of an incipient spine, sometimes also seen in the genus *Saukia*.

Dimensions.—Height of cranidium, 24 mm.; width of cranidium, including palpebral lobes, 30 mm. Length of pygidium, measured from the tips of the spines, 22 mm. Width of pygidium, circ. 44 mm. Average width of marginal flange, 8 mm.

Observations.—This species resembles *D. minnesotensis* Owen, in general characters. The glabella, however, is more globosely expanded in the present species, whilst the pygidial spines are situated near the axis. This species is named in honour of the

Government Geologist of Queensland, Mr. B. Dunstan, F.G.S., through whose courtesy I received the fossils for reporting upon.

Occurrence.—Thornton River, NW. Queensland; collected by Mr. Campbell Miles.

Genus **Milesia**, gen. nov.

(For generic characters, see Observations *infra.*)

Milesia templetonensis, sp. nov.

(Plate XXII., Fig. 19.)

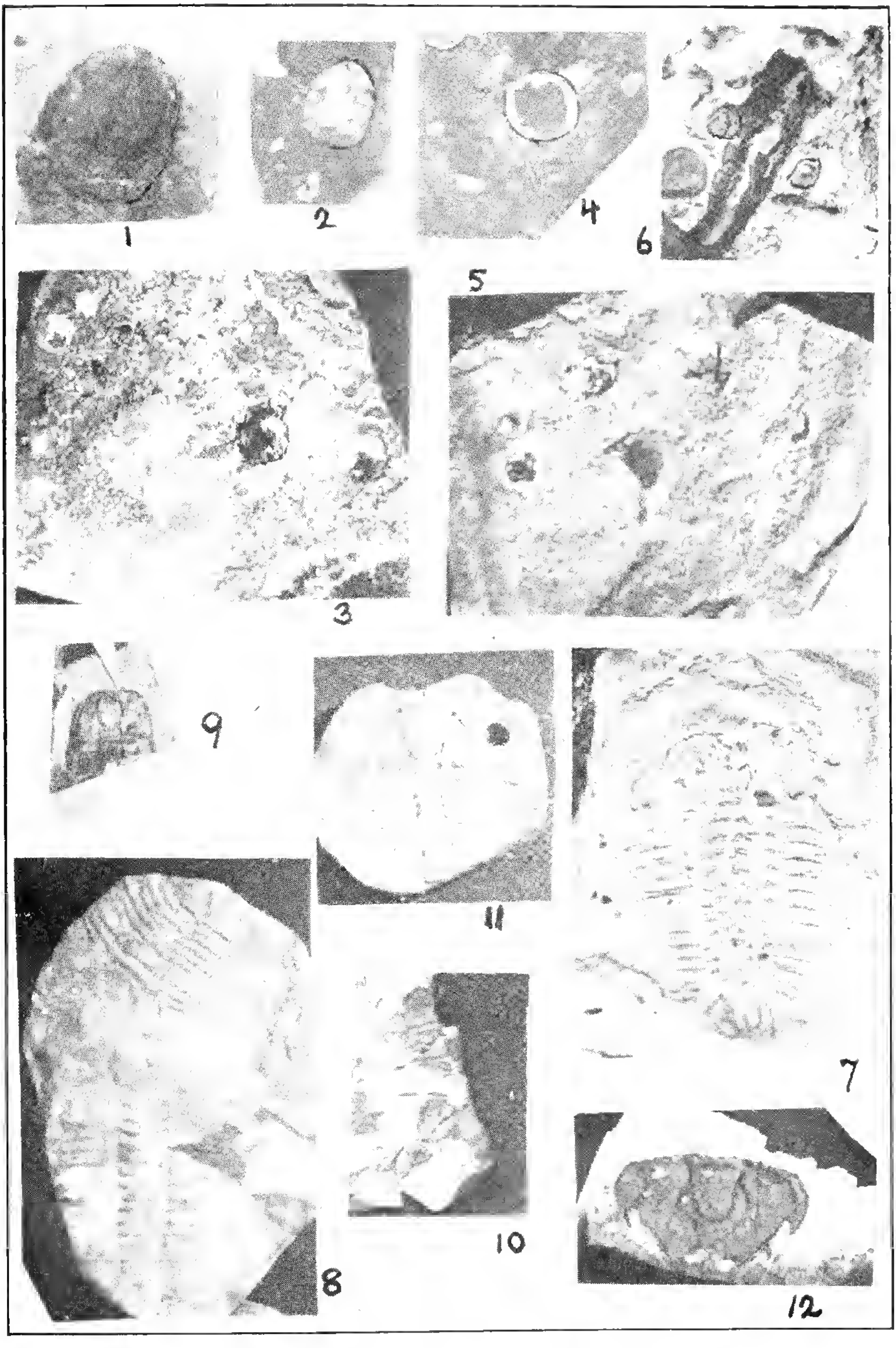
Description.—Holotype, of a nearly complete specimen. General form elongate ovate. Cephalon transversely ovate, showing cranidium with large palpebral lobe. The frontal limb is wanting, but the free cheeks are well represented in outline by a sunken impression of a broad head-shield with short and stoutly falcate genal spines. The axial lobe with indication of the two basal transverse furrows, the posterior furrow strong, extending across the glabella. Thorax with 12 well-marked segments. Axial lobe moderately convex. Pleural lobes flattened, each segment having a distinct transverse furrow to the spinous margin. Pygidium semicircular, well rounded basally, with a deep, depressed flange radially furrowed and transversely wrinkled, and with traces of the strong pygidial spine near thoracic suture. Axial lobe of pygidium tapering distally to a point and pinched or rigid at apex. Lateral lobes of pygidium flattened, numbering about five.

Dimensions. — Approximate height of cephalic shield, 20 mm.; width of cephalic shield, including free cheeks, 42 mm. Height of thoracic series, 34 mm. Greatest width of thorax, 40 mm. Height of pygidium, circ. 18 mm. Greatest width of axial lobe, 13 mm.

Observations.—This handsome form shows some relationship to *Dikelocephalus,* but it is better to refer it to a new genus. This is named in honour of one of the discoverers of this interesting collection, Mr. Campbell Miles.

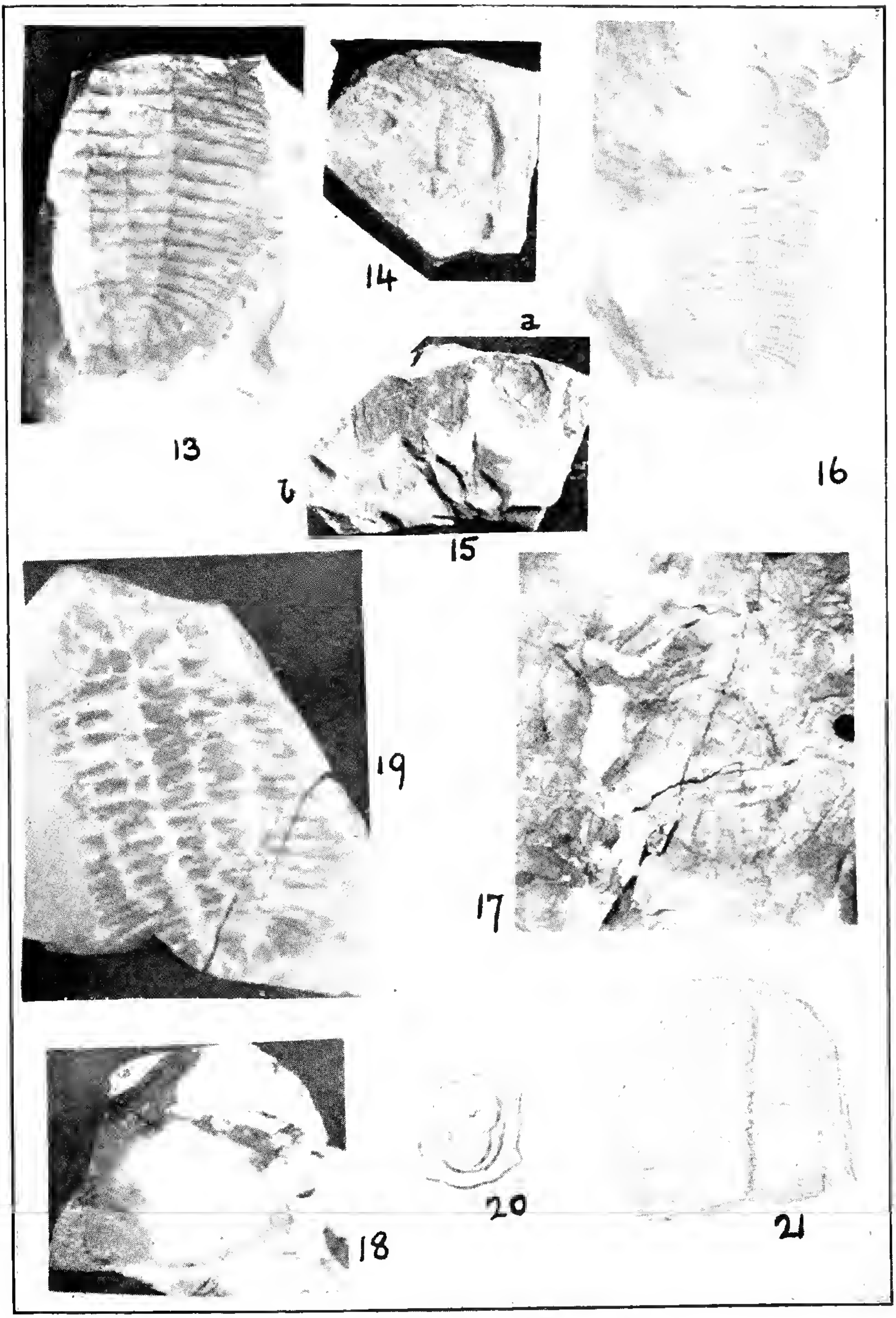
The furrowed glabella and the large number of thoracic segments—12—separate *Milesia* from *Bathyuriscus*, which it otherwise resembles. The expanded base of the pygidium also agrees with *Dikelocephalus.* In *Marjumia* the glabella is narrower and not so conspicuously furrowed, though the number of thoracic segments agrees in that particular. The genal spines are not so slender and prolonged as in *Dikelocephalus,* but more nearly resemble those of *Bathyuriscus.*

Occurrence.—Preserved in sub-cherty shale of a whitish tint, iron-stained on joints and showing as a brown chert on a fractured surface. 12 miles west of Mount Isa, at the head of Templeton River, NW. Queensland (Queensland Geol. Survey Coll.).



F.C. photo.

Cambrian Fossils. Mt. Isa, Queensland.



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EXPLANATION OF PLATES.

PLATE XXI.

Fig. 1.—*Lingulella marcia* Walcott, var. *templetonensis,* nov. Pedicle valve. × circ. $1\frac{1}{2}$.

Fig. 2.—*L. marcia* Walcott, var. *templetonensis,* nov. Dorsal valve. × circ. 2.

Fig. 3.—*Acrothele bulboides,* sp. nov. Holotype. Pedicle valve (on right). × 2.

Fig. 4.—*A. bulboides,* sp. nov. Dorsal valve. × circ. 2.

Fig. 5.—Slab showing group, mainly pedicle valves, of *A. bulboides.* × 2.

Fig. 6.—*Agnostus chinensis* Dames. Two pygidia. × circ. 2.

Fig. 7.—*Bathyuriscus saint-smithii,* sp. nov. Holotype. Natural size.

Fig. 8.—*B. saint-smithii,* sp. nov. Slab with two carapaces. Natural size.

Fig. 9.—*Bathyuriscus nitidus,* sp. nov. Holotype. Circ. natural size.

Fig. 10.—*Bathyuriscus olenelloides,* sp. nov. Holotype. Circ. natural size.

Fig. 11.—*Marjumia milesi,* sp. nov. Holotype, $\frac{3}{4}$ natural size.

Fig. 12.—*M. conspicabilis,* sp. nov. Pygidium, Natural size.

PLATE XXII.

Fig. 13.—*Marjumia conspicabilis,* sp. nov. Holotype. Natural size.

Fig. 14.—*Marjumia elegans,* sp. nov. Paratype. Natural size.

Fig. 15.—*M. elegans,* sp. nov.; *a,* cephalon; *b,* pygidium. Natural size.

Fig. 16.—*M. elegans,* sp. nov. Holotype. × circ. 2.

Fig. 17.—*Dikelocephalus dunstani*, sp. nov. Holotype. Natural size.
Fig. 18.—*D. dunstani*, sp. nov. Paratype, cephalon. Natural size.
Fig. 19.—*Milesia templetonensis*, gen. et sp. nov. Holotype. Natural size.
Fig. 20.—*Agnostus chinensis* Dames. Pygidium. Enlarged drawing. × 3.
Fig. 21.—*Bathyuriscus nitidus*, sp. nov. Holotype. Enlarged drawing. × 6.

NOTE.—The holotypes and paratypes are in the Queensland Geological Survey Collection, with the exception of the holotype of *Bathyuriscus saint-smithii*, which is in the Commonwealth Collection, and the paratype of *Marjumia elegans* Chapm. (pl. xxii., fig. 14) which is in the author's collection.

[Proc. Roy. Soc. Victoria, 41 (N.S.), Pt. II., 1929.]

Art. XV.—*On a New Species of Capulus found attached to a Pterygotus Carapace.*

By FREDK. CHAPMAN, A.L.S., F.G.S., etc.
(Commonwealth Palaeontologist, National Museum, Melbourne.)

(With Plate XXIII.)

[Read 13th December, 1928; issued separately 8th April, 1929.]

Introduction.

Some years ago Sir Frederick McCoy (1899) described a new species of *Pterygotus* (*P. australis*) from the hard blue shale of South Yarra, near Melbourne. The rock in which it was found belongs to the lower or Melbournian stage of the Silurian.

This specimen of *Pterygotus* is represented by both the holotype of a somite figured by McCoy and the counterpart on which the shells of *Capulus* are present. These specimens are in the National Museum collection.

The *Pterygotus* somite measures, post-anteriorly, 61 mm., and it has an estimated breadth of 165 mm. (6½ inches).

Soon after my arrival in Melbourne, in 1902, whilst examining the holotype I noticed that the surface of the carapace bore, besides the conspicuous scale-like markings, several depressed ovate areas which were not noted in McCoy's description. A wax or plasticine impression from these showed a valve in relief which then seemed to be referable to either *Pholidops* or *Orbiculoidea*, the latter genus as well as *Crania* being already known as a brachiopod commensal on cephalopod shells from the Palaeozoic of the United States of America.

Lately, whilst in conversation with Sir Edgeworth David on the subject of his recent discoveries of Eurypterids in the Proterozoic rocks of South Australia, he mentioned the occurrence of generally similar commensal limpet-like fossils. My interest in the Silurian specimens here described was thus revived.

The chief obstacles in referring the present fossils either to *Crania, Pholidops* or *Orbiculoidea* are:—

1. The absence of a cemented valve, or trace thereof.
2. The irregular growth stages of the shell surface, which in *Pholidops* are evenly developed.
3. The absence of a pedicle opening either of *Crania* or *Orbiculoidea*.

The only form to which we can reasonably assign the present specimens seems to be that of a member of the gasteropod genus *Capulus,* which ranges from Cambrian to Recent. I have been greatly helped in this comparison and diagnosis by finding a recent specimen of *Chlamys bifrons* from South Australia in the Dennant Collection, the valves of which are peppered over with small attached shells of an allied genus, *Hipponix.* A common character of both this recent—*H. conicus* (Schumacher) (May, 1921, 1923)—and the Silurian examples is the cleared area around the shell, a feature also to be noticed with living limpets.

It is very remarkable to find so close a resemblance in form, external structure and nearly equal dimensions, in the two Silurian and living genera and species.

In selecting his holotype of *Pterygotus* from the two specimens (counterparts) discovered by F. P. Spry in the Silurian mudstone, McCoy seems to have been influenced by the character of the ornament of the carapace. In the holotype this is a salient squamation, and agrees in the main with that seen in well-preserved specimens from England, North America and Bohemia. Apart from this general character of salient squamation, there appear parts of the carapace in other specimens which have an impressed ornament. So that my selection of the counterpart of McCoy's type of the South Yarra specimen of *Pterygotus* as the actual positive surface, on account of the appearance of the shells of *Capulus* in relief, is not without reason.

Description.

Class GASTEROPODA.

Family CAPULIDAE.

Genus **Capulus** Montfort.

CAPULUS MELBOURNENSIS, sp. nov.

(Plate XXIII., Fig. 1.)

Shell ovate, expanding in ephebic stage. Apex moderately high to depressed and incurved. Concentric growth lines distinct, with strong growth stages at intervals. In some examples an apical ridge extends down the middle of the shell. The shell is seated in a depressed area on the carapace of *Pterygotus australis,* similar to that seen in living examples of the allied genus *Hipponix* attached to *Chlamys* and other bivalves.

Length of holotype, 3·25 mm. Greatest width, 2·25 mm. Height, circ. 1 mm.

Occurrence.

Eleven specimens attached to the carapace of *Pterygotus australis* McCoy. Silurian (Melbournian). Domain Road, South

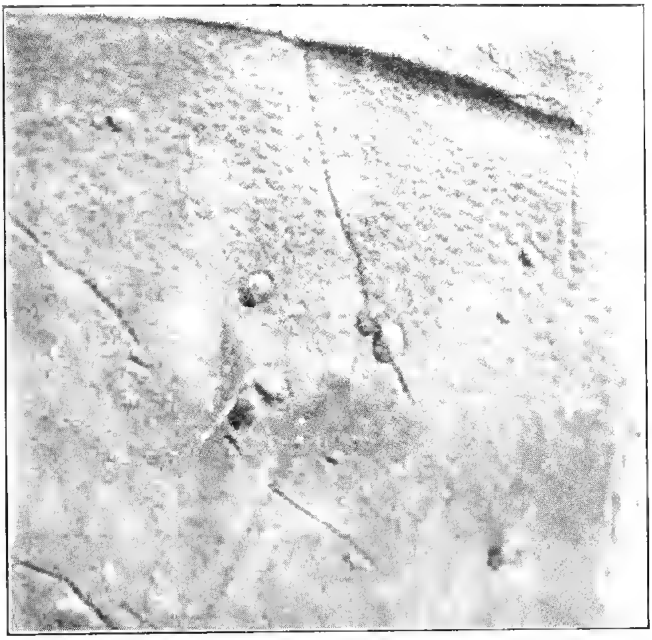
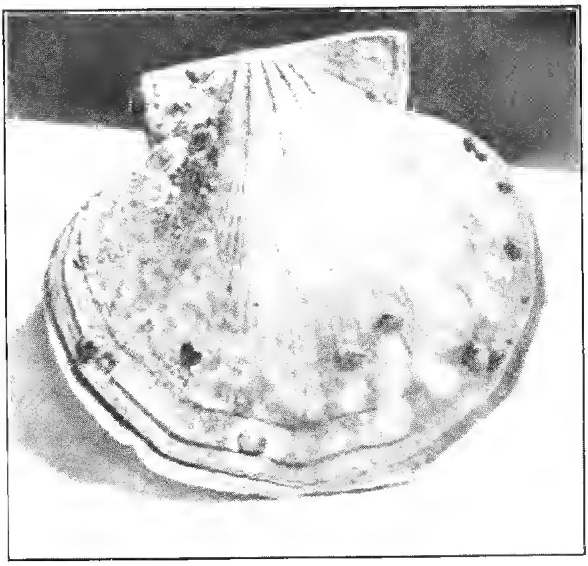


Fig. 1.



F.C. photo. Fig. 2.

Sessile Gasteropods: Capulus (Silurian), Hipponix (Recent).

Yarra (main sewer tunnel). Found by F. P. Spry, and donated to the National Museum. Registered No. of present counterpart No. 1085. Registered No. of McCoy's Holotype, No. 577.

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EXPLANATION OF PLATE XXIII.

Fig. 1.—Portion of somite of *Pterygotus australis* McCoy, with attached shells of *Capulus melbournensis*, sp. nov. Silurian (Melbournian). S. Yarra. × circ. 2.

Fig. 2.—*Chlamys bifrons* (Lam.). Living, S. Australia. Valves with attached shells of *Hipponix conicus* (Schum.). 2/3rds natural size.

[Proc. Roy. Soc. Victoria, 41 (N.S.), Pt. II., 1929.]

Art. XVI.—*Notes on and Additions to Australian Fossil Polyplacophora (Chitons).*

By EDWIN ASHBY, F.L.S., etc.

(Communicated by F. Chapman, A.L.S.)

(With Plate XXIV.)

[Read 13th December, 1928; issued separately 8th April, 1929.]

Introduction.

Mr. Francis A. Cudmore has placed in my hands for description a large number of valves of Fossil Chitons, both from the Table Cape beds in Tasmania and the Balcombian beds in Victoria. The Rev. George Cox, of Mornington, and Dr. H. J. Finlay, of Dunedin, N.Z., have also permitted me to study important material from Balcombe Bay. Two species are added to the fossil fauna: one, a unique example of *Ischnochiton (Heterozona) cariosus* Pilsbry, is the first fossil representative of its genus to be found in Australia; the other discovery, for which the new genus *Oöchiton* is instituted, is still more remarkable, the nearest apparent relatives being two rare deep water forms from Cape Horn and Antarctica, one of which is figured for comparison. A discussion of the systematic position of the new discoveries is given and a classified list of the Australian Fossil Polyplacophora is furnished.

Systematic Description.

Lorica compressa Ashby and Torr, 1901.

From the Crassatella Beds, Table Cape, Tasmania, Mr. Cudmore has taken complete, or portions of, 24 median valves and three portions of anterior valves, one almost complete, all referable to the above species.

Lorica compressa var. affinis Ashby and Torr, 1901.

In the collection is one median valve and two fragments of median valves of this variety in which the longitudinal ribbing is much more widely spaced than is the case in *L. compressa*, s.str.

LORICA CUDMOREI Ashby, 1925.

From the same bed as the foregoing two imperfect median valves of this species were taken.

Mr. Cudmore has found 32 valves or portions thereof belonging to the genus *Lorica* from one bed. It not only evidences that the genus *Lorica* was numerically very strong in the ancient sea in which this Crassatella bed was laid down, but also that this genus of Chitons was almost the only one represented in association with the *Crassatella*. In the seas of to-day the genus *Lorica* is but poorly represented as compared with other groups of Polyplacophora, and it is only recorded from Australasian waters.

LORICELLA GIGANTEA Ashby and Torr, 1901.

(Plate XXIV., Fig. 9.)

One beautiful example of the head valve of this species is in the collection; it was taken from the Lower Bed, Table Cape, Tertiary (Janjukian).

In the original description the locality was given as Mornington, although thought to have been a mistake. This, the second example of this valve, is a small replica of the holotype, measures 24 × 12·5 mm., and settles the question as to the true locality of the original find. The median valve described by Hull as *Loricella magnifica*, which, as I have already indicated, is referable to this species, was also from Table Cape: I therefore indicate the Lower Bed, Table Cape, as the type locality and horizon.

Oöchiton, n. gen.

This new genus is proposed for the reception of a new and unique form which is herein described under the name *Oöchiton halli*, n. sp., which species I designate as type of this genus.

The median valve has in common with the genus *Notochiton* a very strongly carinated shell with very steep side-slope, the sutural laminae joined across the middle line, insertion plate in median valve broad, edge smooth, slits 1/1, broad and deep. It differs from *Notochiton* in the absence of regular longitudinal ribbing, and possesses peculiar ovate pustules which stand erect in irregular rows or widely scattered over the whole of the tegmentum; these pustules apparently are associated with the nerve fibres, for most of them have a minute aperture at the summit, and differs also in the greater width of the insertion plate. The name is suggested by the peculiar sculpture which suggests strings of minute eggs.

Since the above definition was written, the tail valve has been discovered. This valve differs widely from the genus *Notochiton*, and, to the best of my belief, is quite unique in its characters. The upturned and greatly thickened extremity, with the deep sinus immediately behind the mucro and the extended fold of the tegmentum into this sinus, in a limited degree, resemble the genus *Lorica;* the entire absence of the insertion plate immediately behind the mucro together with the greatly thickened extension of the insertion plate laterally with its single slit on either side, faintly reminds one of some members of the Mopaliidae.

The contour of the anterior valve is remarkably like that of *Notochiton mirandus* Thiele, the insertion plate is also similar in being grooved and bevelled, but the slits in *Oöchiton* are proportionally broader. Whereas *Notochiton mirandus* possesses ray-ribs corresponding with the slits, the species under discussion has no ray-ribs and no correspondence between the sculpture and the slits. It will be seen that both the anterior and the median valves show some affinity with the genus *Notochiton,* but the tail valve is strikingly dissimilar and unique. I consider the genus *Oöchiton* more primitive than the genus *Notochiton,* but it might well be placed immediately preceding that genus.

Oöchiton halli, n.sp.

(Plate XXIV., Figs. 1*a,b; 2; 3a-c; 8a,b.*)

Mr. F. A. Cudmore has placed in my hands two median valves of an entirely new species of Chiton; the one I am making the holotype was found by him at Balcombe Bay, near Mornington, Victoria, Tertiary (Balcombian); the other is also in Mr. Cudmore's collection, and was collected by the late Dr. T. S. Hall at Belmont, Geelong, Victoria, Tertiary (Barwonian), and is separately described herein.

Since writing the following description I have received from the Rev. George Cox, of Mornington, through Mr. R. A. Keble, the Palaeontologist of the National Museum, Melbourne, a tail valve and some additional median valves of the same species. Mr. Cox writes as follows: "The tail valve and several median valves were found [in the Balcombian Beds] at Mornington, by a lad aged 12 years, named Evan Chitts; two median valves and the tail valve were washed out of one cubic inch of clay, and may have belonged to the same animal."

Still more recently Dr. H. J. Finlay of Dunedin, N.Z., has sent me an example of the anterior valve of *Oochiton halli,* which had been collected by himself in the Balcombian beds at Mornington. He is generously allowing me to keep this specimen, which I am describing hereunder as the type of the head valve of this species: up to the present this example of the head valve is unique.

I am naming this interesting species at the suggestion of Mr. Cudmore after the late Dr. T. S. Hall, the discoverer of the first median valve found.

Median valve.

Holotype, Balcombe Bay, Victoria. — Pl. (XXIV., Fig. 1*a,b*). Strongly carinated, very elevated, side-slope straight and steep, angle of divergence 70°, surface smooth and polished, areas indistinguishable, one or two shallow growth lines parallel with the margin towards the girdle. The ornamentation is unique, and consists of six longitudinal broken strings of minute bead-like pustules; the pustules are ovate, and together resemble strings of minute white eggs, which feature has suggested the name of the genus. The first row nearest the jugum has 12 of these pustules; the second has nine only, traverses only half way across the pleural area and is bowed upwards; the third has 14 pustules; the fourth has 9; the fifth has 10; and the sixth has only 2 pustules. It must be noted that all these rows have gaps, the string not being continuous, but this is in some places undoubtedly due to the breaking off of some pustules. The dorsal ridge is slightly raised, anteriorly a little broader than at the beak, and in a faint degree is subgranulose. The foregoing is as seen under a simple lens, × 20.

Under a Zeiss binocular microscope, ×65, some very interesting features are made clear. The whole of the surface of the shell is highly polished, and everywhere thickly perforated with megalopores. It is also transversely, concentrically crossed by numerous growth grooves or lines, these running across the jugum from side to side. To these grooves is due the apparent subgranulose appearance of the dorsal ridge. The bases of detached pustules are visible, the pustules themselves are definitely ovate, attached by the smaller end and almost vertical; each pustule has a small perforation at the summit, looking like a black dot, which is a little larger than the megalopores of the normal surface of the shell; except for this aperture the pustules are solid, not hollow, as in *Protochiton*. The channel connecting nerve fibres with the black dot can be seen in places where the pustules have been broken. Corresponding with the rows of pustules is an irregular series of deep pits with a black, probable eye-dot at the bottom; these rows of pits are on the lower and outer side of the pustules, and are overhung and almost hidden by these. The perforations at the base are much larger than the megalopores, and therefore must have functioned much like what are known as "eyes" in recent species. This description is taken from the right side of the shell; the other had met with some injury during life, and the process of mending has caused the outer part of the lateral area to bend upwards, and the strings of egg-shape pustules have somewhat merged into one another. The inside of the valve is white, and the tegmentum is folded over at the beak, the margin of the fold being coarsely pustulose.

Dimensions.—The holotype, median valve, is 4·5 mm. in width and 3·75 mm. in length; angle of divergence, 70°.

Paratype, Belmont.—(Pl. XXIV., Fig. 2). Median valve, beaked, carinated, side-slope very steep, dorsal area arched except near the beak, where it is narrowed to a mere ridge, smooth except for several narrow ridges unsurmounted by pustules, separating this area from the pleural. The character of the strings of egg-like pustules is similar to that of the type, but the rows are shorter and in places a narrow ridge connects widely-spaced pustules; near the insertion plate, grains are scattered. The sutural laminae are broken, but are joined across the centre line; the lateral area is separated from the pleural by a shallow diagonal fold. The colour of the tegmentum is silvery grey, the pustules opaque white. The pitting, although present, does not appear to be associated with the pustules, as is the case in the holotype. Interior creamy white, insertion plate undamaged on one side, teeth sharp, slits 1/1, well-defined and broad, callus imperceptible, tegmentum extensively folded over at the beak forming a "pocket." This median valve, Nat. Mus. No. 13497, is longitudinally narrow, measuring 4 × 3 mm.; dorsal area without pustules.

Paratypes, Balcombe Bay.—No. 1 measures 4·25 × 3·75; No. 3 certainly has the articulamentum joined across the middle line between the sutural laminae; No. 4 is imperfect, has a V-shaped notch in the articulamentum between the sutural laminae; No. 5 is fragmentary, dorsal area ornamented with egg-shaped pustules but without raised dorsal ridge; No. 6 is a fragment only.

Tail valve.

Paratype, Balcombe Bay. (Type of tail valve.)—(Pl. XXIV., Fig. 3*a-c*.). Small, measuring longitudinally 2·75 mm., laterally 2·25 mm., very strongly carinated; mucro at the posterior margin or more correctly subposterior, because the tegmentum is bent over at the mucro and turned down vertically; the portion immediately behind the mucro is concave and in this cavity or sinus, are two of the egg-shaped pustules common to the sculpture of the rest of the tegmentum; from the mucro is a raised diagonal rib or fold, the strings of egg-shaped pustules of the pleural area are continued across this fold to the posterior edge of valve. This valve is upturned at the mucro and the extremity very much thickened, the insertion plate here is subobsolete, and reduced to a mere callus or ridge behind the mucro, but on either side the insertion plate is developed into a highly thickened extension of the articulamentum with one diagonal slit on either side, and in addition on one side a supplementary groove, but not a true slit. The sutural laminae are well developed, the sinus between being very narrow, and are joined to the thickened posterior insertion plate by a broad extension of the articulamentum which is suggestive of the Acanthochitonidae.

Anterior valve.

Paratype, Balcombe Bay. (Type of anterior valve).—(Pl. XXIV., Figs. 8*a,b*.). Valve highly elevated, apex slightly recurved, anterior slope very steep and concave (due to recurved apex). The ornamentation consists of strings of egg-like pustules similar to those in the other valves; the arrangement is generally speaking longitudinal, the strings commencing at the posterior margin and continuing to the insertion plate with considerable irregularity, several strings bifurcate, and in some places there are short intermediate rows; the strings or rows of pustules do not seem to have any relationship with the slits in the insertion plate.

Articulamentum, or inner layer of shell creamy white, highly polished, smooth, without any grooves; the tegmentum infolded at the apex, this infolded portion is thickly studded with the egg-like pustules; the insertion plate is well produced, perfect, except for a few minute chips; slits 7, broad and short, spacing irregular; the upper side of the insertion plate is numerously grooved, the plate is broad and proportionally thick, but the upper edge is bevelled off, so that the actual edge is sharp, the grooves not continuing to the inner edge. Valve measures $4 \cdot 5 \times 2 \cdot 25$ mm.

NOTOCHITON MIRANDUS Thiele.

(Plate XXIV., Figs. 4, 5, 6*a,b*.)

(*N. mirandus* Thiele, Subantarktischen Chitonen, pp. 12. 13.)

In the preparation of this paper comparisons have had to be made with this species, of which I have in my collection a cotype given to me by Major Dupuis. Pilsbry does not refer to it, Thiele (in *Revis. des Syst. der Chitonen,* p. 107) neither figures nor describes it, making a bare reference and stating that Edgar Smith considered it a *Chetopleura*, but Thiele considers it allied to the genus *Nuttallochiton*, and is probably correct. For purposes of comparison with *Oöchiton halli*, n. sp., figures are given.

ISCHNOCHITON (HETEROZONA) CARIOSUS Pilsbry, 1892.

(Plate XXIV., Fig. 7.)

The Rev. George Cox has sent me a single median valve of the above *Ischnochiton*, collected by Master Evan Chitts in the Balcombian Beds at Mornington. This is the first true record[1] of the discovery of a fossil *Ischnochiton* in Australia.

This example appears to have a well-defined diagonal rib, and for that reason I at first thought it would likely prove to be a new species, but on careful examination I find that this apparent

1.—F. Chapman was in error when he referred *Protochiton granulosus* to this genus (*Proc. Roy. Soc. Vic.*, n.s., xx. (2), pp. 218-220, 1908).

feature is due to a slight wearing of the anterior of the raised lateral area. As compared with a half-grown example from Marino in South Australia, in which the valves are of a corresponding size, I find the sculpture similar, though a little more deeply cut, in this respect corresponding with the form from Western Australia, but it differs slightly in that the infolding of the tegmentum under the jugum is about double the width as compared with the Marino example, but in the lateral extension of this infolding it is similar. There are no differences to be distinguished in this valve to justify separation, but such may be revealed when fossil end valves are discovered. The fossil valve measures $5{\cdot}5 \times 2{\cdot}25$ mm.

Discussion on Classification.

I have retained the genera *Lorica* and *Loricella* under Pilsbry's subfamily Liolophurinae, while recognising that this is not their true setting. Thiele found that the radula showed relationship with the Ischnochitonidae, and treated these genera as advanced forms of that group, but I feel that more work needs to be done on characters other than that of the radula, before their true niche in the Natural Taxis can be determined. I therefore retain them in the setting in which Pilsbry placed them, until the study of this problem, from the points of view suggested above, supplies added data upon which we may form a considered opinion.

All students of the Polyplacophora are greatly indebted to Dr. Thiele for the specialized work he has done in the radula of that order. He has laid a good foundation, and it is unfortunate that since the production of his valuable work, " Revision des Systems der Chitonen," no material work has been done on the radula of this group. One should hesitate to accept too hastily conclusions based chiefly on one feature alone, until such time as other supporting features have been studied and made known.

Thiele has pointed out that in the family Lepidopleuridae there is some variation in the characters of the radula. Iredale and Hull have assumed that this discovery of Thiele's means that the absence of insertion plates and other accepted primitive characters, are the result of degeneracy, and have founded their classification on this assumption. Thiele himself drew no such conclusion from his discovery, and proposed a suborder, Lepidopleurina, for this group, numbering it (I.). I feel sure a right conception of taxonomic values will endorse Thiele in his treatment, and I have suggested that the Chitons living in the seas of to-day have not arisen from primitive stock in one phylum alone, but through more than one. This I have demonstrated in the case of the Acanthoid group, and have expressed the opinion that the existence of divergences in the radula of members of the Lepidopleuridae is important evidence that gathered together in this group are the progenitors of more than one phylum that have developed along parallel lines.

The discovery, in addition to the median ones, of the end valves of the fossil *Protochiton granulosus* (Ashby and Torr), has made it quite clear that this species could not have been derived through any members of the Lepidopleuridae, and its evident relation to the Acanthoid Group of Chitons makes necessary a partial revision of our previous conception of the Classification of Polyplacophora.

This revision was foreshadowed in my Phylogenetic Diagram, page 75 (l.c.); I have endeavoured in the following Classification List to give expression to this revised conception, made necessary by the recent discoveries named above.

The proposal of Iredale and Hull to substitute the word " Loricates " for the universally used " Chitons," dating as this latter does from the days of Linné, surely can commend itself to no one. The proposal to substitute the word " Loricata " for " Polyplacophora," and " Cryptoconchidae " for " Acanthochitonidae," is not compulsory, and surely can serve no good purpose. The law of priority does not apply to ordinal and family names; also the use of the term "Type Genus" is understood by most workers to mean " typical genus," which the specialized form *Cryptoconchus* certainly is not.

Since the issue of my Monograph on Australian Fossil Polyplacophora, Iredale and Hull have described the cast of a Chiton from the Permo-Carboniferous beds of Bundanoon, New South Wales, and have called it *Permochiton australianus*. This specimen is a very interesting one, in face of the fact that Etheridge's *Chelodes calceoloides* has already been disallowed, for although its true character is still in doubt, there seems a consensus of opinion that it is not a representative of the order Polyplacophora; *Permochiton australianus* comes from the oldest series of beds in which Chitons have yet been found in Australia. These gentlemen suggest some resemblances between *P. australianus* and the genera *Ischnochiton* and *Lepidopleurus*, but judging from their figures I can see no resemblance, though certainly there is a general resemblance to the Palaeozoic genus *Helminthochiton*, and it is quite natural to suppose that members of that genus would persist from the Carboniferous into the Permo-Carboniferous.

Classification of Australian Fossil Polyplacophora.

Class AMPHINEURA.

Order POLYPLACOPHORA (Blainville em.) Gray, 1821.

[Primitive.]

Suborder EOPLACOPHORA Pilsbry, 1900.

[Fossil only.]

Family GRYPHOCHITONIDAE Pilsbry, 1900.

Genus Permochiton Iredale and Hull, 1926 (without definition).
Permochiton australianus Ire. and Hull, 1926.

Suborder PROTOCHITONINA Ashby, 1928.

Family PROTOCHITONIDAE Ashby, 1925.

Genus Protochiton Ashby, 1925.
Protochiton granulosus (Ashby and Torr, 1901).

Family ACANTHOCHITONIDAE Hedley, 1916.

Subfamily AFOSSOCHITONINAE Ashby, 1925.

Genus Afossochiton Ashby, 1925.
Afossochiton cudmorei Ashby, 1925.
A. rostratus (Ashby and Torr, 1901).

[Advanced.]

Subfamily ACANTHOCHITONINAE Ashby, 1925.

Genus Acanthochiton Gray em., 1821.
Acanthochiton chapmani Ashby, 1925.

Subfamily CRYPTOPLACINAE Thiele, 1910.

Genus Cryptoplax Blainville, 1818.
Cryptoplax pritchardi Hall, 1905.
C. gatliffi Hall, 1905.

[Primitive.]

Suborder LEPIDOPLEURINA Thiele, 1910.

Family LEPIDOPLEURIDAE Pilsbry, 1892.

Genus Lepidoplerus Risso, 1826.
Lepidopleurus magnogranifer Ashby, 1925.

[ADVANCED.]

Suborder CHITONINA Thiele, 1910.

Family CALLOCHITONIDAE Thiele, 1910.

Subfamily TRACHYDERMONINAE Thiele, 1910.

Genus NOTOCHITON Thiele.
Notochiton mirandus Thiele. Recent.
N. hyadesi Rochebrune, 1889. Recent.

Genus OÖCHITON Ashby, n. gen.
Oöchiton halli Ashby, n. sp.

Family MOPALIIDAE Pilsbry, 1892.

Genus PLAXIPHORA Gray, 1847.
Plaxiphora concentrica Ashby and Torr, 1901.

Family ISCHNOCHITONIDAE Pilsbry, 1892.

Subfamily ISCHNOCHITONINAE Pilsbry, 1892.

Genus ISCHNOCHITON Gray, 1847.

Subgenus HETEROZONA (Cpr. MS.) Dall, 1878.
Ischnochiton (Heterozona) cariosus Pilsbry, 1892.

Subfamily CALLISTOPLACINAE Pilsbry, 1892.

Genus CALLISTOCHITON Carpenter, 1882.
Callistochiton meridionalis Ashby, 1919.

Family CHITONIDAE Pilsbry, 1892.

Subfamily CHITONINAE Pilsbry, 1892.

Genus CHITON Linné, 1758.

Subgenus RHYSSOPLAX, Thiele, 1893.
Chiton (Rhyssoplax) fossicius Ashby and Torr, 1901.

Subfamily LIOLOPHURINAE Pilsbry, 1893.

Genus LORICA H. and A. Adams, 1852.
Lorica compressa Ashby and Torr, 1901.
L. compressa var. *affinis* Ashby and Torr, 1901.
L. cudmorei, Ashby, 1925.

Genus PROTOLORICA Ashby, 1925.
Protolorica atkinsoni Ashby, 1925.

Genus LORICELLA Pilsbry, 1893.

Loricella gigantea Ashby and Torr, 1901.
L. paucipustulosa Ashby and Torr, 1901.
Subgenus PSEUDOLORICELLA Ashby, 1925.
Loricella (Pseudoloricella) sculpta Ashby, 1921.

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EXPLANATION OF PLATE XXIV.

Fig. 1.—*Oöchiton halli*, n. sp. Balcombe Bay, Vic.; Balcombian. Holotype, median valve. (*a*) side view, ornamentation and broken insertion plate, × 7; (*b*) upper side, × 7. Nat. Mus. No. 13496.

Fig. 2.—*O. halli*, n. sp. Belmont, Vic.; Balcombian. Paratype, median valve, showing ornamentation and complete insertion plate, × 6·5. Nat. Mus., No. 13497.

Fig. 3.—*O. halli*, n. sp. Balcombe Bay, Vic.; Balcombian. Paratype, taken as type of tail valve. (*a*) posterior of valve tilted upwards, to show truncated posterior, also ornamentation, × 6·5; (*b*) side view, showing complete insertion plate, slit and truncated posterior, × 7. Nat. Mus. No. 13494.

Fig. 4.—*Notochiton mirandus* Thiele. Antarctica, dredged: Recent. Cotype, anterior valve, side view showing insertion plate and sculpture for comparison with *Oöchiton halli*, × 5. Ashby Coll.

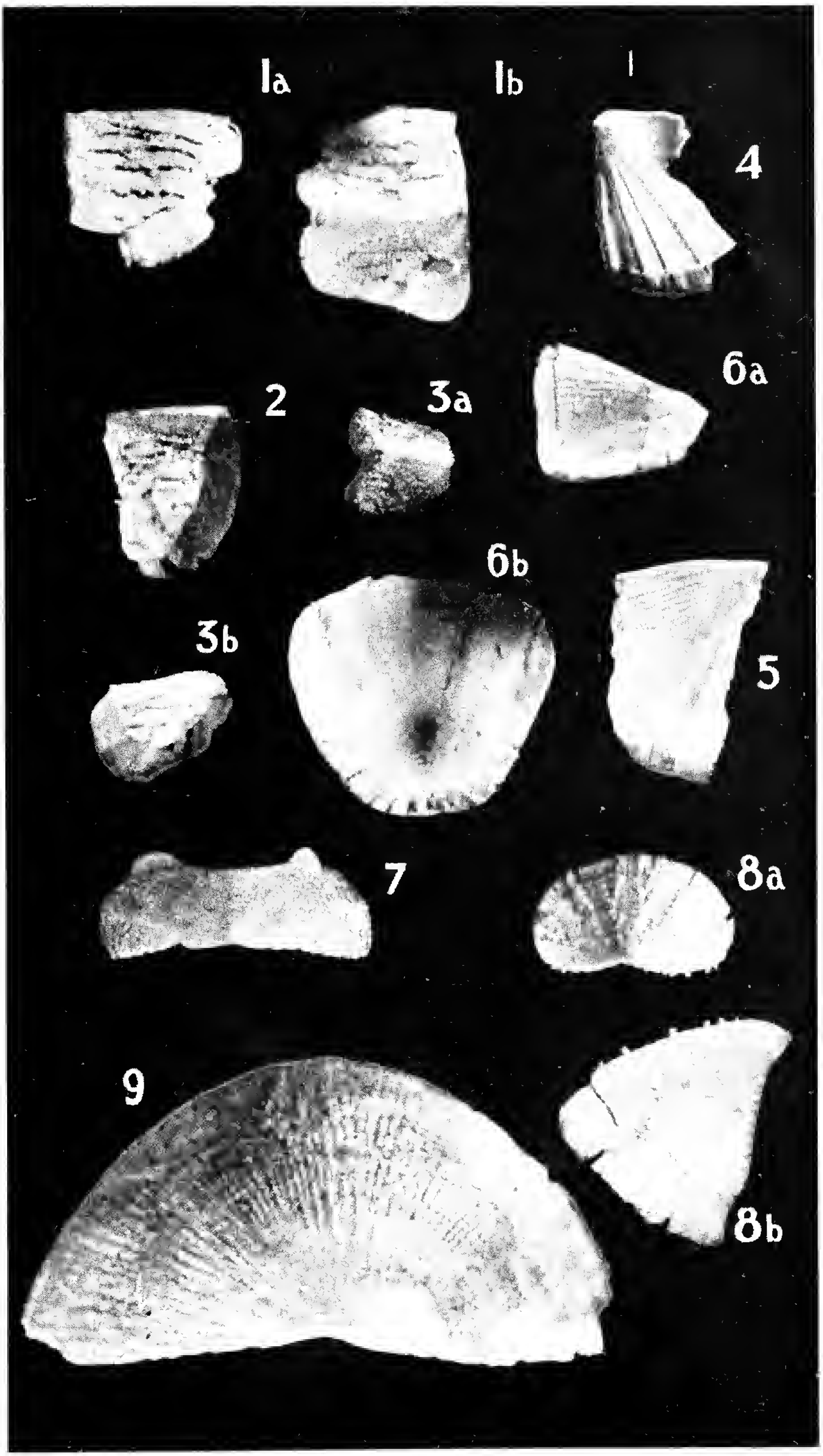
Fig. 5.—*N. mirandus* Thiele. Median valve, side view. × 5. Ashby Coll.

Fig. 6.—*N. mirandus* Thiele. Tail valve. (*a*) side view showing sculpture, mucro and insertion plate, × 5; (*b*) same valve, inside, showing teeth, × 7. Ashby Coll.

Fig. 7.—*Ischnochiton (Heterozona) cariosus* Pilsbry. Balcombe Bay; Balcombian. Median valve, × 7.

Fig. 8.—*Oöchiton halli*. Ashby. Balcombe Bay; Balcombian. Paratype, here taken as type of anterior valve. (*a*) showing sculpture and insertion plate, × 6; (*b*) side view, showing anterior slope, sculpture and insertion plate, × 12. Ashby Coll.

Fig. 9.—*Loricella gigantea*. Ashby and Torr. Table Cape, Tas., Lower Bed; Janjukian. Anterior valve showing shape and sculpture, × 3·5. Nat. Mus. No. 13499.



E. Ashby, photo.

Australian Fossil Polyplacophora.

Royal Society of Victoria.

1928.

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Oliver, C. E., M.C.E., c/o J. E. Minifie, 12 Martin-street, Elwood, S.3. 1878
Selby, G. W., Glenbrook-avenue, Malvern, S.E.5 1889

Ordinary Members.

Agar, Prof. W. E., M.A., D.Sc., F.R.S., University, Carlton, N.3. 1920
Anderson, George, M.A., LL.M., M.Com., 222 Beaconsfield-parade, Middle Park, S.C.6. 1924
Aston, R. L., B.E., M.Sc., Trinity College, Parkville, N.3 1927
Austin, E. G., Boeri Yallock, Skipton 1922

Baldwin, J. M., M.A., D.Sc., Observatory, South Yarra, S.E.1. 1915
Bale, W. M., F.R.M.S., 83 Walpole-street, Kew, E.4 1887
Balfour, Lewis J., B.A., M.B., B.S., Burwood-road, Hawthorn, E.3. 1892
Baragwanath, W., Geological Survey Department, Treasury Gardens, Melbourne, C.2. 1922
Barrett, A. O., 25 Orrong-road, Armadale, S.E.3 1908
Barrett, Sir J. W., K.B.E., C.M.G., M.D., M.S., 105 Collins-street, Melbourne, C.1. 1910
Chapman, F., A.L.S., F.R.M.S., F.G.S., National Museum, Melbourne, C.1. 1902
Cudmore, F. A., 12 Valley View-road, East Malvern, S.E.6 1920

Davis, Captain John King, " St. Carols," Caroline-street, South Yarra, S.E.1. 1920

Dunn, E. J., F.G.S., "Roseneath," Pakington-street, Kew, E.4. 1893
Dyason, E. C., B.Sc., B.M.E., 92 Queen-street, Melbourne, C.1. 1913

Elliott, R. D., 395 Collins-street, Melbourne, C.1 1927
Esserman, N. A., B.Sc., A.Inst.P., Research Laboratories, Maribyrnong, W.3. 1923

Gault, E. L., M.A., M.B., B.S., 4 Collins-street, Melbourne, C.1. 1899
Gepp, H. W., Kurrajong House, 175 Collins-street, Melbourne, C.1. 1926
Gilruth, J. A., D.V.Sc., M.R.C.V.S., F.R.S.E., 7 Clowes-street, South Yarra, S.E.1. 1909
Green, W. Heber, D.Sc., University, Carlton, N.3. 1896
Greenwood, Prof. J. N., D.Sc., University, Carlton, N.3. .. 1928
Grimwade, W. Russell, B.Sc., 420 Flinders-lane, Melbourne, C.1. 1912

Hurst, W. W., B.Sc., Ph.D., Urquhart-street, Hawthorn, E.2. 1927

Jutson, J. T., B.Sc., LL.B., "Darlington," 9 Ivanhoe-parade, Ivanhoe, N.21. 1902

Kelly, Bowes, Glenferrie-road, Malvern, S.E.4 1919
Kenyon, A. S., C.E., Lower Plenty-road, Heidelberg, N.22 1901
Kernot, Assoc. Prof. W. N., B.C.E., M.Mech.E., M.Inst.C.E., University, Carlton, N.3. 1906
Kershaw, J. A., F.E.S., National Museum, Melbourne, C.1. 1900

Laby, Prof. T. H., M.A., Ph.D., Sc.D., F.Inst.P., University, Carlton, N.3. 1915
Lewis, J. M., D.D.Sc., "Whitethorns," Boundary-road, Burwood, E.13. 1921
Littlejohn, W. S., M.A., Scotch College, Hawthorn, E.2 .. 1920
Lyle, Prof. Sir Thos. R., M.A., D.Sc., F.R.S., Irving-road, Toorak, S.E.2. 1889

MacCallum, Prof. Peter, M.C., M.A., M.Sc., M.B., Ch.B., D.P.H., University, Carlton, N.3. 1925
Mahony, D. J., M.Sc., Geological Survey, Public Offices, Treasury Gardens, C.2. 1904
Mann, S. F., Caramut, Victoria 1922
Masson, Prof. Sir David Orme, K.B.E., M.A., D.Sc., F.R.S.E., F.R.S., 14 William-street, Sth. Yarra, S.E.1. 1887
Merfield, C. J., F.R.A.S., Observatory, South Yarra, S.E.1 1913
Merfield, Z. A., F.R.A.S., University, Carlton, N.3 1923

Michell, J. H. M.A., F.R.S., 52 Prospect Hill-road, Camberwell, E.6. 1900
Millen, Senator J. D., 90 William-street, Melbourne, C.1 1920
Miller, Leo F., "Moonga," Power-avenue, Malvern, S.E.4 1920
Miller, E. Studley, 396 Flinders-lane, Melbourne, C.1 .. 1921
Monash, Lieut.-General Sir John, G.C.M.G., K.C.B., Doc. Eng., LL.D., State Electricity Commission, 22 William-street, Melbourne, C.1. 1913
Mullett, H. A., B.Ag.Sc., Dept. of Agriculture, Melbourne, C.2. 1923

Osborne, Prof. W. A., M.B., B.Ch., D.Sc., University, Carlton, N.3. 1910

Patton, R. T., B.Sc., M.F., Hartley-ave., Caulfield, S.E.8 1922
Payne, Prof. H., M.Inst.C.E., M.I.Mech E., University, Carlton, N.3. 1910
Penfold, Dr. W. J., M.B., Alfred Hospital, Commercial-road, Prahran, S.1. 1923
Petrie, A. H. K., B.Sc., University, Carlton, N.3 1925
Picken, D. K., M.A., Ormond College, Parkville, N.3 1916
Piesse, E. L., 43 Sackville-street, Kew, E.4 1921
Pratt, Ambrose, M.A., 376 Flinders-lane, Melbourne, C.1 1918

Quayle, E. T., B.A., 27 Collins-street, Essendon, W.5 .. 1920

Rae, F. J., B.Sc., B.Ag.Sc., Botanic Gardens, South Yarra, S.E.1. 1927
Reid, J. S., 498 Punt-road, South Yarra, S.E.1 1924
Rivett, Dr. A. C. D., M.A., D.Sc., Council for Scientific and Industrial Research, 314 Albert-street, East Melbourne, C.2. 1911
Rogers, J. Stanley, B.A., M.Sc., University, Carlton, N.3 . 1924
Ryan, Rev. Wilfrid, S.J., M.A., F.G.S., Newman College, Carlton, N.3. 1926

Schlapp, H. H., 31 Queen-street, Melbourne, C.1 1906
Shephard, John, "Norwood," South-road, Brighton Beach, S.5. 1894
Shillinglaw, Godfrey V., 64 Dandenong-road, Caulfield, S.E.7. 1925
Singleton, F. A., M.Sc., University, Carlton, N.3 1917
Skeats, Prof. E. W., D.Sc., A.R.C.Sc., F.G.S., University, Carlton, N.3. 1905
Smith, B. A., M.C.E., Mutual Building, 395 Collins-street, Melbourne, C.1. 1924
Spencer, Prof. Sir W. Baldwin, K.C.M.G., M.A., D.Sc., F.R.S., National Museum, Melbourne, C.1. 1887
Stillwell, F. L., D.Sc., 44 Elphin-grove, Hawthorn, E.2 .. 1910
Summers, Associate Prof. H. S., D.Sc., University, Carlton, N.3. 1902

Sweet, Georgina, D.Sc., Cliveden Mansions, Wellington-parade, East Melbourne, C.2. 1906

Thirkell, Geo. Lancelot, B.Sc., 4 Grace-street, Malvern, S.E.4. 1922
Thomas, Dr. D. J., M.D., 12 Collins-street, Melbourne, C.1. 1924
Tiegs, O. W., D.Sc., University, Carlton, N.3. 1925
Trinder, E. E., M.I.H.V.E., "Ruzilma," Orrong-grove, Caulfield, S.E.7. 1922

Wadham, Prof. S. M., M.A., Agr.Dip., University, Carlton, N.3. 1927
Walcott, R. H., Technological Museum, Melbourne, C.1 .. 1897
Weber, E. K., 49 Armadale-street, Armadale, S.E.3 1927
Wickens, C. H., F.I.A., F.S.S., Commonwealth Statistician, Canberra, F.C.T. 1923
Woodruff, Prof. H. A., M.R.C.S., L.R.C.P., M.R.C.V.S., Veterinary School, Parkville, N.2. 1913

Young, Assoc. Prof. W. J., D.Sc., University, Carlton, N.3 1923

Country Members.

Caddy, Dr. Arnold, "Chandpara," Tylden, Vic. 1924
Crawford, W., Gisborne, Vic. 1920

Drevermann, A. C., Dookie Agricultural College, Dookie, Vic. 1914

Easton, J. G., "Kiewa," Murphy-street, Bairnsdale, Vic. 1913

Harris, W. J., B.A., High School, Echuca, Vic. 1914
Hart, T. S., M.A., B.C.E., School of Mines, Bairnsdale, Vic. 1894
Hope, G. B., B.M.E., "Carrical," Hermitage-road, Newtown, Geelong, Vic. 1918

James, A., B.A., M.Sc., High School, Colac, Vic. 1917

Kitson, Sir Albert E., C.M.G., C.B.E., F.G.S., 75 Cornwall Gardens, Kensington, London, S.W.7, England. 1894

Langford, W. G., M.Sc., B.M.E., "Vailala," Elizabeth-street, Gordon, Sydney, N.S.W. 1918
Lea, A. M., F.E.S., 241 Young-street, N. Unley, S. Aus. 1909

Mackenzie, H. P., Engr. Commr. R.N.(Ret.), Trawalla, Vic. 1924

Parker, L. C., B.Sc., High School, Ballarat 1927

Sutton, J. W., 127 Doncaster-avenue, Kensington, Sydney, N.S.W. 1924

Trebilcock, Captain R. E., M.C., Wellington-street, Kerang, Vic. 1921

White, R. A., B.Sc., School of Mines, Bendigo, Vic. 1918

Corresponding Member.

Lucas, A. H. S., M.A., B.Sc., Sydney Grammar School, Sydney, N.S.W. 1895

Associates.

Albiston, H. E., M.V.Sc., Veterinary School, Parkville, N.2. 1925
Allen, J. M., M.A., 41 Nirvana-avenue, East Malvern. S.E.5. 1924
Allen, Miss N. C. B., B.Sc., University, Carlton, N.3 1918
Archer, Howard R., B.Sc., c/o J. M. Moffatt, Faulkner-street, Armidale, N.S.W. 1921
Ashton, H., "The Sun," Castlereagh-street, Sydney, N.S.W. 1911

Bage, Mrs. Edward, "Cranford," 7 Gellibrand-street, Kew, E.4. 1906
Bage, Miss F., M.Sc., Women's College, Kangaroo Point, Brisbane, Qld. 1906
Baker, F. H., 167 Hoddle-street, Richmond, E.1 1911
Barkley, H., Meteorological Bureau, Melbourne, N.3. .. 1910
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Bordeaux, E. F. J., G.M.V.C., B. ès L., Mangalore-street, Flemington, W.2. 1913
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Clinton, H. F., Produce Office, 605 Flinders-street, Melbourne, C.1. 1920
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Cookson, Miss I. C., B.Sc., 154 Power-street, Hawthorn, E.2. 1916
Coulson, A. L., M.Sc., D.I.C., F.G.S., "Finchley," King-street, Elsternwick, S.4. 1919
Cox, E. H., Literary Staff, "The Argus," Elizabeth-street, Melbourne, C.1. 1924
Crespin, Miss I., B.A., 67 Studley Park-road, Kew, E.4 .. 1919

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Deane, Cedric, "Cloyne," State-street, Malvern, S.E.4 .. 1923

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Fenner, C., D.Sc., Education Department, Flinders-street, Adelaide, S.A. 1913
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Flecker, Dr. H., 71 Collins-street, Melbourne, C.1 1922

Gabriel, C. J., 293 Victoria-street, Abbotsford, N.9 1908

Hardy, A. D., F.L.S., Forests Department, Melbourne, C.2. 1903
Hartung, Prof. E. J., D.Sc., University, Carlton, N.3. 1923
Hauser, H. B., M.Sc., Geology School, University, Carlton, N.3. 1919
Hercus, E. O., D.Sc., A.Inst.P., University, Carlton, N.3 1923
Heslop, G. G., D.V.Sc., 7 Hudson-street, Caulfield, S.E.7. 1923
Hill, Gerald F., Council for Scientific and Industrial Research, 314 Albert-street, East Melbourne, C.2. 1924
Hills, E. S., B.Sc., Geology School, University, Carlton, N.3. 1928
Holmes, W. M., M.A., B.Sc., Observatory, South Yarra, S.E.1. 1913
Howitt, A. M., Department of Mines, Melbourne, C.2 ... 1910

Jack, A. K., M.Sc., 49 Aroona-road, Caulfield, S.E.7 1913
Jessep, A. W., B.Sc., M.Ag.Sc., Dip. Ed., Horticultural Gardens, Burnley, E.1. 1927
Jona, J. Leon, M.D., B.S., D.Sc., "Hazelmere," 104 Wattle Tree-road, Malvern, S.E.4. 1914

Kannuluik, W. G., M.Sc., Natural Philosophy Dept., University, Carlton, N.3. 1927
Keartland, Miss B., M.Sc., Cramer-street, Preston, N.18 1919
Keble, R. A., National Museum, Melbourne, C.1 1911

Lambert, C. A., Bank of N.S.W., Melbourne, C.1 1919
Lambert, J. R., 135 Drummond-street, Carlton, N.3 1928
Leslie, J. R., 99 Toorak-road, South Yarra, S.E.1 1923
Lewis, Miss R. M., 52 Campbell-road, East Kew, E.4 1925

Llewelyn, Miss Sybil, M.A., M.Sc., St. Quentin, Broadway, Elwood, S.3. 1928

Luly, W. H., Department of Lands, Public Offices, Melbourne, C.2. 1896

Macdonald, B. E., Dairy Export Branch, Rialto, Collins-street, Melbourne, C.1. 1920

Mackenzie, G., 1 High-street, Prahran, S.1 1907

Maclean, C. W., 56 Cole-street, Elsternwick, S.4 1879

McLennan, Ethel, D.Sc., University, Carlton, N.3. .. 1915

Melhuish, T. D'A., M.Sc., Adelaide Chemical and Fertilizer Co., Currie-street, Adelaide, S.A. 1919

Mollison, Miss E., M.Sc., Royal-crescent, Camberwell, E.6. 1915

Moore, F. E., O.B.E., Chief Electrical Engineer's Branch, P.M.G.'s Department, Treasury Gardens, Melbourne, C.2. 1920

Morris, P. F., National Herbarium, South Yarra, S.E.1. .. 1922

Nelson, Miss E. A., M.A., M.Sc., University, Carlton, N.3 1924

Newman, B. W., Meteorological Offices, Melbourne, C.1 1927

Oke, C., 56 Chaucer-street, St. Kilda, S.2 1922

Orr, D., B.Sc., 860 Mount Alexander-road, Essendon, W.5 1927

Parr, W. J., 17 Bokhara-road, Caulfield, S.E.8 1927

Pern, Dr. Sydney, M.R.C.S., L.R.C.P., 16 Collins-street, Melbourne, C.1. 1920

Petersen, Miss K., B.Sc., 56 Berkeley-street, Hawthorn, E.2. 1919

Pretty, R. B., M.Sc., Technical School, Warrnambool, Vic. 1922

Raff, Miss J. W., M.Sc., F.E.S., University, Carlton, N.3 1910

Richardson, Sidney C., 2 Geelong-road, Footscray, W.11 1923

Rosenthal, Newman, H., B.A., B.Sc., 11 Wimbledon-ave., Elwood, S.3. 1921

Ross, Miss D. J., M.Sc., Merton Hall, Anderson-street, South Yarra, S.E.1. 1924

Sayce, E. L., B.Sc., A.Inst.P., Research Laboratories, Maribyrnong, W.3. 1924

Sharman, P. J., M.Sc., "Glenalvie," 9 Daphne-street, Canterbury, E.7. 1916

Shearer, J., B.Sc., Queen's College, Carlton, N.3 1924

Sherrard, Mrs. H. M., M.Sc., "Balnagowan," Bromley-ave., Cremorne, N.S.W. 1918

Shiels, D. O., M.Sc., Ph.D., Chemistry School, University, Carlton, N.3. 1927

Simpson, H. W. C., 64 Dandenong-road, Caulfield North, S.E.7. 1927

Smith, J. A., 25 Collins-place, Melbourne, C.1	1905
Stickland, John, 433 Brunswick-street, Fitzroy, N.6.	1922
Sutton, C. S., M.B., B.S., Education Department, Melbourne, C.2.	1908
Thomas, R. G., B.Ag.Sc., c/o Dr. Thomas, Northam, W.A.	1922
Thompson, Mrs. G. R., 26 Fawkner-street, St. Kilda, S.2	1922
Thorn, Wm., 37 Chrystobel-crescent, Hawthorn, E.2	1907
Traill, J. C., B.A., B.C.E., 630 St. Kilda-road, Melbourne, S.C.3.	1903
Treloar, H. M., Meteorological Offices, Melbourne, C.1 ..	1922
Trüdinger, W., 27 Gerald-street, Murrumbeena, S.E.9 ..	1918
Turner, A. H., M.Sc., Natural Philosophy Dept., University, Carlton, N.3.	1927
Turner, A. W., M.V.Sc., Veterinary School, Parkville, N.2.	1925
Wilcock, E. L., B.Sc., University High School, Carlton, N.3.	1925
Williamson, H. B., F.L.S., "The Grange," 231 Waverley-road, East Malvern, S.E.5.	1919
Wilson, F. E., F.E.S., 22 Ferncroft-avenue, E. Malvern, S.E.5.	1921
Wilson, Major H. W., O.B.E., M.C., C.de G., B.Sc., 630 Inkerman-road, Caulfield, S.E.7.	1923
Withers, R. B., 10 Nicholson-street, Coburg, N.13.	1926
Woodward, J. H., Queen's Buildings, 1 Rathdown-street, Carlton, N.3.	1903

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The names of the new genera and species are printed in italics.

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END OF VOLUME XLI.

[PART II. PUBLISHED 11th APRIL, 1929.]