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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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CORRIGENDA.

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Plate VII. A small area near Badger Creek is inaccurately mapped The correct mapping is shown in Plate XVII.

Page 92, line 7, for "1930" read "1931"

[Proc. Roy. Soc. Victoria, 44 (N.S.), Pt. 1, 1932].

Art. I.—*Victorian and South Australian Shallow-Water Foraminifera.—Part I.*

By WALTER J. PARR, F.R.M.S.

(With Plate I.)

[Read 11th December, 1930; issued separately 29th February, 1932.]

Introduction.

For several years the writer has been engaged in the study of the coastal foraminifera of Victoria and South Australia, and the present contribution is the first of a series which are intended to deal with the new and more interesting species.

The foraminifera of this area are comparatively well known as a result of the researches of Parker and Jones (*Phil. Trans.*, clv, 1865, p. 438), Howchin (*Trans. R. Soc. S.A.*, xiii, 1890, pp. 161-169), and Chapman (*Journ. Quek. Micr. Club,* [2], x (for 1907), 1909, pp. 117-146, pls. ix, x). It may be mentioned here that the locality given by Parker and Jones for one list (No. 30) is almost certainly not Melbourne nor elsewhere on the Victorian coast, but probably on the coast of South Australia. Two of the species listed, *Valvulina polystoma* and *V. mixta*, have not occurred in any of my material from Victoria, while others mentioned are much commoner in South Australian waters.

With one or two exceptions, which will be noted later, all of the species figured are from one or more of the following localities:—

Station 1.—San Remo, Vic. Shore sand (collected by W.J.P.).
Station 2.—Westernport Bay, Vic. A shallow-water dredging (dredged by C. J. Gabriel).
Station 3.—Black Rock, Vic. Anchor mud (collected by A. C. Collins).
Station 4.—Williamstown. Silty mud (collected many years ago by the late J. Gabriel).
Station 5.—St. Leonard's, Vic. Shore sand (collected by W.J.P.).
Station 6.—Point Lonsdale, Vic. Several samples of shore sand collected at various dates by my father, W. G. Parr.
Station 7.—Torquay, Vic. Shore sand (collected by A. C. Collins).
Station 8.—Port Fairy, Vic. Shore sand (collected by F. Chapman).
Station 9.—Glenelg, S.A. Two samples of shore sand.
Station 10.—Gulf St. Vincent, S.A., from the *Posidonia* deposit (collected by D. J. Mahony).
Station 11.—Hardwicke Bay, S.A. Shore sand.

In the systematic portion of this paper, only the station numbers are given. The letters P. and J., H., or C., placed after the station numbers, indicate that the species has been recorded previously in the papers of Parker and Jones, Howchin, or Chapman.

I am indebted to my friend, Mr. Frederick Chapman, the Commonwealth Paleontologist, for suggesting the writing of these notes, and providing much of the material studied. He has also given me the benefit of his experience in settling several problems. To another collaborator, Mr. Arthur C. Collins, A.R.V.I.A., I owe the dredging from off Black Rock and the shore gathering from Torquay. Mr. Collins has also drawn the plates illustrating this paper. Mr. father, Mr. W. G. Parr, collected the rich shore sand from Point Lonsdale.

The classification followed is that recently published by Dr. J. A. Cushman.

Systematic Description of Species.

Order FORAMINIFERA.

Family SACCAMMINIDAE.

Sub-Family SACCAMMININAE.

Genus **Proteonina** Williamson, 1858.

Proteonina spiculifera, sp. nov.

(Plate I, Fig. 1.)

Description.—Test free, consisting of a single fusiform chamber, broadest in the lowest third, and tapering towards the circular aperture; wall composed of a single layer of coarse acerose sponge spicules arranged more or less longitudinally, with some sand grains of different sizes, most of which are built into the early part of the shell, the whole firmly cemented with a small quantity of brown cement; colour of test brown. Length up to 2·1 mm.

Holotype (Parr Coll.) from shore sand, Point Lonsdale, Vic., collected by W. G. Parr.

Remarks.—This species seems to be quite distinct from other members of the genus. *P. hystrix* (Egger), described (*Abh. bay. Akad. Wiss. München*, xviii, 1893, p. 256, pl. iv, fig. 14), from off the Cape Verde Islands, 69 metres, also uses sponge spicules in the construction of its test, but is otherwise a very different form. Except for its partially spicular shell wall, the present species is much like Williamson's *P. fusiformis*, the type species of the genus. The outline of one specimen is suggestive of the genus *Nouria*, but the test in the examples found is undivided. The only locality at which *P. spiculifera* occurred was Point Lonsdale, in shore sand collected by my father. It was rare here.

Family REOPHACIDAE.

Genus **Reophax** Montfort, 1808.

Reophax scorpiurus Montfort (?).

(Plate I, Fig. 3.)

Stns. 6, 8. C.

There are several examples agreeing closely with Fig. 16 of Plate xxx of the "Challenger" Report, which Brady records as *R. scorpiurus.* This form is common on the eastern coast of Australia. Brady's example was from off Raine Island, Torres Strait, 155 fms. Comparison of this with Soldani's figure on which Montfort based his species (*vide Ann. Mag. Nat. Hist.* [4], viii, 1871, pl. ix, fig. 29, where Soldani's figure is reproduced), discloses that our form is of irregular outline and obscurely segmented, while Soldani's figure represents a neatly built, distinctly chambered test, apparently of a different species. His specimens were from the Mediterranean. *R. scorpiurus* may be a very variable species, but until more is known of its mode of occurrence in the type region, it seems best to regard the Australian form as possibly distinct. Hada (*Trans. Sapporo Nat. Hist. Soc.*, xi (1), 1929, p. 10, text-figs. *a-d*) has recently described a new species, *R. enormis,* from the coast of Japan, which resembles the Australian form more closely. It may be distinguished from the latter by its fewer (three) chambers and the produced apertural neck.

Reophax friabilis, sp. nov.

(Text-fig. 1A; Plate I, Figs. 2*a*, *b*.)

Description.—Test in the megalospheric form consisting of about five chambers increasing slightly in size as added; in the microspheric stage there are up to eight chambers increasing rapidly in size, the chambers in both forms being arranged in a straight or slightly curved series; chambers about as long as broad; the segmentation of the test is obscure from the exterior. but broken specimens show it to be as in the genus *Reophax;* wall thick, composed of fairly large sand grains of even diameter, rather loosely cemented, especially in the last-formed chamber, with a small amount of brown cement; apertural end truncate; aperture rounded, without a definite neck; colour of test brown.

Length of holotype, a microspheric specimen, 3·9 mm.; greatest diameter, 0·98 mm.; length of larger megalospheric example, 3·5 mm.; diameter of last-formed chamber, 1 mm.

Holotype (Parr Coll.) from shore sand, Point Lonsdale, Vic., collected by W. G. Parr.

Remarks.—Five examples, one megalospheric and the others microspheric, were found in the Point Lonsdale gathering. The occurrence of such a large proportion of microspheric specimens is unusual. I have another example of the megalospheric stage from a dredging made by Dr. Verco off the coast of South Australia. The most nearly related species appears to be *R. insectus* Goës (*Bull. Mus. Comp. Zool. Harvard*, xxix, No. 1, 1896, p. 28, pl. iii, figs. 6, 7), described from off the W. coast of Mexico and from near the Galapagos Islands, 772-795 fms., and also recorded by Cushman (*Bull.* 71, *U.S. Nat. Mus.*, pt. 1, 1910, p. 89, text-fig. 124) from off San Diego, California, 617-680 fms. This is a larger species, reaching 8 mm. in length, the diameter of the last-formed chamber ranging from 1·5 mm. to 2 mm. It also has more chambers, the specimen figured by Goës having twelve which are separated by very distinct sutures. Goës notes that the aperture of his species is often slightly limbated or protruding.

Family VERNEUILINIDAE.

Genus **Clavulina** d'Orbigny, 1826.

Clavulina multicamerata Chapman.

(Plate I, Figs 4, 5.)

Clavulina parisiensis d'Orbigny, var. *multicamerata* Chapman, 1909. *Journ. Quck. Micr. Club*, [2], x (for 1907), p. 127, pl. ix, fig. 5.
Stns. 1, 2, 7, 8, 9, 11. C.

This form was described by Mr. Chapman from Shoreham, Vic., and has proved to be quite common on the Victorian coast. The shell wall in all of the examples, except those from Westernport Bay, where the specimens are also slenderer, is largely constructed of small fragments of sponge spicules, the longest of which are built in along the suture lines of the chambers. In the majority of specimens, the first three or four chambers of the uniserial series are roughly triangular in section. This character is illustrated by the figured examples, and is also suggested by Mr. Chapman's figure. Specimens which have not passed this stage of growth are very like Sidebottom's figure (*Mem. Proc. Manchester Lit. Phil. Soc.*, liv (3), 1910, p. 11, pl. i, fig. 10), of *Clavulina angularis* d'Orb., from Palermo, Sicily, which is itself very close to d'Orbigny's type figure (*Ann. Sci. Nat.*, vii, 1826, p. 268, No. 2, pl. xii, fig. 7) of that species. It is of interest to note that Parker and Jones recorded *C. parisiensis* and *C. angularis* (as *Valvulina*) from coast sand, Melbourne, Australia. Probably the present form was that met with.

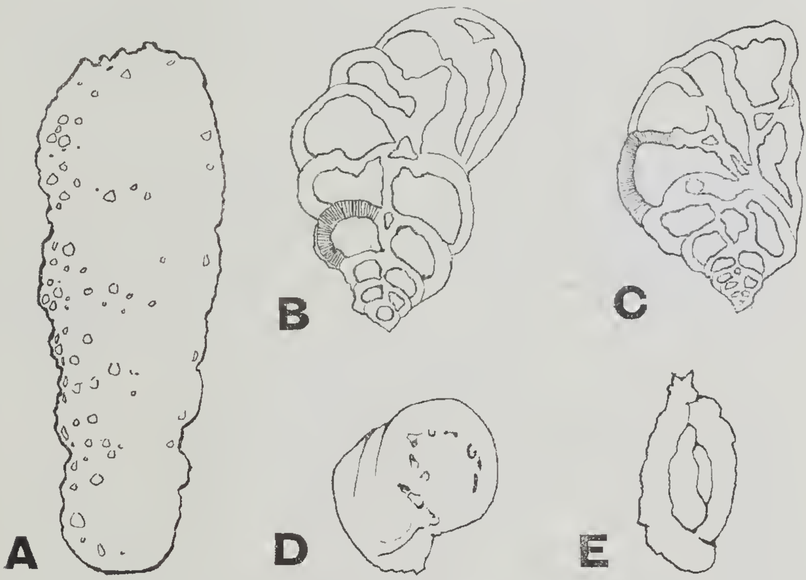
C. multicamerata was originally described as a variety of *C. parisiensis*, but after comparing the much larger number of specimens now available, including some from the type sample, with examples of *C. parisiensis* from the Eocene of the Paris Basin, and *C. angularis* from the Mediterranean, I think it should be given specific rank.

CLAVULINA DIFFORMIS Brady.

(Plate I, Fig. 6.)

Clavulina angularis d'Orbigny, var. *difformis* Brady, 1884, *Rept. Voy. "Challenger," Zool.*, vol. ix, p. 396, pl. xlviii, figs. 25-31.
C. difformis Brady: Cushman, 1924, Publ. 342, *Carn. Inst. Wash.*, p. 23, pl. vi, figs. 5, 6.
Stns. 1, 2, 8, 10, 11, and Shoreham, Vic.

This rare form was described from Nares Harbour, Admiralty Islands; the only other records are from the Kerimba Archipelago, off Portuguese East Africa (Heron-Allen and Earland), Guam and Samoa (Cushman). The figured example is from Gulf St. Vincent, where the species is common, and the specimens exceptionally fine.



Text-Figure I.

A—*Reophax friabilis*, sp. nov. Megalospheric example from Point Lonsdale, Vic., ×21. B—*Cribrobulimina polystoma* (Parker and Jones). Megalospheric form from Gulf St. Vincent, S.A., ×37, vertical section. C—Microspheric form of same, ×27, vertical section. D—*Cribrobulimina polystoma* (Parker and Jones), from Gulf St. Vincent, S.A., ×21. E—*Quinqueloculina ammophila*, sp. nov. from Western Port Bay. Front aspect, ×21.

Family VALVULINIDAE.

Genus **Cribrobulimina** Cushman, 1927.

Cribrobulimina polystoma (Parker and Jones).

(Text-fig. 1, B.C.D.; Plate I, Figs. *7a, b.*)

Valvulina spp. Parker and Jones, in Carpenter, Parker and Jones, 1862, Introd. Foram., p. 147, pl. xi, figs. 19, 20, 21, 24, 25, 26.
V. polystoma Parker and Jones, 1865, *Phil. Trans.*, clv, pp. 437, 438.
V. mixta Parker and Jones, 1865, *op. cit.*, p. 438.
Cribrobulimina mixta (Parker and Jones): Cushman, 1927, *Contrbns. Cush. Lab.*, ii (4), p. 80, pl. xi, figs. 1-5.
Stns. 9, 10, 11. P. & J.

Description.—Test in the early stages trihedral, angled, the sides flattened, chambers triserially arranged, adult chambers in a loose spiral, five or more in a coil; sutures distinct; wall arenaceous; aperture in the young as in *Valvulina*, later developing an opening in the plate-like tooth and in the adult a series of small openings forming a cribrate plate.

Remarks.—The above is Dr. Cushman's description of the genus *Cribrobulimina*, *C. mixta* being selected by him as the genotype. The type material was from Australia.

Although this species was first figured in 1862, it was not until three years later that Parker and Jones named it in their paper on foraminifera from the North Atlantic and Arctic Oceans (*op. cit. supra*). On page 437 of this work, a list of foraminifera from " Swan River, white shelly mud, 7-8 fms." is given, and in this the occurrence of *Valvulina polystoma* is recorded, the name being applied, in a footnote, to figs. 21 and 24 of Plate xi of Carpenter's " Introduction." Fig. 21 represents a short, very broad specimen, in which the early triangular growth is almost completely hidden by the later coiled series of chambers, and the aperture is cribrate. A similar example is here figured (Text-fig. 1D).

On page 438, another list, from " coast sand, Melbourne, Australia," appears. Here in addition to *V. polystoma*, another species, *V. mixta*, is recorded, this name being given to figs 19, 20, 25 and 26 of Plate xi of the " Introduction." This form has an aperture with a simple valvular tooth, and is about twice as long as wide. This type of shell is figured on Plate I. of the present paper. (Figs. *7a, b.*)

In the sample of material from the *Posidonia* deposit in Gulf St. Vincent, examples of both forms occur, that named by Parker and Jones, *Valvulina mixta*, being extremely common. Because of their association here and at other localities and the comparative rarity of the short, broad type of shell, it appeared likely that the two represented the megalospheric and microspheric stages of the one species. Sections made of a number of specimens prove this to be the case, the so-called *V. mixta* being the megalospheric stage and *V. polystoma* the microspheric. (Text-figs. 1B and 1C.) *V. mixta* is therefore a synonym of the previously-named *V. polystoma.* Within well-defined limits, represented by figs. 19 and 21 of Carpenter's "Introduction," the species is very variable in form. Some of the intermediate forms have been figured by Dr. Cushman (*loc. cit.*).

The writer's sections confirm Carpenter's statement as to the presence of two shell layers. The inner, or perforate layer, is by far the thicker. The outer is often practically absent, particularly in the earlier chambers, and is seldom more than a mere film of sand grains. The inner layer is closely tubulated, the tubules being clearly visible under a magnification of 40 diameters. Although tests with acid show the shell to be almost entirely calcareous in its composition, the inner layer does not appear to be wholly secreted by the organism, but to consist of minute grains of adventitious material embedded in abundant calcareous cement. The material forming the outer layer is largely quartz sand.

The only records of this interesting species are those given above. They are all from shallow water. The writer has met with *C. polystoma* in an "Endeavour" dredging from 30 miles S. of Cape Nelson, Vic., 300 fms., and it is not uncommon in some soundings made by the trawler "Bonthorpe" in the Great Australian Bight, off the coast of West Australia, at depths of about 100 fms. As a fossil it occurs with *Marginopora vertebralis* Q. and G., in the Lower Pleistocene limestone of Yorke Peninsula, South Australia.

Family MILIOLIDAE.

Genus **Quinqueloculina** d'Orbigny, 1826.

Quinqueloculina australis, sp. nov.

(Plate I, Figs. 8*a-c*.)

Miliolina subrotunda Brady (*non Vermiculum subrotundum* Montagu), 1884, *Rept. Voy. "Challenger," Zool.*, vol. ix, pl. v, figs. 10, 11.

Description.—Test in front view rounded, as long as broad; chambers roughly triangular in transverse section, especially in the early portion of the test, with the wall thickened on the outside angle; periphery subangular, but occasionally rounded; sutures distinct, not depressed; surface smooth; aperture semicircular, wih a tooth of the same shape a little in front of the aperture.

Length up to 0·5 mm.; thickness, 0·24—0·3 mm.

Holotype (Parr Coll.) from 7 miles E. of Cape Pillar, Tas., 100 fms. Other examples are from shore sand, Point Lonsdale, Vic., and from several dredgings from depths of about 100 fms. off the coast of New South Wales and in the Great Australian Bight. The specimens figured by Brady were from "Challenger" Station 162, off East Moncoeur Island, Bass Strait, 38 fms.

Remarks.— The figures give an excellent idea of the characters of this species. Related species are *Q. dilatata* d'Orb., also found on the coast of Victoria, and *Q. subrotunda* (Montagu), described from the coast of Great Britain. These are more compressed, less regularly formed, and have a rounded margin at all stages of development. The thickened outside angle of the chambers, amounting in many cases to almost a broad keel, particularly in the early stages, is a very distinctive feature of the present species. The slightly oblique early chambers are also characteristic.

QUINQUELOCULINA COSTATA d'Orbigny.

(Plate I, Fig. 9.)

Quinqueloculina costata d'Orbigny, 1826, *Ann. Sci. Nat.*, vii, p. 301, No. 3. Schlumberger, 1893, *Mém. Soc. Zool. France*, vi, p. 69, text-fig. 20; pl. iii, figs. 75, 76. Fornasini, 1905, *Mem. Acc. Sci. Ist. Bologna*, [6], ii, p. 62, pl. ii, figs. 6*a*-*c*.
Miliolina costata (d'Orb.): Heron-Allen and Earland, 1915, *Trans. Zool. Soc. London*, xx, p. 579, pl. xliv, figs. 9-12.

Stn. 1.

There is one specimen agreeing with Schlumberger's figures and description of this species. His specimens were from the Gulf of Marseilles, 30-40 metres, while those of d'Orbigny were also from the Mediterranean Sea. The figures in the Planches Inédites show a slenderer shell more like those from the Kerimba Archipelago, figured as this species by Heron-Allen and Earland, except that the apertural tooth appearing in d'Orbigny's and Schlumberger's figures is absent from the Kerimba specimens.

QUINQUELOCULINA AMMOPHILA, sp. nov.

(Plate I, Figs. 10*a*, *b*; Text-fig. 1E.)

Description.—Test elongate-ovate, about twice as long as broad, somewhat flattened; chambers rounded in cross section, distinct; sutures depressed; wall composed of coarse sand grains; apertural end produced, aperture circular, with a small plate-like tooth.

Length up to 1·3 mm.

Holotype (Parr Coll.) from Westernport Bay, dredged by C. J. Gabriel.

Remarks.—This form was common at the type locality. I have other specimens from Port Fairy, Vic. (Stn. 8), and from two "Bonthorpe" soundings in the Great Australian Bight, at depths of 89 and 75 fms. It is extremely common in the Lower Pliocene of the Lake Bunga district, near Lakes Entrance, Vic.

There are several other species with agglutinated tests which have been recorded from the Australian region. Millett's *Miliolina bosciana*, agglutinated var. (*J.R.M.S.*, 1898, pl. vi, fig. 4) is perhaps the same as the present species. *Q. agglutinans* d'Orb. and *Q. bidentata* d'Orb., both of which were described from the West Indian region, and *Q. sclerotica* Karrer, from the Miocene of Hungary, are proportionately wider, with a squarish periphery, and the apertural characters are different. Another form which is more closely related is *Q. anguina* Terquem, var. *agglutinans* (Wiesner), recorded by Heron-Allen and Earland from the Kerimba Archipelago, with the note that the Kerimba specimens agreed with co-types supplied by Wiesner. This is similar to Terquem's *Q. anguina,* from the Pliocene of the Island of Rhodes, except that there is a sub-arenaceous investment to the shell. The coarsely-arenaceous shell-wall of the present species separates it from Wiesner's form.

Genus **Spiroloculina** d'Orbigny, 1826.

Spiroloculina antillarum d'Orbigny.

(Plate I, Fig. 11.)

Spiroloculina antillarum d'Orbigny, 1839, in De La Sagra, *Hist. Fis. Pol. Nat. Cuba, "Foraminifères,"* p. 166, pl. ix, figs. 3, 4. Cushman, 1924, Publ. 342, *Carn. Inst. Wash.*, p. 55, pl xx, fig. 1.
Stns. 1, 2, 3, 5, 6, 7, 8, 9, 10, 11. C. (as *S. grata*).

There are many fine examples of this species measuring up to 1·3 mm. in length. They vary considerably in width. The figured specimen is exceptionally broad, and in front view is like Fornasini's figure (*Mem. Acc. Sci. Ist. Bologna* [6], i, 1904, p. 5, pl. i, fig. 9) of *S. striata* d'Orb. from the Planches **Inédites.** In end view, however, that species has a subcarinate margin, while that of *S. antillarum* is rounded. Although Parker and Jones recorded *Spiroculina* (*sic*) *striata* d'Orb. from coast sand, Melbourne, no individuals with angular margins have been found in the present material.

S. antillarum is a common species in the warmer shallow-water areas of the Pacific. In Australia, it occurs as a fossil in the Lower Beds at Muddy Creek, near Hamilton, Vic. (Oligocene), and in the Miocene of Table Cape, Tas.

Genus **Triloculina** d'Orbigny, 1826.

Triloculina insignis (Brady).

(Plate I, Fig. 12.)

Triloculina striato-trigonula Parker and Jones, 1865, *Phil. Trans.*, clv, p. 438 (*nomen nudum*).
Miliolina insignis Brady, 1881, *Quart. Jour. Micr. Sci.* (*London*), n.s., xxi, p. 45; 1884, *Rept. Voy. "Challenger," Zool.*, vol. ix, p. 165, pl. iv, figs. 8, 10.
Stns. 6, 7, 8, 9, 10, 11. P. & J.

There can be no doubt that this is the same species as that recorded by Parker and Jones as *T. striato-trigonula* nov., from coast sand, Melbourne, Australia, but as the latter was a *nomen* *nudum*, Brady's name must stand. Brady's figures seem to represent two species. The present specimens are nearest his Fig. 10, the original of which was from Bass Strait. This is a common shallow-water form on the Australian coast. The other specimen figured by Brady (Fig. 8) was from the West Indies, 390 fms.

Triloculina bertheliniana (Brady).

(Plate I, Fig. 13.)

Miliolina bertheliniana Brady, 1884, *Rept. Voy. "Chall.," Zool.*, vol. ix, p. 166, pl. cxiv, fig. 2.
M. tricarinata (d'Orb.) (reticulated var.): Millett, 1898, *J.R.M.S.*, p. 503, pl. xi, fig. 12.
Stn. 7.

One typical example. The records of this species are all from the Indo-Pacific region, where it occurs in shallow water. The specimen figured by Brady was from shore sand, Tamatavé, Madagascar.

Triloculina oblonga (Montagu).

(Plate I, Figs. 15*a-c*.)

Vermiculum oblongum Montagu, 1803, *Test. Brit.*, p. 522, pl. xiv, fig. 9.
Miliolina oblonga (Montagu): Williamson, 1858, Recent Foram. Gt. Brit., p. 86, pl. vii, figs. 186, 187.
Stns. 1, 2, 3, 4, 5, 6, 7, 9. C., H.

Examples of this species are fairly common, and are nearly all of the narrow type figured by Williamson, with a few broader specimens approaching *T. laevigata* d'Orb. and *T. elongata* d'Orb. From Point Lonsdale, Vic., there are several examples of the biloculine form, which does not appear to have been recorded previously (Plate I, Figs. 15*a-c*).

Triloculina cultrata (Brady).

(Plate I, Figs. 14*a, b*.)

Miliolina cultrata Brady, 1881, *Quart. Journ. Micr. Sci. (London)*, n.s., xxi, p. 45; 1884, *Rept. Voy. "Chall." Zool.*, vol. ix, p. 161, pl. v, figs. 1, 2. Heron-Allen and Earland, 1915, *Trans. Zool. Soc., Lond.*, xx, p. 564, pl. xlii, figs. 1-5 (*non* figs. 6-10).
Stn. 3.

The figured specimen is the only one found, but it is very typical. Brady recorded this species from Humboldt Bay, Papua, 37 fms., and Calpentyn, Ceylon, 2 fms. Heron-Allen and Earland's record was from the Kerimba Archipelago, also from comparatively shallow water.

Family LAGENIDAE.

Sub-Family LAGENINAE.

Genus **Lagena** Walker and Jacob, 1798.

Lagena distoma-margaritifera Parker and Jones.

(Plate I, Figs. 16, 17.)

Lagena distoma-margaritifera Parker and Jones, 1865, *Phil. Trans.*, clv, p. 357, pl. xviii, figs. 6*a*. *b*. Brady, 1884, *Rept. Voy. "Chall." Zool.*, vol. ix, p. 458, pl. lviii, fig. 16.
Stns. 6, 7, 8, 9, 11. P. & J., H.

Occasional specimens occur. An exceptionally fine one from Point Lonsdale, found after the plates were drawn, is perfect and shows this species to have one end closed and the other produced to form a long neck with a phialine neck as in *L. gracillima*. It was described from the Victorian coast, and the only records of its occurrence are: Near Melbourne, from shore sand (Parker and Jones); off East Moncoeur Island, Bass Strait, 38 fms., and off the west coast of New Zealand (Brady); and the mouth of the Port Adelaide River, S.A. (Howchin). The species is found fossil in the Balcombian of Grice's Creek, near Frankston, Vic.

Lagena tetragona Parker and Jones.

(Plate I, Fig. 18.)

Lagena tetragona Parker and Jones, 1865, *Phil. Trans.*, clv, p. 420, pl. xviii, figs. 14*a*, *b*.
Stn. 4.

This species does not appear to have been recorded since it was described from the Middle Eocene (Calcaire Grossier) of Grignon, France. The specimens from Williamstown agree exactly with the figures given by Parker and Jones.

Lagena acuticosta Reuss, var. ramulosa Chapman.

(Plate I, Fig. 19.)

Lagena acuticosta Reuss, var. *ramulosa* Chapman, 1909, *Journ. Quek. Micr. Club*, [2], x (for 1907), p. 129, pl. ix, fig. 9.
Stns. 6, 7, 11. C.

Rare. The present records extend the range of this very distinct form to South Australian waters. It was described by Mr. Chapman from McHaffie's Reef, Phillip Island, and occurs also in the Post-Tertiary of Victoria.

Family POLYMORPHINIDAE,

Sub-Family POLYMORPHININAE.

Genus **Sigmomorphina** Cushman and Ozawa, 1928.

SIGMOMORPHINA WILLIAMSONI (Terquem).

(Plate I, Fig. 20.)

Polymorphina lactea (Walker and Jacob), var. *oblonga* Williamson, 1858, Rec. Foram. Gt. Brit., p. 71, pl. vi, figs. 149, 149*a*.
P. williamsoni Terquem, 1878, *Mém. Soc. Géol. France*, [3], i, p. 37.
Polymorphina oblonga Will. (*non* d'Orbigny): Heron-Allen and Earland, 1922, Brit. Ant. ("Terra Nova") Exped., 1910, *Nat. Hist. Rep. Zool.*, vol. vi, pt. 2, p. 180, pl. vii, fig. 2.
Sigmomorphina williamsoni (Terquem): Cushman and Ozawa, 1930, *Proc. U.S. Nat. Mus.*, lxxvii, Art. 6, p. 138, pl. xxxviii, figs. 3, 4.

Stns. 3, 4.

Four very typical examples were met with in the silty material from Hobson's Bay. This species is common around the British Isles. Heron-Allen and Earland's record quoted above is from off the coast of New Zealand. I have *S. williamsoni* also from a dredging off the Snares, S. of New Zealand, 60 fms., and as a fossil from the Miocene of Birregurra, Vic.

Family BULIMINIDAE.

Sub-Family VIRGULININAE.

Genus **Bolivina** d'Orbigny, 1839.

BOLIVINA SUBRETICULATA, sp. nov.

(Plate I, Figs. 21*a*, *b*.)

Bolivina reticulata Brady (*non* Hantken), 1884, *Rept. Voy. "Chall." Zool.*, vol. ix, p. 426, pl. liii, figs. 30, 31.

Description.—Test small, in front view rhomboid, thickest along the median line and with sharp edges; chambers numbering about fourteen in the megalospheric form, but more in the microspheric form, much longer than wide, slightly inflated in the later portion of the test; sutures distinct, limbate, sinuous, with processes of varying length on the posterior margin; wall calcareous, finely perforate, and ornamented in the early part of the test with a few irregular costae, later with a network of raised lines formed by the projecting processes extending more or less across the face of each chamber; aperture bolivine, elongate-oval; colour white. Length about 0·35 mm.

Holotype (not figured) (Parr Coll.) from "Challenger" Station 185, off Raine Island, Torres Strait, 155 fms.

Remarks.—The present species is almost certainly the same as that figured by Brady as *B. reticulata* Hantken. The specimens figured by him were from "Challenger" Stn. 177, off the New Hebrides. His records were from off the New Hebrides, 130 fms., off Raine Island, 155 fms., off Kandavu, 255 fms., off Tahiti, 420 fms., and from the South Atlantic, in mid-ocean, 1425 fms., the last-mentioned with a note that the specimens were not as typical as the others. Although Brady had examined specimens of *B. reticulata* from the *Clavulina szaboi* beds of Hungary, the only point of difference noted by him between these and the Recent form was the larger size of the fossil examples. His figures certainly do not agree with Hantken's (*vide Mitt. Ung. Geol. Anstalt*, iv (for 1875), 1881, p. 65, pl. xv, figs. 6*a*, *b*). I have recently received some material from the *Clavulina szaboi* beds in the vicinity of Budapest, and from this have obtained a good series of *B. reticulata*. The study of this leads me to regard the two forms as distinct. The Hungarian specimens in their earlier stages bear some resemblance to Brady's figures, but in the adult, instead of being in front view rhomboid, are broadest in the apertural half of the shell, while there is a much greater development of the reticulate ornament giving the species its name. In Recent specimens this is most conspicuous along the median line, and is nothing more than a development of the limbate sutures. In typical examples of *B. reticulata*, the whole of each face is closely and evenly ornamented with a network of raised lines which are independent of and largely obscure the sutures, and under this the surface is very finely, longitudinally striated. These striae are obscured by the more conspicuous ornament, and were apparently overlooked by Hantken, but are visible quite clearly on the last-formed two chambers under a magnification of 40 diameters.

The description of *B. subreticulata* is almost wholly based on a number of specimens from "Challenger" Stn. 185, off Raine Island, 155 fms. For these I am indebted to my friend, Mr. F. Chapman. Both megalospheric and microspheric stages are present, the latter having a longer test, with a larger number of chambers than the former, and resembling *B. reticulata* in being broadest in the apertural half of the shell. The figured example is a worn microspheric one from Point Lonsdale, Vic., drawn before those from Raine Island were studied. Others have since been found at the same locality, but not elsewhere on the coasts of Victoria and South Australia.

Sub-Family REUSSIINAE.

Genus **Reussia** Schwager, 1877.

Reussia decorata (Heron-Allen and Earland).

(Plate I, Figs. 22*a*, *b*.)

Verneuilina decorata Heron-Allen and Earland, 1924, *J.R.M.S.*, p. 138, pl. vii, figs. 7-9. Parr, 1926, *Vict. Nat.*, xliii, p. 18.

Stn. 4.

There is one small, but otherwise typical example of this species, which is now recorded for the first time in the Recent condition. The type-specimens were from the Miocene of the Filter Quarry, Batesford, Vic. I have examples from the same locality, and have recorded the species from the Oligocene of Muddy Creek, near Hamilton, Vic.

Explanation of Plate I.

Fig. 1.—*Proteonina spiculifera*, sp. nov. Point Lonsdale, Vic. Holotype. ×15.

Fig. 2*a*, *b*.—*Reophax friabilis*, sp. nov. Point Lonsdale, Vic. Holotype. Microspheric form. *a*, side view; *b*, apertural view. ×9.

Fig. 3.—? *Reophax scorpiurus* Montfort. Port Fairy, Vic. ×12.

Figs 4, 5.—*Clavulina multicamerata* Chapman. Port Fairy, Vic. Two specimens showing early angular chambers. ×24.

Fig. 6.—*Clavulina difformis* Brady. Gulf St. Vincent, S.A. ×24.

Fig. 7*a*, *b*.—*Cribrobulimina polystoma* (Parker and Jones). Glenelg, S.A. Example showing simple form of aperture. ×24.

Fig. 8*a-c*.—*Quinqueloculina australis*, sp. nov. Dredgings, 7 miles E. of Cape Pillar, Tas. Holotype. *a*, front view; *b*, rear view; *c*, view of apertural end. ×36.

Fig. 9.—*Quinqueloculina costata* d'Orb. San Remo, Vic. ×24.

Fig. 10*a*, *b*.—*Quinqueloculina ammophila*, sp. nov. Westernport Bay. *a*, rear view; *b*, end view (apertural end is broken off). ×24.

Fig. 11.—*Spiroloculina antillarum* d'Orb. Glenelg, S.A. Side view of an exceptionally broad specimen. ×24.

Fig. 12.—*Triloculina insignis* (Brady). Glenelg, S.A. ×24.

Fig. 13.—*Triloculina bertheliniana* (Brady). Torquay, Vic. ×36.

Fig. 14*a*, *b*.—*Triloculina cultrata* (Brady). Black Rock, Vic. *a*, front view; *b*, apertural view. ×36.

Fig. 15*a-c*.—*Triloculina oblonga* (Montagu). Point Lonsdale, Vic. Biloculine form. *a*, front view; *b*, side view; *c*, apertural view. ×20.

Figs. 16, 17.—*Lagena distoma-margaritifera* Parker and Jones. Point Lonsdale, Vic. Two examples showing different types of ornament. ×24.

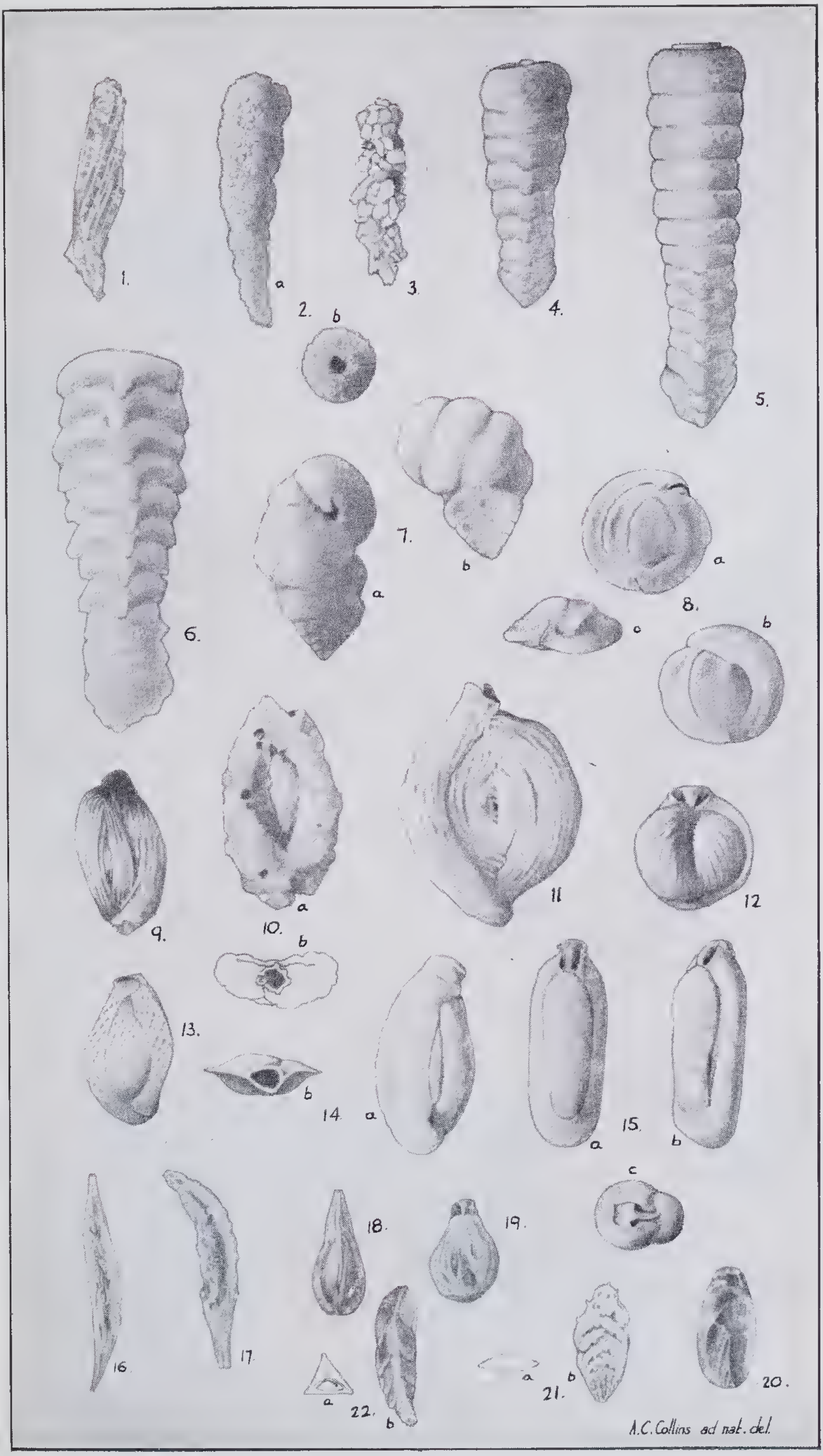
Fig. 18.—*Lagena tetragona* Parker and Jones. Williamstown, Vic. ×60.

Fig. 19.—*Lagena acuticosta* Reuss, var. *ramulosa* Chapman. Point Lonsdale, Vic. ×48.

Fig. 20.—*Sigmomorphina williamsoni* (Terquem). Black Rock, Vic. ×48.

Fig. 21*a*, *b*.—*Bolivina subreticulata*, sp. nov. Point Lonsdale, Vic. Worn example of microspheric form. *a*, end view; *b*, side view. ×48.

Fig. 22*a*, *b*.—*Reussia decorata* (Heron-Allen and Earland). Williamstown, Vic. *a*, end view; *b*, side view. ×48.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[PROC. ROY. SOC. VICTORIA, 44 (N.S.), PT. I, 1932.]

ART. II.—*The Development of the Tabulate Coral, Pleurodictyum megastomum.*

By ROBERT B. WITHERS, B.Sc., Dip.Ed.

[Read 9th April, 1931; issued separately 29th February, 1932.]

Introduction.

The species dealt with in this paper was established by W. S. Dun (Dun, 1898, p. 83, pl. iii, fig. 1) on fragments from Kilmore and Mansfield. Though Sir Frederick McCoy (McCoy, 1867, p. 201, footnote) at an earlier date had recorded from the Upper Yarra district a form he called *Pleurodictyum megastomum*, he had not described it. The description of the first complete corallum under this name was made by F. Chapman (Chapman, 1903, p. 105, pl. xvi, figs. 2-5), who described from the junction of the Woori Yallock and the Yarra a specimen showing 14 corallites. It is interesting to note, however, that as early as 1888 Dr. Foerste (Foerste, 1888, p. 132, pl. xiii, fig. 22) had described a similar specimen with 15 corallites, referring it with some doubt to the European species, *Pleurodictyum problematicum* Goldfuss. Mr. Chapman made a further contribution to our knowledge of this species in 1921 (Chapman, 1921, p. 216, pl. ix, figs. 4, 5, 6) by describing an eight-celled form from Kinglake West. Specimens recently collected from the same district by the author, together with material and figures from other sources, indicate that the number of cells can range from 6 to 15. At the same time, these specimens make clear the stages of development in this interesting species, and demonstrate a parallelism in this regard with the American species, *Pleurodictyum lenticulare*.

Development of Pleurodictyum lenticulare.

C. E. Beecher (Beecher, 1891) has been able to establish the mode of development of the American species, *Pleurodictyum lenticulare* (Hall) (=*Michelinia lenticularis* Hall) (Hall, 1887), which occurs in the Lower Helderbergian (Lower Devonian) of New York State. He was fortunate enough to obtain a specimen of the initial corallite (Fig. 1*a*), and one showing the second corallite budding off from it (Fig. 1*b*), thus establishing the nepionic and the first nealogic (or neanic) stages in growth. The succeeding neanic stages up to the eighth corallite he elucidated by an examination of an excellently preserved epitheca (Figs. 1*c* and 1*d*). From this, by means of the growth lines and the relative sizes of the corallites, he was able to demonstrate the origin of the first and second buds near the apex of the initial corallite, and to show that succeeding buds originate respectively further away. In the absence of an epitheca, Beecher found the relative sizes of the corallites, up to the completion of the eighth, a reliable guide to their order of development (Fig. 1*e*).

Development of Pleurodictyum megastomum.

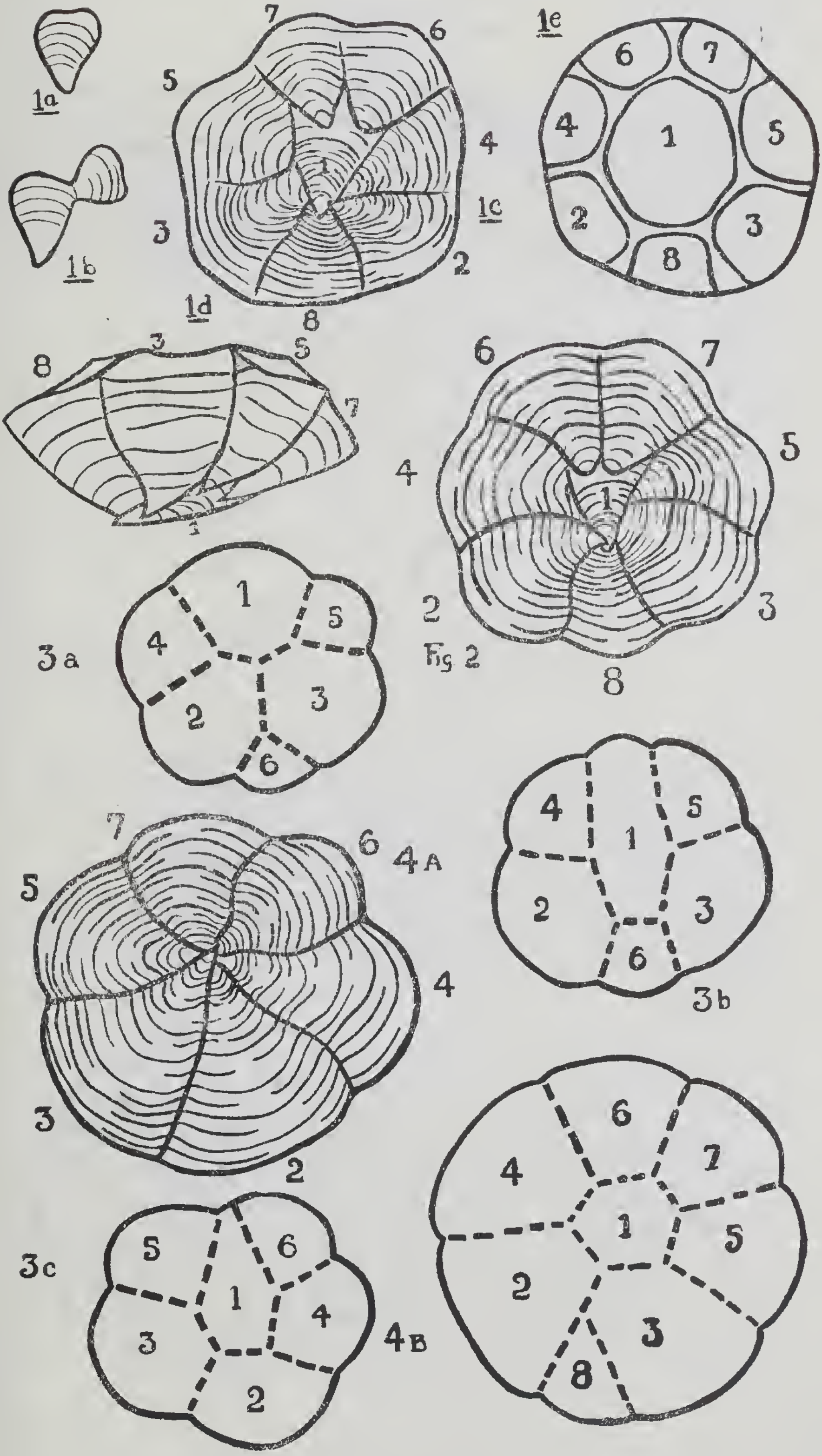
The application of these principles to the Victorian species shows a close relationship with the American. Fig. 2 shows an epitheca of *P. megastomum* from Kinglake West, from which the order of development of the first eight corallites can be clearly seen to be similar to the American species.

A departure from these principles is shown in Figs. 3*a* and 3*b*, which are views of the upper surface of two 6-celled specimens. If relative size is taken as a sure indication of order of development, then the sixth corallite has grown in the normal position for the eighth. As there seems no reason for doubting the above rule, this mutation probably represents an adaptation to some new feature of the environment. A second abnormality is shown in Fig. 3*c*. The second and third corallites appear to have grown from the calyx of the initial corallite instead of the apex. If so, the specimen is comparable with Fig. 1*b* for *P. lenticulare;* but it could just as well be an appearance due to the partial obscuring of the calicular end of the initial corallite by the fifth and sixth corallites. That the latter process does occur is shown by Fig. 4*a*, in which the first corallite is totally obscured.

Figs. 4*a* and 4*b* are two later stages, showing the successive development of a seventh and eighth corallite respectively in the position already established from Fig. 2.

No specimens are available to show the successive addition of corallites from the second to the sixth, but possibly further search will yield these, or an ancestral form which *P. megastomum* could be expected to recapitulate in the course of its development. *P. lenticulare* appears to have an ancestral form, *P. trifoliatum* Dunbar (Dunbar, 1920, p. 118, pl. i, figs. 5-7), reaching maturity, as the name indicates, at the three-celled stage. *P. trifoliatum* is found at the base of the Lower Helderbergian in Western Tennessee, where *P. lenticulare* is abundant in the overlying Lower Helderbergian rocks. The two species are definitely allied by the rounded cross-section of the conical corallites, which is in contrast to the polygonal, commonly trapezoidal, shape seen in the Victorian form.

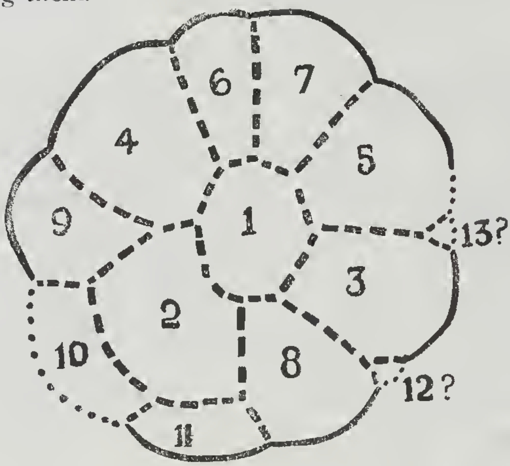
In the American species, after the completion of the eighth corallite, the corallum enters upon an ephebic or mature stage, wherein it enlarges, without the addition of further corallites, to about twice its diameter. It is obviously difficult to establish the existence of a stage of this type without a large number of specimens, for one cannot be sure whether an observed variation in size among a number of specimens is indicative of stages in growth, or is the normal range one would expect among mature



Text Figures 1—4

members of a particular species. With a limited number of specimens, it is not surprising therefore that this stage has not been established with certainty for our Victorian species, though it is highly improbable that it is absent.

The gerontic stage, or old age (Fig. 5) is marked by the addition of a second outer ring of corallites, which grow in a highly irregular manner, so that no definite plan of budding can be discerned among them.



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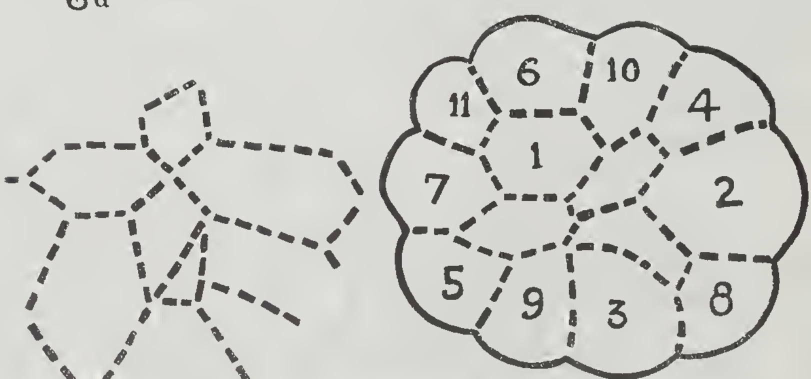
TEXT FIGURE 5

A frequent feature in this stage is the insertion of two or three additional corallites in the centre of the corallum. Their origin is best explained by intermural gemmation, such as occurs in *Favosites,* after the individual begins vertical growth. Such corallites are, to begin with, characteristically triangular in cross-section (Fig. 6*a*) ; but become more of a regular polygonal shape later, owing to compression (Fig. 6*b*). Their occurrence is indicative of the close natural affinity between *Pleurodictyum* and *Favosites.*

6a



6b

TEXT FIGURE 6

Central corallites characterize the gerontic stages not only of *P. megastomum,* but also of *P. lenticulare,* as pointed out by James Hall (*op. cit.,* p. 7). The central corallites in the latter are usually two, and in the former three or four.

It is significant that it is the gerontic stages of these two species which exhibit the closest parallelism. Hyatt (Hyatt, 1895) has observed that this is usually the case with species derived from a common stock, and conversely, of course, its existence is strong proof of a common ancestry. He states (p. 89): "In the young, hereditary similarities derived from more or less remote ancestors are repeated, but these are more and more overgrown and replaced by more recently acquired characteristics as the adult period is approached. In old age, these more recently acquired characteristics disappear, and in consequence of their disappearance, certain parts of the body, and finally the whole body, assume aspects which can be more or less closely compared with those of the same parts and of the entire body in the young, before the differential characteristics of the adolescent and adult periods arose."

Summary and Conclusion.

Summarizing, the mode of development of *Pleurodictyum megastomum,* a tabulate coral from the Silurian (Yeringian) of Victoria, has been investigated. The stages are:

(1) a neanic stage, completed when the central corallite has been surrounded by seven peripheral corallites according to a definite plan,

(2) an ephebic stage, during which the form enlarges to adult size, and

(3) a gerontic stage, in which corallites are added and enlarged in an irregular manner.

This mode of growth is shown to be similar to that of the American species, *Pleurodictyum lenticulare,* which is found in the Lower Helderbergian. The result, besides proving of palaeontological interest, should be of value in establishing the homotaxial relationships between the Victorian and North American rocks of Silurian and Devonian age.

In conclusion, it is with pleasure that I take this opportunity of acknowledging my indebtedness to Mr. F. Chapman and Mr. R. A. Keble, for their encouragement and practical assistance in my work at the National Museum. I should like to thank Professor Skeats and Dr. Summers, who have been good enough to give me facilities for work at the Geology School of the Melbourne University; and also Mr. F. Singleton for his interest, and the loan of some specimens from the University Collection.

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Explanation of Figures.

With the exception of figure 1, all figures are based on specimens from the Silurian of Victoria. Numbers in brackets refer to collections in the National Museum, Melbourne.

Fig. 1.—Development of *P. lenticulare* (after Beecher). a—nepionic stage (epitheca); b—first neanic stage (epitheca); c—completed neanic stage (epitheca); d—the same stage, side view; e—the same stage, upper view of corallites. × 2.

Fig. 2.—Development of *P. megastomum*. Epitheca, showing completed neanic stage. From Silurian (Yeringian), Carman's Quarry, 2 miles below Tommy's Hut, Kinglake West, on east side of road to Whittlesea. (13643.) × 2.

Fig. 3.—Development of *P. megastomum* at six-celled stage, as seen from upper surface. a—showing abnormal position of sixth corallite. From Silurian (Yeringian), Kinglake West. (13640.) b—another abnormal position for the sixth corallite. From same district, MacPherson's Quarry, about ¾ mile north-east of Tommy's Hut. (13641.) c—the second and third corallites here seem to have developed from calyx of first corallite, instead of apex (cf. fig. 1b). From Silurian (Yeringian), Kinglake West. (13642.) Natural size.

Fig. 4.—Development of *P. megastomum* at seven- and eight-celled stages. a—epitheca, showing position of growth of seventh corallite. The initial corallite has been obscured by development of later ones. From above district, in quarry about ½ mile below Tommy's Hut, and short distance east of road to Whittlesea. (13644.) b—view of upper surface of another specimen, showing position of growth of eighth corallite. From above district. (13186.) Figured by F. Chapman, 1921 (*op. cit. supra*). × 2.

Fig. 5.—Development of *P. megastomum*. Beginning of gerontic stage, showing second ring of corallites and irregular growth from seventh corallite on (348). From Silurian (Yeringian), 1½ miles below Simmons' Bridge Hut on Yarra, Geol. Surv. Loc. B 16. × 2.

Fig. 6.—Development of *P. megastomum.* a—portion of gerontic specimen, showing a triangular corallite inserted by intermural gemmation. Specimen (342) from Silurian (Yeringian) at junction of Woori Yallock creek and Yarra, Geol. Surv. Loc. B 23. b—a large gerontic specimen showing a possible mode of development. The corallites not numbered appear to have originated by intermural gemmation. Specimen (340) from Silurian (Yeringian) at same locality B 23. Figured by F. Chapman, 1903 (*op. cit. supra*). Natural size.

[Proc. Roy. Soc. Victoria, 44 (N.S.), Pt. I, 1932.]

Art. III.—*Aculagnathidae. A New Family of Coleoptera.*

By CHARLES OKE.

(With Plate II.)

[Read 11th June, 1931; issued seperately 29th February, 1932.]

Introduction.

The insect described in this article is a very anomalous beetle and might almost be thought to be excluded from the order as its mouthparts are not strictly formed for biting. A similar condition is found in the Clavergerinac, where the mouthparts are so atrophied that they are very indistinct and quite useless. In the present family there is a highly specialised mandible, placed somewhat transversely, with a long, thin process on its outer edge, which normally rests within the labrum. When the mandible is moved the end of this process protrudes beyond the labrum and is evidently used for piercing its prey. The labrum itself is curled over on its edges and forms an open sheath for the styliform processes of the mandibles, the sheath being partly closed by a thin, membranous extension of the labium below.

The tarsi are also distinctive. Two small basal joints with the third segment twice their combined length are also found in Lathridiidae, but without the appendiculate claws or the empodium of this new family.

ACULAGNATHIDAE, n. fam.

Antennae nine segmented. Eyes lateral. Labrum produced in front. Mandibles not formed for biting and having a long styliform process in front. Maxillary palpi with three segments. Labial palpi with two segments. Abdomen of five visible segments. Tarsi with three segments, the apical segment with two claws and a small empodium.

Aculagnathus, n.gen.

Body elongate-ovate, apterous. Head convex, rounded in front, clypeal suture not traceable. Eyes small, acinose, subbasal, visible on both surfaces. Labrum produced into a cuneiform projection in front. Mandibles with a thick bulbous basal part having on its outer edge a long, thin, styliform process, normally resting within the labrum. Maxillary palpi of three segments: first segment cylindrical, rather short, lightly curved; second segment one and a half times as long as first, cylindrical; third segment a little longer than second, broadly securiform, suddenly constricted near base on inner side, with a small, pointed appendage on apex. Labial palpi of two segments: first segment rather short, cylindrical, second segment of same size and shape as third segment of maxillary palpi. Antennae of nine segments: the first segment large, the intermediate segments small, the last two segments large, and with the seventh, forming a strong club. Prothorax transverse. Scutellum small. Elytra elongate, seriate punctate. Epipleurae fairly wide at base and gradually narrowing to near apex. Prosternum strongly raised or keeled down centre, this partly covering coxae. Mesosternum rather short, subtriangularly keeled in centre, this process projecting between intermediate coxae. Metasternum long, concave down centre, emarginate on apex, its episterna nearly covered by the elytra. Abdomen of five visible segments: the first segment as long as next two combined; second, third and fourth equal in length; fifth about as long as the first. The fifth segment has six small crenulations on either side of its centre and these fit into short grooves in the under surface of elytra. Anterior coxae rounded, fairly close; intermediate globular, well separated; posterior transverse, rather widely separated. Anterior and intermediate trochanters subglobular; posterior triangular. Legs of moderate length. Tarsi fairly long, three segmented: first segment longer than wide; second short, transverse; third about twice the length of the two basal ones combined, with two strong, appendiculate claws and a small empodium, the latter bearing two strong setae.

The mouthparts are very small and consequently difficult to deal with. The mandible has been described as seen in a KOH preparation in balsam, but as the parts overlap one another it is extremely difficult to be sure of the exact edge of each piece. In the photomicrograph the two labial palpi are seen pushed to one side, and on the opposite side the base of the mandible has moved forward, and the styliform part has been displaced and is seen touching the tip of the maxillary palp.

In front of the base of each labial palp there is a minute projecting organ and from each of these, two or three exceedingly fine filamentous pieces extend to the apex of the labium.

Aculagnathus mirabilis, n. sp.

Pale castaneous, antennae, palpi and tarsi paler. With sparse, short, pale pubescence; upper surface almost glabrous; antennal club with long, fine setae.

Head convex, with very fine punctures. Antennae with first segment large, inner edge convex, outer concave, apex truncate; second moderately stout; third thin, increasing to apex, the length of next three combined; fourth to sixth short, equal, subquadrate; seventh wider, strongly transverse and applied to eighth; eighth widest, transverse; ninth bluntly conical, a little narrower at base than eighth. Prothorax transverse, rounded on sides, where it is finely crenulated; with coarse, subreticulate punctures. Elytra with fourteen rows of seriate punctures on each elytron, the subsutural row composed of thirty-two punctures. Prosternal and mesosternal keels subopaque. Whole under surface with large, close punctures; most of sternum and first abdominal segment with punctures deep and rough; sides of prosternum and rest of abdomen with punctures shallow and smooth. Length, 1·50 mm.

Hab. Victoria: Belgrave (C. Oke) in nests of *Amblyopone obscurus.*

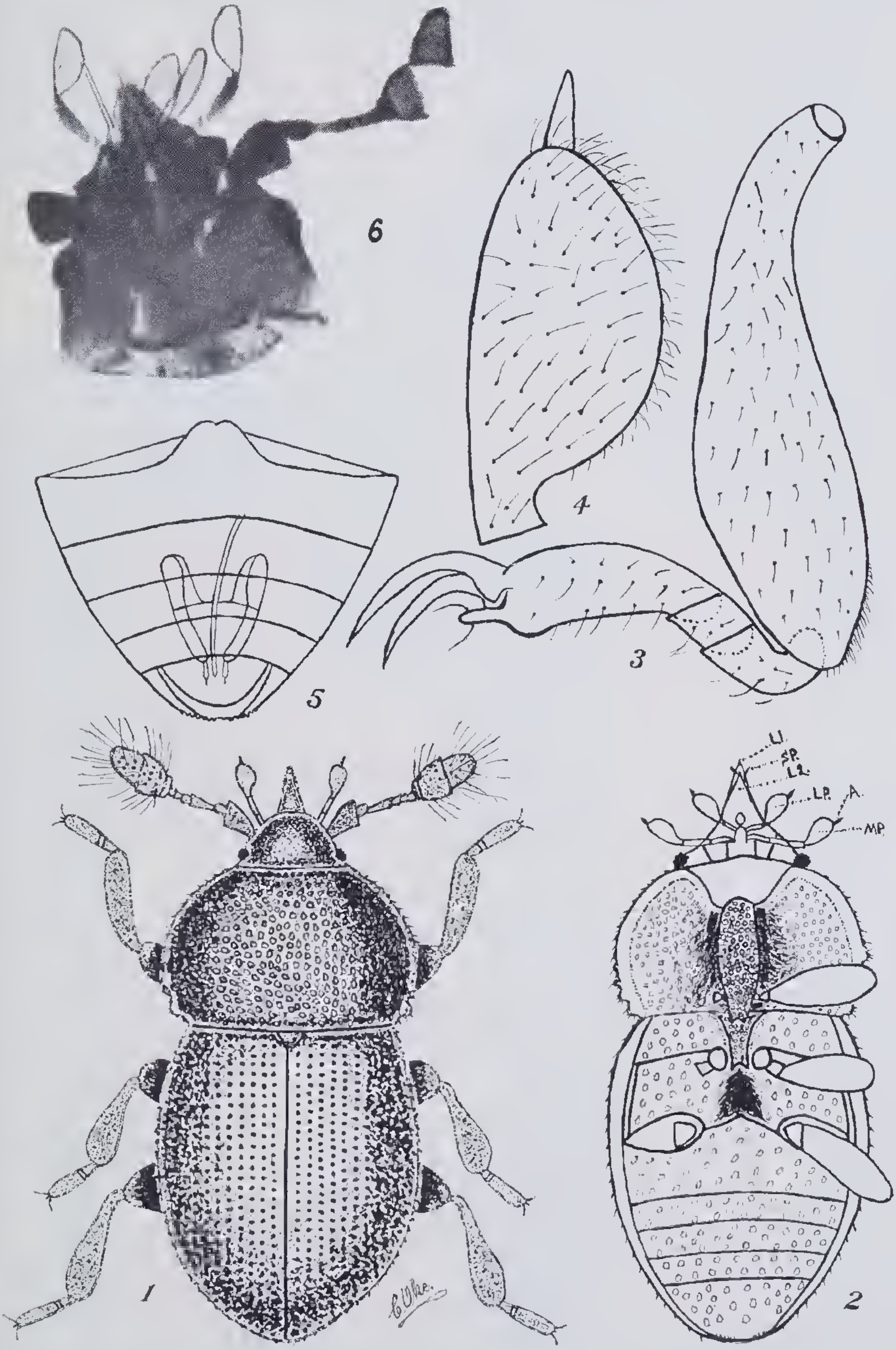
Only a few specimens have been found, but as they have all been taken right in the nests, where they appeared to be on quite friendly terms with the ants, they must be considered genuine inquilines.

There are no clusters of hairs anywhere to suggest trichomes, except, perhaps, those on the antennal club, where there is fine pubescence and some unusually long setae.

Type in author's coll.

Explanation of Plate II.

Fig. 1.—*Aculagnathus mirabilis,* n. sp. Upper Surface.
Fig. 2.—Ditto. Lower Surface. Lettering: L1. labrum, L2. labium, SP. styliform process of mandible, LP. labial palp, MP. maxillary palp, A. appendage to palp.
Fig. 3.—Tibia and tarsus.
Fig. 4.—Apical segment of maxillary palp.
Fig. 5.—Abdomen, showing genitalia.
Fig. 6.—Photomicrograph of head.
3 4, 5, 6, from KOH preparations.


6
4
3
5
L1.
SP.
L2.
LP.
A.
MP.
1
2

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Art. IV.—*Victorian Graptolite Zones, with Correlations and Description of Species.*

By WM. J. HARRIS, B.A.

and R. A. KEBLE, F.G.S.

(With Plates III-VI.)

[Read 11th June, 1931; issued separately 29th February, 1932.]

I.—History of Research.

More than two decades have elapsed since the publication of any notable paper on the general classification of Victorian graptolites. Indeed, only two such papers occur to mind, both by the late Dr. T. S. Hall (6 and 7).

At the conclusion of his life's work on Australian graptolites he (9) summed up the state of knowledge as follows:—"Large collections made by the Survey (Geological Survey of Victoria) have somewhat extended our knowledge of the fauna and its distribution but without adding any features of importance." At the time when this rather pessimistic summary of the position was made, the study of Victorian graptolites was about to enter on a new phase of expansion, revealing many "new features of importance." This expansion owes much to the sympathetic and methodical encouragement of the Director of the Survey, Mr. W. Baragwanath, himself the pioneer in the exploration of an interesting but rugged Upper Ordovician and Silurian area near Walhalla. Under Mr. Baragwanath's judicious guidance, the officers of the Survey have examined many important areas of Palaeozoic rocks with an intelligent appreciation of the value of palaeontological evidence, and the present writers have not only had the advantage of examining collections from widely separated districts, but have been able to test their evidence in the field. Some of the more important developments since 1914 may be summarized as follows:—

(a) The detailed work of Keble on collections from the Bendigo district and his field work in the Mornington Peninsula have made possible the zoning of the Lancefield and Bendigo series.

(b) The field work of Harris (12) in the area east of Castlemaine showed the existence of previously unrecognised beds between the Castlemaine and Darriwil series as known to Hall, and enabled the Darriwil beds to be zoned.

(c) Harris and Crawford (4) discovered near Romsey a *Staurograptus-Dictyonema* bed, marking a lower Lancefield horizon than had before been recognised in Victoria. They also checked the Darriwil succession in the Gisborne district, demonstrated the improbability of any considerable break in the sedimentation between Lower and Upper Ordovician, and suggested outlines of Upper Ordovician zones.

(d) A. T. Woodward discovered at Bendigo East graptolites which on examination proved to belong to the Upper Darriwil, and already recognised at Gisborne by Harris and Crawford (13), at Mornington by Keble, and since found among earlier collections made by O. A. L. Whitelaw from the Enoch's Point Lower Ordovician inlier in the Upper Goulburn basin. Field work at Bendigo East by J. C. Caldwell, of the Survey, and Harris, showed these beds to be more extensively developed there than elsewhere, and they have since been recognised near Romsey by D. E. Thomas, and along the Gibbo River, north of Omeo, by Harris and Thomas.

(e) A minor but interesting discovery was made of Bendigo forms at Boolarra in Gippsland by W. H. Ferguson (4), far east of the better known Lower Ordovician belt of Central Victoria.

(f) In the Walhalla-Aberfeldy district, W. Baragwanath, Trentham district, H. Foster, Axedale district, J. C. Caldwell, Bendigo district, the Bendigo Underground Survey Staff, and Keilor-Lancefield district, D. E. Thomas have made known large areas of graptolite shale. Their efforts constitute a noteworthy continuation of the earlier work of W. H. Ferguson, formerly of the Victorian Geological Survey, and the pioneer efforts of A. R. C. Selwyn, N. Taylor, R. Daintree, C. S. Wilkinson, C. D. Aplin, Sir Frederick McCoy and others of the early Victorian Geological Survey onwards from 1850.

(g) In many instances our identification and descriptive work has not been published, or is included in publications on general geology dealing with a district. A complete list of the unpublished work is far too comprehensive to be listed here.

(h) Much time has been devoted to the study of the Upper Ordovician and Silurian beds, and though a tentative zoning is now possible the paucity of continuous sections makes the task of checking this difficult. Work at present being carried on by Thomas under the direction of the Geological Survey in the Keilor-Lancefield area will yield important results in this connection.

Dr. Hall in 1894 (5) placed the Victorian graptolite series in the ascending order, Lancefield, Bendigo, Castlemaine, zoned the Castlemaine series and correlated the Darriwil beds as then known with the Upper Castlemaine. In 1899 (6) he elaborated his serial zoning. The Lancefield series was based on the famous "Lancefield Quarry" outcrop north of the old Mount William station on the disused and now dismantled Lancefield-Kilmore railway line. For Bendigo beds more widely spread localities were referred to, but in Dr. Hall's opinion "no salient differences have been noted between the faunas of the different exposures." The association of *Tetragraptus approximatus* with Lancefield forms at Inglewood and with Bendigo forms on the Mornington Peninsula later enabled Dr. Hall to suggest the line of demarcation between the Lancefield and Bendigo series (8). The detailed zoning of the Castlemaine series has stood the test of later work by T. S. Hart (15) at Daylesford, and Harris (12) in the type area at Castlemaine. The Darriwil beds were known to Dr. Hall (11) only from one locality in the parish of Darriwil, until in 1913 (6) he examined a large suite of graptolites from the Steiglitz district collected by W. H. Ferguson. A large number of his determinations of the Steiglitz graptolites have not been published. He here made his first acquaintance with what we may call the previously unknown zones of the Darriwil, but not having any opportunity for field work, was quite at sea. He placed some of the Darriwil beds among the Lower Castlemaine zones, and though he placed others correctly in the Darriwil, he relegated them to a position too low in that series.

Before dealing with each series and its zones in detail attention may well be called to a point which is of importance in all attempts at zoning, and which has been well expressed by Dr. Elles (3). That experienced graptolithologist from her extended study of British graptolite zones writes: " Some commingling at the boundaries of the zones must naturally be expected, especially when dealing with a succession of purely shaly deposits, but as a rule even then *the coming in of new forms in abundance* should be taken as an index of the passage to a higher horizon. This fact is one upon which great emphasis should be laid; it is upon this, *the coming in of new forms,* usually indicative of a more advanced stage in evolution, that the basis of modern zonal stratigraphy is laid; the persistence of old forms tends to vary greatly in different localities. There does not appear to be any justification for action which results from focussing too much attention upon the index fossil rather than upon the *assemblage,* which is the determining factor."

This advice is necessary in considering zonal tables. Such tables must be at the best tentative. Many zonal differences, when set down in words, appear trifling, whether a bed is L2 or L3, for example, and it is only by extended field work that one is able to weigh all the evidence. Even in the field it may be difficult to say in exactly what the differences consist, and when one has to decide, Miss Elles' dictum that " it is the assemblage which is the determining factor " comes with added force. The tables which follow should be read with this in view, and not regarded as a royal road to the determination of graptolite zones.

II.—Victorian Graptolite Series.

At the outset it may be stated that Dr. T. S. Hall's serial order, Darriwil, Castlemaine, Bendigo and Lancefield, still stands. It is now possible to zone each of these series, and for this purpose we have adopted the initial letters D, C, B, and L, with a numeral to indicate the zone, zone 1 being the highest in each series. To conform to the accepted practice we would have preferred to number the zones in the reverse order, but the system used is that introduced by Dr. Hall, and has been in use for so long that a change now would lead to endless confusion.

It should be stated that ordinary stratigraphical methods have amply demonstrated the accuracy of this zonal subdivision, and on the other hand, the zonal subdivision has either corroborated or elucidated the stratigraphy. The main purpose of this contribution is to place in the hands of the field geologist a simple means of checking his work; elaboration tending to complicate is to be deprecated. For this reason we have refrained from referring to those still finer subdivisions used by us where close differentiation is asked for, and we take this opportunity of warning future workers on the Victorian succession against multiple subdivision, unless it has been established by ample field evidence over a wide area.

(A.) Darriwil Zones.

Although the Darriwil series is less known than any of the others, since Harris outlined it (12) in 1916, our knowledge of it has been extended considerably. The absence of mining and consequent lack of exposures, the abnormal development of shales which are difficult to differentiate, the graptolite assemblages which elsewhere have no equivalents, are problems confronting the stratigrapher and palaeontologist. In it the characteristic Lower Ordovician *Axonolipa* give place to the Upper Ordovician *Axonophora,* consequently there are a number of specialised and unique forms which do not conform with accepted genera, and which necessitate the formation of new genera, often monotypic.

It has been already stated that Dr. Hall's "Darriwil Beds" form but a small part, a portion of the uppermost beds, of the Darriwil series as recognised at the present time. The lowest zone, D5, is characterised by the occurrence of *O. upsilon,* which is rare in C1, the Castlemaine zone below it. Zone D5 may be called the *Oncograptus* zone, though the genus ranges rather indefinitely higher, being then associated with the allied genus *Cardiograptus.* The zone is also separated from C1 by the appearance of *Trigonograptus* and *Didymograptus v-deflexus,* while *D. caduceus* is still common, but is usually represented by variant forms, var. *manubriatus,* and *D. forcipiformis.* In D4, *Cardiograptus* is associated with *Oncograptus,* otherwise the facies is much the same.

At Castlemaine and Gisborne, *Cardiograptus* occurs without *Oncograptus,* and this characterises the zone D3. At Lancefield, however, D. E. Thomas has recently discovered a bed in which *Oncograptus* occurs without *Cardiograptus* in the typical assemblage of zone D2. It will be interesting to see whether *Oncograptus* is recessive or whether there are morphological differences sufficient to separate its higher from its lower forms.

After the disappearance of *Cardiograptus morsus,* beds are found characterised by the abundance of a small *Diplograptus,* which has been identified by Dr. Hall as *D.* cf. *inutilis,* but which is here described as a new species under the specific name *Diplograptus austrodentatus.* This form crowds the D2 beds and other forms are relatively rare. These include the long-range species *Tetragraptus serra* and *Didymograptus caduceus,* and the typically high-ranging genera, *Trigonograptus, Glossograptus* and *Lasiograptus.* Lastly, we have D1, the highest Darriwil, a zone of unknown extent and of such great development and richness in graptolites that it is almost certain that it will ultimately be further divided. This zone is extensively developed east and southeast of Bendigo, where field and laboratory work by the authors and Mr. J. C. Caldwell, of the Geological Survey, is still proceeding. The fauna is so characteristic that it cannot be confused with those in the lower zones. Very typical, but not present in the same profusion at all outcrops, is *Didymograptus nodosus,* an aberrant form, the nearest relation to which among Old World species is probably *D. spinosus. Atopograptus woodwardi,* hard to recognise except when favourably preserved, is still more aberrant, combining a *Didymograptus* polypary with volute monograptid thecae. *Cardiograptus crawfordi* is a paracmic *Cardiograptus. Cryptograptus tricornis* is a forerunner of the Upper Ordovician, as are also the numerous *Diplograpti, Glossograpti,* and the occasional *Climacograpti. Lasiograptus* is common, *Trigonograptus* persists, while *Phyllograptus,* which is found sporadically from D5, is here represented by the well-marked species, *P. nobilis,* sp. nov., described later. Multiramous forms are not uncommon, one of the commonest being *Brachiograptus etaformis,* gen. et sp. nov., also described later, which is closely related to Bulman's *Loganograptus logani,* var. *boliviensis* (1), from South America. Another is a dichotomously branching, pendent species, reminiscent of a *Tetragraptus pendens*-like form, which has developed by several successive dichotomies. *D. caduceus* persists in a dwarfed form.

(B.) Castlemaine Zones.

The Castlemaine zones remain much as they were left by Dr. Hall, and need not be treated in great detail. The lowest zone, C5, still often referred to by Dr. Hall's term, the Wattle Gully beds, shows its position by the occurrence of *D. bifidus* without *Tetragraptus fruticosus.* Associated forms are numerous, most of them survivals from the Bendigo series. The only other form that need be noticed is *Didymograptus caduceus,* which here makes its first appearance, in some beds with the characteristic horseshoe polypary well shown although small, in others showing only three or four thecae on each side of the characteristic sicular V. C4 is marked by the absence of *D. bifidus,* and, in general, a comparative poverty as regards species. *Phyllograptus* cf. *typus,* often large, is the commonest graptolite. C3, separated from the next lower bed by the comparative rareness of *Phyllograptus,* is still retained as a separate zone, though it is doubtful whether it is better entitled to zonal rank than certain other beds which have been merged. Like C4, it is usually poor in species and individuals, but at most outcrops *D. caduceus,* without any great increase of size, is the commonest fossil. In C2, Dr. Hall's Victoria Gully beds, *D. caduceus* is well on its way to maturity, and gives character to the zone. At most localities *Phyllograptus* is not found. Since, however, it occurs with Victoria Gully forms in one collection, and with C1 forms in New Zealand, it seems better not to exclude it from this zone. Continuing to flourish, *Didymograptus caduceus* is still the predominant fossil in the highest beds of the series, C1. It has here every indication of having reached its acmic stage, and the variations which mark particularly its progress and decline through the Darriwil series begin. *Loganograptus logani,* selected by Dr. Hall as characteristic of this zone, occurs also in C2, but is usually so rare as to be of little use as a zonal fossil. *Diplograptus,* which is common in some C2 beds, is also found in C1 and higher beds, but it does not give character to the zone.

(C.) Bendigo Zones.

The Bendigo series is the best known portion of the Lower Ordovician, and the Bendigo district provides typical outcrops of all its zones and finer subdivisions. The fauna is varied and readily differentiated, and by constant application of its finer divisions to economic problems, a high degree of precision has been attained in regard to the stratigraphical succession.

The broad subdivision is based on the advent and extinction of *Tetragraptus fruticosus,* and the zonal subdivisions mainly on the development of that species. *T. fruticosus* (*sensu lato*) commences as a 4-branched form in zone B5, reaches its acmic stage in zone B4, and paracmic stage in zone B3, where it disappears. By catagenesis a 3-branched form appears in zone B3, by rejuvenescence passes to its acmic stage in zone B2, to its paracmic stage, and thence on to extinction in zone B1. In zone B5 the 4-branched *T. fruticosus* is associated with *T. approximatus,* the zonal species of the Lancefield zone L1 next below it, and in zone B1 the 3-branched *T. fruticosus* is associated with *D. bifidus,* the zonal species of zone C5 next above it, so that the succession is essentially normal.

In zone B5 *Trichograptus fergusoni, Tetragraptus decipiens,* and *Didymograptus aureus* are survivals from the preceding zone; none of them range further than zone B5. In B4 the more typical

Bendigo fauna appears, and in zone B3 we have such forms as *Goniograptus thureaui, G. macer, Didymograptus extensus, D. dilatans, Tetragraptus serra, T. harti, T. similis,* and *Phyllograptus* spp.

In zone B2 *G. macer, T. harti, T. similis* and *Phyllograptus* spp. are common, and in zone B1 a very similar fauna occurs with the addition of *D. bifidus.*

(D.) Lancefield Zones.

For the present we designate as L5 a bed not yet found in Australia, but which from analogy with the northern hemisphere may be expected to occur—a zone which would be characterised by *Dictyonema sociale* or a vicarious form. It is confidently believed by us that when this zone is found in Australia the vicarious Dictyonemas will be those which occur with *Staurograptus* in the next higher zone, *D. scitulum* and *D. campanulatum.* The lowest zone with which we are at present acquainted is characterised by these two Dictyonemas, with *Staurograptus,* but apparently without any other species. This facies occurs north-east of Romsey, and is referred to L4. The next or L3 zone is that most familiar to students, the Lancefield Quarry beds. It is characterised by the absence of *Staurograptus* and the species of *Dictyonema* found in L4, and by the presence of *Dictyonema macgillivrayi, Tetragraptus decipiens, Bryograptus victoriae,* and *Clonograptus* spp., including *C. flexilis* and *C. tenellus.* The L2 zone is represented in the Lancefield district and elsewhere. *Bryograptus victoriae* persists from L3, and is perhaps the commonest species, though many of its associates from L3 also occur. *D. macgillivrayi* is rare or absent. *Tetragraptus approximatus* has not yet made its appearance.

The uppermost Lancefield zone, L1, is marked by the appearance of *T. approximatus,* the rarity of *Bryograptus,* and the absence of *Tetragraptus fruticosus,* the appearance of which in the next higher bed delimits the Bendigo series. The typical outcrop of this zone is on Bull Dog Creek in the Mornington Peninsula.

TABULATION OF ZONES.

DARRIWIL SERIES.

Zone	Typical Locality	Zonal Species	Associated Forms
D1 -	Bendigo East -	Didymograptus - nodosus Atopograptus - woodwardi Brachiograptus etaformis	Cardiograptus crawfordi Climacograptus Didymograptus caduceus (rare) Phyllograptus nobilis Lasiograptus Glossograptus Diplograptus Cryptograptus tricornis Trigonograptus ensiformis Tetragraptus quadribrachiatus

Zone	Typical Locality	Zonal Species	Associated Forms
D2 -	Loc. 7SZ Geol. Surv. Vic. Sutherland's Creek Steiglitz -	Diplograptus austrodentatus -	D. caduceus Trigonograptus Glossograptus C. tricornis Tetragraptus
D3 -	Castlemaine-Maryborough Railway W. of Strangways -	Cardiograptus morsus -	D. caduceus D. v-deflexus Tetragraptus Phyllograptus Diplograptus gnomonicus Trigonograptus
D4 -	Chinamen's Creek - Muckleford -	Cardiograptus morsus - Oncograptus -	D. caduceus D. v-deflexus Trigonograptus Phyllograptus Tetragraptus Strophograptus trichomanes D. gnomonicus
D5 -	Castlemaine-Walmer Rd. E. of borough Boundary, Castlemaine	Oncograptus upsilon -	Much as in D4 D. forcipiformis Goniograptus speciosus
	CASTLEMAINE SERIES.		
C1 -	McKenzie's Hill - Castlemaine, water race in paddock N. of Castlemaine-Maldon Rd.	D. caduceus (maximum development) -	Loganograptus logani Diplograptus sp. Didymograptus uniformis Tetragraptus quadribrachiatus
C2 -	Victoria Gully, Castlemaine -	D. caduceus (sub-maximal development) -	Diplograptus sp. Didymograptus spp. Dendroid forms Dichograptus cf. octonarius.
C3 -	Victoria Gully east of the Type locality of C2 -	D. caduceus (small forms) - Phyllograptus cf. typus -	Comparatively few.
C4 -	Burns Reef, Chewton -	P. cf. typus. D. caduceus (small and rare)	Comparatively rare
C5 -	Wattle Gully, Chewton -	D. bifidus -	D. caduceus (small) Clonograptus spp. D. octobrachiatus Phyllograptus Goniograptus laxus G. crinitus Tetragraptus similis T. pendens
	BENDIGO SERIES.		
B1	Paddy's Gully, Bendigo -	Tetragraptus fruticosus 3-br. - D. bifidus -	D. octobrachiatus Phyllograptus cf. typus Clonograptus abnormis Tetragraptus similis T. quadribrachiatus G. laxus G. macer

Zone	Typical Locality	Zonal Species	Associated Forms
B2 -	Napoleon Syncline - Bendigo	T. fruticosus - 3-br.	Much as in B1 Didymograptus similis Goniograptus thureaui D. extensus
B3 -	Red, White and - Blue Reef, Bendigo	T. fruticosus - 3-br. & 4-br.	Didymograptus dilatans D. extensus Goniograptus thureaui T. pendens
B4 -	Garden Gully, - Bendigo	T. fruticosus 4-br.	T. similis T. serra Clonograptus spp.
B5 -	Hustler's Hill, - Bendigo	T. fruticosus - 4-br. T. approximatus	D. aureus T. decipiens T. quadribrachiatus T. acclinans Loganograptus logani Clonograptus tenellus
		LANCEFIELD SERIES.	
L1 -	Bull Dog Creek - Mornington Peninsula	T. approximatus	T. decipiens T. quadribrachiatus T. acclinans C. tenellus
L2 -	Lancefield, near - Deep Creek	Bryograptus - victoriae T. decipiens	Clonograptus tenellus
L3 -	Lancefield Quarry, - N.E. of Old Mt. William Railway Station	Dictyonema - macgillivrayi B. victoriae -	T. decipiens Clonograptus spp. Didymograptus pritchardi D. taylori
L4 -	North east of - Romsey	Dictyonema - campanulatum D. scitulum Staurograptus diffissus	No associates have been found
L5 -	Not yet recognised - in Victoria	(Dictyonema)	

In the Castlemaine Series large and variant forms of *D. caduceus* predominate in C1 and give the zone its character. In C2 *D. caduceus* is characteristic, and comprises 80% of the assemblages. C3 is separated from C4 by the relative abundance of *Phyllograptus* associated with *D. caduceus* (T. S. Hall). C3 and C4 are separated by the "absence of *D. bifidus* and the comparative rarity of *D. caduceus*" (T. S. Hall). This is not an important distinction as far as zones C3 and C4 are concerned since *D. caduceus* is not common in some C5 beds. Zones C3 and C4 have often to be grouped as Middle Castlemaine. They are well developed in the Castlemaine district and elsewhere, but thick beds of blue-black slate of favourable appearance yield comparatively few species or even individuals, an interesting contrast with the higher beds, whose richness is largely due to the rapid deployment of *D. caduceus*.

IV.—Correlation of Victorian Zones with those of the Northern Hemisphere.

The examination of Victorian graptolites and their occurrence in the field leads us to the conclusion that, while there is a general resemblance to the succession of the Old World, there are significant differences. Through this resemblance, too, may be seen minor modifications due to the distance apart of the respective provinces.

In making a tentative correlation we have relied largely on the following works; for British Graptolites, Elles and Wood (2), and Elles (3); and for North American Graptolites, Ruedemann (16 and 17).

Lower Ordovician graptolites are found in Victoria in slates alternating with sandstones (there are no limestones or coarse sediments) showing an unusual uniformity in the conditions of sedimentation. The rapidity of the alternation gives a regular succession of more or less complete faunules that go to make up the zones. Compared with it, any other succession with which we are acquainted appears to be incomplete. This apparent incompleteness and the lack of a first-hand knowledge of overseas stratigraphy makes correlation difficult. Although we have used this zonal succession for a considerable period we are presenting it for the first time, and hope that the information embodied in it may induce oversea workers to enter on correlations from their own viewpoints. To bring out the significant differences as well as the general resemblances we venture to correlate the faunas from two standpoints, viz.:

(1) Their essential Lower Ordovician elements, the Dichograptidae.

(2) Their adventitious Upper Ordovician element, predominantly the Axonophora.

Before this can be done it is necessary to decide roughly the equivalence of the Old World and Victorian beds, but the separation of the forms into the two diverse elements makes this easier than it appears at first sight. Roughly, the British zones 1, 2 and 3 appear to represent, incompletely, the Lancefield beds. Zones 4, 5, 6, and 7, without any exact equivalence, may be placed under the Upper Bendigo and Lower Castlemaine, while the next highest British zones do not agree with any Victorian beds lower than the Upper Ordovician. Any further discussion will be valuable or otherwise according to the opinion formed as to the permissibility of this correlation, which has been arrived at after a careful balancing of resemblances and differences.

Accepting it, it will be noticed that a majority of the common forms appear first in the Victorian succession in an association which is regarded as stratigraphically below the British occurrence, and practically all disappear later in Victoria than in Britain. The ranges of the common Dichograptidae appear to show, then, that the range as illustrated in Britain is but a portion of the maximum range. Where conditions appear to have been favourable, the phylogenetic stages of forms appear to be more characteristically developed in one province or the other. For example, the dependent Didymograpti are much more strongly developed in Britain than in Victoria. There they are well exemplified by a number of species, but in Victoria and New Zealand there seem to be only two species and a number of merging varieties considered unworthy of distinction. This is a striking difference when the apparently extended range of dependent forms in South America is considered (1). On the other hand the phylogeny of the reclined Didymograpti (*D. caduceus=gibberulus*) is represented in Victoria by a number of readily recognised and progressive species developed from a small form which first appears in the Lower Castlemaine beds (C5). Some of the anagenetic forms appear in British zones 4 and 5, but the acmic and paracmic forms do not, as far as we know, occur in Britain at all.

Evidence in support of our correlation is suggested by:—

(a) *Tetragraptus fruticosus.* This form, as figured in the Monograph of British Graptolites (2, Pt. 1) is, in Victoria, a catagenetic phase such as occurs in the upper portion of the Bendigo beds associated with dependent Didymograpti. Even allowing that this stage may have been reached earlier in Britain, there seems little doubt that the stages represented in our lower Bendigo beds do not occur there.

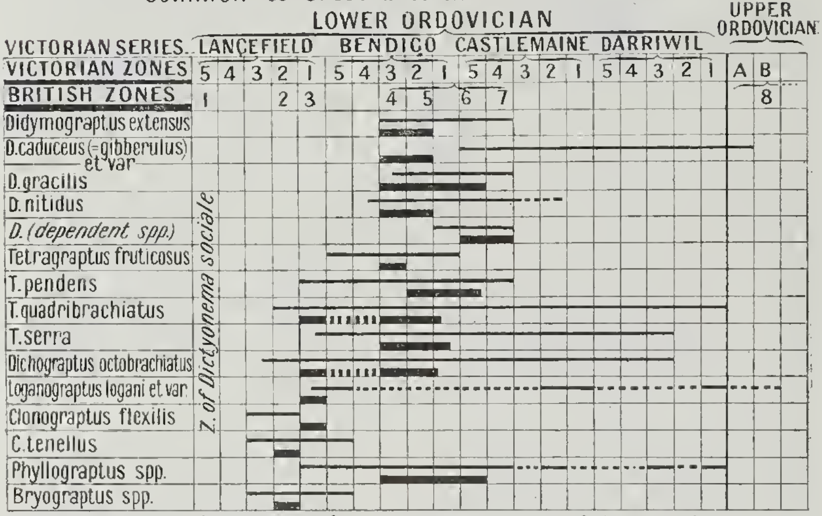
(b) The elaboration of the dependent Didymograpti. These forms, as we have already mentioned, are much more fully developed in Britain than in Victoria. In both provinces their elaboration follows the disappearance of *T. fruticosus.* British zones 6-7 may therefore be well regarded as corresponding approximately to the Victorian zones C5-4, and perhaps including B1. It is questionable, however, whether very much reliance should be placed on a series like this, which, contrary to experience with most other groups, seems to be pauperized in Victoria.

(c) *D. caduceus.* This form, enormously better developed in Victoria than in Britain, does not occur here with *T. fruticosus.* However, its acmic and paracmic forms seem to be missing in Britain, and this suggests the absence there of graptolite shales from the beds at least corresponding to the Victorian Upper Castlemaine and Darriwil.

The correlation of the adventitious Upper Ordovician element must be made on genera, since few species are common to each province. The Dichograptidae, so poorly represented in the Upper Ordovician, have been taken as typically Lower Ordovician, and the Axonophora, although including genera restricted to the Lower Ordovician (e.g. *Trigonograptus*), are by common consent regarded as characteristic of the Upper beds of the Ordovician (16).

Table A

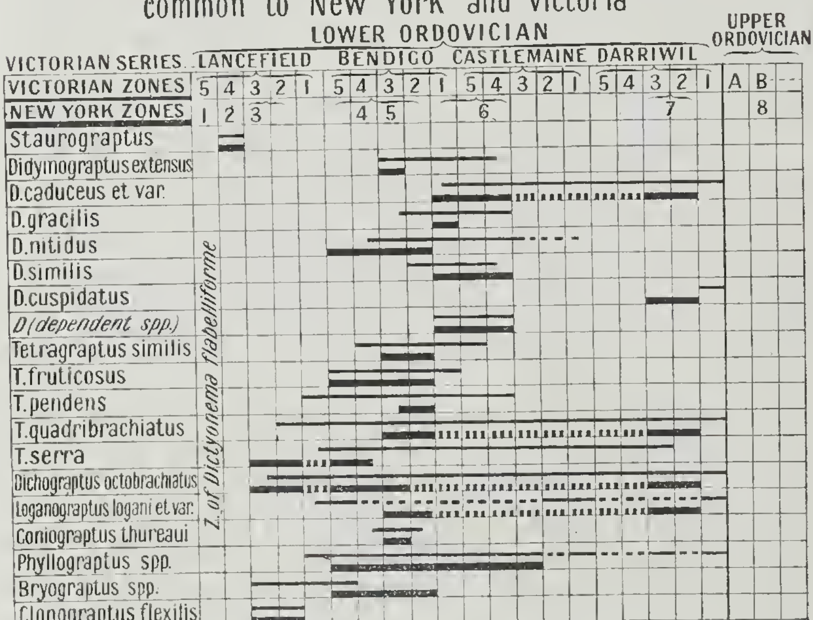
Correlation of species of Dichograptidae common to Great Britain and Victoria



—— Range of Victorian forms ▬▬ Range of British forms

Table B

Correlation of species of Dichograptidae common to New York and Victoria

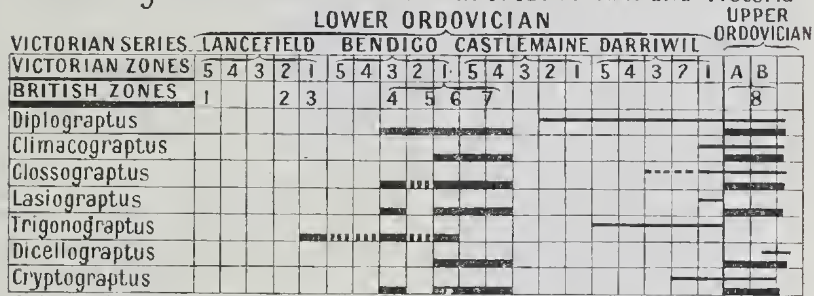


(New York Zones as numbered on p.130 Rpt Dir. N.Y. State Museum 1919.)

—— Range of Victorian forms ▬▬ Range of New York forms

TABLE C

Correlation of Upper Ordovician Genera occurring in the Lower Ordovician in Great Britain and Victoria

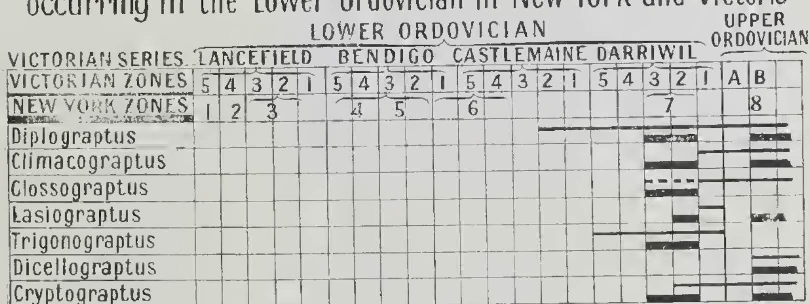


Owing to the non-recognition of beds in Britain equivalent to the Darriwil, the range of the genera in Britain appears broken. This is not really the case between Zones 7 and 8.

——Range of Victorian forms ▬▬ Range of British forms

TABLE D

Correlation of Upper Ordovician Genera occurring in the Lower Ordovician in New York and Victoria



There is no actual break between N.Y. Zones 7 and 8

——Range of Victorian forms ▬▬ Range of New York forms

The outstanding feature of this correlation is that the Upper Ordovician element appears in the British succession before it does in Australia or North America. The American correlation is based on too meagre evidence to enable definite conclusions to be drawn. There appears to be, according to our correlation, too great a gap between zones 6 and 7, which is supported by Ruedemann's statement (16) that at the Deep Kill Beds 6 and 7 (zone 7, zone of *D. dentatus*) are separated by an interval of several hundred feet of non-exposure from the zone of *D. bifidus*, and his note on the profound change between the successive graptolite faunas due to the suppression of the Dichograptidae and the unheralded appearance of the axonophorous Diplograptidae with the genera *Diplograptus*, *Glossograptus*, *Trigonograptus*, *Climacograptus*, and *Retiograptus*.

This break is minimized by the intercalation of the "Ashgill Quarry shales," which have much in common with our upper Darriwil beds. *Tetragraptus quadribrachiatus, D. forcipiformis, D. cuspidatus, Trigonograptus ensiformis,* are common to both hemispheres, while the following American forms have Victorian allies: *P. angustifolius* is allied to *P. nobilis, P. dentatus* to *D. austrodentatus. Glossograptus hystrix* to *G.* sp. nov., *Climacograptus pungens* to *Cl.* cf. *exiguus, Didymograptus filiformis* to *D.* sp. nov., and *D. spinosus* to *D. nodosus.*

Summarizing these Correlations it would appear:—

1. That the successions of Victoria, Britain, and North America approximately agree in so far as they may be correlated on their essential Lower Ordovician element, the Dichograptidae.
2. That in the Victorian sedimentation, zones are preserved which are missing from the records of the British and North American provinces. These "lost zones" leave much to be desired in the way of direct evidence for correlation, but the phylogeny of some of the common species as interpreted by us in Australia indirectly confirms the suggested correlation.
3. The outstanding difference between the British and the Victorian and North American successions is that the Upper Ordovician element appears earlier in Britain than in either Victoria or North America.

In conclusion it is only fair to repeat that the authors are very conscious of the shortcomings of this attempt at correlation. One great drawback is the lack of adequate data. The idea would be for a worker to revise the correlation with the advantage of a personal acquaintance with the "characteristic assemblages" of each province. In the present case the mere occurrence of forms has been made the main basis of correlation, yet the records show provincial differences. Thus *T. fruticosus* seems to be so very poorly represented in Britain that it is not included in a characteristic assemblage of any zone (3), while its development in North America is comparable to its development in Victoria. The tuning fork graptolites, so well developed in Britain, are represented by only two species in both New York and Victoria, and yet are strongly developed in South America. What weight in any attempt at correlation should be placed on points such as these must be left for future discussion.

Description of Species.

The species described and figured in the following pages are for the most part Darriwil forms which are important for zonal purposes.

Diplograptus austrodentatus, sp. nov., is a *Diplograptus* allied to *D. dentatus,* and is the zonal fossil of the D2 beds. *Phyllograptus nobilis,* sp. nov., is the first species of *Phyllograptus* to be recorded with certainty in Victoria, and is characteristic of the D1 zone. Hitherto most of the Phyllograpti have been recorded as showing affinities to *P. typus* or *P. angustifolius*. *Didymograptus forcipiformis* Ruedemann, a late mutation of *D. caduceus*, although often recorded, has not hitherto been figured among Victorian specimens. *Brachiograptus etaformis*, gen. et. sp. nov., is a multiramous form which does not seem to us to fit into any known genus. It is also a D1 form.

Two Castlemaine forms of special interest are described. *Goniograptus palmatus*, sp. nov., is notable for its extensive disc membrane, while *Didymograptus dependulus*, sp. nov., adds another species to the Victorian tuning fork graptolites, till now represented only by *Didymograptus bifidus*.

The forms dealt with are:—

Diplograptus austrodentatus, sp. nov.
Phyllograptus nobilis, sp. nov.
Didymograptus forcipiformis Ruedemann.
Brachiograptus, gen. nov., *B. etaformis*, sp. nov.
Goniograptus palmatus, sp. nov.
Didymograptus dependulus, sp. nov.

Diplograptus (Glyptograptus) austrodentatus, sp. nov.
(Pl. V, Figs. 4, 5.)

Description.—Polypary short, with an average length of about 10 mm.; subquadrate at the base where it is 1·5 mm. broad, increasing to a width of 2 mm. at the 12th theca. Sicula about 1 mm. wide, with a comparatively short virgella.

Figs. 1—4.

Fig. 1.—Sicula and initial thecae. Spec. 6493A. × 4.
Fig. 2.—Polypary, showing proximal spine. Spec. 31365 (1). × 4 (approx.).
Fig. 3.—Complete polypary. Cotype. The virgella and virgula are shown but no proximal spine. Spec. 3165 (2). × 4.
Fig. 4.—Polypary showing excavations. Spec. Sd.6. × 4.

Thecae 12-14 in 10 mm., 1·5 mm long and 0·5 mm. wide, overlapping half to two-thirds their length, impressed below and with thickened apertural margins, which are normal to the axis of the polypary in the proximal portion and to the axis of the thecae in the distal portion. The proximal thecae are furnished with both sub-apertural and inconspicuous mesial spines.

Remarks.—The sicula appears to be about 0·4 mm. wide; like the thecae it has a thickened apertural margin. Th 1 (1) arises near the aperture of the sicula, and grows outwards and upwards. Th 1 (2) also grows outwards, presumably from Th 1 (1). The inconspicuous mesial spines are given off where the thecae change direction. These, however, are often absent.

The aspect of the polypary depends wholly on the angle of compression. In the normal bi-profile view the ventral margins of the thecae are straight or slightly sigmoidal. Although they are impressed below no excavation is visible (Pl. V, Fig. 4). In any other mode of compression, either in the obverse or reverse aspect, the impression of the thecae and their thickened apertures facilitate introtorsion and introversion. The proximal portion of the polypary then exhibits excavations occupying one-fourth the width of the polypary and a small fraction of the ventral margin of the thecae (Fig. 3). The distal thecae are more or less introtorted, making oblique excavations occupying one-third the width of the polypary and one-fourth the ventral margin of the thecae (Pl. V, Fig. 4). Thecae showing the characteristics of Climacograptus occasionally occur, but the polypary is more typically Diplograptus than is *D. dentatus*.

The periderm seems to have been moderately thick, and the septum is usually invisible; in some specimens, however, it may be traced at intervals through the polypary.

A photograph (Pl. V, Fig. 4) shows the apertural spines from the medial thecae. There is a suggestion of fine apertural spines in some specimens, while in others they are not seen.

Diplograptus austrodentatus is characterised by its:—

(a) squatness.
(b) sub-quadrate proximal end.
(c) short virgella and sub-apertural and inconspicuous mesial spines on the proximal thecae.
(d) thecal characteristics of a compromise between normality and introtorsion, brought about by impression and apertural thickening relative to the angle of compression.

Affinities.—There seems little doubt that *D. austrodentatus* is closely related to *D. dentatus*. The origin of the initial thecae from the sicula and the peculiar disposition of the spines are suggestive of *D. dentatus*. *D. austrodentatus* was probably less concavo-convex, a feature which made for its compression as a more typical Diplograptus. Its virgella, and usually its virgula, are much less conspicuous, and the number of its thecae in a given length is more constant. The apertural thickening is characteristic of *D. perexcavatus*, of which the obverse aspect as a whole bears many resemblances to the present species. *D. austroden-*

tatus may, however, be regarded as the Australian equivalent of *D. dentatus,* which has not been revealed here in comprehensive collecting over a number of years. Dr. Hall in unpublished identifications referred to this form as *D.* cf. *inutilis*, but examination shows that the two species are quite unlike in thecal characters.

Horizon.—*D. austrodentatus* is the D2 Zone fossil of the Darriwil, though with a range somewhat above and below this zone.

Associates.—In zone D2, *D. austrodentatus* often crowds the beds to the almost entire exclusion of other species, the mature forms being associated with juvenile forms (Fig. 1) in all stages of growth. Its associates in this zone are therefore usually few, but *D. caduceus, Trigonograptus, Cryptograptus, Glossograptus, Lasiograptus, T. serra* and *T. quadribrachiatus* are recorded as associated. When found in higher or lower beds its associates are naturally the forms noted as occurring on those horizons.

Localities.—Steiglitz, Lancefield North, Brisbane Ranges, Bendigo East, Bacchus Marsh, Woodend, Guildford, Bullengarook (Jackson's Creek), Muckleford, etc.

Phyllograptus nobilis, sp. nov.

(Pl. VI, Figs. 3, 4.)

Description.—Stipes united to form the characteristic phyllograptus polypary, with elongate-ovate, broad oval, or obovate outline. Thecae 11 in 10 mm., direction of curvature varied, but with ventral margins, when clearly seen, sigmoidal. In contact for not quite the full length, apertural margins concave, mucronate with distinct denticle.

Remarks.—This species approaches closely both *P. typus* and *P. angustifolius.* It is distinguished from both by the sigmoid curvature of the thecal walls and the nature of the aperture. Both these characters are strongly reminiscent of *Didymograptus caduceus, Oncograptus* and *Cardiograptus,* a fact probably of genetic importance. Owing to the sigmoid curvature of the thecal walls slightly magnified specimens often appear as if in relief.

Although *Phyllograptus* in Victoria ranges from at least the lower Bendigo beds to the upper middle Castlemaine, it has not yet been recorded from the Upper Castlemaine (C1) nor from more than one C2 locality. It reappears in the Darriwil, and though its occurrence there is rather sporadic (Dr. Hall does not record it from these beds at Steiglitz) it seems to range right through the series. Collections have been made from all horizons, but no detailed examination of the genus has yet been made, chiefly because the state of preservation is not sufficiently good. Our own observations lead us to the conclusion that the Darriwil and lower Phyllograpti are almost certainly specifically distinct, the forms from the lower beds being separable only with difficulty from *P. typus.* Whether more than one other species occurs in the Darriwil series must be left for later determination. It may be mentioned that *Phyllograptus* has been recorded in New Zealand from beds equivalent to our C1. The polyphylogenetic origin of the genus is a possibility which needs consideration in any comprehensive treatment.

Localities and Horizon.—The type specimens are from the D1 (Upper Darriwil) belt of Bendigo East. Undoubted examples have also been obtained lately by Harris and Thomas from the Gibbo River, in north-eastern Victoria. The associated forms are in each case *Diplograptus* and *Climacograptus*, and in the Bendigo East localities, the whole D1 assemblage.

Didymograptus forcipiformis Ruedemann.

(Pl. VI, Figs. 6, 7.)

1904 *Didymograptus forcipiformis* Ruedemann, Grap. New York, Pt. I.

Description.—Nema filamentous, extremely thin. Sicula long and slender. Two branches bent at their base to such a degree that their distal parts, which are straight, become sub-parallel. Angle of divergence 350° or more. Branches rarely exceeding 10 mm. in length and tapering distally. Thecae long, but becoming shorter in the distal portion where the angle of inclination becomes less than 45°, 11-12 in 10 mm., curved, about twice as long as wide, in contact throughout their length. Apertural margins concave; thecae with the pronounced mucros of *Didymograptus caduceus*.

Remarks.—The above description is based on Ruedemann (*supra cit.*), who points out that *D. forcipiformis* is a late derivative of *D. caduceus*. The differences he mentions are:—

(1) greater divergence of branches.
(2) smaller width of the distal parts of branches.
(3) great width of proximal part.
(4) less close arrangement of thecae.
(5) presence of apertural mucros or spines.

The first three differences can be seen in our specimens, but the thecae of our forms are not more closely arranged than in many forms of *D. caduceus*, which is also a mucronate form.

Like its antecedent *D. caduceus*, *D. forcipiformis* is extremely common at certain outcrops, along with other mutations of *D. caduceus*, such as var. *manubriatus*. *D. caduceus* Salter var. *nanus* Rued. seems to fall between *D. caduceus* Salter var. *manubriatus* T. S. Hall and *D. forcipiformis*.

Horizon and Localities.—Dr. Hall (10) records *D. forcipiformis* in Darriwil associations from the Woodend-Macedon and Steiglitz districts. Harris (12) records it from the Castlemaine district. It occurs often in large numbers in the lower Darriwil beds, D5, and ranges through the Darriwil series. To the localities given above may be added Gisborne and Bendigo East.

Associates.—The associates of this form are those of the zone of the Darriwil in which it occurs, and are set out elsewhere in this paper.

Brachiograptus, gen. nov.

(Pl. VI, Figs. 8, 9.)

Description.—Polypary bilaterally symmetrical. The first two thecae which arise from the sicula comprise the funicle, which is slightly declined, though straight as compressed. Each of these thecae gives rise to two thecae, constituting the branches of the second order, which diverge at an angle of from 105° to 130°. The later development may be expressed in terms of (a) lateral branching, or (b) dichotomous branching.

(a) Each of the branches of the second order develops at right angles to the funicle, forming a characteristic H; and lateral branches up to 16 or more and remaining undivided, grow outwards from the successive thecae forming the H.

(b) The branches of the second order bifurcate giving rise to a terminal branch, which grows outwards, and a stolonal theca at right angles to the funicle. Dichotomy may be so repeated until there are up to 16 or more terminal branches growing outwards from the characteristic H formed by the stolonal thecae.

Remarks.—While the branching of graptolites is, as at present, used as a character of generic value, the erection of a new genus for such forms is, in our opinion, necessary. This decision is made after a careful consideration of the opinions of previous workers, which have recently been summed up by Bulman (1, pp. 23-5). Bulman accepts as of generic importance "the significant distinction which was rather to be found in the varying capacity of the genera for dichotomy," in this following Dr. Elles. He notes in a South American form, but does not consider as of more than varietal importance, the limitation of the power of dichotomy to the "inner" third order stipes. In our form it does not appear that this is a stage in the reduction of stipes, as Bulman appears to consider it, since 16-branched forms commonly occur, and even more branches may be developed. We do not wish to raise the question as to whether the branch development is the result of the dichotomy or of unilateral branching, as at present there seems no test which will separate the results of either method, but if limitation of dichotomy is of systematic value, the very definite limitation as shown in this case is as important as that on which the genera of Dichograptus and Loganograptus are founded. We may add that the whole matter of these multiramous forms is in an unsatisfactory state, since the thecal characters which are almost certainly of at least as great systematic value as nature of branching are neglected altogether. Under both of these genera, forms which differ greatly in thecal characters are separated only as varieties. This is the case, for example, with *Loganograptus logani* J. Hall, var. *boliviensis* Bulman. The long tubular thecae are quite unlike those of *Loganograptus logani, forma typica,* so also the variety of *Dichograptus octobrachiatus* figured on the same page (1, Pl. 1).

BRACHIOGRAPTUS ETAFORMIS, gen. et sp. nov.

(Pl. VI, Figs. 8, 9.)

Description.—Sicula small, slender, not always visible, but of an observed length of 1 mm. First theca budding aperturally, this and the second forming the funicle, which is probably declined, though in compressed specimens it is often straight; these thecae narrow, tubular, and long (1 mm.). Branches of the second order arising by dichotomy and diverging at angles of from 105° to 130°. From near the aperture of each successive theca on the outer side of the H later branches are given off which divide the outer 180° more or less evenly. There are usually three of these tertiary branches from each secondary branch, making a 16-branched polypary, but the number may be less, or, occasionally, an extra branch may be developed. Thecae long (0·9 mm.), slender, tubular, and slightly concavo-convex, especially on the secondary branches, overlap slight, 8-10 in 10 mm., apertural margins normal to axis. The tertiary branches do not subdivide.

This description, based on the assumption that the branching is unilateral, can be easily adapted to express the same result by successive dichotomy.

Remarks.—The relation of this form to *Loganograptus* has been touched on in the description of the genus. The arrangement of branches seems to be conditioned by food supply, and lateral branching solves the problem of an equal distribution of the thecae on a plan different from that adopted by *Loganograptus*. The difference in mode of branching, the characteristic outline of the polypary resulting from this, the different type of thecae, and the development of branches from successive thecae, all serve to distinguish the present species from *Loganograptus logani*, the only species it resembles even superficially. It is, moreover, a much less robust form, and polyparies are common which appear to have been stripped of their thecae. Its closest relations are with *Loganograptus logani* var. *boliviensis* Bulman var., which as we have already stated is, according to our interpretation, best regarded as an allied species of *Brachiograptus*.

Horizon and Localities.—*Brachiograptus etaformis* is very common at many Upper Darriwil (D1) localities, particularly on the McIvor Road (Bendigo East), and south-east of Strathfieldsaye in the same belt. It also is found in beds on about the same horizon at Guildford, Woodend, Gisborne, and near Romsey. Its associates are the common D1 assemblage. (Tabulation of Zones, p. 31).

GONIOGRAPTUS PALMATUS, sp. nov.

(Pl. VI, Fig. 5.)

Description.—From the sicula which has not been observed, two thecae arise, forming the funicle which is straight and 4 mm. in length. By dichotomy two short branches of the second order arise from each end of the funicle, the angles between them being 85° and 105° in the type specimen. From the angles of these branches other branches arise alternately from each side, till a 16-branched form is produced. The angle included between all but the most distal branches varies from 40° to 80°, the angle between the two last branches in each of the four main stems being less than this.

5.

Text Fig. 5.

Fig. 5.—Distal thecae. Type Spec. Xc.4.

The thecae are long and narrow, with little overlap, only 6-7 in 10 mm. with concave ventral walls, inclined to the axis of the stipe at a low angle. Apertural margins often apparently convex, though this appearance may be due to the delicacy of the apertural walls except along the ventral margin. A feature of the type specimen is the disc, which not only " clasps the funicle and principal branches to the base of the terminal denticulate branches," as described in Ruedemann's account of *Goniograptus thureaui* (16), but extends as a web on each side of the funicle and between each pair of branches. At its widest it spans a distance of 5 mm., with a catenary curve. In spite of its prominence on the type specimen it would probably be unsafe to predict that it would always be present.

Remarks.—The type specimen is preserved on two slabs, one showing the funicle and three of the four main branches, the other, part of the reverse slab, showing the funicle and the fourth branch. From the two the figure (Pl. VI, Fig. 5) has been restored. The general appearance of the form is quite distinctive. Its thecae resemble those of *Goniograptus geometricus* Rued. and *G. perflexilis* Rued. From *G. geometricus* the less definite angular junctions distinguish it, while it is an altogether more robust form than *G. perflexilis*.

Horizon and Locality.—Middle Castlemaine (C4), Campbell's Creek (Castlemaine).

Associated Forms.—On the same slab occur *Didymograptus* cf. *extensus, Dichograptus* cf. *octonarius, Tetragraptus similis* and *T. serra. Phyllograptus, Clonograptus* and *Triaenograptus neglectus* were also found at the same outcrop.

Didymograptus dependulus, sp. nov.

(Pl. VI, Figs. 1, 2.)

Description.—Stipes robust, about 1·5 cms. long, expanding gradually to a width of rather more than 1 mm., and then narrowing towards the distal extremity; diverging from a large sicula at an angle of about 90°, and then gradually approaching till they lie at an angle of about 45°. Thecae 10-11 in 10 mm., about twice as long as wide, inclined to the axis of the stipe, but at a lower angle in the distal portion. The apertural angle varies according to the mode of preservation from distinctly concave to convex, the latter appearance being due perhaps to fracture of the apertural edge. The sicula is usually provided with a conspicuous nema, which may be 5 mm. or more long.

Remarks.—This very characteristic tuning fork Didymograptus cannot be confused with any other species with which we are acquainted, and, seeing that it is present in some of the older collections of the Geological Survey, it is remarkable that it so long escaped notice. It is not closely related to the other Victorian dependent *Didymograptus, D. bifidus;* it appears to have more affinity with *Tetragraptus fruticosus* than any other Victorian form with which we are acquainted.

Horizon and Localities.—Middle Castlemaine (C4)—the bed above that characterized by *D. bifidus*. So far this form has been found only at a few localities, near Quartz Hill (Castlemaine), by the Geological Survey and Harris, south of Axedale by Caldwell and Harris, and at Steiglitz by W. H. Ferguson. The Steiglitz forms are in a collection examined by Dr. Hall, but no note of them appears in the published report. From the labels on them in Dr. Hall's handwriting, we conclude that he put them aside for later examination.

Associated Forms.—As stated elsewhere, the C4 beds are not rich in graptolites as a rule. *D. caduceus* (small), *Tetragraptus serra* and *Phyllograptus* cf. *typus,* are perhaps the commonest associates.

VI.—Acknowledgments.

We desire to acknowledge our indebtedness to Mr. C. W. Brazenor, of the National Museum, who is responsible for the photographic illustrations of the zonal species in the plates. His effort will appeal to those who are acquainted with the difficulties of graptolite illustration.

To the Director of the Geological Survey and his draughting staff we are indebted for the legible presentation of the Correlation Tables.

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Description of Plates III-VI.

Plate III.

Dictyonema macgillivrayi, T. S. Hall. Quarry Allot. 56, Parish of Goldie. Nat. Mus. No. 13126. (Figd. in part *Proc. Roy. Soc. Vic.* iv (1892), pl. ii, fig. 2. Photo. × 1⅓.

Plate IV.

Fig 1.—*Tetragraptus fruticosus* (J. Hall). 4-branched form. Sailors Creek, Daylesford. Nat. Mus. No. 51. Photo × 2.

Fig. 2.—*Bryograptus victoriae* T. S. Hall. Quarry, Allot. 56, Parish of Goldie. Nat. Mus. No. 237. Photo. × 1½.

Fig. 3.—*Cardiograptus morsus* Harris and Keble. Shicer Gully, between Guildford and Rocky Water Holes. Nat. Mus. No. 13083. Geol. Surv. Q.S. 15 SE. Ba 91. Photo. X 1½.

Fig. 4.—*T. approximatus* Nich. Allot. 16A. Parish of Campbelltown. Nat. Mus. No. 13094. Photo. × 1½.

Fig. 5.—*T. fruticosus* (J. Hall). 3-branched form. South New Moon Mine, Eaglehawk, Geol. Surv. Vic. Photo. × 1½.

Fig. 6.—*Didymograptus bifidus* (J. Hall). East of Guildford. Nat. Mus. No. 25, Geol. Surv. Q.S. 15, SE, Ba 93. Photo. × 2⅔.

Fig. 7.—*Phyllograptus* sp. Bendigo. No. 9755. Geol. Surv. Vict. Loc. 79 BO. Photo. × 1½.

Fig 8.—*Oncograptus upsilon* T. S. Hall. Campbell's Creek, N.W. of Yapeen. Nat. Mus. No. 13071. Geol. Surv. Q.S. 15 NE, Ba 90, Photo × 1½.

Fig. 9.—*D. caduceus* Salter. Sub-maximum development, Barker's Creek, Castlemaine. W. J. Harris Coll. Photo. × 1½.
Fig. 10.—*D. caduceus* Salter. Small form. Steiglitz. No. 6287, Geol. Surv. Vict. Loc. 26, ZS. Photo. × 1½.
Fig. 11.—*D. caduceus* Salter. Maximum development. McKenzie's Hill, Castlemaine. W. J. Harris Coll. Photo. × 1½.

Plate V.

Fig. 1.—*Staurograptus diffissus* Harris and Keble. Stauro Gully, N 18° W from SW corner of Allot. 26, Parish of Springfield, on water reserve. Nat. Mus. No. 13639. Photo. × 7.
Fig. 2.—*Didymograptus nodosus* Harris. Bendigo East, W. J. Harris Coll. No. 77. Photo. × 2.
Fig. 3.—*Loganograptus* cf. *logani* (J. Hall). Sutherland Creek, Parish of Darriwil. Nat. Mus. No. 89. Geol. Surv. Q.S. WL S1. Photo. × 1½.
Fig. 4.—*Diplograptus austrodentatus*, sp. nov. Cotype. Geol. Surv. Vict. No. 31328 Loc. WL/34, Allot. 74, Parish of Lancefield. Photo. × 8.
Fig. 5.—*D. austrodentatus*, sp. nov. Steiglitz. No. 7475. Geol. Surv. Vict. Loc. 7 Sz. Drawing × 6 (approx.).

Plate VI.

Fig. 1.—*Didymograptus dependulus*, sp. nov. Holotype, Steiglitz. No. 6290. Geol. Surv. Vict. Loc. 26, Sz. Drawing × 1½.
Fig. 2.—*D. dependulus*, sp. nov. Paratype. Quartz Hill, Castlemaine. No. 29625. Geol. Surv. Vict. Loc. 54. Drawing × 1½.
Fig. 3.—*Phyllograptus nobilis*, sp. nov. Group including holotype type Strathfieldsaye, Bendigo East. W. J. Harris Coll. S3A. Drawing × 1½.
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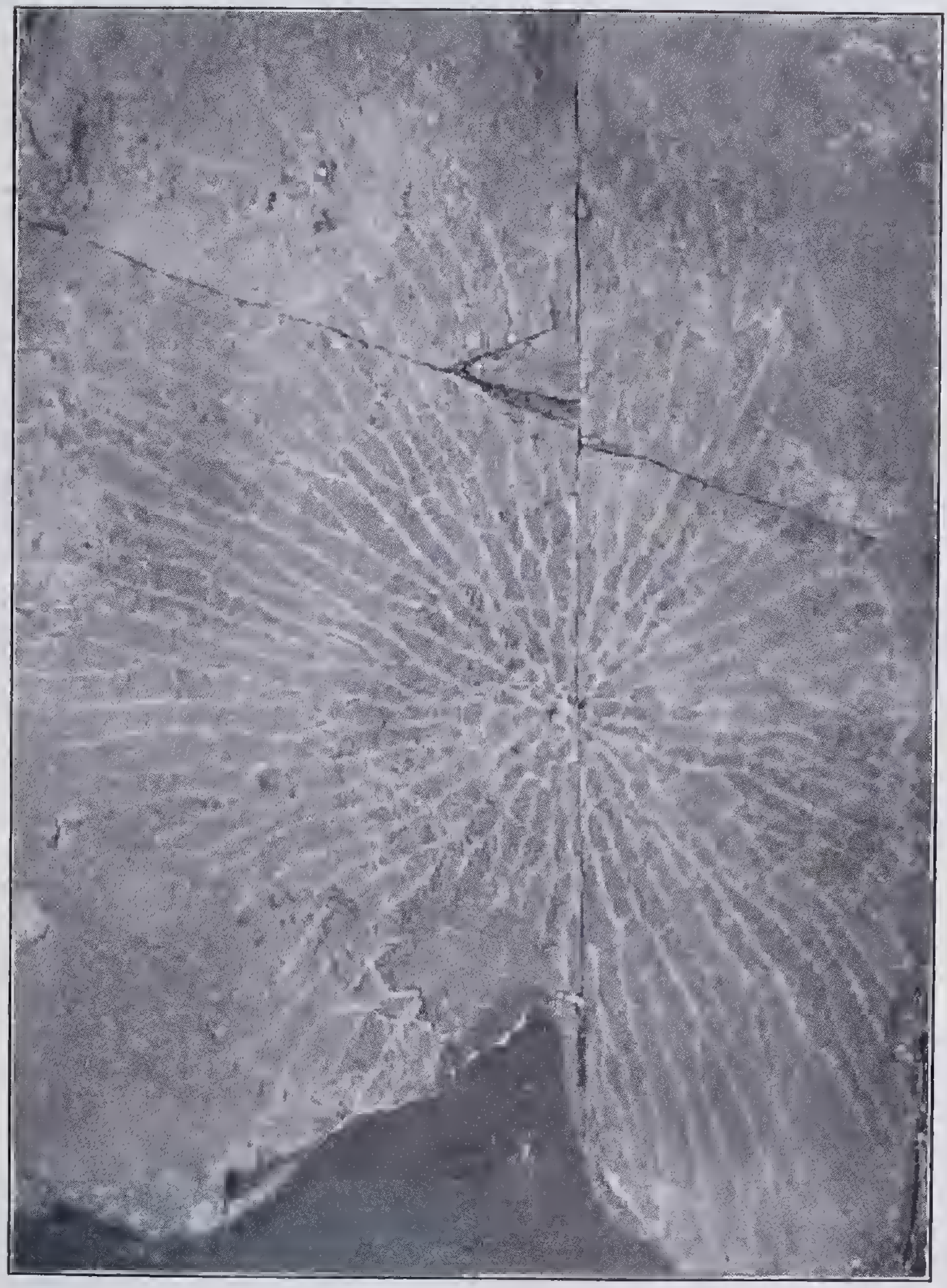
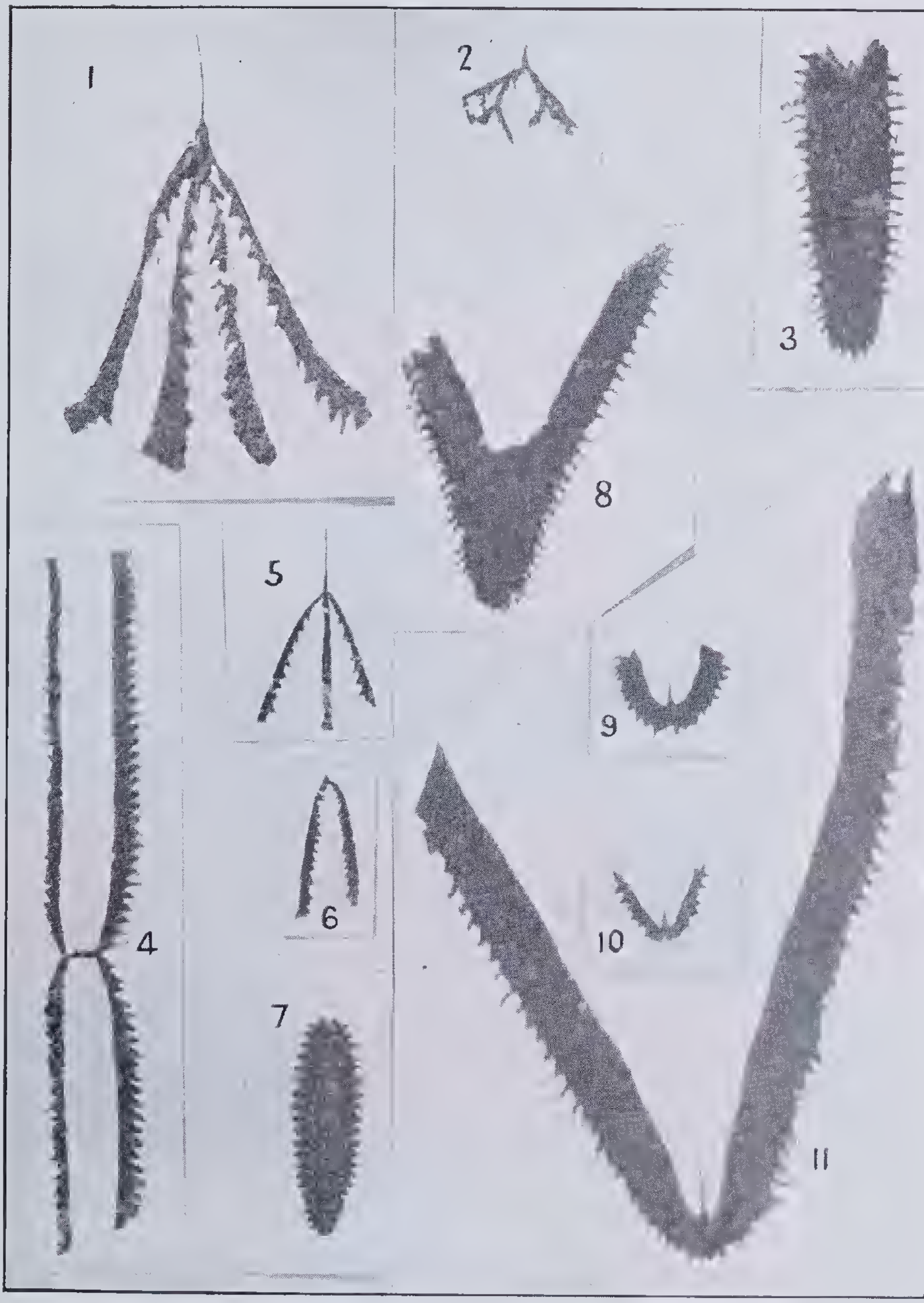
Fig. 6.—*Didymograptus forcipiformis* Ruedemann. Waterloo Flat, Gisborne. W. J. Harris Coll. XO. Drawing × 1½.
Fig. 7.—*D. forcipiformis* Ruedemann. Waterloo Flat, Gisborne. W. J. Harris Coll. XP. Drawing × 1½.
Fig. 8.—*Brachiograptus etaformis*, gen. et sp. nov. Strathfieldsaye, Bendigo East. Paratype. W. J. Harris Coll. S3K. Drawing × 1½.
Fig. 9.—*B. etaformis*, gen. et sp. nov. Holotype. Strathfieldsaye, Bendigo East. W. J. Harris Coll. S3, 100. Drawing × 1½

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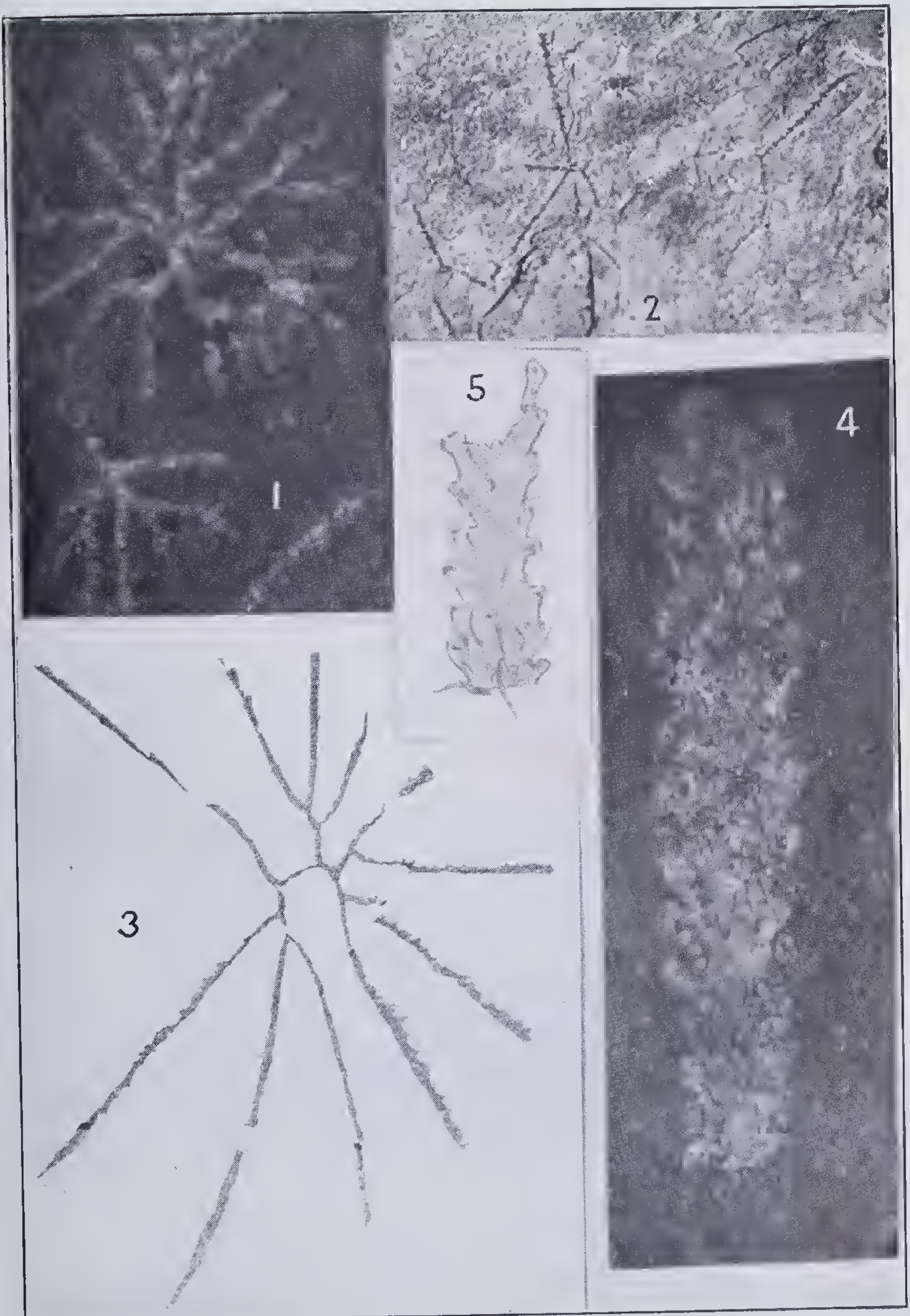
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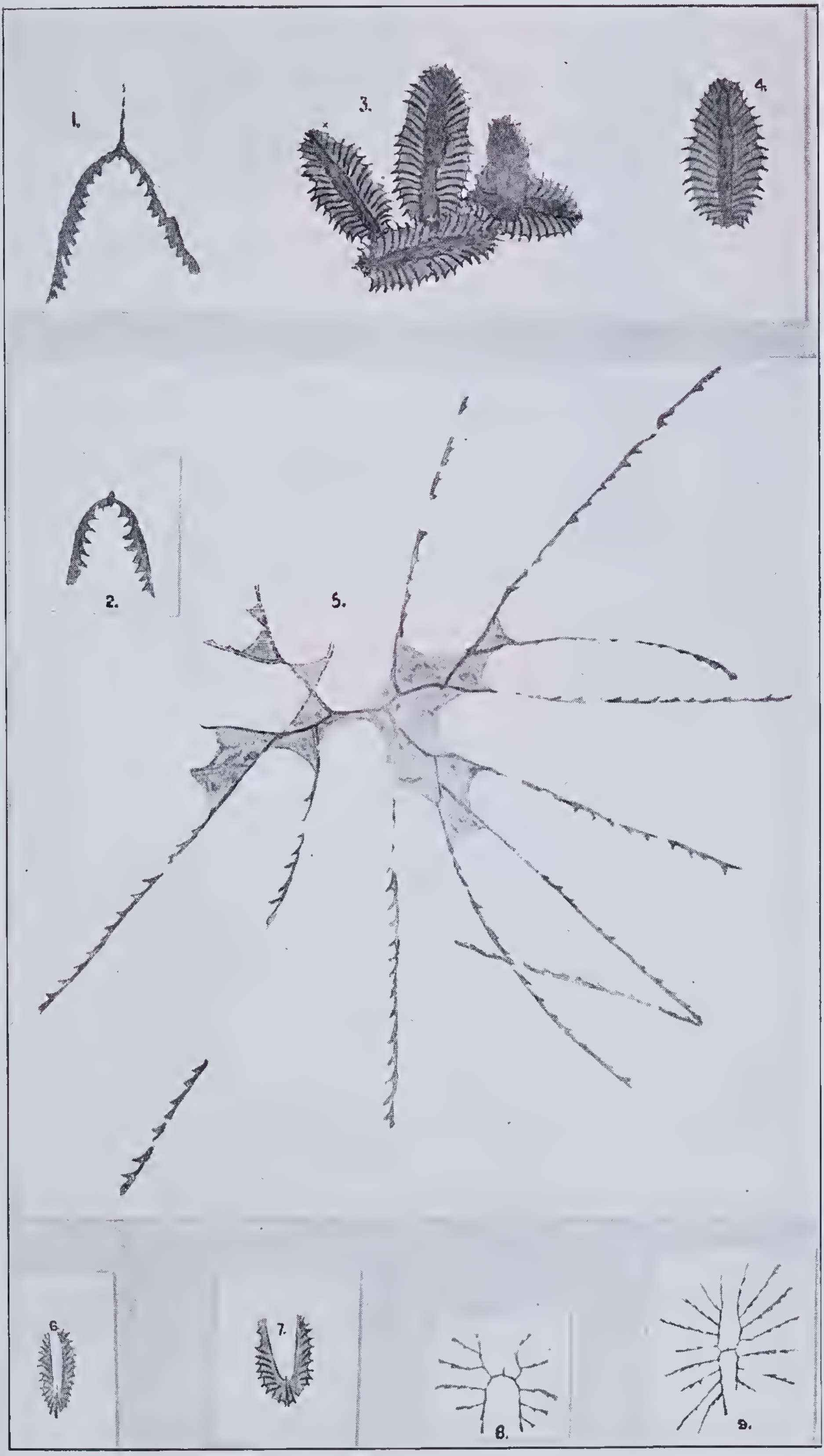
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ART. V.—*The Geology and Petrology of the Black Spur Area (Healesville).*

By A. B. EDWARDS, B.Sc.

(Howitt Scholar in Geology, University of Melbourne.)

(With Plates VII. and VIII.)

[Read 11th June, 1931; issued separately 29th February, 1932.]

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[Note:—Numbers in brackets thus—No. (1522)—refer to slides in the University Collection.]

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Introduction.

The area dealt with in this paper is an approximately rectangular block of country, stretching from Healesville to Granton in the north-east, and bounded by the Acheron Way on its north-easterly frontage, and by the Don road along its southern extremity; and extending westerly as far as Mt. Monda. Its greatest length is about twelve miles, and its maximum width about ten miles. It is known variously as "The Black Spur," the "Blacks' Spur" (after the aborigines) and "Black's Spur" (after the surveyor). I use the former name, since throughout the district it is invariably referred to as "the Black Spur."

THE BLACK SPUR AREA

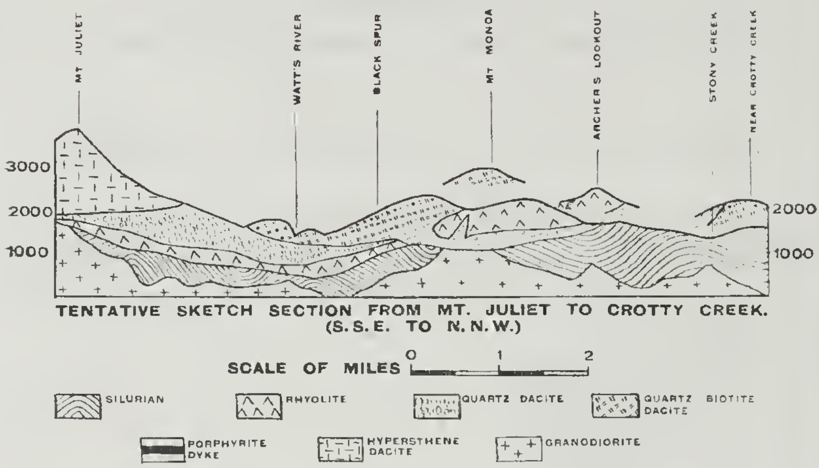

Fig. 1.

A geological map of the area (Plate VII.) and a cross-section (fig. 1) have been prepared. The mapping is generally approximate, and has been done throughout by compass and pacing. Contouring was attempted in order to demonstrate the rugged topography, but time limited such work to aneroid readings during traverses over the northern half of the area, from which form-lines were drawn. Over the southern half extempore form-lines were drawn, based on a few known levels and a knowledge of the country. Where boundaries are plotted with broken lines, considerable linear error may exist, but a full line indicates accurate determination in the field.

I desire to express my sincere thanks to Professor Skeats, Dr. Summers, Dr. Stillwell, Mr. Singleton, and others in the Geology School; to Mr. Ampt of the Chemistry School and to Mr. Mahony of the Mines Department for help with rock analyses; to the Metropolitan Board of Works; to Miss O'Neil and Mr. Vale of Narbethong; to Mr. Chapman, F.L.S., F.G.S., and Mr. Keble, F.G.S., for determining my fossils; and to Mr. McCance and Mr. Bladin.

Previous Work.

A list of the earlier literature concerning the area is furnished in a paper by Dr. N. R. Junner (6) which marks an important advance in the knowledge of the geology of the area. Junner's paper, which has served as an invaluable guide and basis throughout my work, deals with a considerably larger area than is covered by the present detailed examination. He mapped the outcrops of the granodiorite and the junction of the igneous series with the Silurian sediments; he recognised the variable character of the dacites, but did not appreciate the separate entities of their fourfold division; and he indicated the position of rhyolite, dacite, and tuff on his map by the letters R, D and T respectively, but had not sufficient time to map their boundaries. He made a detailed study of the pyroclastics, and did some work on the Silurian sediments; and gave a description of the physiography.

An unpublished report by Professor Skeats on the Geology of the Maroondah Dam, together with a map showing speculative boundaries of the main rock types, and recognising three of the four dacite flows, was also used.

Physiography.

As described by Junner (6, p. 261) the country falls into three belts from north to south; (1) the valley of the Acheron; (2) the central mountain ranges; (3) the valleys of the Watts and the Yarra. The central ranges of igneous lavas rise up sharply from the open, rolling country of sedimentary character to the north and south, and form a part of the main divide of Victoria. Valleys in this region are narrow, deep, and immature, as opposed to the wide and mature topography of the lower Acheron, the lower Watts, and the Yarra. These rivers rise in the mountain zone. The high ranges radiate as several ridges from Mt. Donna Buang. Spurs radiate from these ridges in turn, and serve as the mediums for roads to cross the hills. The well-known Black Spur is one of these. Low "gaps" mark the junction of the ridges. Streams rising in the dacites have mud bottoms, while those from the rhyolite are stony-bottomed.

Sedimentary Rocks.

Silurian.

The oldest rocks outcropping in the area are sediments of Silurian age, and include mudstones and sandstones, with occasional shales and conglomerates. The sandstones outcrop mainly to the north-east. They are hard and compact, and inclined to induration by iron oxide, resembling very closely the sandstones of the Cathedral Mount. Blue slaty shales showing curious white stains are found interbedded with a friable purple sandstone in a section on the Tarnpirr private road.

Junner (p. 204) records two outcrops of "fossiliferous conglomerate" near Narbethong, one west, the other east of the main road. Unfortunately the western outcrop was not located, but the eastern conglomerate was found in an old road-metal quarry, about 300 yards west of the Old Marysville Road. Six bands of coarse to fine conglomerate, never more than three feet thick per bed, alternate with very friable shales. A fossiliferous grit bed, varying from six inches to one foot three inches in thickness, directly overlies the uppermost conglomerate bed. The beds dip at 50°W. and strike at 340° (mag.). The individual pebbles are very well rounded, but are never large. They consist of quartzite (the larger sizes), shales and vein-quartz. The grit is similar to fossiliferous grits seen in the Yea-Alexandra district. It is packed with very poorly preserved casts of crinoids and brachiopods, and several identifiable forms were obtained.

Sufficient dips and strikes were obtained to indicate the approximate positions of the anticlines and synclines. The folding is moderately close in character, with high dips. Just east of the Narbethong Post Office the probable existence of a small "crush" zone is indicated.

That the Devonian igneous rocks unconformably overlie the Silurian is indicated by the varying levels at which the junction of the two is found. These vary from 400 ft. at Maroondah Dam to 1000 ft. near Wade's Lookout. Evidently the Silurian was neither level nor peneplaned when the igneous activity occurred.

Near Wade's Lookout the sandstone in contact with the dacite has been altered to quartzite. Section No. (1522) shows it to be a nearly pure quartz rock, consisting of crenulated, interlocked quartz grains, with a very little muscovite. Along the Acheron Way was found a small bedded outcrop of baked mudstone, striking at 280° (?) and dipping at 80°N. It was surrounded by dacitic soil, containing cores of weathered dacite.

Fossil Forms.

Junner records plant remains from the red-coloured sandstones and mudstones in the north of the area. Mr. Chapman has referred them to *Haliserites* (now *Psilophyton*) *Dechenianus* Goeppert—a form characteristic of the Silurian from Wood's Point. Examination of the rocks has yielded poor, but definite remains at several localities. These have been named for me by Messrs. Chapman and Keble.

1. *Fossiliferous Grit, Conglomerate Quarry.*

Casts of: Brachiopoda—*Leptaena* sp. (aberrant form—only known from the Yeringian) ; *Stropheodonta* (?) ; *Chonetes* sp. Anthozoa—*Lindstroemia* sp. (Silurian) ; *Tryplasma* cf. *murrayi.* (Upper Silurian to Lower Devonian) ; Crinoidea—Numerous casts.

2. *Boulders on the ridge south of the Acheron Way.*

Casts of: Brachiopoda—*Chonetes* sp.; *Stropheodonta* sp.; Anthozoa — *Lindstroemia* sp.; *Tryplasma* cf. *murrayi;*

CRINOIDEA—casts of stems. ARTHROPODA—Cephalic border of a Trilobite, bearing a genal spine.

3. *St. Fillan's.*

PLANTAE—*Psilophyton* (?).

These remains indicate that the beds are of Upper Silurian (Yeringian) Age. The fossil remains in conjunction with the lithological types suggest that the disposition took place under coastal marine conditions.

Igneous Rocks.

The igneous rocks of the area consist of a series of acid lavas. They are described in their apparent order of extrusion.

1. ANDESITE.

No outcrops of andesite have been discovered in the area, but proof of its existence has been afforded by xenoliths found in the quartz-hypersthene-biotite-dacite, along the track to Mt. Monda, and in the quartz-biotite-dacite in the Chosen Valley (S. of Mt. Dom Dom).

Andesite has been recorded from Wade's Lookout by Junner, but sections cut from there and other localities marginal to the flows appear to be chilled borders of the main hypersthene-dacite flow.

The xenoliths of andesite are dark brown in colour, and very fine-grained. A section No. (2343) shows it to be a porphyritic rock, with a felted or hyalopilitic groundmass of fine lathes of felspar set in a glassy base. The hypersthenes form numerous phenocrysts and dominates over the felspar. They show a very slight tendency to form reaction rims of secondary biotite, particularly in the presence of ilmenite; and they have clotted together giving rise to a glomeroporphyritic structure. The felspars are labrodorite with some andesine. They form small phenocrysts which grade into the groundmass, and are very distinct from the felspars of the including dacite. Quartz crystals are absent. The ratio of the groundmass to the phenocrysts is about 2:1.

It is remarkable that no xenoliths of andesite are found in the rhyolite, while they are prevalent in the quartz-hypersthene-biotite-dacite, so close to the rhyolite. This latter when intruding the rhyolite appears to have brought the andesite up with it from below.

2. RHYOLITE.

This has been figured and described by Junner (6, pp. 276-279). His analysis is quoted on p. 65. The rhyolite is "characterised in handspecimens by the abundant quartz phenocrysts, and by the paucity of the femic minerals. Rhomb-shaped sections of glassy or pearly orthoclase can often be recognised." Thin sections show plentiful phenocrysts of strongly embayed quartz and orthoclase (often microperthite) set in a glassy to microcrystalline groundmass. Femic minerals are almost absent.

This rock outcrops in a long narrow belt, near the margin, or marginal to the igneous rocks, along their northern boundary. It often shows well developed jointing, as in the cliff face at Archer's Lookout and along the Acheron Way.

Tuffs and breccias are developed along the lower spurs north-west of the Hermitage (Narbethong), and boulders of lapilli have been found there. These pyroclastics are well described by Junner (pp. 271-276). Beautifully banded rhyolite, resulting from differential flowage, is found in this locality.

Examination of thin sections Nos. (2347, 2349) shows that in addition to the minerals recorded by Junner, cordierite is frequently present and is characteristic of the rock.

Hills (4) has described a similar rock from the Blue Hills, near Taggerty, and thinks that the two flows are connected.

3. Quartz-dacite.

This dacite outcrops over an extensive area. It abuts the granodiorite in the south, and extends along both sides of the Maroondah Dam, continuing as far north as the Acheron Way. It almost pinches out at Carter's Gap. The rounded hill on the western side of Maroondah Dam represents a volcanic centre of this flow. On its northern slope a large amount of coarse breccia is found, containing angular fragments of sandstone and shale. On the western slope a volcanic agglomerate occurs, with quartzite and sandstone pebbles as big as a clenched fist. A pebble of rhyolite was found here, but no quartz-biotite-dacite fragments could be discovered.

The rock is grey in colour (often greenish from chlorite). It consists of a fine groundmass with numerous glassy phenocrysts of quartz and felspar, together with chloritised biotite, and occasional pink garnets. The rock is closely similar in appearance and composition to the Lower Dacite of the Dandenong series (7).

A typical section No. (1324), (Analysis No. III.), from Maroondah Dam, is a porphyritic rock with a glassy groundmass containing numerous microlites of quartz, and patches of small, aggregated felspars. Flow structure is well developed. The quartz phenocrysts are common and have fantastic shapes, having been deeply embayed by corrosion. The outlines of the crystals are usually sharp. The predominant felspars are labradorite and andesine, in about equal volumes. A few phenocrysts of orthoclase, sometimes showing microperthite, are present. The felspar crystals are also corroded but not so fantastically as the quartz crystals. This is probably due to the cleavage of the felspars tending to maintain a more or less rectangular outline in the crystal. The felspars are often sericitised, and clouded by secondary reactions. They grade in size from the largest phenocrysts down to tiny lathes in the groundmass. Bleached biotite often occurs, being generally partially or entirely replaced by chlorite. Chlorite, alone, is frequently observed. A little apatite is included in the biotite. Small ilmenite grains are present. A cordierite trilling, with radial extinction, occurs. It is partially altered to a micaceous substance—pinite (?). In section No. (2338), from Carter's Gap, the felspars show a tendency to clot. The biotite contains zircons; and a cordierite, with marked radial twinning, shows partial pinitisation. An example from the Acheron Way contains a large, altered garnet, which is surrounded and impregnated by an iron-rich chlorite showing beautiful ultra-blue polarisation colours. Small patches of calcite, after biotite or sericitised felspar are common. No. (2340), from Mt. Juliet track (1000 ft. level), is much altered. The felspars are clotted and sericitised, and the ilmenite is altering to leucoxene. An intergrowth of biotite (altering to chlorite) and lathes of felspar is observed.

The chloritisation of this rock is so general, and so characteristic, even in the very freshest of material obtainable from the huge Maroondah Dam quarry, that it cannot be regarded as a weathering effect. The chlorite seems to be of "deuteric" origin, after pyroxene (?), biotite and sometimes garnet.

Near Maroondah Dam the rock contains numerous xenoliths of hornfels. A section No. (2372) shows them to be fragments of altered mudstone.

4. Quartz-hypersthene-biotite-dacite.

This is the first record in Victoria of a dacite which contains quartz and hypersthene phenocrysts freely associated together. It has been found at four separate localities, all marginal to the rhyolite; (1) at Crotty Creek in the north-west; (2) below Archer's Lookout; (3) from the Acheron Way, along an axis of 300° (magnetic) to Mt. Dom Dom, and Bladin's Quarry, near which it disappears under the rhyolite; (4) it reappears along this line of "strike" on the other side of the rhyolite, and continues towards Mt. Monda, merging into the quartz-biotite-dacite in this direction by the replacement of the hypersthene by biotite.

The rock is dark blue when fresh, and is markedly porphyritic. Phenocrysts of clear quartz, white felspar, and frequent but not numerous flakes of biotite are set in a very glassy groundmass. Sporadic pink garnets are characteristic; and pyritic minerals are often seen. Coarse patches develop locally in the normal dacite in the Mt. Monda outcrop. It is closely similar to the Middle Dacite of the Mt. Dandenong series (7), both in appearance and in chemical composition.

A typical section No. (2341), (Analysis No. VII.), from Bladin's Quarry, 2½ miles from Narbethong, on the Spur road, shows that the groundmass is a fine glass, with local developments of cryptocrystalline texture, exhibiting beautiful flow structure. The quartz phenocrysts are the largest crystals, and are equal to half the volume of the felspars. They show deep embayments and rounding of the edges from corrosion; but such corroded edges are generally sharply defined. The felspars are clear and fresh. Plagioclases predominate as labradorite with some albite and andesine. There is an occasional orthoclase. Carlsbad and albite twins, and zoning are prominent. Hypersthene crystals are the dominant ferromagnesians, but are subordinate to the felspar or quartz in quantity. They show green to pink pleochroism, and contain inclusions of ilmenite and apatite. The rims of the crystals show considerable alteration to a green chloritic mineral, itself secondary after secondary biotite. Sometimes the unaltered biotite remains. Biotite of primary character occurs in thin flexed ribbons, often curving about quartz or felspar crystals. It shows light yellow to brown pleochroism and perfect cleavage. Secondary biotite as coronas, or unorientated aggregates (after hypersthene), is about equally present. Grains of pyrrhotite appear occasionally. There is no garnet in this section.

Section No. (2344), also from Bladin's Quarry, is from the contact with the rhyolite. It is quite normal. The phenocrysts are smaller and apatite is more abundant. A cordierite trilling is seen, and a large pink garnet, altering to an iron-rich chlorite with fine ultra-blue polarisation colours. The garnet is included (?) by orthoclase crystals, which are much sericitised, and contain zircons. A large orthoclase contains a centrally included fragment of primary biotite. The groundmass is entirely glassy, and most beautifully marked by flow structure. A specimen from the Crotty Creek turn-off, No. (2342), differs in that the groundmass is crypto-crystalline. The felspars show coarse lamellar twinning, and contain inclusions of more basic felspar, as shown by the higher refractive indices of the inclusions. One was sufficiently twinned for an extinction angle to be measured. This was 30°, indicating anorthite. The hypersthene crystals are more numerous and contain inclusions of ilmenite and plagioclase. They all show stages of the hypersthene-biotite reaction, from hypersthene with biotite coronas to clots of secondary biotite, representing complete reaction. Primary biotite contains inclusions of zircons, with pleochroic haloes, ilmenite and fragments of felspar. Apatite is common, and there is a trilling of cordierite. No. (2343) from the Mt. Monda track near the rhyolite junction, resembles the Crotty Creek specimen. A hypersthene is present abutting an orthoclase crystal. A layer of secondary biotite marks their junction (see fig. 2). This demonstrates beyond doubt the character of the reaction.

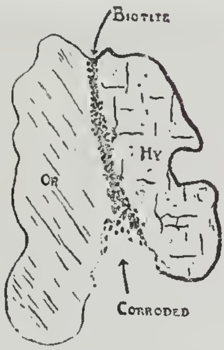

Fig. 2.

No. (2345), nearer to Mt. Monda, illustrates the linear gradation of quartz-hypersthene-biotite-dacite into quartz-biotite-dacite. There is a marked decrease in the amount of hypersthene, and a corresponding increase in the amount of biotite. Much of the hypersthene shows alteration to secondary biotite. A pink garnet is present, framed with secondary biotite.

Mode of Occurrence.

The quartz-hypersthene-biotite-dacite is intrusive into the rhyolite. At Bladin's Quarry it is seen in sharp contact with the latter rock, the contact bearing at 290° (magnetic). The dacite dips under the rhyolite at the junction at an angle of 60° in a southerly direction. It is extremely well jointed into blocks or columns, and these dip away at 40° to the north, at right angles to the contact, suggesting growth columnar fashion from the contact inwards.

The rhyolite at the junction shows a slight mineral alteration, which increases as the contact is approached. This metamorphic zone, while never more than 10 ft. wide, can be traced all along the contact from the Acheron Way to Bladin's Quarry. Thus, in section No. (2386), ten feet from the contact, the felspar in the rhyolite is partially sericitised; the groundmass is locally coarse; and small patches of fine grained quartz and femic aggregates have developed. No. (2388), two feet from the contact, has the orthoclase generally sericitised, and a coarser groundmass. Strings of blue tourmaline are present and the fine aggregates have developed into coarse clots of a green femic mineral (chloritised biotite (?)). Grains of magnetite are associated with these clots. At the contact macroscopic crystals of green biotite (?) are developed. In No. (2387) these appear as flexed green crystals which are strongly pleochroic and have a high double refraction. They show perfect cleavage and seem chloritised. Magnetite grains are included. Blue tourmaline is prevalent as crystals and as fine stringy or mossy aggregates. The groundmass has been recrystallised. Near the summit of Mt. Dom Dom, No. (2384), blue tourmaline is strongly developed, and shearing and foliation are evident.

The dacite tapers out under the rhyolite just west of Bladin's Quarry, and reappears again on the Mt. Monda track on a continuation of the "strike" of the outcrop extending from the Acheron Way to Bladin's Quarry. It V's up the valleys as would be expected from its dipping junction. On the Mt. Monda track the rhyolite shows a development of biotite where the dacite appears from under it. Apparently the rhyolite forms only a thin cover, and has been considerably metamorphosed. No. (2350), from near the contact contains more albite than usual. Three large cordierites are observed altering to pinite; and tourmaline occurs as crystals of trigonal outline. An intergrowth of quartz and decomposed felspar is seen. Biotite is prevalent. The groundmass retains its glassy character. In No. (2351) at the contact brown and blue tourmaline are a feature, as crystals and as mossy aggregates, often bordering crystals. Biotite and secondary mica have developed, and the felspars are sericitised. The groundmass is micro- to cryptocrystalline from recrystallisation.

Small xenoliths of typical rhyolite have been found in the dacite outcrop below Archer's Lookout.

Owing to the minor character of the intrusion, and to the lithological nature of the sediments, little evidence of the relation to Silurian rocks is apparent, but at Crotty Creek, at the eastern edge of the dacite, there is a sedimentary rock of schistose habit. A section No. (2363) contains a large amount of muscovite, arranged more or less in foliation planes. There is no trace of plagioclase or of large quartz crystals, although certain areas have a related extinction. No biotite is present, and crenulated quartz grains make up the remainder of the rock. These show strained polarisation phenomena.

The dacite appears to have intruded as dykes or sills into fissures in the rhyolite, or into the planes of weakness between the rhyolite and the sediments. It may represent a chilled border phase of an upward stoping magma, which broke through to the surface in places, or may have been exposed only by erosion. Fissuring of the rhyolite from differential floating would permit the intrusion of the linear outcrop described.

5. Porphyrite Dykes.

(1). Junner describes a patch of granodiorite, extending from the Malory's Cascades, east of Archer's Lookout, down to the Silurian sediments. Four traverses, through dense undergrowth, failed to locate the granodiorite; but in its place were discovered a patch of quartz-hypersthene-biotite-dacite of nearly the same dimensions, and a porphyrite dyke, four chains wide, extending from the dacite across the saddle south-east of Archer's Lookout, and causing the Malory's Cascades.

This dyke could not be traced in the dacite, but seemed to be an apophysis of it. Fresh samples from the Cascades were similar to the granodiorite in hand specimen, consisting of quartz, white felspar, and biotite; and garnets. Its porphyritic character is masked.

A section No. (2353) from Malory's Cascades displays a markedly porphyritic rock, with a microcrystalline groundmass of quartz and orthoclase as a setting for deeply embayed phenocrysts of quartz, plagioclase, and biotite. The plagioclase is labradorite, with some andesine, and is often sericitised. The quartz crystals are large and most irregularly shaped. The biotite occurs in large primary crystals and includes quartz, felspars and zircons —the latter with dark pleochroic haloes. Apatite, ilmenite, and pyrrhotite are common accessories. A secondary radiating micaceous mineral commonly replaces biotite, while retaining the inclusions. Clots of biotite, muscovite, and quartz form coarse patches in the groundmass. A large shattered pink garnet rimmed with chlorite and containing inclusions of quartz and biotite is present.

The contact effect of the dyke on the rhyolite is well displayed in specimens from the saddle south-east of Archer's Lookout. The dyke No. (2354) shows small blue tourmaline crystals near the margins of the phenocrysts. No. (2352) from the rhyolite has green and blue tourmaline strongly developed as mossy aggregates and as crystals bordering the phenocrysts, and filling the cleavages and cracks. Crystals of andalusite, with strong pink to colourless pleochroism, are found, in one instance associated with a fibrous substance, (sillimanite (?)). Yellowish, pinitised crystals of cordierite are common. The groundmass has been recrystallised and is commonly coarsely microcrystalline.

(2). A porphyrite dyke intrudes the sediments near Toolangi, along the New Chum road. It resembles a hornblende-granite in hand specimen, and consists of crystals of quartz, pink and white felspars, and green biotite, resembling hornblende, set in a fine groundmass. A section No. (2364) shows that it is a coarsely porphyritic rock. The groundmass is microcrystalline, and small in quantity. The felspar phenocrysts vary from microcline with sharp cross hatching, to strongly zoned labrodorite, and andesine. Quartz is present as corroded phenocrysts, or in granophyric intergrowths, microcrystalline or coarser, with orthoclase. There are large flakes of brown biotite containing pleochroic haloes; and small mossy aggregates of tourmaline occur associated with sericitised felspars.

This second dyke is probably associated with the granodiorite, whereas the first is part of the quartz-biotite-dacite series.

6. Quartz-biotite-dacite.

This lies in a belt between the rhyolite and the quartz-dacite, and forms the Black Spur. It is well exposed in the roadside quarries from Fernshawe to the top of the Spur (3 miles from

Narbethong). At Carter's Gap it ends in almost precipitous slope of about 300 ft. descent, and abuts a narrow neck of quartz-dacite at the foot of the slope, appearing to overlie it. It is similar in character to the Middle Dacite of the Dandenong series (7).

It is a dark slaty-coloured rock, bluish on a fresh surface. Phenocrysts of quartz and white felspar, occasionally of quite large dimensions, are characteristic. Biotite and garnet are more prevalent than in the quartz-hypersthene-biotite-dacite. Pyrrhotite appears occasionally.

A typical section No. (2356), (Analysis No. V.), is from a quarry about 4½ miles from Narbethong, on the Black Spur road. The groundmass is glassy to cryptocrystalline, and appears to consist of quartz and orthoclase. Flow structure is not very evident. The larger phenocrysts are of quartz and plagioclase, all showing the effects of corrosion. The plagioclase consists of labradorite, and to a lesser extent andesine. In places the felspars show shearing, and strained polarisation. Zoning is eminent, and there is a tendency towards clotting. A coarse patch of ophitic character shows numerous small plagioclase and biotite crystals caught up in a large quartz phenocryst. Large ribbons of primary biotite are present, often flexed, and containing pleochroic haloes centred about zircons. Two small phenocrysts of hypersthene occur, edged with secondary biotite; and ghosts of hypersthene (?), replaced by chlorite, calcite and micaceous or serpentinous minerals, are seen. Two pink garnets are present, unshattered. They are rounded by corrosion, and bordered with chlorite (after biotite(?)), but preserve something of a rhomdodecahedral outline. One contains small inclusions of biotite, while the other is associated with pyrrhotite.

A specimen No. (2377), from a quarry just south of the 5-mile post on the Black Spur, carries a xenolith of rhyolite, and has been semi-propylitised. The dacite contains cubes of pyrite, and the felspar is extremely sericitised. The groundmass coarsens locally about the pyrite, having been recrystallised during the introduction of the sulphides. The xenolith is divided from the dacite by a microcrystalline layer, containing minute trigonal tourmalines(?). In No. (2376), from Fernshawe, coarse bands are found, apparently the last part of the base to consolidate, since crystals of quartz grow columnar fashion towards the centre from both glassy walls.

Near the Devil's Elbow, and along the main divide, patches of coarser rock are found, rich in garnets. Two sections Nos. (2378-2379), from the Devil's Elbow, show very large phenocrysts of quartz, felspar, and biotite, set in a microcrystalline groundmass of quartz and orthoclase. The felspars are basic labradorite and a little andesine. The phenocrysts are strongly corroded, and in places only fragments in optical continuity remain. The biotites are generally fresh. Corroded hypersthenes are occasionally present, with deep coronas of green biotite. The garnets are comparatively large, shattered, and associated with chloritised biotite.

These coarse patches may be local developments in the dacite, or may be recrystallised fragments of the quartz-hypersthene-biotite-dacite, regarding the latter as a chilled border phase of the original magma chamber.

Relation to the Quartz-hypersthene-biotite-dacite.

These two dacites are closely similar. A micrometric analysis shows:—

		Q.H.B.Dacite.		Q.B.Dacite.
Quartz	-	13·18	-	11·46
Hypersthene	-	6·24	-	1·63
Biotite	-	4·28	-	13·95
Felspars	-	28·92	-	27·04
Groundmass	-	48·00	-	45·65

The only marked difference is in the relative proportion of biotite to hypersthene; and as Mt. Monda is approached from the north-east, the amount of hypersthene in the quartz-hypersthene-biotite-dacite decreases and the biotite increases, until the rock becomes a quartz-biotite-dacite without any sharp junction being observed. The evidence suggests that the quartz-hypersthene-biotite-dacite is a chilled intrusive facies of the quartz-biotite-dacite.

7. Hypersthene-dacite.

This rock outcrops widely over the south-eastern part of the area. It is similar, both chemically and mineralogically, to the hypersthene-dacites of Macedon and the Dandenong Range series, and evidences several interesting reactions.

It is a light-coloured rock of an apparently fine, even texture, which masks its porphyritic character. The colour darkens locally where the groundmass is more glassy. It differs from the other types in the area by the entire absence of quartz phenocrysts, and the increased visibility of the biotite. The absence of garnets is characteristic.

Examination of a thin section from Mt. Juliet summit, No. (2330), (Analysis No. VIII.), shows that the rock consists of phenocrysts of labradorite and hypersthene, with smaller and less numerous crystals of ilmenite and biotite, set in a fine granulitic groundmass of quartz and orthoclase, with some biotite and ilmenite. Occasional coarse patches appear in the groundmass. The felspars form small but numerous phenocrysts. They are corroded, strongly zoned, and twinned (albite and Carlsbad laws), and show a general extinction angle of 25°, i.e. labradorite. Some andesine is also present, and small inclusions of a more basic plagioclase are common in the labrodorite. The hypersthene crystals are larger and show definite crystal boundaries, and a strong green to pink pleochroism. Ilmenite and apatite are commonly included, and felspars occasionally. Secondary biotite fringes many of the hypersthenes, and sometimes infills the cleavages. The biotite occurs in two forms: (1) a light brown, primary biotite, in flakes with well defined cleavage, often showing flexure as from flowage; (2) a darker secondary biotite, in small unorientated flakes, or aggregates of such, fringing hypersthenes and ilmenites, which originates from a reaction of the phenocrysts and the groundmass. Ilmenite is present as small crystals, also.

A specimen from Mt. Vinegar, No. (2375), contains a notable phenocryst of hypersthene in which all the cleavages are filled with biotite. In No. (2374), from Malleson's Lookout, the groundmass is unusually coarse and variable. Slower cooling than usual has permitted the hypersthene crystals to react strongly with the groundmass, and all stages of the reaction can be seen. Ilmenite is commonly included in the peripheral zones of the hypersthene; or occurs as the nucleus of the biotite aggregates, owing to the complete reaction of the including hypersthene; and the hypersthenes show a tendency to clot. One of the felspars in No. (2332) from the Badger Weir has the appearance of anorthoclase. It shows perfect cleavage, but no twinning, and slight zoning at the margin, where it is free from light patches. It is cut parallel to the (010) face. The extinction angle is 27° showing it to be basic labradorite. The light patches, giving the anorthoclase-like appearance, have a lower index of refraction, straight extinction, and show no twinning, so that they appear to be orthoclase. They are not inclusions since the cleavages are continuous through them. Dr. Summers has suggested the following explanation. It is known that plagioclase forms a solid solution with orthoclase, and that the solubility of the orthoclase decreases as the plagioclase becomes more basic. Probably the solid solution can hold less orthoclase when cold than when at a high temperature, so that on cooling the excess orthoclase has been thrown down, and has segregated into microscopic patches. Such "anorthoclases" are common, but sporadic in occurrence.

Section No. (2335) from Sunny Lodge represents a chilled border phase. The hypersthene crystals show narrow reaction zones of minute granules of a green mineral—probably chlorite after biotite. Zircons, with pleochroic haloes, idiomorphic ilmenite, and small felspars are included in the hypersthene. Secondary biotite occurs along the cleavages and cracks. The ilmenite shows a well developed reaction with the groundmass. Where it abuts the hypersthene or felspar, its fresh character is preserved, but where it comes into contact with the groundmass it loses its metallic lustre at that edge, and the immediately adjacent zone is coloured brown, owing to the formation of a narrow biotite corona. This secondary rim may be granular, but it often shows a columnar structure, the crystals of it growing normal to the edge of the ilmenite crystal (Microphotograph No. 5). Stringers or veins of pyrite are prevalent. They are later than the consolidation of the rock, filling cracks, and sometimes interposing between crystals and their reaction rims. The pyrite borders both felspar and hypersthene. Sometimes the veins follow the crystal boundaries; others continue straight across groundmass or crystal equally, following cleavage planes or cutting across them at will. No. (2373) from Wade's Lookout is a glassy rock, with coarse patches containing clots of tourmaline and secondary biotite. In No. (2334), from S.W. of Mt. Riddell pipe line the groundmass is very glassy. The hypersthenes have very narrow reaction rims, but the earlier formed ilmenites show very distinct coronas.

8. Granodiorite.

The only outcrop of granodiorite observed in the area occurs as a ridge between the Meyer's Creek road and Donnelley's Creek (Junner, p. 226 and map). It has a medium, holocrystalline texture, and consists of colourless quartz, greenish-white felspar, and green (chloritised) and black biotite. It is often much contaminated with clots of ferromagnesians, and with xenoliths. Garnet is commonly associated with these contaminated patches. The rock is very similar to the Macedon granodiorite. Superficially it resembles the No. 1 porphyrite dyke.

Xenoliths in the Granodiorite.

Numerous xenoliths were collected from the granodiorite at the Maroondah Aqueduct Tunnel dump, south of Donnelley's Weir. Many were as big as one foot or more in diameter. Typically they consist of a core of brown porphyritic rock, showing needles of felspar, and noticeably free from biotite, surrounded by an outer zone of fine-grained, dacitic appearance, consisting of quartz, biotite and calcite, and characteristic large green or white felspars.

The core, No. (2367), is a porphyritic rock with phenocrysts of plagioclase and hypersthene set in a coarsely trachytic groundmass made up equally of plagioclase, quartz, and granular pyroxenes, with subordinate orthoclase and secondary biotite flakes. There is no glass. Ilmenite grains are present. The plagioclase is labradorite with some anorthite. It shows the effects of strong corrosion or solution, and includes numerous granules of hypersthene. Some is schillered. Fresh hypersthene is uncommon as large crystals. It is generally corroded, and much altered to biotite. Smaller crystals of pyroxene are plentiful. The pyroxene varies in composition from hypersthene, through intermediate types, to augite. The extinction angle increases from 0° to 45° as the proportion of the lime molecule increases. Biotite is always subordinate and secondary as coronas, or flakes in the groundmass.

Section No. (2368) shows the junction of the core with the outer zone. The junction is irregular, but sharply defined. The hypersthenes are increasingly altered towards the outer zone, and form the "phenocrysts." The augite-pyroxene is limited to the groundmass. A remarkable "kelyphitic structure" is developed in an original aggregation of plagioclase and hypersthene phenocrysts (Microphotograph No. 6). It consists of a zone of plagioclase intergrown with needle-like crystals of a pale green ferromagnesian. The femic needles develop with their long axes normal to the edge of the hypersthene crystals. They form only where the hypersthene makes contact with the felspar; where it meets quartz or has been altered to biotite, they are absent. They are pleochroic (?) and have extinction angles of about 25°. They are doubly refractive, but the strength and nature of the double refraction are indeterminable. They seem to be similar to the augitic pyroxene of the groundmass. The felspar associated with the needles has a lower refractive index than the felspar a little removed from the intergrowth. It appears that the lime-rich felspar has reacted with the hypersthene to form a lime-magnesia pyroxene and a more sodic felspar. This intergrowth differs from the "symplektites" recorded by Sederholm (13, pp. 41-46) in that there the intergrown felspar is more calcic than the unaffected felspar. The plagioclase is well schillered.

The outer zone is of a distinctly different character. The "groundmass" consists of a very coarse intergrowth of quartz and felspar, together with ilmenite and biotite. The felspar is entirely altered to calcite and sericite. The large felspar phenocrysts still show albite twinning, and zoning, but have been considerably altered. They are labradorites. There is no hypersthene. The biotite shows bleaching and chloritisation, and the numerous inclusions of ilmenite contained by it suggest that it has replaced the hypersthene in situ. Pyrrhotite is present.

No. (2371) shows the junction of the outer zone with the granodiorite. The groundmass is increasingly coarse and intergrown. The junction is fairly definite, but irregular; and patches of the xenolith are seen within the granodiorite, suggesting assimilation by the latter. The felspars are totally decomposed to calcite and sericite.

The original rock has been a plagioclase-hypersthene-porphyrite, and was probably the hypersthene-dacite. Although this latter rock does not outcrop close at hand, a tremendous amount of erosion has taken place at this locality, and it is quite conceivable that the hypersthene-dacite might have formed the cover into which the granodiorite stoped its way, and that all trace of such a cover has now been removed.

Basic Clots in the Granodiorite.

The granodiorite is commonly contaminated with clots of ferromagnesians. These generally consist of aggregates of biotite, probably remnants from the assimilation of larger xenoliths. Garnet is commonly associated with them, a point of comparison with the granodiorite now outcropping in the tennis court at

Clyde (Braemar House), Macedon. One of these clots, No. (2398), was examined. It contains several crystals of hypersthene associated with a large pink garnet. The garnet appears to have developed from the hypersthene. The hypersthenes mark the centre of the clot; away from this nucleus, the section closely resembles the outer zone of the xenolith described above. Nearly all the hypersthenes show partial alteration to biotite; and they are embedded in a "holocrystalline" intergrowth of quartz and sodic plagioclases (albite and andesine). No orthoclase can be discerned; it is probably in solid solution in the sodic plagioclase.

Further reference to these clots and xenoliths will be made when the hypersthene-biotite reaction relation is dealt with (p. 72).

TABLE OF ANALYSES.

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.
SiO_2	74·39	74·72	67·85	68·73	65·80	65·83	66·17	61·43	63·27	62·54	64·04
Al_2O_3	14·28	13·05	14·65	13·16	16·87	14·89	14·75	15·95	16·50	16·66	13·58
Fe_2O_3	0·52	0·52	0·64	1·17	3·97	0·73	0·30	1·21	0·68	1·04	0·80
FeO	1·09	1·42	3·40	2·74	1·08	4·63	4·73	5·64	5·10	5·54	4·47
MgO	0·27	0·41	1·39	1·22	1·76	1·88	1·71	2·83	2·48	2·68	2·64
CaO	0·24	0·66	3·05	3·03	3·16	3·13	3·31	4·98	4·18	3·92	3·52
Na_2O	2·78	3·62	2·12	2·30	3·45	2·12	2·45	2·96	2·36	2·66	2·42
K_2O	5·33	4·31	3·19	2·59	2·54	2·32	3·53	2·26	2·68	2·47	2·80
H_2O+	0·22	0·61	2·25	1·86	1·05	2·41	0·66	0·81	0·52	0·46	2·25
H_2O-	0·56	0·13	0·15	0·09	—	0·17	0·01	0·12	0·09	0·17	0·38
CO_2	—	0·08	—	1·50	—	0·47	n.d.	—	—	—	—
TiO_2	0·29	0·16	0·63	0·50	—	0·89	0·97	1·13	1·30	1·20	0·80
P_2O_5	Tr.	0·38	0·32	0·17	—	0·16	1·15	0·53	0·15	0·20	0·18
MnO_2	n.d.	—	—	0·09	Tr.	0·10	0·20	—	0·03	Tr.	Tr.
Li_2O	n.d.	n.d.	n.d.	Tr.	—	—	—	n.d.	Tr.	Tr.	Tr.
S	—	—	—	0·18	—	0·10	0·13	—	0·16	—	—
Cl	n.d.	Tr.	—	Tr.	—	Tr.	0·04	Tr.	—	Tr.	Tr.
Less O_2	—	—	—	0·07	—	0·04	0·06	—	0·08	—	—
Total	99·97	100·07	99·64	99·47*	99·68	99·93*	100·05	99·85	99·50	99·54	99·88
SP. GR.	2·49	—	—	2·69	2·71	2·70	2·71	—	2·76	2·78	2·72

* Not complete.

TABLE OF NORMS.

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.
Quartz	36·20	35·58	33·36	35·52	26·72	32·10	28·14	18·66	23·91	22·08	25·20
Orthoclase	31·69	25·58	18·90	15·57	15·01	13·90	21·13	13·34	16·12	12·79	16·68
Albite	23·63	30·39	18·82	19·39	29·34	18·82	20·96	25·15	19·91	19·39	20·44
Anorthite	1·11	0·56	13·62	14·18	15·67	14·73	9·73	21·41	20·02	21·68	16·68
Corundum	3·47	2·24	2·75	1·33	2·75	5·50	3·16	0·80	2·35	2·45	2·14
Hypersthene	1·76	2·85	8·00	6·30	5·00	11·07	9·60	14·25	12·47	17·37	12·80
Magnetite	0·70	0·70	0·93	1·62	3·48	1·16	0·42	1·86	1·16	0·93	1·16
Ilmenite	0·61	0·30	1·21	0·91	—	1·52	1·82	2·83	2·43	2·28	1·52
Apatite	—	0·93	0·62	0·31	—	0·36	2·50	1·24	0·31	0·31	0·34
Pyrite	—	—	—	—	—	0·31	0·48	—	0·30	—	—

Normative Classification.

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.
Class	1 -	1 -	1 -	1 -	1 -	2 -	2 -	2 -	2 -	2 -	2
Order	3 -	3 -	3 -	3 -	4 -	3 -	4/3 -	4 -	4 -	4 -	4
Rang.	1 -	1 -	3 -	3 -	3 -	2 -	2 -	3 -	3 -	3 -	3
Sub-rang.	3 -	3 -	3 -	3 -	4 -	3 -	3 -	4/3 -	3 -	3 -	3

I. Rhyolite; Archer's Lookout, Narbethong. (N. R. Junner) (6).
II. Rhyolite; Blue Hills, Taggerty (E. S. Hills) (4).
III. Quartz Dacite; Maroondah Dam Quarry (Evans—Mines Department).
IV. Lower Dacite (Morris), Allot. 30C. Railway Cutting, Lilydale-Evelyn (Mines Department) (7).
V. Quartz-biotite-dacite; Black Spur, Narbethong (Stone) (6).
VI. Middle Dacite (Morris); Dandenong Ra., N.E. flank (Mines Department) (7).
VII. Quartz-hypersthene-biotite Dacite; Bladins Quarry, Black Spur, Narbethong (A. B. Edwards).
VIII. Hypersthene Dacite; Mt. Juliet, near Black Spur (Evans—Mines Department).
IX. Upper Dacite (Hypersthene); Upwey (Richards) (8).
X. Dacite (Hypersthene); Braemar House, Macedon.
XI. Granodiorite; Braemar House, Macedon (11).

Evidence of Consanguineity.

There can be but little doubt that the rocks of the area constitute a petrographic province, and are consanguineous. All the extrusive types are porphyritic, and in every case the phenocrysts show marked corrosion, probably resulting from resolution on release of pressure. All possess acid characteristics. Apatite is relatively abundant, and zircons characterise the biotite. Cordierites have been discovered in all the extrusives; and pink garnets typify the series. The felspars show a gradational relation:—

1. Rhyolite—orthoclase (max.); microperthite; albite.
2. Quartz-dacite—orthoclase; andesine (max.); labradorite.
3. Quartz-biotite-dacite—orthoclase (rare); andesine; labradorite (max.); anorthite.
4. Hypersthene-dacite—andesine; labradorite (max.); anorthite.

The rhombic pyroxene, hypersthene, is characteristic of the series, being replaceable by biotite. The quartz phenocrysts decrease in quantity from the rhyolite, through the quartz-dacite, and the quartz-biotite-dacite types, and disappear before reaching the hypersthene-dacite.

The variation diagram (fig. 3) plotted from analyses (calculated to 100% without water) gives a fair curve, approaching that derived from similar rocks in other localities.

Comparison of the ideal, or average variation curves (drawn as close to all the fixed points as possible, and hence representing variation or differentiation under ideal conditions), with that

VARIATION DIAGRAM

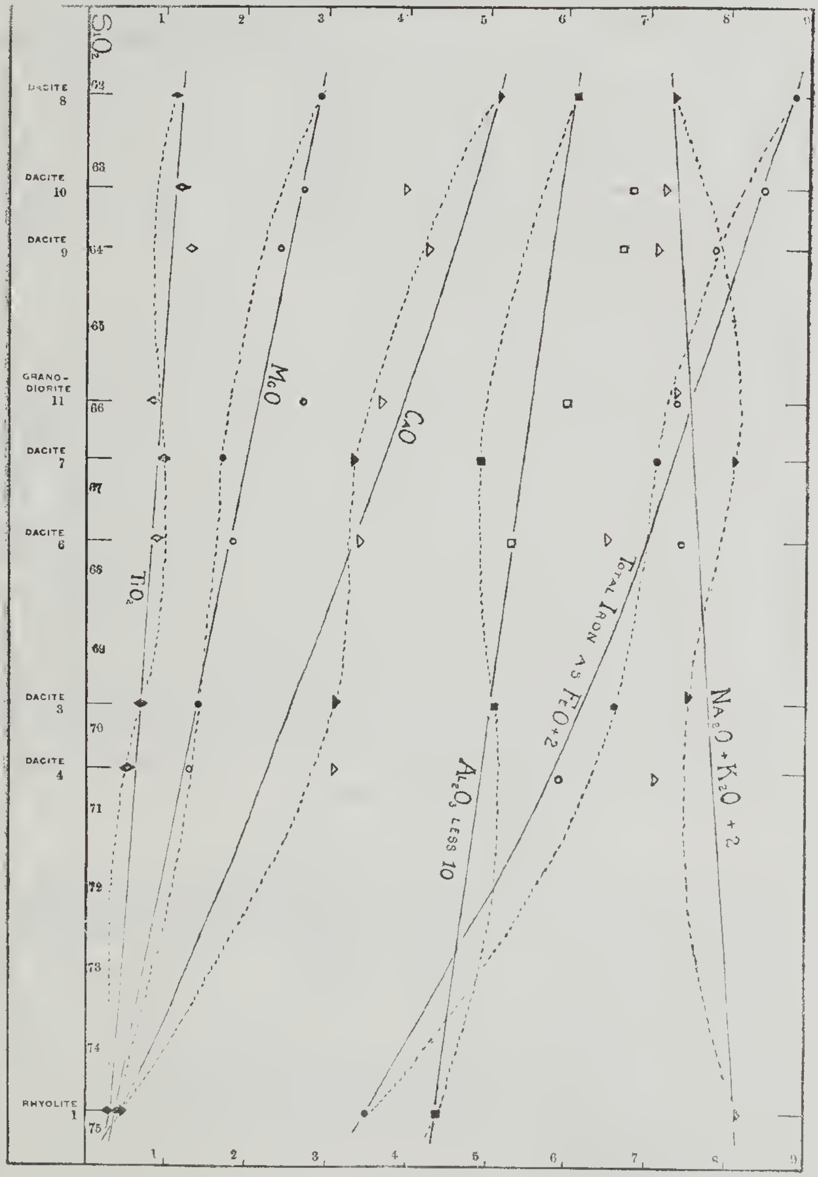

FIG. 3

drawn through the fixed points, and hence representing approximately the actual variation in composition, demonstrates a curious difference between the two curves for any given constituent. In all cases this variation is marked by a compound flexure of the "actual" variation curve, representing an excess or deficit of the constituent considered in the quartz-biotite-dacite series, with a corresponding deficit or excess of the same constituent in the quartz-dacite. Moreover, related constituents—i.e., those occurring together in the molecular groupings, exhibit similar relations —if one member of the group is in excess, so are all the others. Thus the quartz-hypersthene-biotite-dacite, with regard to its ideal composition, is (1) poorer in: Al_2O_3; Iron as FeO; MgO; CaO. (2) richer in: Na_2O; K_2O; TiO_2; P_2O_5. This suggests that minerals containing alumina, iron, magnesia and lime have sunk in greater degree than required for normal differentiation. The crystals most likely to sink would be those formed in the early stages of crystallisation—the basic lime-rich plagioclases, and the magnesia-iron-rich pyroxenes. Inclusions of basic felspars, in less basic felspars, are very common in the "underlying" hypersthene-dacite. They could have originated in the hypersthene-dacite, but this would require a standstill in the crystallisation, which is not probable. Again the quartz-dacite, with regard to its ideal composition, is (1) richer in: Al_2O_3; FeO (total iron); MgO; CaO; (2) poorer in: Na_2O; K_2O; TiO_2; and P_2O_5. If this rock were of less acid character all these constituents would approach the ideal curve. Taken in conjunction with the very numerous, large quartz crystals in the rock, this suggests an enrichment from the rhyolite in silica-rich crystals,—quartz, and possibly orthoclase. The excess of alumina, iron, lime and magnesia could be accounted for by a sinking of femic crystals from the rhyolite (as evidenced by their almost complete absence in this latter). Cordierite, which is so prevalent in the rhyolite as to suggest a magmatic origin, is also common in this dacite. It might have entered with the quartz.

Sequence of Extrusion.

Insufficient evidence is available to enable a complete sequence of extrusion to be constructed. Indirect evidence strongly supports the order which is suggested below.

6. Granodiorite.
5. Hypersthene-dacite.
4. Quartz-biotite-dacite series { Q.B. Dacite. / Q.H.B. Dacite. / Porphyrite dyke. }
3. Quartz-dacite.
2. Rhyolite.
1. Andesite.

The andesite is pre-quartz-biotite-dacite series, since fragments of it are included in the latter. Along the Mt. Monda track it is apparent that the quartz-hypersthene-biotite-dacite in breaking through the rhyolite has brought the andesite fragments with it from below. They must therefore be regarded as pre-rhyolite.

In the Marysville-Taggerty district, Hills (5) has placed the andesite as earlier (?) than the rhyolite; while Junner (6) has made them post-rhyolite (?).

The rhyolite precedes the quartz-biotite-dacite series, since both the porphyrite dyke (No. 1) and the quartz-hypersthene-biotite-dacite are intrusive into it, and the quartz-biotite-dacite contains xenoliths of rhyolite. It is also older than the quartz-dacite since pebbles of rhyolite are found in a volcanic agglomerate formed by the quartz-dacite; and since this dacite is overlain by the hypersthene-dacite, the relative age of the rhyolite is fixed.

Direct evidence of the relative superposition of the quartz-dacite and the quartz-biotite-dacite series is lacking, but field relations and indirect evidence point to the quartz-dacite as the earlier. At the volcanic centre in the quartz-dacite on the western side of the Maroondah Dam no quartz-biotite-dacite fragments have been found in the pyroclastics, although sedimentary breccia and lapilli abound. This negative evidence, together with the fact that at the foot of this steep volcanic hill the two dacites are in close proximity, suggests that the quartz-biotite-dacite abuts against the quartz-dacite, or rests upon it. This view is supported by the fact that bores about the dam site show a thickness of over 100 ft. of quartz-dacite below the present water level, without passing into any other type of rock, whereas the junction of the two dacites is above the water level.

At Carter's Gap and below Mt. Juliet, two interpretations of the sequence are possible; the more probable of the two places the quartz-biotite-dacite on top of the quartz-dacite; and this view is supported by the variation diagram.

The quartz-dacite closely resembles the Lower Dacite of the Dandenong series, while the quartz-biotite-dacite compares equally well with the Middle Dacite of that series.

The hypersthene-dacite overlies the quartz-dacite at Carter's Gap, near the 1000 ft. contour on the Mt. Juliet track, and again on slopes below Mt. Riddell. Its relation to the quartz-biotite-dacite is indefinite, since the two types are not in contact. It outcrops over the higher parts of the ranges, and its more basic character suggests that it is the latest member of the extrusives. It closely resembles the Upper Dacite of the Dandenong Range series, which is the uppermost member of three types, the lower two of which agree closely with the quartz-dacite and the quartz-biotite-dacite.

Finally, the granodiorite intrudes into the Silurian sediments, converting them locally into hornfels, and probably causing the pyritisation and carbonisation of the rhyolite blocks found in the dump material at the Echo Tunnel. Large xenoliths of, apparently, recrystallised hypersthene-dacite are very commonly included in the granodiorite at the tunnel south of Donnelley's

Weir. Small quartz veins are found penetrating the hypersthene-dacite at Mt. Juliet; and the dacites in contact with the granodiorite in the neighbouring areas of Nyora and Warburton have been rendered schistose. Elsewhere, at Selby (9, 10), and Macedon (11), the granodiorite is post-hypersthene-dacite.

Correlation with Related Areas.

The following table of rocks in related areas shows that the rocks of the Black Spur Area disclose an important link between the definitely Upper Devonian igneous rocks of Blue Hills (Taggerty) (4, 5) and the Devonian igneous rocks of other areas.

BLUE HILLS (Taggerty) (4, 5)	MARYSVILLE (5)	BLACK SPUR (Healesville)	LILYDALE (Mt. Dandenong) (7)	MACEDON (11)
	8. Granodiorite	6. Granodiorite	6. Granodiorite	2. Granodiorite
		5. Hypersthene-Dacite	5. Hypersthene-Dacite	1. Hypersthene-Dacite
	7. Dacite			
		4. Quartz-Biotite-Dacite series	4. Middle-Dacite	
		3. Quartz-Dacite	3. Lower Dacite	
			2. Upper Toscanite	
			1. Lower Toscanite	
5. Rhyolite (a)	6. Rhyolite (a)	2. Rhyolite		
4. Rhyolite (b)	5. Rhyolite (b)			
	4. Andesite (?)	1. Andesite (?)		
3. Melaphyre (Basalt)	3. Melaphyre (Basalt)			
2. Tuffs (and foss. seds.)	2. Tuffs			
1. Basal-Congl.	1. Basal-Congl.			
		UNCONFORMITY		
SILURIAN	SILURIAN	SILURIAN	SILURIAN	ORDIVICIAN

Magmatic Differentiation.

Following Bowen (1) we may postulate a parental magma of basaltic character. This is in agreement with the occurrence of basalts and melaphyres described by Hills at Taggerty (4) and at Marysville (5) as the basal members of this igneous series.

Differentiation of this magma by sinking and zoning of crystals gave rise to an upper layer of andesitic composition. When this had partially crystallised, extrusion occurred, probably at numerous points but without producing any widespread flow.

The magma body, continuing its course of differentiation, ultimately reached a state of more or less stratification in its upper layers corresponding to:—

Rhyolite
Quartz-dacite
Quartz-biotite-dacite
Hypersthene-dacite

representing the increasingly basic nature of the rocks grading downwards. This stratification is suggested by the gradational relation between the extrusive types, and their acid to basic order of extrusion. Crystallisation was well advanced by this stage.

An explosive extrusion of the upper layer of rhyolite occurred, giving rise to tuffs and breccias. The violence died down, and viscosity increased with loss of mineralisers, so that the later rhyolite welled up into a massive ridge. There were probably several centres of extrusion.

With the consolidation of the rhyolite, the rents in the magma chamber closed, and the gases again accumulated, to lesser extent than previously, in the upper layers. A second explosive extrusion, of quartz-dacite, followed, with less violence. It was accompanied by an outpouring of lava, fluid despite its partially crystalline state, as shown by its wide outcrop and glassy groundmass.

The magma chamber resealed, and stoping up, the magma repeated its attempt to break the cover. Differential flotation of the rhyolite gave rise to weakness or fissures, which was followed by intrusion of dykes and sills of quartz-hypersthene-biotite-dacite into these weakened areas and along junctions of rhyolite and Silurian sediments. Simultaneously a breaking of the cover allowed the main part of the magma to overflow as quartz-biotite-dacite.

Consolidation blocked the channels of extrusion, and when the rising magma burst through again, it took a fresh course through the Silurian, as evidenced by the hornfels in the hypersthene-dacite, rather than through the now thickened igneous cover. The lava poured out was more viscous than the earlier lavas, as evidenced by its crystalline groundmass; or it cooled more slowly. It was a much larger flow than those preceding it, being extruded, probably, through fissures produced by a partial collapse of the roof of the magma chamber.

When this extrusion ceased the remaining magma may have been relatively more basic, or it may have been of much the same composition, only part of the "layer" having been extruded. A second period of differentiation and stoping set in, and the magma commenced to stope up through the thick igneous cover that sealed it. Its energy failed before it could complete its task, but it came close to the surface. Erosion has uncovered patches of the granodiorite, as which it consolidated, about the margins of the igneous rocks.

The Reaction Relation—Hypersthene to Biotite.

Examination of the hypersthene-dacites of Victoria has demonstrated the existence of a relation between hypersthene and biotite. It was first observed by Skeats (9) and Richards (8) at Selby, in the metamorphosed zone of the dacite, and later by Skeats and Summers (11) at Macedon, under similar conditions. In both areas a hypersthene-dacite is intruded by granodiorite. In the metamorphic aureole, as the granitic contact is approached, the hypersthene is increasingly replaced by biotite, until at the contact, biotite only is found. The production of biotite was accompanied in both cases by the deposition of quartz.

Richards (8) separated and analysed the hypersthene and biotite from Selby. He found that an addition of an orthoclase molecule to the analysed hypersthene molecule would give the biotite molecule, as determined chemically, and excess quartz. This agreed with the petrological facts. He suggested the following equation:—

Hypersthene + Orthoclase + Water = Biotite + Quartz.

Summers (12) and Hatch (3, p. 190) view this reaction as of more than metamorphic significance, and consider that it is related to the ferromagnesian discontinuous reaction series of Bowen (1). The hypersthene is thought to crystallise out at a high temperature, become unstable with cooling, and to react with the orthoclase and water molecules of the fluid magma to form biotite and quartz.

Summers (12) found the body of the Macedon dacite to be practically free from biotite. He inferred "that the temperature of the magma at the time of extrusion was rather higher than the reaction temperature between hypersthene and alkali felspar, but that in parts the cooling after the extrusion was sufficiently slow for some reaction to take place." He described quartz-porphyrites from the Strathbogie Ranges and the Tolmie Highlands as containing biotite and rare examples of corroded hypersthenes, and considered that these rocks were examples in which the temperature at which crystallisation had ceased had been sufficiently low for the reaction between hypersthene and felspar to go almost to completion.

The dacites of the present area contribute a considerable amount of evidence in support of a reaction of this character. They reveal: (1) the incipient stages of the reaction, in the hypersthene-dacite; (2) the reaction well under way, in the quartz-hypersthene-biotite-dacite; (3) the final stages of the reaction, in the quartz-biotite-dacite; (4) an abnormal retention of hypersthene in xenoliths in the granodiorite; (5) an association throughout the series of hypersthene and biotite, without any trace of an intermediary amphibole. It is necessary then, to show why the hypersthene should form biotite directly, instead of following the reaction series of Bowen (1, p. 60); and to investigate the conditions controlling the reaction.

If the cooling were intratelluric throughout, as in the granodiorite, a rock should result, containing not hypersthene, but hornblende and biotite. This is illustrated by the hornblende-granodiorite at Selby. Temperature, however, while an essential factor in the controlling of the action, is not of itself sufficient. This reaction is not the spontaneous breaking down of a complex form to simpler forms, resulting from a sudden instability, but a chemical double decomposition between hypersthene and orthoclase, so that an "environment" factor must be considered. The effect of cooling is to render the hypersthene "potentially reactive"; but if it is shielded in some way from the other reactants no biotite will form. This is clearly demonstrated by the presence of fresh, primary hypersthene in the xenoliths and clots in the granodiorite (p. 64). The original rocks, of which these are the remnants, must have been raised to the temperature of the granodiorite and then have cooled with it intratellurically, so that the hypersthene would have been rendered "potentially reactive"; and if, as supposed, the original rock was the hypersthene-dacite, the conditions would appear ideal for the transformation of the hypersthene into biotite. It has been shown however, that the inclusions were completely recrystallised, except for the more basic phenocrysts, and that in the recrystallisation, lime from the felspars entered the ferromagnesians, and left the plagioclase soda-rich (Nos. 2368; 2398). Orthoclase seems to have disappeared from the recrystallised rock. Knowing that the albite-plagioclases can hold a greater amount of orthoclase in solid solution than the original basic plagioclases could, it seems probable that the orthoclase has formed such a solid solution; and that the hypersthene has thus been protected.

In the normal hypersthene-dacite such shielding factors are absent, and the temperature is the responsible factor. Extrusion of the lava at the hypersthene-labrodorite stage of crystallisation would occasion a sudden and very rapid cooling, which slackened in rate as the lava approached consolidation, after the manner of the cooling curve shown (fig. 4). The cooling in the amphibole range would be too rapid to permit hornblende to develop, and although slowing down in the biotite range, the lava would be too close to consolidation for more than an incipient reaction to take place. Variation in the rate of solidification, as marked by glassy or microcrystalline groundmasses, is accompanied by the development of narrow or deep reaction coronas of biotite, corresponding to the rapid or (relatively) slow solidification.

In the quartz-biotite-dacite and the quartz-hypersthene-biotite-dacite, the composition is about 4.5% richer in SiO_2 and about 5% poorer in ferromagnesians than that of the hypersthene-dacite, i.e., there is a large relative increase in free "quartz." When these magmas reached the temperature at which they were intruded, this extra silica had crystallised as quartz, and since in both these rocks there is still hypersthene, varying markedly in amount with the manner in which the two varieties cooled, we can safely consider the reaction as commencing at a temperature below the inversion temperature of tridymite-quartz, 870°C. In these more acid rocks the consolidation tem-

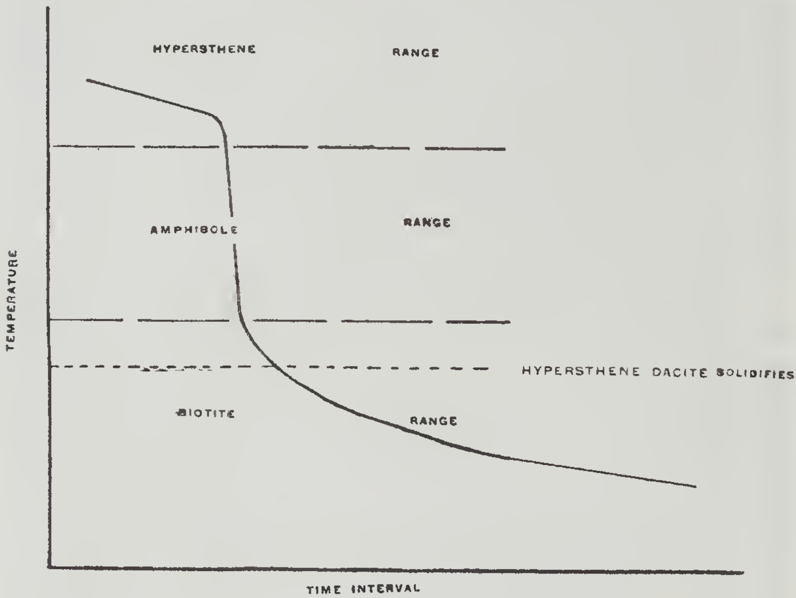

Fig. 4

perature is probably a little lower than for the hypersthene-dacite, and there would be a little less initial hypersthene, both of which factors would contribute to a more complete reaction.

A lower limit to the "stability" of the hypersthene is determined by the temperature of consolidation of normal granitic magmas, viz., 500°C. The temperature at which hypersthene becomes "potentially reactive" is probably in the neighbourhood of 650°C.-700°C. This does not mean that hypersthene cannot continue to be present below this temperature; but only that it will react if allowed to by its environment.

The metamorphic reaction first observed, represents a special case of this reaction. In the metamorphic zones described, the hypersthene-dacite was extruded, and quenched before the hypersthene could react in the normal way, i.e., following the reaction series. An incipient hypersthene to biotite reaction occurred with consolidation. The intrusion of granodiorite reheated the rocks to a temperature below the temperature of "stability" for hypersthene. It also increased the molecular activity of the minerals, giving their molecules opportunity or tendency to stabilise at the new temperature; and accordingly the hypersthene reacted to form biotite in proportion to its infused energy, which increased in the direction of the contact.

It is postulated that this reaction of hypersthene with orthoclase and water to form biotite and quartz is the natural path of the ferromagnesian discontinuous reaction series, when the hypersthene fails to react normally from some external cause, viz., extrusion and the rapid cooling resulting. The reaction is a double decomposition, so that environment is of equal importance with temperature.

The existence of primary charnockites (hypersthene-granites) and biotite-gabbros might be explained by this "environment" factor. Thus it is found very generally that charnockites, particularly the intermediate types, have dominant soda-felspars; and that although they contain abundant potash, it rarely appears as orthoclase, but enters into solid solution with the soda-felspar, and is therefore not available to react with the pyroxene. With gabbros the dominant felspars are anorthitic, so that any potash present is insoluble, and will so be free to attack the pyroxene.

Ilmenite to Biotite Reaction.

It was shown by Skeats (10) and Richards (8) at Selby that as the result of metamorphism, ilmenite reacted to form biotite. Richards showed from his analyses that the addition of orthoclase to ilmenite will give a biotite very low in magnesia, and very rich in ferrous oxide. Such a biotite would possess optical properties similar to the biotite actually observed replacing the ilmenite.

In the rocks here described, it has been found that this reaction of ilmenite with orthoclase or other molecules, to form a secondary biotite, is a pyrogenetic change rather than specially characteristic of a metamorphic zone. The microscopical evidence of the change has been described (p. 62, No. 2335). The reaction commences earlier than the similar reaction of hypersthene, and seems to have the effect of initiating the hypersthene-biotite reaction, if the ilmenite is included in the hypersthene, and to act as a catalyst once the action is started.

The microphotograph No. 5 shows a typical example of a biotite corona about an ilmenite crystal which has reacted with the groundmass.

Sederholm (13) describes a reaction between ilmenite and plagioclase to give biotite in similar growths. He summarises the work of several previous authors on the subject. This ilmenite-plagioclase reaction is described as general in gabbros and dolerites. Richards has shown that there is about 14.5% plagioclase in the groundmass of the hypersthene-dacite, so that the ilmenite could as easily react with this as with the orthoclase.

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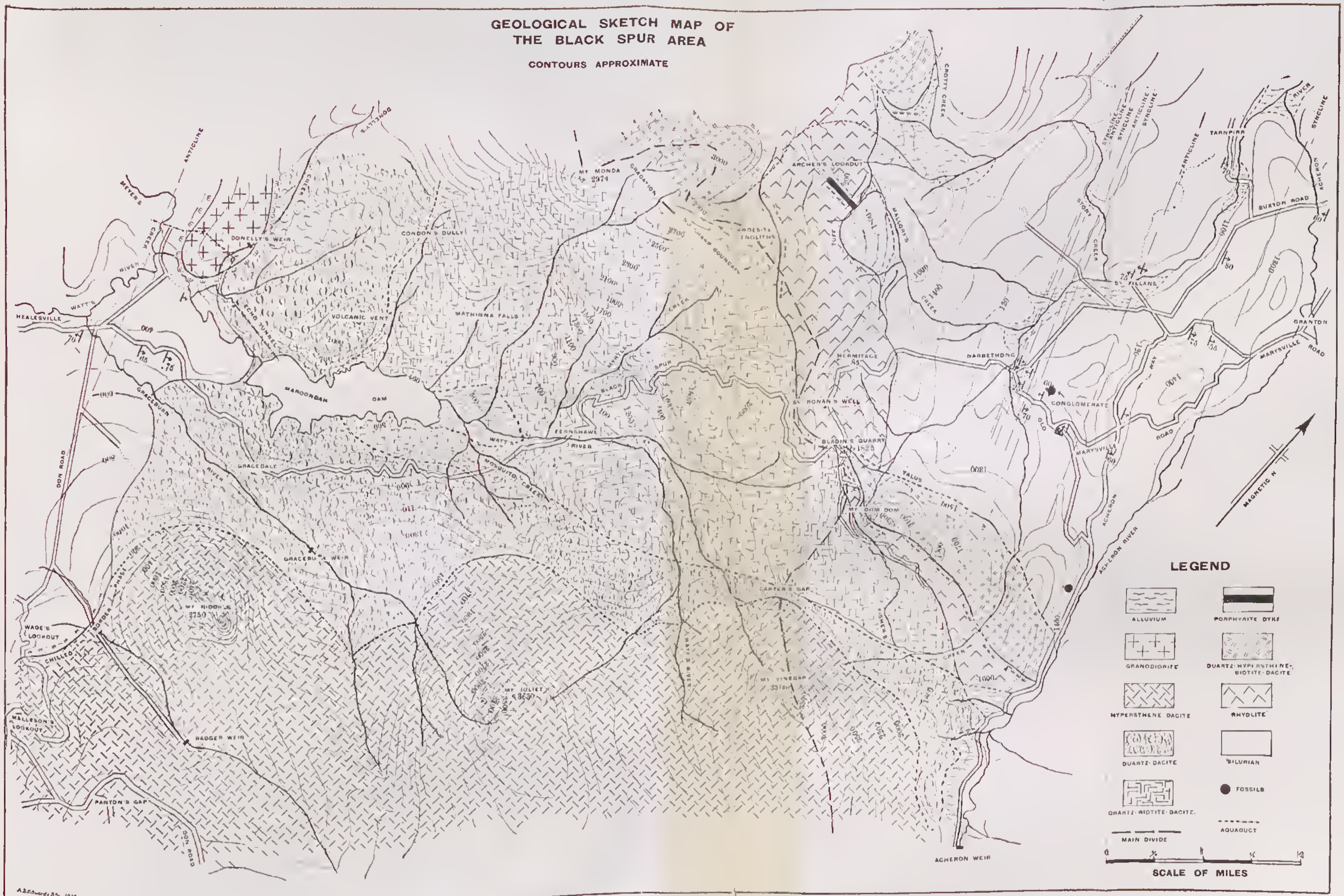
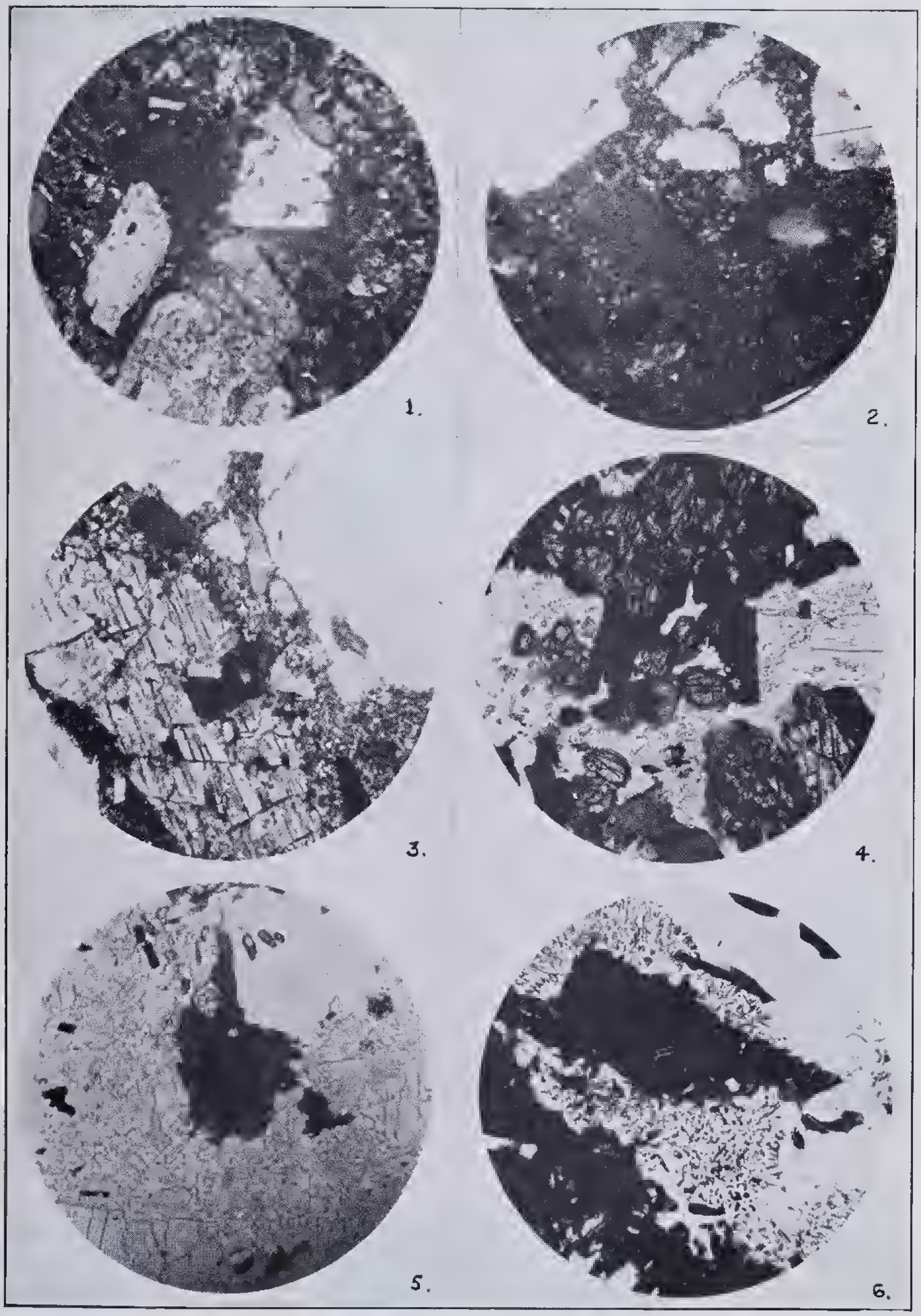
Explanation of Plate VIII.

1. Quartz-dacite. Showing typical corroded quartz and sericitised felspar.
2. Quartz-biotite-dacite.
3. Quartz-hypersthene-biotite-dacite. Shows quartz (right-top), hypersthene (central) reacting with orthoclase (lower left), the junction being marked by secondary biotite.
4. Intergrowth of hypersthene (light) and biotite (black) in the hypersthene-dacite.
5. Corona of secondary biotite surrounding ilmenite.
6. Kelyphitic intergrowth round hypersthene in xenolith in the granodiorite. The hypersthene is dark with light patches of secondary biotite along the edge.


GEOLOGICAL SKETCH MAP OF
THE BLACK SPUR AREA
CONTOURS APPROXIMATE
LEGEND
ALLUVIUM
PORPHYRITE DYKE
GRANODIORITE
HYPERSTHENE DACITE
RHYOLITE
QUARTZ-DACITE
SILURIAN
FOSSILS
AQUADUCT
MAIN DIVIDE
SCALE OF MILES
HEALESVILLE
MAROONDAH DAM
VOLCANIC VENT
CONGLOMERATE
MAGNETIC N
ACHERON WEIR
ACHERON RIVER
MARYSVILLE
NARBETHONG
ST FILLANS
BUXTON ROAD
ARCHER'S LOOKOUT
ST RONAN'S WELL
BLADIN'S QUARRY
MT DOM DOM
CARTER'S GAP
BADGER WEIR
GRACEBURN WEIR
GRACEDALE
FERNSHAWE
WATTS RIVER
WATHINNA FALLS
CONDON'S GULLY
DONELLY'S WEIR
WADE'S LOOKOUT
MALLESON'S LOOKOUT
PANTON'S GAP
MT MONDA
MT RIDDELL
MT JULIET
MT VINEGAR
HERMITAGE
TALUS
GRANTON
MARYSVILLE ROAD
DON ROAD
ANTICLINE
SYNCLINE



(J. S. Mann, Photos)

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Art. VI.—*The Readvancement of the Vegetation over the Mined Areas of Bendigo.*

By LEONARD A. THOMAS, M.Sc.
(Senior Demonstrator in Botany in the University of Melbourne.)

(With Plates IX. and X.)

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Introduction.

The Bendigo mining field is situated in an area of regularly folded sedimentary rocks of Ordovician age, consisting almost exclusively of sandstones and shales. River gravels of ? Pliocene age occur as hills in one part of the area and Recent alluvium is extensive in many of the valleys. The area is of rather mature topography, the streams are small and the valleys wide. Except for occasional periods of a few days throughout the year, the streams either are dry or consist of a series of pools.

The vegetation consists of a sclerophyllous *Eucalyptus* forest with an abundance of shrubs of various sizes which exhibit xerophilous characters.

Extensive mining operations were carried out in the district up to about sixteen years ago, with the result that the original vegetation has been to a large extent destroyed. It was therefore decided to inquire into the nature of the vegetation that has since invaded the mining field, and to compare it with that of the untouched forests.

I am indebted to Dr. A. H. K. Petrie for his helpful criticism and his untiring interest in this work, and to the late Mr. H. B. Williamson, F.L.S., for the identification of many of the plants.

The Habitat Factors.

A. Climate.

Bendigo is situated 101 miles by rail from the seaboard and has an elevation of 758 feet above sea level. The average annual precipitation over a period of 66 years (1863-1929) is 21·16 inches, and the average temperature of the air over a period of 62 years (1859-1921) is 58·7°F. The mean monthly rainfall and the temperature of the air during these periods are plotted in Fig. 1. It will be seen that, in general, the lowest rainfall periods correspond to the periods of highest temperature and vice versa. Thus the plants receive least water during the time of highest temperatures and with this fact may be associated the presence of many xerophytic types among the vegetation.

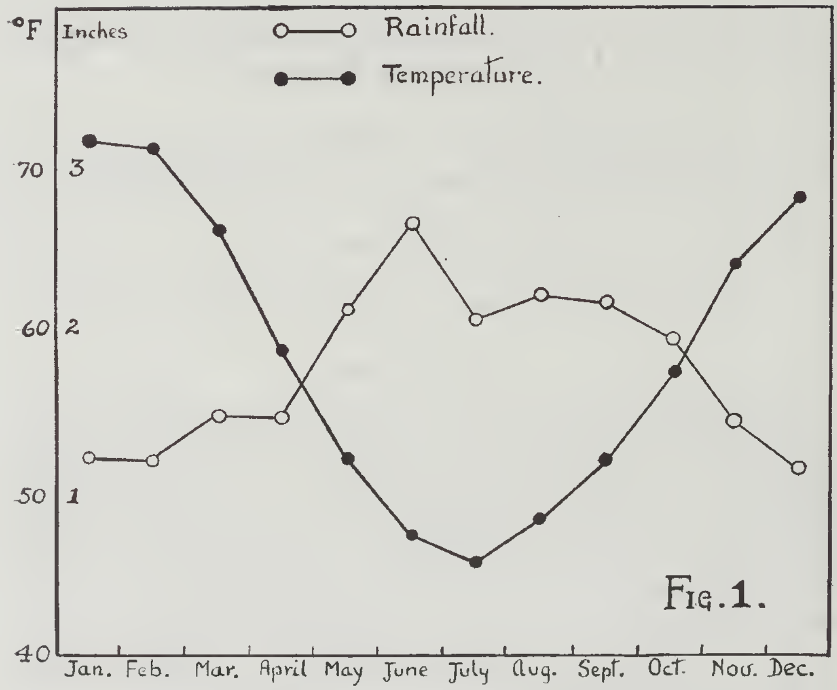

Fig. 1.—Average monthly temperatures determined over a period of 62 years (1859-1921), and average monthly rainfall over a period of 66 years (1863-1929).

The reliability of the rainfall moreover is variable, owing to the fact that droughts are not unknown in the area, and the irregular occurrence of these dry periods cannot be without influence on the type of vegetation that occupies the area.

B. Soil.

The soil types fall into two main groups, namely those formed by the weathering of the original rocks, and those formed by mining operations. These are briefly described below.

(a) Soil formed by the weathering of the original rocks.

The weathering of the Ordovician sedimentary rocks yields varying types of soil. The shales, which contain a fair percentage of iron pyrites, yield a stiff red clay: the sandstones, which unweathered are dark blue-grey, dense rocks, yield a poor hungry soil only a few inches deep. Outcrops of iron-cemented sandstone occur on many hilltops and in such rocky places as these, as we shall see later, *Eucalyptus sideroxylon* finds its home. Intermediate soil types occur where shales and sandstones are closely associated.

Alluvium in the valleys varies from gravelly shingle to yellow loam. The river gravels of ? Pliocene age consist mainly of rounded quartz pebbles set in a matrix of clayey material, forming a poor soil. In parts this is very porous, and in other parts swampy conditions prevail. Bands of iron-cemented clay form barriers impervious to water, and if these bands occur at or near the surface, swampy conditions arise.

(*b*) *Soil formed by mining operations.*

Deep quartz-mining operations have been responsible for the accumulation of "mullock heaps" and "sludge dumps." "Mullock" is the unwanted material mined along with the quartz. From deep workings it comes to the surface as large pieces of unweathered rock and is deposited in heaps; shallow workings provide partially or completely weathered material, and the debris from such workings dots the area. "Sludge dumps" represent the quartz and country rock which has been crushed in the mine batteries. This is spread over large areas in the form of a thin watery suspension of fine rock particles. Where this contains a large percentage of binding material it forms a permanent "dump" on drying, which is resistant to weathering. Some "sludge dumps" have had a life of 30 years and are little altered at present; but where the amount of binding material is small, the "dump" disintegrates on drying and forms a "sand heap," which is gradually blown away.

The detritus from alluvial mining is heaped up into mounds of greater or less extent. These represent the surface soil from the valleys together with the gravel and other alluvium from the valley floors.

The Natural Vegetation of the District.

The Eucalyptus sideroxylon-Eucalyptus polyanthemos Association.

The vegetation of the non-mined areas, which may be regarded as the original and natural vegetation of the district, consists of an open sclerophyllous *Eucalyptus* forest. This forest represents a single association, dominated by *Eucalyptus sideroxylon, E. polyanthemos* and *E. macrorrhyncha;* the community has been designated by the first two of these names.

The forest is constructed of three strata: these are the tree-stratum, varying in height from 10 to 30 feet, and consisting of *Eucalyptus* spp. alone; a shrub stratum of from 3 to 10 feet in height; and a ground stratum.

The three dominant trees occur commonly together in varying proportions and occupy all soil types; they also occur individually as consociations. Other species, viz. *E. leucoxylon, E. hemiphloia, E. elaeophora, E. viridis,* and *E. rostrata* are found in various localities as subordinates, but have not been observed to form consociations.

The Floristic Composition of the Association.

The species occurring in the tree stratum have been mentioned above, and a further, more detailed account of these will be given later. The floristic composition of the remaining strata is given below in Column A., with the frequency of the constituent species denoted by the following symbols:

a = abundant
f = frequent
o = occasional
r = rare
vr = very rare
l = local

Shrub Stratum.

	A	B	C
Acacia armata	vr	r	f
Acacia aspera	r	r	f
Acacia diffusa	o	o-r	o
Acacia leprosa	r	r	—
Acacia obliqua	r	r	—
Acacia pycnantha	o	f	f
Acacia vomeriformis	vr	vr	—
Astrotricha ledifolia	vr(1)	—	—
Bursaria spinosa	o	r	r
Calytrix tetragona	o	—	—
Cassinia arcuata	a	a	a
Cassinia complanata	o	f	r
Cassytha melantha	r	—	—
Cassytha glabella	r	—	—
Correa rubra	vr	—	—
Daviesia ulicina	o	f	f
Exocarpus cupressiformis	r	vr	r
Goodenia ovata	vr	r	—
Grevillea alpina	o	vr	f
Hakea rugosa	r	vr	r
Helichrysum obcordatum	f	o	o
Humea ozothamnoides	o	f	r
Hybanthus floribundus	vr	—	—
Indigofera australis	vr	—	—
Leucopogon rufus	r	vr	—
Loranthus pendulus	r	—	—
Melaleuca decussata	r	o	f
Persoonia rigida	vr	—	vr
Prostanthera denticulata	vr	—	—
Pultenaea largiflorens	o	o	f
Senecio Cunninghamii	vr	vr	—
Westringia rigida	r	—	—

Ground Stratum.

	A	B	C
Acrotriche serrulata	vr	—	—
Anguillaria dioica	r	r	—
Aristida Behriana	vr	vr	—
Astroloma humifusum	r	vr	o
Brunonia australis	vr	vr	—
Burchardia umbellata	vr	—	—
Calamagrostis filiformis	vr	f	—
Carex pseudocyperus	—	vr	o

Cheiranthera linearis	vr	vr	—
Crassula Sieberiana	vr	vr	—
Danthonia pallida	o	o	—
Danthonia semiannularis	o	o	r
Danthonia setacea	r	r	—
Dichopogon fimbriatus	r	vr	—
Dianella revoluta	r	vr	r
Diuris maculata	r	—	—
Drosera glanduligera	o	—	—
Drosera Menziesii	o	—	—
Epilobium junceum	vr	r	—
Eragrostis Brownii	r	r	—
Eriostemon obovalis	o	vr	o
Halorrhagis tetragyna	o	f	—
Hardenbergia monophylla	vr	—	—
Helichrysum apiculatum	r	vr	r
Helichrysum bracteatum	vr	vr	—
Helichrysum semipapposum	vr	—	—
Hibbertia acicularis	r	vr	o
Hibbertia stricta	vr	—	o
Hovea heterophylla	vr	—	—
Hydrocotyle laxiflora	vr	—	—
Hypoxis glabella	vr	—	—
Juncus bufonius	vr	vr	—
Juncus holoschoenus	vr	r	—
Juncus pallidus	vr	a	vr
Juncus pauciflorus	r	f	f
Juncus polyanthemos	r	f	f
Juncus prismatocarpus	vr	vr	—
Kennedya prostrata	vr	—	—
Leptorrhynchus tenuifolius	vr	—	—
Loudonia Behrii	vr(1)	—	—
Melichrus urceolatus	r	r	—
Orthoceras strictum	vr	vr	—
Pelargonium Rodneyanum	r	vr	—
Pimelea humilis	o	—	—
Poa caespitosa	vr	vr	r
Pultenaea pedunculata	vr	vr	—
Rhagodia nutans	vr	vr	—
Stipa semibarbata	o	f	f
Stipa variabilis	f	a	a
Stylidium graminifolium	vr	—	—
Tetratheca ciliata	r	—	—
Tetratheca ericifolia	r	—	—
Themeda triandra	o	r	vr
Vittadinia australis	vr	o	—
Wahlenbergia gracilis	o	r	—

The Eucalyptus sideroxylon Consociation.

The most widespread of the three dominant trees is *Eucalyptus sideroxylon,* which finds its home on the rocky, sparsely soil-covered hills. According to Patton (1), the physical condition of the soil is the controlling factor in the distribution of this tree, it being restricted to well drained soils. However, although well drained soils may be occupied by *E. sideroxylon,* they may also be occupied by consociations of *E. polyanthemos* and *E. macrorrhyncha,* and these trees may occur on all soil types and in all proportions.

The trees of *E. sideroxylon* attain their best development on ridges capped with iron-stone gravel, and in places form a pure forest. Not only does this species occupy the rocky ridges but it may also occupy the alluvium-filled valleys to the exclusion of the other species.

In several parts of this *E. sideroxylon* consociation there may be no other plants present except lichens, the soil conditions presumably being unfavourable for the development of the shrub or ground strata; but in the majority of cases there are representatives of both strata present.

The Eucalyptus polyanthemos Consociation.

Eucalyptus polyanthemos is generally found with *E. sideroxylon* on the hills, but often in the valleys it occurs alone in pure stands, or is accompanied by a number of subordinate species, viz. *E. hemiphloia, E. melliodora, E. leucoxylon, E. elaeophora,* or *E. rostrata,* which occurs along the banks of the larger creeks.

It is generally noticed that when growing on the hills, this tree is of stunted growth, perhaps owing to the porous nature of the soil, but when the valleys are reached, a much more robust tree is developed.

The Eucalyptus macrorrhyncha Consociation.

Although regarded as one of the dominants, this tree is seldom of high frequency of occurrence except where it forms a consociation of its own. It may be a tree of about 25 feet in height, but on rocky quartz-covered hills it may be stunted and attain only about 6 feet in height. In these cases, its growth form approaches that of some of the species of *Eucalyptus* typical of the Victorian Mallee area which are described as "Whipsticks." Such trees have very thin trunks, are of small stature and often have more than one trunk springing from the base.

The Occurrence of Eucalyptus viridis in the Association.

The presence of *E. viridis* in the *Eucalyptus sideroxylon-E. polyanthemos* Association is noteworthy. Typically this tree is found in the Mallee area of Victoria which receives a rainfall of less than 15 inches a year; but it is also found in widely separated areas in northern Victoria which receive a greater rainfall than this. Four miles north of Bendigo is the Borough of Eaglehawk and both on the west and east of this place, *E. viridis* is found in the typical *E. sideroxylon-E. polyanthemos* association. From Eaglehawk there is a belt of country running in a north-easterly direction for about 15 miles known as the "Whipstick Scrub." In this belt are found in association with *E. sideroxylon E. polyanthemos* and *E. macrorrhyncha,* four other species, viz. *E. viridis, E. Behriana, E. polybractea,* and *E. incrassata,* which are prominent constituents of the vegetation of the Mallee area. The presence of *E. viridis* in the *E. sideroxylon-E. polyanthemos* association was further noticed at a point about 4 miles west of Bendigo and at least 5 miles from Eaglehawk where *E. viridis* begins to become abundant. Thus this Eucalyptus species is seen to have a very wide and a very scattered occurrence.

The Cassinia Society and the Juncus Society.

Within the *Eucalyptus sideroxylon-E. polyanthemos* association, two well defined stratum-societies occur, namely, the *Cassinia* society and the *Juncus* society. The former is a large community and occurs throughout the association, the dominant being *Cassinia arcuata,* a shrub of 3 to 8 feet in height. It comprises all the plants of the shrub and ground strata listed in column A on pages 80-81, with the exception of the *Juncus* species and *Carex pseudocyperus,* which together form the *Juncus* society. The latter community is developed along the creeks, or in places where water lodges during some period of the year.

The Vegetation of the River Gravels at White Hills.

These river gravels form what are known as the White Hills and they give the name to the district in which they occur. They consist of rounded quartz pebbles set in a matrix of white clay which carries varying amounts of iron oxides. This soil is quite different from that of the Ordovician hills, and the possibility that these gravels carried a different flora to that of the general Bendigo area was inquired into.

The gravels were extensively mined for their gold content and now are a source of material for road-making purposes. These operations have almost stripped the area of its vegetation, but here and there remnants exist which give some indication of the former flora. Suckers of *E. sideroxylon* are found and a few stunted trees of *E. macrorrhyncha* and *E. polyanthemos.* The other plants of the area are listed in column C on pages 80-81, and their frequency of occurrence denoted as usual. It will be seen that this vegetation differs very little in composition from that occupying the Ordovician hills, there being only a slight variation in the frequency of the individuals. The hills, however, are so disturbed that this may not be of any real significance.

The Vegetation of the Mined Areas.

Where mining operations occurred, the original vegetation was destroyed over considerable areas in which the bareness and absence of trees now contrasts strikingly with the surrounding forest country. (See Plate XA.)

During the sixteen years that have elapsed since extensive mining operations ceased, however, these once almost bare areas have been invaded by the vegetation of the surrounding forests. Trees are still absent, but several members of the *Cassinia* society, such as the dominant *Cassinia arcuata,* and some grasses, are of general occurrence on the hills; while the *Juncus* society has migrated as a whole and is well developed along the creeks.

The Choice of an Area for Intensive Study.

For the intensive study of the vegetation migrating from the forest into the mined areas, a valley was chosen which runs for about three miles in an almost east-west direction. This tract of country was the scene of concentrated mining activities in the past, especially the ground below the confluence of two creeks which drain the area (the Long Gully and the Ironbark creeks). Here the surface soil has been largely removed by alluvial mining methods. Other portions of the valley are covered with "sludge dumps" and "mullock heaps." Little settlement has taken place, so that a study was able to be made of the egress of the plants from the forest which is found on the western, eastern and, in places, along the northern boundaries.

The Cassinia Society in the Mined Areas.

The dominant *Cassinia arcuata* often occupies tracts of country to the almost total exclusion of all other plants except mosses and lichens (*Parmelia* and *Cladonia* spp.), and in parts it forms a closed society of from 6 to 8 feet in height. It is a hardy perennial which bears an enormous quantity of seed, and when in fruit the shrub takes on a light yellow-brown colour which contrasts with the dark dull-green colour of the plant in the vegetative season.

Other members of the *Cassinia* society occurring in the mined areas are found to be distributed spasmodically and these are listed with their frequency of occurrence in column B, on pages 80-81.

Certain of the subordinates of the society are found in considerable abundance in some areas, especially those that fringe the forest. The chief of these are *Acacia pycnantha, Vittadinia australis,* and *Mclaleuca decussata.*

1. *Acacia pycnantha.*

Acacia pycnantha is found abundantly in parts of the mined areas fringing the forest and also in partially cleared forest land, where numerous seedlings spring up each year. It is well known that bush fires after having swept an area, will be followed by a vigorous growth of Acacias in their wake. But this pyric factor could not explain the growth and spread of *A. pycnantha* in this area, as no fires have occurred for at least twenty years.

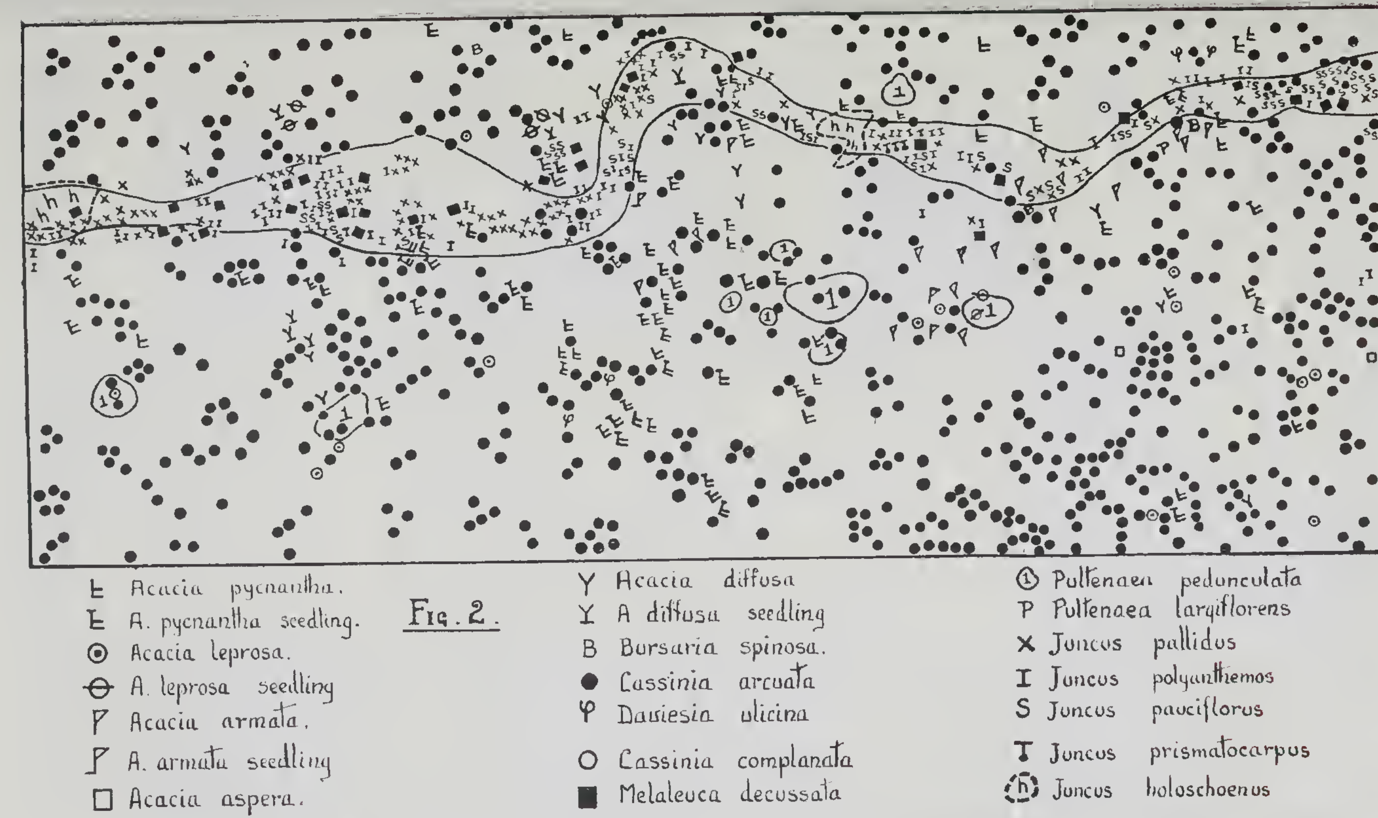

Fig. 2.—Chart of an area along a small creek near the fringe of the forest, illustrating the occurrence of members of the *Juncus* society and the development of *Acacia pycnantha* seedlings near the parent trees.
Scale 3/40 inch = 1 yard.

Fig. 2 is a chart made in mined country fringing the forest where young *A. pycnantha* plants are abundant.

It might be suggested that the turning over of the soil during alluvial mining would give dormant seed the opportunity to germinate. But this area in which the chart was made has lain idle for at least 20 years and young plants still spring up each year; while on the contrary, the stretch of country below the confluence of the Long Gully and the Ironbarks creeks, which was extensively mined (dredged) up to fifteen years ago, shows an almost total absence of *A. pycnantha.*

The localities where *A. pycnantha* plants are abundant are either in or near the forest areas, where other *A. pycnantha* plants are found as normal members of the *Cassinia* society. Seed dispersal in Acacias is brought about by the exploding of the pods, and by this means seeds are thrown a distance of only a few feet; hence the young plants which develop are generally found near the parent tree. (See fig. 2.) Thus it is probable that the sources of spread of this Acacia are the forest areas.

The dormant seeds of *A. pycnantha,* like those of other Acacias, have a hard testa, which is impermeable to water. Under normal conditions, germination does not take place until the seeds have lain dormant for a long period and the testa has decayed sufficiently to allow the entrance of water. Prolific germination at a single particular time is generally brought about by some abnormal factor; such a factor is fire which cracks by heat and so renders them permeable. In the present instance it is suggested that the prolific germination is a consequence of the structure of the vegetation of the mined areas being more open than that of the normal forest. The insolation of exposed seeds, falling on the hard soil, is thus considerably greater than in the forest; and this, with the periodical wetting of the seeds after rain, may render the testas permeable and permit germination to ensue. Other Acacias such as *A. leprosa, A. aspera, A. diffusa,* and *A. vomeriformis,* also show signs of spreading in the mined areas and the areas fringing the forest. In these cases the sources of spreading are probably remnants of the former vegetation, as the present shrubs near which many of the seedlings occur are very old.

2. *Vittadinia australis.*

At the eastern end of the mining field on the river gravels of ? Pliocene age, and to the east and west of these, there is a widespread occurrence of *Vittadinia australis.* This plant is found in situations often devoid of other vegetation, such as sandy and gravelly banks which occur in the creek beds, or which represent the detritus from alluvial mining.

3. *Members of the family Chenopodiaceae.*

To the west of the above river gravels, on stretches of clayey soil, several members of the family *Chenopodiaceae* occur,

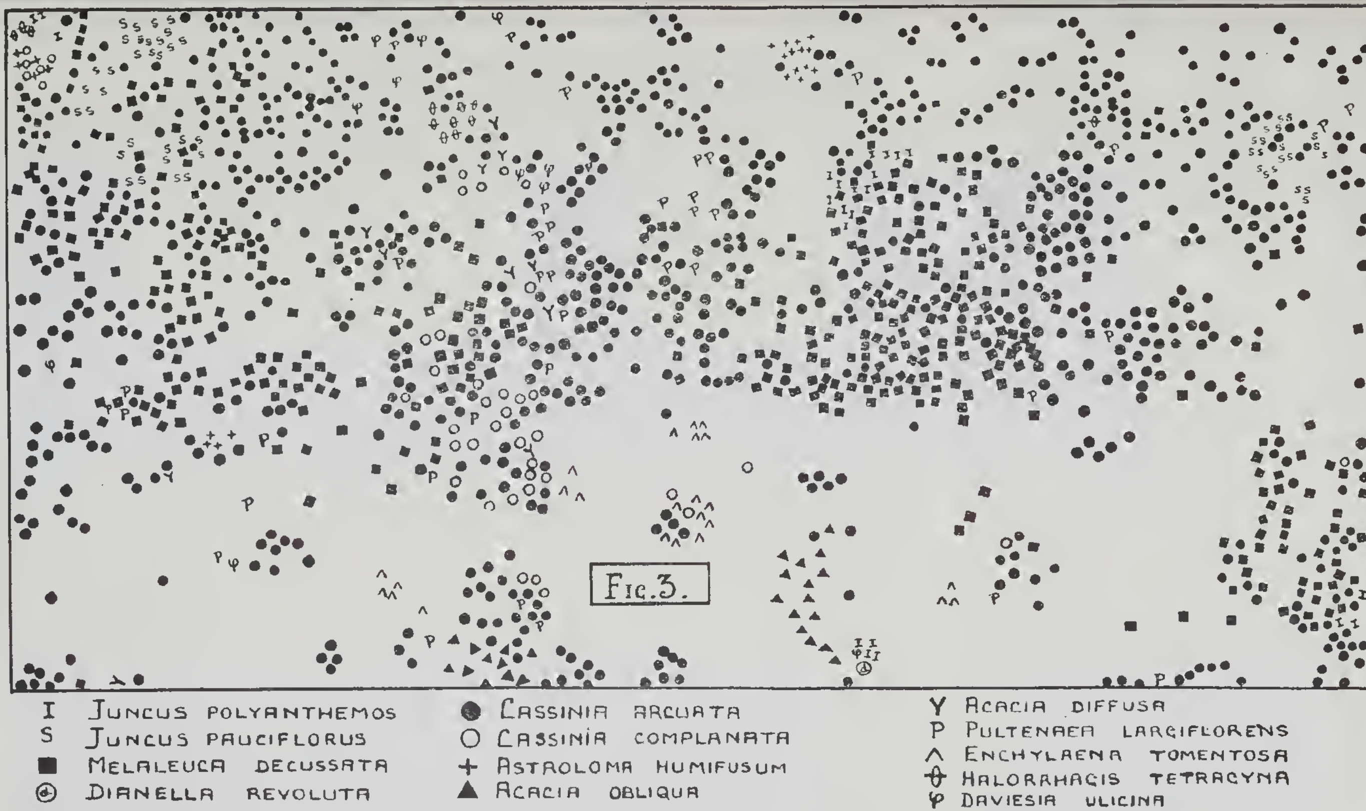

Fig. 3.—Chart of part of an area of about two acres in extent which shows a remarkable development of *Melaleuca decussata* on the silt accumulated against a barrier on the downslope of a hillside. Scale 3/40 inch = 1 yard.

namely, *Salsola Kali, Atriplex semibaccatum, Kochia villosa, Bassia quinquecuspis* and *Enchylaena tomentosa.* The presence of these plants has not been observed in the forest areas.

4. *Melaleuca decussata.*

In fig. 3, an area is plotted which shows an abundance of *Melaleuca decussata.* In the forest areas this plant occurs only rarely and developed in small local societies; it appears to be confined to situations which are moist or swampy during some period of the year. In the country that has been mined, it is found most usually spreading along the creek bottoms (see fig. 2). In fig. 3 is charted a portion of an area whose total extent is about two acres, and which shows a great development of young *M. decussata* plants. This area receives the drainage of a hillside, and on the silt accumulated against a barrier on the downslope, these plants are quickly developing.

The Juncus Society in the Mined Areas.

In the forest areas, *Juncus* spp. are comparatively rare, occurring only along the creeks or in places which are moist at some time during the year. Here *Juncus polyanthemos* and *J. pauciflorus* are the most common species.

The society flourishes much more abundantly in the treeless mining areas. It fringes the dams which formerly supplied the mines with water; the creek bottoms which have been widened and silted up in such a way as to cause the streams to flow over wider beds than previously, are often solely occupied by the society; and it also occurs in the numerous small depressions which have been formed by mining operations, and which hold water for a short time after rain. The most abundant member of the society in these habitats is *Juncus pallidus,* which forms almost pure communities in the wide, shallow, sandy creek bottoms to the exclusion of the other members with which it is elsewhere associated. It occupies a variety of soil types. It is found on the Ordovician hills where it can receive water only at times when the normal forest vegetation does; it occurs abundantly in the alluvium-filled creek bottoms where again it obtains water only periodically, since normally these creeks are dry altogether for the greater part of the year; and on "sludge dumps" and "sand heaps" it may be the only plant living. It lives throughout the year in all the above mentioned situations.

Under moister conditions this species is accompanied by other members of the society, and in fig. 2 is plotted an area along a small creek, showing their occurrence.

Small shallow depressions which hold water for a week or two after rain, are generally found to support a stunted growth of *Juncus polyanthemos* and *J. pauciflorus.* If the water is permanent, the plants live throughout the year and attain a height of from 2 to 3 feet; but if the water is ephemeral. the plants are found to be small, and they are short-lived.

In dams which periodically become dried up, it is often seen that *J. polyanthemos* has grown to the centre of the depression, and *J. pallidus* forms a fringe of vegetation around the banks. The other members of this society, *J. bufonius, J. prismatocarpus, J. holoschoenus,* and *Carex pseudocyperus,* occur to a limited extent accompanying the above-mentioned species, mainly along the creeks and around the edges of the larger dams.

The Vegetation of the "Mullock Heaps" and "Sludge Dumps."

The description that has just been given applies generally to the whole of the mined areas. There are, however, certain peculiarities in the vegetation of the "mullock heaps" and "sludge dumps" that call for separate mention.

The "mullock heaps" which represent the weathered rock from the shallow workings support the ordinary vegetation of the mined areas; but those composed of unweathered stone, which through the course of time have come to contain some fine material, derived either from the weathering of the rock or from dust blown into them, support the growth only of *Cassinia arcuata* and some grasses such as *Stipa variabilis*. The "sludge dumps" (and "sand heaps") support in most instances a vigorous growth of *Juncus pallidus*. *Cassinia arcuata,* however, is also found on them along with the following: *Stipa semibarbata, Danthonia setacea, Stipa variabilis, Bassia quinquecuspis, Kochia villosa, Atriplex semibaccatum, Wahlenbergia gracilis, Dichopogon fimbriatus, Cynodon Dactylon* and *Acacia pycnantha.*

Acacia pycnantha was found on one "sludge dump" on the fringe of the forest area quite near the locality of fig. 2. *Cynodon dactylon*, although not observed in the forest, is found on many "sand heaps" where it forms a good sand-binder.

The Recolonization of the Mined Area.

The general composition of the mined areas, apart from the absence of trees, is sufficiently similar to that of the forested areas to indicate that recolonisation is tending towards a redevelopment of the *Eucalyptus sideroxylon-E. polyanthemos* association. It is a matter of interest, however, to gain some knowledge of the order in which the various species have appeared during the period in which the recolonisation has been taking place. The evidence indicates that there is no long succession of seral communities; the *Cassinia* society may in fact be said to have commenced redevelopment directly, although it appears that not all the subordinates have reinvaded the areas at the same rate as the dominant.

A general survey of the mined areas showed that in the central parts, the number of species occurring were few, and that as the fringing forest areas were approached, the number of species increased. This suggested that there was a difference in the time taken for individual species to invade the mined areas, and that the depth of penetration of any particular species into the mined area would be an indication of its rate of spreading; and the different rates would thus indicate the order of appearance of the species with the readvancement of the vegetation from the forested areas into the mined areas.

The data for the order of appearance of the species from the forest into the mined areas were obtained by taking a series of traverses from the central portions of the mined country to the surrounding forest. From the information gathered from the traverses it was hoped that the frequency of occurrence of the different species and their depth of penetration into the mined areas would be revealed. But it was found that there were residual patches of the former vegetation present in the mined areas, and these patches were the sources for the distribution of their own members; hence the evidence gained in this manner was not conclusive.

The areas fringing the forest were therefore examined for the presence of seedlings. The frequency of occurrence of these seedlings should indicate, to a certain extent, the rate of spread of the various species which were advancing from the forest into the mined country; this evidence, considered with that that obtained from the traverses, was sufficient to establish the order of appearance of the species in the mined areas. This order of appearance is shown below in three groups.

The Order of Appearance of the Species in the Redevelopment of the Vegetation.

Group 1.

(a) Cassinia arcuata and grasses such as Stipa variabilis, Stipa semibarbata, Danthonia pallida, Danthonia semiannularis. These species mainly occupy the hills.

(b) Juncus spp.—mainly J. pallidus at first, but with J. polyanthemos and J. pauciflorus; followed later by J. bufonius, J. prismatocarpus and J. holoschoenus. These are found generally in the creeks and around the dams.

(c) Vittadinia australis.

These plants in Group 1 occupy the major portion of the mined areas, and often occur to the exclusion of all others. Their spread has been rapid and is perhaps due to their types of seed dispersal. *Cassinia* and *Vittadinia* are members of the family *Compositae* and their seed is provided with a pappus by means of which the seed is dispersed by wind. The seeds of the *Juncus* spp. are very small and may be carried either by water or wind.

Group 2.

Acacia pycnantha	Daviesia ulicina
Melaleuca decussata	Acacia aspera
Cassinia complanata	Acacia obliqua
Bursaria spinosa	Acacia vomeriformis
Humea ozothamnoides	Epilobium junceum
Halorrhagis tetragyna	Calamagrostis filiformis

A.—This shows a typical dam formerly supplying a mine (Koch's Pioneer) with water. *Juncus pallidus* is seen growing round the fringes and also along the shallow edges of the dam. In the background is an old "sludge-dump" which has partially disintegrated to the "sand-heap" state and which supports the growth of *Juncus pallidus*.

B.—*Juncus pallidus* is here seen growing on a "sludge-dump" close to the edge of the forest. In the foreground shrinkage cracks are seen in the sludge.

A.—This is a typical patch of alluvially-mined country showing the rough and disturbed nature of the soil. *Cassinia arcuata* is predominant in this type of country.

B.—A small creek in the fringing forest area which shows *Juncus pallidus* in its bed and *Cassinia arcuata* along the banks. The area charted in fig. 2 is a few yards downstream from that represented here.

These plants are mainly shrubs which only occur to any extent in the fringing forest areas, from whence they spread slowly into the mined areas. Seedlings of these plants are commonly met with in the fringes of the forest. The last two members are mainly found with the *Juncus* society in the creek beds.

Group 3.

Pultenaea pedunculata	Cheiranthera linearis
Pultenaea largiflorens	Anguillaria dioica
Hypoxis glabella	Orthoceras strictum
Dichopogon fimbriatus	Pterostylis sp.
Wahlenbergia gracilis	

These plants belong to the ground stratum, with the exception of *Pultenaea largiflorens*; they are practically confined to the fringing forest areas where they are of rare occurrence.

Plants which do not show any marked signs of spreading are exemplified by *Exocarpus cupressiformis* and *Hakea rugosa,* which form clumps in the forest. Although seedlings of these were found, they all occurred near the parent trees. The spread of such types as these over an area would be probably very slow indeed.

The *Eucalyptus* trees of the forest show very little sign of invading the mined country, although seedlings of these are found in the forest itself and in the areas between the forest and the mined country, where also an abundant growth of suckers is noticed. These suckers and the saplings are cut down for timber and firewood as often as possible, so that the chances for a tree to become a seed-bearing one are limited owing to this biotic factor.

Although certain plants such as *Vittadinia australis* and *Melaleuca decussata* may develop extensively in some places, in general the *Cassinia* and *Juncus* societies of the forest are redeveloping with unchanged composition: there is no inhibition of the reoccurrence of any of their subordinates. Such peculiarities in relative frequency as occur, may be temporary phases in redevelopment; and it may be expected that, if the trees of the forest were given every opportunity to migrate also, they would again take their place as the dominants of the association.

The redevelopment of the shrub societies in the absence of the trees is an indication of the feeble dominance exerted by *Eucalyptus* on its subordinates, a characteristic which is abundantly illustrated in the study of *Eucalyptus* forests.

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[Proc. Roy. Soc. Victoria, 44 (N.S.), Pt. I, 1932.]

Art. VII.—*Rare Foraminifera from Deep Borings—Part III.*

By FREDERICK CHAPMAN, A.L.S., F.G.S.
(Palaeontologist to the Commonwealth Government),

and IRENE CRESPIN, B.A.
(Assistant Palaeontologist).

(With Plates XI-XIII.)

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In continuation of former papers on "Rare Foraminifera from Deep Borings," we here describe some new and rare foraminifera obtained from various borings in Victoria and New Guinea, and also from outcrops in Papua and New Guinea.

Included in this paper are *Spiroclypeus margaritatus* (Schlumberger) from the Hamilton Bore, the first definite record in Australia; two new species of *Lepidocyclina, L. hamiltonensis* and *L. howchini* from the bore at Hamilton, Western Victoria; *L. martini* from borings in Gippsland, Victoria; *L. radiata* from borings in Western Victoria and Gippsland, previously known only from Java; also the occurrence of *L. sumatrensis* (Brady) var. *mirabilis* Yabe and Hanzawa for the first time in Australian Tertiaries; *Miogypsina mamillata* Yabe and Hanzawa, and *M. saitoi* Yabe and Hanzawa from borings and outcrops at Matapau, New Guinea, previously described only from the Island of Formosa (Taiwan).

Genus **Spiroclypeus** H. Douvillé, 1905.

Spiroclypeus margaritatus (Schlumberger).

(Plate XI, Figs. 4. 5.)

Heterostegina margaritata Schlumberger, 1902, p. 252-3, pl. vii, fig. 4.
Spiroclypeus margaritatus (Schl.), Boussac, 1906, p. 94.
Heterostegina margaritata (Schl.), Chapman, 1914, p. 293, pl. ix, fig. 11.
Spiroclypeus margaritatus (Schl.), Yabe and Hanzawa, 1928, p. 187, pl. xxiii, figs. 1-4, pl. xxiv, figs. 1-5.

Observations.—We are enabled to place on record the first undoubted occurrence of *Spiroclypeus margaritatus* in the Australian Tertiaries. This specimen occurred in the bore at Muddy Creek, near the junction of the Grange Burn about six miles west of Hamilton. It was found in a thin section of the ochreous limestone in association with the Nephrolepidines (*Lepidocyclina sumatrensis, L. tournoueri,* and *L. hamiltonensis*) described below. In the same section of limestone there also occur numerous species of polyzoa common to the Tertiary. The section, which is cut through the equatorial zone, represents a typical specimen of the species earlier described by Schlumberger as *Heterostegina margaritata.* The condition of preservation is fairly good for these ironstained limestones, and the disposition of the pillars in the lateral zones is well shown, together with the unequal arrangement of the central chambers.

A doubtful reference to the species by one of us (F.C.) previously was made from a limestone at Batesford near Geelong, Victoria, though this has not been confirmed by additional specimens. We also figure here a limestone from Tumleo Island, Aitape, New Guinea, which is extremely rich in *Spiroclypeus margaritatus.*

Dimensions of Hamilton Specimens.—Diameter of test, 2·47 mm. Thickness of test, 0·9 mm.

Occurrence.—*Spiroclypeus margaritatus* occurs at the following localities:—In Victoria, Hamilton Bore, at 36-38 feet, ? and Batesford; in Papua, at Bootless Inlet, Boira and Red Scar Head, Lagaba Island; and in New Guinea in the Aitape Area, at Tumleo Island, Wanfela Creek, Mene River, Nofula Creek, Upper Bliri Creek and Pinbim Creek, and in the Wanimo Area at Umoni Creek, Primpri Hill, Pluro Creek and Mapri-Kipri Hills; in the New Hebrides at Santo.

Age.—The original type specimen, described by Schlumberger as *Heterostegina margaritata,* came from the Miocene of Borneo. The genus *Spiroclypeus* is regarded by Umbgrove, (1930), p. 4, as one of the principal guide fossils of Tertiary "e," which is regarded by Van der Vlerk as Lower Miocene. This genus is usually associated with the Eulepidines and certain Nephrolepidines, in the East Indies, New Guinea and Papua. In the Hamilton Bore it is found with large and small Nephrolepidines. From the above asssociations we may conclude that *Spiroclypeus margaritatus* in Victoria distinctly points to a Lower Miocene horizon.

Genus **Lepidocyclina** Gümbel, 1868.

Lepidocyclina (Nephrolepidina) hamiltonensis, sp. nov.

(Plate XII, Figs. 8, 9, 10.)

Lepidocyclina martini Chapman (*non* Schlumberger), 1910, p. 297, pl. liv, figs. 3, 4.

Description of Holotype (from Hamilton Bore, 48-53 feet).—Test small, surface moderately and evenly convex, periphery angulate, with 7 blunt processes, papillae small, generally scattered on the whole surface, with a few larger ones near the centre.

Description of Tectotypes.—(a) Transverse section, from 68-80 feet. Centrosphere nephrolepidine, moderately thick-walled.

Median chambers, short, spatulate, arranged in about 20 annulations. (b) Vertical section from 26-38 feet. Lateral chambers arranged in 7 layers on either side of the centrosphere; 8 strong pillars distributed through the lateral series of chambers.

Dimensions.—Diameter of test, 2·88 mm.; thickness of test, 0·76 mm. Diameter of centrosphere, 0·17 mm.; longest diameter of nucleoconch, 0·35 mm.

Observations.—The form to which *Lepidocyclina hamiltonensis* is most nearly allied is *L. tournoueri.* The points of difference are the more regular and compact characters of the equatorial chambers in the present series. Externally it shows a more even outline with regular angulation. This angulation is seen to some extent in the equatorial sections just near the margin, and by the more compressed character of the chamberlets at the points. Some specimens which are more variable in character, but which we refer to this species, occur in the Batesford Limestone, recorded by one of us (F.C.), under the name *L. martini,* which, however, is not referable to Schlumberger's species.

Occurrence.—In the Hamilton Bore, Western Victoria, at 35-53 feet, 68-85 feet, 86-91 feet, 135-137 feet, 159-160 feet, 181-187 feet; and Batesford, near Geelong.

Age.—Lower Miocene. It is associated with *L. marginata, L. radiata, L. howchini,* and *Spiroclypeus margaritatus.*

Lepidocyclina (Nephrolepidina) howchini, sp. nov.

(Pl. XIII, Figs. 18, 19.)

? *Orbitoides stellata,* Howchin (*non* d'Archiac), 1889, p. 17, pl. i, figs. 9, 10 *a,b.*

Description of Holotype (from Hamilton Bore, 80-85 feet).—Test small, discoidal with 8 blunt marginal prolongations. Surface strongly convex, central part of test with a group of strong papillae, smaller on the surrounding area.

Description of Tectotype.—Vertical section from 68-80 feet. Equatorial series narrow, lateral, chamberlets forming 6 layers superimposed on centrosphere, 5 vertical pillars shown in cross section in the central region.

Dimensions.—Diameter of test, 2·9 mm.; thickness of test, 1·17 mm. Diameter of centrosphere, 0·14 mm.; longest diameter of nucleoconch, 0·41 mm.

Observations.—It is possible that the specimen referred to by Howchin as *Orbitoides stellata* (1889) is specifically the same as the present species, judging from the figure of the external surface which Howchin gives, but a small measure of doubt is thrown upon it by the transverse section accompanying *O. stellata* (pl. I, fig. 10*a*), for this figure of a vertical section appears to belong to the outline of the species we have here named as *Lepidocyclina hamiltonensis,* or an allied form. On the other hand, the comparison between the external view of Howchin's specimen and our species is strengthened by a fragment of a vertical section of a specimen from Muddy Creek, showing a strong pillar, which he figures on pl. I, fig. 10*b*.

Occurrence.—Western Victoria, in Hamilton Bore, at 36-38 feet, 43-53 feet, 68-85 feet, 86-91 feet, 109-114 feet, 135-137 feet, 157-159 feet, 160-161 feet, 166-171 feet, 181-187 feet; Gippsland in No. 16 Bore, Parish of Stradbroke, at 610 feet.

Age.—Lower Miocene. *L. howchini* is associated with *L. radiata, L. hamiltonensis, L. sumatrensis* and *L. marginata.*

Lepidocyclina (Nephrolepidina) martini Schlumberger.

(Pl. XII, Figs. 11, 12, 13.)

Lepidocyclina martini, Schlumberger, 1900, p. 131, pl. vi, figs. 5-8; Douvillé, H. 1916, p. 28, pl. iv, figs. 3-7; Crespin, 1926, p. 115, pl. viii, fig 8.

Observations.—*Lepidocyclina martini* is a very variable species which in the more regularly rayed forms approaches *L. radiata.* The distinguishing features are the pustule-bearing rays, the rays themselves being of a more irregular character than those met with in *L. radiata.* The original type specimen given by Schlumberger was afterwards supplemented by a fine series, figured by H. Douvillé from Rembang, Java, and by means of which we were enabled more definitely to assign the Australian species to their proper position. Although *L. martini* is met with at Batesford, the figures given by one of us (F.C.) rightly belong to *L. hamiltonensis.* The feature of irregularity in the rays of *L. martini* is well shown in the equatorial section which is here figured.

Occurrence.—Western Victoria. In Hamilton Bore at 36-48 feet, 53-63 feet, 68-85 feet, 89-96 feet, 104-114 feet, 119-129 feet, 135-142 feet, 152-157 feet, 159-160 feet, 161-171 feet, 176-187 feet. In Gippsland, Parish of Stradbroke, Bore No. 15, at 45 feet; in No. 16 Bore, at 640 feet; No. 5 Bore, Parish of Glencoe, at 40-80 feet; in No. 1 Bore, Parish of Bumberrah (Metung) at 872 feet; at Batesford, near Geelong, and Green Gully, Keilor.

Age.—Almost the whole of the recorded examples of *L. martini* from the Australian Tertiaries are in the Lower Miocene (stage "e"), although in the East Indies and New Guinea it has been recorded in the stages of "e" and "f."

Lepidocyclina (Nephrolepidina) radiata (Martin).

(Pl. XIII, Figs. 15, 16, 17.)

Orbitoides radiata Martin, 1880, p. 163, pl. xxviii, fig. 4.
Lepidocyclina radiata (Martin), Douvillé, H. 1916, p. 22, pl. v, fig. 4, Van der Vlerk, 1928, p. 35, fig. 25.

Observations.—*Lepidocyclina radiata* was first described from the Miocene of Java associated with *Cycloclypeus communis.* There is no doubt that our specimens, which were met with in the Metung Bore, are conspecific with Martin's species. This is an important discovery in regard to the Australian Tertiaries since *L. radiata* is typically referable to stage " e " in the Dutch East Indies, and so helps to fix the exact horizon in the Miocene of South-eastern Australia. The most typical specimens of *L. radiata* occur in the East Gippsland borings, but the species is also met with, in a less developed condition, in Western Victoria, where on account of its variability it may easily be mistaken for the smaller or less regular form *L. martini.* The figure of the transverse section here given is apparently the first that has been published of this species. In addition to the typical test of *L. radiata* a figure is included of the juvenile stage. In this it will be seen that the radii of the test of the adult stage, which are within the circumference, in the early stages are represented by spur-like processes beyond the margin.

Dimensions.—Diameter of test of figured specimen from No. 5 Bore, Parish of Glencoe, 4·7 mm. Average diameter of examples from Hamilton Bore, about 2·5 mm.

Occurrence.—Western Victoria. In Hamilton Bore, at 38-43 feet, 48-53 feet, 58-63 feet, 68-96 feet, 104-114 feet, 119-124 feet, 135-137 feet, 152-161 feet. In Gippsland, in No. 1 Bore, Parish of Bumberrah (Metung), at 872 feet; No. 5 Bore, Parish of Glencoe, 50-80 feet; No. 15 Bore, Parish of Stradbroke, at 45 feet.

Age.—Lower Miocene. *L. radiata* is associated with *L. martini, L. sumatrensis, L. hamiltonensis, L. marginata, L. howchini,* and *Cycloclypeus communis.*

Lepidocyclina sumatrensis (Brady) var. mirabilis Yabe and Hanzawa.

(Pl. XI, Figs. 1, 2.)

Orbitoides stellata Howchin *pars.* (*non* d'Archiac), 1889, p. 17, pl. i, figs. 11, *a, b.*

Lepidocyclina murrayana Crespin (*non* Chapman), 1926, p. 116, pl. xiii, fig. 9.

Lepidocyclina sumatrensis (Brady) forma *mirabilis* Yabe and Hanzawa, 1930, p. 31, pl. vi, figs. 1-7; pl. vii, figs, 1-11.

Observations.—Howchin has figured and described an exactly similar form of the above variety of *L. sumatrensis* under the name of *Orbitoides stellata,* and coming from the lower beds at Muddy Creek, Hamilton, was probably obtained from the red limestone of that locality, washed down or in situ. We have found identical examples in the Hamilton Bore at Muddy Creek, at 91-98 feet, as well as at the Batesford Quarry, near Geelong.

Figures of this variety from both localities are here given. The form referred to as *L. murrayana* from Keilor is now seen to be also similar. Yabe and Hanzawa, in the work above quoted, suggested that these "Trigonolepidine" forms may be found, as monstrous varieties, in other species. They also state their belief that these are not produced by an accidental lobe-formation of test, because the same nucleoconch lies at the centre of the test. On the other hand, the section of one of the trigonal forms which we here figure appears to show definitely that this trigonolepidine habit in some individuals is due to the duplicated budding of the second or kidney-shaped chamber.

Further than this we have met with other species of *Lepidocyclina* which have shown the same tendency to produce monstrous forms through prolific budding of the second chamber.

Thus, the monstrous form of *L. martini,* which occurs at 45 feet in No. 15 Bore, Parish of Stradbroke, Victoria, shows an even more aberrant condition and a section showing four rays to the test is here figured under the name of *L. martini* var. *mirabilis.*

Occurrence.—In Hamilton Bore, Western Victoria, at 38-48 feet, 80-85 feet, and 91-98 feet.

Age.—Lower Miocene. *L. sumatrensis* var. *mirabilis* is associated with *L. radiata, L. martini, L. marginata, L. hamiltonensis* and *L. howchini.*

Genus **Miogypsina** Sacco, 1893.

Miogypsina mamillata Yabe and Hanzawa.

(Pl. XI, Fig. 6.)

Miogypsina mamillata Yabe and Hanzawa, 1930, p. 34, pl. i, fig. i, pl. iii, figs. 7, 8, pl. iv, fig. 6, pl. vi, fig. 13, pl. xi, figs. 7, 8, pl. xii, fig. 1, pl. xiii, fig. 8.

Observations.—The above species was recently described by H. Yabe and S. Hanzawa, from the island of Taiwan (Formosa). During our examination of bore material and outcrop samples from Matapau, New Guinea, obtained by the officers of Oil Search Ltd., we have found the same species in the limestones of that area, and associated similarly with other genera, as recorded by these Japanese authors. This is the only occurrence of *M. mamillata* at present known, beyond the island of Taiwan (Formosa). The Matapau examples are beautifully preserved, and many of them have the tests so thickened that they appear almost subspherical.

Occurrence.—Bore No. 7, Matapau, at 1200-1210, and at Mabam River, Matapau, New Guinea.

Age.—Middle Miocene, Tertiary "f." *M. mamillata* is found associated with *Operculina, Lepidocyclina (N.) angulosa, L. (N.) sumatrensis, L. (N.) ferreroi, L. (N.) verbeeki* and *Miogypsina saitoi.*

MIOGYPSINA SAITOI Yabe and Hanzawa.

(Pl. XI, Fig. 7.)

Miogypsina saitoi Yabe and Hanzawa, 1930, p. 34, pl. v, fig. 8, pl. xii, fig. 3, pl. xiv, fig. 7.

Observations.—This species, like the one above mentioned, was first described by Yabe and Hanzawa, from Taiwan (Formosa). It may be distinguished from *M. irregularis* by the more compressed form and regular median series. In vertical section the test shows a greater inflation on one side than the other.

Occurrence.—At Mabam River, Atob River, and Head of Mindik Creek (Atob R.), Matapau, New Guinea.

Age.—Middle Miocene, Tertiary " f." *M. saitoi* is associated with *Lepidocyclina sumatrensis* and *L. angulosa* and *Miogypsina mamillata.*

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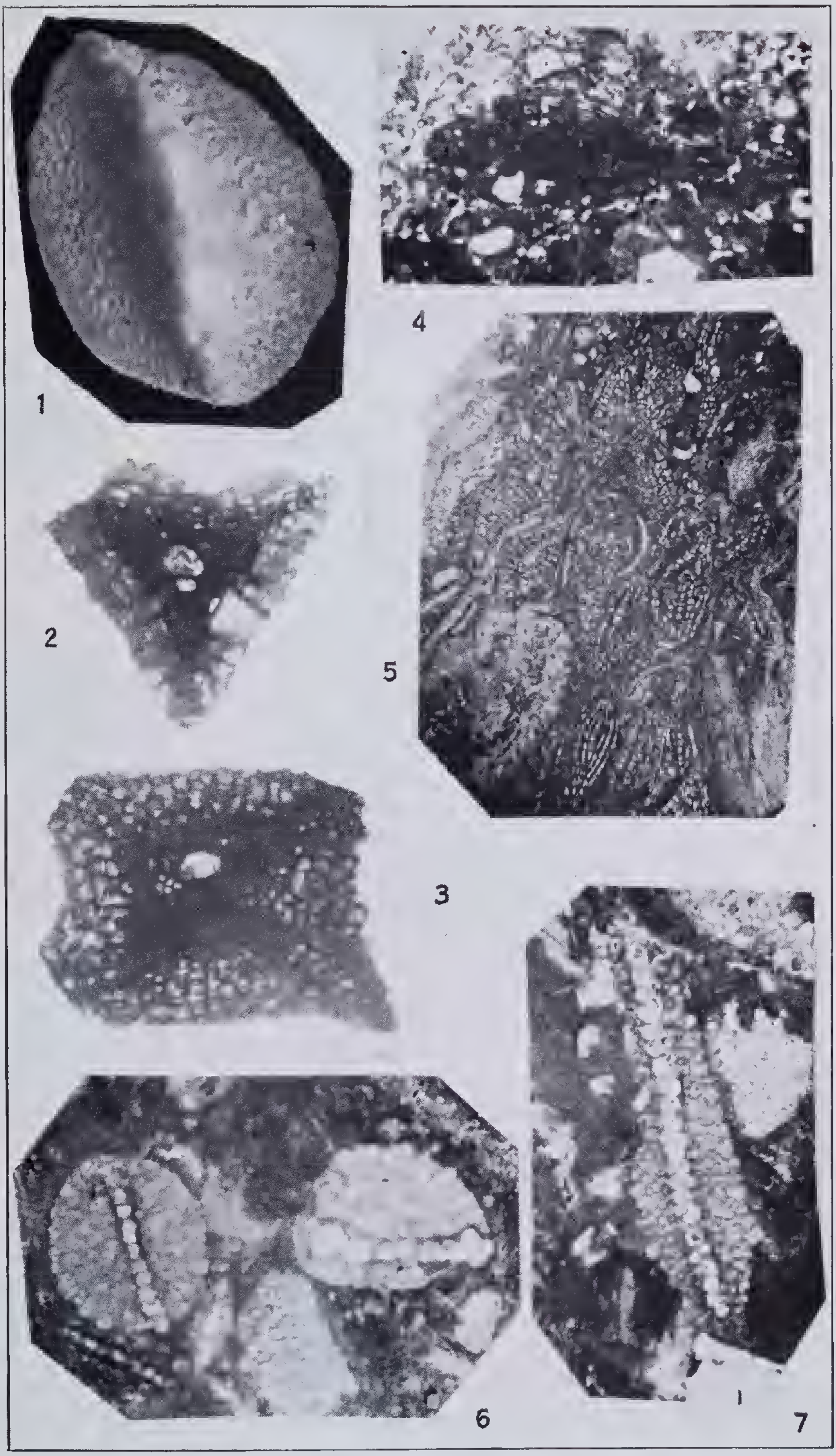
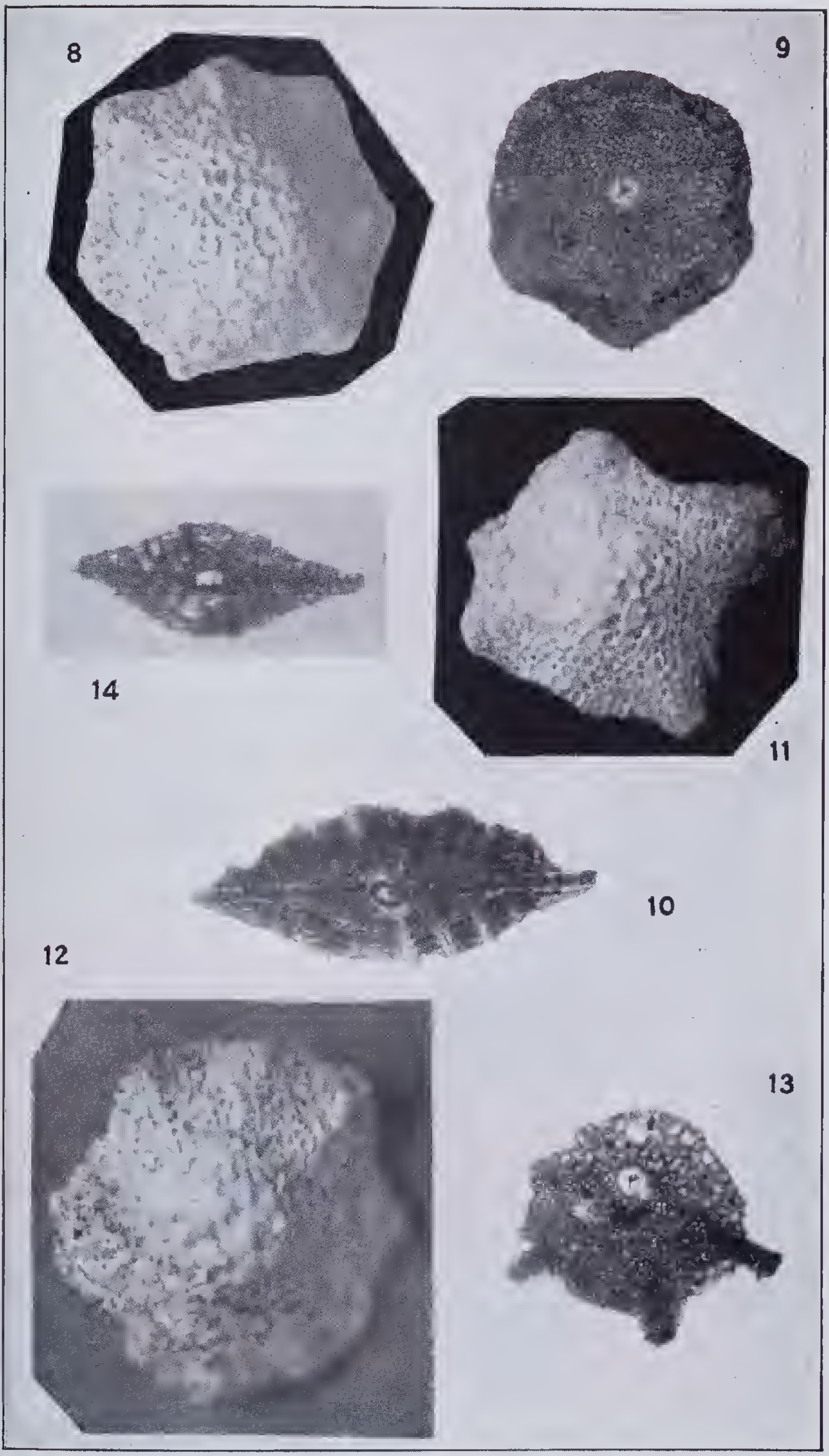


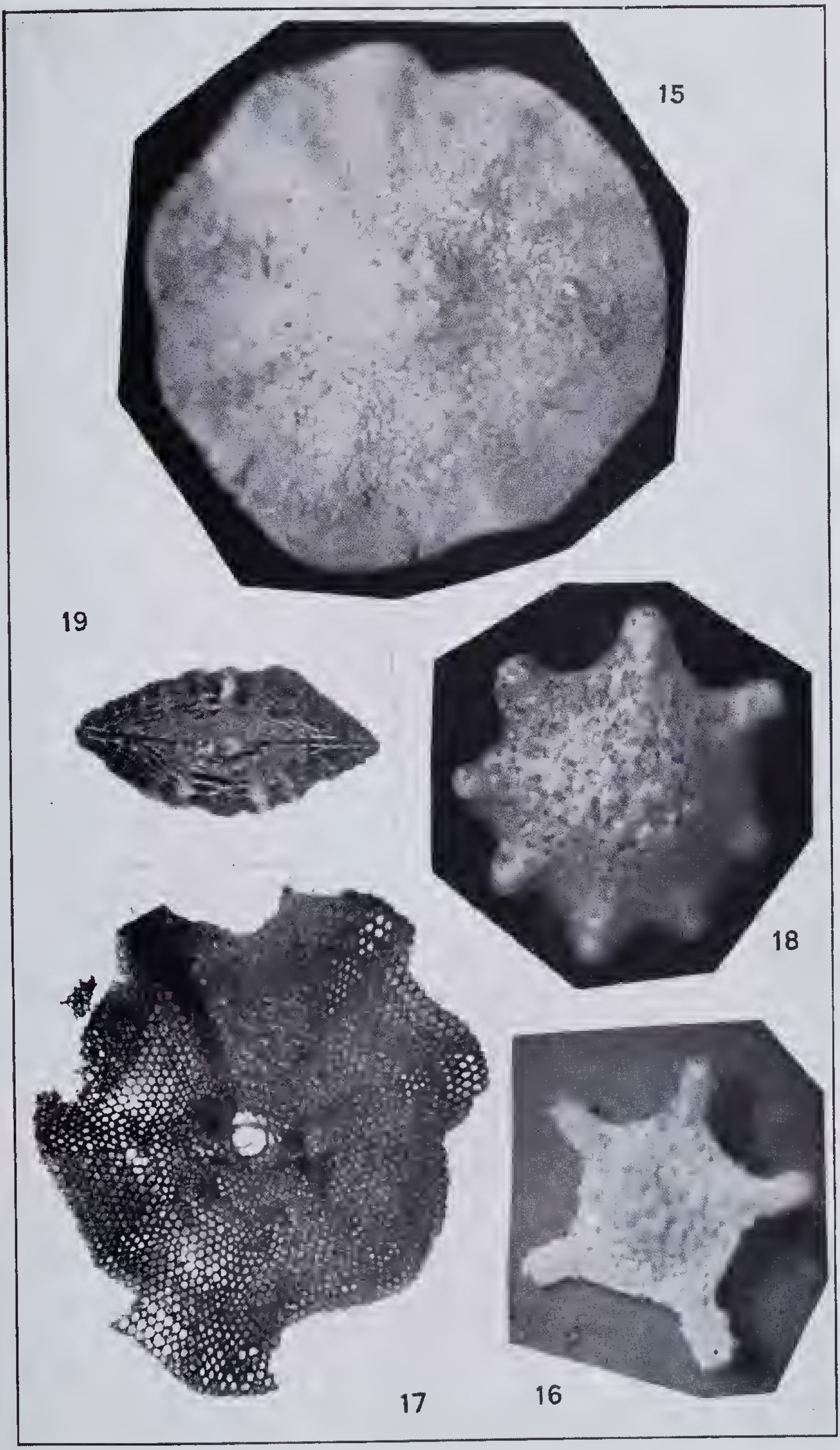
F.C. Photo

Lepidocyclina, Spiroclypeus and Miogypsina from Victoria and New Guinea.



F.C. photo

Lepidocyclina from Borings in Victoria.



F.C. Photo

Lepidocyclina from Borings in Victoria.

Explanation of Plates XI-XIII.

Plate XI.

Fig. 1.—*Lepidocyclina sumatrensis* (Brady) var. *mirabilis* Yabe and Hanzawa. Hamilton Bore, Victoria, 80-85 feet. Lower Miocene, Plesiotype. ×14.

Fig. 2.—*L. sumatrensis* (Brady) var. *mirabilis* Yabe and Hanzawa, Cross section. Batesford, Victoria, Lower Miocene. ×17.

Fig. 3.—*L. martini* Schl. var. *mirabilis* Yabe and Hanzawa. Cross section, No. 15 Bore, Parish of Stradbroke, Victoria. Lower Miocene. ×14.

Fig. 4.—*Spiroclypeus margaritatus* (Schl.). Limestone showing test in vertical section. Hamilton Bore, Victoria, 35-36 feet. Lower Miocene. ×17.

Fig. 5.—*S. margaritatus* (Schl.). Section of limestone showing numerous tests of the species. Tumleo Island, Aitape Area, New Guinea. Lower Miocene. ×6.

Fig. 6.—*Miogypsina mamillata* Yabe and Hanzawa. Section of limestone from No. 7 Bore, Matapau, New Guinea. Middle Miocene. Plesiotype. ×19.

Fig. 7.—*M. saitoi* Yabe and Hanzawa. Section of limestone from Mabam River, Matapau, New Guinea. Middle Miocene. Plesiotype. ×19.

Plate XII.

Fig. 8.—*Lepidocyclina hamiltonensis*, sp. nov. Hamilton Bore, Victoria, 48-53 feet. Lower Miocene. Holotype. ×17.

Fig. 9.—*L. hamiltonensis*, sp. nov. Median section. Hamilton Bore, 68-80 feet. Lower Miocene. Tectotype. ×15.

Fig. 10.—*L. hamiltonensis*, sp. nov. Vertical section. Hamilton Bore, 36-38 feet. Lower Miocene. Tectotype. ×21.

Fig. 11.—*L. martini* Schl. No. 15 Bore, Parish of Stradbroke, Victoria, 45 feet. Lower Miocene. Plesiotype. ×15.

Fig. 12.—*L. martini* Schl. No. 5 Bore, Parish of Glencoe, Victoria, 80 feet. Lower Miocene. Plesiotype. ×14.

Fig. 13.—*L. martini* Schl. No. 15 Bore, Parish of Stradbroke, Victoria, 45 feet, Lower Miocene. Median section. ×14.

Fig. 14.—*L. martini* Schl. No. 15 Bore, Parish of Stradbroke, Victoria, 45 feet. Lower Miocene. Vertical section. ×14.

Plate XIII.

Fig. 15.—*Lepidocyclina radiata* (Martin). No. 5 Bore, Parish of Glencoe, Victoria, 70 feet. Lower Miocene. Plesiotype. ×17.

Fig. 16.—*L. radiata* (Martin). No. 15 Bore, Parish of Stradbroke, Victoria, 45 feet. Juvenile stage. Lower Miocene. ×15.

Fig. 17.—*L. radiata* (Martin). No. 15 Bore, Parish of Stradbroke, Victoria, 45 feet. Lower Miocene. Tectotype. ×17.

Fig. 18.—*L. howchini*, sp. nov. Hamilton Bore, Victoria, 80-85 feet. Lower Miocene. Holotype. ×17.

Fig. 19.—*L. howchini*, sp. nov. Vertical section. Hamilton Bore, Victoria, 68-80 feet. Lower Miocene. Tectotype. ×17.

ADDENDUM.

Since publishing the record of the age of the foraminiferal genus *Victoriella* (These Proceedings, vol. XLII, pt. II-1930, p. 110-112) further researches have shown that the range of this important zone fossil is from Upper Oligocene to Lower Miocene, but that it is more characteristic of the Upper Oligocene, as found at Dartmoor, the Torquay boring, and borings in the Gippsland area.

[Proc. Roy. Soc. Victoria, 44 (N.S.), Pt. I, 1932.]

Art. VIII.—*Two New Australian Fossil King-Crabs.*

By FREDERICK CHAPMAN, A.L.S., F.G.S., etc.
(Commonwealth Palaeontologist),

(With Plate XIV.)

[Read 9th July, 1931; issued separately 29th February, 1932.]

The two fossil forms belonging to the orders Xiphosura and Synxiphosura, are herewith described as new to Australia. One of these is a new generic type, *Pincombella,* of Permian age, and the other a new species of the Silurian genus *Hemiaspis.* The species from the Permian (Belmont beds) of New South Wales, viz., *Pincombella belmontensis,* is a small, but interesting predecessor of the living King-Crabs, and allied to the Carboniferous *Belinurus.* This specimen was left with me at the National Museum on the 15th January, 1924, by the late Mr. T. H. Pincombe, who expressed his desire that I should describe it. This description has unfortunately been delayed until now, owing to a lack of some necessary literature dealing with this group.

The second fossil specimen belongs to the Synxiphosura, an order which contains only Silurian genera, with the one Cambrian exception (*Aglaspis*). The genus to which this second specimen belongs is *Hemiaspis,* of which four species are known from the Silurian of Scotland.

The present species, *Hemiaspis tunnecliffei,* was found by Master T. Tunnecliffe, and I am indebted to Prof. Skeats for kindly handing it to me for description.

Phylum ARTHROPODA.

Class ARACHNIDA.

Sub-Class MEROSTOMATA.

Order XIPHOSURA.

Family BELINURIDAE.

Genus **Pincombella,** gen. nov.

Description of *Pincombella,* gen. nov. Cephalic shield more roundly ovate than in *Belinurus,* and having the anterior margin spinous instead of evenly rounded; posterior angles terminating in blunt spines, whereas in *Belinurus* they are produced. Abdominal segments spinose, 5, as against 8 in *Belinurus.* Telson long.

PINCOMBELLA BELMONTENSIS, sp. nov.

(Plate XIV, Figs. 1-3.)

Description (based on the ventral aspect).—Carapace with the cephalothorax broadly ovate, narrowing in the abdominal region and terminating in a long spine-like telson. The broadest part is measured across the medium lateral angles of the cephalothorax. Anterior border of cephalothorax bluntly and numerously spinose, thin in texture and with the peripheral region marked out by a definite rust-stained impression. Area of genal angles sub-rounded or bluntly angular. Median line of cephalothorax fairly well defined, with vestiges of basal joints of ambulatory appendages visible; two of the minute chelate claws are seen protruding across the upper left ventral margin. Opercular plates stout, oblong and divergent posteriorly; colour of a rich plum-brown, and with the surfaces finely granular. Five abdominal segments visible, the anterior transversely quadrate, the 2nd, 3rd, 4th low and narrow, the 5th posterior quadrate and bispinose behind; telson long, slender and acuminate, about five times the length of the last posterior segment.

Dimensions.—Length of carapace without spine, 11 mm. Length of cephalothorax, 8 mm. Width of cephalothorax, 13 mm. Spine, 5 mm. Total length, 16 mm.

Affinities.—The relationships of the present genus *Pincombella* lie with the limuloids rather than with the Synxiphosura (*Hemiaspis*), for the abdominal segments are greatly reduced in the present fossil, amounting to only 5 narrow divisions. It partakes somewhat of the characters seen in *Palaeolimulus*, Dunbar (C. O. Dunbar, 1923, p. 443), of the Permian of Kansas, but the abdominal segments in that genus are more numerous and rigid, whilst the cephalothoracic shield is produced posteriorly into sharp genal spines.

The sub-ovate shape of the cephalic shield resembles *Prestwichia,* where, however, the abdominal segments number eight. Possibly the relationship of *Pincombella* is nearest to *Belinurus,* of the Upper Old Red Sandstone and Coal measures of Great Britain and Northern France, another form of which genus is also found in the coal measures of Illinois, U.S.A. In that genus the carapace is lower, with prominent genal angles. The opercular plates are of much the same character and disposition, whilst the abdominal segments (8 in *Belinurus* and 5 in *Pincombella*) are similarly spinose. Both have also a very long and slender telson.

The true form of *Limulus* first appears in the Trias (Bunter Sandstone of the Vosges), so that the present Permian genus is an additional and important link with the earlier, Carboniferous limuloids.

Locality and Horizon.—Belmont Fossil Bed, 2 miles on Newcastle side of Belmont, N.S.W. Collected by T. H. Pincombe, Esq., and presented to the National Museum, 15th January, 1924.

Order SYNXIPHOSURA.

Sub-Order BUNODOMORPHA.

Family HEMIASPIDAE.

Genus **Hemiaspis** H. Woodward.

HEMIASPIS TUNNECLIFFEI, sp. nov.

(Plate XIV, Figs. 4, 5.)

Description.—Head-shield low and probably broad when complete; anterior border arcuate, marked with radiating lines. Glabella obscurely subquadrate. Thoracic segments low and narrow, probably numbering six in complete carapace, with marginal spine on each extremity. Median axis rounded, lobed on each segment of thorax. Abdominal somites contracted, probably subquadrate. Telson wanting.

Dimensions.—Length from anterior margin of head-shield to abdominal extremity, 50 mm. Length of head-shield, 15 mm.; width, circ. 36 mm. Length of thoracic series, 27 mm. Length of abdominal somites, 8 mm. The specimen is crushed along the median axis. A carbonaceous stain on the surface of the fossil with the exception of the anterior rim of the head-shield emphasises the surface structure to some extent, by defining the sutures and rendering the lateral margins more distinct.

Affinities.—Apparently the first recorded member of the family *Hemiaspidae* in Australia, this interesting fossil shows the nearest relationship to *Hemiaspis limuloides* H. Woodward (1865, p. 490, pl. xiv, fig. *7a-c*) of the Silurian (Lower Ludlow) Leintwardine, Shropshire, England.

Locality and Age.—Road cutting, Studley Park, Kew, Melbourne, Victoria. Silurian. (Melbournian). Found by Master T. Tunnecliffe, Fitzroy, Melbourne. Type in museum of Geology School, Melbourne University. Reg. No. 1801.

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Explanation of Plate XIV.

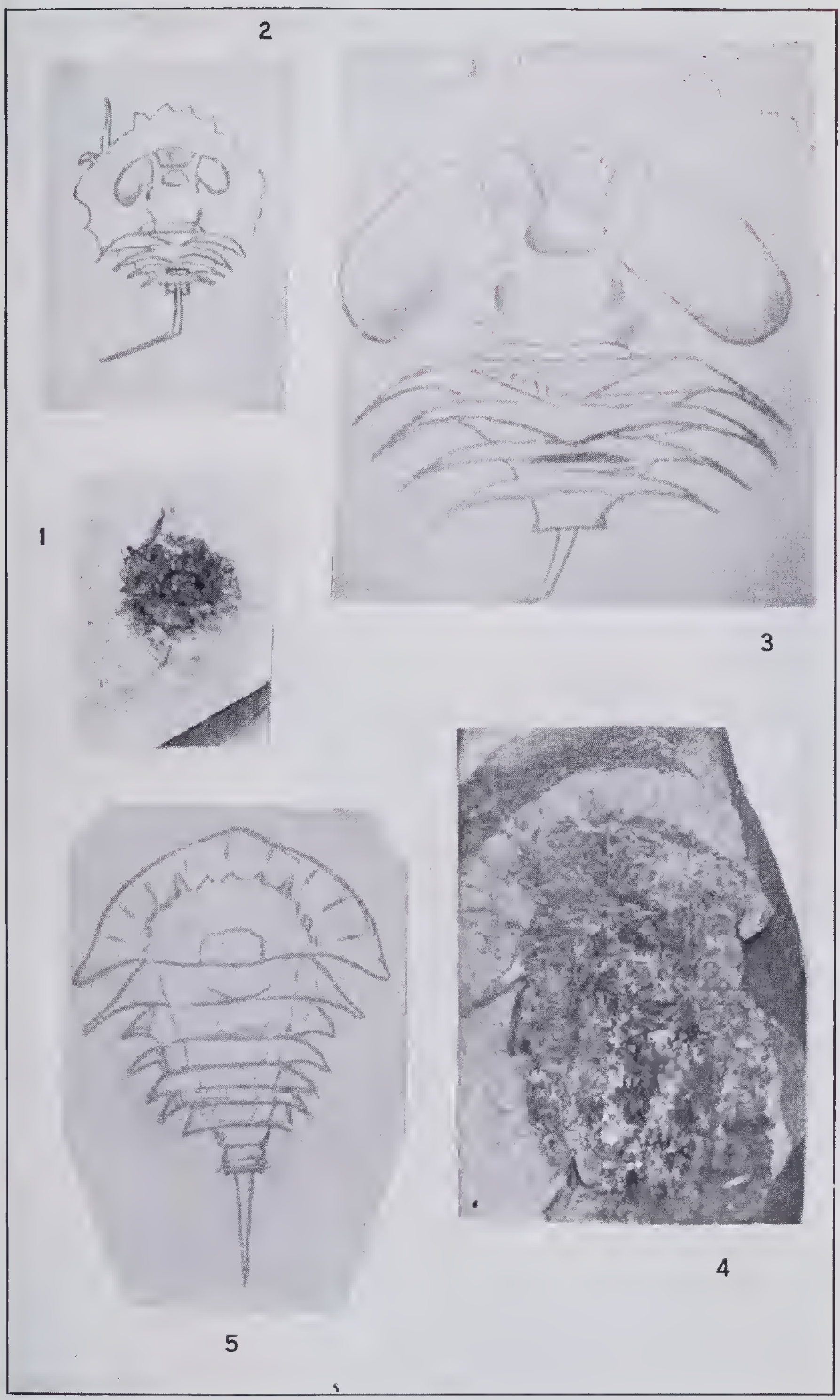
Fig. 1.—*Pincombella belmontensis,* gen. et sp. nov. Photograph of carapace, ventral aspect. Permian. Belmont, near Newcastle, New South Wales. ×1½.

Fig. 2.—Ditto. Restored outline of fossil. ×2½.

Fig. 3.—Ditto. Enlarged outline of portion of carapace. ×6½.

Fig. 4.—*Hemiaspis tunnecliffei,* sp. nov. Photograph of carapace. Probably dorsal aspect. Silurian. Studley Park, Kew, Melbourne. × circ. 1½.

Fig. 5.—Ditto. Restoration of fossil, circ. nat. size.



F.C. Photo

Fossil King-Crabs from Australia.

[Proc. Roy. Soc. Victoria, **44** (N.S.), Pt. II., 1932.]

Art. IX.—*Studies in Australian Spiders, No. 2.*

By L. S. G. BUTLER.

[Read 8th October, 1931; issued separately 20th April, 1932.]

Introduction.

This paper deals with seven small new spiders, which have been collected by Mr. C. Oke, of St. Kilda. Six new genera have been erected, and the genus *Tetrablemma* is now added to the Australian list. Some of these new genera have been placed tentatively in existing sub-families, but the examination of further new specimens may necessitate their removal.

Savory's statement(3) that the Amazon spider *Ogulnius obtectus,* 1.0 mm. in length, is the smallest known, has been refuted by the discovery of *Microlinypheus bryophilus,* gen. et sp. nov., which measures male 0.6 mm., female 0.8 mm.

The following details are worthy of notice:—*Plectochetos longissimus,* gen. et sp. nov., has an extraordinary male tarsal organ; *Eterosonycha alpina,* gen. et sp. nov., has different claws on the fourth tarsi from the other tarsi; *Perissopmeros castaneous,* gen. et sp. nov., reveals uncommon coxae; *M. bryophilus* has one joint absent from the pedipalp; *Tetrablemma okei,* sp. nov., has four eyes and illustrates the primitive condition of segmentation. *T. okei* is the third record of the genus; it was originally described from Ceylon in 1873(1) (not 1870 as in Simon's(4) and Petrunkevitch's(2) works).

Unfortunately the biology of these seven spiders is unknown.

The type of *Alaxchelicera ordinaria,* gen. et sp. nov., is mounted in balsam on a glass slip; the remainder have been hermetically sealed in glass tubes. All have been presented to the National Museum, Melbourne.

Family LINYPHIIDAE.

Sub-Family LOPHOCARENINAE.

Genus **Microlinypheus,** gen. nov.

Eyes eight, heterogeneous, in two rows of four, both lines recurved. Pedipalps, patella wanting. Chelicera, anterior margins furnished with strong spines. Abdomen, dorsal surface completely covered with scuta; spinnerets surrounded with a chitinized circular wall.

Genotype. *M. bryophilus.*

MICROLINYPHEUS BRYOPHILUS, gen. et sp. nov.

(Text-fig. 1, Nos. 1-7.)

Female.

Total length of specimen preserved in 60% alcohol 0.8 mm. Length of cephalothorax to overhang of abdomen 0.3 mm. Breadth of cephalothorax 0.28 mm. Length of abdomen 0.5 mm. Breadth of abdomen 0.48 mm. Length of chelicera 0.13 mm. Breadth of chelicera 0.09 mm. Length of claw of chelicera 0.08 mm. Width of ocular area 0.16 mm.

Cephalothorax.—Longer than broad, strongly convex, broadly curved in front and gradually widening to the broadest part, which is situated at the position of the third pair of legs. Frontal view of head pyriform; ocular area well forward; from frontal view the eyes are placed centrally. Clypeus vertical, twice as broad as high. Thorax sloping abruptly down from the head to the pedicel. The cervical groove is well defined, radical furrows are present. On the head a central longitudinal furrow is present, this is bisected by a lateral groove.

Eyes.—Eight, heterogeneous, A.M.E. alone diurnal, all circular and hyaline, evenly spaced in two rows of four, both lines recurved, anterior line more strongly so; when viewed from the front they curve downwards. P.M.E. largest. A.M.E. 0.02 mm. P.M.E. 0.027 mm. A.L.E. 0.02 mm. P.L.E. 0.02 mm. Spacing of posterior eyes 0.02 mm. Anterior eyes 0.01 mm.

Chelicera.—Small, smooth, marginal furrow not dentated but furnished with a few strong spines; boss and stridulating ridges apparently wanting. Claw of chelicera small.

Labium.—Free, broader than long.

Endites.—Broader than long, inner margins tapering to a blunted point. The serrula has seventeen teeth.

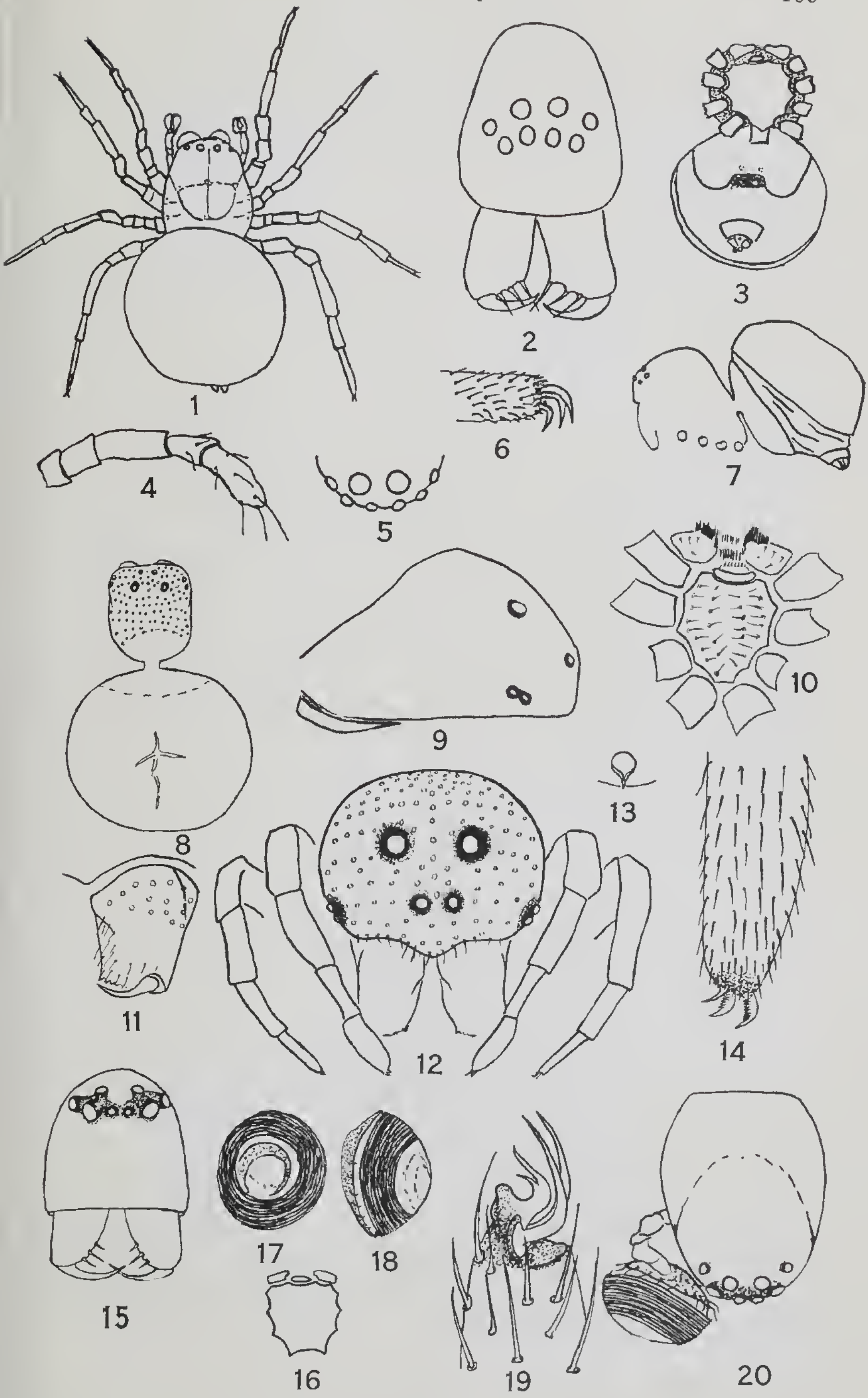
Sternum.—Slightly broader than long, somewhat cordate shaped.

Explanation of Fig. 1.

1–7.—*Microlinypheus bryophilus,* sp. nov. 1, Dorsal view of male. 2, Frontal view of male. 3, Ventral view of female. 4, Pedipalp of female. 5, Eyes of male. 6, Tarsus showing claws. 7, Profile of female.

8–14.—*Platycephala punctata,* sp. nov. 8, Dorsal view. 9, Profile of cephalothorax. 10, Sternum. 11, Chelicera. 12, Frontal view of cephalothorax. 13, Epigynum. 14, Tarsus showing claws.

15–20.—*Plectochetos longissimus,* sp. nov. 15, Frontal view of cephalothorax. 16, Sternum. 17, Tarsal bulb of male pedipalp, front view. 18, same, side view. 19, Tarsus showing claws. 20, Dorsal view of cephalothorax showing one pedipalp.



Text-figure 1.

Pedipalps.—Short, five jointed; the patella is missing. The tarsus has no claw but a few strong hairs are present.

Legs.—Small and nimble, trichobothria and scopulae missing, sparsely clothed with hairs: on the tarsi the hairs are thicker. Three claws, smooth, not dentated, but where the teeth are generally situated there are a few fine serrations present. Formula, $\overline{134}.2$.

Leg.	Coxa.	Trochanter.	Femur.	Patella.	Tibia.	Metatarsus.	Tarsus.	Total Length.
1 ..	·08	·04	·20	·08	·12	·08	·12	·72
2 ..	·08	·04	·16	·08	·12	·08	·14	·70
3 ..	·08	·04	·22	·06	·12	·08	·12	·72
4 ..	·06	·04	·22	·04	·16	·10	·10	·72
Pedipalp	·01	·03	·047	..	·03	..	·045	·162

Abdomen.—Globular. Dorsal surface completely covered with a faintly granulated scuta. Ventral scuta smaller, the posterior edge has two outer curves connected in the centre by a straight line. Dorsal and ventral scutae connected by a soft integument, visible only when the abdomen is swollen.

Epigynum.—A pair of circular openings are situated near the posterior edge of the ventral scuta.

Spinnerets.—Small compact group, completely surrounded by a chitinized circular wall. Fore spinnerets largest, hind shorter, medians not visible.

Colulus.—Wanting.

Colour in alcohol.—Body rich chestnut-brown, legs slightly paler.

Male.

This corresponds to the female in nearly all the detail other than the reproductive organs. Total length 0.6 mm. The other measurements have the same smaller relation to the female.

Epigynum.—Simple slit-like.

Pedipalps.—Short; tarsal joint globular, small, with simple detail in the form of a small spiral.

Type locality.—Lorne, Victoria. January, 1928. Collected from moss by Mr. C. Oke. The moss was gathered by Mr. C. J. Gabriel.

Genus **Plectochetos**, gen. nov.

Eyes eight, heterogeneous, in two rows of four, both lines recurved. Clypeus steep and high. Tarsi three clawed, smooth, inferior claw one large tooth. Abdomen covered with a dorsal scuta; spinnerets surrounded with a chitinized circular wall. Tarsi of male pedipalp very large and globular, ejaculatory duct extremely long and spirally wound around the outer edge.

Genotype. *P. longissimus.*

PLECTOCHETOS LONGISSIMUS, gen. et sp. nov.

(Text-fig. 1, Nos. 15–20.)

Male.

Total length 0.94 mm. Length of cephalothorax 0.4 mm. Breadth of cephalothorax 0.36 mm. Length of abdomen 0.54 mm. Breadth of abdomen 0.6 mm. Height of cephalothorax (front view) 0.28 mm. Length of chelicera 0.12 mm. Width of ocular area 0.24 mm. Diameter of tarsal bulb on pedipalp 0.26 mm.

Cephalothorax.—Longer than broad; oval, truncated at rear. Frontal view of cephalothorax, sides nearly straight to eyes, then curving to vertex. Oscular area high. Clypeus steep, vertical, wider than high. Head strongly convex, situated well above the thorax and sloping down abruptly to the cervical groove. Thorax much lower, lightly convex.

Eyes.—Eight, evenly spread in two rows of four, both lines recurved, hyaline, glistening, surrounded with dark pigment. Laterals largest, slightly oval. Diameter of eyes, A.M.E. .02 mm. P.M.E. 0.04 mm. A.L.E. 0.05 mm. P.L.E. 0.05 mm. Separation of eyes P.M.E. 0.04 mm. A.M.E. 0.015 mm. P.M.E. and P.L.E. 0.03 mm. A.L.E. and P.L.E. 0.03 mm. A.L.E. and P.L.E. 0.01 mm.

Chelicera.—Small, smooth, superior margin furnished with a few strong spines. Claw of chelicera, medium, curved, and evenly tapered.

Labium.—Small, broader than long.

Endites.—Small, broader than long, tapering in front of the labium.

Sternum.—Longer than broad; front broadest, tapering a little to the posterior edge, which is wide and recurved.

Pedipalps.—Short, ending with an extremely large globular bulb. The cymbium is semi-elliptical; the upper two-thirds of the bulb is spirally grooved for the reception of the ejaculatory duct. This duct is exceptionally long and consists of about twenty turns, attached at the centre and entirely free elsewhere. This coiled duct can be pulled out in the manner of a spring, and when released it snaps back into its correct position on the grooved conductor. The duct is translucid, revealing a central channel throughout its entire length.

Legs.—Short and nimble. Three claws are present; superior claws smooth, long and evenly tapered; inferior claw short, thick and dentated with one large tooth. Formula, 4, 3, 1, 2.

Leg.	Coxa.	Trochanter.	Femur.	Patella.	Tibia.	Metatarsus.	Tarsus.	Total Length.
1 ..	·08	·04	·20	·14	·32	·08	·20	1·06
2 ..	·08	·04	·22	·12	·28	·09	·22	1·05
3 ..	·08	·06	·26	·12	·30	·10	·20	1·12
4 ..	·08	·06	·32	·12	·30	·10	·20	1·18

Abdomen.—Obovate, nearly circular. Spinnerets visible from above. Dorsal scuta present. Ventral epigastric plate with lateral edges curved, posterior edge slightly recurved with blunted projections each end.

Epigynum.—Simple, no detail visible.

Spinnerets.—Very short, surrounded by a chitinized circular wall.

Colulus.—Wanting.

Colour in alcohol.—Cephalothorax yellow-brown, with darker markings especially at the ocular area. Legs, chelicera, yellow-brown. Pedipalps yellow-brown; ejaculatory duct very dark brown. Abdomen, dorsal scuta yellow-brown, edges darker. Ventral epigastric plate rich brown; soft connecting integument ornamented with dark dotted ridges or bands.

Type locality.—Mt. Donna Buang, 4,080 feet, near Warburton, Victoria. February, 1931. Under logs and similar places. (C. Oke.)

The female is unknown.

Sub-Family ERIGONINAE.

Genus **Alaxchelicera,** gen. nov.

Eyes eight, homogeneous, in two rows of four, both rows recurved. Legs evenly clothed with hairs, scopulae and trichobothria wanting. The paracymbium, also the apophysis of the tibia of the male pedipalp, is wanting. Abdomen soft, scuta wanting.

Genotype. *A. ordinaria.*

Alaxchelicera ordinaria, gen. et sp. nov.

(Text-fig. 2, Nos. 14–17.)

Female.

Total length 0.9 mm. Length of cephalothorax to overhang of abdomen, 0.42 mm. Breadth of cephalothorax 0.32 mm. Length of abdomen 0.40 mm. Breadth of abdomen 0.40 mm.

Cephalothorax.—Longer than broad, obovate, anterior portion narrowest. Head strongly convexed, central furrow present. Ocular area well forward. Clypeus broad, steep. Thoracic and cervical grooves scarcely visible. Thorax lightly convexed.

Eyes.—Eight, homogeneous, hyaline, in two recurved rows of four. Posterior row more widely separated than the anterior row. Frontal view, anterior row straight, posterior row curving downwards. Measurements of eyes, A.M.E. 0.022 mm. P.M.E. 0.035 mm. A.L.E. 0.03 mm. P.L.E. 0.035 mm.

Chelicera.—Small, superior margin four teeth; inferior margin three teeth. Claw small and fine.

Labium.—Hidden.

Endites.—Partially hidden, scopulated.

Sternum.—Oval, closely following the lines of the coxae and broadly separating the hind coxae.

Pedipalps.—Hidden.

Legs.—Short, evenly clothed with hairs, bristles or spines on fourth tibia wanting. Three claws, superiors finely dentated, inferior claw smooth. Trichobothria wanting. Formula, 4, 2, 3, 1.

Leg.	Coxa.	Trochanter.	Femur.	Patella.	Tibia.	Metatarsus.	Tarsus.	Total Length.
1 ..	·12	·05	·44	·14	·20	·16	·20	1·31
2 ..	·12	·08	·44	·16	·36	·26	·24	1·66
3 ..	·10	·08	·34	·12	·40	·20	·18	1·42
4 ..	·12	·10	·42	·14	·42	·32	·28	1·80
Pedipalp	·06	·05	·16	·08	·06	..	·08	·49

Abdomen.—Oval. Epigastric plate with three small apertures near the epigynum, posterior edge of the plate recurved with short blunt projections at each end; the lateral edges curve out broadly to the anterior portion of the abdomen.

Epigynum.—Simple slit-like.

Spinnerets.—Short, small compact group.

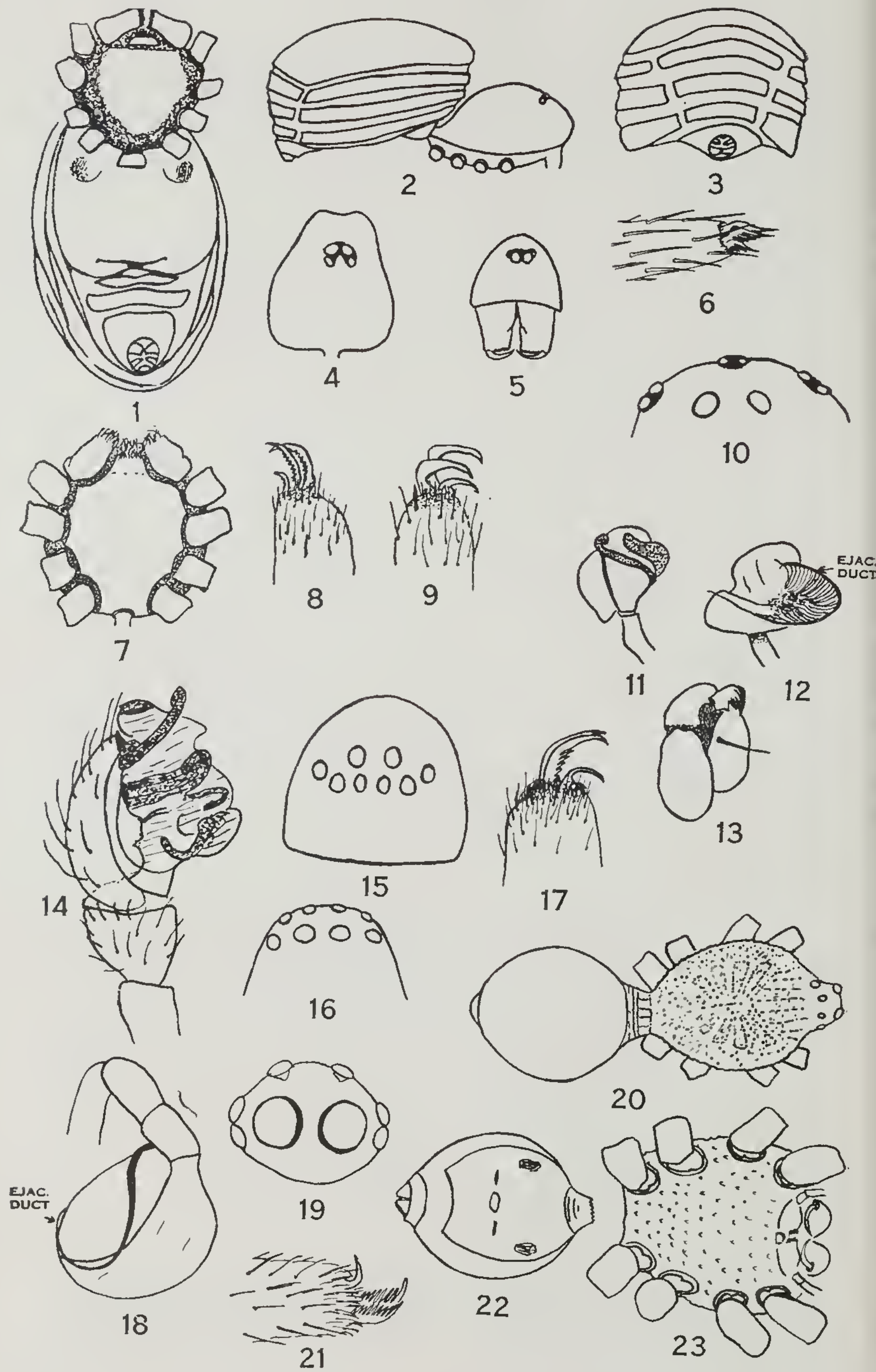
Colulus.—Very small, possibly wanting.

Colour in alcohol.—Cephalothorax and appendages brown; abdomen dark grey with lighter markings.

Male.

This corresponds to the female in nearly all the detail other than the following. Measurements approximately the same.

Chelicera.—Very fine stridulatory ridges. Female not examined for the same.



Text-figure 2.

Pedipalps.—Short. Tarsal bulb small when contracted, when extended the following detail can be observed:—The terminal apophysis, also the three divisions of the bulb and its various detail, is visible. The apophysis of the tibia and the paracymbium are wanting. On the inside edge of the femur corresponding to the position of the stridulatory ridges of the chelicera a small blade or ridge can be noticed.

Type locality.—Lorne, Victoria. January, 1928. Collected from moss by Mr. C. Oke. The moss was gathered by Mr. C. J. Gabriel.

Family OONOPIDAE.

Sub-Family GAMASOMORPHINAE.

Genus **Tetrablemma** O. P. Cambridge.

(*Proc. Zool. Soc. London*, 1873, p. 114.)

TETRABLEMMA OKEI, sp. nov.

(Text-fig. 2, Nos. 1–6.)

Female.

Total length, 1.27 mm. Length of cephalothorax, 0.5 mm. Length of cephalothorax to overhang of abdomen, 0.4 mm. Breadth of cephalothorax, 0.42 mm. Length of abdomen, 0.87 mm. Breadth of abdomen, 0.62 mm. Length of chelicera, 0.18 mm. Breadth of chelicera, 0.1 mm. Length of claw of chelicera, 0.07 mm.

Cephalothorax.—Longer than broad, convex, anterior edge slightly hollowed in centre; lateral edges curved and wider at rear; cervical and thoracic grooves hardly visible. Ocular area compact, central. Thorax sloping abruptly to rear. Carapace faintly marked with fine granulations and clothed with a few coarse hairs.

Explanation of Fig. 2.

1–6.—*Tetrablemma okei*, sp. nov. 1, Ventral view. 2, Profile. 3, Posterior view of abdomen. 4, Dorsal view of cephalothorax. 5, Frontal view of cephalothorax. 6, Tarsus showing claws.

7–13.—*Eterosonycha alpina*, sp. nov. 7, Sternum of female. 8, Claws of fourth tarsus. 9, Claws of first, second or third tarsi. 10, Eyes of female viewed from above. 11, Tarsul bulb of male pedipalp, dorsal view. 12, same ventral view. 13, same frontal view.

14–17.—*Alaxchelicera ordinaria*, sp. nov. 14, Tarsal bulb of male pedipalp. 15, Frontal view of cephalothorax. 16, Eyes of female viewed from above. 17, Tarsus showing claws.

18-23.—*Perissopmeros castaneous*, sp. nov. 18, Tarsal bulb of male pedipalp, front view. 19, Frontal view of eyes. 20, Dorsal view. 21, Tarsus showing claws. 22, Ventral view of abdomen. 23, Ventral view of cephalothorax.

Eyes.—Four, in two straight rows evenly situated from anterior and lateral edges of the carapace. Anterior eyes largest, sub-contiguous; posterior eyes separated by a distance of 0.04 mm. All elliptical, hyaline. A.E. pale greenish-pearl; P.E. clear. A.E. 0.05 mm. P.E. 0.45 mm. All eyes are surrounded and connected by dark pigment.

Chelicera.—Small, claw feeble.

Labium.—Free, broader than long, scopulated.

Endites.—Converging, longer than broad, scopulated, straight at apex, broad and curved at base.

Sternum.—Convex, longer than broad, separating the posterior coxae; main area slightly raised and granulated. The coxa of each leg is completely surrounded by extensions of the sternum; the outer edge of the sternum meets the lower edge of the dorsal carapace in a faint straight line.

Pedipalps.—Small and feeble, clothed with a few coarse hairs; claw missing.

Legs.—Moderate, clothed with a few coarse hairs; trichobotharia and scopulae missing. Three claws, superior pair dentated with long fine teeth; inferior claw smaller and similarly dentated. Formula, 4, 1, 2, 3.

Leg.	Coxa.	Trochanter.	Femur.	Patella.	Tibia.	Metatarsus.	Tarsus.	Total Length.
1 ..	·13	·05	·27	·10	·26	·20	·20	1·20
2 ..	·10	·05	·20	·08	·24	·16	·18	1·01
3 ..	·09	·05	·12	·09	·20	·16	·18	·89
4 ..	·12	·05	·24	·11	·32	·20	·20	1·24
Pedipalp	·04	·04	·10	·08	·06	..	·06	·38

Abdomen.—Obovate, overhanging the cephalothorax. Dorsal chitinous scuta present. Lateral and posterior edges steep. Three longitudinal and three posterior transverse bands divide and segment the steep edges of the abdomen.

Anterior ventral scuta meets the epigastric furrow, two dark patches are situated each side of the pedicel. The posterior edge of this ventral shield curves past the spiracles and inwards to the epigynum; a shaped transverse band is connected here. At the rear of this band a curved transverse plate is located, and further back is a chitinous conical wall, flattened anteriorly; this wall encircles the spinnerets.

Epigynum.—Simple slit-like; the nearby markings have no relation to the structure of this organ.

Spinnerets.—Small and short, fore largest, hind smallest, medians possibly wanting.

Colulus.—Wanting.

Colour in alcohol.—Around the eyes piceus, elsewhere light chestnut-brown.

Type locality.—Bairnsdale, Victoria. June, 1930. Under the bark of a eucalypt. (C. Oke.)

The male is unknown.

Family ZODARIIDAE.

Sub-Family ZODARIINAE.

Genus **Platycephala,** gen. nov.

Eyes.—Eight, in two rows, anterior row recurved, posterior row slightly procurved nearly straight. Scopulae wanting on tarsi; claws three, dentated. Cephalothorax broad in front, lateral edges parallel. Spinnerets rosette shaped.

Genotype. *P. punctata.*

Platycephala punctata, gen. et sp. nov.

(Text-fig. 1, Nos. 8-14.)

Female.

Total length 3.2 mm. Length of cephalothorax 1.2 mm. Breadth of cephalothorax 1.0 mm. Length of abdomen 2.0 mm. Breadth of abdomen 2.2 mm. Length of chelicera 0.44 mm. Breadth of chelicera 0.40 mm. Length of claw of chelicera 0.2 mm. Width of ocular area 0.96 mm.

Cephalothorax.—Longer than broad, broadly convex, front edge square blunted at corners; lateral edges straight, parallel; posterior edge semi-spherical. Frontal view somewhat oval with a small projection between the chelicera; head sloping abruptly upwards to the centre of the cephalothorax. Cervical groove just visible at the lateral edges. Ocular area well spread. Carapace punctuated, punctures evenly spread in an irregular pattern, posterior portion of thorax smooth. Thorax sloping downwards abruptly to rear. Epimera, a narrow tapering band at rear only. Clypeus broad, lower edge fringed with a row of hairs.

Eyes.—Eight, well separated in two rows of four. Anterior row recurved, posterior row slightly procurved nearly straight. All hyaline and encircled with heavy black pigment. P.M.E. largest. Laterals sub-contiguous. Diameter of eyes, A.M.E. 0.05 mm. P.M.E. 0.08 mm. A.L.E. 0.04 mm. P.L.E. 0.04 mm. Separation of eyes, A.M.E. 0.09 mm. P.M.E. 0.32 mm. Spacing between the eyes, P.M.E. and P.L.E. 0.39 mm. A.M.E. and A.L.E. 0.34 mm. P.M.E. and A.M.E. 0.24 mm.

Chelicera.—Small, faint boss present, upper portion punctated, lower inner portion clothed with a few scattered hairs. Inferior margin two large and about five small teeth, superior margin hairs. Claw medium.

Labium.—Four times broader than long, well curved.

Endites.—Broader than long, inner and portion of anterior edge scopulated. Serrulae present.

Sternum.—Longer than broad, clothed with scattered adpressed hairs.

Pedipalps.—Short, sparsely clothed with hairs, tarsi more thickly so, ending with a pectinated claw.

Legs.—Medium. Tarsi three clawed, superiors strongly dentated, inferior claw nearly smooth; clothing as on pedipalps. Formula 1, 2, 4, 3.

Leg.	Coxa.	Trochanter.	Femur.	Patella	Tibia.	Metatarsus.	Tarsus.	Total Length.
1 ..	·42	·14	·60	·32	·36	·34	·28	2·46
2 ..	·28	·10	·60	·32	·36	·30	·32	2·28
3 ..	·18	·06	·40	·12	·42	·12	·20	1·50
4 ..	·20	·10	·70	·30	·45	·20	·24	2·19
Pedipalp	·05	·05	·14	·10	·16	..	·20	·70

Abdomen.—Globular.

Epigynum.—Small, circular, with a pointed projection at rear.

Spinnerets.—Small, rosette shaped. Fore largest, hind smaller, medians very small and hidden.

Colulus.—Very small.

Colour in alcohol.—Cephalothorax, chelicera, sternum, legs, pale brown. Eyes encircled with black pigment. Abdomen, dorsal view, granulated pattern in a creamy white with a central pattern showing the underlying integument of a light greenish-grey. Ventral view light greenish-gery.

Type locality.—Mount Macedon district, Victoria. April, 1929. (C. Oke.)

The male is unknown.

Genus **Eterosonycha,** gen. nov.

Eyes.—Eight, homogeneous, in two rows; anterior row recurved, posterior row procurved nearly straight. Anterior medians small and sub-contiguous, laterals similar. Tarsi, scopulae wanting; claws three, smooth; fourth tarsus only, claws finely dentated.

Genotype. *E. alpina.*

ETEROSONYCHA ALPINA, gen. et sp. nov.

(Text-fig. 2, Nos. 7–13.)

Female.

Total length 1.14 mm. Length of cephalothorax 0.52 mm. Length of cephalothorax to overhang of abdomen 0.46 mm. Breadth of cephalothorax 0.36 mm. Length of abdomen 0.68 mm. Breadth of abdomen 0.58 mm.

Cephalothorax.—Elliptical, lateral edges slightly constricted well forward; cervical groove just visible. Ocular area well spread. Head strongly convexed. Thorax much lower, slightly convexed.

Eyes.—Eight, homogeneous, in two rows of four; anterior row recurved; posterior row slightly procurved, nearly straight. P.M.E. largest, A.M.E. smallest, A.M.E. 0.03 mm. circular sub-contiguous. Laterals 0.035 mm. sub-contiguous slightly elliptical. P.M.E. 0.04 mm. + 0.03 mm. A.M.E. and laterals surrounded by a dark pigment; all eyes pale greenish-pearl in colour. Separation of eyes, P.M.E. 0.03 mm. P.M.E. and P.L.E. 0.05 mm. A.M.E. and A.L.E. 00.4 mm.

Chelicera.—Small, claw feeble.

Labium,—Immobile, scopulated.

Endites.—Converging, well separated at apex, broad at base; scopulated.

Sternum.—Longer than broad, broadly separating the posterior coxae.

Pedipalps.—Small, tarsi clothed with a few coarse hairs; claw wanting.

Legs.—Moderate, lightly clothed with hairs, trichobothria and scopulae wanting. Fourth tarsus three claws, set with fine saw-like teeth; other tarsi, three claws sharply hooked and smooth. Formula, 1, 4, 3, 2.

Leg.	Coxa.	Trochanter.	Femur.	Patella.	Tibia.	Metatarsus.	Tarsus.	Total Length.
1 ..	·10	·04	·28	·08	·28	·11	·20	1·09
2 ..	·08	·04	·16	·09	·16	·10	·18	0·81
3 ..	·08	·04	·24	·10	·20	·16	·12	0·94
4 ..	·08	·04	·24	·11	·22	·12	·20	1·01
Pedipalp	·04	·02	·08	·04	·05	..	·05	0·28

Abdomen.—Obovate, tapering to the spinnerets, slightly overhanging the cephalothorax; a small epigastric plate is present with raised and curved chitinous pattern centrally placed.

Epigynum.—Simple slit-like.

Spinnerets.—Small rosette shaped.

Colulus.—Wanting.

Colour in alcohol.—Cephalothorax and appendages light rich yellow brown; sternum dark brown; eyes surrounded with black pigment. Abdomen dark-greenish black with a pattern of curved stripes in fawn and brown spots. This pattern is more strongly marked on the ventral view.

Male.

Measurements and other detail similar to female other than the reproductive organs.

Pedipalps.—Large, bulbous, complex in detail. The ejaculatory duct is not entirely free, but is connected to the bulb for part of its length by a striated translucent tissue.

Type locality.—Mt. Kosciusko, New South Wales. January, 1931. In sphagnum moss. (C. Oke.)

Genus **Perissopmeros,** gen. nov.

Eyes.—Eight, heterogeneous, in two rows of four, both rows recurved. A.M.E. largest and alone diurnal. Thoracic and cervical grooves present. Dorsal and ventral scutae present. Claws three. Coxae of legs, outer portion swollen, base narrow and straight. Sternum completely surrounds the coxa of each leg. Spinnerets surrounded by a chitinized circular wall.

Genotype. *P. castaneous.*

PERISSOPMEROS CASTANEOUS, gen. et sp. nov.

(Text-fig. 2, Nos. 18–23.)

Male.

Total length 2.84 mm. Length of cephalothorax 1.32 mm. Breadth of cephalothorax 0.8 mm. Length of abdomen 1.32 mm. Breadth of abdomen 0.8 mm. Length of pedicel 0.2 mm.

Cephalothorax.—Longer than broad, convex, oval with an anterior prolongation. Head.—Strongly elevated and projecting forwards. Cervical groove present, but not sharply defined. Thoracic grooves and radical striae present. Thoracic punctations forming the positions of the grooves and striae; lateral edges covered with small aculate processes. Clypeus.—Steep, slightly higher than broad.

Pedicel.—Broad and strong, punctated.

Eyes.—Eight, heterogeneous in two rows of four, both rows recurved. A.M.E. largest and alone diurnal. Laterals contiguous. Diameter of eyes, A.M.E. 0.12 mm. P.M.E. 0.075 mm. A.L.E. 0.08 mm. P.L.E. 0.08 mm. Separation of eyes, A.M.E. 0.05 mm. P.M.E. 0.10 mm. P.M.E. and P.L.E. 0.06 mm.

Chelicera.—Small, claw small.

Labium.—Small.

Endites.—Vertical curving inwards, lightly scopulated.

Sternum.—Convex, covered with small aculate processes; completely surrounding the coxa of each leg and meeting the dorsal carapace in a straight line.

Pedipalps.—Short, tarsal bulb large, smooth, and fairly simple. Ejaculatory duct about the length of the circumference of the bulb. Cymbium sparsely covered with fine hairs.

Legs.—Long, tarsi three clawed, superiors dentated with long even teeth. Coxae, outer portion bulbus, base narrow and straight; base of coxae longest on posterior coxae and graduating to shortest on anteriors. Formula 1, 4, 2, 3.

Leg.	Coxa.		Trochanter.	Femur.	Patella.	Tibia.	Metatarsus.	Tarsus.	Total Length.
	Base.	Main Portion.							
1 ..	·04	·38	·18	1·41	·40	1·32	1·00	·64	5·37
2 ..	·06	·32	·16	1·20	·39	·90	·60	·50	4·13
3 ..	·08	·26	·13	·88	·36	·68	·68	·40	3·47
4 ..	·09	·30	·16	1·32	·28	1·00	·88	·60	4·63
Pedipalp	·08		·04	·33	·16	·08	..	·40	1·09

Abdomen globular. Dorsal and ventral scutae, smooth; posterior edge of ventral scuta recurved.

Epigynum.—Simple opening situated near the centre of the ventral scuta.

Spinnerets.—Short, rosette shaped, fore pair largest. Encircled with a chitinized circular wall.

Colulus.—Wanting.

Colour in alcohol.—Rich chestnut brown. Integument on abdomen between scutae also joints of pedipalp light yellow. Dark patches at the position of the book-lungs.

Type locality.—Mt. Kosciusko, New South Wales. January, 1931. (C. Oke.)

The female is unknown.

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Art. X.—*Phosphatic Nodules in the Geelong District.*

By ALAN COULSON, B.Sc.

(With Plate XV.)

[Read 8th October, 1931; issued separately 20th April, 1932.]

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I. Introduction.

In July, 1930, my attention was drawn to the fact that, wherever an outcrop of the remanié phosphatic nodule bed occurs in the Geelong district, it invariably rests on Miocene limestones and beneath Lower Pliocene ferruginous sands. The nodules contain a characteristic fauna of which about 30 per cent. of the identifiable forms are crabs(5), and it soon became evident, that in the numerous outcrops, one was dealing with the same bed. The fact that it was a remanié bed occupying valleys in the Miocene limestone, in contrast with the concretionary nodules, embedded in that limestone, afforded a means of comparing methods of phosphatisation and necessitated an inquiry into the diastrophic phases and palaeogeography of the area.

II. Remanié Phosphatic Nodules.

The remanié bed, usually fairly horizontal, averages about 2 or 3 inches in thickness; the nodules are not cemented, the interstices being filled with a mixture of sand and quartz pebbles from the overlying ferruginous sands. About 95 per cent. of the fragments in the remanié bed are waterworn nodules of phosphatised sandy limestone, while the remainder includes abraded shells of Ostrea, Cardium, &c., shark's teeth, fragments of cetacean bone, and (at Curlewis) a few pebbles of Older Basalt.

The nodules are suboval with an average shorter axis of from 3 to 6 inches. Most of them are smooth on the outside; some, however, are coated with a white inflorescence; many are pitted. The exterior is usually of a cream or brown colour, but the interior is bluish-brown or grey, and of a fine granular texture. There is a definite relation between the colour and the degree of phosphatisation; hard black nodules contain up to 25 per cent. of P_2O_5, brown nodules about 12 per cent., and soft yellow nodules about 1 per cent. or less. Phosphatisation is not always uniform throughout a nodule, and one can distinguish concentric, oolitic, and irregular structures of varying richness.

Mr. J. G. Doyle determined P_2O_5 percentages in some remanié nodules with the following results:—

	Curlewis.	Batesford.	Baker's Bridge.
Relatively rich ..	24.60	20.62	—
Medium	18.59	—	12.15

Mr. J. C. Watson, of the Geological Survey Laboratory, made a complete analysis of a moderately phosphatic nodule from Curlewis, as follows:—

	per cent.
SiO_2	26.36
Al_2O_3	2.18
Fe_2O_3	7.49
MgO	1.31
CaO	30.64
H_2O above 110° C.	2.50
H_2O below 110° C.	0.98
CO_2	6.20
P_2O_5	18.59
TiO_2	0.36
	96.61

Sections of this rock examined under the microscope show that it was originally a sandy limestone or marl, the calcite in which has been almost entirely replaced by amorphous calcium phosphate. The replacement mineral is oolitic in part, and interstitial; it surrounds scattered small angular grains of quartz and dark-brown fragments of shells, tests of foraminifera and other shelly material. In the cavities of the darker shelly fragments were found opaque flakes of carbonaceous matter, and occasionally minute flakes of decolorised biotite. Apart from some small grains of calcite found in the interior of the globular foraminifera, very little calcite is present. On the other hand, in poorly phosphatic nodules, particles of crystalline calcite are fairly common.

The hard parts of crabs are common, and fish scales, cetacean bone, mollusca, polyzoa, and foraminifera fairly common in the nodules.[5] The associated shells are Ostrea, Cardium, and similar stout types; they are all more or less abraded. No true coprolites were found.

III. Concretionary Phosphatic Nodules.

A. M. Howitt[3] has recorded concretionary phosphatic nodules in soft Miocene limestone at Thompson's Creek, near Moriac, about 16 miles W.S.W. from Geelong. Similar concretionary nodules were found in many of the Miocene exposures near Geelong during the progress of these observations.

They are difficult to distinguish from the containing limestone, the exterior being of the same creamy colour and earthy appearance as the limestone. By fracturing them, however, their greater hardness and internal blue-brown to black colour afford a ready means of detection. They are usually spheroidal, from 2 to 9 inches in diameter, of granular texture, and contain fossils similar to those of the containing limestone.[5]

Often a fossil is found imbedded partly in the concretionary nodule and partly in the containing limestone. A cetacean fragment, a large gasteropod, or the hard parts of a crustacean often form the nucleus of a concretion.

The following estimations of the percentages of P_2O_5 in concretionary nodules were made by Mr. Doyle:—

	per cent.
Thompson's Creek	24.74
"Woodlands," near Moriac	23.40
Torquay, near Eagle Rock	11.01
Waurn Ponds	14.99
Western Beach, Geelong	17.40

In Howitt's paper[3] the percentages of P_2O_5 in three samples from Thompson's Creek were given as 22.6, 26.6, and 23.1.

The nodules are thus concentrates, and are chemically very similar to the remanié type—the richest contain about 26 per cent. of P_2O_5, the medium about 12 per cent., while the enveloping limestone has less than 1 per cent.

Microscopically these nodules are similar to the remanié type, consisting of amorphous calcium phosphate, calcite, quartz grains and carbonaceous matter, with fragments of shells and foraminifera.

IV. Method of Phosphatic Replacement.

The mechanism of the growth of concretions is not yet satisfactorily explained. In the present case, a decided concentration of phosphate has taken place, as the following table of P_2O_5 percentages in the dried skeletons of some common marine forms, likely to be present in the Miocene limestone, will show:—

—	1	2	3	4	5	6	7	8	9	10
P_2O_5 %	41·28	31·03	22·03	8·87	7·21	6·52	3·86	3·26	3·01	0·04

1. Brachiopod: Lingula. Analyst W. Wheeler(1).
2. Whale, Waurn Ponds. Analyst J. G. Doyle.
3. Mullet, Port Phillip. Analyst Hilda Kincaid(6).
4. Shark, Port Phillip. Analyst Hilda Kincaid(6).
5. Spider Crab: Lithodes. Analyst W. C. Wheeler(1).
6. Blue Crab: Callinectes. Analyst W. C. Wheeler(1).
7. Alcyonaria: Phyllogongia. Analyst W. C. Wheeler(1).
8. Lobster. Analyst W. H. Hudleston(4).
9. Crab. Analyst W. H. Hudleston(4).
10. Oyster. Analyst Hilda Kincaid(6).

With regard to the percentage of P_2O_5 in the flesh or muscle of these forms there is little information available, but it is unlikely to exceed 1 per cent. in any case. Hilda Kincaid(6) obtained the following figures for P_2O_5 in fresh muscle:—Mullet 0.51 per cent., Oyster 0.57 per cent., Lobster 0.33 per cent.

From the foregoing it appears that the source of the phosphate for the concretions has been the tri-calcic phosphate in the bones and shells of the fossils in the limestone. The solution of such basic phosphate, disseminated throughout a rock, might be brought about by carbonated ground water, especially if the latter contains NaCl or NH_4Cl. Bischoff(2) and Rama Rao(8) support this view. Doubtless the decomposition of the protein substances of the entombed forms, particularly burrowing crabs, would produce a certain amount of soluble phosphate, e.g., ammonium phosphate, which when in contact with a suitable calcareous shell would metasomatically replace the carbonate, as has been shown by Renard and Cornet.(7)

Proof that soluble phosphates exist in circulating ground waters was obtained by Mr. G. B. Hope at Demon's Bluff, on the coast about a mile east of the Anglesea River. Here the cliffs are 200 feet high, the surface beds consisting of Lower Pliocene ferruginous sands and gravels, the middle beds of Tertiary carbonaceous sands, and the lowest beds of carbonaceous marls. At certain places on the beach, seepages from the carbonaceous marls occur, and the water in these is highly phosphatic. Nodules of blue-green vivianite, about 3 inches in length, have formed at these seepages. One analysis showed 18.95 per cent. P_2O_5 and 26.21 per cent. Fe. The surrounding carbonaceous marl contains only 0.36 per cent. P_2O_5. Evidently here the carbonated ground waters dissolved the disseminated phosphate and it became concentrated at the beach level, thus forming the nodules of vivianite.

" The experimental work of Reese on the solubility of calcium phosphate has shown that it dissolves freely in swampy carbonated waters, especially in the presence of decaying organic matter. It is interesting to note that when such a solution is allowed to stand over calcium carbonate, the calcium phosphate is redeposited."[8]

The growth of the calcium phosphate cemented concretions in the Miocene limestones is therefore probably due to the replacement of the carbonate of the argillo-calcareous material surrounding the original nucleus, which is always of a phosphatic nature, e.g., a piece of cetacean bone, the hard part of a crab, or the like.

Replacement is clearly indicated by an analysis made by Mr. Doyle of a concretion taken from a marl pit between Waurn Ponds and Grovedale. This dark concretionary nodule and the yellow limestone immediately enclosing it were partially analysed to ascertain (*a*) the extent of replacement of the carbonate by phosphate, (*b*) if the relatively dark colour of the concretion was due to increase in the iron content.

	P_2O_5	CO_2	Fe
Dark concretion	14.99	18.75	1.53
Yellow containing limestone ..	4.32	28.48	1.55

An increase of 10 per cent. in the P_2O_5 is thus balanced by a decrease of 10 per cent. in the CO_2, indicating proportionate replacement. No increase in the iron content occurred, but there is the possibility that the original iron oxides have formed iron phosphate (dark-coloured) by replacement. Otherwise the dark colour must be ascribed to carbonaceous matter.

V. Comparison of Remanié and Concretionary Nodules.

Enough has been said to show that the two types are lithologically and chemically strikingly similar. The concretionary nodules are ovoidal or spheroidal in shape, and on the average rather larger than the remanié. Subjected to wave action or tidal scour, they would readily acquire the elongated shape and surface smoothness of the remanié type. Immersion in water would result in the relative bleaching of the remanié nodules.

Palaeontologically the remanié nodules differ from the concretionary type in the preponderance of remains of crabs, though otherwise they are very similar. Often the remanié nodules which contain the crab do not contain any other fossils, and this suggests that the crab is adventitious to the fauna; probably the crab-containing nodules were formed later in the depressions in which the ordinary type of remanié nodules were accumulated.

VI. Accumulation of Remanié Beds.

The remanié bed always rests on the surface of the Miocene limestones and beneath the Lower Pliocene ferruginous sands, but there are many instances of Lower Pliocene sands resting on Miocene limestones without the intervention of the remanié bed. This is notably the case along the banks of the Leigh River, Sutherland's Creek, Batesford open cut, and the Bellarine Peninsula (east side).

The remanié bed, which is clearly a detrital deposit, outcrops in the banks of Bruce's Creek from Bannockburn to Murghebolue, the banks of the Moorabool River from above Baker's Bridge to Newtown, Western Beach, Fisherman's Gully, Cowie's Creek, and on the western Bellarine Peninsula from Curlewis to Ocean Grove.

An examination of these outcrops shows that the upper surface of the Miocene limestone beneath the nodule bed is always at a lower elevation than that of the general surface of the limestone. It is evident that the nodule bed has been deposited in valleys or depressions due to erosion. The diastrophic phases responsible for this erosion were as follows:—

A. Uplift and emergence of Miocene limestones, and growth within them of concretionary nodules.

B. Erosion of the Miocene limestones, resulting in the removal of the containing limestone and the accumulation of the resistant concretionary nodules in the river valleys.

The valleys never got beyond a juvenile stage; they were still being vertically eroded when they were again submerged. The trend of the remanié beds indicates the courses of the post-Miocene valleys, and these agree approximately with those of the present rivers; furthermore their fall, as indicated by the underlying surface of Miocene limestone, is about the same.

A third diastrophic phase,

C. Slow subsidence and emergence,

involved the drowning of the valleys and the formation of rias or narrow arms of the sea extending for some distance inland and well protected. In these rias detrital nodules and mud accumulated below wave base, and as erosion was checked by the subsidence, the conditions of sedimentation were placid. In the finer mud were the burrows of the mud-haunting crabs,

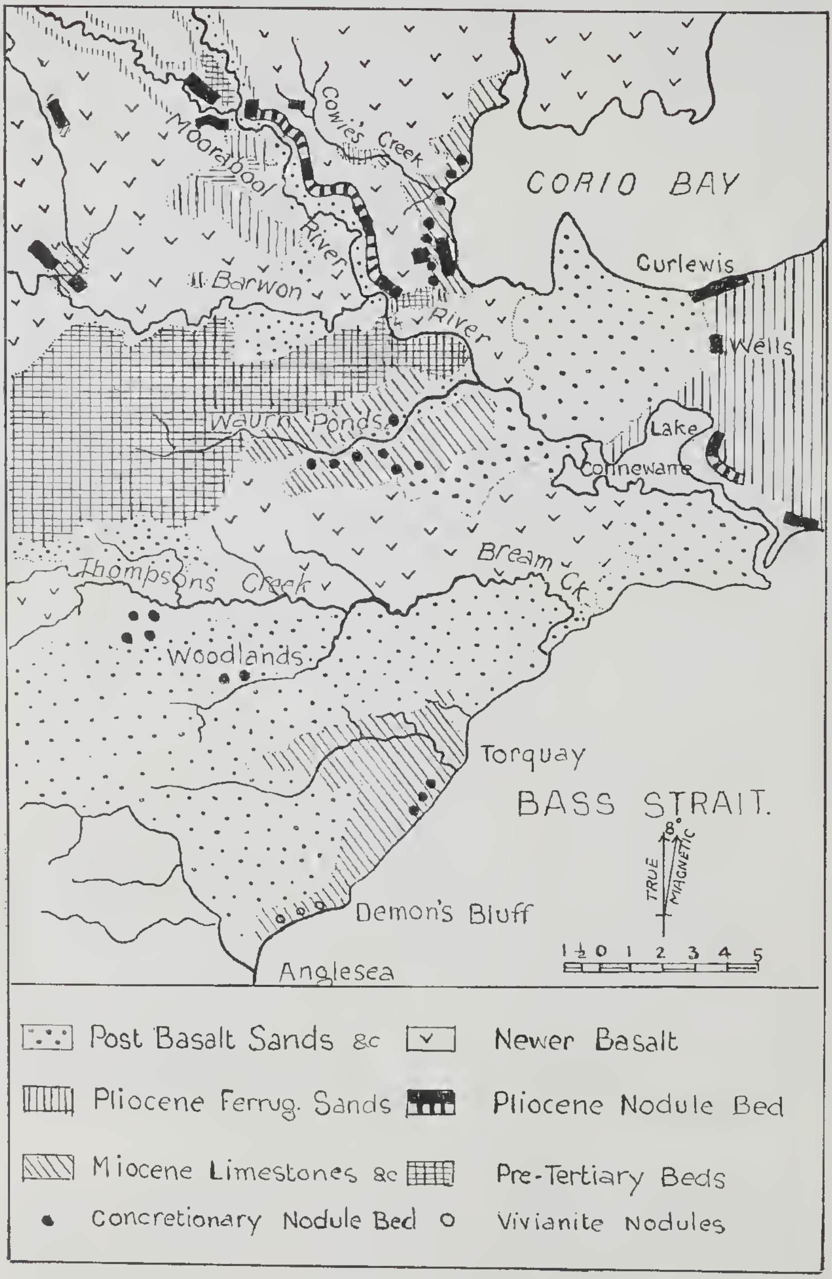
Cowies Creek
CORIO BAY
Moorabool River
Barwon River
Curlewis
Wells
Waurn Ponds
Lake Connewarre
Bream Ck.
Thompsons Creek
Woodlands
Torquay
BASS STRAIT.
8°
TRUE
MAGNETIC
Demon's Bluff
Anglesea
1½ 0 1 2 3 4 5
Post Basalt Sands &c
Newer Basalt
Pliocene Ferrug. Sands
Pliocene Nodule Bed
Miocene Limestones &c
Pre-Tertiary Beds
Concretionary Nodule Bed
Vivianite Nodules

FIGURE 1.

and as these died they formed calcium phosphate cemented nodules of considerable richness, up to about 8 per cent. P_2O_5. Such nodules have not been further enriched.

The fourth diastrophic phase,

D. Gradual uplift,

brought the accumulated sediments within wave base, and caused their disintegration. The fragments were rolled and accumulated to form the remanié bed as it now outcrops. An extension of this phase was

E. Complete emergence,

and the resumption of terrigenous conditions which marked the beginning of the deposition of the Pliocene ferruginous sands. Owing to the ease with which the Pliocene sands could be eroded,

F. A post-Pliocene cycle of erosion

cut valleys in them. This cycle was terminated by the

G. Newer Basalt,

which filled the valleys and initiated

H. The post-Newer Basalt cycle,

characterised by erosion on the flanks of the infilling basalt. This cycle is still in progress, and by deep vertical erosion the remanié beds resting on Miocene limestones and beneath Older Pliocene ferruginous sands have been exposed.

The exposure of the remanié beds is therefore dependent on the post-Miocene cycle of erosion, subsidence, sedimentation, uplift and subsequent erosion. Their extent is limited to the valleys of the post-Miocene cycle, and their exposure to the post-Newer Basalt erosion.

If an area was on the watershed during the post-Miocene cycle no remainié nodule bed will be found. Thus the Dog Rocks during the post-Miocene cycle was almost certainly a watershed; hence we do not see the nodule bed in the open cut at Batesford.

VII. Conclusions.

The Miocene limestone and marl of the Geelong district contains concretionary phosphatic masses, from 2 to 9 inches in diameter, which contain fossil organisms of the same character as the containing limestone. The phosphate is amorphous, and the growth of the phosphate concretions is due to the replacement of the calcium carbonate around the nuclei by phosphate carried in solution by carbonated ground waters.

Resting on the Miocene limestone, and beneath the Lower Pliocene sands, is a thin bed of rolled phosphatic pebbles, the remanié bed. Lithologically and chemically the remanié nodules are identical with the concretionary nodules, and palaeontologically they are very similar. They represent residual concretionary nodules from which the containing limestone has been removed. Associated with these nodules are abraded Miocene shells which are also remanié from the erosion of the limestone. Many of the nodules contain fossil crabs exclusively, and these were later formed, probably during the accumulation of the remanié bed.

The following diastrophic phases are involved in the formation of the nodule bed and its subsequent exposure:—

(*a*) Uplift and emergence of the Miocene limestone.
(*b*) Erosion of post-Miocene valleys.
(*c*) Slow subsidence and invasion of sea.
(*d*) Gradual uplift. Complete emergence.
(*e*) Deposition of Pliocene sands.
(*f*) Erosion.
(*g*) Newer Basalt flows.
(*h*) Formation of flanking valleys and exposure of remanié nodule bed by vertical erosion.

On account of its small size the remanié bed is of no economic value. Likewise the concretionary nodules are too few and scattered to repay collection. There may be some slight value in the low grade phosphatic marls of the Anglesea district, but at present this region is too remote from a market.

VII. Acknowledgments.

My sincere thanks are due to Mr. G. B. Hope, B.M.E., who introduced to me the problem of the origin of the remanié bed, and assisted me throughout the work. I am also indebted to Mr. R. A. Keble, F.G.S., of the National Museum, for identification of fossils[5] and criticism of the form of this paper. The informative analyses made by Mr. J. G. Doyle, of the Gordon Institute of Technology, and Mr. J. C. Watson, of the Geological Survey Laboratory, proved very useful, as also did the rock sections prepared for me by Prof. Skeats and Mr. D. J. Mahony. Lastly, I would thank Messrs. A. M. Howitt, J. M. Hennessy, R. McSweeney, and J. M. Hobba for their help in various ways.

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Remanié Nodule Bed exposed in road cutting, Fyansford Hill, Geelong.

Typical Remanié Nodules from Curlewis.

[Proc. Roy. Soc. Victoria, **44** (N.S.), Pt. II., 1932.]

Art. XI.—*Notes on the Faunas of the Geelong Nodule Beds.*

By R. A. KEBLE, F.G.S.

(Palaeontologist to the National Museum, Melbourne.)

[Read 8th October, 1931; issued separately 20th April, 1932.]

The following observations were made on collections of fossils made by Mr. Alan Coulson from the nodule beds of the Geelong district. An examination was made to obtain any evidence as to the conditions of sedimentation and incidentally as to age. A check list of the fossils obtained will take some considerable time to prepare, and will be published later.

Comprehensive collections were made by Mr. Coulson from nodule beds at:—

(*a*) Thompson's Creek, Moriac.
(*b*) Near the Viaduct, Batesford.
(*c*) Coghill's Hill, near Australian Cement Company's bridge.
(*d*) Curlewis.
(*e*) Lake Connewarre.
(*f*) Bowman's Well, Wellington.
(*g*) Equivalent of the nodule bed, "Learmonth," near Gheringhap.

In the previous paper[1] he has described the nodules from these several localities, and it is found that with his differentiation into (A) concretionary nodules, and (B) remanié nodules, corresponding differences in the fauna are shown. It is proposed to discuss only those critical forms that throw some light on the conditions of sedimentation and incidentally the age of the beds.

(A) Concretionary Nodules.

The concretionary nodules are bedded in the Tertiary series at Waurn Ponds and Thompson's Creek, and their age is the age of the containing beds. A comparison of Dennant and Kitson's[8] lists of Tertiary fossils from Waurn Ponds with those from Table Cape and similar faunas show that there are many forms in common. Although there are others common to the Oligocene faunas of Mornington and Muddy Creek, the Table Cape element is the critical characteristic, and the fauna of the concretionary nodule beds may be regarded as the equivalent of that of Table Cape.

(B) Remanié Nodules.

In the nodule material from all the localities except (*a*) and (*g*) more or less complete fragments of the crab *Ommatocarcinus corioensis* Creswell sp., are exceedingly common. This crab was described by the Rev. A. W. Cresswell[2] in 1886, and his description was subsequently amplified by Dr. T. S. Hall[4] in 1904. As stated by Hall,[4] it is very closely related to *O. macgillivrayi* White,[6] and the numerous parts from the Geelong beds show that they may be separated only with difficulty from White's species. The habits and environment of *O. macgillivrayi* may with reasonable certainty be taken as those of *O. corioensis* for there is nothing in the minute differences between them that could modify these.

O. macgillivrayi was first netted on a mud flat between tides at Port Curtis, Queensland.[6] The *Challenger*[5] also dredged in Queen Charlotte Sound, near Long Island, at the north end of the South Island of New Zealand on a muddy bottom at 10 fathoms. Hall[4] observes that the condition of many specimens at Port Campbell suggests that they must have been entombed in their burrows. He adds that other fossils in the crab beds were rare, and consisted mainly of a few spatangoids and mud haunting brachiopods.

Teeth of Cestracion were found at Curlewis and Strophodus on the Moorabool River, Lethbridge. Both these forms have a dentition adapted to the prehension and mastication of crustaceans and hard-shelled animals, and are shore fishes common to the Temperate Zone (30°–50° S.). Teeth of the Blue Pointer Shark, *Isurus hastalis*, were found at Curlewis and Bowman's Well. At all the localities except (*g*) cycloid scales were common, showing that the smaller fishes were well represented in the fauna. From Coghill's Hill, near the Australian Cement Company's Bridge, the cleithrum and median spine of a fish suggesting one of the Monocanthidae or Leather Jackets was found. Although Mr. Coulson has made comprehensive collections from all the remanié nodule beds in the Geelong district, no part of a cetacean has so far been determined. The quantity of bone fragments, however, leaves little doubt that they were fully represented.

Of the few undoubted molluscan remains, *Turritella tristira* Tate and *Crassatellites communis* have a long range through the Janjukian and Balcombian. *Astralium flindersi* is restricted to the Table Cape and Royal Park beds, and *Turris trilirata* to Fishing Point, Shelford, Mornington, and the Mitchell River. *Calliostoma* sp. occurs in the nodule bed near the Viaduct, Batesford. *Calliostoma* has several specific representatives in the beds at Table Cape but not elsewhere.

Evidence of Faunas.

There is little doubt that the bed or beds from which the remanié nodules were directly or indirectly formed comprised the equivalent of the Table Cape bed of Tasmania. The precise position of this bed in the Tertiary succession is problematical, and a comparison of its molluscan fauna with others suggests that it may be equally well placed in the Middle or Lower Janjukian. The Table Cape element is undoubtedly mixed with the fauna that existed at the time the remanié nodule beds were being formed, and the general association may be compared with that of known Lower Pliocene localities such as Beaumaris, or the upper beds at Muddy Creek.

Apart from the question of age, however, the nature and mode of preservation of the fossil forms in the remanié nodule beds leads us to other considerations that could materially influence the process of phosphatisation. Two possibilities are suggested, viz., that the remanié nodules were formed from (*a*) a Table Cape bed or beds *in situ,* in which case they would be rolled Janjukian nodules and the phosphatisation may have occurred in Janjukian times; (*b*) from an intermediate bed, in the first case derived from a Table Cape bed or beds, but also containing the remains of the fauna existing at the time of the deposition of the intermediate bed. The intermediate bed is the Lower Pliocene one referred to above, and the nodules derived from it should exhibit a mixed fauna. The later fauna contained elements such as cetaceans, fishes, crabs, &c., that could, when their remains were fossilised, account for or enrich the phosphatisation.

From their relative abundance and uniform size, their efficient sorting and homogeneity, the nodule beds are shallow water deposits, perhaps littoral. They show evidence of wave action, and were certainly deposited within the influence of wave base. Their uniformity in shape and size show that they were derived from a thin bed and rounded by abrasion.

Ommatocarcinus, by far the commonest fossil present, ranges in depth from the littoral to the uppermost limits of the benthos, and is a mud-haunting crab. Hall found his specimens in a sandy clay suggesting a muddy bottom with an admixture of sand. Where fragments are found enclosed by nodules, they show signs of abrasion, while those free from a matrix show few signs of it. It is inconceivable that unprotected fragments of such a fragile crab could escape comminution in the agitated conditions implied by the formation of the nodules and unlikely that they were subjected to the process.

If these fragments, either isolated or enclosed in the nodules, were derived from an *Ommatocarcinus* bed in the Janjukian, such a bed would have to be in close proximity to the site of the forming nodule bed at each and every locality, a coincidence that is known not to exist.

The only reasonable inference seems to be that the fragments of *Ommatocarcinus* were preserved in an intermediate bed—a calcareous mud or sandy clay bed, which was formed in one of the valleys or depressions of the dissected Janjukian land surface afterwards drowned.(1) This bed was derived (*inter alia*) from the Janjukian sediments, and the fossil fauna found in it is a mixed one, representing in part that of the beds from which it was denuded, and in part that living at the time of its formation. Besides *Ommatocarcinus* the latter fauna comprised such sea scavengers as *Cestracion, Strophodus,* and probably many others that lived on the inshore life of the period. With such a predatory fauna, death by senile decay is unusual, and we would scarcely expect to find crabs buried simply by the accumulation of sediment. Apart from this factor the scour of the inlets, while it was to a certain extent instrumental in building sediments, was no less destructive, and the possibility of the preservation of the fragile parts of a crab with the surface layer of such a deposit was slender.

To obtain such a quantity of well preserved fragments such as we have in the collections from the nodule beds shows that *Ommatocarcinus* was abundantly preserved, and in some manner different to the ordinary methods of fossilisation. Hall's inference(4) that those specimens found by him in the sandy clays at Port Campbell were probably entombed in their burrows, appears to afford a rational explanation. In both the specimens found by him and those in the collections the appendages are frequently preserved, which shows that the crabs were not exposed to disintegrating influences and were preserved as they died. The mud between the appendages and in front of the thorax seems to bind the whole together, and appears to form the nucleus of the nodule. In the National Museum collection there are several specimens of the crab *Hemiplax,* which were found while the Yarra improvement works were in progress, suggesting the same method of preservation and the formation of nodules.

The bed from which the nodules were derived was the upper crust of this mud or silt bed that has by subsequent phosphatisation and various processes become hard and compacted. This was disintegrated and the fragments were abraded, subsequently assuming that uniformity of shape and size characteristic of the remanié nodules. Those fragments that are unenclosed by a matrix were preserved in the interstitial softer sediment.

All the fishes suggested by the remains in the nodules are shore fishes and existed through the conditions imposed by the formation of the nodule bed. On the other hand, the existence of these fish seems to be more in accord with such conditions than those implied by the Janjukian sediments.

Conclusions.

The age of the concretionary nodules is that of the containing beds, Janjukian, and the horizon approximately that of Table Cape. The evidence of the fossils of the remanié nodule beds suggests that it is a composite one, made up partly from the older Janjukian limestones, and partly from that living at the time the nodule bed was being formed.

The fragility of some of the fossils, such as *Ommatocarcinus*, shows that they could not have been transported from an older bed, nor existed during the formation of the nodule bed, without comminution. They probably came from an intermediate bed which immediately preceded the nodule bed.

The sea in which the nodule bed was formed was probably considerably under 100 feet deep in depth.

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[Proc. Roy. Soc. Victoria, **44** (N.S.), Pt. II., 1932.]

Art. XII.—*Australian Termites (Isoptera). Biological Notes and Descriptions of New Species.*

By GERALD F. HILL.

(Senior Entomologist, Section of Forest Pests, Division of Economic Entomology, C.S.I.R.)

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This paper contains notes on the biology, distribution and synonymy of several species of Australian *Calotermes, Coptotermes, Heterotermes,* and *Eutermes,* which have come under notice recently. Two species of *Calotermes,* one species of *Heterotermes,* and one species of *Eutermes* are described as new, and a new name is proposed for *Coptotermes flavus* Hill.

Genus **Calotermes.**

Calotermes (Calotermes) oldfieldi Hill.

Proc. Roy. Soc. Vic. (n.s.), xxxvii., p. 207, 1925.

This species, described originally from Kiata, Mallee District, Victoria, has been taken more recently on Kangaroo Island, South Australia (Miss W. Hughes), where alates, soldiers and larvae were found on 29th November and alates (at lamp) on 31st January.

Calotermes (Calotermes) oldfieldi var. chryseus Hill.

Proc. Roy. Soc. Vic. (n.s.), xxxviii., p. 201, 1926.

This termite is very variable in the size of the head, eyes and pronotum of the imago and in the size and colour of the soldier. The antennae of the former have from 16-20 segments and those of the latter 10-15 segments.

Additional localities.—New South Wales: Bungendore and Galston; Federal Capital Territory: various localities at elevations of from 2,300–4,000 feet.

Biology.—The normal habitus of this species is in branch stubs and adjacent truewood of living Eucalyptus trees at heights of from a few feet to 140 feet from the ground; it occurs also in the branches and trunks of dead trees. In the former positions it is often associated with other species, e.g., one soldier with a king, queen and larvae of *Calotermes rufinotum* in branch stub 140 feet from the ground; a queen and many nymphs with a queen of *Calotermes rufinotum* in a branch stub 75 feet from the ground; soldiers, nymphs and larvae with a soldier and nymphs of ? *Calotermes spoliator*, n. sp.; a queen with king, queen and larvae of *Calotermes tillyardi*, n. sp., in a branch stub 76 feet from the ground; two kings, two queens, one soldier and four larvae with a king, queen and one larva of *Calotermes (N.) insularis* (White).

The winged form, which flies by night, has been taken from 29th of November to 8th February.

Calotermes (Neotermes) insularis (White).
Walker, Cat. Neurop. Ins. Brit. Mus. (3), 1853.

Calotermes longiceps Froggatt.
Proc. Linn. Soc. N.S.W., xxi., p. 528, 1896.

Calotermes robustus Froggatt.
Proc. Linn. Soc. N.S.W., xxi., p. 529, 1896.

? *Calotermes (Neotermes) deuqueti* Hill.
Proc. Roy. Soc. Vic. (n.s.), xxxviii., p. 196, 1926.

In a previous paper the writer[4] suggested that *C. longiceps* Frogg. is synonymous with *C. insularis* (White). Since then many complete series from New South Wales and the Federal Capital Territory have been compared with Froggatt's type (soldier) and with Victorian specimens, with the result that this synonymy has been established. Further, two alates from Froggatt's collection, labelled by him "*Calotermes longiceps*, Sydney, in logs" are also referable to White's species, as is the unique type (imago) of *Calotermes robustus* Froggatt and the soldier associated with it by Froggatt[5]. *Calotermes (N.) deuqueti* also is probably referable to *C. insularis*. Alates from the same colony often differ markedly from each other in colour and in the size of the head, eyes, ocelli and pronotum.

Additional localities.—New South Wales: Galston, Mona Vale, Collaroy; Victoria: Orbost; Federal Capital Territory: various localities at elevations of from 2,100–2,600 feet.

The paucity of material in the older collections has conveyed the impression that *C. insularis* is an uncommon species, which is by no means the case. The explanation of its apparent rarity is probably to be found in the fact that its normal habitus is not in logs and stumps, the situations in which it has generally been found, but in large living trees of various species of Eucalyptus, which few entomologists have an opportunity of examining closely.

Biology.—This is the largest species found in South-eastern Australia and one which is responsible for very considerable damage to living Eucalyptus trees. The attack appears always to begin by the foundation of a colony in a branch stub or fire scar at heights varying from a few feet to upwards of 100 feet from the ground, whence galleries are excavated in the sapwood and truewood upwards into the secondary branches and downward into the butt and even into the roots. In the Federal Capital Territory it causes great damage at lower elevations, but it has not been found at elevations of from 3,500–4,000 feet, at which small Ash forests occur. There is good reason to believe that it is one of the species which cause enormous losses in the commercial forests of Victoria.

The winged form, which has been taken from 13th February to 21st May, possesses considerable powers of flight, thus differing markedly from the mound-building and subterranean Rhinotermitidae and Termitidae.

Calotermes (subgen. ?) rufinotum Hill.

Proc. Roy. Soc. Vic. (n.s.), xxvii., p. 207, 1925.

This species occurs commonly in the Federal Capital Territory in branch stubs and adjacent truewood of several species of Eucalyptus trees.

Additional localities.—New South Wales: Eden; Federal Capital Territory: Brindabella Range, at elevations of from 2,600–4,100 feet.

Biology.—The habits of this termite are very similar to those of the previously mentioned species, with which it sometimes associates, as already noted. It has been found in association also with *Calotermes tillyardi,* n. sp., as follows:—Soldiers and ? larvae with soldiers and larvae; queen and larvae with soldier; and king, queen and ? larvae with two kings, two queens and ? nymphs. In several instances incipient colonies of *C. rufinotum* have been found to comprise two or more kings and queens and a few larvae. Apart from the presence of two or even three species in the same system of galleries the occurrence of additional species in other parts of the tree has been noted frequently. *Porotermes adamsoni* (Frogg.) and *Coptotermes frenchi* (*nom. nov.* for *C. flavus* Hill *nec* Bugnion and Popoff) are commonly to be found in the heart and truewood of trees attacked elsewhere by some or all of the above-mentioned species of *Calotermes*.

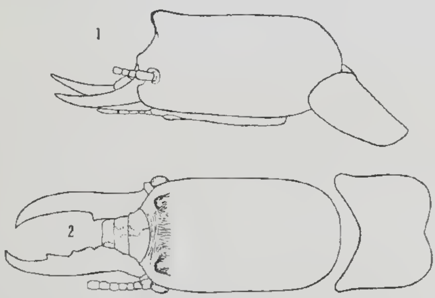
Calotermes (subgen. ?) spoliator, n. sp.

(Figures 1 and 2.)

Soldier.

Colour.—Head orange-rufous behind, shading to dark ferruginous and thence to black anteriorly; proximal fourth of mandibles dark ferruginous, anterior three-fourth black; labrum, antennae, palpi and pronotum orange-rufous; gula dark orange-rufous shading to dark ferruginous or blackish anteriorly; legs and dorsal sclerites of abdomen a little lighter than pronotum.

Head (Figs. 1 and 2).—Long and narrow, parallel on the sides to the antennal carinae, where it is slightly narrower; with very few hairs; antennal carinae very large and markedly projecting; frons sloping sharply to the clypeus; anterodorsal margin with two large prominences. Post- and ante-clypeus short, truncate in front, the former with a fringe of hairs. Labrum large, nearly twice as wide as long, wide at the base, narrowed anteriorly to the broadly truncate apex, with a fringe of five or six hairs near the apex and two pairs posteriorly to these. Antennae short and stout, with from 11 to 14 segments; the 1st short and stout, twice as long as the 2nd; 2nd quadrate; 3rd, 4th and 5th subequal, as wide as 2nd, or 3rd shorter and narrower than 4th and 5th, or 3rd and 4th subequal, smaller than 5th; the following segments, excepting the last, longer than the preceding ones; the apical segment short and narrow. Eyes moderately large, elongate oval, oblique, widely separated from the posterior margin of the antennal carinae. Mandibles very long and slender, parallel with the axis of the head when



Figs. 1 and 2.

1. *Calotermes spoliator,* n. sp. soldier: head and basal segments of antennae, lateral view.
2. *Calotermes spoliator,* n. sp. soldier: head and basal segments of antennae, dorsal view.

viewed laterally; the right with two short stout triangular teeth in the proximal half, the anterior half very narrow and parallel-sided to near the apex, the left with two broad teeth in the proximal half and a somewhat smaller angular one in the distal third.

Thorax.—Pronotum as wide as head, with few hairs, the anterior margin bent up, the sides nearly parallel and markedly arched, the anterior margin deeply and widely notched in the middle, the posterior margin wide and less deeply notched than the anterior margin. Meso- and metanotum with short wing rudiments.

Legs.—Short and stout, with scanty short hairs; claws and tibial spurs very short and stout; tibial spurs 3 : 3 : 3.

Measurements.

	mm.
Total length	5.20–7.00
Head, base to apex of mandibles, long	2.40–2.88
Head, base to clypeofrontal suture, long	1.80–1.92
Head, wide	0.99–1.11
Gula, at narrowest part, wide	0.20–0.26
Mandibles, from external articulation, long	1.07–1.18
Antennae, long	1.11
Pronotum, long 0.44–0.59; wide	0.88–1.11
Tibia iii., long	0.66–0.74

Localities. — Federal Capital Territory: Uriarra (Type locality) and Black Mountain at elevations of about 2,400 feet; New South Wales: Galston, Kuring-gai Chase.

Biology.—The habits of this termite are very similar to those of the previously mentioned species in that it is generally found in branch stubs and adjacent truewood of species of Eucalyptus trees and very often in association with other species of termites. Soldiers only, or soldiers, larvae and nymphs, have been taken in association with soldiers, nymphs and larvae of *Calotermes* (*C.*) *oldfieldi* var. *chryseus* on two occasions, once with alates, nymphs and larvae of *Calotermes tillyardi*, n. sp., and once in very close proximity to, if not in association with, a complex comprising alates of *Calotermes* (*G.*) *eucalypti* Frogg., soldiers of *Calotermes* (*G.*) *tuberculatus* Frogg., and unidentified larvae in a tree which was infested also with *Coptotermes acinaciformis* (Frogg.) and *Heterotermes ferox* (Frogg.). On another occasion three soldiers were found with, or very close to, a complex comprising alates of *Calotermes tillyardi*, n. sp., soldiers of *Calotermes* (*G.*) *tuberculatus* Frogg., and larvae of *Porotermes adamsoni* (Frogg.).

Affinities.—The imago is unknown, hence the impossibility of determining the subgenus to which this species belongs. The soldier is strikingly distinct from any known Australian species and does not appear to fall into any of the established subgenera.

Type.—In the collection of the Division of Economic Entomology, C.S.I.R., Canberra.

Calotermes (subgen. ?) tillyardi, n. sp.

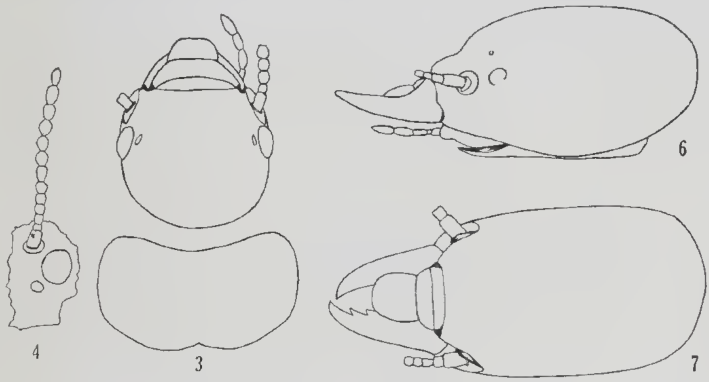
(Figures 3–8.)

Imago.

(Figures 3–5.)

Colour.—Head, thorax, palpi, abdomen, legs, and wing veins dark brown; clypeus whitish; labrum and antennae buckthorn-brown; wing membrane dark brown, lighter than veins.

Head (Fig. 3).—Small, widest midway between the eyes and the posterior margin, narrowed anteriorly; clothed scantily with minute hairs. Eyes small, not very prominent, variable in size and shape, circular (0.222–0.259 diam.), or subtriangular (0.185 x 0.222 diam.). Ocelli small, nearly circular (0.074 long diam.), less than their length from the margin of the eyes. Antennae (Fig. 4) with 13–15 segments, usually with 13, rarely with 15 segments, the 1st segment short and stout; 2nd about half as long as, and much narrower than, 1st, more or less quadrate; 3rd globose, longer and wider than 2nd, or 2nd and 3rd subequal, the latter narrowed at the base; 4th generally a little shorter and more rounded than 3rd, 3rd to penultimate segments



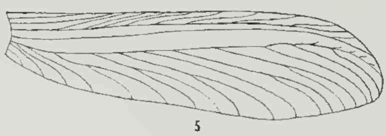
FIGS. 3, 4, 6, AND 7.

3. *Calotermes tillyardi,* n. sp. imago: head and basal segments of antennae and pronotum.
4. *Calotermes tillyardi,* n. sp. imago: antenna, showing relative position of eye and ocellus.
6. *Calotermes tillyardi,* n. sp. soldier: head and basal segments of antennae, lateral view.
7. *Calotermes tillyardi,* n. sp. soldier: head and basal segments of antennae, dorsal view.

increasing very slightly in size progressively; the last segment shorter and narrower than those near it, nearly parallel on the sides, bluntly rounded at the apex. Labrum short, wider than long, nearly parallel on the sides and nearly truncate in front.

Thorax.—Pronotum very large, much wider than head, more than twice as wide as long, markedly arched dorsally, the anterior margin broadly concave, the anterolateral corners slightly rounded, the sides nearly parallel, very little swollen, the posterolateral corners cut off obliquely, the posterior margin with wide and shallow notch. Posterior margin of the meso- and metanotum wide and slightly sinuate. Stumps of forewings very large, more than twice as long as those of the hind wings.

Wings (Fig. 5).—Short and moderately wide, the venation extremely variable. Subcosta and radius of the forewing short, the latter rarely branched; the radial sector with from nine to twelve or more branches to the costa, the distal branches sometimes forked; the media generally heavily chitinized, like the veins preceding it, and situated a little nearer to the former than to the latter, rarely midway between the radial sector and the cubitus, unbranched or with many branches distally; often joins the radial sector near the apex of the wing, where it may form a succession of loops with the latter vein. The cubitus generally passes through the middle of the proximal one-third of the wing, thence through the anterior one-third and joins the margin above or below the apex. This vein and its numerous branches nearly always occupy the greater part of the wing area. In the head wing the subcosta does not extend beyond the suture; the radius is short, as in the forewing; the radial sector has from five to nine branches to the costa; the media branches from the radial sector well beyond the suture (not near the base of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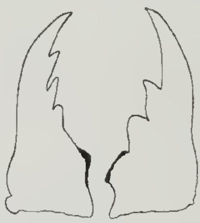
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Figs. 5 and 8.

5. *Calotermes tillyardi,* n. sp. fore-wing.
8. *Calotermes tillyardi,* n. sp. soldier: mandibles.

the stump as in the forewing) and passes midway between the radial sector and the cubitus, or nearer to the former than to the latter, to the apex of the wing. It is rarely branched, but often has short stout cross veins to the radial sector. The cubitus is generally similar to that of the forewing. The entire membrane and all the veins are dotted with scale-like micrasters.

Legs.—Short and stout, with few hairs, femora markedly thickened; tibial spurs 3 : 3 : 3, without serrations.

Measurements.	mm.
Length with wings	9.00–10.00
Length without wings	6.25– 6.50
Head, base to apex of labrum, long	1.14– 1.22
Head, to clypeofrontal suture, long	0.77– 0.88
Head, at and including eyes, wide	0.85– 1.03
Antennae, long	1.40
Pronotum, long 0.51–0.74; wide	0.88– 1.29
Forewings, long 5.75–6.00; wide	1.66– 1.80
Tibia iii., long	0.74

Soldier.

(Figures 5–8.)

The identity of the soldier of this species has not been established beyond doubt, owing to the fact that more than one species of this caste has been found to consort with the imagos at present available for examination. For the purpose of recording the results of investigations that are now being made into the causes of the destruction of commercial forest trees the naming of hitherto undescribed species cannot be deferred indefinitely. From a study of the material at hand one is reasonably satisfied with the selection of the form described below as the soldier of *C. tillyardi;* it is possible, however, that the acquisition of further series may necessitate the designation of another as the sterile caste of the species under notice.

Colour.—Head pale orange-yellow behind, shading to dark ferruginous in front; antennae, pronotum and dorsum of abdomen as in base of head.

Head (Figs. 6 and 7).—Long and narrow, less than half as wide as long, the sides almost parallel to the base of the mandibles, the posterior margin broadly rounded, sutures distinct, frons sloping at an angle of about 45°. Eyes large, hyaline. Ocelli very small and widely separated from the eyes. Gula long and narrow. Antennae short and stout, of 11 or 12 segments; 1st segment short and wide; 2nd about half as long and two-thirds as wide as 1st; 3rd and 4th very variable; the following segments, excepting the last, short and wide, becoming progressively longer, the apical segment shorter and narrower than the next. Labrum short and wide, truncate in front. Mandibles (Fig. 8) short and stout; the left with three angular forwardly directed teeth, the right with two large teeth, the anteriormost far from the tip of the mandible.

Thorax.—Pronotum with very few hairs, moderately flat, concave in front, broadly rounded on the sides and behind, the posterior margin slightly sinuate. Posterior margin of meso- and metanotum truncate, with short wing-rudiments.

Legs.—Short and stout; tibial spurs 3 : 3 : 3.

Measurements.	mm.
Total length	4.50–6.00
Head, base to apex of mandibles, long	1.96–2.44
Head, wide	0.92–1.11
Gula, at narrowest part, wide	0.20–0.25
Pronotum, long 0.48–0.62; wide	0.81–1.07
Tibia iii., long	0.59–0.77

Localities.—Federal Capital Territory (type locality): at elevations from 2,100–4,100 feet; New South Wales: Galston.

Biology.—As with the preceding species, this termite is generally found in branch stubs and adjacent truewood of species of Eucalyptus trees. Its association with other species has been noted in the preceding pages. The winged form occurs from the beginning of December to the end of March.

Affinities.—The alate form is readily distinguished from all previously described species by its colour and wing venation. The latter approaches that of the subgenus *Neotermes* and agrees closely with that of *Calotermes rufinotum* Hill and *Calotermes obscurus* Walker, which, however, are not *Neotermes*. The soldier closely resembles that of *Calotermes rufinotum* and *Calotermes (G.) eucalypti* Frogg., both of which have relatively longer and narrower heads and narrower gula.

Types.—In the collection of the Division of Economic Entomology, C.S.I.R., Canberra.

Genus **Coptotermes.**

Coptotermes lacteus (Froggatt).

Ag. Gaz. N.S.W., viii., p. 297, 1897.

Coptotermes sedulus Hill.

Proc. Linn. Soc. N.S.W., xlvii., p. 40, 1923.

The examination of many complete series collected recently in various localities near Melbourne, throughout Gippsland, south-eastern New South Wales and the Federal Capital Territory leaves little doubt but that *C. sedulus* is synonymous with Froggatt's species.

Coptotermes frenchi, nov. nom.

Coptotermes flavus Hill, *nec* Bugnion and Popoff.

Proc. Roy. Soc. Vic. (n.s.), xxxviii., p. 207, 1926.

The name given originally to this species has been used previously(1) for a Ceylon species; it is proposed, therefore, to rename it in honour of Mr. Chas. French, Jun., Government Entomologist of Victoria.

It occurs commonly in the Federal Capital Territory, where it does considerable damage to living Eucalyptus trees. There are no records to indicate that it ever builds mounds in any of the localities in which it is known.

Additional localities.—New South Wales: Galston and Eden; Victoria: Craigieburn; Federal Capital Territory: various localities at elevations of from 2,100 feet to 2,600 feet.

? Coptotermes australis (Walker).

Cat. Neurop. Ins. Brit. Mus., iii., p. 525, 1853 (Termes).

This species remains unrecognized in recent Australian collections, but it is of interest to note that a wing identified many years ago by Froggatt as *Termes australis* Walker is that of a pale-winged species of *Coptotermes*.

Genus **Heterotermes.**

Heterotermes platycephalus Froggatt.

Proc. Linn. Soc. N.S.W., xxi., p. 551, 1896.

Leucotermes clarki Hill.

Bull. Ent. Res., xxi., p. 395, 1922; *Mem. Nat. Mus., Melbourne*, No. 7, p. 45, 1927.

Since the publication of the writer's revision of the genus(4) a wing from the type and a complete series from the type locality (Kangaroo Island, South Australia) have become available for examination, with the result that it can be stated definitely that *Heterotermes* Froggatt, 1896, replaces *Leucotermes* Silvestri, 1901, and that *Leucotermes clarki* Hill is synonymous with *Heterotermes platycephalus* Frogg. *Psalidotermes* Silvestri, 1909, also, is synonymous with *Heterotermes*,(7) to which genus should be referred all the species listed by the writer(6) under *Leucotermes*. No changes in specific names are involved.

Additional localities.—South Australia: American River, Kangaroo Island (all castes, 29th November); Western Australia: Barronhurst, Mt. Barker, Wuraming (in Jarrah log), Pemberton (queen, soldiers and workers in mound of *Hamitermes obeuntis* Silv.), Manjimup (under log), Armadale (in "white gum" stump), Fairbridge Experimental Farm (in "marri" stump, with *Hamitermes obeuntis* Silv.), Kirup Siding and Greenbushes (in mound of *Hamitermes obeuntis* Silv.).

Heterotermes ferox Froggatt.

Proc. Linn. Soc. N.S.W., xxii., p. 724, 1897 (*Termes*).

Leucotermes occiduus Hill.

Mem. Nat. Mus. Melbourne, No. 7, p. 50, 1927.

The above synonymy has been established as a result of the examination of numerous complete series from New South Wales, Federal Capital Terirtory, Victoria, and Western Australia.

Additional localities.—New South Wales: Captain's Flat, Appin, Leura (at 3,200 feet), Uralla, Mittagong, Galston, Brookvale, French's Forest, and Nowra; Federal Capital Territory: various localities at elevations of from 2,100 to 2,600 feet; Victoria: Ouyen, Kiata, Mildura, Linga, Kewell, Warrandyte, and Melton; Western Australia: Growangerup, Watheroo, Mullewa, Wickepin, and Yilgan.

Biology.—This species is found in small colonies under stones and logs, and occasionally in the mounds of other species of termites and ants (*Iridomyrmex detectus*), as well as in dead trees. It is often very destructive to imported soft-woods, but does little damage to local hardwoods. The winged form has been taken from 25th October (in New South Wales) to 27th May (in Western Australia).

Heterotermes venustus (Hill).

Mem. Nat. Mus. Melbourne, No. 7, p. 55, 1927 (*Leucotermes*).

This species was described from a complete series collected at Stapleton, Northern Territory, on 4th November, 1914. A variety, or very closely allied species, represented by a complete series from Wyndham, W.A. (2nd December, 1930), differs from the type series in its slightly smaller size and distinctly small ocelli. In the description of *Heterotermes venustus* it is stated that ocelli are absent, whereas in a few examples they are present, as in the Wyndham material.

Heterotermes intermedius, n. sp.

(Figures 9–12.)

Imago.

(Figures 9–11.)

Colour.—Head, pronotum and dorsum of abdomen dresden-brown; remainder of body, legs and antennae clay colour; wings buffy-brown, costal margin as in head.

Head (Fig. 9).—Moderately hairy, longer than wide, widest before the eyes, narrowed posteriorly. Postclypeus small (0.18 long x 0.44 wide), strongly convex, divided by a distinct suture, with three long hairs on either side of the mid-line, two being near the anterior margin and one in the middle. Eyes very small, sub-triangular (0.185 max. diam.), not projecting beyond the lateral margin of the head, widely separated from lower lateral margin. Ocelli present, very small, in contact with the eyes. Labrum large, bluntly rounded in front, strongly inflated on the sides, markedly convex. Fontanelle very small but distinct, midway between the clypeofrontal suture and posterior margin of the head. Antennae (Fig. 10) with 17 segments; the 1st segment long and nearly cylindrical, twice as long and a little wider than 2nd; 2nd slightly widened at apex, longer than wide; 3rd half as long and markedly narrower than 2nd; 4th, 5th, and 6th as wide as 2nd, globose; 7th to 15th elongate, increasing in length progressively; 16th as long as 15th; 17th elongate oval, a little shorter than the 15th and 16th.

Thorax (Fig. 11).—Pronotum of typical form, narrower than head, the anterior margin slightly elevated and convex and with distinct median notch, anterolateral angles rounded, sides sloping in sharply to the sinuate posterior margin; hairs moderately large and dense. Meso- and metathorax wide in front, narrowed sharply to the deeply notched and narrow posterior margin, the notch in metanotum always less than in mesonotum.

Wings.—Long and slender, the radius, radial sector, proximal branches of the cubitus and the extreme proximal end of the media distinct.

Legs.—Moderately slender, short, with scanty hairs; tibial spurs long and slender, 3:2:2.

Abdomen.—Long, narrow, and moderately hairy. Cerci with basal segment short and very wide. Styli (males only) slender.

Measurements.	mm.
Length with wings	10.00–10.50
Length without wings	4.75– 5.25
Head, base to apex of labrum, long	1.25– 1.29
Head base to fontanelle, long	0.37
Head, base to clypeofrontal suture, long	0.74
Head, wide 0.83–0.85, narrowed to	0.77– 0.81
Antennae, long	1.80
Pronotum, long 0.48*; wide	0.70
Forewings, long 8.00; wide	2.14
Tibia iii., long	0.81– 0.85

*Measured along midline, i.e., minimum length.

Soldier.

(Figure 12.)

Colour.—Head yellow, palest behind; mandibles ferruginous; labrum and antennae yellow, the latter darker than head; articulations of mandibles forming dark ferruginous spots at either end of the postclypeus; anterodorsal prominences of head suffused with dark brown; legs straw coloured; thorax and abdomen whitish.

Head (Fig. 12).—Long and narrow, nearly parallel on the sides. Mandibles long and moderately stout, of typical form. Labrum large, bluntly conical. Antennae of 16 or 17 segments.

Measurements.	mm.
Total length	5.00
Head, with mandibles, long	2.73–2.81
Head, wide	0.96–1.00
Mandibles, left, entire	1.11
Mandibles, left, from basal tooth to apex	0.96
Gula, at narrowest part, wide	0.18
Pronotum, long 0.38–0.48; wide	0.72–0.83
Tibia iii., long	0.85

Worker.

Measurements.	
Total length	5.25
Head, wide	0.96
Pronotum, long 0.44; wide	0.70

Locality.—Western Australia; near Kalgoorlie (A. G. Nicholls, 19th March, 1928).

Affinities.—The imago differs from *Heterotermes platycephalus* Frogg. in its markedly smaller size, darker and relatively longer and narrower head, the position of the ocelli and in the distinctly narrower and more deeply notched meso- and metanotum. The soldier differs in being smaller, and having the anterodorsal prominences of the head suffused with dark brown. From *Heterotermes validus* Hill the imago differs in having ocelli, considerably smaller head, eyes and pronotum, pronotum relatively shorter and narrower, more strongly convex postclypeus, and meso- and metanotum of different form (in *Heterotermes validus* these sclerites are broad and truncate, or only sligthly sinuate, posteriorly), the total length is about the same in both species. The soldier of the proposed new species is distinctly smaller than that of *Heterotermes validus*, the head is narrower in proportion to width, and is not so markedly truncate in front and behind and the mandibles are more slender. In *Heterotermes paradoxus* (Frogg.) the ocelli, when present, are larger and well separated from the eyes, the eyes are larger and the posterior margin of the meso- and metanotum is either convex or very slightly sinuate, never deeply notched. The soldier of *Heterotermes paradoxus* has a larger and relatively narrower pronotum than *Heterotermes intermedius*.

Types.—In the collection of the Division of Economic Entomology, C.S.I.R., Canberra.

Genus **Eutermes.**

Eutermes exitiosus Hill.

Proc. Roy. Soc. Vic. (n.s.), xxvii. (2), p. 222, 1925.

This species is widely distributed and very abundant throughout southern Australia, and is without doubt one of the most destructive species to timber structures. Their low dome-shaped mounds, which are familiar objects wherever the species occurs, rarely exceed 3 feet in height by about 2 ft. 6 in. in diameter at the base, and are composed of an intensely hard mass of earthy material and triturated wood generally covered externally with particles of earth or sand cemented together to form a more or less durable thin outer wall. The "nursery," which rests upon the ground about the middle of the mound, is composed of thin layers of brittle woody material moulded to form innumerable flattened cells and galleries connected with each other by small circular openings. The queen cell lies in the lower part of the "nursery," and appears to be permanently occupied only by the queen. In no instance has a king been found in the queen-cell or elsewhere in the mound, which appears to indicate that he dies at a comparatively early stage of the development of the colony. The feeding range of a colony has not been ascertained, but it is probably not less than 30 to 40 yards. The damage done by this termite to fence-posts, telephone poles, structural timber, &c., is usually clearly indicated by the presence of shelter-tubes on the external surfaces of the object attacked, but in the case of a wooden building considerable damage may result from attacks confined to the concealed bearers, and joists, and to the interior of floor-boards and wall-boards, access to which may be gained either by means of shelter-tubes built externally over the supporting brickwork or wood piers or piles or by galleries tunnelled in the latter. In two cases the main colony was traced to the fire-place, under which an extensive nest was found to have been constructed in wood debris. In other cases damage appeared to have resulted from attacks of foraging parties from a mound in the vicinity of the building.

This is the species identified by Froggatt[2] as *Eutermes fumipennis* Walker, as disclosed by an examination of a specimen so labelled (from Shoalhaven, N.S.W.) which is now in the C.S.I.R. Collection. Reasons for differing from Froggatt in this connexion have been stated previously by the writer.[3] The identity of the arboreal termite referred to by Froggatt has not been satisfactorily established; that certain arboreal *Eutermes* from near Sydney are specifically distinct from *E. exitiosus* is beyond doubt.

E. exitiosus appears to be a variable species both in the alate and in the soldier castes, but even with the large number of complete series now available for examination it has been found impossible to differentiate forms which might be regarded as varieties or subspecies.

The alate form has been taken from 11th October to 20th November.

Additional localities.—New South Wales: Dubbo, Prospect, Kuring-gai Chase, Hornsby, National Park, Appin, Nowra, Nerriga, Goulburn, Galston, Parramatta, Eden; Federal Capital

Territory: various localities at elevations from 2,100 to 2,500 feet; Western Australia: Armadale; South Australia: Kangaroo Island, Mt. Gambier; Victoria: Mallee District, ? Broadford.

Correction.

In the description the total length of the alate imago is stated to be from 25.00–26.50 mm.; this should read 17.00–17.50 mm.

EUTERMES FUMIGATUS Brauer.

Reise der Novara, Zool. Theil, 2A., 1866.

This species was described from specimens collected in Sydney. Well preserved cotypes are to be found in the collections of the C.S.I.R. and the writer. Froggatt records it from the type locality and from Newcastle and Colo Vale, N.S.W., his identifications being based on comparisons with cotypes. Mjöberg records it from Perth, Western Australia, and from Mt. Lofty, South Australia. He had specimens identified by Froggatt for comparison. The specimens examined by the writer include many complete and incomplete series from numerous localities in New South Wales and the Federal Capital Territory at elevations from 2,100 to 3,200 feet. Many of these series agree with the typical form described by Brauer; others show rather considerable variation in dimensions and colour in the alates, and colour of the head in soldiers. An attempt has been made to distinguish the more marked of these variants as subspecies or varieties, but this has been found unsatisfactory, and for the present, at any rate, it is proposed to regard Brauer's species as a variable one. A series comprising a queen, soldier and worker from Mt. Lofty (Adelaide Museum) appears to be referable to this species, but none of the extensive Western Australian collections examined include specimens very closely allied to it. *Eutermes dixoni,* n. sp., though clearly allied to the above, cannot be regarded as a variety, a conclusion arrived at independently by Dr. Emerson.

The form commonly found in the Federal Capital Territory differs from the cotypes and from typical series from Hornsby and Pillaga Scrub in that the alates are paler in colour and often have larger eyes, and the soldiers lack the brown suffusion on the sides and base of the head. The following description of examples from the F.C.T. is given for comparison with closely allied species which will be described subsequently in similar terms:—

Imago.

Colour.—Head, thorax and tergites of abdomen dark brown, paler than in *E. dixoni,* n. sp.; legs, clypeus and palpi orange-yellow; antennae brown; wings light brown; sternites of abdomen mostly yellow, one to six suffused laterally with light brown.

Head.—Densely clothed with long and short hairs. Fontanelle large and very distinct, elongate, narrowed posteriorly, expanded anteriorly. Postclypeus large, strongly convex above, a little shorter than half its width. Eyes very large (diam. 0.296–0.333) and prominent, very close (0.037) to lower lateral margin of head. Ocelli very large, broadly oval (0.074 x 0.110–0.120), 0.037 from the eyes. Antennae with 15 segments; 1st twice as long as 2nd; 2nd nearly cylindrical; 3rd very short and narrow, smallest of all; 4th globose, as long and as wide in the middle as 2nd; 5th globose, shorter and narrower than 4th and 6th; 6th very little longer than 4th; 7th to 14th elongate and becoming progressively longer.

Thorax.—Pronotum moderately densely clothed with mostly stout hairs, the anterolateral angles broadly rounded; side rounded to the slightly sinuate posterior margin; meso- and metanotum with posterior margin slightly sinuate, as in pronotum, or distinctly notched, clothed with scanty stout hairs.

Wings.—Wing stumps with scanty stout hairs, veins, excepting radial sector and proximal branches of cubitus, distinct.

Legs and Abdomen.—Clothed as in head.

Measurements.	mm.
Length with wings	10.00–11.00
Length without wings	5.00– 6.00
Head, from base to apex of labrum, long ..	1.07– 1.18
Head, from base to clypeofrontal suture, long ..	0.66
Head, wide	1.05
Antennae, long	1.80– 1.90
Pronotum, long 0.48; wide	0.74– 0.81
Forewings, long 8.50–9.50; wide	2.40– 2.59
Tibia iii., long	1.18

Soldier.

Colour.—Head light orange-yellow, rostrum ferruginous, antennae darker orange-yellow, palpi and tergite of abdomen paler, legs stramineous.

Head.—With very few hairs, rostrum long and moderately thick, more than one-third longer than the remainder of head, dorsum of head nearly straight in profile; outline of head (without rostrum) when viewed from above broadly oval; antennae inserted midway between base and apex of head, of 13 segments; 1st nearly cylindrical, one-third longer than 2nd; 2nd and 3rd almost equal in length and maximum width, 3rd narrower than 2nd at base; 4th about half the length of 3rd but nearly as wide; 5th to 12th elongate, of about equal length; 13th a little shorter than 12th.

In certain otherwise normal colonies there occur a small proportion of soldiers with short, curved snouts.

Measurements.

	mm.
Total length	3.50
Head, from base to apex or rostrum, long ..	1.48
Head, wide	0.88
Antennae, long	1.36
Pronotum, long 0.18; wide	0.44
Tibia iii., long	0.85

Worker.

Head.—Sparsely clothed with reddish hairs, orange-yellow, posterior half suffused with light brown, clypeus and antennae light yellow, antennae of 14 segments, 4th shortest of all.

Biology.—This species does not build mounds, but it occurs commonly in the walls of mounds of *Coptotermes lacteus* (Frogg.), in which the complete life-cycle may be passed. Small colonies are to be found also under stones, logs, and in stumps and trunks of trees, in all of which situations the alate form may occur. Colonizing flights leave the parent nest at night during the period from 8th November to 11th December. There are no records of serious damage by this species to structural timber or living trees.

Eutermes dixoni, n. sp.

(Figures 13–16.)

Imago.

(Figures 13 and 14.)

Colour.—Very dark brown; head, antennae, pronotum and tergites of abdomen darkest; behind the anterior margin of the pronotum a paler area about one-third the width of the sclerite and extending posteriorly in the middle; clypeus yellowish, suffused with brown, labrum and palpi of paler yellow; pleurites and sternites dark brown, lighter than head; tarsi yellow, tibiae and femora paler than pleurites; wings fuliginous, veins very dark.

Head (Fig. 13).—Densely clothed with mostly short hairs, hemispherical behind the eyes; fontanelle indistinct excepting in cleared preparations, linear, a little longer than, but only half as wide as ocelli; postclypeus about two-thirds wider than long, moderately convex above, slightly arcuate behind; eyes large (0.296–0.333 diam.) prominent, 0.045 from lower lateral margin of head; ocelli 0.110–0.120 long, broadly oval, about 0.045 from eyes; antennae with 15 segments, 1st about twice as long as 2nd and much wider; 2nd a little longer than wide, cylindrical; 3rd a little more than half as long as 2nd and very narrow, smallest of all; 4th to 6th globose, 4th nearly as wide as 1st, 5th shorter and narrower than 4th, 6th longer and wider than 4th; 7th to 14th becoming progressively longer, 15th as long as 14th but narrower.

Thorax.—Pronotum (Fig. 13) densely clothed with moderately long hairs, slightly sinuate in front, anterolateral angles broadly rounded, sides narrowed to the posterior border, which is wide and more or less distinctly emarginate; posterior margin of meso- and metanotum generally deeply emarginate.

Wings (Fig. 14).—Veins very dark and distinct to their extremities; membrane behind the radial sector suffused with deep yellow; median of the forewing without, or with from 2 to 7, branches; cubitus with ten or more branches, some of which may be forked; wing membrane densely hairy.

Measurements.	mm.
Length with wings	14.00–14.50
Length without wings	5.50– 6.50
Head, from base to apex of labrum, long	1.40
Head, from base to clypeofrontal suture, long	0.80– 0.88
Head, at and including eyes, wide	1.14– 1.22
Antennae, long	1.92
Pronotum, long 0.55–0.59; wide	0.88– 0.96
Forewings, long 11.50–12.00; wide	3.30– 3.75
Tibia iii., long	1.30– 1.48

Queen.

Total length, 21.00; width of abdomen, 5.00.

Soldier.

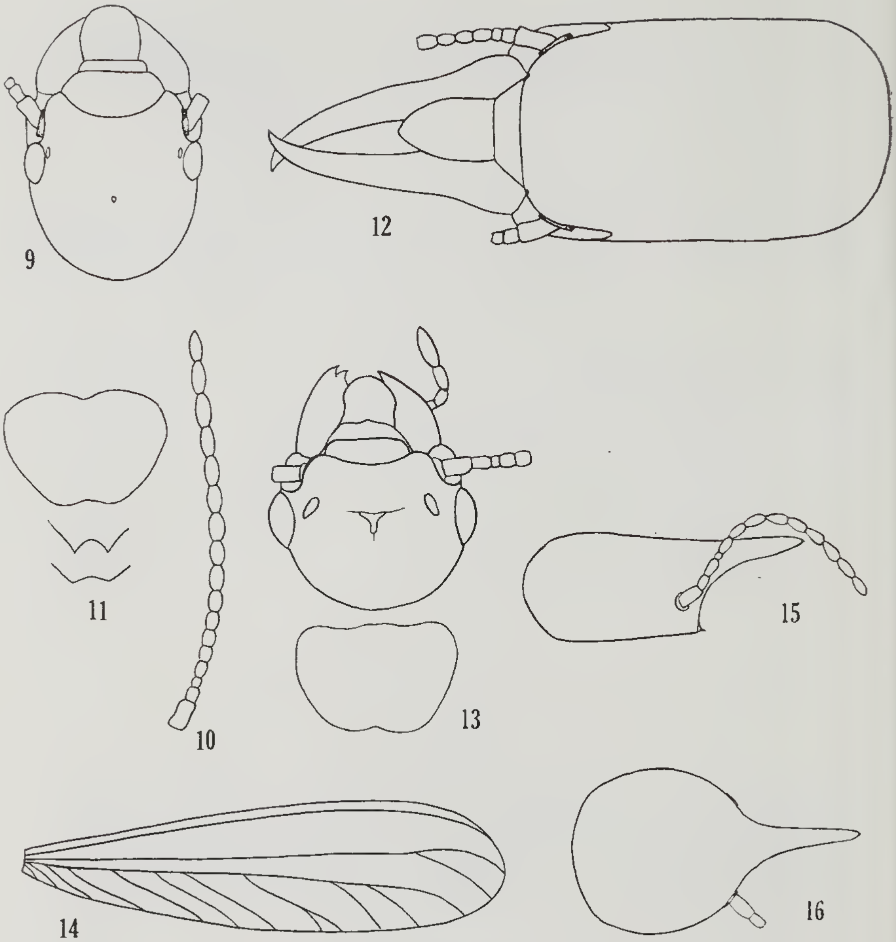
(Figures 15 and 16.)

Colour.—Head chamois-yellow, base lightest, richly suffused with brown on sides and above, snout ferruginous shading to deep orange-yellow at base; antennae same as base of snout; tergites of abdomen rather darker than base of head; legs stramineous.

Head (Figs. 15 and 16).—Snout long and moderately thick, about one-third the length of entire head, anterior two-thirds of dorsal surface nearly straight in profile, posterior one-third slightly inflated; posterior part from insertion of antennae circular when viewed from above; hairs very scanty. Antennae inserted midway between base of head and apex of snout, with 13 segments; 1st segment three-fifths longer and much wider than 2nd; 2nd about as long as 3rd, nearly cylindrical; 3rd swollen apically; 4th shortest and narrowest of all; 5th as long as 3rd but wider; 6th longer and wider than 5th; 6th–12th about equal in length; 13th as long as 10th, but narrower.

Thorax.—Of typical form; sparsely clothed with reddish hairs.

Abdomen.—Moderately densely clothed with long and short hairs.



Figs. 9 to 16.

9. *Heterotermes intermedius*, n. sp. imago: head and basal segments of antennae.
10. *Heterotermes intermedius*, n. sp. imago: antenna.
11. *Heterotermes intermedius*. n. sp. imago: pronotum and posterior margin of mesa- and metanotum.
12. *Heterotermes intermedius*, n. sp. soldier: head and basal segments of antennae.
13. *Eutermes dixoni*, n. sp. imago: head and basal segments of antennae and pronotum.
14. *Eutermes dixoni*, n. sp. imago: fore-wing.
15. *Eutermes dixoni*, n. sp. soldier: head, lateral view.
16. *Eutermes dixoni*, n. sp. soldier: head and basal segments of antennae, dorsal view.

Legs.—Moderately stout; with fewer hairs than on abdomen.

Measurements.	mm.
Total length	3.50–3.70
Head, from base to apex of rostrum, long	1.55–1.60
Head, wide	0.99
Antennae, long	1.40
Pronotum, long 0.18–0.20; wide	0.48–0.51
Tibia iii., long	0.74

Abnormal soldiers have been found in association with others of the normal form in several colonies from the Federal Capital Territory; these have the rostrum shorter than usual and strongly bent downwards.

Worker.

Head.—Above mostly yellow, shading to light brown posteriorly, frontal and transverse sutures very distinct, sides and base mostly pale bluff, elypeus somewhat paler; antennae of 14 segments, light orange-yellow; thorax and abdomen yellowish; legs creamy white.

Measurements.	mm.
Total length	4.25
Head, from base to apex of labrum, long	1.29
Head, to clypeofrontal suture, long	0.92
Head, wide	1.11–1.14
Pronotum, long 0.37; wide	0.62–0.66
Tibia iii., long	1.11

Brachypterous (2nd form) reproductives.

A portion of the rotten stump containing part of the type colony was removed to an even-temperature ehamber on 25th March, 1930, where it was placed in a vertical position in a box of sandy soil with two-thirds of the timber exposed. When some of the wood near soil level was broken off on 19th June, 1930, it was found to contain about 80 brachypterous reproduetives and numerous soldiers and workers. As only larvae, alate imagos, workers, and soldiers were present in the colony on 25th March, 1930, it is presumed that these neotenic forms were not more than 55 days old when discovered.

Description. — Head light brown; antennac, thorax and abdomen somewhat paler; fontanelle and head sutures very distinet; legs and palpi stramineous; ocelli well developed; eyes partly pigmented; thorax worker-like; wing buds of various lengths and stages of development even in the same individual; in extreme cases one bud greatly enlarged, the others vestigial.

There are many variations in size, colour, and degree of development, but the above is typical of the most advanced forms.

Measurements.	mm.
Total length	4.50
Head, to apex of labrum, long	1.18
Head, to clypeofrontal suture, long	0.84
Head, wide	1.03
Eyes, diam.	0.15
Pronotum, long 0.37; wide	0.66

Localities.—Federal Capital Territory (type locality): various localities at elevations of from 2,100 to 3,500 feet; Victoria: Waratah Bay, Hurstbridge, Beaconsfield, Upper Berwick, Kilsyth, Healesville, Dartmoor, Mallacoota, Ferntree Gully, Cann River, Traralgon, Ararat (Mt. Langi Ghiran), Melbourne, Wilson's Promontory, Emerald, Leongatha, Taggerty.

Biology.—The habits of this species are generally similar to those of *Eutermes fumigatus* Brauer, excepting that it does not appear to inhabit the mounds of other species. The alate form has been taken from 11th December to 11th March.

Affinities.—The proposed new species is most closely allied to *Eutermes fumigatus* Brauer, from which it differs, *inter alia,* in the following details:—Imago: body and wings larger and darker; head always longer and wider; eyes generally larger; pronotum generally wider and longer and less markedly notched posteriorly; tibia iii. longer; soldier: head larger and distinctly darker in colour.

Types.—In the collection of the Division of Economic Entomology, C.S.I.R., Canberra.

This species has been named after Mr. J. E. Dixon, a veteran entomologist of Melbourne.

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3. Hill, G. F. *Proc. Roy. Soc. Vic.* (n.s.), xxxvii. (2), p. 225, 1925.
4. ———. *Proc. Linn. Soc. N.S.W.*, xxxviii., p. 194, 1926.
5. ———. *Ibid.*, xxxviii., p. 195, 1926.
6. ———. *Mem. Nat. Mus. Melbourne*, No. 7, pp. 40-59, 1927.
7. Holmgren, N. Termitenstudien. *Kungl. Svenska Vetensk, Akad. Handl.*, xlvi. (6), 1911.

[Proc. Roy. Soc. Victoria, **44** (N.S.), Pt. II., 1932.]

Art. XIII.—*Australian Unionidae.*

By BERNARD C. COTTON and CHARLES J. GABRIEL.

(With Plate XVI.)

(A contribution in part from the South Australian Museum.)

[Read 12th November, 1931; issued separately 20th April, 1932.]

Australian members of the family *Unionidae* are difficult to classify owing to the variability of the individuals which constitute a species and the tendency of one species to merge into another.

Simpson placed all the Australian *Unionidae* under the generic name *Diplodon* Spix, and under the subgeneric names *Hyridella* Swainson and *Cucumeria* Conrad. Accepting Simpson's diagnosis of *Diplodon,* no Australian fresh-water mussel could be included in it, for they have neither " beaks which are more or less radially sculptured, the ridges usually curved and approaching below," nor " beak sculpture consisting of unbroken ridges covering the whole beaks."

Swainson's description of *Hyridella* is " Transversely oval; bosses not sulcated; posterior margin elevated and winged; one cardinal and one lateral tooth in each valve." Type, *H. australis* Lamarck.

It is proposed to locate *Unio australis* Lamarck and allied species in the genus *Hyridella* Swainson. In this genus the hinge teeth are weakly formed. The left valve has the posterior lateral tooth bilaminate to form a groove for the reception of the unilaminate tooth of the right valve.

The paper includes the descriptions of two new genera, *Propehyridella* and *Protohyridella.*

Genus **Hyridella** Swainson.

Hyridella australis (Lamarck).

(Pl. XVI., Fig. 1.)

1819. Unio australis Lamarck, Anim. S. Vert. Ed. 1, vi., p. 80.
1836. Margarita (Unio) depressus Lea, Syn., p. 32.
1843. Unio australis (Lamarck) Hanley, Bivalve Shells, p. 192, pl. xxi., fig. 25.
1850. Unio balonnensis Conrad, P. Ac. Nat. Sc. Phil., v., p. 10.
1856. Unio shuttleworthi Kuster, Conch. Cab. Unio, p. 152, pl. xliv., fig. 2.
1861. Unio philippianus Kuster, op. cit., p. 235, pl. lxxix., fig. 2.
1868. Unio moretonicus Reeve, Conch. Icon., pl. xxiv., fig. 118.
1871. Unio danieli Villa, Journ. de Conch., xix., p. 328.
1882. Unio bednalli Tate, T.R.S.S.A., v., p. 56.

1888. Unio australis Lamarck. Cox, P.L.S., N.S.W., iii. (2), p. 1253.
1888. Unio australis Lamarck. Tate, T.R.S.S.A., xi., p. 69.
1889. Unio legrandi Pett, P.R.S. Tas., p. 81.
1900. Diplodon australis (Lamarck) Hanley. Simpson, P.U.S.N. Mus., xxii., p. 890.
1900. Diplodon (Hyridella) australis var. legrandi Petterd. Simpson, op. cit., p. 891.
1900. Diplodon moretonicus Reeve. Simpson, op. cit., p. 891.
1921. Diplodon australis Lamarck. May, Check List Moll. Tas., p. 21, No. 155.
1921. Diplodon moretonicus Reeve. May, op. cit., p. 21, No. 156.
1923. Diplodon moretonicus Reeve. May, Ill. Index Tas. Shells, pl. ix., fig. 12.
1923. Diplodon australis Lamarck. May, op. cit., pl. ix., fig. 11.

Localities.—Queensland: Rockhampton (C. L. Barrett). New South Wales: River Allyn (C. L. Barrett), River Namoi at Narrabri (Cox), River Clarence, Richmond (Nat. Mus. Melb.), South Creek near Sydney (Cox), Reedy Lake at junction of Murray and Darling Rivers. Victoria: River Yarra, River Tanjil near Longford, River Mitchell, Chalka Creek near River Murray, River Mackenzie, Longerenong (J. L. Gatliff), Horsham (J. H. Gatliff), Birregurra, Lake Lonsdale (C. L. Barrett), River Glenelg (W. H. Dillon), River Murray, Gooramadda (A. S. Kenyon), Gardiner's Creek, Saltwater River, Keilor Plains, River Goulburn, Kialla West. Tasmania: River Esk. South Australia: River Murray and Onkaparinga. Western Australia: Exact locality not known (Nat. Mus. Melb.).

Observations.—Lamarck gave "Nouvelle Hollande" as type locality. Three whole shells and two valves sent by Dr. Cox of Sydney have the label inscribed "*Unio australis* Lamarck, from South Creek near Sydney where Lamarck's types were first secured." These are typical *Hyridella australis,* and therefore South Creek near Sydney may be accepted as the type locality. An average specimen measures 71 mm. x 44 mm. The specimen illustrated measures 94 mm. x 55 mm.

Hyridella ambigua (Philippi).

(Pl. XVI., Fig. 2.)

1848. Unio ambiguus Philippi, Abbild. iii., lief. 2, p. 47, pl. iii., fig. 2.
1859. Unio vittatus Lea, P. Ac. Nat. Sc. Phil. iii., p. 153.
1864. Unio (Alasmodon) evansi Adams and Angas, P.Z.S. Lond., p. 39.
1868. Unio evansi Adams and Angas. Reeve, Conch. Icon., pl. lvi., fig. 285.
1868. Unio vittatus Lea. Reeve, Conch. Icon., pl. xviii., fig. 83.
1887. Unio vittatus Lea. Tate, T.R.S.S.A., ix., p. 101.
1888. Unio ambiguus Phil. Tate, ibid., xi., p. 69.
1888. Unio evansi Adams and Angas. Tate, ibid., xi., p. 69.
1900. Diplodon (Hyridella) vittatus Lea. Simpson, P.U.S. Nat. Mus., xxii., p. 890.
1900. Diplodon (Hyridella) evansi Adams and Angas. Simpson, op. cit., p. 892.
1916. Diplodon ambiguus Philippi. Hedley, J.R.S.W. Aust., i., p. 7.

Localities.—New South Wales: Reedy Lake at junction of Murray and Darling (Nat. Mus. Melb.). South Australia: River Murray at Mannum, Point Sturt, Lake Alexandrina, Moorook near Overland corner. Western Australia (Hedley).

Observations.—This species is very common in the River Murray. Fifty specimens taken at Mannum, South Australia, agree closely with Philippi's illustration. It inhabits only the lagoons, whereas *H. australis* is found in the main stream. The present species is thinner, higher, more compressed and lighter coloured than *H. australis.* The sub-fossil, *Unio protovitatus* Hale and Tindale, from Tartanga, River Murray, South Australia, is closely related to this species but has a consistently thicker shell formation. A typical specimen measures 77 mm. x 54 mm. (illustrated).

Hyridella angasi (Reeve).

(Pl. XVI., Fig. 3.)

1856. Unio shuttleworthi Lea, P. Ac. Nat. Sc. Phil., viii., p. 94 (nom. preoc.).
1868. Unio angasi Sowerby. Reeve, Conch. Icon., p. 55, fig. 282.
1882. Unio angasi Reeve. Tate, T.R.S.S.A., v., p. 56.
1888. Unio angasi Sowerby. Tate, T.R.S.S.A., xi., p. 69.
1900. Diplodon (Hyridella) shuttleworthi Lea. Simpson, P.U.S. Nat. Mus., xxii., p. 893.
1917. Diplodon shuttleworthi Lea. Odhner, K. Sv. Vet. Ak. Handl., lii. (16), p. 74.

Localities.—Queensland: River Coleman. North Australia: Strangeways River (type), Gulf of Carpentaria, Croydon Goldfields, Mackinlay River. New South Wales: Woolloomooloo, Macquarie River, Dubbo (largest specimen 130 mm. x 72 mm.), Upper Richmond River, Boro, Shoalhaven River, Darling River, junction of Darling and Murray Rivers. Victoria: Cramenton.

Observations.—An average specimen measures 100 mm. x 58 mm. (illustrated).

Hyridella wilsoni (Lea).

(Pl. XVI., Fig. 4.)

1859. Unio wilsoni Lea, P. Ac. Nat. Sc. Phil., p. 153.
1863. Unio (Alasmodon) stuarti Adams and Angas, P.Z.S. Lond., p. 417.
1896. Unio stuarti Adams and Angas. Tate, Horn Exped. Zool., p. 217.
1917. Diplodon wilsoni Lea. Odhner, K. Sv. Vet. Ak. Handl., lii. (16), p. 74.
1918. Id. Hedley, Proc. Roy. Geog. Soc. Aust., S.A. Branch (1916-17), p. 2.
1900. Id. Simpson, P.U.S. Nat. Mus., xxii., p. 892.

Localities.—Central Australia: (Spencer and Gillen Exped., 1901), Nat. Mus. Melb., Lagoon, Mt. Margaret (type), Algebuckina Creek, River Stevenson. North Australia: Red Lily Lagoon (Sir Baldwin Spencer), Nat. Mus. Melb. South Australia: Oodnadatta. Western Australia: River Fitzroy.

Observations.—A typical specimen measures 86 mm. x 40 mm. Two examples from Red Lily Lagoon, obtained by Sir Baldwin Spencer, possess a slightly broader posterior end, but otherwise answer to the above species.

Hyridella jeffreysiana (Lea).

1871. Unio jeffreysianus Lea, P. Ac. Nat. Sc. Phil., i., p. 188.
1882. Id. Smith, J.L.S., Lond., xvi., p. 311.
1900. Diplodon jeffreysianus Lea. Simpson, P.U.S. Nat. Mus., xxii., p. 891.

Locality.—Australia.

Observations.—Smith states, "The remarkable peculiarity of this species consists in the lateral teeth in both valves being single. In all other respects it agrees with *U. ambiguus*." Melbourne has been given as the locality for this species, but no Victorian collection is known to us containing specimens bearing this name. We have never seen a specimen.

Propehyridella, gen. nov.

Shell similar in shape to *H. australis* Lamarck; divaricately, irregularly wrinkled in the juvenile, becoming gradually smooth in the adult; solid, hinge teeth well developed; epidermis shining, smooth.

Type.—*Unio nepeanensis* Conrad.

This genus is intermediate between *Hyridella* and *Protohyridella*, a new genus described below. The corrugated sculpture present only in the umbonal area in *Propehyridella* extends over a far greater area in *Protohyridella*.

Propehyridella nepeanensis (Conrad).

(Pl. XVI., Fig. 5.)

1830. Unio depressus Lesson. Voy. Coquille, ii., p. 427, pl. xv., fig. 5 (nom. preoc.).
1850. Unio nepeanensis Conrad, P. Ac. Nat. Sc. Phil., v., p. 10.
1852. Id. Conrad, J. Ac. Nat. Sc. Phil., ser. 2, p. 297, pl. xxvi., fig. 4.
1865. Unio lessoni Kuster, Conch. Cab. pl. xxxvi., fig. 4.
1900. Diplodon (Hyridella) dorsuosus Gould. Simpson, P.U.S. Nat. Mus. xxii., p. 889.
1900. Diplodon (Hyridella) lessoni Kuster. Simpson, ibid., p. 890.

Localities.—New South Wales: River Nepean. Victoria: River Mitchell at Bairnsdale, River Wallagaraugh.

Observations.—A typical specimen measures 62 mm. x 38 mm.

PROPEHYRIDELLA CULTELLIFORMIS (Conrad).

(Pl. XVI., Fig. 6.)

1819. Unio depressus Lamarck, An. s. Vert., vii., p. 79 (preoc. Donovan, 1801).
1841. Id. Delessert, Rec. Coq. Lam., pl. xii., fig. 5.
1850. Unio cultelliformis Conrad, P. Ac. Nat. Sc. Phil., v., p. 10.
1850. Unio profugus Gould, P. Boston Soc. Nat. Hist., p. 295.
1854. Unio depressus Lamarck. Lea, J. Ac. Nat. Sc. Phil., p. 295, pl. 26, fig. 2.
1862. Unio (Niaa) depressus Lamarck. Chenu, Man. de Conch. ii., p. 140, fig. 679.
1882. Unio depressus Lamarck. Smith, J.L.S. Lond., xvi., p. 308.
1887. Unio depressus Lamarck. Tate, T.R.S.S.A., xi., p. 101.
1900. Diplodon (Hyridella) profugus Gould. Simpson, P.U.S. Nat. Mus., xxii., p. 891.
1900. Diplodon (Hyridella) mutabilis Lea. Simpson, ibid., p. 308.

Localities.—New South Wales: Richmond River (153 mm. x 71 mm.), Byangum, Nepean River near Penrith, Clarence River, Parramatta River, Bargo River, Picton. Victoria: Glengarry River, Mitchell River at Bairnsdale, River Yarra at Wooriyallock, River Erskine at Lorne, River Wallagaraugh, Tarra Creek, Mt. Evelyn (M. E. Gatliff), Heidelberg, Lilydale, Bunyip (Nat. Mus. Melb.)

Observations.—Delessert's figure is that of a juvenile. In very young specimens, the umbos, not being eroded, are seen to be distinctly wrinkled. A typical specimen measures 84 mm. x 41 mm.

PROPEHYRIDELLA NARRACANENSIS, sp. nov.

(Pl. XVI., Fig. 8.)

Shell ovate, elongate, rounded anteriorly, produced and angled posteriorly; divaricately wrinkled near the umbos, but smooth elsewhere; epidermis yellowish-brown, dull; hinge teeth strongly formed; a weak depression runs from the umbo to the ventroposterior margin; accremental striae close, fine, and irregular.

Localities.—Victoria: Narracan River at Thorpdale, Gippsland (type), 25.3 mm. x 15.5 mm. (Nat. Mus. Melb.); collected by W. Kershaw. Birregurra.

Observations.—The Birregurra examples are darker and a little more inflated, but otherwise inseparable.

Protohyridella, gen. nov.

Shell solid, subrhomboidal, sub-depressed, inequilateral, rather produced posteriorly; an indistinct rib running from the umbo to the postero-ventral margin divides the surface into two areas, an anterior corrugated area and a posterior smooth area; umbos not prominent; hinge teeth well developed. Type, *Unio glenelgensis* Dennant.

The peculiar sculpture occupying the greater portion of the shell, readily distinguishes this from any other Australian species.

so that it is here made the type of a new genus. *Protohyridella* is probably even more primitive than *Propehyridella.* The corrugated sculpture, typical of fresh-water mussels inhabiting quick-flowing rivers seems scarcely warranted in present day, slow-flowing Australian rivers.

PROTOHYRIDELLA GLENELGENSIS (Dennant).

(Pl. XVI., Fig. 9.)

1898. Unio glenelgensis Dennant, P.R.S. Vict., x., p. 112, pl. 4.
1900. Diplodon (Hyridella) glenelgensis Dennant. Simpson, P.U.S. Nat. Mus., xxii., p. 889.

Localities.—Victoria: River Glenelg at Dartmoor (J. Dennant and W. H. Dillon), Roseneath (J. Dennant and Rev. W. Whan).

Observations.—The type specimen measures 40 mm. x 23 mm. The specimen illustrated here measures 31 mm. x 18 mm. (Both in Nat. Mus. Melb.)

Genus **Cucumeria** Conrad.

Shell elongated, trapezoidal, widest behind; pseudocardinals irregular, small, not well developed, showing a tendency to break into denticles; laterals feeble; pallial line strongly pitted; nacre much thicker in front.

Type.—*Unio novaehollandiae* Gray.

CUCUMERIA NOVAEHOLLANDIAE Gray.

(Pl. XVI., Fig. 7.)

1834. Unio novaehollandiae Gray, P.Z.S. Lond., p. 57.
1840. Unio cucumoides Lea, P. Amer. Phil. S., p. 285.
1852. Unio cumingianus Dunker, Zeits. f. Mal., ix., p. 53.
1900. Diplodon (Cucumeria) novaehollandiae Gray. Simpson, P.U.S. Nat. Mus., xxii., p. 893.

Localities.—New South Wales: Richmond River, Byangum, Tweed River, Macquarie River (type).

Observations.—The type in the British Museum is labelled "Macquarie River." according to Smith. A typical specimen measures 168 mm. x 67 mm.

The following species listed by Smith are probably not Australian:—Unio fulmineus Philippi, multidentatus Philippi, semiplicatus Kuster, rugulosus Charpentier, gratiosus Philippi.

Explanation of Plate XVI.

Fig. 1.—*Hyridella australis* Lamarck.
Fig. 2.—*H. ambigua* Philippi.
Fig. 3.—*H. angasi* Reeve.
Fig. 4.—*H. wilsoni* Lea.
Fig. 5.—*Propehyridella nepeanensis* Conrad.
Fig. 6.—*Propehyridella cultelliformis* Conrad.
Fig. 7.—*Cucumeria novaehollandiae* Gray.
Fig. 8.—*Propehyridella narracanensis,* sp. nov.
Fig. 9.—*Protohydridella glenelgensis* Dennant.

Australian Unionidae.

13801.

[Proc. Roy. Soc. Victoria, 44 (N.S.), Pt. II., 1932..

Art. XIV.—*The Geology and Petrology of the Warburton Area, Victoria.*

By A. B. EDWARDS, B.Sc.

(Bartlett and Government Research Scholar, University of Melbourne).

(With Plate XVII.)

[Read 12th November, 1931; issued separately 20th April, 1932.]

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(Note.—Numbers in brackets thus—No. (2462)—refer to slides in the University Collection.)

Introduction.

The area described in this paper is an approximately rectangular block of country, made up of the parishes of Yuonga and Warburton, the northern half of the parish of Woori Yallock, and the southern part of the parish of Gracedale (all in the County of Evelyn). It lies south of, and is contiguous with, the Black Spur Area.[8]

A geological sketch map has been prepared from parish plans, and compass and pacing traverses. Form lines have been drawn, based on aneroid traverses, in order to demonstrate the very rugged topography. Where geological boundaries are marked with broken lines, they are inferred from the mapping; full lines indicate boundaries which have been traced.

I am indebted to Dr. Summers, Dr. Stillwell, Mr. Singleton, Mr. Hauser, and the staff of the Geology School for their generous help, and to the University authorities, who made the work possible.

Previous Literature.

Scanty references to the district are found in the progress reports of the Geological Survey for 1876 and 1877, and in the annual report of the Secretary for Mines for 1907. In 1901 E. Hogg[12] in a paper on Victorian granitic types summarized the characters of the granodiorite from Old Warburton, and in the following year Professor J. W. Gregory[10] included the Warburton dacites in the Tertiary igneous rocks of Victoria. Short geological notes on the area are found in the *Victorian Naturalist* for 1904 (Chapman) and 1905 (Kitson). There is a brief report on the mining features of Hoddle's Creek by O. A. L. Whitelaw, in the *Records of the Geological Survey of Victoria* for 1906. Two important maps, prepared by J. C. Easton, appeared in the *Records of the Geological Survey* for 1908, accompanied by short reports. These show the boundaries of the igneous rocks and the Silurian for the Woori Yallock Basin, and the head of the Acheron and Yea rivers, with the Yarra. Professor E. W. Skeats[20, 21] in 1909 appreciated the Palaeozoic age of the igneous rocks. He observed the general similarity between the gneissic contact aureole at Warburton and that at Selby, and recognized the intrusive relation of the granodiorite to the dacite both at Warburton and at Nyora, despite the absence of gneissic rocks at the latter. J. T. Jutson[15] described the physiography and development of the Yarra in 1911; and in the *Records of the Geological Survey* for 1921, A. M. Howitt recorded the characters of the wolfram deposits at the head of Britannia Creek.

Physiography.

The Warburton area has a mountainous topography, which falls into four zones: (1) the east-west dacite range in the north, (2) the deep valley of the Yarra, (3) the mountains of granodiorite in the south-east corner of the area, and (4) the Silurian foot-hills in the south-west corner.

The east-west dacite range is bounded on its north side by the head waters of the Acheron, Watts, and Badger rivers, and on its south side by the valley of the Yarra. It slopes down from 4,080 feet at Donna Buang in the east, to 3,400 feet at Ben Cairn in the west. West of these it is deeply cut into by the north-south valley of the Don river, so that Mt. Toole-be-wong is all but isolated, being connected with the main range by a narrow neck at the head of the Don. Erosion has formed two low gaps in this neck—Don Gap (2,500 feet) and Panton's Gap (1,700 feet). The resistant granitic base of Mt. Toole-be-wong has diverted the erosion of the Yarra.

The valley of the Yarra is fully described by Jutson.[15] In the east it forms, in the Silurian sediments, a wide, mature valley. At Warburton, where a narrow tongue of dacites crosses the stream, it narrows into a deep rocky gorge, which opens again into a wide flat valley as the river progresses westwards.

The granodiorite mountains of the south-east corner are rugged, but less so than the dacitic ranges. They rise to about 2,000 feet. Mt. Little Joe (1,500 feet) in Warburton, consists of sediments, metamorphosed by the granodiorite, and thus rendered resistant to erosion.

To the south-west occur the low foothills of Silurian sediments, separated from the south-eastern zone by the Little Yarra river.

In the eastern part of the area the northern tributaries to the Yarra, from the dacite, are more numerous, more torrential, and generally stronger than those from the south. Owing to their torrential character they tend to form "alluvial fans" about their junctions with the Yarra, thus forming deposits of river gravels, which mask the igneous outcrops. In the western part of the area, the southern streams increase in importance, and the torrential character disappears.

According to the varying richness and depth of soil in these four zones, there is a marked difference in the vegetation, which increases in richness and intensity from the poorly clad Silurian with its poor, thin soil, through the granodiorite, to the richly forested dacite. The undergrowth shows a parallel enrichment.

The Silurian Sediments.

The oldest rocks outcropping in the area are moderately openly folded sandstones and mudstones of Silurian (Yeringian) age. Blue slates appear occasionally, and thin beds of conglomerate with sandstone pebbles have been observed along the Cement Creek road. The beds dip at up to 80°, and strike at 20° west of north, with anticlines from one to two miles apart. Local crumpling appears along some of the axes. The thickness of the bedding varies enormously.

This present survey has dealt very scantily with the sedimentary rocks. No new fossils were discovered. The following forms have been recorded at intervals by Mr. Chapman[3-5]:—

1. *From the junction of Woori Yallock Creek and the Yarra.*

   Conularia sowerbii; Fenestella margaretifera; Stropheodonta (Leptostrophia) alata; Trachyderma cf. squamosa; Turrilepas yeringae.

2. *From Starvation Creek.*

   Styliola fissurella; Panenka gippslandica; Paracardium filosum; Lunulicardium antistriatum.

These are all Yeringian in horizon.

The Igneous Rocks.

The igneous rocks of the area comprise an acid suite of lavas, hypabyssal intrusives, and plutonic and associated aplitic phases. The earlier, more acid varieties are generally covered by the later flows, and are only found in small peripheral patches, or where deep erosion has exposed them. Occasionally, small blocks of them have been brought up by the later intrusions. There is fairly complete evidence for the sequence of extrusion:—

1. Soda-rhyolite
2. α-quartz-biotite-dacite
3. β-quartz-biotite-dacite
4. Hypersthene-dacite
5. Felspar-hornblende-porphyrite
6. Granodiorite
7. Aplites, pegmatites, quartz-porphyries, quartz veins

—i.c., an acid to basic series of lavas, reverting to increasingly acid intrusive types.

The suite is genetically related to, and individually contiguous with the Black Spur suite.[8] The rocks are petrographically related to the Macedon, Dandenong Ranges, Marysville, and Taggerty complexes. Accordingly they are to be regarded as of the same age as these—Upper Devonian.

The Soda-Rhyolite.

Small outcrops of soda-rhyolite are found marginal to the southern boundary of the igneous rocks, generally in association with the α-quartz-biotite-dacite. The rhyolite appears in two phases, both finely porphyritic, which may both be present in one locality. The one phase is a dark, often tuffaceous, glassy rock, with numerous quartz phenocrysts of 1 mm. diameter: the other is a white rock with quartz and felspar phenocrysts both apparent, flow structure, and often greenish glassy patches. The white phase may represent the dark phase devitrified, though they might be separate intrusions.

Section No. (2,460) is typical of the white phase, from the road cutting west of Scotchman's Creek. This rock is a glassy porphyry. The phenocrysts consist of quartz, anorthoclase, orthoclase, and albite occasionally. Clots of secondary biotite flakes occur, representing a previous pyroxene or amphibole. Individual phenocrysts reach 2 mm. diameter, but the majority average 0.2 mm. They are much embayed. The anorthoclase crystals are commonly edged with a narrow microscopic rim of clear material, probably orthoclase or albite. Kaolinisation often renders the determination of the felspars difficult.

The groundmass is cryptocrystalline to glassy, consisting mostly of quartz. It shows beautiful flow bands which curve about the phenocrysts. Lenticles of coarser groundmass of finely microscopic texture are drawn out and curved concentric with the flow structure. Ilmenite and accessories other than apatite are absent.

A Rosiwal volumetric analysis shows the following proportions:—quartz 12.2, anorthoclase (and other felspars) 13.8, biotite 2.3, and groundmass 71.7.

A chemical analysis (No. 1) shows it to be equally as acid as the potash rhyolites of Narbethong (No. 3)[14] and Taggerty,[11] but poorer in total alkalies. The nearest approach to it of a soda-rich type is the quartz-keratophyre from Navigation Creek, Noyong, analysed by Howitt, and described by Skeats.[20]

Section No. (2,462) from the Cement Creek Road quarry is from the dark phase. Compared with the white phase, it appears rather richer in quartz phenocrysts, and the base is strongly glassy. Both anorthoclase and orthoclase are present, together with some oligoclase. There is considerably more biotite, as chloritised primary flakes, and an increase in ilmenite often altered to leucoxene. Flow structure is well marked.

Associated with this dark rock is the white phase, which is free from the tuffaceous fragments common to the dark rhyolite. These fragments are generally sedimentary in character.

In the cutting west of Scotchman's Creek the white rhyolite has been locally kaolinised by the intrusion of a dyke related to the felspar-hornblende-porphyrite, which outcrops nearby. The edge of the dyke is similarly altered.

Two small patches of the rhyolite are found on the road between Ben Cairn and Donna Buang, surrounded by felspar-hornblende-porphyrite, which when intruding the dacites, appears to have brought this large xenolith up with it. Fragments of the white rhyolite (?) are also found in the hypersthene dacite at the summit of Donna Buang.

The α-quartz-biotite-dacite appears to overlie the white rhyolite near the kaolin patch, and the dark rhyolite wherever the two are associated, while the rhyolite is always found resting on the Silurian sediments.

While the outcrops of the dark rhyolite appear to represent the same flow, its relationship to the white rhyolite is obscure. These rhyolite flows rarely exceed 30 feet in thickness.

The α-Quartz-Biotite-Dacite.

This rock is outcropping in small patches around the southern margin of the igneous rocks. Fresh specimens are a dark-blue grey colour, and strongly porphyritic. The phenocrysts are of quartz and white felspar, with numerous flakes of black biotite, set in a very fine-grained base. The phenocrysts vary somewhat in grain size. They may be as large as 5 mm. in diameter, but average 2 mm. The rock is quite distinct from the quartz-dacite of Maroondah Dam, but resembles somewhat closely the quartz-biotite-dacite of the Black Spur. Chemically it approaches closest to the composition of the quartz-dacite. It is to be regarded as an intermediate phase between these two. As in the soda-rhyolite, but to a lesser extent, the soda dominates over the potash.

A typical section No. (2.449) from the boundary of allotments 20, 21, Yuonga exhibits these intermediary characters. The rock is a porphyrite, with phenocrysts of quartz, felspar, and biotite set in a glassy to cryptocrystalline groundmass.

The quartz crystals are strongly embayed, and often cracked and shattered. They about equal the total felspars in volume. The largest phenocrysts are of quartz, and their edges are sometimes granulated. Plagioclase dominates the felspars as oligoclase (about $Ab_{75}An_{25}$), with some andesine and a little anorthoclase (?). The biotite belongs to two generations.

There are numerous flakes of strongly pleochroic brown biotite of primary habit. These invariably show a deposition of iron ore along the cleavages. In addition there are aggregates of structureless biotite with a deeper brown colour. These probably replace enstatite, which is found rarely as small remnants. Muscovite is fairly common, silghtly chloritic, and replacing biotite. Primary ilmenite is absent.

Section No. (2,450), a few feet from the base of this flow, shows a rather more basic plagioclase ($Ab_{65}An_{35}$), together with rare microperthitic orthoclase. The phenocrysts show fracturing and shearing, and are crowded together to the partial exclusion of the groundmass, which is full of biotite granules. Enstatites are rare, and occasional pyrite stringers are present. In No. 2,451, from the road cutting west of Scotchman's Creek, enstatite is again present, and also some microperthitic orthoclase (anorthoclase ?). The plagioclase is about $Ab_{70}An_{30}$. Muscovite is present, and primary ilmenite is characteristically absent.

The β-Quartz-Biotite-Dacite.

Only one small patch of this rock occurs within the area, near Sunny Lodge, north-west of Mt. Toole-be-wong, and marginal to the igneous lavas. Associated with it are tuffs which contain what are apparently fragments of rhyolite. This rock is the same as that described as quartz-biotite-dacite, from the Black Spur,[8] and does not call for further description.

Distinctions between the Quartz-Bearing Dacites.

The following Rosiwal analyses illustrate the distinctive differences of the quartz-bearing dacites:—

	I. Quartz Dacite	II. α-Q. B. Dacite	III. β-Q. B. Dacite
Quartz	9.56	20.82	11.46
Felspars	15.30	21.32	27.04
Biotite	3.82	10.22	15.58
Groundmass ..	72.32	47.64	45.65

Primary ilmenite is absent from I and II, but is commonly present in III. Deuteric chloritisation is characteristic of I and is absent from II and III. The original pyroxene in II was enstatite (?) while that of III was hypersthene. With respect to felspars, II appears to be intermediate between I and III.

It would appear that the extrusion from the magma chamber occurred at different times at different localities, giving rise to slightly differing local phases. The sequence of the α and β varieties cannot be determined in the field. They both pre-date the hypersthene-dacite; and it has been thought advisable from the suggestive indirect evidence to consider the α type as post-dating the quartz-dacite, but as preceding the β type.

The Hypersthene-Dacite.

The hypersthene-dacite outcrops over most of the northern part of the area, being contiguous with the hypersthene-dacite described from Mt. Juliet in the Black Spur area.[8] Just at Warburton a narrow tongue of it crosses the valley of the Yarra, and makes contact with the granodiorite. It is the thickest and most widespread of the effusives, but the estimation of the thickness is rendered difficult by the irregular contour of its junction with the Silurian, or other igneous types. At Ben Cairn and at Donna Buang it appears to be at least 2,000 feet thick.

In chemical and mineral composition it is so closely allied to the Mt. Juliet type, and the hypersthene-dacites of Macedon[22] and the Dandenong Ranges,[18, 21] as not to warrant a further description.

Felspar-Hornblende-Porphyrite.

This presents a facies previously unrecorded in the dacitic suites of Victoria. A section from the Don-road outcrop has been described by Junner[14] as an andesite; while a reference by Easton[7] to trachyphonolite just west of the Dee river may represent a border phase of the outcrop found there.

An analysis (No. 8) shows the rock to be closely similar to the granodiorite in chemical composition, and more acid than the hypersthene-dacite, so that it cannot be termed andesite. Moreover, its intrusive, dyke-like form precludes the name dacite. Hence it has been called "porphyrite." The prefix "felspar-hornblende" is added to distinguish it from the post-granodiorite hornblende-porphyrites of Selby and Dandenong,[21, 23] and to accord with the descriptive nomenclature adhered to throughout.

The outcrops are in the form of long narrow dykes, often with a strong dip. This dip, if taken in conjunction with the contours, accounts for the major irregularities of the various outcrops. It is significant that these dykes have been found only along the deeply eroded dacitic range from Donna Buang to Toole-be-wong (and in the Badger Valley ?) in the proximity of the granodiorite massif.

These great porphyrite dykes intruded the hypersthene dacite. At the immediate contact granulation has occurred in conjunction with chemical rearrangement. The hypersthene phenocrysts of the dacite have been altered, in some cases to a structureless biotitic mineral, and quite commonly to fibrous sheaves of, apparently, anthophyllite. Further outwards, up to 30 feet or more from the contact the granulation is the main alteration. The granodiorite is found intruded into the dykes in the Warburton contact zone. There is evidence also, from xenoliths, that they post-date the soda-rhyolite and the α-quartz-biotite-dacite, so that their position in the sequence of the types is fixed.

It seems probable that these porphyrite dykes represent tongues of magma from the uprising granodiorite fluid, and that they demonstrate the mechanics of the extrusion of the preceding lavas.

The various outcrops vary a great deal in the size of the phenocrysts, their proportion, and the nature of the groundmass. A very good exposure, obliquely transverse to one of the main dykes, is found along a fire-break on the southern slope of Ben Cairn. A series of specimens taken across the outcrop make it possible to correlate all the irregularities observed into progressive relationship and serves better to describe the character of the rock than specimens from any other locality.

It is possible to trace the rock through a glassy stage to a trachy-doleritic phase. This, in turn, is replaced by a finely porphyritic rock which transcends to a coarse porphyrite. From this stage, the size of the phenocrysts decreases, until a glassy border phase is again met with on the upper edge of the outcrop.

Specimens of the lower glassy phase show a dense black fine-grained rock, almost free from even minute phenocrysts, and exhibiting a fine, platy banding from differential movement. The banding is parallel to the wall of the dyke. In section No. (2,414), a few feet within the dyke, the rock has a trachy-doleritic texture, and consists of orthophyric prisms of felspar and green hornblende. The felspar is a labradorite plagioclase ($Ab_{30}An_{70}$). Occasional large phenocrysts of bytownite stand out. The hornblende prisms are generally altering to chlorite, and occasionally to epidote. Iron ore is noticeably subordinate. Section No. (2,415), from the same lower inner border phase, presents certain "orbicular" structures in a similar trachy-doleritic base. The outstanding feature is a quartz ovoid 1.5 cms. x 2.5 cms. This ovoid has smooth rounded walls, and is entirely crystalline. It consists mainly of quartz. A little andesine, and one crystal of microcline (?) appear near its outer edge. A few crystals of chloritised hornblende associated with epidote appear in the peripheral parts, and fine radial and hair-like microlites of hornblende abound in the quartz throughout. Epidote needles and granules are also found as minor constituents of the ovoid. They often appear at right angles to the wall, or parallel to it, suggesting a radial and concentric structure within the ovoid. Circular "orbicules" with an inner zone of hornblende and an outer rim of quartz (?) or, possibly, felspar are also observed. These are of microscopic dimensions. The hand specimens show distinct "orbicules" up to 0.5 cm. diameter. In section these show a nucleus of radially crystalline quartz surrounded by a zone of hornblende and, lastly, a fine rim of either quartz or felspar. These "orbicules" break out distinctly from the trachy-doleritic groundmass. All these orbicular phenomena seem related, and apparently owe their origin to the viscosity relations set up by sudden cooling (cf. Sederholm, p. 19).

Section No. (2,416) is cut from about 30 yards from the lower (southern) edge of the dyke outcrop. It is a porphyritic rock with phenocrysts of plagioclase and chloritised green hornblende, together with occasional biotites, and rare quartz crystals, set in a glassy groundmass. The plagioclases are bytownite (about $(Ab_{25}An_{75})$, with small quantities of andesine. It shows well-developed Ab twinning, and Carlsbad twins, and less frequently zoning. The crystals are generally corroded and often cracked and crushed. Clots of crystals are not uncommon. Individual phenocrysts are rarely larger than 2 mm. diameter, and average from 0.5 mm. to 1.0 mm.

The hornblende is possibly sodic. It is pleochroic from green to blue or yellow, and shows a high double refraction. It is often idiomorphic in section, and is generally altered to chlorite or a fibrous mineral. Less commonly it is altered to brown biotite of structureless character. Such biotite as occurs is often surrounded by a fringe of "intergrown" iron ore and quartz. "Mosaic" intergrowths of hornblende prisms and plagioclase are present.

The groundmass is highly glassy, and is full of fine grains of ilmenite, chloritised microlites of hornblende, and incipient microlites of quartz or felspar. Little stringers of quartz commonly penetrate the groundmass, and also the phenocrysts. Zircons are accessory.

Section No. (2,417) was taken from the centre of the dyke. The dominant phenocrysts in this are basic andesines ($Ab_{50}An_{50}$). These are much coarser in grain size than in the border phase, being commonly 4.5 mm., and larger in diameter. The smaller phenocrysts, also abundant, often show clotting together. Hornblende is rarely found, its place being taken by biotite, which now occurs in crystals showing normal structures. The groundmass is still strongly glassy, but is free from hornblende needles or granules, and contains more numerous and more strongly developed microlites of quartz and felspar.

This coarse central phase merges again into a finely porphyritic stage similar to that described above, and this passes into a fairly wide trachy-andesitic border phase. Section No. (2,418) from this upper (northern) border phase is very greenish owing to a richness in hornblende material. Clots of small hornblende crystals are set in a hyalopilitic base of plagioclase, hornblende, glass and iron ore. The groundmass makes up over 80 per cent. of the rock. Phenocrysts of felspar are small, and not common. They are of basic labradorite. Lens-shaped patches of quartz and felspar (orthoclase ?), and related veinlets, showing columnar growth from the walls inwards, are of common occurrence. They represent the last part of the rock to consolidate. Some secondary biotite is developed from the hornblende.

All these types, in various associations, of which the finely porphyritic and the glassy to trachy-andesitic border phases are most general, are found recurring in the other dykes of felspar-hornblende-porphyrite.

It seems evident that it was intruded in an almost completely fluid state, and that crystallisation set in rapidly. In the outer phases the chilling gave mainly a glass: in the trachy-doleritic phase, viscosity was rapidly induced giving orbicular developments and completer crystallisation, about many centres. Further in, the individual felspars and hornblende crystals developed freely for a time. The time of free development increased towards the centre, so that progressing inwards the felspars are larger and increasingly acid. Differential movement is marked in the outer border phases. A further result of the slower central cooling has been to permit the intratelluric replacement of the hornblende by biotite to occur increasingly towards the centre of the dyke. The order of crystallisation of minerals was apparently—ilmenite, anorthite, hornblende, labradorite, andesine, biotite, quartz. The chloritisation may have been of "deuteric" origin. Larsen[16] quotes the reversion temperature of green hornblende to give a basaltic hornblende as 750° C. If this is so, then the dyke could scarcely have been above 800° C. when intruded, and it must have cooled relatively slowly.

Granodiorite.

Two outcrops of granodiorite occur within the area. The one forms the northern end of a large massif extending from just south of Warburton township to as far south as Tynong, where it appears as a typical granite. The other outcrop is a stock-like body, of satellitic character, forming the core of Mt. Toole-be-wong and exposed on the western slopes, and the ridge of that mountain.

A summary of the characters of the granodiorite from Old Warburton has been given by Hogg[12] in a paper on Victorian Granites. An analysis (No. 9) gives further information.

In hand specimen it is an even-grained, holocrystalline rock, grey to white in colour, and consisting of quartz, felspar and abundant biotite, closely similar to the Braemar House granodiorite.[22] The Nyora rock is slightly coarser grained than the Warburton. The chemical analysis of the Braemar House granodiorite and the Warburton one, emphasize their close resemblance.

A typical section No. (409) from Scotchman's Creek is a fine-grained granodiorite rich in biotite. Plagioclase dominates over orthoclase. The plagioclase is an acid oligoclase (about $Ab_{80}An_{20}$) showing zonal structure, and twinning on both albite and pericline laws. It has well-marked edges except when it occurs as inclusions in the orthoclase, when the edges are generally corroded. The orthoclase occurs in large allotriomorphic plates, and tends to be microperthitic. The quartz also occurs in plates, and often contains numerous bubbles. It includes biotite. Zircons and apatites are present as accessories.

It differs then from the Braemar House granodiorite in possessing a more acid plagioclase. It is also richer in orthoclase as shown by the comparison of Rosiwal analyses:—

Braemar House.—Quartz 26.3, orthoclase 6.6, plagioclase 38.1, biotite 27.3, accessories 1.7.

Warburton.—Quartz 28.1, orthoclase 12.4, plagioclase 34.5, biotite 24.0; accessories 1.0.

The order of crystallisation was—(1) accessory minerals, (2) biotite, (3) plagioclase, (4) orthoclase, (5) quartz.

The granodiorite from Nyora is slightly coarser in texture and slightly richer in quartz, but is not different in any essential.

The granodiorite about the Backstairs Creek is very decomposed. Shafts have been sunk in this decomposed rock to a depth of 100 feet.

Quartz Nodules in the Granodiorite.

A distinctive feature of the Warburton granodiorite is the common presence in it of quartz nodules, varying in diameter from 1 cm. to 30 cms. or larger. The general size is from 3 cms. to 10 cms. The shapes of the nodules are irregular. They vary from subangular to subspheroidal, and are sharply differentiated from the granodiorite so that they weather out, with the appearance of partially waterworn boulders or pebbles.

The nodules consist of granular crystalline quartz, the individual grains being 2–3 mm. in diameter, generally transparent and colourless. In weathered specimens the quartz is often snow white, and when rubbed, after breaking open the nodule, the individual grains come loose like grains of rice. Some examples exhibit a tendency towards acicular growth, so that certain faces of the nodule truncate numerous grains, whilst other faces more or less at right angles, or at 60° to these former, tend to permit development of free crystals parallel to the faces. From this the subangular form arises. Generally these nodules consist entirely of quartz, but muscovite flakes have been found in some. Two nodules have been found enclosing tiny needles of black tourmaline, and another encloses what is apparently a small piece of granodiorite. Lastly, in one, a minute internal vugh was present. Such cases are all exceptional. These nodules are characteristic of the granodiorite close to the margin. This margin is also marked by the presence, in equally large numbers, of partly digested xenoliths, both of sedimentary and of igneous origin, and the individual nodules are commonly found close to the xenoliths. This association of nodules and xenoliths appears more significant when it is observed that the nodules are of rare occurrence in the Nyora margin granodiorite, which is typically free of xenoliths.

Such phenomena seem to be rather rare. Adams[(1)] describes quartz nodules in a granite from Ontario, where they are "confined to a portion 200 to 300 yards from the contact with an amphibolite, so that they cannot be regarded as a contact development." These nodules are spherical to ovoid, and predate the foliation of the granite. They are of a size similar to the Warburton nodules, and often show a small aggregation of black tourmaline near the centre. Microscopically they show an outer zone of quartz and sillimanite replacing an inner zone of quartz and muscovite. Radial structure is absent. Adams explains their origin (following von Chrustoff) as a primary magmatic differentiation, during the "crystallisation of a magma which was free to gather itself into rounded drop-like forms," i.e., partial immiscibility.

Per Geijer[9] describes quartz-muscovite nodules in a granite from Sydvarangar. No other minerals are present in the nodules. He considers that they have resulted from metamorphism of the granite.

Two other occurrences of quartz nodules are known in Scandinavia, but translations are not available.

It is difficult to explain the origin of the Warburton nodules. Lack of connected exposures renders any theory hypothetical. The nodules in the Warburton granodiorite are identical with those in the related aplitic dykes, and they may be related to the occasional quartz ovoids found in the felspar-hornblende-porphyrite, andesite xenoliths and in the hypersthene dacite. Possible origins seems to be (1) Immiscibility, cf. Adams; (2) Inclusion of quartzites, or reef quartz; (3) Pneumatolysis; (4) Viscosity, cf. Sederholm[19]; (5) Crystallisation as the result of supersaturation, cf. Bowen.[2]

Any theory of immiscibility is open to objection, both from the present accumulation of evidence opposing immiscibility in silicate melts of such composition, and from the irregular shape and structure of the nodules. The inclusion theory is practically precluded by the widespread occurrence of the nodules and the absence of quartzites, pure sandstones, or pre-granitic quartz reefs from the contact zone or its neighbourhood. Moreover the quartz has a magmatic character, and a coarseness of grain quite unlike that of xenoliths of sediments, but equal in size to that of individual crystals of the granodiorite, and the nodules occur equally bordering the dacite or the sediment.

There is very little evidence for a pneumatolytic origin, as shown by the disconnected occurrence of the nodules and the general absence of pneumatolytic minerals or of vughs in the nodules. They appear to have crystallised at about the same time as the granodiorite.

Sederholm[19] regards viscosity as a sufficient factor to produce such nodules as described by Adams if a local concentration in one mineral can be effected. Bowen[2] postulates that in assimilation, if a magma is saturated with respect to a mineral, then an attempt by the magma to absorb more of that mineral from a xenolith will cause supersaturation or, and, a nearby local deposition of that same mineral. The granodiorite must of necessity have been practically saturated with silica. Then any assimilation of dacite (SiO_2 60%) or sediment (SiO_2 60–70%) should have rendered it locally supersaturated, so that quartz would crystallise out locally. Moreover, the heat used up in assimilating the xenolith might produce locally viscous patches, so that the supersaturated quartz could not diffuse away into the main mass of magma.

The Hypabyssal Forms.

1. *Aplitic Dykes.*—Sections (467, 2,430, 2,431).

Two large aplitic tongues or dykes and one lesser one are found at Warburton passing from the granodiorite out into the dacite. All three appear to intrude the granitic and dacitic rocks equally.

The eastern tongue or dyke is a holocrystalline, porphyritic rock, with phenocrysts of quartz and perthitic orthoclase set in a coarse granular groundmass of quartz. The crystals are characterised by bubble-like inclusions. "Phenocrysts" and small crystals of pink andalusite are a feature of this dyke, and an occasional oligoclase crystal is seen. Biotite and muscovite are subordinate constituents, and brown tourmaline is often present.

The central tongue is easily the largest, and is characterised by the presence of quartz nodules, and ferromagnesian inclusions generally of biotite. It is rather coarser grained than the eastern aplite, and contains abundant muscovite. Quite a quantity of biotite, probably derived from digested inclusions, is present, and pyrrhotite is frequent. Andalusite is absent. Much of the orthoclase is sericitised, and some of the oligoclase also.

2. *Quartz Porphyry Dykes.*—Section (2,432 to 2,434).

Numerous quartz porphyry dykes are found in the Warburton granodiorite aureole. A series of eight, sub-parallel to the granodiorite boundary are found in the railway cutting west of the Scotchman's Creek. These dykes are from 4 to 20 feet wide, and cannot be shown on the general map of the area.

These dykes consist of small phenocrysts of quartz and microperthitic orthoclase set in a finely granular base of quartz and biotite granules. A little biotite is present, and mosaic patches of coarsely granular quartz are to be seen. These granular patches can be seen developing from the phenocrysts. The dykes commonly metamorphose the intruded dacites for about one to two feet from the contact.

3. *Pegmatites.*

These occur locally in both granodiorite and dacite, but it was not possible to trace their outcrops. They vary considerably from a finely granophyric rock to a coarse pegmatite with individual crystals up to 4 or 5 inches in diameter. A section No. (2,435) from one of the finer pegmatites shows a granophyric intergrowth of quartz and blue tourmaline.

4. *Quartz Veins.*

Quartz veins are found penetrating the schistose and gneissose dacites of the contact zone (Section No. 460) and also the granodiorite.. Section No. (2,436) of a vein in the granodiorite, 1½ inches wide, is really an aplite.

All these dykes and veins post-date the granodiorite and represent the final stages of the igneous activity.

TABLE OF ANALYSES.

—	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.
SiO_2 ..	74·70	72·39	74·39	67·85	68·68	66·17	61·43	64·43	64·87	64·04
Al_2O_3 ..	14·73	4·42	14·28	14·65	14·61	14·75	15·95	16·52	16·24	13·58
Fe_2O_3 ..	1·00	0·56	0·52	0·64	0·81	0·30	1·21	1·70	1·03	0·80
FeO ..	1·13	0·30	1·09	3·40	4·33	4·73	5·64	3·80	4·80	4·47
MgO ..	0·32	1·85	0·27	1·39	1·14	1·71	2·83	2·37	2·62	2·64
CaO ..	0·92	0·85	0·24	3·05	3·01	3·31	4·98	3·80	3·20	3·52
Na_2O ..	4·13	5·93	2·78	2·12	3·15	2·45	2·96	2·50	2·83	2·42
K_2O ..	1·54	1·23	5·33	3·19	2·48	3·53	2·26	3·44	2·49	2·80
H_2O ..	0·66	1·13	0·22	2·25	0·32	0·66	0·81	0·43	0·50	2·25
H_2O ..	0·28		0·56	0·15	0·44	0·01	0·12	0·16	0·12	0·38
CO_2 ..	n.d.	n.d.	n.d.	..	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
TiO_2 ..	0·19	n.d.	0·29	0·63	0·60	0·97	1·13	0·78	0·73	0·80
P_2O_5 ..	0·36	tr.	tr.	0·32	0·12	1·15	0·53	0·29	0·16	0·18
CoO ..	n.d.	..	..	..	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
NiO ..	n.d.	..	..	..	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Li_2O ..	n.d.	..	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	tr.
ZrO_2 ..	0·02	..	..	..	0·02	..	..	Nil	0·05	n.d.
Cl ..	0·03	..	n.d.	..	0·04	0·04	tr.	0·01	0·07	tr.
S ..	nil	..	..	nil	0·17	0·13	..	0·14	0·10	nil
SO_3 ..	nil	..	..	..	nil	nil	..	nil	nil	nil
BaO ..	0·01	..	..	..	0·01	n.d.	..	nil	tr.	n.d.
Cr_2O_3 ..	nil	..	..	..	nil	n.d.	..	nil	nil	n.d.
MnO_2 ..	0·05	0·01	n.d.	nil	0·03	0·20	nil	nil	nil	tr.
Less O_2 ..	..	..	..	..	0·08	0·06	..	0·07	0·05	..
Total ..	100·07	98·67	99·97	99·64	99·88	100·05	99·85	99·90	99·76	99·88
Sp. Gr. ..	..	..	2·49	2·68	..	2·71	2·78	..	..	2·72

TABLE OF NORMS.

—	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.
Quartz ..	40·98	..	36·20	33·36	30·54	28·14	18·66	23·42	25·44	25·20
Orthoclase	9·45	..	31·69	18·90	15·01	21·13	13·34	20·57	15·01	16·68
Albite ..	36·68	..	23·52	18·82	26·20	20·96	25·15	20·96	23·52	20·44
Anorthite	2·78	..	1·11	13·62	14·18	9·73	21·41	17·42	13·90	16·68
Corundum	5·61	..	3·47	2·75	1·33	3·16	0·80	2·24	3·47	2·14
Hypersthene	2·38	..	1·76	8·00	11·71	9·60	14·25	9·86	12·70	12·80
Magnetite	1·39	..	0·70	0·93	1·16	0·42	1·86	2·56	1·39	1·16
Ilmenite ..	0·32	..	0·61	1·21	1·11	1·82	2·83	1·52	1·52	1·52
Apatite ..	0·30	..	..	0·21	0·18	0·83	0·41	0·21	0·36	0·34
Pyrite ..	..	..	..	..	0·72	0·48	..	0·24	0·36	..
Class ..	I.	..	I.	I.	I.	II.	II.	II.	II.	II.
Order ..	3	..	3	3	4 (3)	4 (3)	4	4	4	4
Rang ..	1	..	1	3	3	2	3	3 (4)	3 (4)	3
Sub-rang	4	..	3	3	3	3	3	3	3	3

I. Soda-Rhyolite: Railway Cutting Corner, Warburton: (A.B.E.).

II. Quartz Ceratophyre: Nowa Nowa: (Howitt)[20].

III. Potash-Rhyolite: Archer's Lookout, Narbethong: (Junner)[14].

IV. Quartz-Dacite: Maroondah Dam, Healesville: (Evans)[8].

V. α-Quartz-Biotite-Dacite; Allot. 20-21 (Yuonga), Warburton; (A.B.E.).

VI. β-Quartz-Biotite-Dacite (Hypersthene bearing facies); Bladin's Quarry, Narbethong: (A.B.E.)[8].

VII. Hypersthene-Dacite; Mt. Juliet, Blake Spur Area; (Evans)[8].

VIII. Felspar-hornblende-porphyrite; Ben Cairn, Southern slope; (A.B.E.).

IX. Granodiorite; Scotchman's Creek, Warburton; (A.B.E.).

X. Granodiorite, Braemar House, Macedon; (Hall)[22].

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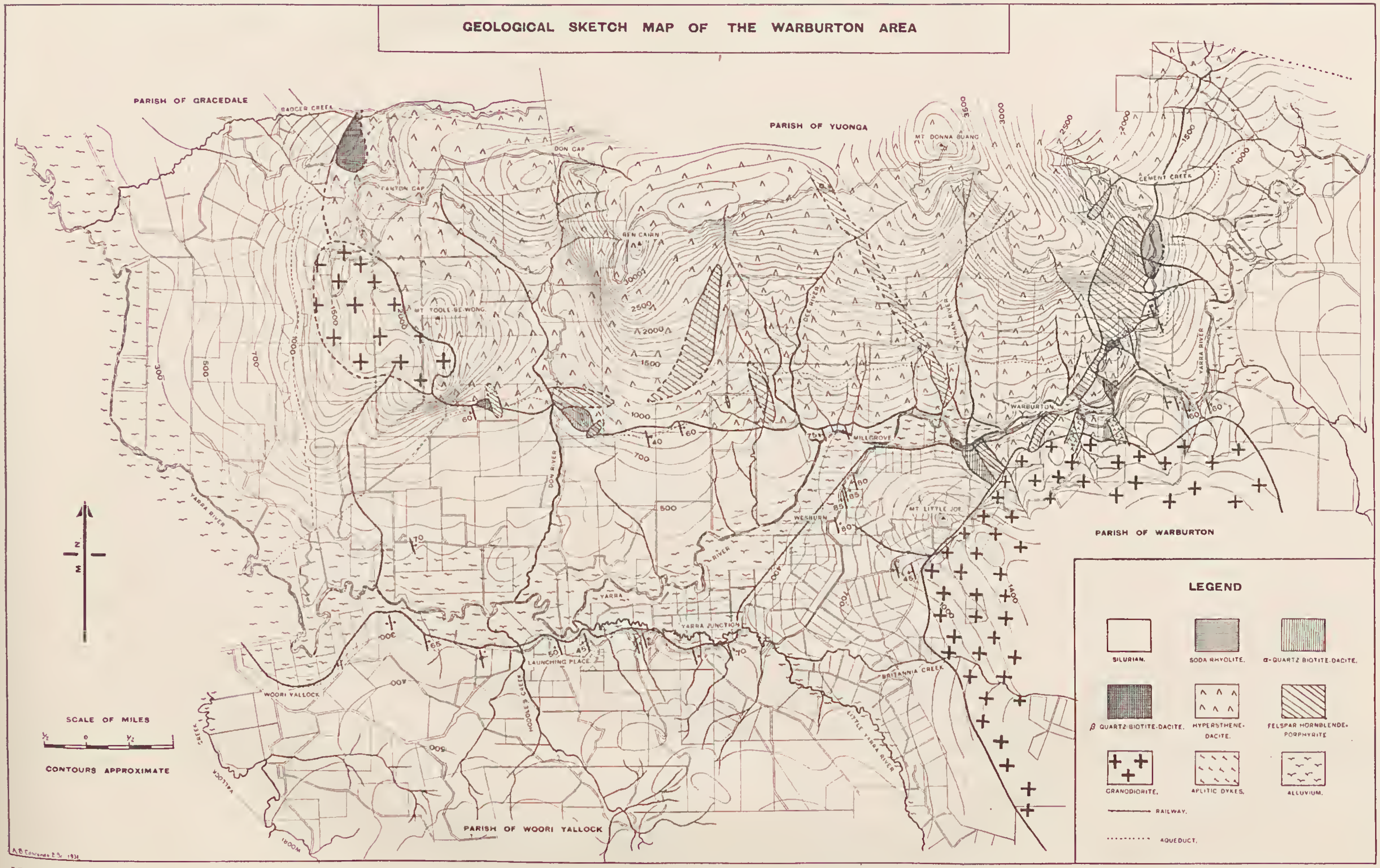
GEOLOGICAL SKETCH MAP OF THE WARBURTON AREA
PARISH OF GRACEDALE
PARISH OF YUONGA
PARISH OF WARBURTON
PARISH OF WOORI YALLOCK
MT DONNA BUANG
MT TOOLE-BE-WONG
BEN CAIRN
DON CAP
FANTON GAP
CEMENT CREEK
WARBURTON
MILLGROVE
WESBURN
MT LITTLE JOE
YARRA JUNCTION
LAUNCHING PLACE
WOORI YALLOCK
BRITANNIA CREEK
LITTLE YARRA RIVER
YARRA RIVER
DON RIVER
SCALE OF MILES
CONTOURS APPROXIMATE
LEGEND
SILURIAN.
SODA RHYOLITE.
α-QUARTZ BIOTITE DACITE.
β QUARTZ BIOTITE DACITE.
HYPERSTHENE-DACITE.
FELSPAR HORNBLENDE-PORPHYRITE
GRANODIORITE.
APLITIC DYKES.
ALLUVIUM.
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Art. XV.—*On the Dacite-Granodiorite Contact Relations in the Warburton Area.*

By A. B. EDWARDS, B.Sc.

(Bartlett Research Scholar in the University of Melbourne).

(With Plates XVIII. and XIX.)

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(Note.—Numbers in brackets, thus—No. (1,515)—refer to sections in the University Collection.)

Introduction.

The contact relations of dacite and granodiorite constitute an important feature of the geology of the Warburton area.[2] and have been found worthy of a detailed study. Two localities exist where these relations can be observed:—(1) in and immediately south of Warburton township, and (2) in the Nyora estate, on the ridge and western slopes of Mt. Toole-be-wong.

The only previous work done on these metamorphic aureoles is by Professor Skeats, who visited both localities in 1909.[7] He recognised the general similarity between the gneissic contact aureole at Warburton, and that at Selby,[6] as well as the intrusive relation of granodiorite to dacite at Nyora, despite the absence there of gneissic rocks, in which respect this latter contact zone is similar to dacite-granodiorite contacts in the Macedon district.[8]

The Nyora Contact Metamorphic Zone.

The Nyora contact zone of itself would scarcely furnish sufficient evidence to establish the intrusive relation of the granodiorite to the dacites. Gneissic developments are quite absent except for rare xenoliths of dacite found in the granodiorite. The dacite shows alteration only for a foot or two from the granitic margin, and such alteration is merely an incomplete changing of the hypersthene to biotite, with a slight development of schistosity.

The contact is found here at 2,400 feet elevation, the dacite forming a thin shell over the granodiorite. It is evident that the granodiorite has been only recently exposed, and the weak contact effect lies in the fact that it marks the most upward progress, and hence the most feeble activity of the granodiorite.

The Silurian sediments are found metamorphosed to hornfels and to a very pure quartzite, No. (1,515), along the western margin of the granodiorite.

The Warburton Contact Metamorphic Zone.

The township of Warburton is built upon a narrow tongue of dacite which crosses the Yarra at this point, and comes into contact with a large granodiorite massif about a quarter of a mile south of the River Yarra.

The part of the contact aureole which is described has an east-west trend, and is about 1½ miles in length. It has an apparent width at its western end of over three-quarters of a mile, but is generally less than a quarter of a mile wide. Its true width is from 100 to 200 yards. The apparent width is due to the Yarra having cut a deep gorge parallel to the contact, and at the western end of the contact the hidden granodiorite surface shelves down relatively gently, and at a slight angle to the actual surface, so that only a thin shell of metamorphosed dacite remains, forming the outcrop. This enables careful study of the progressive metamorphism to be made. The geological features and the approximate zoning of the aureole are illustrated in the accompanying maps (Pl. XIX., Fig. 1).

At Selby only the hypersthene-dacite enters the granodiorite aureole, but at Warburton several rock types do so. In addition there is a wide sedimentary contact zone.

The irregular patches of coarsely gneissic dacite at Selby are absent. The Warburton "gneiss" is a fine-grained porphyroblastic rock, and occurs as a regular inner zone of the aureole. The occurrence of a patch of anthophyllite-garnet-rock in the latter area is also a new feature.

The aplitic and pegmatitic dykes of the Selby contact are repeated, but the post-granodiorite hornblende-porphyrite dyke facies is absent, unless the pre-granodiorite felspar-hornblende-porphyrite-dykes of Warburton are to be regarded as its equivalent.

A. The Igneous Rocks and their Alterations.

The rock types metamorphosed by the granodiorite are (1) the hypersthene-dacite; (2) the felspar-hornblende-porphyrite; (3) the α-quartz-biotite-dacite. The soda-rhyolite is within the outer limit of the contact aureole, but shows no sign of metamorphism.

The Hypersthene Dacite.

This exhibits progressive metamorphic alterations as the granodiorite is approached. The more distinct " stages " are described below.

1. *The Initial Stage.*—In the normal dacite the hypersthene phenocrysts are very generally bordered by a narrow granulitic rim of green, chloritic biotite. In this initial stage of metamorphism, Section No. (2,438) (Pl. XVIII., Fig. 1) a new granular phase of brown biotite and quartz (?) has formed between the old, outer, green rim and a remnant of the nucleus of the fresh hypersthene which still remains. In places the granules of the brownish biotite phase have aggregated to form flakes of biotite, all within the green rim. The formation of such flakes is heralded by the appearance of brown spots. In some crystals the brownish zone has widened to such an extent that the hypersthene nucleus has disappeared entirely. The green outer rim, while remaining distinct, also alters to a brown colour. The groundmass remains perfectly glassy or cryptocrystalline, showing flow structure, and the plagioclase phenocrysts are fresh and clear. Some pyrrhotite and a trace of chalcopyrite are introduced.

2. *" Spotty "-Schist Stage.*—In this stage the glassiness of the groundmass has given place to a patchy " spottiness " and a development of free quartz. The spottiness is reflected in the hand specimen. Individual plagioclases are sometimes clotted together in aggregates with these newly developed quartz grains, and with biotite flakes, forming mosaics.

The original hypersthene crystals are represented by aggregates of straw yellow to brown biotite flakes, which are generally minute in size, and are often associated with clots of structureless biotite. The ilmenites, so characterically included in the fresh hypersthene, are now surrounded with secondary biotite, and in many cases have themselves reacted to form biotite (2,441).

A very small quantity of green hornblende is present as small flakes or granules in the groundmass, and, rarely, small garnets are seen associated with the biotite.

3. *Schistose Stage.*—In the central part of the contact zone the groundmass loses its " spotty " appearance, owing to a more general growth in grain size.

The individual flakes in the biotite clots have grown in size (Pl. XVIII., Fig. 2), but decreased in number, the clots remaining about the same size, and showing an increased parallelism. Ilmenite is quite absent, and there is no further development of garnet. The plagioclase phenocrysts vary from the perfectly unaltered to the highly sericitised. They often contain numerous inclusions of biotite, suggesting recrystallisation.

Quite large irregularly shaped porphyroblasts of quartz are developed, sometimes as mosaics. A little green hornblende, as flakes of minute size and larger crystals, is again present.

4. *Coarsely Schistose Stage.*—Still nearer the granodiorite the groundmass becomes more coarsely microcrystalline, and a schistose texture is developed by the parallel arrangement of strings of biotite flakes.

Porphyroblasts of quartz are prominently developed. These crystals show evidence of incipient granulation, in that they sometimes form coarse mosaic clots. Green hornblende is far more prevalent, particularly in medium-grained, sometimes idiomorphic porphyroblasts. It develops at the expense of the biotite, with which it is generally associated. The individual flakes of biotite are still coarser than in the preceding stage, and the clots are elongated lenticles. The felspars are still fresh, but appear to be crowded together owing to the growth size of the groundmass. They are commonly injected by granular quartz, and show evidence of marginal solution and compression.

5. *Gneissic Stage.*—This stage is found in a fairly narrow zone in immediate contact with the granodiorite. It is a fine-grained orthogneiss (" gneiss " in that it is completely recrystallised). The groundmass is finely granular and very even grained. The coarse patches and inequalities of the groundmass of the previous stage are completely absent. Parallel orientation of the numerous minute biotite flakes is strongly pronounced. The parallel or " banded " structure curves about the " phenocryst " remnants and porphyroblasts, as in augen structures.

Biotite is still a prominent constituent, both in the groundmass and as lenticular aggregates, drawn out parallel to the foliation. The individual flakes are now moderate sized crystals. The hornblende has become equal or superior in quantity to the biotite, and is frequently idiomorphic (Pl. XVIII., Fig. 3). It is commonly associated with the biotite lenticles. Some of the biotite associated with the hornblende appears to be of a different character to the "clotted" biotite, and from its fringing position to have formed from the hornblende, depositing the excess silica as quartz. Circular clots of granular hornblende apparently formed by the aggregation of hornblende granules produced by the reaction of biotite granules with the groundmass, are also a feature. These are often stained a red-brown by reaction to form secondary biotite or from iron staining.

The plagioclases are generally recrystallised, and have grown by molecular absorption of neighbouring phenocrysts, so that they are much fewer in number, but larger in size (up to 5 mm. diameter). Many of them have an idiomorphic contour, and have a core of decomposed felspar, often rich in inclusions of biotite and hornblende, with an outer rim of fresh, clear felspar, of more sodic character.

The quartz porphyroblasts have been granulated down into the groundmass. Layers of granular quartz are found sheltering against the rim of plagioclase crystals, and "stringers" of granular quartz are seen, oriented parallel to the foliation. Ilmenite is absent.

Anthophyllite-Garnet-Rock.

This rock has been found only in one small patch, about 1 chain square, of the contact zone, and has formed from the hypersthene-dacite, under special conditions. The meagre evidence available points to its being the product of a "double metamorphism" firstly by the felspar-hornblende-porphyrite, and secondly by the granodiorite.

1. *Initial Stage.*—What apparently represents the initial stage of this alteration is recorded in Section Nos. (2,400–2,402) (Pl. XVIII., Fig. 4) cut from the contact of the felspar-hornblende-porphyrite with the hypersthene dacite on the southern slopes of Ben Cairn.[2] In these sections the hypersthene crystals retain their original biotitic rim—here a brown one (cf. p. 184). The hypersthene of the interior of the crystals is entirely replaced, in some cases by granular biotite, but equally commonly by sheaves of a pleochroic, colourless to plum-brown mineral, which has a high double refraction, and appears to be anthophyllite; i.e., the metamorphic action of the porphyrite has been to induce a paramorphic change in the ferromagnesians.

These sections have not been matched in the Warburton locality, perhaps owing to insufficient exposure, or possibly because similar specimens are absent. At this locality the contact zone appears narrower than usual, probably owing to an increase in the angle between the slopes of the surface and the granodiorite surface.

2. *Incipient Anthophyllite-Rock.*—This rock, Section No. (2,425), is from the margin of the outcrop which is farthest from the granodiorite. It has been strongly recrystallised, and to some extent foliated. The groundmass is quite irregular, varying from a crypto- to a coarsely micro-crystalline texture, and consisting of quartz, felspar, biotite, ilmenite, and anthophyllite. Mosaic patches and "stringers" of clear, inclusion-free quartz are prevalent. A characteristic feature is the presence of patches of quartz, full of minute inclusions of biotite, ilmenite, and anthophyllite needles. It seems probable that the clear quartz is of an earlier generation.

Anthophyllite occurs in small plates and sheaves of needles, but it is far more generally scattered throughout the groundmass as small needles or bundles of them. It is commonly associated with biotite. Ilmenite occurs in quite fresh grains and crystals, and is rarely associated with secondary biotite. It is equally common in the groundmass or as inclusions in patches of fibrous or granular anthophyllite, or clots of biotite after hypersthene. The original biotite tends to become structureless. The plagioclase phenocrysts remain fresh, but are corroded, and are often crowded together by the recrystallisation. Some have grown a border of fresh felspar.

3. *Anthophyllite-Rock.*—In this specimen, Section No. (2,426), taken from the centre of the outcrop, anthophyllite is the dominant ferromagnesian, occurring as plates, sheaves, and granular aggregates, and commonly associated with biotite. Anthophyllite needles commonly fringe the patches of inclusion-rich. "biaxial" quartz. The more granular crystals have not the rich plum colour of the large flakes and crystals.

The plagioclases occur as crystals, and as coarsely granulated mosaics, associated with clear, interlocking quartz grains. They show flexing and shearing, and parallel orientation by pressure (?) has often brought them into contact. Fresh ilmenite is frequently found included in the anthophyllite, or in the groundmass, and structureless, partially altered biotites occur. In phases the rock is locally holoblastic in texture.

4. *Anthophyllite-Garnet-Rock.*—The greater part of this small outcrop contains garnet, in varying quantities. In one specimen, No. (2,427) (Pl. XVIII., Fig. 5), anthophyllite and to a lesser extent garnet dominate, almost to the exclusion of biotite. The garnet is a pink type, forming sub-lenticular porphyroblasts often with clear rims around a granular or fractured core. It commonly contains inclusions of quartz, anthophyllite needles, large ilmenite grains, and zircons. It has the appearance of having formed from some reaction which set free quartz, since granular quartz is commonly associated with it, either as inclusions or as a border to the garnet. The plagioclases are less numerous than in the

anthophyllite rock, and are generally more altered and intruded by the groundmass, which is of a variable texture, and consists of quartz, anthophyllite, biotite, and felspar. Fresh ilmenites (or iron ore) are prevalent.

In another example, No. (2,428), there is an increase in the proportions of anthophyllite and garnet, while the plagioclase crystals are practically absent. Foliation is well marked.

The origin of the iron ore is well illustrated in specimen No. (2,429) (Pl. XVIII., Fig. 6). Large crystals of primary biotite are seen, which are much corroded, and have discharged iron ore and quartz granules in considerable quantities. The same specimen illustrates the rapid variation of the relative quantities of the constituents, and in two sections 4 inches apart, Rosiwal volumetric analyses are as follows:—

	I.	II.
Anthophyllite	27%	20%
Garnet	17%	8%
Bytownite ($Ab_{70}An_{30}$)	9%	13%

There is also a noticeable unmeasured increase in the proportion of biotite in II. This variation may be due to irregularity of reaction, but seems more probably due to local migration of constituents.

The garnet is often found wedged between anthophyllite and plagioclase, and its development seems to be at the expense of those two minerals.

There is a general similarity between these metamorphic changes and those recently described by Sugi,(9) in which anthophyllite-garnet-rock is apparently developed from a hypersthene-bearing amphibolite. The anthophyllite-rock is of unusual occurrence, the common alteration of the hypersthene being to a green hornblende. Sugi considers that the anthophyllite develops from the hypersthene under special conditions of metamorphism which are produced by "local increase of vapour pressure, and the presence of volatile matter."

The Felspar-Hornblende-Porphyrite.

This rock enters the contact area in two places:—(i) a dyke running diagonally south-west, from just east of the Warburton Railway Station, and (ii) a dyke running slightly east of south, just west of Scotchman's Creek. Although distinctive in its normal condition, it is difficult to distinguish between the gneissic facies of the porphyrite and the gneissic facies of the hypersthene dacite.

The normal rock is porphyritic, containing large phenocrysts of labradorite and andesine set in a groundmass of glass, quartz, and granules of biotite. Ferromagnesian phenocrysts are subordinate to the felspar. They consist of yellow biotite, and a green to blue-green (soda ?) hornblende, and the latter is generally replaced by aggregated flakes of biotite (cf.[2]). Ilmenite grains with biotitic rims are prevalent, and granular quartz, as stringers or aggregates, is present frequently.

1. *Initial Stage.*—As the outer limit of the contact aureole is left behind the groundmass becomes cryptocrystalline and sometimes "patchy." Lenticles of granulated quartz mosaics occur more frequently, and the biotite granules of the groundmass tend to aggregate. The plagioclase phenocrysts show a considerable degree of alteration and clouding, and some show partial granulation. The hornblende is much less in quantity than the biotite. Occasional fractured phenocrysts of quartz occur.

2. *Schist Stage.*—Section No. (2,457) cut from the central part of the aureole shows a development of parallel orientation of both groundmass and phenocrysts. The former is glassy to cryptocrystalline in texture. Hornblende dominates over biotite, replacing the clots and crystals of the latter with more or less idiomorphic porphyroblasts of green hornblende. Ilmenite grains are bordered by leucoxene. The larger plagioclase phenocrysts are coarsely granulated, and are intermingled, in clots, with the newly developed hornblende. The felspars are usually reduced in size, and have a distinctive dark rim. Granular quartz is occasionally associated with the felspars.

3. *Gneiss Stage.*—Section No. (2,458) is an example from the inner contact zone close to the granodiorite, and to the anthophyllite-garnet-rock. It consists of elongated lenticles of biotite flakes and hornblende crystals, and remnants of plagioclase phenocrysts, set in a coarse micro-crystalline groundmass of quartz, felspar, and biotite. This groundmass is very granular in appearance, and tends to form fine-grained mosaics of quartz. Remnants of coarse mosaics, fading into finer mosaics may represent original quartz porphyroblasts. The general parallelism of the groundmass is broken by the porphyroblasts and phenocrysts. There is an obvious tendency for "augen structure" to form in such cases. Hornblende dominates over a reddish-brown biotite. The plagioclases sometimes show clear zones of secondary rim growth, with partially decomposed cores, and equally commonly they have dark rims. Fresh crystals of felspar show shearing, fracture, solution and granulation marks.

The α-Quartz-Biotite-Dacite.

The α-quartz-biotite-dacite forms the most westerly outcrop of the igneous lavas which enter the contact zone. Section No. (2,454), from the hill behind the Warburton Chalet, illustrates the more altered phase of this rock. The characteristic alteration is the copious development of green hornblende. This is found as granules, small idiomorphic crystals and large clots. It is commonly associated with yellow biotite, which it replaces. The original primary biotite crystals are commonly frayed at the edges, and partially absorbed. The clotted aggregates of biotite flakes (probably after enstatite) in the original rock are the first to form hornblende. Some of the felspar phenocrysts appear to have been recrystallised, and the quartz crystals show incipient granulation. There is a complete lack of schistose structure.

The α-quartz-biotite-dacite is also found near Pheasant Creek, at the eastern end of the contact zone. In this locality, Section No. (412), hornblende is absent. The rock has suffered considerable recrystallisation, so that the phenocrysts are ragged, and elongated parallel to the schistose foliation. The grain size is microcrystalline and coarser and muscovite is developed. This section, and also No. (431), from closer to the granodiorite, represent the gneissic zone of the aureole with regard to the α-quartz-biotite-dacite.

A section No. (410) of a xenolith in the granodiorite, presumably of this dacite originally, is a strongly foilated biotite-felspar gneiss, the constituents showing marked coarse banding. The felspar consists of perthite, anorthoclase (?) and oligoclase. Quartz is of rare occurrence, and the biotite is rich in zircons. A complete recrystallisation has occurred, giving rise to an intergrowth of biotite flakes of very variable size with the large interlocked sodic felspars, and to an almost complete exclusion of quartz and calcic constituents. As a xenolith, this specimen is unique among those collected.

B. The Sedimentary Rocks and their Alteration.

The types of Silurian sediments metamorphosed by the granodiorite are blue slates, mudstones, and sandstones. The products of the metamorphism are chiastolite slates, "spotted" hornfels and andalusite-hornfels, and quartz-muscovite hornfels, respectively. The outcrops are not such as to permit the progressive metamorphism of any one bed to be traced, but it is possible to correlate the changes for any one rock type.

The blue slates are transformed into chiastolite-slates, Section No. (475). The square chiastolite crystals often contain a nucleus of andalusite. Apart from these porphyroblasts of chiastolite, the rock is strongly spotted by the development of patches of andalusite (?) or quartz (?).

The mudstones show two alterations, according as they are quartzitic or argillaceous. The quartzitic mudstones are the dominant type, and are converted into "spotted" hornfels. This is a very fine-grained rock, with an occasional coarse patch of matrix. The rock is crowded with colourless lenticular "spots," which give a biaxial positive figure and appear to consist of granular quartz. These spots include granules of biotite and ilmenite, and are often fringed with tiny biotite flakes. They show a sub-parallel orientation of their long axes, and often "coalesce." Brown biotite flakes are concentrated between the spots. A little muscovite is present.

The argillaceous mudstones have been found represented by an andalusite-quartz-tourmaline-rock, Section No. (2,446), as their most intensely altered facies. This rock consists of quartz, andalusite, tourmaline, iron, muscovite in this order of abundance. The andalusite is a colourless variety, showing perfect cleavage. The smaller, irregular shaped crystals of it occur in patches, associated with granular quartz and ilmenite grains. Brown and blue tourmaline are common as crystals, or as "cement" between grains. Grains of iron ore are very numerous, though small, and muscovite in moderate sized flakes is prevalent.

The impure sandstones appear as quartz-muscovite-hornfels, Section No. (471), with the quartz grains commonly cemented by an iron oxide, and with the muscovite subordinate, but copiously developed.

Mineralogical Changes.

The mineral changes produced by the metamorphism of the dacites are summarised below:—

I. Hypersthene reacts with orthoclase to form biotite and quartz. This reaction has been explained previously.[1, 6]

II. Hypersthene under certain conditions undergoes a paramorphic change to produce anthophyllite. Pressure probably is an important factor in this alteration.

III. Anthophyllite reacts, probably with calcic plagioclase, to form a pink garnet (almandine-pyrope) and quartz.

IV. Ilmenite reacts to form biotite, as previously described.[1, 6]

V. Biotite reacts to form ilmenite (or magnetite) and quartz.

VI. With "intratelluric" cooling, in the felspar-hornblende-porphyrite dyke on Ben Cairn, hornblende is replaced by biotite. The biotite forms clots of small flakes where the reaction was partially inhibited by viscosity preventing local diffusion, and primary crystals where the cooling was slowest. In the contact zone hornblende on cooling appears to give rise to biotite and quartz.

VII. Biotite reacts, probably with quartz in the groundmass, to form common green hornblende, at a temperature below 750° C., if a sufficient pressure is attained.

Associated with these reactions is a growth, followed by later granulation, of quartz porphyroblasts, and a molecular migration and recrystallisation of plagioclase phenocrysts.

Mechanics of Intrusion.

It appears that the granodiorite entered into its present position in a quiet manner. The Silurian strata appear free from any dynamic disturbance by the rising magma. Three large quarries in the "spotted" hornfels, one south of Old Warburton, and the other two near the "debouchures" of Postman's Creek and Big Pat's Creek, permit observation of the undisturbed strata close to the contact. There is no sign of puckering or distortion. The general regularity of the igneous part of the contact aureole supports this view. The most satisfactory method of intrusion to fit the evidence would be by magmatic stoping (after Daly).

Marginal assimilation undoubtedly played a minor part. Near the head of Pheasant Creek the marginal hornfels is partially assimilated for about 5 feet from the granodiorite. The marginal granodiorite is full of rounded and partially assimilated xenoliths of dacite and of gneissic sediments.

The lack of porphyritic textures in the granodiorite suggests that it came into its final position in a probably viscous-fluid state, and crystallisation occurred generally in a more or less eutectic manner, the fine grain size resulting from the viscosity. The xenoliths appear to have fallen into the magma before crystallisation commenced, or viscosity arrested their sinking. The majority of these inclusions cannot have sunk more than 100 feet.

The Intensity of the Metamorphism at Warburton.

The controlling factors during the metamorphism appear to have been pressure and temperature. Temperature appears to have been the dominant factor, but neither can have developed great intensity.

The pressure was of a compressional nature, and was not of a sufficient strength to distort the sedimentary strata. Its more marked effect on the igneous rocks is not the result of any inferior strength in these, nor yet of greater local pressure. In the igneous types, instability developed in certain of the constituents as the result of an infusion of molecular energy by the rise in temperature and a molecular rearrangement towards stability under the new conditions, followed. It is to be expected then that any pressure acting during this rearrangement would impress itself on the rock in an increasing degree corresponding to an increasing degree of rearrangement. The sediments, however, in most cases, presented a stable complex at the temperature induced by the metamorphism, and were generally unaffected. Recrystallised xenoliths of the sediments, however, show a perfect gneissic foliation, for the same reason as the dacites do; and the "spotted" hornfels show a tendency towards a parallel orientation.

The temperature at which the metamorphism occurred cannot have been very high. The most altered, innermost rocks in the contact aureole may be regarded as having experienced the maximum induced temperature. The minerals developed in such rocks act as temperature indicators. In the Warburton igneous rocks common green hornblende is the typical development, and garnet and anthophyllite are found in one patch; in the sediments the only minerals developed from the original constituents are andalusite, chiastolite and muscovite. These all indicate low temperatures, but unfortunately no data as to the temperature of formation of andalusite or hornblende appear to be available. Kozu, Yoshiki, and Kani[5] state that, in an atmosphere of nitrogen, green hornblende alters to basaltic hornblende at 750° C. We may assume then that the hornblende was developed below this temperature. In zones of contact metamorphism where the temperatures were intense (1,200° C.), e.g., Christiania,[3] pyroxene, plagioclase, and cordierite are formed. The absence of these minerals may be regarded as evidence for low temperatures.

Mineralisation.

Locally considerable mineralisation has occurred. Pneumatolysis has played a major part in the introduction of material. Tourmaline, both blue and brown, is found in pegmatites and in the metamorphosed sediments. Pyrite, pyrrhotite, chalcopyrite, and rarely galena, are introduced into the joint planes of the granodiorite, and occasionally into the contact rocks. Some gold has accompanied them.

Gold and stibnite are found in quartz reefs along Hoddle's Creek, cassiterite is found along the Mississippi Creek, and also near Beenak, where it is associated with kaolinised granodiorite. Wolfram occurs with tourmaline in quartz veins and as stockwerks in the granodiorite at the head of Britannia Creek;[4] and a 12-inch vein of galena is recorded from McMahon's Creek. Gold colours are found throughout the granitic country. It seems probable that gold occurs in a very finely disseminated fashion throughout the granodiorite massif: but there seem to be very few localities in which any concentration of gold has taken place.

Between Backstairs Creek and the Scotchman's Creek the granodiorite is decomposed to a gravel of quartz and mica (bleached biotite) for a depth of over 100 feet. Whether this is due to removal of felspars by percolating surface waters, or to pneumatolytic agents is unknown. This area of decomposed rock has been very thoroughly combed for gold, but with very little reward.

Comparison with other Victorian Contact Zones.

In the Bulla contact-zone,[10] cordierite and plagioclase were developed in the sediments, so that the temperature must have been considerably higher than that experienced at Warburton. At Selby[6] no hornblende was developed, despite the presence there of hornblende in the granodiorite. This suggests that temperature alone is not a sufficient factor in the formation of hornblende. Differential pressure is considered as a probable agent in the development of gneissic patches at Selby, but the general compressional forces developed throughout the contact zone were much less intense than those set up at Warburton.

Previous workers have been at a loss to explain the variability of the dacite-granodiorite contacts, viz., that the Macedon and

Nyora contacts are weakly developed, while that at Selby is more strongly marked, and, as now seen, the Warburton aureole is still further developed. A clue to the explanation appears to lie in the degree of erosion or "roof removal" in each locality.

It seems safe to assume that the more abysally the metamorphism occurred, the higher the temperature and the pressure, and the greater the changes resulting, other factors being equal. Then, according to the degree of "de-roofing" or the depth of erosion in the contact zone, we should find a weakly or strongly developed metamorphism. At Nyora the granodiorite is only just de-roofed, so that the most feebly developed metamorphism is exposed. At Selby the de-roofing has gone further, and at Warburton the Yarra River has cut deeply into the contact zone.

Another factor determining the intensity of metamorphism will be the thickness of dacite penetrated by the intruding granodiorite magma.

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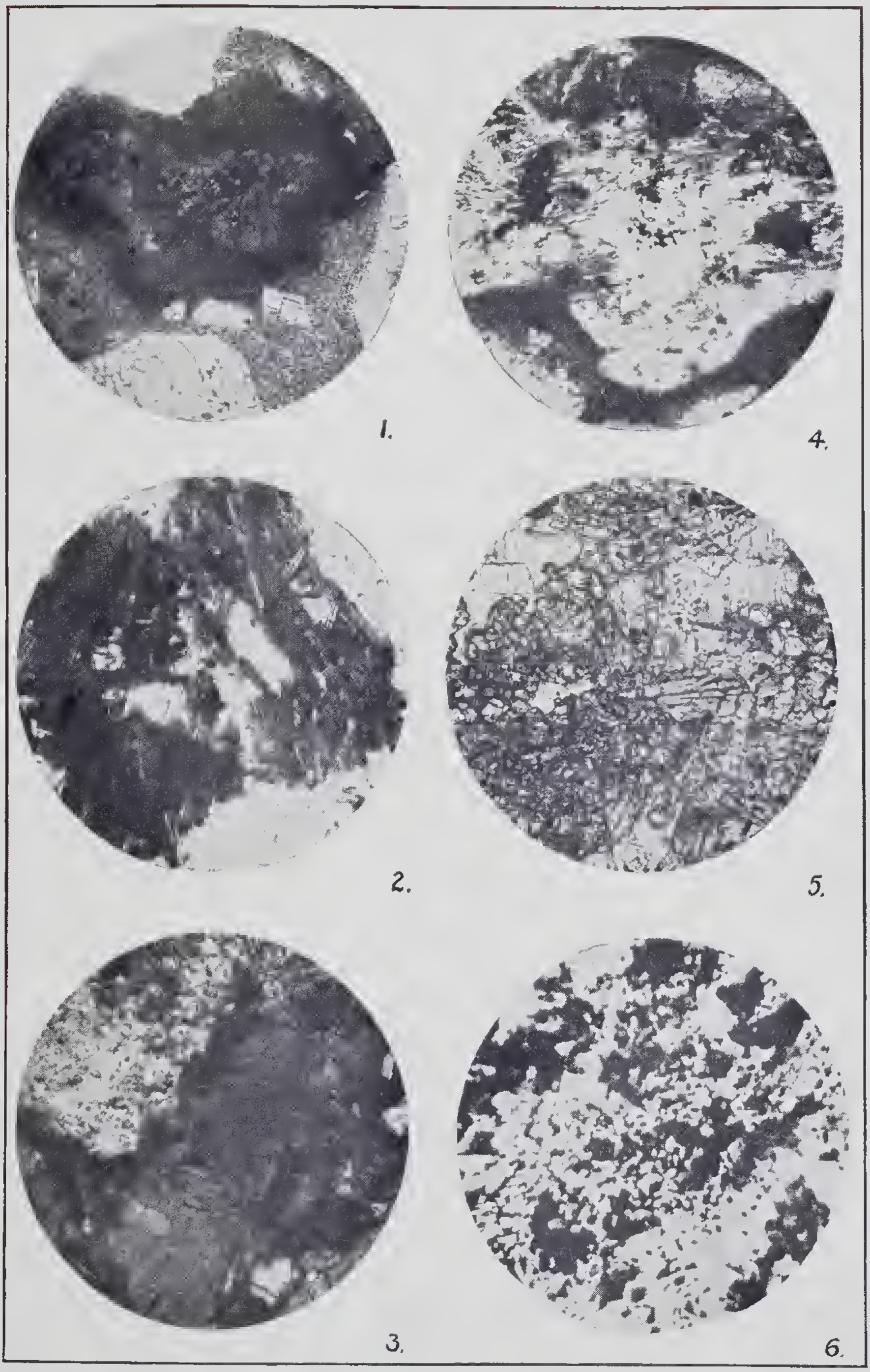
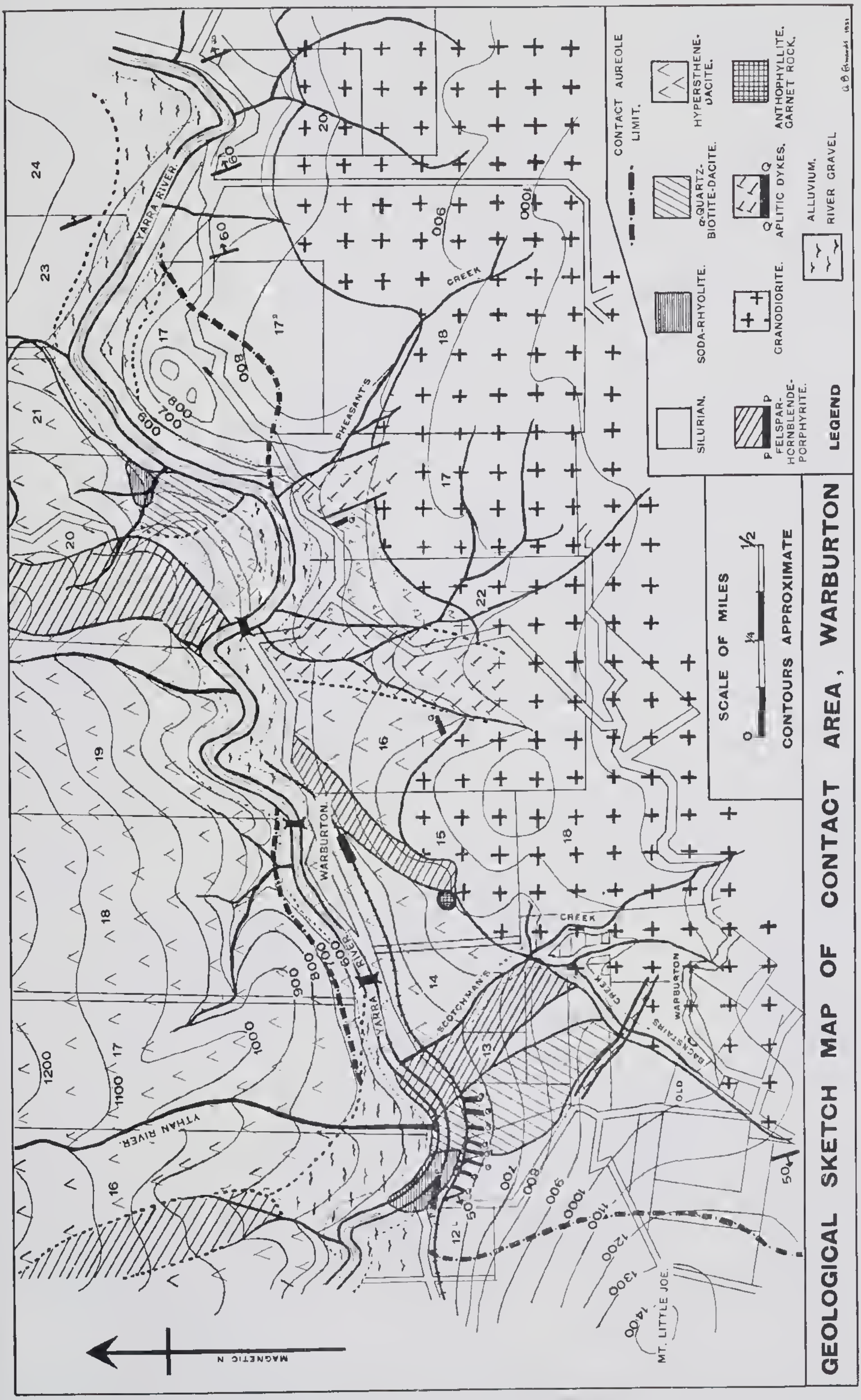
Explanation of Plate XVIII.

1. Hypersthene-dacite. Nucleus of fresh hypersthene, surrounded by granular and crystalline biotite to which it is altering. The dark rim is granular biotite which formed during consolidation of the rock and pre-dates the biotite formed within it by the metamorphism. (x. 65.)
2. A clot of biotite flakes which have replaced the hypersthene (from the hypersthene-dacite ortho-schist). (x. 65.)
3. Green hornblende replacing biotite in the ortho-gneiss stage of the hypersthene-dacite. (x. 65.)
4. Hypersthene forming fibrous anthophyllite. The black rim consists of granular biotite, and was formed during the consolidation of the rock. (cf. 1.) (x. 65.)
5. Anthophyllite-garnet-rock, formed from the hypersthene-dacite, showing the garnet porphyroblasts, and plates of anthophyllite. (x. 65.)
6. A mosaic intergrowth of quartz and iron ore deposited by the decomposition of biotite, in the anthophyllite-garnet rock. (x. 65.)



Miss J. Wilson-Smith, Photo.



GEOLOGICAL SKETCH MAP OF CONTACT AREA, WARBURTON

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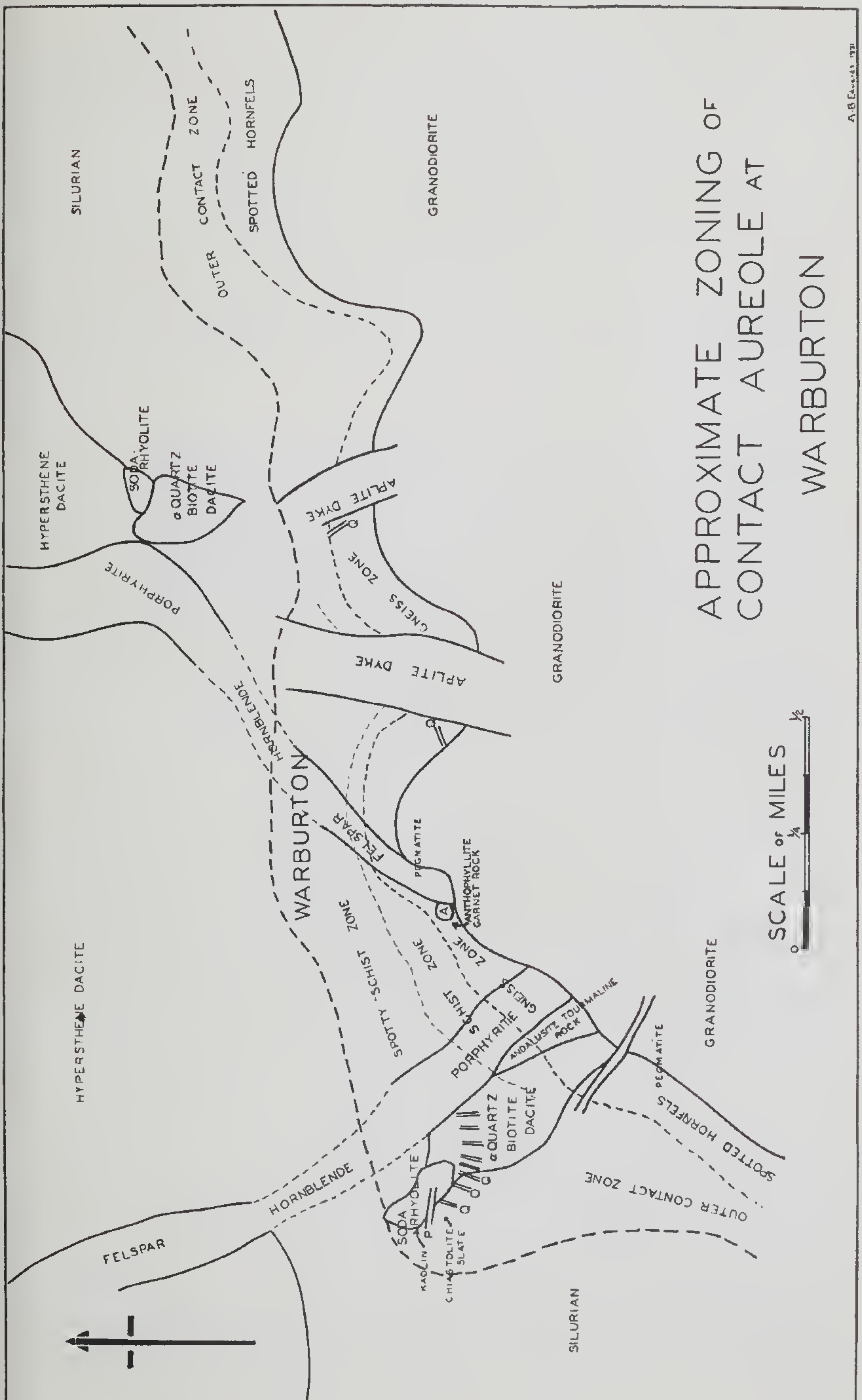
APPROXIMATE ZONING OF
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GRANODIORITE
HYPERSTHENE DACITE
SODA RHYOLITE
a QUARTZ BIOTITE DACITE
PORPHYRITE
APLITE DYKE
GNEISS ZONE
HORNBLENDE
WARBURTON
FELSPAR
PEGMATITE
ANTHOPHYLLITE GARNET ROCK
SPOTTY SCHIST ZONE
SCHIST ZONE
GNEISS ZONE
ANDALUSITE TOURMALINE ROCK
KAOLIN
CHIASTOLITE SLATE

Fig. 1.

[Proc. Roy. Soc. Victoria, **44** (N.S.), Pt. II., 1932.]

Art. XVI.—*The Distribution of the Zones of the Castlemaine and Darriwil Series near Ingliston.*

By ELIZABETH A. RIPPER, B.Sc.

(Howitt and Wyselaskie Research Scholar in Geology, University of Melbourne).

(With Plate XX.)

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Introduction.

The area dealt with is about 3 miles S.-E. of Ingliston, which is a few miles west of Bacchus Marsh. It is, roughly, equivalent to the Ironbark Ranges, the rugged topography produced by the erosion of the Lower Ordovician being replaced to the north and west by the open country characteristic of granitic outcrops. South-east of Pyramid Rock, an abrupt change in the form of the Werribee Valley and in the type of country generally, occurs at the junction of the Ordovician and the Permo-Carboniferous. The Newer Basalt, with its associated Tertiary deposits, forms a plain, dissected by the Ironbark Creek, in the southern part of the area.

The Ordovician is the only system studied in detail, and in the present paper an attempt is made to deduce the structure of the area from the distribution of the various graptolite faunas of the black slates, applying the now well-established divisions of the Darriwil series. Observations of dip and strike were made at many points and the evidence from them taken in conjunction with that of the graptolites. The black slate outcrops shown on the map were located by means of compass and chain traverses on the road and railway section, and compass and pace traverses on the Ironbark Creek and Creeks B and C.

Previous Work.

The northern part of the area is shown on quarter-sheet No. 12 N.-E., and contours for this part, used in constructing the section, were obtained from the Military Survey Contour Map, Sheet South J55 G.III. IV.

An unpublished map on the scale of 4 inches to the mile, based on the work of Mr. H. Foster, for the use of which I am indebted to Mr. W. Baragwanath (Director of the Geological Survey of Victoria), shows in detail the black slate outcrops and graptolite localities of the southern half of the area.

It has long been well known that the graptolite faunas of the black slates were of Darriwilian age. Hall[1] recorded *Tetragraptus serra, Phyllograptus* sp., *Didymograptus caduceus, D.* sp. nov. (large form) from the railway cutting $42\frac{3}{4}$ miles from Melbourne. These forms enabled him to correlate the beds with the Castlemainian of Yapeen or Woodend. This report was written prior to the extension downwards of the Darriwil by W. J. Harris.[3]

In the course of descriptions of new graptolite species Hall[2] recorded *Oncograptus upsilon* from a quarry near the viaduct ($42\frac{1}{2}$ miles from Melbourne) on the railway, and Harris[4] similarly noted the occurrence of *Cardiograptus morsus* in the Ingliston district.

Nature of the Ordovician Sediments.

Graptolites are restricted to thin black slate bands which, however, are very persistent over the area. Sandstones are fairly common, but white to yellowish slates make up the bulk of the sediments. The slates are highly cleaved, and as bedding and cleavage are frequently inclined, it is difficult at some localities to obtain a representative fauna. For the same reason, in deducing the structure of the area, more weight is attached to the evidence of the graptolites, since at times in unfossiliferous localities the cleavage and dip are almost indistinguishable, and dip observations are therefore impracticable. This difficulty is absent in the centre of the area, where sufficient depth of exposure is obtained in the cuttings along the road and the railway.

Though most of the black slates examined are within the metamorphic aureole of the adamellite, the graptolites are usually well preserved if the slates are not too weathered. As the adamellite is approached, however, the slates become indurated and spotted, and develop a rough fracture, so that any graptolites preserved are difficult to obtain. Along the Werribee River, the original muds were probably slightly different in composition, and metamorphism produced phyllitic slates which are not conspicuously spotted. This lithological distinction has been used in fixing a tentative lower boundary for D2, since graptolites are rare in the critical locality.

Basis of Palaeontological Zoning.

The whole of the Ordovician in this area belongs to the Castlemaine and Darriwil series. The following scheme of subdivisions is based on that of Harris and Keble.[5] Slight additions, for example the passage beds between D5 and D4, appear; but as these are not recorded in other areas of Darriwilian age, they may be only of minor importance.

Series.	Zone.	Zonal Fossils.	Other Characteristic Fossils.
Darriwil ..	D2	*Diplograptus austrodentatus* H. and K. *Glossograptus* sp. (absence of *Cardiograptus morsus* H. and K.)	*Didymograptus caduceus* Salt. *D. v-deflexus* Harris *Trigonograptus*
	D3	*Cardiograptus morsus* (absence of *Oncograptus*)	*Didymograptus caduceus* *D. v-deflexus* *Phyllograptus* sp. *Trigonograptus*
	D4	*Cardiograptus morsus* .. *Oncograptus* sp.	*Didymograptus caduceus* *D. v-deflexus* *Tetragraptus serra* (Brongniart) *Trigonograptus*
	D5–D4	*Oncograptus biangulatus* .. *O. upsilon* T. S. Hall	*Didymograptus caduceus* *D. caduceus* var. *manubriatus* T. S. Hall *D. v-deflexus* *Tetragraptus serra* *Dichograptus* sp.
	D5	*Oncograptus upsilon* (absence of *Cardiograptus*)	As for D5–D4 *Trigonograptus*
Castlemaine	C1	*D. caduceus* (maximum development) (absence of *Oncograptus*)	*Didymograptus caduceus* *D. caduceus* var. *manubriatus* *D. forcipiformis* Ruedemann *D. v-deflexus* *D.* cf. *uniformis* Elles and Wood *D. nitidus* (J. Hall) *Tetragraptus serra* *Goniograptus speciosus* T. S. Hall *Dichograptus* sp.

The succession in this locality is normal, and the zonal fossils have apparently the same range as in other Darriwilian areas. D5 with *Oncograptus upsilon* only is poorly represented, but this is probably due to the lack of exposure rather than to actual absence of deposition. Beds on the Ironbark Creek, about a mile from its source, containing an abundant fauna without *O. upsilon*, are C1 since *Didymograptus caduceus* is very abundant and not associated with *Oncograptus*. No evidence of the passage of these into D5 could be found on the Ironbark Creek, and the next beds observed contain *O. biangulatus,* in addition to *Oncograptus upsilon*. It seems likely, therefore, that *O. upsilon* appeared first, in accordance with the development of *Oncograptus* and *Cardiograptus* from *Didymograptus caduceus,* as worked out by Harris, to be joined later in passage beds between D5 and D4 by *Oncograptus biangulatus*. In these beds there is some difficulty in distinguishing the two species, since the gap between the two extreme forms, which are distinguished by the difference in the angle of divergence of the uniserial stipes, is bridged by several intermediate forms with mean values of that angle. These observations are confirmed by Harris (personal communication), but he has not so far found the two species in association. This record therefore requires confirmation in other localities. The passage beds in all localities are succeeded by normal D4 in which *Oncograptus biangulatus* and *Cardiograptus morsus* are associated, though *C. morsus* is rather rare until D3 is reached. There *O. biangulatus* is completely replaced by *Cardiograptus.*

The passage from D3 to D2 has not been observed owing to insufficient exposure. The fauna of D2 is very distinctive, *Diplograptus austrodentatus* occurring to the exclusion of most other forms. *Didymograptus caduceus* is rare and *Glossograptus* sp. is occasionally found.

Details of Sections.

The axial lines shown on the map and section (Pl. XX.) are based on exposures in:—

1. The Ironbark Creek.
2. Sloss's Gully.
3. The Ballan-Bacchus Marsh road.
   The cuttings along the Ballarat-Melbourne railway.
4. Creek C.
5. Creek B.
6. The Werribee River.

Creek B and Creek C are two of the western tributaries of the Werribee, unnamed on the maps of the district, and so lettered for convenience of reference.

These features give a more or less E.-W. section across the area, and are so placed that they cover almost the whole of it. The correlation of the black slate bands in any two adjacent sections is made difficult by the varying pitch of the folds. The prevailing pitch is to the north as is shown by the variation in the strike, but exceptions in which a pronounced southerly pitch is developed are not rare. Longitudinal sections would probably show the type of structure already proved to exist at Bendigo ([6] and [7]) where the "pitch lines" show undulations rather than a persistent slope.

Few observations have been made close to the adamellite owing to lack of exposure, the nearest being on the railway, in Sloss's Gully and in a tributary of the Ironbark Creek. In the railway cutting, the strikes are similar to those in other parts of the area, and the fold axes maintain their original direction until the contact is reached. An anticline less than 5 chains from the contact shows a decided northerly pitch, so that adamellite probably reached its present position by magmatic stoping rather than by forcible intrusion. Similarly in the other localities, 10 or 12 chains from the contact, the observed dips show no deflection of the axial lines.

1. Ironbark Creek.

The black slates exposed along this creek are fossiliferous only in the western part, i.e., within the metamorphic aureole of the adamellite. The bands in the extreme west (I 3) yield—

Didymograptus caduceus Salter (large and abundant).
D. nitidus (J. Hall).
D. cf. uniformis E. and W.
Tetragraptus sp.
Dichograptus sp.

This assemblage is correlated with a well preserved fauna obtained further east at I 6, containing—

D. caduceus Salter.
D. caduceus var. manubriatus T. S. Hall.
D. nitidus (J. Hall).
D. cf. uniformis E. and W.
D. forcipiformis Rued.
Tetragraptus serra (Brongn.).
T. cf. quadribrachiatus (J. Hall).
Goniograptus speciosus T. S. Hall.
Dichograptus sp.
(?) Diplograptus sp.

These beds are C1.

Slightly to the east of I 3, and in a syncline, occur beds (I 1) containing *Oncograptus biangulatus, Didymograptus caduceus, D. v-deflexus, Phyllograptus* sp., and *Tetragraptus serra*. The horizon of these is D4. They fail to repeat on the other limb of the syncline, and are replaced by black slates (I 5) with *Oncograptus biangulatus, O. upsilon, Didymograptus caduceus, Tetragraptus* sp., and *Trigonograptus* sp., which are probably passage beds between D4 and D5. Since the thickness of beds separating C1 and normal D4 does not accord with the thickness of D5, observed in other parts of the area, and the beds belonging to D5-D4 do not occur on both limbs of the syncline, it is inferred that trough-faulting has taken place, this cutting out on the west limb the beds corresponding to I 5 and reducing the apparent thickness between D5 and D4.

The other black slate outcrops marked are either unfossiliferous or contain poorly preserved examples of *Didymograptus caduceus* and crustaceae, so that on this section no further evidence as to structure, beyond that given by observation of dip and strike, is available.

2. Sloss's Gully.

Exposures are few, and black slates outcrop only in the head of the gully, the eastern outcrops being mainly sandstones. The beds at S2 contain *Didymograptus caduceus, Dichograptus* sp. (abundant) and *Tetragraptus quadribrachiatus,* and are tentatively placed in C1. They are succeeded in a syncline about 2 chains to the west by black slates (S1 and S3) with *Oncograptus biangulatus, Didymograptus caduceus, Tetragraptus serra* and *T. quadribrachiatus.* I 2 is probably the same bed which is repeated in an anticline still further west.

The exposures in the eastern part of Sloss's Gully, while unfossiliferous, are of use in confirming the axial lines set up on the evidence of sections along the road, railway and Creek C.

3. Ballan-Bacchus Marsh Road and Melbourne-Ballarat Railway.

Fossiliferous black slates are common along this section, and show the presence of D5, D4, and D3, as well as of the passage beds between D5 and D4. D4 is the most extensively outcropping zone owing to the repetition by folding of a small thickness of slates. Going east from RD9 (D5), with a fauna containing—

Didymograptus caduceus Salter
D. caduceus var. manubriatus T. S. Hall
D. v-deflexus Harris
Phyllograptus sp.
Oncograptus upsilon T. S. Hall,

a gradual passage upwards is observable, beds belonging to D3 occurring at RD5, about $\frac{1}{4}$ mile to the east. The ascent is not continuous, however, as numerous minor puckers bring beds belonging to D5 to the surface for some distance east of RD9. At the quarry near the 42-mile post on the railway (RL2) and at RD6 a fauna including—

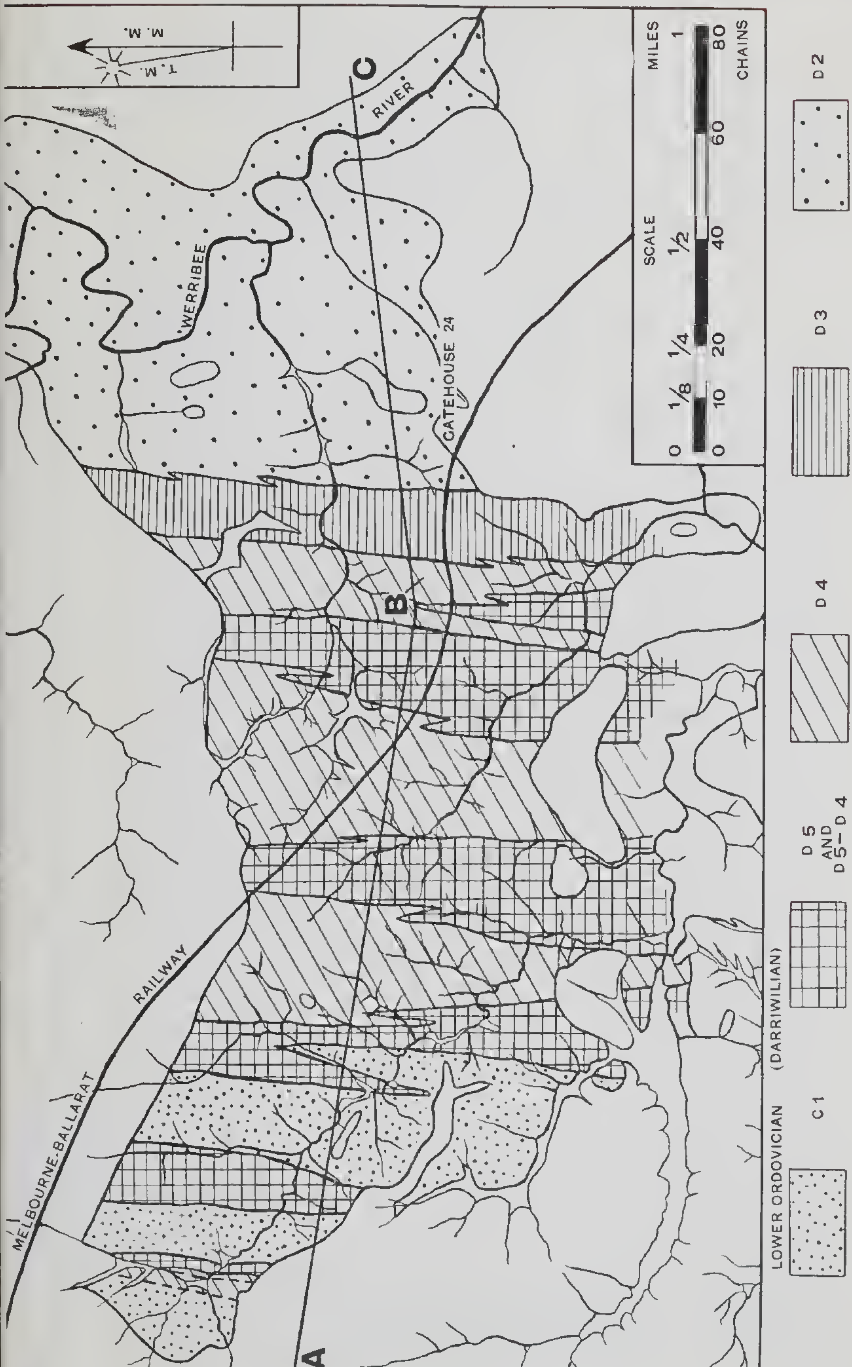
Didymograptus caduceus Salter
Oncograptus biangulatus H. and K.
Cardiograptus morsus H. and K.
Tetragraptus serra (Brongn.)
T. quadribrachiatus (J. Hall)
Phyllograptus sp.
Goniograptus sp.
Trigonograptus sp.
Lasiograptus sp.,

places the beds in D4. The graptolites, though plentiful, are not very well preserved, since the slates are weathered and have been further metamorphosed by the intrusion of an acid dyke along the axis of the anticline. At RD5 *Cardiograptus morsus* is associated with *Didymograptus caduceus, D. v-deflexus* and *Phyllograptus* sp. East of this locality the black slates contain only poorly preserved examples of *Didymograptus caduceus, D. v-deflexus* and *Phyllograptus* sp. and are repeated by a number of small acute folds that pitch towards the south.

Going west from RD9, where the highly cleaved, horizontal black slates are at the axis of an anticline, the next fossiliferous slates are passage beds between D5 and D4, as shown by the association of *Oncograptus upsilon* and *O. biangulatus.* These are repeated, RD10 and RD11 being the same band, by a minor fold on the western limb of the anticline at RD9. The remainder of the section is made up of closely folded beds belonging to D4. Two faults were observed in the railway cutting near the 42½-mile post, but the displacement of the beds does not appear to have been very great. *Oncograptus biangulatus* is plentiful in the slates on the road west of RD11, but is not common in the railway cuttings, where the slates seem more indurated. West of RL7 *Didymograptus caduceus* was the only form found, but the bands can be connected with the corresponding slates in the road. The contact of the adamellite and the Lower Ordovician occurs at the western end of the railway cutting, about 12 chains from the last fossiliferous black slates on Creek C near the railway. The intervening bands are fossiliferous at the head of Sloss's Gully, and serve to connect this section with the outcrops along the Ironbark Creek.

4. Creek C.

The western localities (W9 and W10) yield *Didymograptus caduceus* only, and the age of the beds is thus uncertain, though by comparison with those in the railway cutting, they are probably D4. At W12 and W13, on the north flowing tributary of Creek C rising at the railway bridge, *Oncograptus biangulatus* and (?) *Cardiograptus* were obtained, and the beds were thus to be correlated with those in the small quarry on the road west of the bridge (RD6a). The next fossiliferous band is about ¼ mile to the east of W13, on a north-flowing tributary rising at Gatehouse 24, and the occurrence of small Diplograpti and of *Didymograptus caduceus* shows these beds to belong to D2. The slates here are of the same type as those of the Werribee Gorge. The next outcrop to the west, at the head of a small south-flowing tributary, is unfossiliferous, but the slates are of the same lithological type as the Lower Darriwilian of the road and railway cuttings, Ironbark Creek, &c. The boundary D3–D2 is therefore placed with some hesitation between these two outcrops.



T.M.
M.M.
C
RIVER
WERRIBEE
GATEHOUSE 24
B
MELBOURNE-BALLARAT
RAILWAY
A
SCALE
MILES
0 1/8 1/4 1/2 1
0 10 20 40 60 80
CHAINS
LOWER ORDOVICIAN
C 1
(DARRIWILIAN)
D 5
AND
D 5–D 4
D 4
D 3
D 2

FIG. 1.

13801.—4

5. Creek B.

Though black slate bands are numerous, graptolites are rare and not well preserved. The only fossiliferous locality, where small Diplograpti were obtained, is about 5 chains from the Werribee River. The unfossiliferous slates are correlated with corresponding bands in the graptolite-bearing slates in Creek C to the north, and additional evidence for the axial lines, crossing the valleys of the Werribee River and Creek C, was obtained.

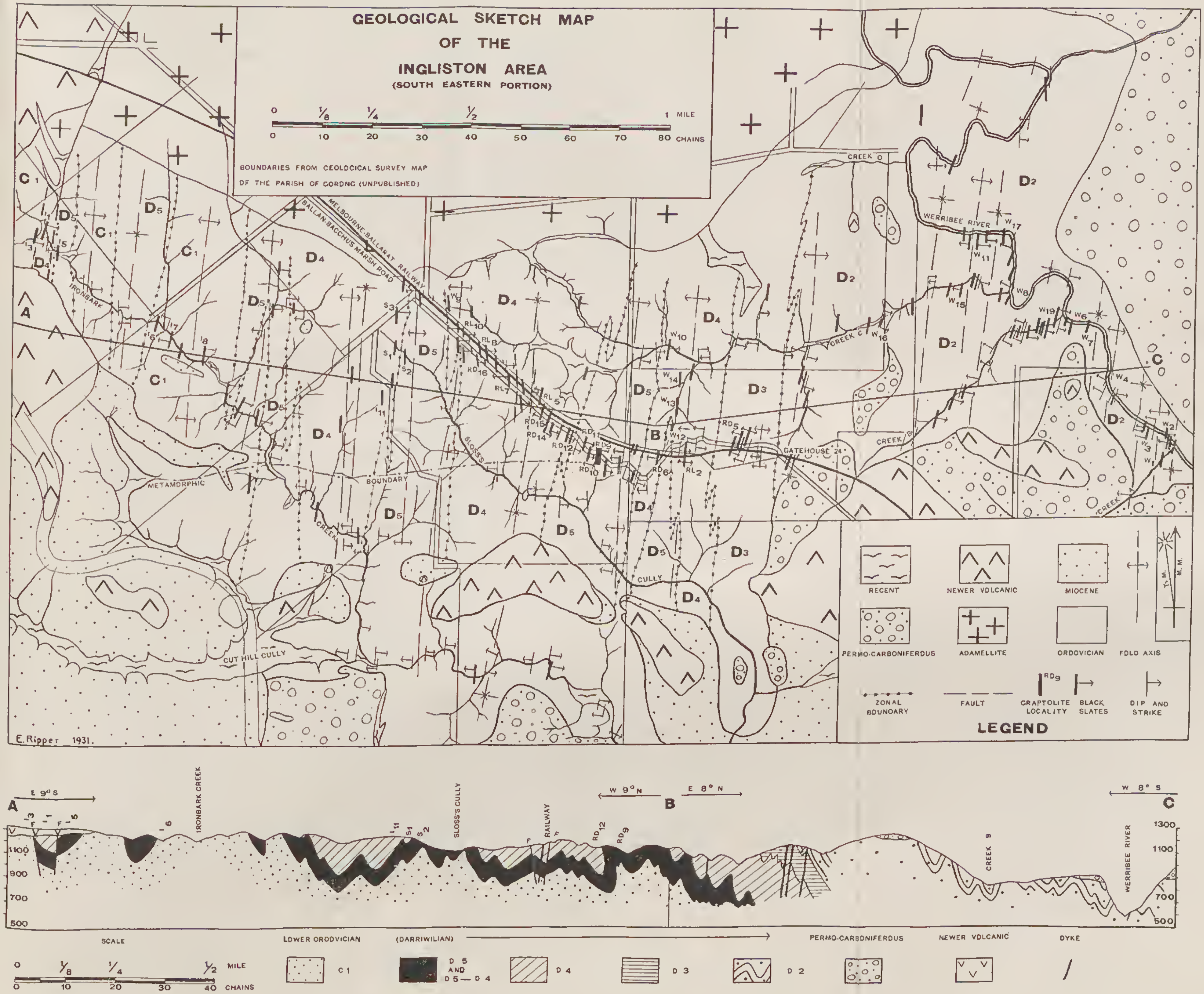
6. Werribee River.

Much of the information on which the axial lines in this part of the area are based was obtained from an unpublished map by Mr. C. C. Brittlebank. Graptolites are fairly abundant, the best preserved faunas occurring south-east of Pyramid Rock, at W3 and W4. The beds belong to D2, *Diplograptus austrodentatus* being very common, and associated with *Glossograptus* sp., *Didymograptus caduceus*, and *Tetragraptus* sp. As the river is followed northwards, graptolites are more difficult to obtain as the slates become more metamorphosed. The slates north of Creek D are unfossiliferous. As none of the assemblages contain *Oncograptus* or *Cardiograptus*, they are probably all D2. No graptolites belonging to D1, e.g., *Didymograptus nodosus*, *Climacograptus*, or large Diplograpti, have been obtained.

Conclusion and Acknowledgments.

The Ordovician of the area comprises the uppermost zone of the Castlemaine series (C1) and the whole of the Darriwil series except D1. The distribution of the zones is shown in Fig. 1. The oldest bed occurs in the western part of the area, along the Ironbark Creek, and passes up into D5 and D4 in the railway and road cuttings. Still further east *Cardiograptus* appears, but these D3 beds are not well exposed along any of the lines of section. A higher zone (D2) outcrops in the Werribee Gorge and in the valleys of its western tributaries, but the passage from D3 to D2 has not been observed. The area is, therefore, the western limb of a syncline, of which the axis is unknown, since few observations east of the Werribee are possible owing to the presence of the Permo-Carboniferous tillite. The ascent from D5 to D2 is not continuous, as the beds are very closely folded, and older beds are frequently brought to the surface by minor anticlines.

In conclusion, I wish to thank Mr. R. A. Keble for drawing attention to the area, Mr. W. Baragwanath for allowing me to use the map on which Pl. XX is based, and Mr. C. C. Brittlebank for the use of his unpublished map of the Werribee Gorge area. I should like also to thank Mr. W. J. Harris for many valuable suggestions and help in identifying the graptolites, and Dr. Summers for his assistance throughout the year.


GEOLOGICAL SKETCH MAP
OF THE
INGLISTON AREA
(SOUTH EASTERN PORTION)
0 1/8 1/4 1/2 1 MILE
0 10 20 30 40 50 60 70 80 CHAINS
BOUNDARIES FROM GEOLOGICAL SURVEY MAP
OF THE PARISH OF GORONG (UNPUBLISHED)
MELBOURNE-BALLARAT RAILWAY
BALLAN-BACCHUS MARSH ROAD
IRONBARK
METAMORPHIC
SLOSS'S
BOUNDARY
CREEK
CULLY
CUT HILL CULLY
WERRIBEE RIVER
CREEK C
CREEK B
CREEK A
GATEHOUSE 24
RECENT
NEWER VOLCANIC
MIOCENE
PERMO-CARBONIFEROUS
ADAMELLITE
ORDOVICIAN
FOLD AXIS
ZONAL BOUNDARY
FAULT
GRAPTOLITE LOCALITY
BLACK SLATES
DIP AND STRIKE
LEGEND
E. Ripper 1931.
E 9° S
W 9° N
E 8° N
W 8° S
IRONBARK CREEK
SLOSS'S CULLY
RAILWAY
CREEK B
WERRIBEE RIVER
SCALE
0 1/8 1/4 1/2 MILE
0 10 20 30 40 CHAINS
LOWER ORDOVICIAN
(DARRIWILIAN)
C 1
D 5 AND D 5 — D 4
D 4
D 3
D 2
PERMO-CARBONIFEROUS
NEWER VOLCANIC
DYKE

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[Proc. Roy. Soc. Victoria, **44** (N.S.), Pt. II., 1932.]

Art. XVII.—*On some Palaeozoic Fossils from Deep Creek and Evans' Creek, Saltwater River, Victoria.*

By F. CHAPMAN, A.L.S., F.G.S.

[Read 10th December, 1931; issued separately 20th April, 1932.]

Introduction.

On the 28th of August, 1856, Chas. D'Oyley Aplin, of Selwyn's first Victorian Geological Survey, made a collection of fossiliferous sandstones and grits from the vicinity of Deep Creek near Diggers' Rest, and from Evans' Creek, north of Sunbury.

Soon after arriving in Melbourne, to take charge of the Palaeontological collection at the National Museum, the writer examined and described (Chapman, 1903, p. 118) the typical *Siphonotretae* of the Upper Ordovician rocks of the higher reaches of the Saltwater River, and whilst incidentally clearing up a discrepancy in the naming of the different parts of the same river, as Deep Creek and the Saltwater River, he studied the samples noted above, that were obtained from the true Deep Creek, determining the fossils (Ba 60) as Silurian and probably Yeringian. The note appended to the paper cited (Chapman, 1903, pp. 78, 79) includes some general determinations of the fossils, a note upon which was promised shortly. The naming of this small collection, which had been shelved for many years through pressure of work at the time, has now been revived by the desire of the present geological surveyor of this area, Mr. David Thomas, B.Sc. The results of the writer's investigations are now recorded, together with a note on the second locality, of Evans' Creek, which seems to represent an horizon recently named as the Riddell Grits.

Description of Survey Specimens, Ba 60.

The Geological Survey reference to the locality of Ba 60 is "W. Bank of Deep Creek with the Saltwater River, Quarter Sheet 7 S.E."

The rock of the Ba 60 locality is a fossiliferous and hardened mudstone, with a conglomeritic structure in parts, and of an ochreous to liver-brown colour. The fossils are chiefly in the condition of moulds and casts, and are abundant but generally poorly preserved.

The fossils here identified are as follows:—

ANTHOZOA.

Lindstroemia conspicua Chapman.

(Chapman, 1925, p. 106, pl. xii., f. 5-7, pl. xv., f. 23.)

Observations.—This present specimen is a faithful cast of the basal end of the cup and some of the lateral wall. It shows the typical number of septa, as recorded for this species. By its general short and stoutly conical form it could not be confused with the other species recorded in the same descriptive paper above noted. *L. conspicua* was described by the writer from the Melbournian of South Yarra and Moonee Ponds Creek, and from the supposed passage bed of Wandong and Glenburnie road, Whittlesea, in the Jutson collection in the National Museum.

Heliolites sp.

The specific relationship of a cast in mudstone is doubtful, but comparison may be made with *H. megastomum* McCoy, in regard to the size of the autopores.

CRINOIDEA.

Stem ossicles are of frequent occurrence. Some measure as much as 14 mm. in diameter; one at least resembles a centro-dorsal plate of a form like that seen in the *Cyathocrinidae*. Other smaller stems and ossicles of narrower diameter and less height occur, belonging to other indeterminate genera.

VERMES.

Keilorites cf. crassituba (Chapman).

Solid casts and hollow moulds of the crypts of *Keilorites* occur in the more compact and uniformly textured mudstones. *Keilorites* was formerly referred by the writer to *Trachyderma*, a name now found to be preoccupied by a beetle (*Trachyderma* Latreille 1829, non *Trachyderma* Phillips 1848), as pointed out by R. S. Allan (Allan, 1927, p. 240). *Keilorites* is a common fossil in the Melbournian, and rare in the Yeringian.

Apropos of Dr. Bather's letter in the *Geological Magazine* (Bather, 1927, p. 286), this does not seem to have received a reply from R. S. Allan. The present writer would therefore here suggest that, since he was the original describer of the Australian specimens, he is justified in expressing his opinion that the Australian and the British specimens are congeneric, and that he agrees with Dr. Bather, who has already fixed the genotype as *Trachyderma squamosa* Phillips.

POLYZOA.

Ceramoporella sp.

Quite good casts of the subencrusting zoarium of a cyclostomatous form allied to the above genus, measuring up to 16 x 10 mm., occur here. The comparatively short, trumpet-shaped tubes with oblique apertures afford distinguishing generic characters.

BRACHIOPODA.

? Orthis sp.

Although many fragments of brachiopods are visible, they are so comminuted as to make their determination impossible, beyond the recognition of *? Orthis*.

PELECYPODA.

cf. Edmondia perobliqua Chapman.

Edmondia perobliqua Chapman (1908, p. 18, pl. i., f. 7–9). A cast of a shell with valves united may be referred tentatively to the above species, which was formerly described from fossils found in the Melbournian of South Yarra. The shape of the valves is nearer to *Edmondia* than the described forms of *Nucula,* whilst there is no taxodont dentition present.

GASTEROPODA.

cf. Pleurotomaria.

This is a depressed conical shell having a keeled whorl. The basal surface shows a lirate ornament.

Murchisonia sp.

Several casts of low turreted shells occur, which appear to be more nearly related to the above genus than to *Goniostropha.*

Description of Survey Specimens, Ba 65.

The locality note, forwarded by the Geological Survey of Victoria to Frederick McCoy, then Palaeontologist to the Survey, is as follows:—" Ba 65. Banks of Evans' Creek, about a mile above its junction with Jackson's Creek, Q.S. 7 N.-E., C. D. Aplin, 29.8.56."

The rock containing the fossil remains is a dense, hard, to fairly friable, gritty sandstone containing moulds (impressions) and casts of fossils, often very abundant. These gritty sandstones vary from plum-brown to reddish and ochreous and bluish-grey rocks. They are occasionally seamed with thin quartz veins, and the fossil cavities are frequently lined with an ochreous layer.

Description of the fossils:—

CRINOIDEA.

Crinoids indeterminate. Stem ossicles are common, having narrow columnars, and rounded margin. They appear to be referable to the *Cyathocrinidae*.

CYSTOIDEA.

cf. Caryocrinus.

A negative impression of the exterior of a basal plate occurs here, having a more or less complete hexagonal outline and slightly convex granulose surface. It measures 13 x 10 mm.

VERMES.

Keilorites cf. crassituba (Chapman).

This is represented by a negative cavity of a mud-infilled crypt of irregularly cylindrical and distally tapering contour. The thin transverse partitions seen crossing the cavity are the infillings of the spaces between the original shrunken mud-filled tube.

BRACHIOPODA.

Chonetes melbournensis Chapman.

(Chapman, 1903, p. 74, pl. xi., f. 2–4.)

A cast of a brachial valve occurs in a fine-grained ochreous sandstone. The width of the valve was 6 mm. when complete, and thus of normal dimensions as compared with topotypes from the Melbournian of South Yarra. Another rather doubtful specimen also occurs, in a less sandy matrix, in which the original valve is replaced by an ochreous deposit.

Camarotoechia decemplicata Sowerby.

A sandstone cast of a pedicle valve, sufficiently preserved for identification, is found in the present collection. It is interesting to be able to confirm, in this paper, the identification of the British with the Australian fossils referred to the above species. Having lately investigated the characters of these fossils from the two widely separated localities, the writer has no doubt of their identity as one species. In both the British and the Australian examples, the plications on each side of the mesial fold number from 5 to 7, as originally stated by McCoy in the Prodromus of Palaeontology.

TREMATOSPIRA LIOPLEURA McCoy.

Moulds of the above species were found in the hard sandy ochreous-grey rock. This form appears to have been correctly referred to *Trematospira*, although in none of the Australian specimens do the spiralia seem to have been preserved. The transverse character of the shell, with the divergent crurae and strong septum, show its affinities with the *Athyridae*.

T. liopleura has been recorded from Melbourne (excavations), Moonee Ponds Creek, Wallan Road, Bruce's Creek, Broadford, Whittlesea, and Mt. Disappointment. The main localities are Melbournian, but it also occurs in the passage beds (slightly higher) of Whittlesea.

RHYNCHOTRETA cf. BOREALIS (Schlotheim).

A fairly well-preserved mould of a brachial valve, leaves little doubt that it is referable to *R. borealis*. A typical European Silurian brachiopod ranging from Llandovery to Upper Ludlow. (=Melbournian to Yeringian.)

CEPHALOPODA.

PROTOBACTRITES sp.

A cast of the interior of a neat little orthoceracone occurring in the ferruginous grit of Ba 65 may be referred to the above genus. It exhibits the slender cylindrical habit of *Protobactrites*, with few, widely separated chambers. It may be matched, to some extent, with certain undescribed Melbournian species. The incomplete specimen has a length of 6 mm., and a diameter at the proximal end of 2.5 mm. The fragment comprises two complete chambers, and portions of the earlier and later ones.

TRILOBITA.

ENCRINURUS cf. PUNCTATUS Emmrich.

A portion of the furrowed glabella with the punctate free cheeks, occurs in a fractured and seamed cavernous sandstone. The fossil fragment, as usual in this rock, is coated with limonite. The species is common to both the Melbournian (passage beds) and the Yeringian of the Australian Silurian.

cf. PHACOPS sp.

A portion of the surface of a facetted eye-lobe is here represented in a limonite-coated mould. It may be compared with *Phacops sweeti* Eth. fil. and Mitch., rather than with *Dalmanites meridianus* (Eth. fil. and Mitch.) on account of its flat or complanate surface. *Phacops sweeti* was found at Broadhurst's Creek near Kilmore (probably passage beds between Melbourne and Yeringian).

Summary.

The collective evidence of the suite of fossils from the Geological Survey locality Ba 60 is in favour of a Melbournian age for these fossiliferous sandstones. This conclusion is supported by the presence of such typically older Silurian forms as *Lindstroemia conspicua, Heliolites megastomum, Keilorites* cf. *crassituba,* and cf. *Edmondia perobliqua.* The polyzoan, *Ceramoporella,* introduces an Ordovician element into the facies, but the balance of the evidence is in favour of its Melbournian age. The trilobite referred to in 1903 (Chapman, 1903, p. 79) should be transferred to the locality Ba 65, where *Encrinurus* and *Phacops* occur.

The age of the fossil assemblage from the Geological Survey locality Ba 65 points mainly to a Melbournian age. At the same time there is an upward tendency in the stratigraphical scale as shown by the trilobites. The occurrence of such a restricted Melbournian fossil, however, as *Chonetes melbournensis,* together with *Protobactrites* and *Camarotoechia decemplicata,* supports the idea of a Melbournian age.

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[Proc. Roy. Soc. Victoria, **44** (N.S.), Pt. II., 1932.]

Art. XVIII.—*Victorian and South Australian Shallow-Water Foraminifera. Part II.*

By WALTER J. PARR, F.R.M.S.

(With Plates XXI. and XXII., and one text-figure.)

[Read 10th December, 1931; issued separately 20th April, 1932.]

Introduction.

This is the second and concluding part of a paper dealing with new and interesting foraminifera found during the examination of a number of shore sands and shallow-water dredgings from the coasts of Victoria and South Australia. Details of the material studied will be found in Part I. Since Part I. was written, further samples from the same stations have been examined, with the result that additional species have been discovered and are included here. The following species and variety are described as new:—

Gaudryina hastata
Vaginulina vertebralis
Bolivinella elegans
Reussia armata
Discorbis australis
Discorbis collinsi
Discorbis vesicularis (Lam.), var. *acervulinoides*.
Anomalina nonionoides.

Systematic Description of Species.

Order FORAMINIFERA.

Family SACCAMINIDAE.

Sub-Family SACCAMMININAE.

Genus **Proteonina** Williamson, 1858.

Proteonina spiculifera Parr.

(Plate XXII., Fig. 39.)

Proteonina spiculifera Parr, 1932, *Proc. Roy. Soc. Vic.*, xliv. (n.s.) (1) (for 1931), p. 2, pl. i., fig. 1.

A figure of a broad example, also from the type locality for this species, viz., Point Lonsdale, is here given.

Family VERNEUILINIDAE.

Genus **Gaudryina** d'Orbigny, 1839.

Gaudryina hastata, sp. nov.

(Plate XXII., Figs. 40*a, b*.)

Description.—Test elongate, tapering, the triserial portion trihedral, with sharp angles and concave faces; biserial portion broadly ovate to sub-quadrate in end view; apertural end truncate; chambers numerous, distinct, later ones slightly inflated; sutures distinct; wall arenaceous, fairly smoothly finished; aperture arched, at the base of the inner margin of the last-formed chamber.

Length up to 1.2 mm.

Holotype (Parr Coll.) from shore sand, Port Fairy, Vic., collected by F. Chapman.

Remarks.—Several specimens, all megalospheric, were found in the material from Port Fairy. The species is common in dredgings from a depth of about 100 fms., off the coast of New South Wales, in Bass Strait, and in the Great Australian Bight. In these, examples of both megalospheric and microspheric stages are present. In adult specimens of the megalospheric form, the triserial portion of the test consists of about eighteen chambers, and forms about one-quarter of the shell. There are usually about fourteen chambers in the biserial portion. The microspheric form is of similar length, but has a much longer, more sharply-angled triserial portion, the chambers numbering as many as 39. There are seldom more than six or eight in the biserial portion.

Several other species of the same general type have been recorded from the Pacific, namely *G. rugosa* d'Orb., *G. triangularis* Cushman, *G. convexa* Cushman, and *G. quadrangularis* Bagg. The last-named is perhaps the nearest to the present species, but has a much larger, rougher test, with blunt angles and fewer chambers. In one dredging from 30 miles south of Cape Nelson, Vic., 300 fms., *G. hastata* is associated with the species figured by Brady in the *Challenger* Report as *G. rugosa*. The latter is easily distinguished from the former by its different shape, fewer chambers, rough finish, and colour. Heron-Allen and Earland (1922, *Brit. Ant.* ("*Terra Nova*") *Exped.*, 1910, *Foram.*, p. 122, pl. iv., figs. 16, 17) have figured as *G. rugosa* what appears to be the microspheric form of the present species. The specimens were from off New Zealand, where they occurred in company with "short, comparatively few-chambered individuals." It would be interesting to know if the two forms can be separated in the same way as those from south of Cape Nelson.

Family MILIOLIDAE.

Genus **Spiroloculina** d'Orbigny, 1826.

Spiroloculina sp. aff. arenaria Brady.

(Plate XXII., Figs. 41*a, b.*)

Stn. 2.

There are several examples of an arenaceous species of *Spiroloculina* in the shallow-water dredging from Westernport Bay. It seems distinct from any known form of the genus, but, as so little material is available, it is here recorded under the name of the species which it most closely resembles, viz., *S. arenaria* Brady, also from the Pacific. The present form has a more compressed test, with a larger aperture than Brady's species, and the chambers are more distinct. The apertural tooth also separates it from *S. arenaria.*

Genus **Triloculina** d'Orbigny, 1826.

Triloculina labiosa d'Orbigny.

(Plate XXII., Fig. 44.)

Triloculina labiosa d'Orbigny, in De La Sagra, *Hist. Fis. Pol. Nat. Cuba, "Foram.,"* p. 178, pl. x., figs. 12-14.

Miliolina labiosa (d'Orb.): Chapman, 1909, *Jour. Quek. Micr. Club,* [2], x (for 1907), p. 122, pl. ix., fig. 2.

Triloculina labiosa d'Orb.: Cushman, 1922, *Publ.* 311, *Carn. Inst. Wash.,* p. 77, pl. xii., fig. 1.

Stns. 1, 6, 8, 9, 10, 11. C., H.

Common. This species was described from the West Indies, and is widely distributed in the Indo-Pacific region. In the present gatherings, it was common at Point Lonsdale, where, in addition to the typical form, many examples of a wild-growing variety were found. These bear a superficial resemblance to *Parrina bradyi* (Millett), in which, however, the early chambers are similar to those of the genus *Calcituba,* and are not arranged on a triloculine plan. They are recorded below as *T. labiosa,* var. *schauinslandi* (Rhumbler).

Triloculina labiosa d'Orbigny, var. schauinslandi (Rhumbler).

(Plate XXII., Fig. 43.)

Miliolina schauinslandi Rhumbler, 1906, *Zool. Jahrb., Abteil. Sys.,* xxiv., p. 41, pl. iii., figs. 20, 21.

Quinqueloculina (?) *schauinslandi* (Rhumbler): Cushman, 1917, *Bull.* 71, *U.S. Nat. Mus.,* pt. 6, p. 56, pl. viii., figs. 7, 8 (after Rhumbler).

Nubecularia schauinslandi (Rhumbler): Heron-Allen and Earland, 1924, *Journ. Linn. Soc.* (London) *Zool.,* xxxv., p. 601, pl. xxxv., figs. 2-5.

Stn. 6.

The best-developed specimens answer perfectly to the description, given by Heron-Allen and Earland, of their Lord Howe Island examples. The early portion of the test is similar to *T. labiosa,* and is followed by a straight or curved series of irregularly-formed chambers, terminating in a large, gaping, irregular aperture into which a number of teeth-like processes project. Less-developed specimens similar to that here figured agree with a form recorded by several authors as *Nubecularia bradyi* Millett. Rhumbler's type-specimens were from shore sand of Laysan Island.

Family LAGENIDAE.

Sub-Family NODOSARIINAE.

Genus **Vaginulina** d'Orbigny, 1826.

VAGINULINA PATENS Brady.

Vaginulina patens Brady, 1884, "*Chall.*" *Rept. Zool.,* vol. ix., p. 533, pl. lxvii., figs. 15, 16.

V. costata Chapman (*non Planularia costata* Cornuel), 1909, *Jour. Quek. Micr. Club* [2], x (for 1907), p. 130, pl. ix., fig. 10. Sidebottom, 1918, *J.R.M.S.,* p. 139, pl. v., figs. 4, 5.

Stn. 4.

One small example. The records of this species are all from the Pacific. It has been confused with *Planularia costata* Cornuel described (1848, *Mém. Soc. Géol. France* [2], iii., Mém. 3, p. 253, pl. ii., figs. 5-8), from the Cretaceous of France, which is a very different form, as the study of Cornuel's description and figures will show.

VAGINULINA VERTEBRALIS, sp. nov.

(Plate XXII., Fig. 42.)

Description.—Test elongate, slightly curved, consisting of up to eleven chambers. The proloculum is about twice as long as the chambers immediately succeeding it, and bears a short blunt spine. The first three chambers have usually six fairly strong costae, the remainder being smooth; the later chambers are set on obliquely, strongly inflated ventrally, and taper dorsally into a stout keel. The sutures are distinct, and are carried into the keel as bands of clear shell substance, hence the specific name. Aperture produced, radiate.

Length up to 2.2 mm.

Holotype (Parr Coll.) from shore sand, Torquay, Vic., collected by A. C. Collins.

Remarks.—This species is rare, but is also found in the Post-tertiary of Victoria, at Boneo, and occurs in the Lower Pliocene beds at Beaumaris. It is very constant in its characters. It is closely related to two species, figured by Soldani and named *Nodosaria* (*Dentalina*) *arcuata* and *N.* (*D.*) *carinata* by d'Orbigny (*vide* Parker, Jones, and Brady, *Ann. Mag. Nat. Hist.* [4], viii., 1871, p. 159, pl. ix., figs. 49, 50, where Soldani's figures are reproduced). These were from the Mediterranean Sea.

Genus **Frondicularia** Defrance, 1824.

Frondicularia advena Cushman.

(Plate XXII., Fig. 47.)

Frondicularia inaequalis Brady (*non* Costa), 1884, "*Chall.*" *Rept. Zool.*, vol. ix., p. 521, pl. lxvi., figs. 8-12. Flint, 1899, *Rept. U.S. Nat. Mus.*, for 1897, p. 313, pl. lix., fig. 2.

F. advena Cushman, 1923, *Bull.* 104, *U.S. Nat. Mus.*, pt. 4, p. 141, pl. xx., figs. 1, 2.

Stn. 4.

There is one small example in which the four chambers following the proloculum are arranged biserially. Brady's Fig. 11 and the left-hand specimen in Flint's figures exhibit a similar arrangement of the early chambers, which is also found in many of the fossil examples at hand from the Oligocene (Balcombian) of Victoria and the Miocene of Trinidad. Apparently the genus *Frondicularia* includes species derived from the recently-described genus *Kyphopyxa* Cushman.

F. advena, according to Cushman, is common in the Western Atlantic and in the Pacific. Brady's figured examples were from off the Ki Islands. It is also found in the Older Tertiary of Victoria. This species may prove to be identical with Stache's *F. whaingaroica,* a fossil species from New Zealand, which has not been recorded since it was described by Stache in the *Novara* Expedition Reports.

Family PENEROPLIDAE.

Genus **Spirolina** Lamarck, 1804.

Spirolina acicularis (Batsch).

(Plate XXII., Figs. 45*a, b*; 46*a, b.*)

Nautilus (*Lituus*) *acicularis* Batsch, 1791, *Conch. Seesandes,* p. 4, pl. vi., figs. 16*a, b*.

Spirolina acicularis (Batsch): Cushman, 1930, *Bull.* 104, *U.S. Nat. Mus.*, pt. 7, p. 42, pl. xv., figs. 1-3.

Stns. 9, 11, and Minlacowie, Sth. Aust.

This species occurs in two forms at each locality. The commoner is thin-shelled and the ornament consists of lines of very small tubercles. The other has a thicker shell-wall and its surface is smooth. In outline both agree with the broader specimen figured by Dr. Cushman from the Tortugas. The original figures given by Batsch represent a much slenderer form, examples of which I have from Jeddah, on the Red Sea.

Parker and Jones recorded *Spirolina lituus* from coast sand, Melbourne, Australia. The present species was probably that met with. It may also be noted that the present records are all from the coast of South Australia, and provide additional evidence that the locality given by Parker and Jones was incorrect.

Family HETEROHELICIDAE.

Sub-Family BOLIVINITINAE.

Genus **Bolivinella** Cushman, 1927.

Bolivinella folium (Parker and Jones).

(Plate XXI., Fig. 23.)

Textularia folium Parker and Jones, 1865, *Phil. Trans. Roy. Soc.*, clv., pp. 370, 420, pl. xviii., fig. 19. Brady, 1884 (*pars*), "*Chall.*" *Rept. Zool.*, vol. ix., p. 357, pl. xlii., figs. 1, 2 (*non* figs. 3-5). Chapman, 1909, *Jour. Quek. Micr. Club,* [2], x (for 1907), p. 127, pl. ix., fig. 4.

Bolivinella folium (P. and J.): Cushman, 1927, *Contr. Cushm. Lab. Foram Res.,* ii. (4), p. 79. 1928, *Cushm. Lab. Spl. Publ.* No. 1, pl. xxxiii., figs. 15, 16 (*non* pl. xxxiv., fig. 8). 1929 (*pars*), *Contr. Cushm. Lab.,* v. (2), p. 29 (*non* pl. v., figs. 1, 2).

B. folia (P. and J.), var. *ornata* Cushman, 1929, *op. cit.,* p. 32, pl. v., figs. 3, 4.

Stns. 6, 7, 9, 11. P. and J., C.

Two species appear to have been recorded under this name, the confusion having arisen, in the first place, through the rather poor type-figure, and later, as the result of Brady's wide interpretation of specific differences. From the study of specimens from the type area, one can state fairly definitely that the form named by Dr. Cushman *B. folia,* var. *ornata,* from Hardwicke Bay, South Australia, and the Post-tertiary of Victoria, is actually *B. folium* (*typica*). The other (Brady, 1884, *op. cit. supra,* pl. xlii., figs. 3, 3*b*, 4, 5. Cushman, 1928, *op. cit.*, pl. xxxiv., fig. 8; 1929, *op. cit.*, pl. v., figs. 1, 2) is a tropical species, which is distinguished from *B. folium* by its fewer, proportionately-higher chambers, the less-convex apertural end, the absence of beading on the sutures, and by the usually more-flaring test.

It may be known as *B. elegans,* sp. nov., the holotype being from off Raine Island, 155 fms. This species does not occur in Bass Strait, nor off the south-eastern coast of Australia, but I have fine examples of it from *Challenger* Stn. 185, off Raine Island, Torres Strait, 155 fms. Well-preserved examples of *B. folium* are invariably beaded on the suture lines, the beads being formed by the cutting of the limbate sutures by longitudinal striae, such as are represented in Mr. Chapman's figure of an example of this species, from the shore sands of McHaffie's Reef, Phillip Island. The specimen here figured is worn, but the characteristic beading is present. It was drawn before the beautifully-preserved material from Hardwicke Bay, South Australia, some of which have been illustrated by Dr. Cushman, was obtained. In the recent condition, the species is usually rare. It is not uncommon in the Post-tertiary of the Vic. Geol. Survey Bore No. 5, at Bonco, near Rosebud, between 177 and 187 feet.

Family BULIMINIDAE.

Sub-Family REUSSIINAE.

Genus **Reussia** Schwager, 1877.

Reussia armata, sp. nov.

(Plate XXII., Figs. 49, 50*a, b.*)

Description.—Test in the adult rhombohedral, with the initial end armed with a short spine, apertural end rounded, the sides slightly concave, margin sharp and with one or two spines on each of the outer angles; chambers arranged in three series, with about twelve in each, increasing in height as added, wider than high; sutures distinct, flush, slightly curved; wall calcareous, smooth, of medium thickness, finely perforate; aperture a curved slit at the base of the inner edge of the last-formed chamber; colour white.

Length up to 0.77 mm.

Holotype (Parr Coll.) from shore sand, Hardwicke Bay, South Australia.

Remarks.—The shape of this species will enable it to be distinguished from *R. spinulosa* (Reuss), to which it otherwise bears some resemblance. The larger number of chambers, their comparative lowness, and the very neat test are also characteristic. *R. armata* is common at Hardwicke Bay, and many double specimens similar to those here figured were met with in the material from that locality. Other examples of the species are from Stns. 6, 7, and 9. The two Victorian specimens, from Stns. 6 and 7, are small and much worn.

Sub-Family UVIGERININAE.

Genus **Siphogenerina** Schlumberger, 1883.

SIPHOGENERINA RAPHANUS (Parker and Jones).

(Plate XXI., Fig. 24.)

Uvigerina (*Sagrina*) *raphanus* Parker and Jones, 1865, *Phil. Trans.*, clv., p. 364, pl. xviii., figs. 16, 17.

Sagrina raphanus (P. and J.): Brady, 1884, "*Chall.*" *Rept. Zool.*, vol. ix., p. 585, pl. lxxv., figs. 21-24.

Siphogenerina raphanus (P. and J.): Cushman, 1926, *Proc. U.S. Nat. Mus.*, lxvii., Art. 25, p. 4, pl. i., figs. 1-4; pl. ii., figs. 1-3, 10; pl. v., figs. 1, 2.

Stns. 6, 7, 8.

There are four small, but otherwise typical specimens, all from the Victorian coast. This appears to be the most southerly record for this species.

Family ROTALIIDAE.

Sub-Family DISCORBISINAE.

Genus. **Annulopatellina** Parr and Collins, 1930.

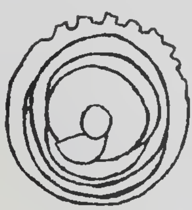
ANNULOPATELLINA ANNULARIS (Parker and Jones).

(Plate XXII., Figs. 48*a-c*; Text-fig. 1.)

Orbitolina annularis Parker and Jones, 1860, *Ann. Mag. Nat. Hist.*, [3], vi., pp. 30, 31.

Annulopatellina annularis (P. and J.): Parr and Collins, 1930, *Proc. Roy. Soc. Vic.*, xliii. (n.s.), (1), p. 93, pl. iv., figs. 8-10. (Gives complete references.)

Stns. 6, 7, 9, 11. P. and J., C. (as *Patellina corrugata* Will.)



Annulopatellina annularis (Parker and Jones).

Apex of microspheric example showing semi-annular chambers. Hardwicke Bay, S.A. Greatly magnified.

Text-figure 1.

Common at Stn. 11 and frequent at Stn. 9; one example from each of the Victorian stations. Because of our inexperience in the more refined methods of examining the finer structures of these minute shells, Mr. Collins and I were unable to see any definite relationship of this genus with *Patellina*. Our friend, Dr. J. A. Cushman, has pointed out to us that if specimens are mounted in glycerine and examined under a high power, several semi-annular chambers can be seen following the first two chambers. He is also sure that he has found, in the later development, chambers which are not completely annular. I have mounted both megalospheric and microspheric forms in glycerine, and find that the relationship to *Patellina* is evident in the microspheric form, but I have not so far observed any semi-annular chambers in the megalospheric form, although Dr. Cushman's camera lucida drawings show that he had them in this. A drawing of the early chambers of a microspheric specimen is figured in the text (text-fig. 1).

Genus **Discorbis** Lamarck, 1804.

Discorbis williamsoni Chapman and Parr MS.

(Plate XXI., Fig. 25.)

Rotalina nitida Williamson (*non Rotalina nitida* Reuss), 1858, *Rec. Foram. Gt. Britain*, p. 54, pl. iv., figs. 106-108.

Discorbina nitida (Will.): Sidebottom, 1908, *Mem. Proc. Manch. Lit. Phil. Soc.*, lii., No. 13, p. 13, pl. iv., figs. 6*a-c*.

Stns. 3, 7, 9.

There are five specimens agreeing exactly with Sidebottom's figure of an example from the Eastern Mediterranean. As Reuss (1844, *Geogn. Skizze Böhmen*, vol. ii., pt. 1, p. 214) had previously used the name of *Rotalina nitida* for another species, Williamson's species will be renamed by Mr. Chapman and the writer in a monograph on the foraminifera, dredged by the Australasian Antarctic Expedition 1911-1914, which is awaiting publication.

Discorbis margaritifera (Heron-Allen and Earland).

(Plate XXI., Figs. 26*a-c*.)

Discorbina margaritifera Heron-Allen and Earland, 1924, *J.R.M.S.*, p. 167, pl. xi., figs. 71-73.

Stn. 6.

Several typical examples. This is the first record of this species in the Recent condition. The only other record is that of Heron-Allen and Earland from the Miocene of Batesford, Vic. I have it also from the Lower Beds at Muddy Creek (Oligocene), the marl beds at Rocky Point, Torquay (Miocene), and a boring near Boneo, Vic., 177-187 feet (Post-tertiary).

DISCORBIS AUSTRALIS, sp. nov.

(Plate XXII., Figs. 31*a-c.*)

Discorbina valvulata Brady (*non Rosalina valvulata* d'Orbigny), 1884, "*Chall.*" *Rept. Zool.*, vol. ix., p. 644, pl. lxxxvii., figs. 5-7. Howchin, 1890, *Trans. Roy. Soc. Sth. Aust.*, xiii., p. 167. Chapman, 1909, *Jour. Quek. Micr. Club*, [2], x (for 1907), p. 137.

Description.—Test nearly circular in outline, plano-convex, ventral side slightly concave, trochoid, consisting of about three whorls; with four or five chambers in the last-formed coil, chambers slightly inflated; sutures strongly recurved, thick, and heavily limbate; wall calcareous, thick, coarsely perforate on the convex side, smooth underneath; aperture an arched slit at the base of the last-formed chamber, opening into the umbilical region; colour light brown in the early portion of the test, becoming paler towards the final chambers and colourless on the inferior side.

Diameter, 0.66 mm.; height, 0.43 mm.

Holotype (Parr Coll.) from shore sand, San Remo, Vic. (Stn. 1); other examples from Stns. 2, 6, 7, 8, 9, 10, 11.

Remarks.—Dr. Cushman (1921, *Proc. U.S. Nat. Mus.*, lix., p. 59) has already pointed out that the species figured by Brady in the *Challenger* Report as *Discorbina valvulata* is entirely different from d'Orbigny's *Rosalina valvulata,* from the West Indies. In its typical form, *D. valvulata* is much compressed, very thin-shelled and translucent, and very finely perforate, while the specimens figured under this name by Brady have a much heavier, thicker test, with coarse punctations, different shape, and thickened limbate sutures. Brady's figs. 5 and 7 were drawn from Pacific specimens, fig. 5 being from off East Moncoeur Island, Bass Strait, 38 fms., and fig. 7 from off Fiji. This form is common in shallow water on the southern coast of Australia, and occurs as a fossil in the Oligocene of Muddy Creek, Vic. There is remarkably little variation in the species over this area.

DISCORBIS VESICULARIS (Lamarck), var. DIMIDIATA (Jones and Parker).

(Plate XXI., Figs. 27*a-c*, 28*a-c*, 29*a-c*.)

Discorbina dimidiata Jones and Parker, in Carpenter, Parker and Jones, 1862, *Intro. Foram.*, p. 201, text-fig. 32*b*.

D. vesicularis (Lamarck): Carpenter, Parker and Jones (*pars*), 1862, *op. cit.*, p. 204, pl. xiii., figs. 2, 3.

D. dimidiata J. and P.; Parker and Jones, 1865, *Phil. Trans.*, clv., pp. 385, 422, 438, pl. xix., figs. 9*a-c*.

D. vesicularis Parker and Jones (*non Discorbites vesicularis* Lamarck), 1865, *op. cit.*, p. 438. Brady, 1884, "*Chall.*" *Rept. Zool.*, vol. ix., p. 651, pl. lxxxvii., fig. 2. Chapman, 1909, *Journ. Quek. Micr. Club*, [2], x (for 1907), p. 135.

D. dimidiata J. and P.: Chapman, 1909, *op. cit.*, p. 136, pl. x., figs. 8*a*, *b*.

Stns. 1, 2, 5, 6, 7, 8, 9, 10, 11. P. and J., C., H.

D. dimidiata was described by Parker and Jones as merely *D. vesicularis*, modified by being sharp-edged and flat, even scooped on the under surface, and with the astral flaps strongly marked over the umbilicus. Their figures show a shell with the coils almost completely involute on the superior face, the central portion of which is depressed, about nine chambers in the last whorl, much depressed sutures, and a flat inferior face. The aperture, which is abnormal, is figured as a slightly curved, fairly broad, elongate slit, nearly parallel to the plane of coiling. This particular form is not widely distributed, and, in my material, occurred only at Stn. 9, Glenelg, South Australia, where it was common. At the same locality, there are numerous examples of the form figured by Carpenter, Parker and Jones, and later by Brady, as *Discorbina vesicularis*. This has strongly inflated chambers and a more or less rounded margin. In the writer's experience, neither form occurs north of the latitude of Sydney, nor on the coast of Victoria and New South Wales, where they are replaced by intermediate specimens of weaker growth, with an evolute test. As similar annectant forms are found at Glenelg with the first two forms mentioned, it is clear that the latter are merely the result of exceptionally favorable conditions of growth. It appears likely that the *D. dimidiata* form represents the attached habit of growth and the so-called *D. vesicularis*, the free specimens. Figures of the two extreme forms and of the intermediate, or central, type of shell are given on Plate (Figs. 27–29).

It is now necessary to decide if the Recent Australian form is the same as the species of the Paris Basin Tertiaries. None of the South Australian specimens corresponds closely with the type-figures of *D. vesicularis* (*Ann. Muséum*, viii., 1806, pl. lxii., fig. 7) or those of a topotype specimen, given by Cushman (1927, *Contr. Cushm. Lab.*, iii. (2), pl. xxiv., figs. 1*a-c*). By the kindness of Mr. F. Chapman, I have a number of examples of *D. vesicularis* from the type locality at Grignon. These vary in much the same way as the Recent specimens, some having a rounded margin and others a sub-acute limbate border and flattened base. The differences between Recent Australian and fossil European specimens appear to consist mainly of the larger size of the test, the greater number of chambers to a whorl, and the better development of the astral flaps on the inferior surface in the former. Whether these differences are of specific value is doubtful, as, in tropical waters, *D. vesicularis* is represented by examples which are inseparable from the smaller specimens from Grignon. Some have been figured by Heron-Allen and Earland in their work on the foraminifera of the Kerimba Archipelago (*Trans. Zool. Soc. London,* xx., 1915, p. 697, pl. lii., figs. 15–18). I have exactly similar specimens from Townsville, Queensland. The number of chambers, the size of the test, and the development of the deposit of shelly matter on the under surface all increase as temperate seas are reached. The Southern Australian form appears to be sufficiently distinct to justify its separation from *D. vesicularis* as a variety of that species, and may be known as var. *dimidiata* (Jones and Parker). It is typically of shallow water habitat, and, on the Australian coast, below the latitude of Sydney, it is by far the commonest representative of the genus. It is also common on some of the beaches near Auckland, N.Z.

The aperture of the present variety is normally an arched slit with a thickened rim, at the base of and near the umbilical margin of the last-formed chamber. In some cases, the lower portion of the centre of the apertural face is occupied by a number of very large perforations which often coalesce and so form supplementary apertures. Occasionally the whole of the coarsely-perforated area may be broken away, and we have then an aperture similar to that in the type-figure.

Discorbis vesicularis, var. acervulinoides, nov.

(Plate XXI., Figs. 30*a-c*.)

Description.—This variety may be distinguished by its conical test, the fewer chambers to the whorl, the coarse tubulation of the wall of the early chambers, and the comparatively slight development of the exogenous shell-growth on the inferior surface.

Diameter, 1 mm.; height, 0.88 mm.

Holotype (Parr Coll.) from *Posidonia* deposit, Gulf St. Vincent, South Australia, collected by D. J. Mahony, M.Sc. Other examples are from Stn. 9, and from the following localities, all from shore sands:—Minlacowie, South Aust.; Garden Island, and Geraldton, W.A. This variety is very common at the type locality.

Remarks.—Both megalospheric and microspheric forms are present, but except for the larger number of chambers in the latter, there is little difference between them. Some of the examples, particularly those which are not at all outspread in the last whorl, do not appear to be related to the preceding variety, but the relationship is made clear by the broader specimens, with their outer coil of well-inflated, coarsely-perforated segments.

Discorbis collinsi, sp. nov.

(Plate XXII., Figs. 33*a-c*.)

Description.—Test almost equally biconvex, the dorsal side somewhat more convex than the ventral, periphery rounded and lobulated; consisting of about two and a half whorls, with usually six chambers in the last-formed whorl, chambers well inflated; sutures oblique, distinct, depressed on the dorsal side, almost radial, sligthly depressed and limbate, particularly at their inner ends, on the ventral side, which is slightly umbilicate; wall coarsely punctate; aperture a narrow slit at the base of the inner margin of the last-formed chamber, opening into the umbilical depression; colour usually white, but occasionally with the early portion a very pale brown.

Diameter. 0.44 mm.; height, 0.23 mm.

Holotype (Parr. Coll.) from shore sand, Port Fairy, Vic., collected by F. Chapman. It was common here. Other examples are from Stns. 6, 7, 9, 11, and from the Post-tertiary of a bore at Boneo, Vic.

Remarks.—The present species is quite unlike any other hitherto recorded from the Australian coast. *D. tuberculata* (Balkwill and Wright) has the same outline, but different apertural characters and ornament. I have pleasure in associating this species with the name of my friend, Mr. A. C. Collins, A.R.V.I.A., to whom I am indebted for the drawings illustrating this paper.

Discorbis disparilis (Heron-Allen and Earland).

(Plate XXII., Figs. 32*a-c*.)

Discorbina disparilis Heron-Allen and Earland, 1922, *Brit. Ant.* ("*Terra Nova*") *Exped.*, 1910, *Nat. Hist. Rept., Foram.*, p. 205, pl. vii., figs. 20-22.

Stns. 8, 11.

Several examples. This species was described from two specimens dredged off New Zealand, 100 fms. In their notes on *D. disparilis*, Heron-Allen and Earland describe it as difficult to diagnose, owing to the obscuration of all of the earlier structure by the tuberculation of the superior surface, and by the fact that the inferior surface, which is plane, is thick-walled and opaque. The present examples agree closely in the shape of the test, the number and the arrangement of the chambers, but are thinner-shelled, and the superior surface is merely rough and irregularly thickened, not tuberculate, the chambers there being separated by raised, limbate sutures, which form a border to the shell. The dimensions of the largest Victorian specimen are—length, 0.46 mm.; breadth, 0.34 mm.; height, 0.13 mm. The length of the New Zealand specimens is given as 0.38-0.42 mm., and the maximum breadth as 0.30 mm. The outer margin of the last-formed chamber is usually rounded as in Heron-Allen and Earland's fig. 20, not angulate as in their fig. 21. The aperture is discorbine.

Sub-Family ROTALIINAE.

Genus **Rotalia** Lamarck, 1804.

ROTALIA PERLUCIDA Heron-Allen and Earland.

(Plate XXII., Figs. 35*a-c*.)

Rotalia perlucida Heron-Allen and Earland, 1913, *Proc. Roy. Irish Acad.*, xxxi., pt. 64, p. 139, pl. xiii., figs. 7-9; 1922, *Brit. Ant.* (" *Terra Nova* ") *Exped.*, 1910, *Nat. Hist. Rept. Zool., Foram.*, p. 219.

Stn. 11.

Many good examples. This appears to be a weak form of *Rotalia beccarii* (Linné). The present specimens are finely perforate, but otherwise typical. The original examples were from the coast of Ireland, and the species has since been recorded from off the coast of New Zealand.

Family CASSIDULINIDAE.

Sub-Family CASSIDULININAE.

Genus **Cassidulinoides** Cushman, 1927.

CASSIDULINOIDES CHAPMANI Parr.

(Plate XXII., Figs. 36*a-c*, 37.)

Cassidulina parkeriana Heron-Allen and Earland (*non* Brady), 1924, *J.R.M.S.*, p. 146.

Cassidulinoides chapmani Parr, 1931, *Vic. Nat.*, xlviii., p. 99, Text-figs. *a-c*.

Stn. 7.

One typical example. This species has recently been described by the writer from the Miocene of Rocky Point, Torquay, Vic. The figures given represent the holotype and the Recent example here recorded. Other Recent specimens have been met with in a dredging from east of Tasmania, 1,320 fms.

Family ANOMALINIDAE.

Sub-Family ANOMALININAE.

Genus **Anomalina** d'Orbigny, 1826.

ANOMALINA NONIONOIDES, sp. nov.

(Plate XXII., Figs. 38*a-c*.)

Description.—Test almost equally biconvex, the thickness being about one-third of the diameter, periphery rounded, lobulated, the last whorl slightly evolute, umbilical region depressed; chambers numbering about ten to the coil in the adult, the later ones inflated; sutures distinct, not limbate, gently curved, depressed in the later portion of the shell; wall coarsely perforate; aperture a narrow slit with a raised lip, at the peripheral margin, extending slightly to the dorsal side.

Diameter.—1 mm.; thickness, 0.33 mm.

Holotype (Parr Coll.) from shore sand, Narrabeen, N.S.W. There is one example from Torquay, Vic. (Stn. 7).

Remarks.—This species is moderately common in a number of shore sands from the vicinity of Sydney, N.S.W., and occurs on the Victorian coast. It does not appear to resemble any previously-described form closely. Of the species of *Anomalina* recorded from this region, Brady's *A. ammonoides* is not the same as Reuss's *Rosalina ammonoides,* from the Cretaceous of Europe, and the same remark applies to the Recent form recorded as *A. grossergosa* (Gümbel).

Genus **Planulina** d'Orbigny, 1826.

Planulina biconcava (Jones and Parker), var. planoconcava Chapman, Parr and Collins MS.

(Plate XXII., Figs. 34*a-c*.)

Stn. 6.

Two specimens. This variety is being described in a paper dealing with the foraminifera of the Oligocene (Balcombian) of the Port Phillip area. It differs from the typical form of *P. biconcava,* which is a common species on the southern coast of Australia, in having a more inequilateral test, with the inferior face flattened.

Family PLANORBULINIDAE.

Genus **Planorbulina** d'Orbigny, 1826.

Planorbulina rubra d'Orbigny, var.

(Plate XXII., Figs. 51*a-c*.)

Planorbulina rubra d'Orbigny, 1826, *Ann. Sci. Nat.* (Paris), vii., p. 280, No. 4 (*nomen nudum*). Fornasini, 1908, *Mem. Acc. Sci. Ist. Bologna,* [6], v., p. 44, pl. ii., fig. 3.

Gypsina rubra (d'Orb.): Heron-Allen and Earland, 1915, *Trans. Zool. Soc. London,* xx., p. 725, pl. liii., figs. 35-37.

Sporadotrema rubrum (d'Orb.): Hofker, 1927, *Siboga Exped., Mon.* iv., pt. 1, p. 21, pl. vii.; pl. viii., fig. 8.

Stn. 9.

There are about ten specimens which answer perfectly to the description given by Heron-Allen and Earland, except that the characteristic pale rose pink colour is absent. A similar white form is common in a shallow water dredging I have from Geraldton, W.A., so it is interesting to note that Heron-Allen and Earland had the typical form of this species from an intermediate locality, viz., Fremantle, W.A., from shore sands. The pink form has also been recorded by them from Lord Howe Island. Hofker's records were from " Siboga " Station 19 and from the Island of Edam, near Batavia.

The plan of growth and the lipped apertures are very similar to those of *Planorbulina mediterranensis* d'Orb., of which it seems to be merely a warm-water form characterised by its much larger size and exuberant shell-growth, as well as by its coloration. As Heron-Allen and Earland regard the pink coloration as a specific character, it is deemed advisable for the present to record the white form as *P. rubra*, var.

Explanation of the Plates.

Plate XXI.

Fig. 23. *Bolivinella folium* (Parker and Jones). Point Lonsdale, Vic. (x 60.)

Fig. 24. *Siphogenerina raphanus* (Parker and Jones). Point Lonsdale, Vic. (x 60.)

Fig. 25. *Discorbis williamsoni* Chapman and Parr MS. Black Rock, Vic. (x 60.)

Fig. 26*a-c*. *Discorbis margaritifera* (Heron-Allen and Earland). Point Lonsdale, Vic. (*a*), inferior aspect; (*b*), superior aspect; (*c*), edge view. (x 72.)

Figs. 27*a-c*. *Discorbis vesicularis* (Lamarck), var. *dimidiata* (Jones and Parker). Intermediate type of shell. Point Lonsdale, Vic. (*a*), inferior aspect; (*b*), superior aspect; (*c*), edge view. (x 20.)

Figs. 28*a-c*. *D. vesicularis*, var. *dimidiata* (J. and P.). Example of type form figured in Carpenter, Parker, and Jones's " Introduction to the Study of the Foraminifera." Glenelg, S.A. (*a*), superior aspect; (*b*), inferior aspect; (*c*) edge view. (x 20.)

Figs. 29*a-c*. *D. vesicularis* var. *dimidiata* (J. and P.). Example of form figured by Carpenter, Parker, and Jones as *D. vesicularis*. Glenelg, S.A. (*a*), dorsal view; (*b*), inferior view; (*c*), edge view. (x 20.)

Figs. 30*a-c*. *D. vesicularis*, var. *acervulinoides*, nov. Gulf St. Vincent, S.A. Holotype. (*a*), inferior view; (*b*), dorsal view; (*c*), side view. (x 25.)

Plate XXII.

Figs. 31*a-c*. *Discorbis australis*, sp. nov. San Remo, Vic. Holotype. (*a*), inferior view; (*b*), dorsal view; (*c*), side view. (x 30.)

Figs. 32*a-c*. *Discorbis disparilis* (Heron-Allen and Earland). Port Fairy, Vic. (*a*), inferior view; (*b*), dorsal view; (*c*), edge view. (x 48.)

Figs. 33*a-c*. *Discorbis collinsi*, sp. nov. Port Fairy, Vic. Holotype. (*a*), ventral view; (*b*), dorsal view; (*c*), edge view. (x 48.)

Figs. 34*a-c*. *Planulina biconcava* (Jones and Parker), var. *planoconcava* Chapman, Parr and Collins MS. Point Lonsdale, Vic. (*a*), dorsal view; (*b*), ventral view; (*c*), edge view. (x 48.)

Figs. 35*a-c*. *Rotalia perlucida* Heron-Allen and Earland. Hardwicke Bay, S.A. (*a*), ventral view; (*b*), dorsal view; (*c*), edge view. (x 56.)

Figs. 36*a-c*; 37. *Cassidulinoides chapmani* Parr. 36. Holotype from Miocene, Rocky Point, Torquay, Vic. (*a, b*), side views; (*c*), end view. 37. Recent specimen from shore sand, Torquay, Vic. (x 36.)

Figs. 38*a-c*. *Anomalina nonionoides*, sp. nov. Holotype from shore sand, Narrabeen, N.S.W. (*a*), dorsal view; (*b*), ventral view; (*c*), edge view. (x 24.)

Fig. 39. *Proteonina spiculifera* Parr. Point Lonsdale, Vic. (x. 18.)

Figs. 40*a, b*. *Gaudryina hastata*, sp. nov. Port Fairy, Vic. Holotype. (*a*), side view; (*b*), end view. (x 15.)

Fig. 41. *Spiroloculina* sp. aff. *arenaria* Brady. Westernport Bay, Vic. (*a*), side view; (*b*), end view. (x 15.)

Fig. 42. *Vaginulina vertebralis*, sp. nov. Torquay, Vic. Holotype. (x 15.)

Fig. 43. *Triloculina labiosa* d'Orb., var. *schauinslandi* (Rhumbler). Point Lonsdale, Vic. (x 15.)

Fig. 44. *T. labiosa* d'Orb. Point Lonsdale, Vic. (x 15.)

Figs. 45*a, b*. *Spirolina acicularis* (Batsch). Hardwicke Bay, S.A. Beaded form. (*a*), side view. (x 30.) (*b*), end view. (x 36.)

Figs. 46*a, b*. *S. acicularis* (Batsch). Hardwicke Bay. Smooth form. (*a*), end view; (*b*), side view. (x 30.)

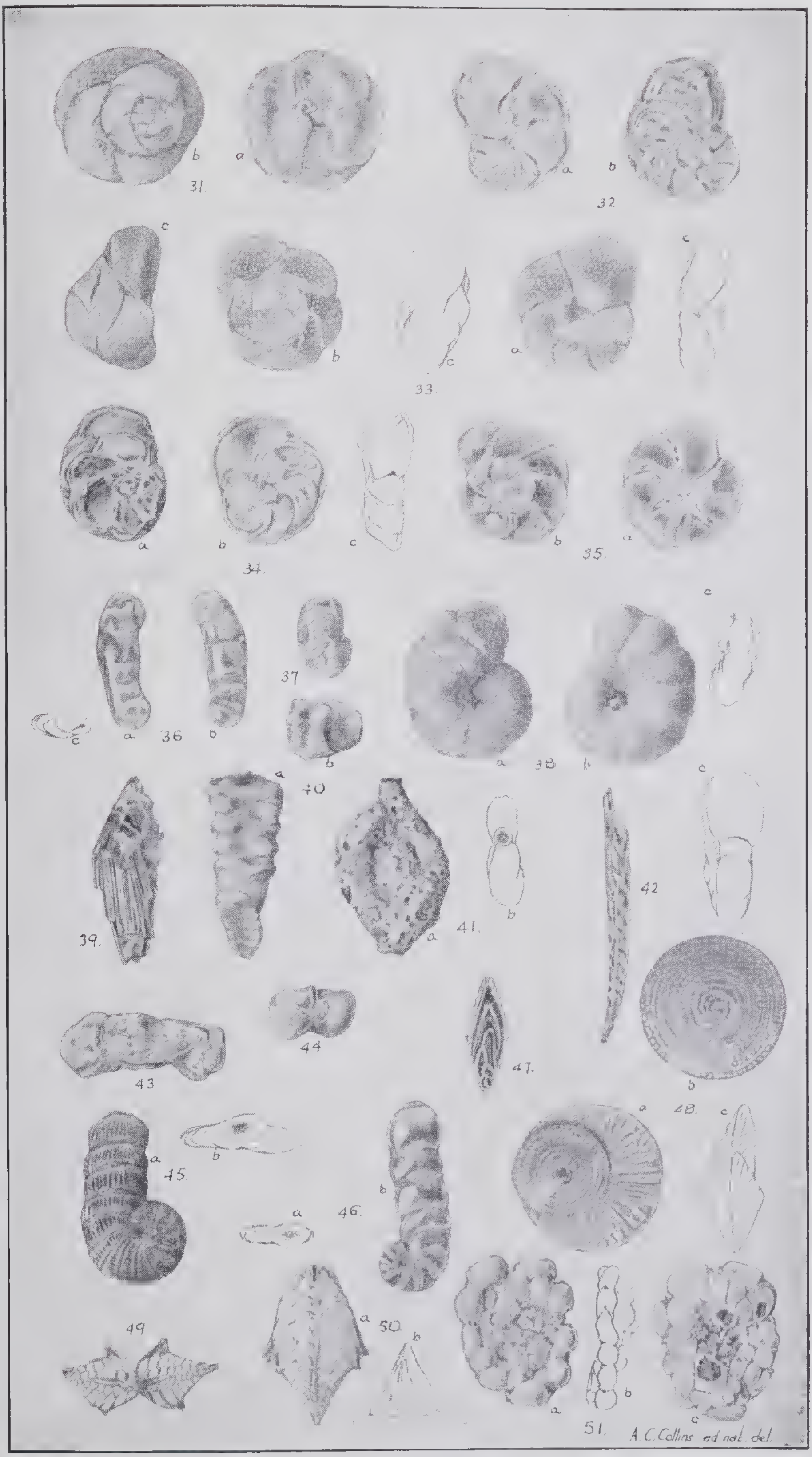
Fig. 47. *Frondicularia advena* Cushman. Williamstown, Vic. (x 36.)

Figs. 48*a-c*. *Annulopatellina annularis* (Parker and Jones). Hardwicke Bay, S.A. Two megalospheric specimens in the plastogamic condition. (*a*), (*b*), dorsal and ventral aspects; (*c*), edge view. (x 50.)

Figs. 49, 50*a, b*. *Reussia armata*, sp. nov. Hardwicke Bay, S.A. 49, specimens in plastogamic condition; 50, holotype. (*a*), side view; (*b*), end view. (x 35.)

Figs. 51*a-c*. *Planorbulina rubra* d'Orb., var. Glenelg, S.A. (*a*), dorsal view; (*b*), edge view; (*c*), ventral view. (x 20.)

Shallow-Water Foraminifera.



Shallow-Water Foraminifera.

[Proc. Roy. Soc. Victoria, **44** (N.S.), Pt. II., 1932.]

Art. XIX.—*Does the Flowering of Plants of the Victorian Flora Repeat the Order of their Evolution?*

By S. ILLICHEVSKY.

(Professor of Botany at Chernigov, U.S.S.R.).

[Read 10th December, 1931; issued separately 20th April, 1932.]

In Volume 43, Part 2, p. 154, (1931) of the Proceedings of the Royal Society of Victoria a paper, "Flowering Periods of Victorian Plants" (by J. Heyward), appeared. In this paper Miss Jean Heyward discussed my theory as to the parallelism between the phylogenetic position of plants and the order of their flowering, i.e., that the percentage of superior flowering types, like Sympetals, flowers with inferior ovaries, the Compositae, &c., gradually increases to the end of the summer so that these superior types begin to prevail to the end of the vegetative season as well as to the end of the process of evolution(1).

Miss J. Heyward has constructed nine tables giving the flowering periods of the Victorian flora, and remarks that "the Victorian flora does not agree with this hypothesis, for of all the tables constructed, No. 9 alone shows any agreement with Illichevsky's theory." I have examined her tables, and my conclusions are quite the opposite. The first reason for the difference between my results and those of Miss Heyward was the wrong method of calculating percentages that she used. Whereas I calculated the number of species of a superior type flowering during a month per cent. to the total number of all the species (all the Dicotyledons, for instance) flowering in the same period, Miss Heyward calculated the percentage of a superior type flowering during a certain month as compared with the whole number of flowers of the same type in the Victorian flora. The first method gives us the relation of the superior type flowering to the total number of flowers of this month, whereas Miss Heyward's tables give only the absolute position of the maximal flowering of blossoms of a certain type without any comparison with the flowering of superior or inferior types. Let us calculate by my method the percentage of superior flowering types shown in Miss Heyward's tables :—

Months.		June.	July.	August.	September.	October.	November.	December.	January.	February.	March.	April.	May.
Total no. of Dicots. (genera) Table No. 1		28	61	118	226	305	328	313	250	160	105	61	29
Dicots. with inferior ovaries	No. of genera	3	8	23	56	81	91	89	76	33	34	22	11
	% from the whole no. of Dicots. for the same month	10·7	13	19·5	24·8	27	28·5	28·4	30·4	20·6	32·4	36·1	38
Sympetals	No. of genera	7	14	34	72	117	128	118	95	53	38	22	11
	% from the whole no. of Dicots. for the same month	25	23	29	31·9	38·4	39	37·7	38	33·1	36·2	36·1	37·9
Compositae	No. of genera	2	4	12	26	35	38	33	28	15	14	10	7
	% from the whole no. of Dicots. for the same month	7·1	6	10	11·5	11·5	11·6	10·5	11·7	9·4	13·3	16·4	24·1

Thus the Dicotyledons with an inferior ovary show a regular increase in percentage number (from 10.7 per cent. in June to 38.0 per cent. in May) during the whole year with the exception of February; the Sympetals show a less regular increase till November (evidently up to the beginning of the secondary flowering(1); the Compositae reach their first maximum per cent. in September, then stop or decrease (December, February), and again increase to the end of the year in March, April, May. We see thus that the percentage of the superior types in flower increases during the growing period.

I must here make the remark that Miss Heyward calculated the number of genera, not species, as I did. The fewer systematic units we use the more precise the results. It is probable that the anomalous results with the flowering of the Orchids in Victoria (whether using Miss Heyward's or my method of calculating percentages) depend on this fact. It seems to me to be a little hazardous to use not only data from field observations, but also those from herbariums, as Miss Heyward has done; the herbarium data often include the data of secondary flowering and of early blossoms which in some seasons appear a month or more earlier than the normal flowering, a phenomenon well known in Russian phenological literature. Probably it would be advisable to include the flowering of Eucalyptus species, although they flower bienially and triennially. Of course, I agree completely with Miss Heyward's remarks on the factors influencing the date of flowering; as for the work done by Miss Heyward, it is a very interesting and valuable confirmation of my theory in a climate and life conditions so distinct from those for which the theory was propounded, and I cannot accept Miss Heyward's statement that her results do not agree with the theory. Especially Dicotyledons with an inferior ovary display as complete an agreement with my theory as I could wish.

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[PROC. ROY. SOC. VICTORIA, **44** (N.S.), PT. II., 1932.]

ART. XX.—*The Relation between Period of Flowering and Degree of Evolution.*

By JEAN HEYWARD, M.Sc.

(Research Scholar, Botanical Department, University of Melbourne).

[Read 10th December, 1931; issued separately 20th April, 1932.]

In his criticism of my paper on the flowering periods of Victorian plants, Professor Illichevsky shows that my method of calculating the percentages of genera in flower each month was different from his. Using my figures, he takes his percentages per month of the number of dicotyledonous genera in flower for that particular month, while I take my percentage of the total number of genera in each particular table. For example, of the dicotyledons with inferior ovaries (see Table II., *Flowering Periods of Victorian Plants*[1]) of which there are 112 genera in our Victorian flora, three flower in June, giving a percentage of 2.7 by my method of calculation; but according to Illichevsky, these three represent a percentage of 10.7, since there are only 28 dicotyledons in all in flower in June.

It seems to me that although these superior types may form a higher percentage of the genera in flower in the later months, the actual majority flower earlier, and hence not in accordance with Illichevsky's theory that the order of flowering of plants during a summer coincides with the order of their evolution.

In any case, in Victoria the seasons differ from those of European countries, and February can be regarded as our hottest month. According to Illichevsky's method of calculation, in the case of the dicotyledons with inferior ovaries, and of these in particular the Compositae, the maximum flowering period comes in May, which in our country is nearing the winter months. Again using his method of calculation, in the Sympetalae the maximum period comes in November, which coincides with the maximum obtained when my method of calculation is used. Hence neither of these groups can agree with Illichevsky's theory by either method of calculation.

Another point raised is that I dealt with genera, not species. But, since the flowering periods of the genera were compiled from the flowering periods of the individual species of each genus, they should, if anything, give more accurate results, since the effect of any irregularly flowering species will be eliminated.

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[Proc. Roy. Soc. Victoria, 44 (N.S.), Pt. II., 1932.]

Art. XXI.—*Weathering of the "Older Basalt" of Royal Park.*

By DONALD M. McCANCE, B.Sc.

[Read 10th December, 1931; issued separately 20th April, 1932.]

1. Introduction.

The olivine basalt occurring in the Royal Park area belongs to a series of volcanic rocks extruded in the Lower Kainozoic era, and known to Victorian geologists as "The Older Basalts," to distinguish them from the "Newer Basalts" of Newer Kainozoic and Recent times.

The "Older Basalts" are widespread in Victoria, occurring at Royal Park, North Melbourne, Kensington, Essendon, Broadmeadows, Keilor, Bacchus Marsh, Berwick, Curlewis, French Island, Phillip Island, Flinders, and Cape Schanck. In South Gippsland they occur at Leongatha, Neerim, Mirboo, &c., and in North Gippsland they cap the highly dissected plateau at elevations of 5,000 to 6,000 feet, as at Mt. Hotham, Mt. Fainter, the Bogong High Plains, and the Dargo High Plains.

At Royal Park, in the railway cutting, the older basalt is seen underlying marine Tertiaries, which have been referred by Chapman[1] to the Barwonian (Janjukian). At Sutton-street, a short distance south of Flemington Bridge Station, the basalt rests on the eroded surface of the Lower Tertiary leaf beds, which, however, do not appear in the railway cutting. In other parts of the Royal Park area, the Tertiary sands rest directly upon the Silurian rocks, without the interposition of the older basalt.

2. Exposures at Royal Park.

The outcrop in the railway cutting consists of a very much weathered basalt, with fresh samples existing only in the cores of spheroidal nodules, which persist here and there in the more decomposed material.

In the south-eastern wall of the cutting, it occurs as a dark crumbly material, containing nodules of fresher basalt, showing spheroidal laminae, or "onion structure." This material consists of a streaky and mottled clay substance, the streaks being due to specks of oxides of iron in the lighter coloured argillaceous substance, formed by decomposition of the original felspars in the basalt.

On the same side of the cutting, further south, the weathering has produced segregated masses of iron oxides, which contain apparently little or no siliceous material. This probably contains much of the iron which has been leached out of the bleached weathered basalt close by. The chemical changes involved in this segregation of iron are as follows:—Surface waters containing carbonic acid, and, perhaps, other organic acids, dissolve the iron contained in minerals such as olivine. The solutions of iron, in the form of iron bicarbonate, are converted into iron carbonate, carbon dioxide, and water, thus:—

$$H_2Fe(CO_3)_2 = FeCO_3 + CO_2 + H_2O.$$

Further oxidation of this iron carbonate produces a hydrated iron oxide, göthite, thus:—

$$2FeCO_3 + O + H_2O = Fe_2O_3.H_2O + 2CO_2.$$

This iron is eventually deposited as limonite ($2Fe_2O_3.3H_2O$).

At the southern end of the north-western wall of the cutting the basalt appears as a hummocky-shaped mass of whitish clay, the lower part containing spheroidal nodules surrounded by well developed concentric laminae of more weathered basalt. This clay merges into the chocolate-coloured surface soil. Further north, along the cutting, it underlies Tertiary fossiliferous iron-stained sands. In the hollows of the basalt the lowest member of the Tertiary sands occurs as thin bedded white sands, which underlie the fossiliferous band. Through the clay run thin veins, about ¼ inch thick, consisting of a fine white clay-like material; these evidently occupy the position of joint planes in the basalt. The upper portion of the basalt outcrop here is remarkable for the intense leaching which has taken place. This leaching appears to be local, for it is absent in neighbouring outcrops in the district. Another small outcrop, showing concentric weathering, occurs in the Royal Park, inside the gate in Flemington-road, about 200 yards from the corner of Gatehouse-street. Other outcrops occur at Spencer-street and North Melbourne railway stations, at Sheil-street "Quarries," North Melbourne, at Kensington, at Ascot Vale, and at Essendon.

From the outcrop in the north-western wall of the railway cutting, samples were taken for chemical analyses. Near the base of the wall, a large nodule was exposed, being about 18 inches long, and surrounded by well-developed concentric laminae of weathered rock. Its interior was unaltered, and has been analysed as a representative sample of the fresh basalt. Near the outside of the fresh core, there is a sudden change from fresh grey basalt to a red iron-stained concentric band, about ½ inch thick. This band is nearly as hard as the fresh basalt, and is not detached at all from it. Outside this is a semi-detached concentric layer of light-brownish crumbly rock, from ¼ inch to ½ inch in thickness. Then occur successive fawny-coloured layers, each semi-detached from the previous one, the layers becoming softer and lighter in colour, as they get further from the core, until they merge into a soft, whitish, incoherent, argillaceous substance, the last stage of decomposition of the basalt. This residual clay has a kaolin-like appearance, and its chemical composition shows a certain resemblance to that of kaolin, but it contains 2.56 per cent. of alkalies (including 1.66

per cent. of potash), and the resulting soil is fertile. The greater part of the lime, magnesia, and soda has been carried away, as well as most of the iron, the little remaining being in the ferric condition. That the decomposition of this basalt has been from without, and not from within, is confirmed by microscopic examination of the rock sections mentioned below.

Closely related to the decomposition of iron-bearing minerals in the basalt is the distribution of small rounded and irregular shaped pellets of ironstone in the Tertiary sands, which overlie the basalt in the Royal Park area. These pellets ("Buck-shot Gravel") vary in size from minute fragments up to pieces $\frac{3}{4}$ inch long. It is assumed that they are formed from solutions containing iron dissolved out of pre-existing rocks. These solutions, on coming in contact with oxygen, have their iron oxidized, and deposited on small particles of sand as nuclei, forming rounded pellets of limonite.

An interesting mode of formation of somewhat similar pellets is suggested by the manner of their occurrence in older basalt outcropping in the "Quarries," abutting on Sheil-street, near the gasometer. This outcrop is about $\frac{3}{4}$ mile south of Royal Park. On the surface soil here was an abundance of the pellets, and their source was found close by in very decomposed vesicular basalt. In nearly every vesicle was one of the pellets, exactly the shape of the vesicle, and completely filling it. These pellets are therefore more regular in shape than those of the buck-shot gravel found in the Tertiary sands at Royal Park. This vesicular basalt was very much bleached and decomposed, and apparently had suffered a great deal of alteration before the deposition of limonite in its vesicles. The following types of decomposition products of the basalt occur at the "Quarries":—

(1) Vesicular basalt, very much decomposed, and some of it containing amygdales of limonite.

(2) Normal basalt, less decomposed than the latter.

(3) Spheroidal cores of weathered basalt. A microscopic section of one showed it to be an olivine basalt similar to that at the railway cutting, but not so fresh, and containing much more magnetite.

(4) Concretions of hematite and limonite, the structure showing cores often quite detached from the outer concentric shells.

(5) Segregated lumps of magnesite.

(6) A greyish waxy substance showing thin streaks of limonite, and films, along cracks, of what appears to be black oxide of manganese. Its appearance suggested halloysite, and the following chemical analysis was made. Comparison of it with the theoretical

composition of halloysite, and with an analysis of halloysite from Silesia,[3] suggests that part of the theoretical alumina may be replaced by iron.

TABLE I.

Substance from the "Quarries."			Halloysite from Silesia.	Theoretical Composition of Halloysite (Dana).
SiO_2	43·38		42·00	43·5
Al_2O_3	17·37		20·12	36·9
Fe_2O_3	13·81		8·53	
H_2O (−)	8·26	17·89	24·00	19·6
H_2O (+)	9·63			
MgO	4·13		2·01	
CaO	1·61		2·81	
Na_2O	0·54	0·87	0·50	
K_2O	0·33			
CO_2	nil			
MnO	0·05			
Total	99·11		99·97	100·0

3. Chemical Analyses.

The following analyses were made to determine the chemical changes which have taken place in the various stages of the decomposition of the Royal Park basalt:—

I. *Fresh Basalt,* from the interior of the large nodule described above. A portion of the nodule was broken into pieces the size of small marbles and carefully sampled in order to get a fairly representative analysis of the fresh rock.

II. *Decomposed Basalt,* selected at a distance of 2 inches laterally from the solid core. It consisted of crumbly concentric layers, about ⅛ inch in thickness, and soft enough to be easily broken between thumb and finger. It was quite unlike the dark-grey fresh basalt, its colour being pale yellowish to brown.

III. *More-decomposed Basalt,* selected at a distance of 12 inches laterally from the core. This was somewhat similar in appearance to the previous sample, being lighter in colour, but softer and more easily broken.

IV. *Residual Clay,* selected at a distance of 6 feet above the nodule. It consisted of a whitish argillaceous material, quite unlike basalt, having lost all concentric structure showing in the less decomposed rock. A few feet above the source of this sample the clay merged into the brown surface soil.

V. *Vein Substance*, existing in the residual clay, in the position of joint planes of the original basalt.

TABLE II.

	Fresh Basalt.	Decomposed Basalt.	More Decomposed Basalt.	Residual Clay.	Vein Substance.
	I.	II.	III.	IV.	V.
SiO_2 ..	45·64	43·74	39·09	43·82	43·97
Al_2O_3 ..	14·35	19·20	19·74	28·76	30·08
Fe_2O_3 ..	2·08	11·57	15·57	2·66	2·39 (Total iron)
FeO ..	10·32	0·65	0·46	0·20	..
MgO ..	9·50	0·94	1·05	0·03	0·38
CaO ..	7·87	2·03	0·49	0·58	0·26
Na_2O ..	2·17	2·00	2·03	0·90	1·37
K_2O ..	1·23	1·86	1·80	1·66	2·44
H_2O (−) ..	1·92	8·56	7·30	7·56	5·63
H_2O (+) ..	1·29	5·43	8·11	9·23	10·31
CO_2 ..	0·47	0·04	0·09	0·04	0·04
TiO_2 ..	2·74	3·60	3·62	4·75	4·21
P_2O_5 ..	0·42	n.d.	n.d.	0·05	n.d.
SO_3	nil	,,	,,	n.d.	,,
Cl	0·02	,,	,,	,,	,,
S	0·14	,,	,,	,,	,,
Cr_2O_3 ..	0·01	,,	,,	,,	,,
V_2O_5 ..	0·05	,,	,,	,,	,,
MnO ..	0·13	,,	,,	,,	,,
BaO ..	nil	,,	,,	,,	,,
SrO	0·02	,,	,,	,,	,,
ZrO_2 ..	0·03	,,	,,	,,	,,
Totals ..	100·40	99·62	99·35	100·24	101·08

Analyst, D. M. McCance.

The Norms and Classification of the fresh basalt, based on the above analysis, are as follows:—

NORMS.

Orthoclase	7·23
Albite	18·34
Anorthite	25·85
Diopside	8·56
Hypersthene	13·22
Olivine	13·98
Magnetite	3·02
Ilmenite	5·17
Pyrite	0·24
Apatite	0·93

CLASSIFICATION.

Class	III.	..	Salfemane
Order	5	..	Perfelic : Gallare
Rang	4	..	Docalcic : Auvergnase
Sub-rang	4–5	..	Presodic : Auvergnose

In comparing the ultimate composition of the decomposed stages of the basalt with that of the fresh rock, as indicated by the above analyses, one may note the following:—In the first stage of decomposition (Col. II.), there is a slight loss of silica and soda, a considerable loss of lime, an almost total loss of magnesia and carbon dioxide, a slight increase in potash, a great increase in alumina, in titanium, and in hydration, and a considerable oxidation of ferrous iron to the ferric state with practically no loss in the total iron content.

In the more decomposed stage (Col. III.), there is a further loss of silica, an almost complete loss of lime, an increase in the total iron, with further oxidation of the small amount of ferrous iron left in the previous stage, and a smaller increase in hydration, while the alkalies, magnesia, titanium, and carbon dioxide are about the same as in the previous stage.

In the residual clay stage (Col. IV.), the silica shows an increase over the previous stage, being only slightly less than in the fresh rock. Soda suffers a marked loss, while potash shows a slight loss, but is still in excess over the potash in the fresh rock. Magnesia, lime, carbon, and phosphorus have practically gone. There is a slight increase in hydration, an increase in titanium, and a very marked increase in alumina.

G. P. Merrill[(2)] has pointed out (p. 187) that the indicated loss or gain of any constituent may be only apparent, and the relative proportions can be learned only by calculating results on a common basis. He adopts a method in which one rock constituent is assumed to be constant, and the other constituents are compared with it. Either ferric oxide or alumina is taken as invariable, and using it as a standard the relative losses of the other constituents can be roughly estimated.

Following this method, the above analyses have been recalculated to a total of 100.00, on a hygroscopic water-free basis, assuming alumina as constant (Table III.).

This treatment of the analyses makes the silica of the residual clay show a gain of 0.94 per cent., whereas, on the figures of the original analysis, it appeared to lose 1.82 per cent. But this is only an apparent gain; for the alumina, which is assumed constant, shows an increase from 14.75 per cent. to 31.03 per cent. This great increase of alumina and of titania points to a concentration of these in the clay. If we calculate what would be the percentage of silica, assuming that the alumina remains constant at 14.75 per cent., we find that there is actually a loss of 23.87 per cent. of silica. Similarly titania and potash, instead of gaining, actually lose 0.34 per cent. and 0.40 per cent. respectively.

The calculations of losses, &c., shown in the following table are made on the following formulae given by Merrill[(2)] (p. 188) :—The "percentage of entire rock lost" in the clay is the percentage of each constituent in the fresh rock minus the percentage of the same constituent in clay multiplied by $\frac{\text{the percentage of alumina in the fresh rock}}{\text{the percentage of alumina in the clay}}$.

The "percentage of each constituent retained" is the $\frac{\text{percentage of it in clay}}{\text{percentage of it in fresh}} \times \frac{\text{percentage of alumina in fresh rock}}{\text{percentage of alumina in clay}} \times 100$.

The "percentage of each constituent lost" is 100 − percentage of it retained. For example, the percentage of entire rock lost in the case of silica is $46.34 - 47.28 \times \frac{14.75}{31.03} = 23.87$ per cent. That is, in the residual clay there has been a loss of 23.87 of the 46.34 per cent. of silica contained in the fresh basalt. This represents a loss of 51.51 per cent. of the original silica, while the percentage of silica retained is 100 − 51.51, or 48.49 per cent.

The residual clay has the general appearance of kaolin, and the analysis indicates that it consists mostly of hydrous silicates of alumina. The leaching out of most of the iron (89.25 per cent. lost) accounts for its bleached look. The 9.96 per cent. content of H_2O (+) indicates combined water, and is an actual gain in substance. The titanium has been mostly retained, only 12.28 per cent. of it being lost. 79.04 per cent. of the soda and 31.92 per cent. of the potash have disappeared. Over 95 per cent. of the phosphorus, carbon dioxide, lime, and magnesia have gone, the last-named being practically absent. This great loss of magnesia (99.85 per cent.) is very noticeable, even in the partially decomposed stage (Col. XI., Table III.). This is due to the breaking down of the abundant olivine present.

Merrill[(2)] (p. 206) quotes analyses of fresh and decomposed basalt from the Haute Loire, France, by Ebelman. The losses calculated on analysis of the residual clay of Royal Park agree very closely with those of the Haute Loire basalt, except that the Royal Park basalt lost 96.26 per cent. of the lime, whereas the Haute Loire basalt lost only 47 per cent. of the lime.

In passing outwards from the fresh rock there is a gradual decrease in the percentage of each constituent retained. An exception to this, however is the iron. The percentage of iron retained in sample II., 2 inches from the core, is 68.68 per cent. (Col. VIII., Table III.), but in sample III., 12 inches from the core, there remains a greater percentage, 87.36 per cent. The residual clay retains only 10.75 per cent. of iron. Probably some of the dissolved iron was re-deposited further out from the core. Magnesia and carbon dioxide also increase slightly in sample III. compared with sample II., so possibly some of the iron and magnesia are re-deposited as carbonates. Further out, in the clay, the iron and the magnesia have suffered very great loss (Col. XIII.).

TABLE III.

CALCULATED LOSS OF MATERIAL IN DECOMPOSED OLIVINE BASALT OF ROYAL PARK.

	Analyses of Fresh and Decomposed Rock Re-calculated to Total of 100·00 and Hygroscopic Water-free.				Percentage of Entire Rock Lost.			Percentage of Each Constituent Lost.			Percentage of Each Constituent Retained.			Remarks.
	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.	XIII.	
	Fresh Basalt.	Partially Decomposed.	More Decomposed.	Residual Clay.	Part Decomp.	More Decomp.	Resid. Clay.	Part Decomp.	More Decomp.	Resid. Clay.	Part Decomp.	More Decomp.	Resid. Clay.	
SiO_2 ..	46·34	48·01	42·47	47·28	12·74	17·14	23·87	27·49	36·98	51·51	72·51	63·02	48·49	
Al_2O_3 ..	14·75	21·09	21·45	31·03	0·00	0·00	0·00	0·00	0·00	0·00	100·00	100·00	100·00	(Constant)
Fe_2O_3 ..	2·11 } 13·75	12·71 } 13·50	16·91 } 17·47	2·87 } 3·11	} 4·31	1·74	12·27	31·32	12·64	89·25	68·68	87·36	10·75	
FeO ..	10·48 }	0·71 }	0·50 }	0·22 }										
MgO ..	9·65	1·03	1·14	0·03	8·93	8·87	9·64	92·53	91·87	99·85	7·47	8·13	0·15	
CaO ..	8·01	2·23	0·53	0·63	6·45	7·65	7·71	80·53	95·45	96·26	19·47	4·55	3·74	
Na_2O ..	2·20	2·20	2·21	0·97	0·66	0·68	1·74	30·05	30·92	79·04	69·95	69·08	20·96	
K_2O	1·25	2·04	1·95	1·79	(gain) −0·18	(gain) −0·09	0·40	0·00	0·00	31·92	100·00	100·00	68·08	
H_2O (+)	1·31	5·96	8·81	9·96	(gain) −2·86	(gain) −4·75	(gain) −3·43	0·00	0·00	0·00	100·00	100·00	100·00	Actual gain
CO_2 ..	0·48	0·04	0·10	0·04	0·45	0·41	0·46	94·17	85·67	96·04	5·83	14·33	3·96	
TiO_2 ..	2·78	3·95	3·93	5·13	0·02	0·08	0·34	0·60	2·77	12·28	99·40	97·23	87·72	
P_2O_5 ..	0·43	n.d.	n.d.	} 0·05	..	..	0·46	..	..	95·05	..	..	4·95	
V_2O_5 ..	0·05	,,	,,	}										
Cl ..	0·02	,,	,,	n.d.	..	..	..	..	..	..	..	..	..	
S ..	0·14	,,	,,	,,	..	..	..	..	..	..	..	..	..	
Total ..	100·00	100·00	100·00	100·00	..	..	..	..	..	..	..	..	..	
Total Loss of Original Material		..	..	..	33·56%	36·57%	56·89%							

NOTE.—Al_2O_3 in fresh rock includes ZrO_2 0·03%, Cr_2O_3 0·01%, and MnO 0·13%. They were not determined in decomposed rock.

4. Summary of Results of Analyses.

In the above table, Columns VIII., IX., and X., which give the respective percentages of each constituent lost, are very illuminating. In the partially decomposed stage (Col. II.) it will be noted that the silica appears to be in greater amount than in the fresh rock (Col. I.), but the above method of calculating losses shows this apparent increase of silica to be really a loss of 12.74 per cent. of the entire rock (Col. V.), equivalent to loss of 27.49 per cent. of the original silica in the fresh rock (Col. VIII.). Similarly, in the more decomposed stage (Col. III.), the silica appears to have decreased slightly from 46.34 per cent. to 42.47 per cent., but actually the loss is much greater, being a loss of 17.14 per cent. of the entire rock (Col. VI.), and a loss of 36.98 per cent. of the silica originally present in the fresh rock (Col. IX.) In the residual clay (Col. IV.), the silica shows an apparent slight increase, but in reality the clay has lost 51.51 per cent. of the original silica (Col. X.). These figures show a progressive increase in the percentages of silica lost in the three stages of decomposition, viz., 27.49 per cent., 36.98 per cent., and 51.51 per cent. respectively, and indicate the progressive breaking down of the silicate minerals —felspars, olivine, and augite.

Magnesia shows the greatest losses, viz., 92.53 per cent., 91.87 per cent., and 99.85 per cent. in the three stages of decay respectively. The great loss in the partially decomposed rock (92.53 per cent.), is evidently due to the early decay of the olivine, and the carrying away of the magnesia in solution.

Lime is nearly equal to magnesia in the large percentages lost. In the three stages it shows a progressive loss, viz., 80.53 per cent., 95.45 per cent., and 96.26 per cent. respectively, of the lime originally present. The great loss in the partially decomposed stage is no doubt due to the early breaking up of the soda-lime felspars. The residual clay retains only 3.74 per cent. of the original lime, this retained portion probably existing in small grains of undecomposed augite.

Carbon dioxide shows an equivalent loss with lime and magnesia in its percentage losses of 94.17 per cent., 85.67 per cent., and 96.04 per cent. respectively. As Column VIII. shows that most of it disappears in the partially decomposed stage, it indicates the early removal of any carbonates present, viz., secondary calcite and magnesite.

Phosphorus also suffers almost complete loss in the residual clay, in which only 4.95 per cent. is retained. Its presence indicates the occurrence in the rock of minute apatite crystals, although none is seen in the microscopic rock sections examined.

The Alkalies suffer great losses, the soda in much greater proportion than the potash. The losses for soda are 30.05 per cent., 30.92 per cent., and 79.04 per cent. in the three stages respectively. The bulk of this will be due to decomposition of the soda-lime felspars, and the removal of the soda in solution. The losses in the first two stages are less than expected, but this indicates that undecomposed felspar is present. Even in the residual clay, which loses 79.04 per cent. of soda, there must still be small fragments of the unaltered felspar. The potash appears to gain slightly in the first two stages (Cols. V. and VI.), but this is possibly due to errors in analysis. This retention of potash is due to the presence of small shreds of biotite, which are seen under the microscope. This biotite may eventually disintegrate, but is relatively stable to decay in basic igneous rocks. Possibly some of the potash is contained in felspar, for potash felspars are known to be more stable than soda-lime felspars. In the residual clay, there is still 68.08 per cent. of the original potash retained.

Titanium, some of which is probably contained in the augites, as these show a pale purplish tint with transmitted light, is apparently in a very stable form, because in the residual clay only 12.28 per cent. of it is lost. Some of the titanium in this clay may exist in small unaltered augites. It is more probable, however, that it exists mostly in ilmenite, which is very resistant to atmospheric agencies. The rock contains a good deal of magnetite, but it is impossible to distinguish this from the ilmenite in the sections examined.

Iron, estimated as Fe_2O_3, has lost 89.25 per cent. in the clay. That remaining exists mostly in the ferric condition, excepting a small fraction in the ferrous condition in the residual magnetite or ilmenite (Col. IV.).

Combined water.—The progressive increase of this with advancing decomposition is evident from the figures in the table. The actual gain is due, of course, to the formation of hydrated minerals.

Alumina, although it has been assumed constant, exists in the clay in quite a different form from that in the fresh rock. In the latter, it occurs in the form of anhydrous silicates of alumina, soda, lime, magnesia, and iron, such as felspar, augite, and biotite; but in the clay a great proportion of it exists as a hydrous silicate of alumina (kaolin).

On the whole, there has been a very decided loss of material in each of the decomposed stages. The partially decomposed stage shows a total loss of 33.56 per cent. of the original rock (Col. V.). The more decomposed stage loses altogether 36.57 per cent. (Col. VI.), and the residual clay loses a total of 56.89 per cent. of the entire rock material (Col. VII.).

5. Petrological Description of the "Older Basalt."

The "Older Basalt" has been previously described by Skeats[4] as a "medium grained ophitic olivine-basalt, with large olivine phenocrysts, brown irregular augites, magnetite, lath-shaped plagioclase, and a little residual interstitial felspar of a more acid character, and which may be in part orthoclase."

Although the basalt is very much decomposed, it is possible to obtain remarkably fresh samples from the interior of spheroidal nodules, which are distributed among the more decomposed rock.

The fresh rock is of a dark grey colour, and its texture is fine-grained, compact, and homogeneous. It has a density of 2.89. It is holo-crystalline, and macroscopically it shows numerous amygdales of carbonate of iron, up to a diameter of about $\frac{1}{4}$ of an inch. This carbonate occurs in the freshest parts of the rock. It is evidently cavity-filling, and was deposited probably during the late stages of crystallisation. Under the microscope it is porphyritic, with abundant phenocrysts of very fresh olivine. The finer ground mass consists of lath-shaped plagioclase, with pale mauve-tinted augite ophitic round the felspars, and contains abundant grains of magnetite.

The plagioclase laths consist largely of basic labradorite with lamellar twinning, and showing extinction angles up to 38°. The laths are clear and fresh, and show trachytic texture. There is also some interstitial felspar which is more acid than the laths, being of lower refractive index than they, but higher than the balsam. It is andesine or oligoclase.

The olivine is remarkably fresh, plentiful, and idiomorphic, with rectangular and rhombic cross sections. It is clear, colourless, and traversed by rough cleavage cracks, and shows alteration to calcite and serpentine along the cracks.

Green and yellowish-green serpentine replaces part of the olivine. In one example there occurs a large, roughly octagonal piece of serpentine with a wavy extinction, and showing a dark cross with crossed nicols under low power.

Magnetite is abundant in square, rectangular, irregular, and spindle shapes. The elongated shapes suggest its being ilmenite in part. Many small grains are included in the olivines.

Biotite is present in a few small brown shreds of basal section, showing no pleochroism.

Amygdales of secondary carbonate occur through the basalt. These are light brownish in colour; under the microscope they are nearly colourless, with a pale creamy tint. This carbonate shows characteristic rhombohedral cleavages, and is surrounded by a narrow rim of green or yellow serpentine. Chemical tests showed it to consist mostly of carbonate of iron, with a small amount of lime.

In the fresh basalt, near the outside of the core, the serpentine loses its green colour, becoming discoloured yellow to brown, due to the deposition of hydrated iron oxides. The olivine which remains looks just as fresh as that in the interior of the core.

In a section of decomposed basalt, taken from the outer shell of the core, there is a sharp line of demarcation between the fresh rock and a red band of more decomposed rock, which forms the outside of the more solid core. In this section the olivines are much decomposed along their edges and along the cleavage cracks, being replaced by brilliant red and brown oxides of iron, and by serpentine. In some cases the olivine is thus wholly replaced.

A section of the first shell of still more decomposed basalt, which is separated from the solid core along a concentric joint crack, is yellowish to red on account of deposition of iron. Not much olivine is left, it being mostly replaced by iron oxides and serpentine. Serpentine occurs interstitially, in large amount, and coloured from yellowish green to orange. The augites and felspars look fresh, except for a slight iron staining in places. Magnetite has been deposited along a crack in the rock, concentric with the core.

A section from the centre of a boulder from the Sheil-street "Quarries" shows it to be a basalt similar to the one in the railway cutting. Magnetite is in greater abundance.

6. Summary.

G. P. Merrill[2] (p. 221), has pointed out that the silicates which are most readily decomposed are those containing protoxides of iron and manganese, or lime, and that the first indication of the decomposition is signalled by a ferruginous discoloration and the appearance of calcite.

This observation is applicable to the Royal Park basalt. Here, the first evidence of decay is the deposition of serpentine and calcite along the cracks of the olivine, while a later stage shows the iron discoloration, accompanied by the gradual disappearance of the olivine.

The freshest samples show phenocrysts of clear olivine, traversed by rough cleavage cracks, and frequently showing prismatic forms of pinacoids and domes with acute terminations. Edges are usually rounded and corroded.

The augites, in small prismatic crystals, the lath-shaped plagioclases, and the magnetite appear quite fresh. The pale mauve tint of the augites suggests the presence of titanium.

The amygdales, which consist of carbonates of iron and calcium, are of magmatic origin, because, apart from a little interstitial serpentine among the felspars, there is no other sign of decomposition in the freshest samples.

The olivine is the first mineral to show any change, this being the formation of thin deposits of serpentine and calcite along the cleavage cracks. In more decomposed samples this serpentisation spreads, becomes iron-stained, and forms a meshed framework of the original crystal shape, leaving only "islands" of undecomposed olivine. Very often there is a rough outline of the original olivine crystal, consisting wholly of a mass of hydrated iron oxides.

The extraction of iron from the fresh rock by solution is shown by a reddish band forming as a crust on the outside of the otherwise fresh nodule. In one example there is a sharp line of demarcation separating the fresh rock from the reddish band. In this band, the identity of many of the original crystals, especially olivine, is masked by the deposited iron oxides. The augites and felspars become iron-stained, and iron is deposited as grains of magnetite along the cracks between concentric laminae.

The chemical analysis of the decomposed stage a little further out, 2 inches from the core, showed that the iron present was mostly in the ferric condition, viz., 12.71 per cent. of ferric iron, and only 0.71 per cent. of ferrous iron (Table III., Col. II). This indicates the breaking up of the iron-bearing minerals, and the oxidation of most of the ferrous iron, of which the fresh rock contains 10.48 per cent. The little ferrous iron remaining at this stage is that contained in undecomposed magnetite or ilmenite. Under the microscope the residual clay shows a multitude of minute grains of magnetite and probably ilmenite, since a great number of them are spindle shaped.

It is probable that a physical analysis of the residual clay would give additional information concerning the nature of undecomposed minerals remaining in the clay.

All the evidence indicates that the decomposition of this basalt has been caused by infiltration of solutions from without the rock, assisted largely by the natural spheroidal jointing of the basalt. The most weathered portions are found nearest the outside, the fresh rock being found only in the interior of boulders occurring among the more decomposed material.

The greater loss of soda than of potash shown in the analyses, is in accord with the investigations of Merrill and of others quoted by him (p. 222). The comparatively small loss of potash here (31.92 per cent.) indicates the greater stability of the potash felspars which lose little by decomposition, but become converted into fine silt by a mechanical splitting up, as Merrill has described.

The analysis of vein substance taken from a joint plane in the residual clay (Table II., Col. V.) was made in order to find out whether it might be due to an accumulation of carbonates of lime and magnesia, deposited from solutions passing along the joint planes. The analysis, however, proves that the substance does not differ very much in chemical composition from that of the residual clay. It contains less lime and iron, and a very little more magnesia. It shows about 1 per cent. more alkalies, but this may be an error in the analysis, because of the high summation in the figures of the analysis, viz., 101.08.

In conclusion, the writer wishes to record his indebtedness to Professor Skeats for his valuable advice and suggestions on many occasions, and for his kind criticism of the paper; also to Associate Professor Summers for his kind help and advice at various times. He also wishes to thank Mr. G. A. Ampt, B.Sc., for his kind advice on chemical analysis, and Dr. F. L. Stillwell for his kind criticism and assistance in the preparation of the paper.

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Art. XXII.—*The Kerrie Series and Associated Rocks.*

By D. E. THOMAS, B.Sc.

(Geological Survey of Victoria).

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(With Plate XXIII.)

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1. Introduction.

The present paper is the outcome of field work in the area to the north and north-west of Riddell, and includes parts of the parishes of Kerrie, Monegeetta, and Rochford. Detailed mapping was confined to the areas where the conglomerates outcrop. Heights are aneroid heights, using the railways levels as a base. Traverses were made by compass and chain, using the theodolite surveys of the Lands Department as a check.

During the course of the work it became necessary to visit some of the surrounding areas. The area around Gisborne was visited under the guidance of Mr. W. Crawford, of Gisborne. While the actual mapping was confined to a small area, the geology of the surrounding districts has been considered in so far as was necessary for the problem in hand.

The conglomerates which have been studied, although recognised by the Geological Survey, were not named until 1892, when T. S. Hart used the term "Kerrie conglomerates." Since the present work shows the continuity of these conglomerates and that thick beds of sandstones are associated with them, the term "Kerrie series" has been adopted to designate this group of rocks.

2. Physiography.

In broad outline the physiography of the area is fairly simple. Basaltic plains extend along the south and east of a mountainous area of granitic and dacitic rocks, which are flanked by Lower Palaeozoic rocks. The contrast between mountains and plains is intensified by the open clear character of the latter compared with the timbered and scrubby nature of the former.

The basalt plains junction near Clarkefield at a level of just over 1,000 feet. One plain, gradually rising to a height of over 1,600 feet, extends northwards towards Lancefield. The monotony of the plain is broken by a few points of eruption which rise to nearly 2,000 feet. The Macedon Ranges form the western edge, and the Lower Palaeozoic hills near the Deep Creek mark the eastern edge of this plain. The other stretch of flat land rises gradually to the west to just over 1,500 feet to the north of Gisborne.

Deep Creek, Jackson's Creek, and their tributaries have deeply dissected these plains, and it is chiefly along the bottoms and sides of these deep gutters that exposures of the sedimentary rocks are to be found.

The basalt plains are "infilled valleys,"(13) and mark the main valleys of the early Tertiary topography. Very often the altered gravels of these ancient valleys can be seen on the slopes of hills that have since been covered by the volcanic rocks and have subsequently been laid bare. As is usual in these cases, " lateral " streams developed along the edges of the lava, e.g., Riddell's Creek to a point a mile west of Riddell; Charlie's Creek to the south and west of Mt. Eliza; Emu Creek to the north-west of Monegeetta; Jackson's Creek between Clarkefield and Sunbury; and the Deep Creek to the west of the basalt area.

Depressions or areas where the basalt sagged frequently enabled streams to flow across the main mass of lava. These valleys are very important, as along the course of these streams " windows " of underlying rocks are exposed. Many of these undoubtedly represent some of the minor divides of the pre-basaltic river system.

The Macedon mountains form a well-marked unit composed chiefly of granodiorite and dacite. To the south and east are the hills of conglomerates, and around this are the Ordovician hills which gradually slope to the basalt plains.

3. Previous Work and References.

1863.—The first geological reference[1] to these conglomerates is in Quarter Sheets 6 N.W. and 6 S.W., surveyed by C. D'O. Aplin, under the direction of A. R. C. Selwyn, Director of the Survey. In these maps the Palaeozoic rocks are marked as Lower Silurian (Ordovician of modern usage), and the conglomerates are mapped as a capping resting on these rocks. A note written across the outcrop is of some interest :—" Extensive beds of coarse conglomerate (carboniferous), consisting almost entirely of smooth rounded pebbles of a purple subcrystalline sandstone with an almost total absence of quartz pebbles, constitute the entire mass of these two parallel ranges with their various spurs and branches; coarse, gritty and fine-grained partially altered sandstones are sparingly interstratified with them. Thickness probably 500 feet or more."

Across " Conglomerate Gully " is another note :—" Fine section showing conglomerate beds exposed and weathered into large tabular masses; bedding obscure, but apparently horizontal."

In the legend the rock is marked as " Oolitic " (i.e., Jurassic).

The Survey roughly indicated the extent of the conglomerates, but no attempt was made to map their boundaries.

The account of the geology of this area with written by Norman Taylor.[2] In this the use of the term " Oolitic " is explained. " The tops of the Monument Range (Black Range), north of it (Mt. Eliza), and also the high densely scrubby ranges to the south have been marked on the maps of the Geological

Survey as carbonaceous (Oolitic) conglomerates lying unconformably (horizontally) on the upturned Silurian rocks." A footnote relative to this sentence is of interest, as it shows that further work was done in this area:—" Subsequent observations tend to place these conglomerates much lower, probably Devonian or Old Red." Unfortunately, I have been unable to trace records of this work.

The Survey thus recognised that the conglomerates were fairly horizontal, rested unconformably on the Ordovician rocks, and were Devonian in age. They show low dips for this series in their plans, and estimate its thickness as more than 500 feet.

1867.—A. R. C. Selwyn[3] mentions this conglomerate among others, and states:—" From Mt. Macedon eastwards, and especially near Mansfield and in the Gippsland localities, greater variations in the general character of the beds occur than is observed in the more western outcrop, and I am inclined to think that the Bacchus Marsh, Ballan, and Grampian Beds are newer than any we have in the eastern district." The Bacchus Marsh deposits are Permo-Carboniferous, so that in Selwyn's opinion the Kerrie conglomerates are older than these and younger than the Upper Ordovician.

1893.—T. S. Hart[5] described the Kerrie conglomerates and believed them to be pre-glacial (i.e., pre-Permo-Carboniferous). He is the first to name these conglomerates the " Kerrie conglomerates." He describes the lithology in detail, and states that they rest unconformably on the Lower Silurian (i.e., Ordovician) rocks.

1903.—Professor J. W. Gregory[7] makes a passing mention of these conglomerates.

1908.—T. S. Hall[8] identified *Climacograptus* sp., collected by A. E. Kitson at Kerrie, and states the age of the rocks in which the specimen occurs is either Upper Ordovician or Lower Silurian.

1912.—Professor E. W. Skeats and Dr. H. S. Summers[10] published their work, " The Geology and Petrology of the Macedon District." In this work references to the workers on the igneous rocks of the area will be found. They describe in detail the igneous rocks and their relationship to the sedimentary rocks, and show that the Kerrie series is intruded and metamorphosed by the granodiorite. They deal at some length with the Kerrie conglomerates. The following quotation (p. 8) summarises their views on this matter:—" This deposit is much thicker and considerably older than is shown by the Geological Survey Quarter-sheets. It may be unconformable to the Lower Ordovician (?) shales, but the appearances may be due to the folding together of hard and of plastic beds. It is closely associated in places with Upper Ordovician shales, and apparently underlies them. The Devonian (?) granodiorite is intrusive into it. The conglomerate has been much sheared and compressed, and "dimpled" pebbles are common. Similar pebbles occur here and there in mudstones at the base of the Silurian series north-east of Romsey. We draw the inference that they are derived from the Kerrie conglomerate, to which we therefore assign a pre-Silurian age. We think that it probably forms the basal member of the Upper Ordovician series."

Other references to this work will be considered as occasion arises.

1912.—F. Chapman[11] identified shelly fossils collected by A. E. Kitson from the Parish of Kerrie, Allot. 18:—"The following forms were identified—*Heliolites* sp., casts of encrinite stems, *Platystrophia* sp., *Spirifer* sp., ? *Camarotoechia*, ? *Atrypa*. The fossil evidence points in a general way to a Yeringian (i.e., Upper Silurian) horizon, but is not entirely conclusive." These come from grits that are interbedded with Upper Ordovician shales.

1921.—W. J. Harris and W. Crawford[16] described in detail the Lower and Upper Ordovician rocks of the area, and show that the Djerriwarrh Fault runs through Gisborne and separates these two series. They also recognise a horizon of grits, the Riddell grits, at the top of the Upper Ordovician. They describe the relationship of the Upper Ordovician to the Kerrie conglomerates, and show that the conglomerates rest unconformably on the Upper Ordovician rocks and contain pebbles of fossiliferous Riddell grits. They conclude (p. 75) that the age of the conglomerate depends on the age of the Riddell grits, which pass under it, and in part at least, seem to have provided the material of which it is formed. These are probably Upper Ordovician, and it is probable that the conglomerate may be a basal Lower Silurian deposit.

In 1923 H. S. Summers in "The Geology of Mt. Macedon and Woodend Area"[18] summarised the position as follows:—"The Kerrie conglomerates were tentatively described as being possibly the basal members of the Upper Ordovician. Later work has been done by Harris and Crawford on the Lower Palaeozoic Rocks to the south of Macedon. They have come to the conclusion that these conglomerates rest unconformably on the Upper Ordovician Rocks, and belong to the basal part of the Silurian. Further work is necessary before either view can be definitely accepted."

Such was the position when the present work was undertaken, which is an attempt to marshal the facts and interpret them in the light of the field evidence.

4. Summary of Present Work.

1. It is shown that the rocks to the west of the Djerriwarrh Fault, Gisborne, and at Rochford belong to the top of the Darriwil.

2. Along Emu Creek at Bolinda and Monegeetta, "windows" in the basalt enable some cherts and diabases of the "Heathcotian," and some rocks of Bendigonian age, to be seen.

3. Between these areas the oldest rocks exposed are Upper Ordovician in age. This area is bounded by faults, of the rift valley type. Associated with the Upper Ordovician rocks are the "Riddell grits" of Harris and Crawford. These are Upper Ordovician in age, and apparently are not confined to one horizon.

4. The Kerrie series of conglomerates and sandstones rests unconformably on the upturned edges of the Upper Ordovician rocks, and nowhere comes in contact with Lower Ordovician rocks.

5. The age of the Kerrie series from direct evidence in this area is post-Upper Ordovician and prior to the granitic intrusions.

6. Some evidence is given that the Lower Ordovician and Upper Ordovician rocks are conformable, and, from work outside the area discussed here, there is no evidence of a post-Ordovician and pre-Silurian diastrophic period.

7. The age suggested for the Kerrie conglomerate is Upper Devonian.

5. Upper Cambrian and Ordovician Rocks.

In this area, Upper Cambrian, Lower Ordovician, and Upper Ordovician rocks are present. The Upper Cambrian rocks consist of cherts and diabases, while the Ordovician rocks consist of alternating sandstones, mudstones, shales, and grits. As Harris and Crawford have pointed out[16] (p. 54), it is a matter of great difficulty to separate individual outcrops of the Upper and Lower Ordovician rocks on lithology alone. The typical slates of the Lower Ordovician cannot be mistaken, but the Darriwil beds are lithologically very similar to the Upper Ordovician. Hard quartzose bands and grits are more characteristic of the upper division, and very often these contain fragmentary fossils.

(A) Heathcotian and Lower Ordovician.

As it has been suggested that the Kerrie series is probably the base of the Upper Ordovician,[10] some observations on the distribution and relationship of these groups are necessary. The

Lower Ordovician rocks outcrop outside the area mapped in detail. The area around Gisborne has been studied by Harris and Crawford,[16, 20] who state that at Gisborne the rocks are the top zone of the Darriwil, but further south, Castlemainian and Bendigonian beds appear. These are separated from the Upper Ordovician rocks to the east by the Djerriwarrh Fault. They point out that the downthrow is to the east, increasing to the south and probably disappearing under the Macedon platform. The alluvial flats near Barringo and the metamorphism of the rocks near the igneous rocks make it impossible to trace the fault in this area. (The zoning used is that of Harris and Keble).[27]

North of Macedon Castlemainian rocks outcrop west of Woodend, but to the east Darriwilian rocks extend right up to Lancefield.

The nearest fossiliferous outcrops of Lower Ordovician age to the north are the Upper Darriwilian rocks near Rochford. Somewhere between this place and Emu Creek is the boundary between the Upper and Lower Ordovician rocks. Further detailed work is necessary before this boundary can be fixed more accurately.

To the east along Emu Creek, near Clarkefield and Bolinda, small patches of older rocks occur. West of Monegeetta, cherts and associated volcanic ash beds are exposed, which under the microscope resemble the ash beds to the east of Romsey. Work in the Lancefield area has shown that the interbedded diabase does not extend to the base of the Lancefieldian, so that this patch has been mapped as "Heathcotian" (Upper Cambrian). These rocks strike N. 20° E. and dip at high angles to the east; they are on the flanks of the south-west continuation of one of the most important axial lines in Central Victoria. This is referred to as the Mount William anticlinorium.

South and a little east of the above exposure, cherty shales with phosphatic inclusions outcrop. In this patch the following fossils were obtainel:—

Tetragraptus fruticosus (3-branched forms) (J. Hall).
T. cf. quadribrachiatus (J. Hall).
Phyllograptus cf. typus J. Hall.
Phyllocarids.

The horizon indicated is Middle Bendigonian, probably B3, but not older. These rocks are similar in strike and dip to those at Monegeetta and confirm the evidence that we are on the eastern flank of the Mount William anticlinorium.

(B) Upper Ordovician.

Lithologically these are similar to the rocks in the Darriwilian, but coarse grits, which have been called the Riddell grits, outcrop in many places. The rocks strike in a general north and south direction, athough due to the pitch of the folds, strikes swing to the east and west of north. On the whole, the strikes are to the east rather than the west of north. Dips are invariably high and very often are perpendicular.

Four areas of Upper Ordovician rocks will be considered, viz., Riddell's Creek-Barringo Creek, Sandy's Creek, Running-Charlie's Creek, and the Emu Creek areas.

1. *Riddell's Creek-Barringo Creek.*—The few graptolite localities in this area are, however, sufficient to give the horizon of these beds. Loc. C/15, near Barringo Creek, was first found by Harris and Crawford.

Climacograptus bicornis var. peltifer Lapw.
Diplog. spp.

occur here and show that the rocks are a low horizon in the Upper Ordovician.

To the east of the mouth of Conglomerate Gully brown shales with thin blue partings outcrop beneath the conglomerate. Harris and Crawford found *Diplograptus* sp. here, and while revisiting this locality in company with W. J. Harris and R. A. Keble, we were fortunate enough to find a specimen of *Dicellograptus sextans,* thus definitely fixing the Upper Ordovician age of these rocks.

The other locality mentioned by Harris and Crawford is on the ridge to the west of Bracken Gully. This is marked C/16 on the map. On revisiting this locality several forms were found:—

Dicellog. cf. forchammeri Gein.
Diplog. (Amplexograptus) perexcavatus Lapw.
Diplog. (Amplexograptus) cf. arctus E. and W.
D. (Orthograptus) cf. quadrimucronatus (J. Hall).
Climacograptus minimus (Carr).
Cl. cf. exiguus H. and K.

The horizon indicated is higher than that of C/15 and the graptolites at the mouth of Conglomerate Creek.

On the south and west of the mass of conglomerates the rocks are thus definitely Upper Ordovician in age.

2. *Sandy's Creek and Area to the South.*—Along Sandy's Creek the rapid erosion of the creek has exposed good sections. The beds unfortunately are metamorphosed near the granodiorite. They strike consistently east of north from N. 5° E. to N. 40° E. and dips are high to the east.

Loc. C/3 is on the creek, and in the blue-black mudstones the following forms were found:—

Diplog. (Amplexograptus) perexcavatus Lapworth.
Diplog. sp.
Climacograptus sp.

S.W. of allot. 75, Parish of Kerrie, some brown shales locally contorted yielded species of *Diplograptus, Climacograptus,* and *Dicellograptus.* Unfortunately the forms as at Loc. C/3 are not well preserved.

Further to the east alluvium masks the underlying rocks. On the hill on the road between Monegeetta and Riddell, brown shales interbedded with typical Upper Ordovician grits occur. The beds strike east of north and dip to the west, indicating the eastern limb of the Riddell syncline.

Running Creek and Charlie's Creek.—Running Creek flows between Mts. Charlie and Teneriffe, while Charlie's Creek flows between Mt. Charlie and Mt. Eliza. Along Running Creek and on the hillsides, exposures are plentiful. Unfortunately the rocks are indurated and metamorphosed. The area is sharply folded and the sharp pitch of these folds causes the direction of the strike of the beds to vary considerably. Further downstream dips and strikes become more constant.

Badly preserved graptolites were found on the Mt. Charlie ridge in Allot. 144, Parish of Kerrie. Loc. C/2 is on the right bank of Running Creek. The graptolites occur in thin blue bands that are interbedded with brown shales and sandstones, and yielded:—

Dicellograptus sp.
Climacograptus sp.
Diplograptus cf. quadrimucronatus J. Hall.

On the watershed between Sandy's Creek and Running Creek a quartz-tourmaline-breccia is found, which was first recognised by Harris and Crawford. This outcrops near the Kerrie conglomerate, which is very quartzose in character here. The silification, tourmalinisation, and brecciation increase in intensity towards the granodiorite. In all probability these phenomena are connected with a fault line along which the vapours from the granodiorite altered the brecciated rocks. Fragments of partially digested bedrock are plentiful in a quartzose matrix, and in these the development of tourmaline is very noticeable.

Although exposures along Charlie's Creek are poorer, the rocks are more normal, so that well-preserved graptolites can be obtained.

At Loc. C/1 only imperfectly preserved graptolites were obtained.

At Loc. C/2 the following forms have been identified:—

Dicellograptus forchammeri var. flexuosus Lapw.
Dicellog. sp.
Diplograptus cf. quadrimucronatus J. Hall.
Diplog. sp.

Loc. C/4 is a very fossiliferous one, and yielded the following forms:—

Dicranograptus Nicholsoni Hopk.
Dicranog. ramosus J. Hall.
D. cf. furcatus J. Hall.
D. hians T. S. H.
D. hians var. apertus T. S. H.
Climacog. caudatus Lapw.
Climacog. sp.
Diplog. (Orthog.) cf. pageanus Lapw.
D. spp.
Cryptograptus tricornis var. insectus Rued.

At Loc. C/5 the following forms were obtained:—

Climacog. sp.
Cryptograptus tricornis (Carr).
Diplograptus cf. perexcavatus Lapw.
Dicranograptus cf. ramosus (J. Hall).
Dicranog. ramosus var. spinifer Lapw.

These beds strike N. 20° E. and dip to the east at 50°.

C/6 is a locality in the small tributary of Charlie's Creek. The exposure is a poor one, and so are the graptolites. *Dicranog* sp. and *Diplog.* were the only forms obtained.

4. *Emu Creek Section.*—South-east of Tye's good exposures of Upper Ordovician rocks occur. As usual they consist of sandstones, grits, shales, and mudstones. The strike, apart from some local deviations, is east of north and the dip is to the east of high angles. The graptolites occur in thin bedded soft blue-black mudstone. Being interbedded with more resistant, massive quartzose bands, they have suffered a great deal from the folding movements. Slickensided faces are so well developed that only with difficulty can well-preserved forms be obtained.

The fossil localities C/8 to C/13 follow each other in rapid succession downstream. Included in this lot is one locality mentioned by earlier workers.

The graptolites indicate that these beds are about the same horizon. Loc. C/10 yielded the following forms:—

Climacograptus bicornis (J. Hall).
Cl. tubuliferus Lapw.
Cl. sp.
Dicranograptus Nicholsoni Hopk.
Dicellograptus elegans Carr.
D. forchammeri var. flexuosus Lapw.
D. sp.
Cryptog. tricornis (Carr).
Diplog. spp.

From Loc. C/11 the following forms were obtained:—

Cl. bicornis (J. Hall).
Cl. putillus cf. mut. eximius Rued.
Cl. sp.
Diplograptus cf. truncatus Lapw.
Diplog. cf. truncatus var. intermedius E. and W.
Diplog. cf. truncatus var. pauperatus E. and W.
Diplog. calcaratus cf. var. vulgatus Lapw.
Cryptograptus tricornis (Carr).

At the other localities the only other forms worth mentioning are *Diplograptus* cf. *quadrimucronatus* (J. Hall) and *Dicranograptus hians* (T. S. Hall). Further downstream the covering of basalt and alluvial wash hides this most interesting section. A small patch of Upper Ordovician rocks dipping to the west occurs about half a mile downstream. The horizon of the beds on Emu Creek corresponds to those of Charlie's Creek and would correspond to the zone of *Dicranograptus clingani* in the British succession.

(C) The Riddell Grits.

This name was applied by Harris and Crawford[15] to a series of coarse sandstones and fossiliferous grits which outcrop in this area. They state that they represent a shallow-water facies of the Upper Ordovician and that they are associated with *Dicranograptus* beds. These grits outcrop in several areas, but the evidence obtained points to the fact that they are not confined to one definite horizon (which reconciles observations which perplexed Harris and Crawford[16] (p. 60) in the Gisborne area), but are interbedded with normal Upper Ordovician graptolite-bearing beds.

Typical exposures of these rocks are to be found:—(*a*) On the road between Riddell and Monegeetta, (*b*) at Riddell's Creek, near Conglomerate Gully and Bracken Gully, (*c*) in Sandy's Creek, and (*d*) between Running Creek and Charlie's Creek.

For the purposes of this paper the Riddell grits will not be considered as a definite horizon, and the detailed discussion of the horizons at which they occur will be left for a further date.

A full discussion of this problem and lists of fossils, &c., are to be found in the paper by Harris and Crawford.(16) As these grit bands are interbedded with Upper Ordovician graptolite shales their age is fixed.

1. The General Structure of Ordovician and Older Rocks, and the Relationship of the Lower and Upper Ordovician Rocks.

On the west the Upper Ordovician rocks have been shown by Harris and Crawford(16) to be bounded by the Djerriwarrh Fault. They have shown that the throw of this fault increases to the south and probably dies out towards the Macedon platform. No evidence of this fault was found near Barringo Creek, but this may be due to the metamorphosed character of the rocks in this area.

North of the Macedon platform, Lower Ordovician rocks are found in the Parishes of Rochford and Newham. The horizon indicated is high in the Darriwil series (D 1 zone), the nearest fossiliferous outcrop to the area under discussion being near Rochford. Here the presence of *Tetragraptus quadribrachiatus* proves conclusively that the beds are Lower Ordovician in age. Along Emu Creek the beds are Upper Ordovician in age and are fairly high in the sequence. More detailed work may place the boundary more accurately.

A consideration of the fossil evidence is interesting, as it definitely shows that there is no break between the Lower and Upper Ordovician rocks. Thus Ba 67, at the junction of Riddell's and Jackson's Creeks, represents the basal bed of the Upper Ordovician. Many forms are common to the lower beds of the Upper Ordovician and the uppermost beds of the Darriwilian, and it is only by careful examination that the beds can be separated. The D1 beds and the basal Upper Ordovician are predominantly *Diplograptus* shales. Both have large typical species of *Diplograptus*, probably of allied species, but distinct from *D. austrodentatus* H. and K. of the D2 beds.

That the fauna of the beds have much in common is shown by the following list of forms which are common to Upper and Lower Ordovician:—

Didymograptus caduceus Salter.
D. ovatus T. S. H.
D. spp.
Diplograptus euglyphus Lapw.

D. spp.
Climacograptus riddellensis Harris.
Cl. spp.
Glossograptus hincksii (Hopk).
Cryptograptus tricornis (Carr).

The absence of *Tetragraptus* and *Phyllograptus* is the criterion of separation of the beds of these series, but the incoming of the typical Upper Ordovician element is the deciding factor.

The great structural feature of this area is the south-westerly continuation of the Mount William anticlinorium. Along this line to the north are the cherts and diabases of Upper Cambrian age. On the west occur Lower Ordovician rocks which follow conformably on the Heathcotian series. These rocks are hidden by the basalt on the Riddell area, but their presence on the eastern limb is indicated by the Bendigonian rocks near Bolinda. Stratigraphically beneath these and with a similar strike of N. 20° E. are the cherts and associated diabasic rocks on Emu Creek near Monegeetta. These strikes show how the north-south Mt. William axis has developed a south-westerly trend. This twist takes place a little to the east of Romsey on the Deep Creek, as along the river sections here the beds have similar strikes. The same line must pass to the west of the junction of Riddell's and Jackson's Creeks, as the fossils at Ba 67 show that the bed is immediately above the Lower Ordovician. East of this is a synclinal structure with the north-easterly trend. In this is a development of typical Upper Ordovician rocks. This synclinal structure has been named the Clarkefield synclinorium.

To the west of the Mount William anticlinorium is the Riddell synclinorium. Further work can be expected to show that the structure is more complicated, as along Emu Creek and Charlie's Creek is a well-marked syncline, while the beds at C/16 indicate a higher horizon than either C/15 near Barringo Creek or the locality near the mouth of Conglomerate Creek. The general structure, however, of this area between the Djerriwarrh Fault with Lower Ordovician rocks to the west and the Mount William axis with Lower Ordovician and "Heathcotian" is a synclinal one.

The sequence on the eastern side of the Riddell synclinorium is probably not a complete one. There is a strong possibility of strike faulting along the eastern edge of this basin. It is very difficult to be certain of this, as the succession of Lower Ordovician rocks in the Lancefield area is a very attentuated one. Added to this is the southerly pitch of the rocks and lack of exposures. But, taking these factors into consideration, it is difficult to see how the thickness of Upper Ordovician beds exposed on the western limb of the syncline along Emu Creek, and the thickness of Lower Ordovician rocks exposed on the flanks of the Mount William axis, further to the north, can be placed in their entirety on the eastern side of this syncline. This is the sole reason for suggesting that a strike fault is hidden beneath the basalt near Clarkefield (*vide* section, fig. 6).

Another interesting feature is that the south-south-westerly trend of the Mount William axis points towards Geelong,[25] where diabases similar to those of the Mount William area occur. Whether the Dog Rocks are on a continuation of the Mount William axis remains to be seen.

The south-westerly trend of this area is a feature of more than local significance as lines of similar trend are a feature of South-Eastern Victoria.[19]

Observations on the contact of the Upper and Lower Ordovician rocks are very few in the State.

Teale[15] describes how Upper Ordovician rocks in the Mount Wellington district rest apparently conformably on Upper Cambrian rocks, with no marked stratigraphical break which the palaeontological evidence demanded.

The same author[14] in describing the Howqua River area states:—" It would be unwise in the present state of our knowledge to attempt to mark the boundaries between the different members of the Lower Palaeozoic. We can only note that the succession probably ranges from Cambrian to Silurian, and no unconformity has with certainty yet been recognised in this area."

Howitt[17] in describing the phosphate deposits of the Mansfield Area shows that here Cambrian (?), Lower Ordovician, and Upper Ordovician rocks outcrop. The presence of *Tetragraptus approximatus* (J. Hall) and *Tetragraptus decipiens* T. S. Hall shows the presence of L1 beds. Further to the east, in Allot. 18B, Parish of Loyola, W. Baragwanath found specimens which have been identified by Keble as of Middle Bendigonian age (recorded in Fossil Register of Mines Department). In this area the structure is so confused that no definite conclusion as to the relationship can be reached.

In both the Mansfield and Mount Wellington areas we are dealing with some of the major structural lines of Victoria. Undoubted disconformities are present along these lines, but no structural break, pointing to a period of intensive earth movements followed by a prolonged period of denudation between the Upper and Lower Ordovician, has been recorded. This is in agreement with observations elsewhere in the State.

Another area where Upper and Lower Ordovician rocks occur is to the north of Benambra. Upper Ordovician rocks outcrop on Wombat Creek[6] and at Nariel.[21] The finding of *Phyllograptus nobilis*[27] on the Gibbo Creek shows that Darriwilian rocks are present in this area, but no observer has suggested that there is an unconformity under the one that occurs above the Upper Ordovician rocks. The Mount William anticlinorium is another of the major tectonic lines of the State, and along this the succession of Lower Ordovician rocks is a very attenuated one.

From the evidence available, no diastrophic period has been proved between the Upper and Lower Ordovician periods. The floor of the geosyncline was probably not stationary as the main axial lines of Victoria were being formed, and on these the movements were sufficient to cause attenuation and disconformities. In the intervening areas the process of sedimentation was uninterrupted and a full sequence of the rocks was formed. This would account for apparent breaks in the sequence along the geanticlines where no direct evidence of unconformities have yet been observed.

In the area under discussion the fringe of Darriwilian rocks around the Upper Ordovician rocks that occur in the southerly pitching syncline, the similarity of fossil content in the beds, and the similarity in lithology, all point to the absence of a stratigraphical break between the Lower and Upper Ordovician periods.

6. The Kerrie Series.

The term "Kerrie series" as applied here comprises the Kerrie conglomerates of T. S. Hart[5] and later workers and the associated sandstones, which rest unconformably on the Upper Ordovician rocks and which are intruded by the granodiorites.

(A) Distribution.

These sediments outcrop in three areas—a southern area in the region south of the "Gap" in Sandy's Creek, the central area near Mts. Charlie and Teneriffe, and the northern area along Emu Creek and the Black Range. The granodiorite north of the "Gap," Sandy's Creek, separates the southern from the central outcrop, while the Tertiary anorthoclase trachyte of Mt. Eliza covers the outcrops between the central and the northern outcrops.

The Southern Area.—The boundaries of this area can be roughly defined as granodiorite to the north and north-west, basalt to the south and to the east. A border of Upper Ordovician rocks surrounds the conglomerate on the east and west, but to the south the main body of the conglomerate passes under the basalt.

North of Riddell's Creek the hills are covered with conglomerate. The eastern boundary is not very well marked, as the detritus from the conglomerate on the steep hill slopes covers any rock outcrops. The boundary can be definitely established along Sandy Creek and two of its tributaries, also near the mouth of Conglomerate Gully. The boundary as shown on the map is indefinite, and perhaps should swing further down hill than shown.

At the outcrops near the mouth of Conglomerate Gully is the lowest level of the occurrence of the conglomerates. Their outcrop continues south of Riddell's Creek until hidden by the basalt. A tongue of basalt overlies the conglomerate here.

To the west of Splitters' Track Gully the boundaries are most unsatisfactory. No conglomerate *in situ* is met with until well up the gully, yet a tongue of conglomerate is well shown on the ridge to the west and continues south until hidden by the alluvium in Riddell's Creek.

The conglomerate does not reach Barringo Creek, and is intruded on the north by the granodiorite.

Inside this area massive conglomerates outcrop. To the east of Mt. Robertson and the northern part of Conglomerate Gully to Sandy's Creek no outcrops of conglomerate occur, their place being taken by hard, fairly fine-grained sandstones, very similar lithologically to some of the bands in the Upper Ordovician age. The field evidence, however, shows that these beds overlie the basal conglomerate of the Kerrie series.

The Central Outcrops.—This area is bounded by granodiorite on the south and west, while to the north are the lavas from Mt. Eliza. Running Creek and Charlie's Creek cut through the outcrops of the conglomerates. The geological relationships in the area between Mt. Teneriffe and Mt. Charlie are clear. The basal conglomerate is well developed and coarse, except near Mt. Teneriffe, where it thins out. The unevenness of the floor of Upper Ordovician rocks is well shown, but the upper limit is more uncertain, as there is a gradual transition from coarse conglomerate into sandstone. The conglomerate being hard resists erosion, and the Mt. Charlie ridge is due to its hard resistant nature. Between the conglomerate and the granodiorite exposures are few, and were it not for the stratigraphic position of the sandstones on the hill to the south-west of Mt. Eliza, they could be taken on lithological grounds as belonging to the Upper Ordovician.

The upstream trend of the conglomerate is well shown, pointing to an upstream dip. Actual dip measurements were obtained along the road west of Flume Gully, and in two " wash outs " on the opposite side of the valley.

The conglomerate in several places forms cliffs, and the inhospitable nature of these beds is indicated by the timber. The eastern slope of Mt. Charlie has well developed timber, but on the summits and western slopes along the conglomerate, the vegetation is stunted, the change taking place abruptly.

As is usual with basal conglomerates, they vary a great deal lithologically and in thickness. The conglomerate in places passes rapidly horizontally and vertically into sandstones. The conglomerate in the central area is thickest near the summit of Mt. Charlie, but thins abruptly towards the north. Near Charlie's Creek, where the outcrop is ill-defined, it is about a chain wide, and near Mt. Teneriffe it is not much thicker.

The Northern Outcrop.—This forms the Black Range—a thickly timbered range running in a north-westerly direction from Emu Creek towards Hesket.

Along Emu Creek the conglomerate can be followed as a narrow belt between Emu Creek on the north and the volcanic rocks to the south. Further upstream the conglomerate crosses the creek, and can be traced to the road cutting and then along the range. The north-western end is not clearly shown, but the conglomerate is not seen on the Romsey-Hesket road. A small patch of granodiorite occurs at this end, and is probably continuous with the area further west.

Above the point where the conglomerate crosses Emu Creek are sandstone beds dipping to the south-west at a comparatively low angle, and upstream the metamorphosed breccia-conglomerate is well shown. Resting on this breccia-conglomerate some sandstone beds occur.

(B) Lithology of the Series.

The Kerrie series consists of alternating sandstones and conglomerates which vary rapidly both vertically and laterally. The sandstones are generally brownish in colour, are much indurated, and resemble many of the Upper Ordovician sandstones.

The basal conglomerate is the more massive member of the series, and generally the larger pebbles are well rounded, although the smaller ones are often subangular. It forms, as a rule, a hard cemented mass of pebbles, the largest ones being about 2 feet in diameter. For the most part the pebbles are of quartzite, subcrystalline sandstone, brown micaceous sandstones, and grits, which lithologically and palaeontologically cannot be separated from the grits of the underlying series. Some of these pebbles of grits, as at the Survey locality Ba 74, contain fragmentary shelly fossils such as occur in the Upper Ordovician grits. Where the size of the pebbles as a whole is smaller than usual, they become subangular.

Skeats and Summers[10] (p. 37) have described in detail the mineralogical changes that take place in the conglomerates and sandstones when metamorphosed by the granodiorites, and the slides that have been examined support their conclusions. Some distance away from the granodiorites, however, in areas where the conglomerates appear normal, as along Emu Creek and Bracken Gully, a few feet at the base of the conglomerate and the top of the Upper Ordovician, have been silicified so that the actual contact is masked. A similar phenomenon has been described by A. W. Howitt[4] from the base of the Devonian conglomerates in North Gippsland.

Generally speaking, bedding planes cannot be recognised in the conglomerate, and dips can only be obtained in the finer grained impersistent bands. Where the sandstones are well developed, there is no difficulty on this account. Jointing and shearing are well developed. These pass indiscriminately through pebbles and matrix, giving perfectly flat faces. In some places these are so regular that only on closer inspection is their true character revealed. Slickensided faces are rare and are nowhere well developed. The jointing has a marked effect on the topography in Conglomerate Gully. Tributaries cut along these, and this, coupled with the weathering along softer planes, gives a cliff-like tiered topography.

"Dimpled pebbles" are common. According to Skeats and Summers, the "dimpling" is probably due to solution under pressure of neighbouring pebbles. The abundance of dimpled pebbles in the Kerrie conglomerate and their occurrence in conglomeritic shales in Lower Silurian strata at Springfield[10] and Jackson's Creek, where the dimpled pebbles are not in contact with each other, has given rise to the idea that these pebbles were derived from the Kerrie conglomerate. Dimpled pebbles, however, are not confined to the Kerrie conglomerate. E. J. Dunn[8] reports and figures "dimpled" pebbles from the Stockdale to Dargo road. These are from a Devonian cong'omerate.

Skeats[21] found dimpled pebbles in the Devonian conglomerates at Tabberabbera. In the Geological Survey Museum there are dimpled pebbles from Freestone Creek, Briagolong, of Upper Devonian or Lower Carboniferous age, collected by W. H. Ferguson. A. W. Howitt (personal communication) records them from Wappan, near Maindample. "Dimpled" pebbles are thus of common occurrence in conglomerates. However, no conglomerates older than the Silurian have been found in Victoria, but the dimpled pebbles may have been derived not from the Kerrie conglomerate but from some other source. In this connexion it is interesting to note that igneous pebbles have been found in these Silurian conglomerates, while continued search has failed to reveal any in the case of the Kerrie conglomerate. This points to different sources of origin for the Silurian and the Kerrie conglomerates.

7. Critical Sections.

Five areas where the relationship of the rock groups are well shown will be described:—

(A) Emu Creek-Black Range, near Tye's (Fig. 1).

This has been described by Skeats and Summers[10] and by Harris and Crawford.[16] The road cutting and the creek give two sections almost parallel to each other and along the Romsey water race some exposures are also seen. Lava flows occur south of the creek, which has carved a valley around these. Along and north of the creek Upper Ordovician rocks and the Kerrie series outcrop.

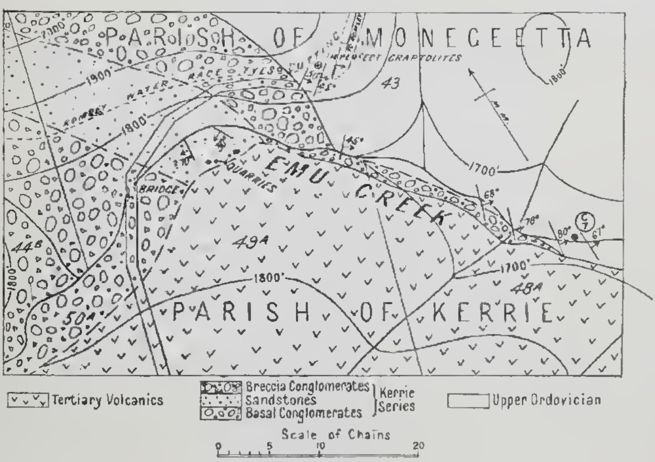

Fig. 1.—Emu Creek—Black Range.

In the road cutting, the Upper Ordovician sandstones are seen. No fossils were found in these, but some blue sandy shales a little below the race yielded some badly preserved *Diplograpti*. They were too badly preserved to be identified with certainty, but from their general appearance look like the Upper Ordovician forms. These rocks strike N.E. and dip S.E. about 50°. Further to the west the conglomerate is well shown. The actual junction is hidden. When traced both up the hill-side and down to the creek, the boundary of the conglomerate is almost at right angles to the strike of the Upper Ordovician rocks.

The belt of conglomerate forms the southern bank of Emu Creek. In the creek the strike of the underlying sandstones is at right angles to the conglomerate. Silicification along the junction of the conglomerate makes it difficult to see the actual junction of the two systems. The creek flows along the conglomerate for some distance, but exposures are not continuous. On the sharp slope to the creek the conglomerate can be seen *in situ*. Where a small creek enters Emu Creek from the south, good exposures of the lava flow and the underlying conglomerate occur. A small patch of Ordovician sandstone lies in the creek bed, and here again the strike would carry these rocks right under the conglomerate. About 2 chains downstream from this point is the last exposure of conglomerate. Below this point only Upper Ordovician sandstones and shales are seen, the latter being very fossiliferous.

Upstream from the point where the conglomerate crosses the creek exposures for a while are poor. Some quarries and small exposures show sandstones. The strike of these is west of north, and the dip is to the south-west at about 30°.

North of the bridge occur good exposures of the altered breccia conglomerate. In this section the Upper Ordovician undoubtedly underlies the Kerrie series with an angular unconformity.

(B) Mt. Charlie-Teneriffe (Fig. 2).

In the area between Mt. Charlie and Mt. Teneriffe, the Running Creek, its tributary Flume Gully, two washouts on the flanks of Mt. Charlie, and a road cutting give good sections.

The physiography is controlled by the hardness of the conglomerate bed and by the granodiorite to the west. The basal conglomerate thins out towards Mt. Teneriffe, and the actual peak is made up of a quartzite of Upper Ordovician age. This passes into a well-defined quartz tourmaline breccia, well shown on the smaller peak S.W. of Teneriffe. The brecciation on this line increases towards the granodiorite. It is a local phenomenon, and is connected with a small fault or crush zone.

The general form of the outcrop is interesting, as it shows a distinct upstream bend. Near the mouth of Flume Gully, along the road cutting, and in the "washouts" to the south-west of Mt. Charlie, the sandstones are well shown. They strike N.N.E. to N.E., and the dip is westerly between 25° and 30°. The passage from conglomerate to sandstones is gradual—nowhere is a sharp demarcation found such as is seen between the Upper Ordovician and the conglomerate. On Mt. Charlie some trenches show the minor folding of the Upper Ordovician, and these are almost at right angles to the conglomerate outcrop. At the same time it should be noticed that the strike of these minor folds does not agree with the general direction of strike over the area. Many of the minor folds in the vicinity have different strikes. The Upper Ordovician rocks are much metamorphosed, and no fossils were found in this area.

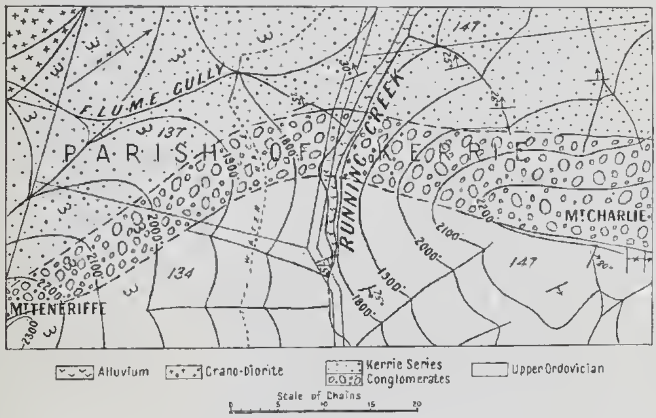

Fig. 2.—Mt. Charlie—Teneriffe.

The relationship of the Kerrie series is thus the same as at Emu Creek.

(C) "The Gap," Sandy Creek (Fig. 3).

The "Gap" is a well-marked physiographic feature. The Sandy Creek valley north of this point is fairly wide. The valley narrows where the line of conglomerate crosses the creek, while downstream the valley widens again. Tongues of grano-diorite intrude and metamorphose the conglomerate and further downstream the Upper Ordovician sediments. These latter consist mainly of quartzose beds, striking north-east with easterly dip. These are well shown as the creek has deeply entrenched itself, and has cut a deep channel through the alluvium. This erosion is recent, and is probably due to cultivation. On the hills to the south it is very difficult to mark with any degree of accuracy the base of the conglomerate, as the hill slopes are covered with debris from the conglomerate. Along some of the gullies this has been taken away for road metal, and along these "dry" gullies erosion is very active. In one of these bedrock has been exposed, thus enabling observations of dip and strike to be obtained.

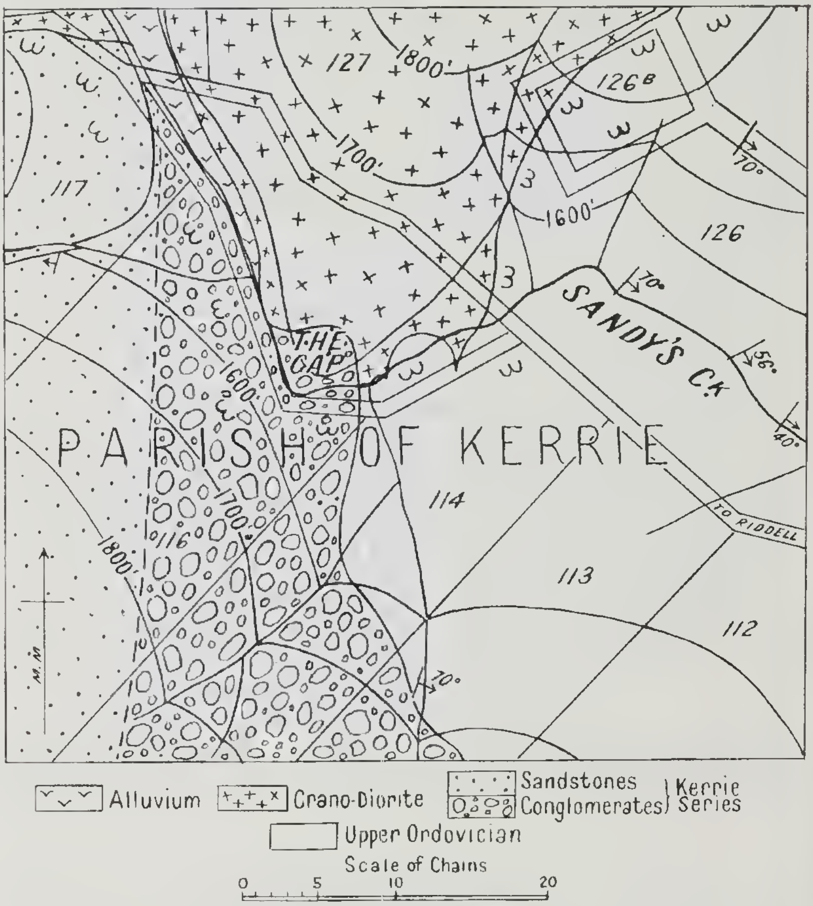

Fig. 3.—"The Gap," Sandy Creek.

(D) Near the Mouth of Conglomerate Gully (Fig. 4).

This area has been described in detail by Harris and Crawford(16) (p. 66), and also by Skeats and Summers, who published a photograph of this section(10) (pl. xxvii.). The south boundary of Allot. 108, Parish of Kerrie, is formed by Riddell's Creek. This creek at the south-east corner of the block flows over basalt, then a small flat is reached. At the western end of this the conglomerate is at creek level. East of the cliff, some vertical shales and mudstones are seen striking north and south, and are interbedded with beds of grit, which can be traced for some distance up the hill. West of the conglomerate cliff vertical grits, shales, and mudstones can be seen underlying the conglomerate. The exact boundaries are rather difficult to see, as hill creep and surface wash nullify accurate observation. The brown mudstones contain thin blue bands in which Harris

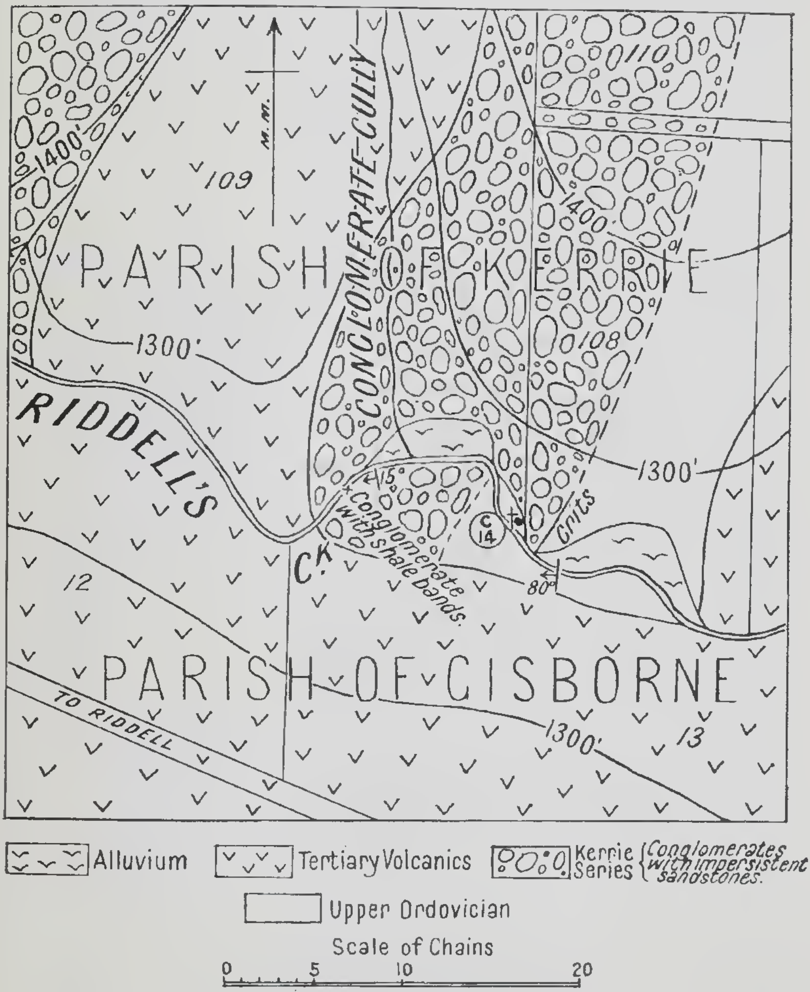

Fig. 4.—Conglomerate Gully.

and Crawford found *Diplograpti* sp. At a subsequent visit *Dicellog. sextans* was found. This fixes the age of the underlying series in this section as Upper Ordovician. A little west of the mouth of Conglomerate Gully, before reaching the patch of basalt which crosses the creek, conglomerates are exposed on the south side of Riddell's Creek. They contain sandy beds, and the dip from these, although not well defined, is south-westerly at 15°, the strike being a little west of north.

(E) Bracken Gully (Fig. 5).

This section was also described in some detail by Harris and Crawford[16] (p. 66) :—" In a small gully west of Conglomerate Creek, grits appear to pass under Kerrie conglomerate. The grits outcrop in the floor of the gully. As the stream is followed northwards a small waterfall is reached. The lower 4 or 5 feet are grit. Above lie impersistent layers of shale, and then the main mass of the conglomerate. The shales on the hillside to the west yielded numerous specimens of poorly preserved *Diplograpti,* and similar fossils are found lower down the gully."

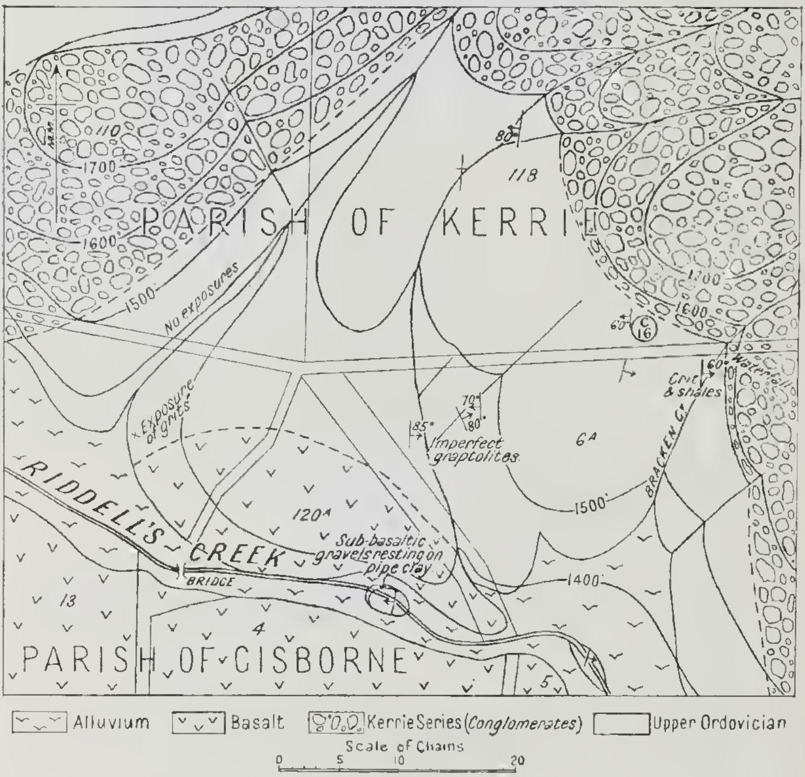

Fig. 5.—Bracken Gully.

The unconformable relationships of the rock groups are clearly shown in this sketch. The Upper Ordovician rocks consist of shales, sandstones and grits, folded at high angles with a general north-south strike. Imperfectly preserved graptolites of undoubted Upper Ordovician age were found in the gully to the west of Bracken Gully and on the ridge between the gullies, a few chains away from the conglomerate, is the locality C/14 mentioned by Harris and Crawford.

The line of outcrop of the conglomerate trends north-west until Splitters' Track Gully is reached. No exposures were seen on the lower course of this creek, yet Kerrie conglomerate is found along the ridge to the west. The boundary is fairly definite on the ridge, and the conglomerate can be seen *in situ* on the sharp slope to Riddell's Creek. This outcrop appears to be a tongue of conglomerate from the main body.

(F) Review.

The similarity in structure, lithology, and geological relationship of the three areas of the conglomerates and associated sandstones shows that they are really one unit. This has been intruded by the granodiorite, &c., which separates the southern from the central outcrop, while the lava flow of Mt. Eliza hides the series between Charlie's and Emu Creeks.

In all cases the Kerrie series rests unconformably on the Upper Ordovician rocks, and they nowhere come in contact with rocks of Lower Ordovician age.

Taken as a whole, the Kerrie series occupies a synclinal basin on the Upper Ordovician rocks. This basin has a north to south axis, and the general slope is to the south. On the northern flanks of the Black Range the base of the series is about 2,000 feet above sea level, and at Emu Creek it is under 1,700 feet, which is the lowest exposed level, while near Conglomerate Gully the observed lowest level is just under 1,300 feet. The highest point reached is just over 2,500 feet at the Black Range. The thickness of the series as taken from the section is between 500 and 1,000 feet.

The exposures along the eastern flank show a decided westerly dip; observations along the western flank are unsatisfactory The surface of Upper Ordovician rocks on which the series rests is very uneven, but from a consideration of the levels of the base of the Kerrie series, there must be an easterly dip in the western area. The observed dips are from 20°-30°, but in the centre of this basin there is a tendency for the dips to be higher. Owing to the smallness of the exposures and the possibility of hill creep, these have not been recorded on the map.

The basal conglomerate of the series is well marked, but varies a great deal in thickness. Near Mt. Robertson this is followed by a series of sandstones. Near the Black Range two conglomerates occur and two thick sandstone beds are present, and it appears as if the upper conglomerate is lens-shaped and passes laterally into sandstone.

8. The Age of the Kerrie Series.

Owing to the incomplete nature of the stratigraphic succession in this area, and the absence of fossils apart from the derived ones in pebbles of the conglomerate, it is difficult to assign an age to the Kerrie series. Two sets of facts give an upper and lower limit to their age. The Kerrie series must be younger than the Upper Ordovician and older than the granodiorite intrusions.

Since the Kerrie series rests with an angular unconformity on the Upper Ordovician rocks, it must be younger than the fold movements which have affected them. Harris and Crawford, on the supposition that the Silurian rocks rest unconformably on the Upper Ordovician, and that the granite intrusions were Lower Devonian in age, suggested a Silurian age for the Kerrie series.

The question of the relationship of the Upper Ordovician and Silurian of this portion of Victoria has yet to be treated in detail. The preliminary statement can be made that there is no evidence of a period of intense earth movements in neighbouring areas in pre-Silurian times, such as could give rise to the angular unconformity at the base of the Kerrie series.

On the northern extension of the Clarkefield synclinorium there are conglomerates similar to the normal interbedded ones that occur in various parts of the State. Nothing approaching the nature of basal conglomerate has been found in the Silurian rocks of the neighbouring areas. It is on evidence such as this that the statement is made that there is no unconformity between the Ordovician and Silurian rocks.

The Kerrie series must thus be younger than Silurian.

The question of the age of granodiorites has undergone a complete change since Ferguson(12) showed that they intruded the Grampian sandstone. A summary of the probable ages of the various intrusions has been given by Skeats.(26) Hills(19, 20) has shown that Upper Devonian sediments are followed by rhyolites on which dacites rest. These dacites are intruded by granodiorites; so that the age suggested for the granodiorites is about the close of the Devonian period. Skeats and Summers(10) have shown that dacites and granodiorites of similar composition occur in the Macedon area, and that the granodiorites metamorphose the dacites. There is thus strong grounds for considering the granodiorites of the Macedon area as of the same as those described by Hills, i.e., they must be post-Upper Devonian in age.

The Kerrie series must, on these grounds, be Devonian in age. To fix the age more definitely presents some difficulties. No sedimentary rocks of Lower Devonian age have yet been found in Victoria, but the Kerrie series presents a strong similarity to beds of Upper Devonian age as described by Howitt.[4] These are described as occupying hollows on a great Palaeozoic rock foundation, and are themselves gently folded.

It is on this close similarity that an Upper Devonian age is suggested for the Kerrie series.

9. The Tertiary and Later Rocks.

The only fossiliferous rocks of sedimentary origin younger than the Kerrie series in this area are the sub-basaltic gravels and sandstones. In Allotment 13, Parish of Kerrie, some basaltic clays with abundant plant remains were found (Loc. C/17). These have been examined by Mr. R. A. Keble, F.G.S., Palaeontologist of the National Museum, who states:—"The moulds of seeds in the sub-basaltic clay from Gisborne are unusually plain and show distinctly the peduncles, the hirsute tests, and some examples, the stigma and portion of the sepals. They may, with confidence, be referred to the genus *Eutaxia*. As there is only one representative of *Eutaxia* in our existing flora, and there is no essential difference between the moulds of the seeds examined and those of *Eutaxia empetrifolia*, the living form, they may be referred to that species." The presence of plants of present-day type beneath the basalts shows how recent are these flows.

Two sets of igneous rocks occur in this area; the granodiorite, granodiorite porphyrites, and dacites, which from evidence elsewhere have been given an Upper Devonian[7] age, and the suite of Tertiary lavas. These have been fully described by Skeats and Summers in their work on the Macedon area.

The only mineral observed in the anorthoclase trachyte of Mt. Eliza not recorded by them is much-resorbed biotite. In several instances the only indications of its former occurrence are rectangular patches of magnetite crystals. Fortunately the change has not proceeded as far in some cases, in which biotite can be identified.

Basalts and rocks approaching basalts in composition, such as the andesitic basalt and the macedonite along Emu Creek, have been treated as one unit on the map, as the relationship of these will be dealt with on a future occasion.

The youngest formation in the area is the deposits of alluvium. Some of these are quite thick, and are due to the basalt flows damming back the streams. At the present day the streams are cutting into these, and along Sandy's Creek over 50 feet of alluvium is exposed.

10. Summary of Geological History.

1. Deposition of Cambrian and Ordovician Rocks.
2. Intense folding of these rocks, their uplift and erosion after the close of the Silurian period.

3. Deposition of the Kerrie series on an uneven surface of Upper Ordovician age.
4. Gentle Folding of the Kerrie conglomerate probably at the close of the Devonian period.
5. Igneous activity in post-Upper Devonian times—the dacites being intruded by the later granodiorites.
6. A period up to Tertiary times of which no evidence has been preserved in this area.
7. A renewal of igneous activity in Tertiary times. This necessitated extensive alterations in the drainage system. Many temporary lakes were formed in which alluvium was deposited. No attempt has been made to work out the Tertiary geology in detail.

11. Acknowledgments.

My thanks are due to Mr. W. Baragwanath, Director of the Geological Survey, for much helpful advice and criticism and for permission to present this paper. The excellent plans are the work of the Geological Survey Draughting Branch. The various members of the Survey have always been ready to help, and have assisted me in many ways. The duties of chainman were carried out by Mr. T. Plews, and without his active co-operation this rough area could not have been mapped.

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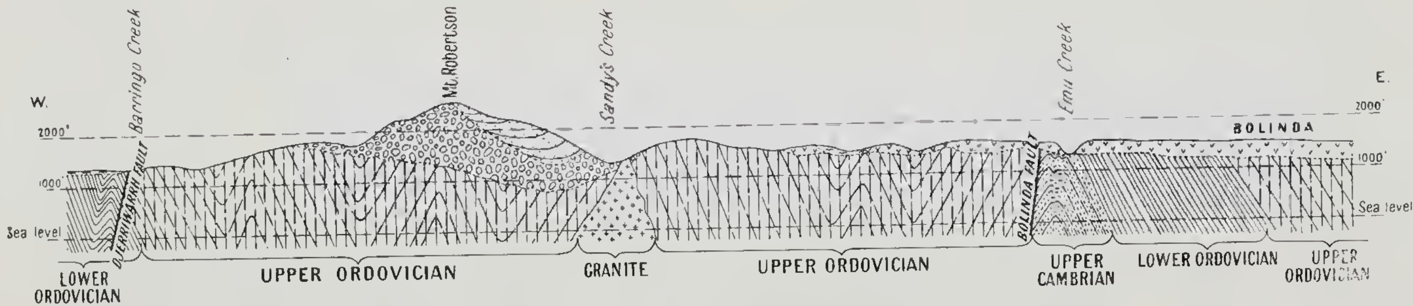
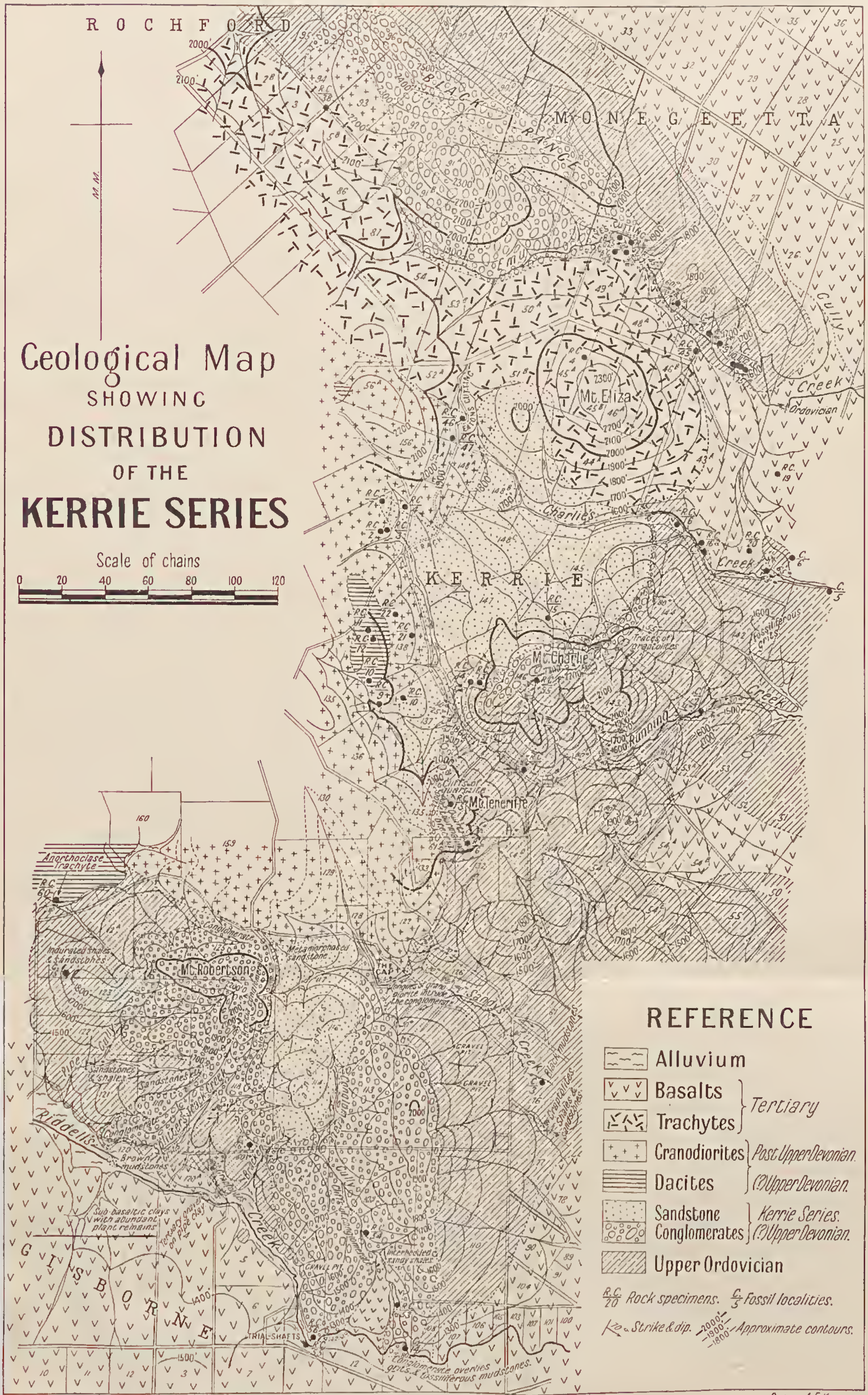


Fig. 6.—Diagrammatic section from point N. of Gisborne through Mt. Robertson to Bolinda to show the relationship of the rock groups. Length of section, 8 miles.



Geologically & topographically surveyed by D E Thomas, B.Sc., Mines Department Victoria 1931.

Drawn A.E.K.

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[PROC. ROY. SOC. VICTORIA, **44** (N.S.), PT. II., 1932.]

ART. XXIII.—*Studies in Australian Tertiary Mollusca, Part I.*

By F. A. SINGLETON, M.Sc.

(Department of Geology, University of Melbourne).

(With Plates XXIV.–XXVI.)

[Read 10th December, 1931; issued separately 20th April, 1932.]

It is hoped to contribute from time to time, under the above title, descriptions of new species and comments upon others already named but as yet insufficiently known.

In the present part, confined to Pelecypoda, the following new names are proposed:—

Nucula kalimnae, sp. nov.

Glycymeris (*Grandaxinaea*) *granti*, sp. nov.

Limopsis chapmani, sp. nov.

Limopsis chapmani valida, subsp. nov.

Cucullaea corioensis praelonga, subsp. nov.

In addition to illustrations of the above, figures are given of portions of the type material of *Cucullaea corioensis* McCoy and *C. adelaidensis* Tate, of topotypes of *Nucula tenisoni* Pritchard and the Patagonian *Limopsis insolita* (G. B. Sowerby), and of a Victorian plesiotype of the Recent *Nucula obliqua* Lamarck.

I am under obligations to the Directors of the Australian Museum, Sydney; the National Museum, Melbourne; and the South Australian Museum, Adelaide; and to Messrs. T. Iredale, R. A. Keble, and B. C. Cotton, of these institutions, for the opportunity of examining specimens in their care; to Sir Douglas Mawson and Mr. C. T. Madigan for the loan of the type series of *Cucullaea adelaidensis* from the Tate Collection, in the Geological Department of the University of Adelaide. To Messrs. F. Chapman, F. A. Cudmore, J. H. Gatliff, C. J. Gabriel, and G. Cox, I am greatly indebted for their generosity in placing at my disposal the whole of the material in their private collections, and to Miss J. Wilson Smith and Mr. J. S. Mann for the photographs. Dr. G. B. Pritchard and Mr. F. S. Colliver have also kindly lent specimens for measurement.

Class PELECYPODA.

Family NUCULIDAE.

Genus **Nucula** Lamarck, 1799.

Nucula Lamarck, Mém. Soc. Hist. Nat. Paris, p. 87, 1799.

Type (by monotypy): *Arca nucleus* Linné. Recent, Europe.

Subgenus **Nucula**, s. str.

Section **Ennucula** Iredale, 1931.

Ennucula Iredale, Rec. Aust. Mus., xviii. (4), p. 202, June 29, 1931.

Type (by original designation): *Nucula obliqua* Lamarck. Recent, Tasmania and Victoria.

Nucula tenisoni Pritchard, 1896.

(Pl. XXIV., Figs. 1–5.)

Nucula tumida T. Woods, 1877, p. 111. Not "*Nucula tumida* Tenison-Woods," Tate, 1886, p. 127, pl. vi., figs. 6*a*, *b* (= *N. kalimnae*, sp. nov.) Not *Nucula tumida* Phillips, Illustr. Geol. Yorkshire, pt. ii., p. 210, pl. v., fig. 15, 1836; nor *N. tumida* Hinds, P. Z. S. Lond., pt. xi. for 1843, p. 98.

Nucula tenisoni Pritchard, nom. mut., 1896, p. 128. Harris, 1897, p. 347.

"*Nucula obliqua* Lamarck," Chapman and Gabriel, 1914, p. 301. May, 1919B, p. 102. Chapman and Singleton, 1927, p. 113. Not *Nucula obliqua* Lamarck, Hist. Nat. Anim. s. Vert., vi. (1), p. 59, 1819.

Description by T. Woods, 1877.—"Shell small, solid, obliquely trigonal, tumid, truncated anteriorly, slightly produced and rounded posteriorly, finely wrinkled with consecutive irregular rounded ribs, increasing in thickness from umbones to margin, and irregularly grooved with deep consecutive lines of growth, margin thickened and bilabiate, hinge teeth small, diverging progressively in an increasing series, interrupted by a narrow deep ligamental pit, largest teeth slightly bent, anterior row short, eight in number, the distal ones smaller, but all high and lamellar, umbones fine and sharply incurved; lunule shallow but well defined, wrinkled and broadly lanceolate. Transverse long. 13, lat. 11; thickness of both valves united, 8 mill. Not unlike the Tasmanian *N. grayi*, Sow., but more tumid and conspicuously sulcate."

Type Locality.—Cliffs between Table Cape and Wynyard, North-west Tasmania. Janjukian (Miocene ?).

Type Material.—In the Tasmanian Museum, Hobart (?).

The type specimen has never been figured, and despite the amount that has been written concerning the species, it has remained unillustrated. Figures are therefore offered of topotypes from the Table Cape section, where it is not uncommon in the lower or "Crassatella" bed.

The identity of the fossil *Nucula tumida* Tenison-Woods with the living Tasmanian and Victorian species, known erroneously as *N. grayi* d'Orbigny and now as *N. obliqua* Lamarck, has been affirmed by Pritchard (1896, p. 129) and by Hedley (1902, p. 292) with the concurrence of Etheridge, and denied by Woods (1877, p. 112), Tate (1886, p. 127), and Iredale (1929, p. 158). Chapman and Gabriel (1914, p. 301) and Chapman and Singleton (1927, p. 113) noted distinctions, but did not allow them specific or sub-specific rank, while the synonymy has been accepted by Harris (1897, p. 347), who lacked sufficient material to form an independent opinion, Pritchard and Gatliff (1904, p. 238), Verco (1907, p. 216) and May (1919B, p. 102), though the South Australian Recent shell dealt with by Verco has since been differentiated as *N. obliqua subdilecta* Iredale (1929, p. 158). Woods's statement that the fossil was "more tumid and conspicuously sulcate" has been confirmed by Tate, whereas it appeared to be usually less inflated and more elongated to Chapman and Singleton, and to Iredale who, writing of *N. obliqua,* states that "the fossil *N. tenisoni* Pritchard is a much larger, crass, and more elongate shell, also much less obese at the same size than the typical south Tasmanian shell, which has also much longer teeth." Iredale has, however, evidently made his comparison with the description and figure furnished by Tate (1886, p. 127, pl. vi., figs. 6*a*, *b*), under the name of *N. tumida* Tenison-Woods, of a shell from Muddy Creek, which is referable to the new species herein described as *Nucula kalimnae.* Tate gives the dimensions of his shell as 21 × 16 × 14 mm. (paired valves), while topotypes of *N. tenisoni* do not exceed the 15.5 × 11.2 × 9.1 mm. of the paired valves figured, or less than *N. obliqua* from Port Phillip, Victoria, which may attain 15.8 × 12.3 × 10.6 mm. (C. J. Gabriel Coll.).

It is difficult to come to any conclusion as to the teeth of *N. tenisoni* owing to the gritty matrix in which the fossils are preserved, none of a long series of topotypes available in the Dennant and Cudmore Collections having a perfectly preserved and exposed hinge, but perfect teeth do not appear to be any shorter than those of the Recent species. *N. tenisoni* is variable both in inflation and in elongation, the paired valves figured (Fig. 3), 15.5 × 11.2 × 9.1 mm. (through pair), being fairly typical, while the left valve (Fig. 4), 13.7 × 10 × 3.4 mm. (single valve) is decidedly more depressed. Younger shells (Figs. 1, 2) are relatively shorter, thus approaching the living *N. obliqua* (Figs. 6*a*, *b*), which measures 14 × 11.2 × 8.4 mm. (paired valves). The concentric folds and sulci towards the ventral margin are also variable in their degree of development, being most conspicuous in the more tumid shells, as in the figured left valve (Fig. 1) and in a larger right valve (unfigured) from the same locality in my own collection, measuring 14 × 10.8 × 4.2 mm. The hinge teeth of *N. tenisoni* (Fig. 4) number 7 posterior and 20 anterior, of which 8 small ones are above the chondrophore, and in *N. obliqua* (Fig. 6*b*) 7 posterior and 21 anterior, of which 6 very small teeth are above the chondrophore, which is not so wide or conspicuous as in the fossil. The dimensions given by Woods indicate a shell even less elongate than the *N. obliqua* here figured, and certainly not more tumid than it.

Nevertheless, it appears desirable to separate the Table Cape shells under the name of *Nucula tenisoni* Pritchard, nom. mut. for *N. tumida* T. Woods, preoccupied. Compared with the Recent *N. obliqua* they are relatively longer in the gerontic stage, and are more sulcate near the ventral margin, but do not appear to be more tumid, and in some cases are considerably less so.

Balcombian shells are of the relatively depressed type, and are more produced posteriorly, making the umbonal angle more obtuse, while the concentric folds on the ventral margin are much weaker. The dimensions of the right valve from Grice's Creek (Figs. 5*a, b*) are 14.3 × 10 × 3.6 mm. This appears to be a deeper water variant bearing to topotypes of *N. tenisoni* a relation analogous to that between *N. obliqua subdilecta* and *N. obliqua*, s. str. In view of the variation in the Table Cape shells it seems undesirable at present to propose subspecific distinction for the Grice's Creek form, which is common in clays at several Balcombian and Barwonian localities.

In its smooth inner ventral margin, oblique chondrophore, and hinge dentition, *N. tenisoni* agrees with *N. obliqua*, genotype of *Ennucula* Iredale (1931, p. 202), but these characters, shared, amongst Australian fossil species, by *N. brevitergum* Chapman and Singleton (1927, p. 114, pl. x, figs. 1*a, b*) and *N. kalimnae*, sp. nov., seem of sectional rather than of generic importance. The last-named species sometimes shows a very obscure marginal crenulation, while the Recent Queensland *N. superba* Hedley (1902, p. 292), of similar hinge characters, has in the adult a microscopically crenulated ventral border.

Nucula kalimnae, sp. nov.

(Pl. XXIV., Figs. 7–9.)

"*Nucula tumida* Tenison-Woods," Tate, 1886, p. 127, pl. vi., figs. 6*a, b*. Not *Nucula tumida* T. Woods, 1877, p. 111.

Holotype.—Shell relatively large, heavy, subovate, posteriorly truncate, very inequilateral, moderately inflated; umbo at seven-eighths of length from anterior; posterior margin short, slightly insinuate, truncating the gently curved ventral margin, anterior margin strongly curved: surface smooth except for lines of growth and weak concentric ridges towards ventral margin; hinge heavy, gently arcuate anterior to umbo, more linear posteriorly; anterior series of 28 slightly uncinate teeth, regularly decreasing in size above the prominent oblique chondrophore, posterior series of 10 broad, slightly curved teeth, becoming lamellate and closely appressed towards umbo; interior nacreous, adductor scars rounded, impressed, the posterior larger, pallial line distinct, below this are developed fine radial striae, giving rise to obscure crenulations on the inner ventral margin, about 12 in a space of 10 mm., only visible under oblique lighting.

Length 20.5; height 15; thickness (right valve) 6.5 mm.

Paratypes.—A single valve and pair from the upper beds at Muddy Creek are somewhat less heavy and inflated than the Gippsland Lakes holotype, which is more inflated umbonally. They are also relatively longer and less abruptly truncated posteriorly, but in other characters agree well. Hinge teeth number 26 and 9 in the two series in the single valve, in which the internal striation is visible adjacent to the pallial line, but the crenulation of the valve margin cannot be seen. The more perfectly preserved external surface of both paratypes shows an exceedingly fine radial striation which cannot be recognized in the holotype.

Length 19; height 13.5; thickness (right valve) 5.4 mm.

Length 19; height 13.8; thickness (paired valves) 11.1 mm.

Type Locality.—Cutting on main road above bridge, Jemmy's Point, Kalimna, Gippsland Lakes, Eastern Victoria. Kalimnan (Lower Pliocene). Paratypes from upper beds, Muddy Creek (probably MacDonald's), Western Victoria. Kalimnan (Lower Pliocene).

Type Material.—Holotype (pl. xxiv., figs. 7*a*, *b*), right valve, No. 1312, and paratypes (pl. xxiv., figs. 8*a*, *b*, 9), right valve and pair, Nos. 1313-4, in Melb. Univ. Geol. Dept.

This species has hitherto been regarded as a very robust form of the Recent *Nucula obliqua* Lamarck, which may readily be distinguished by its less elongate form as well as by its lesser solidity at all stages. The Recent shell is more arched anterior to the umbo, is never marginally crenate, and does not attain the size of the fossil species.

The latter is, however, more closely related to the Janjukian *N. tenisoni* Pritchard, from which it is probably derived, the Muddy Creek (upper beds) form showing a greater resemblance to it than do topotypes from Kalimna. The Table Cape species is usually conspicuously sulcate towards the ventral margin, and, although a littoral shell at the type locality, never attains the solidity or size of the Kalimnan shell, which is also the longer at corresponding sizes, so that specific rather than subspecific distinction appears desirable.

Werrikooian (Uppermost Pliocene ?) shells from the Glenelg River, Western Victoria, though variable, are referred to *N. kalimnae*, which is by far the largest of the Australian Tertiary Nuculas. The differences between the Gippsland Lakes and the Muddy Creek shells, though characteristic of the two areas, do not appear to be of sufficient magnitude to warrant their separation. It is to be noted that the obscure marginal crenulations, though definitely present in the holotype, are only preserved under most favorable conditions, so that in the great majority of specimens the valve margins appear to be smooth.

Family ARCIDAE.

Genus **Glycymeris** Da Costa, 1778.

Glycymeris Da Costa, Hist. Nat. Test. Brit. or British Conch., p. 168, 1778.

Type (by tautonymy, Dall, Trans. Wagner Inst. Sci. iii. (4), pp. 572, 607, 1898): *Glycymeris orbicularis* Da Costa = *Arca glycymeris* Linné. Recent, Europe.

Subgenus **Grandaxinaea** Iredale, 1931.

Grandaxinaea Iredale, Rec. Aust. Mus., xviii. (4), p. 202.

Type (by original designation): *Glycymeris magnificens* Iredale. Recent, New South Wales.

Glycymeris (Grandaxinaea) granti, sp. nov.

(Pl. XXIV., Figs. 10, 11.)

Holotype.—Shell large, not heavy, subcircular, equilateral, moderately convex; umbo opisthogyrate, relatively small; dorsal margin fairly short, gently curved, anterior and ventral margins regularly rounded, posterior margin subangulate; sculpture of 37 slightly curved radiating ribs, narrower and more acute posteriorly, but obsolescent towards dorsal margin, in neanic stage rounded with linear interspaces, in ephebic stage subangular with well defined rounded interspaces, narrower than the ribs, crossed by fine well marked lines of growth which form laminae continuous over ribs and interstices; growth stages well marked, about 12 in number; hinge line nearly straight centrally, arched at either end; hinge teeth strong, linear to uncinate, obliterated medially by area, leaving 6 teeth in anterior and 8 in posterior series; ligamental area fairly long and high, with fine divergent striae, 10 in a space of 3½ mm.; inner margin denticulate ventrally, becoming obsolete at either side; adductor scars large, anterior subtrigonal, posterior obovate, buttressed anteriorly.

Length 58; height 56; thickness (left valve) 15 mm.

Paratype.—In neanic stage, with anterior and posterior dorsal margins relatively more prominent and flattened; umbo small but prominent; radial ribs 40, counting the obsolescent dorsal ones; ligamental area low, with 4 striae; 10 teeth on either side; ridge on anterior side of posterior adductor scar continued towards umbo; inner margin planate at either end of cardinal area, ventrally crenulated by prominent acute denticulae.

Length 35; height 34; thickness (right valve) 8½ mm.

Type Locality.—Lower beds, Muddy Creek, Western Victoria. Balcombian (Oligocene ?).

Type Material.—Holotype (pl. xxiv., figs. 10*a, b*), left valve, No. 1315, and paratype (pl. xxiv., fig. 11), right valve, No. 1316, in Melb. Univ. Geol. Dept.

Glycymeris granti is at present represented only by two examples from the valuable collection recently presented to the University of Melbourne by F. H. McK. Grant, of Woodend, Victoria, in which, with a third specimen here identified as *G. gunyoungensis* Chapman and Singleton, they were labelled as "*Pectunculus McCoyii* R. M. Johnston".

The present species is most closely related to the Janjukian *G. ornithopetra* Chapman and Singleton (1925, p. 32, pl. ii., figs. 9*a, b*), which is more convex, heavier, and with shorter hinge line and subangular rounding of the ventral border. In the new species the ribs are more acute, rendering the interspaces more prominent, while the ventral margin is evenly rounded as in the Janjukian *G. maccoyi* (Johnston), which has much fewer and more rounded ribs, and fewer and heavier hinge teeth. *G. granti* has evidently given rise to both these Janjukian species, having the shape of *G. maccoyi* and the ornament of *G. ornithopetra,* which latter in its neanic stage closely resembles the much larger adult *G. granti,* suggesting recapitulation of ancestral characters.

The Balcombian (Oligocene ?) *G. granti* is thus the earliest member of the lineage represented in the Janjukian (Miocene ?) by *G. maccoyi* and *G. ornithopetra,* and in the Recent fauna by *G. magnificens* Iredale (1929, p. 161, pl. xxxviii., figs. 1, 2), described from 50-60 fathoms off Montague Island, Southern

New South Wales, which is closely related to *G. ornithopetra*, but attains a much larger size, 97 × 106 mm., than the fossil, which does not exceed about 70 mm. in either dimension.

Iredale has recently (1931, p. 202) erected for *Glycymeris magnificens* a new genus *Grandaxinaea*, which, in view of the antiquity of the lineage, is here accorded subgeneric status, though otherwise it would be regarded only as a section. The Pliocene history of the lineage in Australia is unknown, unless it is represented by a fragmentary Kalimnan shell in the Commonwealth collection from a boring in the Gippsland Lakes district, Eastern Victoria, while it does not occur in the Werrikooian fauna of the Glenelg River in Western Victoria.

Grandaxinaea appears to be represented in New Zealand by the Recent and Pliocene *Glycymeris laticostata* (Q. & G.), the Awamoan (Miocene) *G. traversi* (Hutton) and in beds of probably similar age at Campbell Island by *G. chambersi* Marshall. Marwick (1924, p. 320) has indicated that *G. laticostata* was not directly derived from Australian forms, and if the small Waiarekan (Oligocene) species *G. lornensis* Marwick (1923, p. 66, pl. i., figs. 4, 9) be referable to the same subgenus, then the separation of the Australian and the Neozelanic forms must date back at least to early Tertiary times. *G. lornensis*, however, may be more closely related to the Janjukian *G. subtrigonalis* (Tate), which in turn bears some relation on the one hand through *G. gunyoungensis* Chapm. and Singl. to the *granti-ornithopetra-magnificens* series, and on the other to the Kalimnan *G. decurrens* Ch. and S., and the Recent *G. sordida* (Tate) and *G. insignis* Pilsbry.

Family LIMOPSIDAE.

Genus **Limopsis** Sassi, 1827.

Limopsis Sassi, Giorn. Ligustico di Scienze, etc., i., p. 476, 1827.

Type (by subsequent designation, Gray, Proc. Zool. Soc. Lond., pt. 15, p. 198, 1847): *Arca aurita* Brocchi. Miocene and Pliocene, Italy.

Limopsis chapmani, sp. nov.

(Pl. XXIV., Figs. 12-14; Pl. XXV., Fig. 16.)

"*Limopsis aurita* (Brocchi)," McCoy, 1875, p. 23, pl. xix., figs. 5, 6, 6*a*, *b*, 7. Tate, 1885, p. 212; 1886, p. 134. Johnston, 1888, pl. xxxii., fig. 7 (poor fig.). Not *Arca aurita* Brocchi, Conchiologia Fossile Subapennina, p. 485, pl. xi., fig. 9*a*, *b*, 1814.

"*Limopsis insolita* (G. B. Sowerby)," Tate, 1886, p. 134. Harris, 1897, p. 344. Chapman, 1911, p. 425, pl. lxxxiv., fig. 5; pl. lxxxv., fig. 11. Not *Trigonocoelia insolita* Sowerby, in Darwin, Geol. Obs. S. Amer., p. 252 (2nd ed., p. 608, 1876), pl. ii., figs. 20, 21, 1846.

Holotype.—Shell heavy, obliquely ovate, moderately convex, especially in earlier stages; umbo anterior, small, acute and incurved; dorsal margin short, slightly shouldered at either end, anterior and ventral margins regularly rounded, meeting with a slight angulation the more linear posterior margin, which is slightly concave below the end of the hinge; sculpture of numerous closely spaced flattened concentric ridges, subcircular in neanic and more oblique in ephebic and gerontic stages, strongly laminate towards the ventral margin, where they are from 0.6 to 1.2 mm. in width; these are ornamented by slightly undulate lines of growth and by fine slightly irregular radiating grooves, about 18 in 10 mm., not crossing the laminae; between the radiating striae the laminae are shallowly pitted towards their ventral edges, giving rise to an appearance of bifurcation of the radial ornament; hinge line arched, relatively high, bearing 8 anterior and 8 posterior teeth of unequal size, the anterior mostly flattened, the posterior more hooked; ligamental area high, slightly vertically concave, faintly longitudinally grooved; ligament pit large, prominent, with undulous lines of growth, broadly triangular, with sub-umbonal angle about 96°, sides concave, encroaching on hinge teeth; inner margin smooth, strongly and broadly planate, especially at postero-ventral margin; anterior adductor scar small, narrowly ovate, with prominent posterior ridge, posterior scar large, broadly ovate, pallial line simple, well marked, above which interior of shell is faintly and finely radially striate.

Length 20.3; height 21.1; thickness (paired valves) 10.9 mm.

Paratypes.—Two neanic valves which show the greater inflation characteristic of this stage, with nearly subcircular outline in the smaller example and a roundly subtrigonal outline in the larger, which is longer than high; anterior and posterior teeth 8–6 and 9–7 respectively; sub-umbonal angle of the more acute ligament pit 80° and 77°; other characters as in holotype.

Length 16.9; height 15.9; thickness (right valve) 4.9 mm.

Length 13; height 13; thickness (right valve) 3.8 mm.

Type Locality.—Lower beds, Bird Rock Cliffs, near Spring Creek, Torquay, Victoria. Janjukian (Miocene ?).

Type Material.—Holotype (pl. xxv., figs. 16*a, b, c*), right valve of pair, No. 1317, and paratypes (pl. xxiv., figs. 12, 13), right valves, Nos. 1318-9, in Melb. Univ. Geol. Dept.

The description and figures given by McCoy under the name of *Limopsis aurita* (Brocchi) are evidently of Spring Creek examples of the present species, while topotypes have also been figured by Chapman, who defined the distinctions from the European species, but accepted its identity with the Patagonian

L. insolita (Sowerby). While this latter species was originally described as smooth, Ihering (1897, p. 235) has described a well preserved example as having " numerosos sulcos finos um pouco ondulados, formando costas numerosas e finas, 4–5 no espaço de um millimetro," and Ortmann (1902, pp. 91, 92) has confirmed Ihering's statement that the ornament is seen only in very well preserved specimens, the majority of the 175 topotypes studied by Ortmann being apparently smooth.

By the kindness of the Director of the Australian Museum I am enabled to figure two topotypes from Ortmann's series, of which the larger gerontic example (fig. 18), 23.3 × 24 × 6.8 mm. (single valve), shows well the external sculpture, not hitherto illustrated, of depressed undulating costae with much narrower, almost linear interspaces, crossed by fine concentric growth lines. The ephebic example (fig. 15), 16.7 × 16.4 × 4.2 mm. (single valve), represents the commoner less perfectly preserved condition, with concentric ornament only, save for traces of radial grooves, which are more noticeable umbonally. The example of *L. insolita,* which I have before me, on which Chapman (1911, p. 428) based his remarks, is even more poorly preserved, and the radial striae on the posterior angle appear to be part of the typical ornament of the species and do not, in my opinion, show the pseudo-divergent character suggested by Chapman and characteristic of the Australian species. It is certain that if he had had the better preserved material now available to me, Chapman would not have accepted the identity of the two forms, and it is with great pleasure that I dedicate to him the abundant and characteristic Janjukian species. In addition to the striking differences in sculpture, well shown in the figures, *L. chapmani* differs from *L. insolita* in its more trigonal shape, less obliquity at corresponding stages, shorter and less shouldered dorsal margin, evenly rounded anterior margin, more curved hinge line, bearing higher but less numerous teeth, and narrower and less obtusely angled ligament pit in similar sized shells.

Tate (1886, p. 134) accepted McCoy's identification of Spring Creek shells as *L. aurita,* but referred examples from Aldinga, S.A., to *L. insolita.* These South Australian shells, of which a gerontic specimen is illustrated (fig. 14), 26.7 × 34.8 × 9 mm. (single valve), attain a much larger size than do topotypes of *L. chapmani,* with frequently a broader ligament pit in the largest examples and always an almost obsolete ornament, so that they more closely simulate excorticated specimens of the Patagonian species. By their regularly curved anterior borders and the faint pitted ornament between the concentric striae they are, however, to be referred to *L. chapmani.*

Iredale (1931, p. 204) has named a shell trawled in deep water off the southern coast of New South Wales *Senectidens dannevigi,* gen. et sp. nov., and stated it to agree in general with *Limopsis insolita.* Until the genotype is figured and the extremely meagre description amplified, it is not possible to express an opinion as to the relation of *L. chapmani* to Iredale's proposed new genus.

Limopsis chapmani valida, subsp. nov.

(Pl. XXV., Fig. 17.)

Holotype.—Agreeing in characters with *L. chapmani,* s. str., except that shell is more tumid, posterior margin is angulate (145°) above the junction with the ventral margin; concentric laminae, growth lines, and pseudo-divergent radial striae are all much more valid; bevelled inner margin is wider; ligament pit is more acute (88°), encroaching more on the hinge teeth, which are 9 in both anterior and posterior series.

Length 19.1; height 20.2; thickness (right valve) 5.8 mm.

Type Locality.—Birregurra, Victoria. Janjukian (Miocene ?).

Type Material.—Holotype (pl. xxv., figs. 17*a, b, c*), right valve, No. 13673, in Nat. Mus., Melb.

This subspecies, which is represented by the type and a second specimen from Birregurra in the Dennant Collection, where they were labelled *L. insolita* var., differs from the Spring Creek form in the opposite direction to that of the nearly smooth Aldinga shells. The present form, which is readily distinguished by its strongly developed sculpture, is not yet known from any other locality.

Family PARALLELODONTIDAE.

Genus **Cucullaea** Lamarck, 1801.

Cucullaea Lamarck, Syst. Anim. s. Vert., p. 116, 1801.

Type (by monotypy): *Cucullaea auriculifera* Lamarck = *Arca labiata* Solander. Recent, China. The same species, of which *Arca concamera* Bruguière is a synonym, was designated as genotype under the name of *Arca cucullata* Chemnitz by Fleming, Ency. Brit., iii., p. 306, 1818 (*fide* Winckworth, Proc. Mal. Soc. Lond., xviii. (5), p. 226, July, 1929).

Cucullaea corioensis McCoy, 1876.

(Pl. XXVI., Fig. 19.)

Cucullaea corioensis McCoy, 1876, p. 32, pl. xxvii., figs. 4, 5 (*non* 3, 5*a*). Tate, 1886, p. 144. Johnston, 1888, pl. xxix., figs. 4, 4*a*. Harris, 1897, p. 336. Chapman and Gabriel, 1914, p. 302.

Lectoholotype.—Shell moderately large, heavy, obliquely trapezoidal, inequilateral, very tumid, thickness (through one valve) 43% of length; left valve slightly overlapping right; umbo large, prominent, strongly incurved, with a shallow median radial depression; dorsal margin straight, making an angle of 110° with the evenly rounded anterior margin, which passes into the nearly straight but slightly insinuate ventral margin, making an angle of 25° with hinge line, and joining by a rounded angle the somewhat undulating posterior margin, which in turn makes an angle of 103° with the dorsal margin; posterior slope steep, flattened to slightly concave, separated from the moderately convex remainder of shell by an obtusely rounded ridge from umbo to postero-ventral angle; sculpture in neanic stage of fine radiating ridges, about 3 per mm. at 8 mm. from umbo, wider than interspaces, and somewhat granulose at intersections with the fine, regular concentric lines of growth; at about 10 mm. from umbo a longitudinal groove appears centrally in the radial ribs, which are thus doubled in number and become in the ephebic stage flattened radii, about 18 in 10 mm. at centre of surface, with narrow sulcate interspaces; the radial ribbing is crossed by fine closely spaced growth lines, with undulations on the ribs directed ventrally, becoming concentrically wrinkled in the gerontic stage, when the radii are obsolescent; ornament on right valve rather coarser than on left, with undulating concentrics becoming squamose towards ventral margin; growth stages more prominent on ventral slope, which is steeper than remainder of shell; hinge line straight, seven-tenths of total length of shell, with umbo anterior, at three-sevenths of length of hinge; hinge teeth four in anterior and in posterior series, longitudinal, laminar, with rugose upper and lower surfaces, central series small and transverse, largely obliterated by area; ligamental area broad, flattened, 4½ mm. high, with four irregular deep divaricating furrows; inner ventral margin denticulate; anterior adductor scar scalene, posteriorly ridged, posterior scar subquadrate, elevated into plate anteriorly; pallial line well marked, interior of shell radially lineate.

Length 48; height 42½; thickness (paired valves) 41 mm. Length anterior to hinge 3, of hinge 37, posterior to hinge 8: maximum height of hinge from ventral border 35 mm. Ratio of anterior to posterior portion of hinge 0.76.

Lectoparatype.—A gerontic valve of similar character, thickness 44% of length; dorsal margin truncating anterior and posterior margins at 128° and 118°, ventral margin making an angle of 24° with hinge line; hinge teeth four in anterior and in posterior series; ligamental area 5 mm. high, with four oblique furrows anteriorly, the posterior series interrupted; denticulae of inner margin extending to anterior and posterior borders.

Length 63.5; height 56; thickness (left valve) 28 mm. Length anterior to hinge 6.5 of hinge 43, posterior to hinge 14; maximum height of hinge from ventral border 46 mm. Hinge ratio 0.87.

Type Locality.—(Here designated) Geol. Surv. Vic. Locality A^{d}23, Bird Rock Cliffs, near Spring Creek, Torquay, Victoria. Janjukian (Miocene ?).

Type Material.—Lectoholotype (here selected), McCoy's Fig. 4 (pl. xxvi., figs. 19*a, b*), paired valves, No. 12236; and lectoparatype, McCoy's Fig. 5, right valve, No. 12237, in Nat. Mus., Melb.

There is considerable variation in respect to outline and obliquity of the ventral margin, which makes angles of 6°-25° with the hinge line, but is usually fairly oblique; these variations co-exist at the one locality, and do not appear to be purely a function of size, though younger shells are commonly more quadrate. Chapman and Gabriel (1914, p. 302) have recorded the occurrence in some cases of dorsally instead of ventrally directed undulations of the growth lines where they cross the riblets. This is occasionally to be seen, usually on the left valve, but does not seem of significance. In other cases the growth lines are practically straight.

Cucullaea corioensis has been regarded as ranging through the four stages of the Victorian Tertiary, but the Werrikooian (Uppermost Pliocene ?) record is based on an example in the Dennant Collection from the Glenelg River near Limestone Creek, which is almost certainly derived from the Barwonian clays of the vicinity. It is of the thinner, deeper water form of the species, contrasting strongly with the heavy shallow water shells of the Werrikooian fauna of the district. The Kalimnan (Lower Pliocene) specimens are here separated subspecifically, in part on the posterior position of the umbo, so that *C. corioensis*, s. str., is confined to the Barwonian, comprising the Balcombian (Oligocene ?) and Janjukian (Miocene ?). Balcombian shells from Mornington are notable for the usually markedly anterior position of the umbo and their smaller and thinner build, though an example 44.5 mm. long, from Grice's Creek, in the vicinity, has a nearly median umbo, with an antero-posterior hinge ratio of 0.94, and Muddy Creek shells are quite average in this regard, so that a distinction between Balcombian and Janjukian forms seems impracticable. In only one pre-Kalimnan specimen out of more than a hundred, a Murray River shell 42 mm. long, is the umbo appreciably posterior to the centre of the hinge line, while in the much rarer Kalimnan examples this appears to be the normal position.

Ratios of Anterior to Posterior Part of Hinge in Australian Tertiary Cucullaeas.

Locality.	Range.	Average.	No. of Exs.
(a) *C. corioensis.*			
1. Mornington, V.	0.59–0.75 ..	0.67 ..	16
2. Muddy Creek lower, V. ..	0.61–0.93 ..	0.84 ..	19
3. Shelford, V.	0.66–0.81 ..	0.73 ..	6
4. Spring Creek, V.	0.74–0.93 ..	0.81 ..	31
5. Table Cape, T.	0.68–0.95 ..	0.82 ..	11
6. Adelaide Abattoirs, S.A. ..	0.69–0.93 ..	0.79 ..	14
7. River Murray, S.A. (4 miles below Morgan) ..	0.75–1.10 ..	0.92 ..	51
Total Barwonian ..	0.59–1.10 ..	0.83 ..	148
(b) *C. corioensis praelonga.*			
8. Beaumaris, V.	1.07–1.20 ..	1.12 ..	4
9. Gippsland Lakes, V. ..	1.12–1.20 ..	1.15 ..	3
10. Muddy Creek upper, V. ..	1.11–1.33 ..	1.18 ..	5
Total Kalimnan ..	1.07–1.33 ..	1.15 ..	12
(c) *C. adelaidensis.*			
11. Adelaide bore, S.A. ..	0.79–1.00 ..	0.92	5

Stratigraphical Notes on the Table.

1 and 2 are Balcombian, 1 being the type locality, Balcombe Bay.

4 and 5 are Janjukian, 4 being the type locality.

3 and 7 are regarded as Janjukian by Chapman, and as Balcombian by Tate, Dennant, Hall, and Pritchard, and McCoy also for 3.

6 has been referred by Howchin to his Adelaidean, intermediate, as believed by Tate for the Dry Creek bore, between the Kalimnan and Werrikooian of Victoria. The fauna, so far as it has been seen by the writer, appears to be an admixture of Kalimnan and younger forms with a Janjukian element, but it is now under detailed study in Adelaide by Miss N. H. Woods. The Cucullaeas are of a type which is entirely pre-Kalimnan, i.e.. Barwonian, in Victoria.

8 is regarded as Janjukian by Tate, as Kalimnan by Hall and Pritchard, and as a low horizon of the latter by Chapman and the writer.

9 is the type area of the Kalimnan, the specimens being from Jemmy's Point, Kalimna (coll. F.A.S.), Nyerimilang (coll. F. Chapman) and No. 1 Kalimna Oil Co. bore, Rigby Island. 70′ (Commonwealth Coll.).

10 is Kalimnan, four specimens being from "Forsyth's", Grange Burn (T. S. Hall, G. B. Pritchard, and F.A.S. Colls.), and one from "MacDonald's," Muddy Creek (F. S. Colliver Coll.).

On this criterion, which has a stability lacking in such characters as degree of obliquity, it is suggested that of McCoy's four syntypes[1] the largest and original of his Fig. 5*a*, a right valve with hinge ratio 1.16, is a Kalimnan shell probably from the Gippsland Lakes, a locality mentioned by McCoy. The smaller shell he illustrated in Fig. 3, with hinge ratio 1.03, is possibly similar. The originals of Figs. 4 and 5 are marked A^{d}23, the G. S. V. locality of Bird Rock, the type area of the Janjukian, and are here designated as lectotypes, which are re-described in view of the heterogeneous material on which McCoy's diagnosis was based. While McCoy cites Corio Bay (A^{d}15) amongst the localities, none of the syntypes is so labelled, nor have I seen a *Cucullaea* from that locality, so that it is probably an error in localization as with the large *Glycymeris* figured by McCoy (Chapman and Singleton, 1925, p. 25).

C. corioensis, s. str., does not attain the size of the Kalimnan subspecies, except in the case of the littoral shells of the " Crassatella " bed at Table Cape, which may exceed 80 mm. in length. Records from this locality of the Recent *C. concamerata* Reeve by Woods (1876, p. 15) and Johnston (1880, p. 31), are undoubtedly based on *C. corioensis*, as suggested by Tate (1885, p. 212). Possibly another synonym is the Table Cape *Cucullaea minuta* Johnston (1880, p. 39), of which the type was reported as crushed and probably juvenile by May (1919A, p. 73), who advised its abandonment. The only other species recorded from the Australian Tertiary, apart from *C. adelaidensis* Tate, is *Cucullaea cainozoica* T. Woods (1877, p. 111), which is a *Glycymeris*, also originally described from Table Cape.

CUCULLAEA CORIOENSIS PRAELONGA, subsp. nov.

(Pl. XXVI., Fig. 20.)

Cucullaea corioensis McCoy, 1876, pl. xxvii., figs. 3(?), 5*a* (*non* 4, 5).

Holotype.—Shell large, heavy, subquadrate, less inequilateral than *C. corioensis*, s. str., and less tumid, thickness (one valve) 22% of length; dorsal margin truncating anterior and posterior margins at 127°, ventral margin making an angle of 3° with hinge line; anterior slope less steep, margin more produced, ridge from umbo to post-ventral angle very broad, scarcely marked; sculpture in neanic stage granulose, in ephebic stage of flattened radial riblets 1 to 2 mm. in width near ventral margin, the wider usually centrally grooved, interspaces a quarter to a third the width of the ribs, the whole crossed by strongly marked undulating lines of growth, about 4 in 1 mm., convex towards ventral margin where they cross the riblets; hinge heavy, longitudinal teeth strong, sides finely vertically ridged, four in each lateral series,

(1) The term cotype, though having priority, is so commonly misused in the meaning of metatype or homœotype, that its abandonment in favour of syntype seems advisable.

gradually diverging from the transverse central teeth; ligamental area smooth, concave, 4 mm. high, with a single interrupted furrow near base; inner margin broad, denticulate; posterior adductor scar buttressed by a plate anteriorly.

Length 61.5; height 51; thickness (right valve) 21 mm. Length anterior to hinge 7.5, of hinge 42.5, posterior to hinge 11.5; maximum height of hinge from ventral border 43.5 mm. Ratio of anterior to posterior portion of hinge 1.13.

Type Locality.—" Forsyth's," Grange Burn, near Hamilton, Western Victoria. Kalimnan (Lower Pliocene).

Type Material.—Holotype (pl. xxvi., figs. 20*a*, *b*), right valve, No. 1320, in Melb. Univ. Geol. Dept.

This Kalimnan form is usually more quadrate and less oblique than *C. corioensis*, s. str., but the outline is variable and the ventral margin may be inclined at 11° or more with the hinge line. The anterior portion of the shell is more produced, the anterior margin being gently rounded and more obliquely truncated dorsally, and the hinge line is invariably longer anterior to the umbo than behind it, instead of the reverse. It is also typically a larger shell, Beaumaris examples reaching 82 mm. in length, and a fragment, 7 mm. thick, from Kalimna, suggesting a shell considerably over 100 mm. long.

Cucullaea adelaidensis Tate, 1886.

(Pl. XXVI., Figs. 21-24.)

Cucullaea Adelaidensis Tate, 1886, p. 144, pl. xi., figs. 14*a*, *b*.

Syntypes.—This species has been fully described by Tate, but figures are offered of four of the syntypes, which measure in length, height and thickness (one valve), 41 × 34.5 × 15 (fig. 21, Tate's figured specimen), 36 × 32 × 15.5 (fig. 22), 32 × 27 × 12 (fig. 23), and 23.5 × 18.5 × 8.5 mm. (fig. 24). The remainder consist of a large fragmentary left valve, originally about 65 × 44 × 21, a right valve 36 × 30.7 × 13, and juvenile valves 12.5 × 10.3 × 4, 8 × 7.7 × 3.5, and 4.2 × 3.7 × 1.6 mm. (single valves). The measurements given by Tate, though made differently, are those of his figured specimen, whose other dimensions are: Length anterior to hinge 4, of hinge 26, posterior to hinge 11; maximum height of hinge from ventral border 28.5 mm. Hinge bisected by umbo, ratio 1.00. Angle between ventral margin and hinge line 22°.

Type Locality.—Glauconitic sands, Adelaide bore, South Australia. Janjukian (Miocene ?).

Type Material.—9 syntypes (including pl. xxvi., figs. 21*a*, *b*, 22-24), in Adel. Univ. Geol. Dept.

Cucullaea adelaidensis appears to be a locally developed modification characterized by its much finer ornament, with exceedingly fine radial ribbing in the left valve and a median sulcus in the less numerous riblets of the right valve, and greater obliquity than is typical of *C. corioensis*. Juvenile right valves of the latter, in its thin shelled Balcombe Bay form, are scarcely separable from corresponding valves of the present species. In inflation Tate's figured specimen of *C. adelaidensis*, with thickness 37% of its length, is intermediate between the types of *C. corioensis* (43%, 44%) and *C. corioensis praelonga* (22%).

In its finer ornament *C. adelaidensis* somewhat resembles the Indo-Pacific *C. labiata* (Solander), better known as *C. concamera* (Bruguière), but the fossil has a granulose to squamose ornament and is a much longer shell, lacking the strong umbono-ventral keel and subquadrate outline of the living species, from which New South Wales examples have been separated under the name of *Cucullaea vaga* Iredale (1930, p. 385), type from 25-30 fathoms off Norah Head.

The discrepancy between the ornament of the two valves in this genus does not seem to have been recorded, except by Suter in the case of the New Zealand Tertiary *C. worthingtoni* Hutton, and it is scarcely noticeable in the Recent *C. labiata*. In the Australian fossils, however, it is well marked, the sculpture of the left valve always being finer than that of the right, and the differences reach a maximum in *C. adelaidensis*.

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Explanation of Plates.

The figures are approximately natural size, with the exception of Nos. 16*c*, 17*c*, and 18*c*, which are enlarged about three times linear.

PLATE XXIV.

Figs. 1-4.—*Nucula tenisoni* Pritchard. Tertiary (Janjukian); Table Cape, Tas. Topotypes; (1) exterior of left valve, showing concentric sulcations, coll. R. N. Atkinson, National Museum, Melbourne, Reg. No. 13667; (2) interior of left valve, Dennant Coll., Nat. Mus., No. 13668; (3) exterior of left valve of pair, coll. Atkinson, Nat. Mus., No. 13669; (4) interior of left valve, showing chondrophore, the anterior series of teeth being imperfect, Dennant Coll., Nat. Mus. No. 13670.

Fig. 5.—*Nucula tenisoni* Pritchard. Tertiary (Balcombian); Grice's Creek, Port Phillip, Vic. Plesiotype; (5*a*) exterior and (5*b*) interior of right valve, coll. and pres. F. A. Singleton, Melbourne University Geological Department Reg. No. 1311.

Fig. 6.—*Nucula obliqua* Lamarck. Recent; dredged in 8 fathoms off Point Cook, Port Phillip, Vic. Plesiotype; (6*a*) exterior, and (6*b*) interior of left valve, coll. and pres. C. J. Gabriel, Nat. Mus. No. 13671.

Fig. 7.—*Nucula kalimnae*, sp. nov. Tertiary (Kalimnan); Jemmy's Point, Kalimna, Vic. Holotype; (7*a*) exterior and (7*b*) interior of right valve, coll. and pres. F. A. Singleton, Melb. Univ. Geol. Dept. No. 1312.

Figs. 8, 9.—*Nucula kalimnae*, sp. nov. Tertiary (Kalimnan); Muddy Creek, Vic., upper beds. Paratypes; (8*a*) exterior and (8*b*) interior of right valve, Worcester Coll., Melb. Univ. Geol. Dept. No. 1313; (9) exterior of right valve of pair, Worcester Coll., Melb, Univ. Geol. Dept. No. 1314.

Figs. 10, 11.—*Glycymeris* (*Grandaxinaea*) *granti*, sp. nov. Tertiary (Balcombian); Muddy Creek, Vic., lower beds. (10*a*) Exterior and (10*b*) interior of holotype (left valve); (11) interior of paratype (right valve), Grant Coll., Melb. Univ. Geol. Dept. Nos. 1315 (holotype) and 1316 (paratype).

Figs. 12, 13.—*Limopsis chapmani*, sp. nov. Tertiary (Janjukian); Bird Rock Cliffs, Torquay, Vic. Paratypes; exterior of right valves, showing subcircular outline in earlier stages, coll. and pres. F. A. Singleton, Melb. Univ. Geol. Dept. Nos. 1318 and 1319.

Fig. 14.—*Limopsis chapmani*, sp. nov. Tertiary (Janjukian); Aldinga, S.A., lower beds. Plesiotype; exterior of left valve, showing obliquity in gerontic stage, Dennant Coll., Nat. Mus. No. 13672.

Fig. 15.—*Limopsis insolita* (G. B. Sowerby). Tertiary (Patagonian); mouth of Santa Cruz River, Patagonia. Topotype; exterior of right valve, ex J. B. Hatcher Coll., per A. E. Ortmann, Australian Museum, Sydney, Reg. No. C.13963.

PLATE XXV.

Fig. 16.—*Limopsis chapmani*, sp. nov. Tertiary (Janjukian); Bird Rock Cliffs, Torquay, Vic. Holotype; (16*a*) exterior and (16*b*) interior of right valve, (16*c*) the same, ×3, to show ornament, coll. and pres. F. A. Singleton, Melb. Univ. Geol. Dept. No. 1317.

Fig. 17.—*Limopsis chapmani valida*, subsp. nov. Tertiary (Janjukian); Birregurra, Vic. Holotype; (17*a*) exterior and (17*b*) interior of right valve, (17*c*) the same, ×3, to show ornament, Dennant Coll., Nat. Mus. No. 13673.

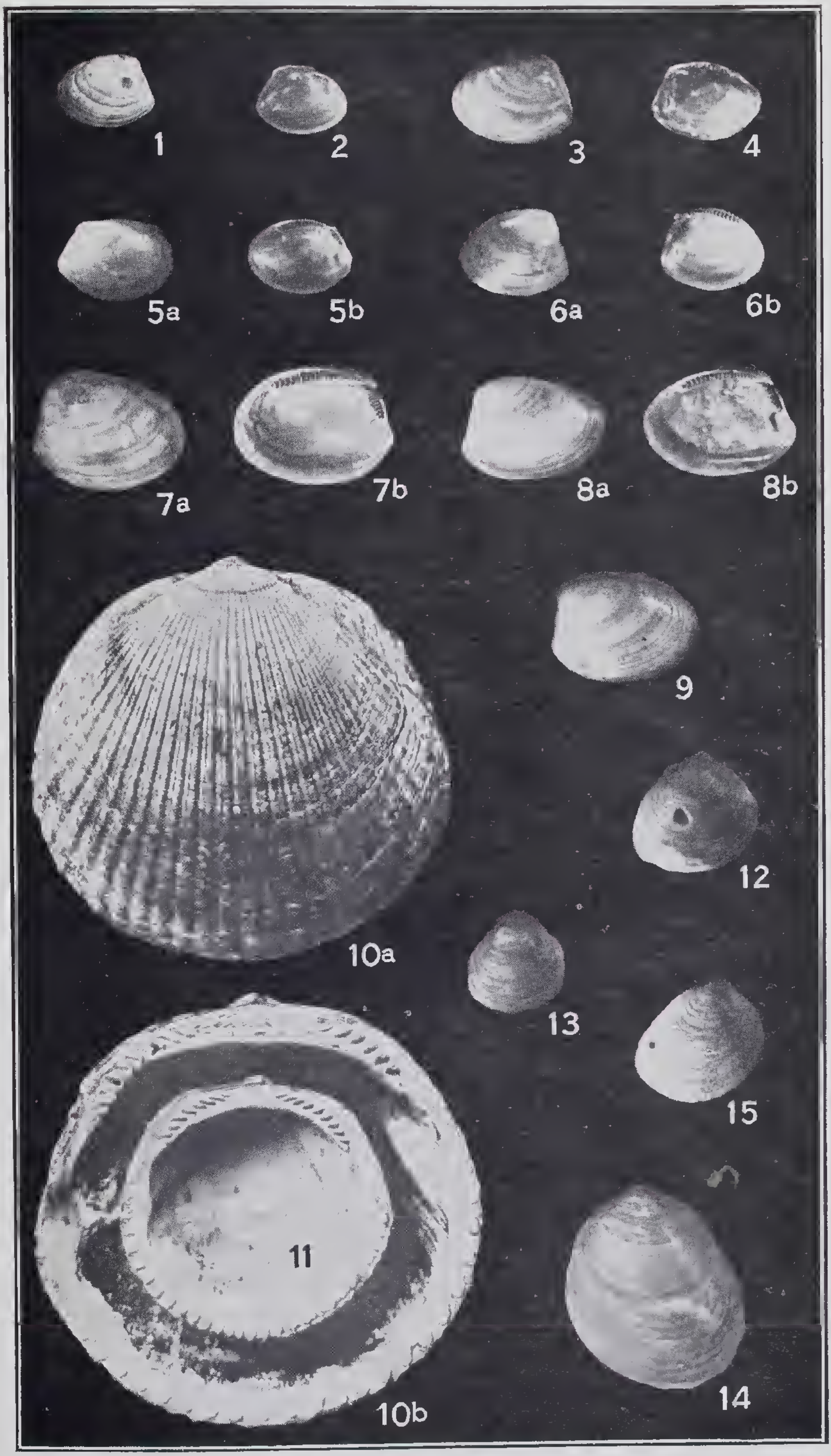
Fig. 18.—*Limopsis insolita* (G. B. Sowerby). Tertiary (Patagonian); mouth of Santa Cruz River, Patagonia. Topotype; (18*a*) exterior and (18*b*) interior of left valve, (18*c*) the same, ×3, to show ornament, ex J. B. Hatcher Coll., per A. E. Ortmann, Aust. Mus. No. C.13963.

Plate XXVI.

Fig. 19.—*Cucullaea corioensis* McCoy. Tertiary (Janjukian); Geol. Surv. Vic. Locality A^d23 = "Bird-Rock Point," Torquay. Vic. Lectotype; (19*a*) exterior and (19*b*) interior of left valve of pair figured by McCoy, Prod. Pal. Vic., dec. iii., pl. xxvi., fig. 4, Nat. Mus. No. 12236.

Fig. 20.—*Cucullaea corioensis praelonga,* subsp. nov. Tertiary (Kalimnan); Forsyth's, Grange Burn, Vic. Holotype; (20*a*) exterior (slightly reduced) and (20*b*) interior of right valve, pres. F. A. Singleton, Melb. Univ. Geol. Dept. No. 1320.

Figs. 21-24.—*Cucullaea adelaidensis* Tate. Tertiary (Janjukian); Adelaide bore, S.A. Syntypes: (21*a*) exterior of right valve figured by Tate, Trans. Roy. Soc. S. Aust., viii., pl. xi., fig. 14*a*; (21*b*) the same, obliquely lit to show ornament; (22) exterior of left valve, to left of figured specimen; (23) interior of left valve, below figured specimen; (24) exterior of juvenile right valve, to right of preceding, Tate Coll., Adelaide University Geological Department.



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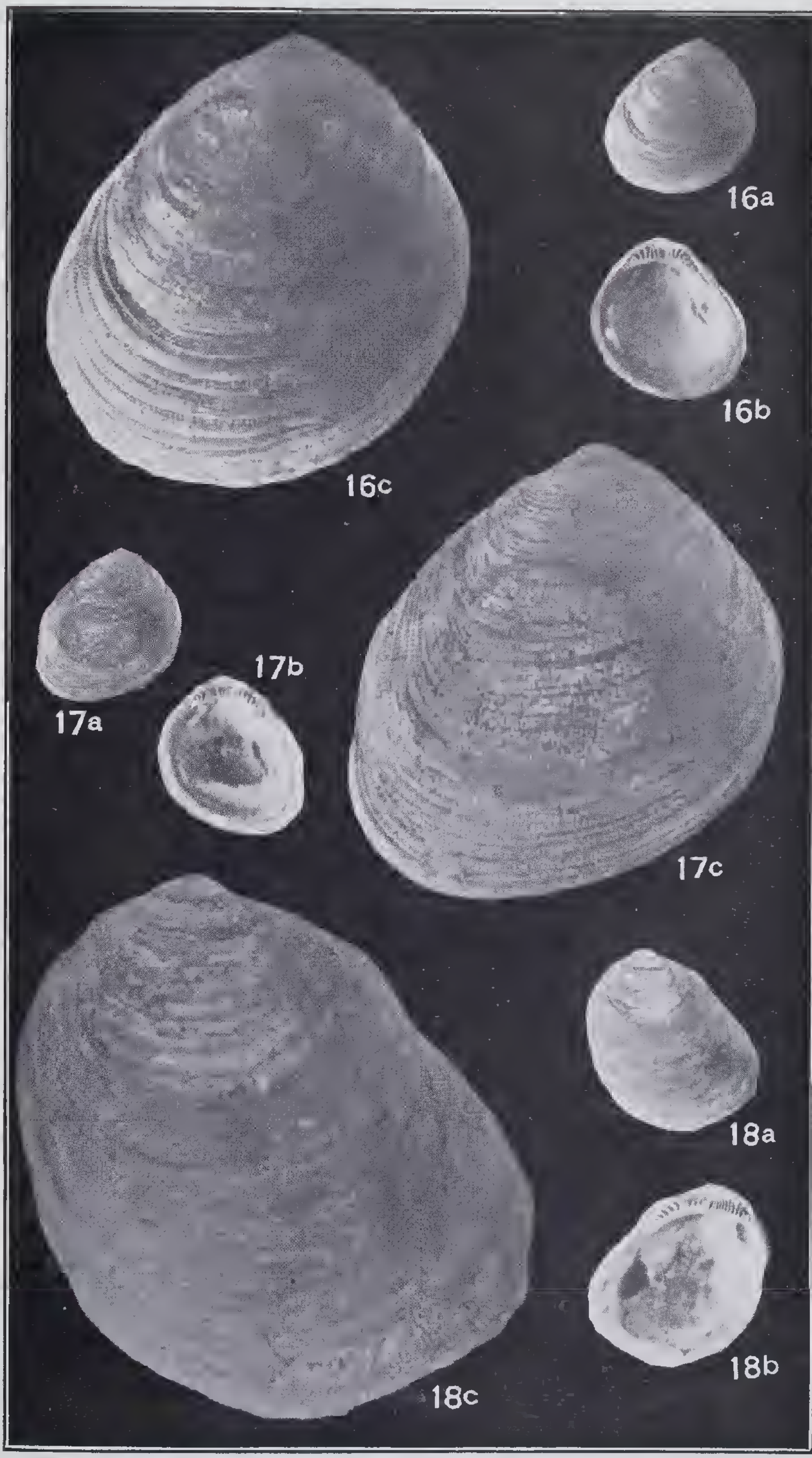
Nucula, Glycymeris, Limopsis. Tertiary, Australia.



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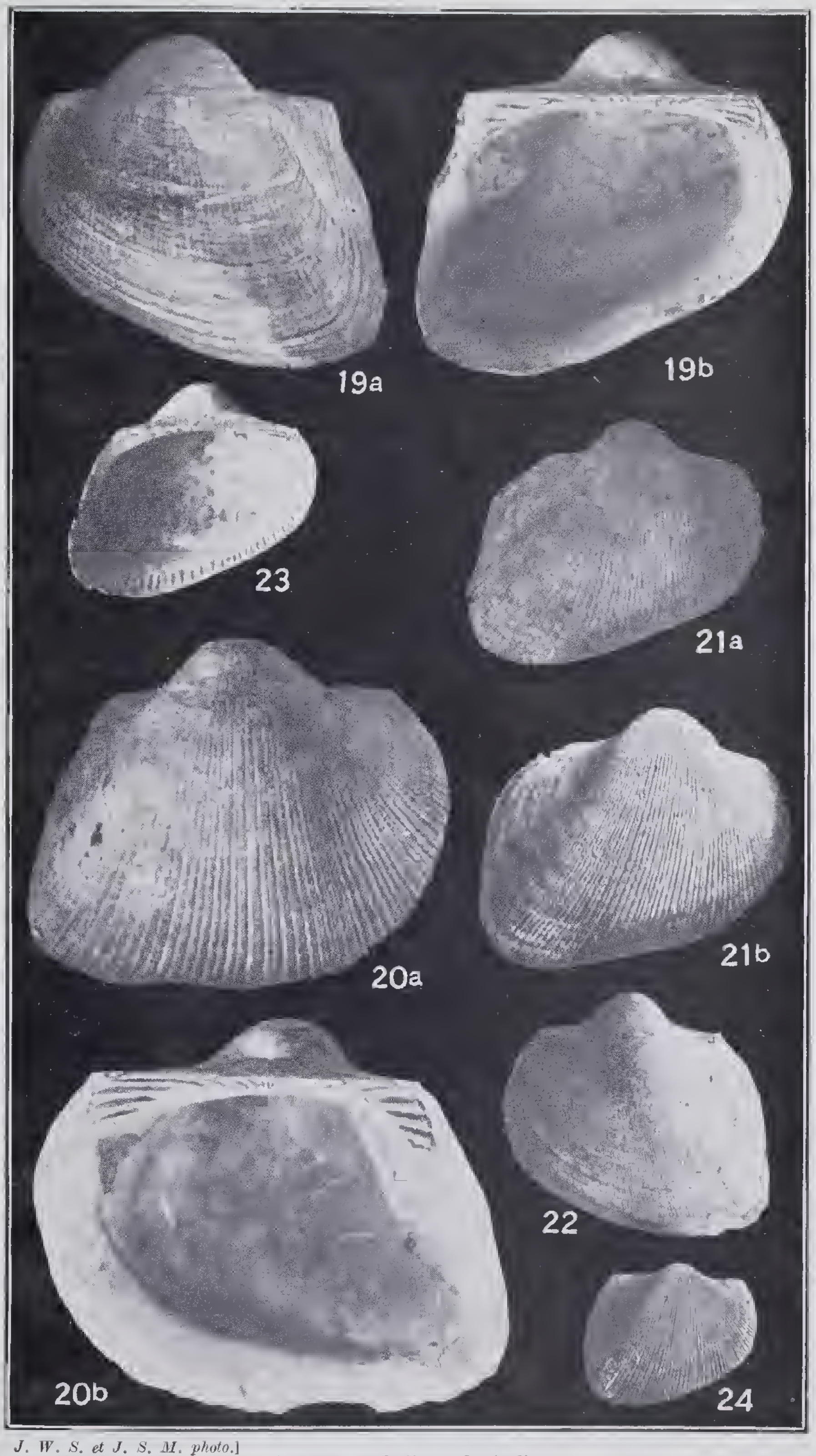

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Balfour, Lewis J., B.A., M.B., B.S., 536 Toorak-road, Toorak, S.E.2 — 1892

Baragwanath, W., Geological Survey Department, Treasury Gardens, East Melbourne, C.2 — 1922

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Barrett, Sir J. W., K.B.E., C.M.G., M.D., M.S., 105 Collins-street, Melbourne, C.1 — 1910

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Hills, E. S., M.Sc., Geology School, University, Carlton, N.3 1928

Holland, R. A., 105 Moreland-road, West Brunswick, N.10 1931

Holmes, W. M., M.A., B.Sc., Observatory, South Yarra, S.E.1 1913

Howitt, A. M., Department of Mines, Treasury Gardens, East Melbourne, C.2 1910

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Lambert, C. A., Bank of N.S.W., Melbourne, C.1 .. 1919

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McCance, D., B.Sc., 106 Gatehouse-street, Parkville, N.2 1931

Macdonald, B. E., Dairy Export Branch, Rialto, Collins-street, Melbourne, C.1 1920

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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

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Newman, B. W., Meteorological Bureau, Adelaide, S.A. .. 1927

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Oke, C., 56 Chaucer-street, St. Kilda, S.2 1922

Orr, D., B.Sc., 860 Mount Alexander-road, Essendon, W.5 1927

Osborne, N., c/o Vacuum Oil Co., 90 William-street, Melbourne, C.1 1930

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
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Shaw, Dr. C. Gordon, 75 Clendon-road, Toorak, S.E.2 ..	1931
Sherrard, Mrs. H. M., M.Sc., 16 Shellcove-road, Neutral Bay, Sydney.	1918
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