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[Proc. Roy. Soc. Victoria, 32 (N.S.), Pt. I., 1919].

Art. I.—*The Origin of the Volcanic Tuff of Pejark Marsh Victoria.*

By R. HENRY WALCOTT
(Curator, Technological Museum).

[Read 8th May, 1919].

In view of the discovery of a native implement associated with fragments of bones of extinct marsupials under volcanic tuff at Pejark Marsh, near Terang, by Mr. A. J. Merry,[1] increased interest is attached to the task of ascertaining the probable age and origin of the tuff.

For this reason the opportunity was taken, while supervising some excavations being made at the Marsh, in 1909, in search of further evidence of man's antiquity, of paying a few hurried visits to various places in the neighbourhood likely to bear upon the subject. The following notes are principally the result of information so gained, but, as the time devoted to field investigation was unavoidably very limited, they must of necessity be brief, and perhaps omit some matter of value in deciding the issue in question.

An account of the excavations referred to, and of the occurrence of the tuff has already appeared.[2] It might be mentioned here, however, that the tuff is seen as a fine-grained bedded deposit, from 15 to 24 inches thick, along a drain made to carry the water away from the Pejark Marsh. The tuff has been laid down in an old swamp, now represented by a stiff, black clay bed, and abundant leaf impressions are present in the lower layers of the tuff. Resting on the tuff again, comes the heavy, black soil of the present marsh, some two or three feet in thickness.

The tuff is locally known as "sandstone," and is also called "sandstone tuff," on the quarter sheet No. 8 N.E. (New Series), of the Geological Survey of Victoria.

Previous reference to the deposit has been made by Professor J. W. Gregory,[3] when he states: "The broad down-shaped hill to the south-west of Camperdown, and the plains between Terang and Noorat, are formed of re-deposited, bedded tuffs. The low cliffs

1. An account of this discovery has not yet been published. The implement is in the possession of the National Museum, Melbourne.
2. Spencer and Walcott, "The Origin of Cuts on Bones of Australian Extinct Marsupials." Proc. Roy. Soc. Vict., pt. I., 1911, pp. 92-123.
3. The Geography of Victoria, Melb., 1903, p. 192, and revised edition, 1912, p. 204.

around Lake Terang, and a bank on the road leading to Gnotuk Park, near Camperdown, show the bedding, which indicates that the materials were laid down under water." If Professor Gregory's assertion be correct, that the tuff of the plains between Terang and Noorat, where the Pejark Marsh is situated, has been re-deposited, then the underlying clay bed may be younger, and not older than the volcanic rocks of the neighbourhood. This is a point of very considerable moment concerning the age of the human relic found in the clay bed, under the tuff.

In regard to the bedding of volcanic tuff, a common enough character in South-East Australia, Dr. T. S. Hall,[4] and Messrs. Mahony and Grayson[5] have shown, that it is by no means proof that the tuffs were laid down under water. On the contrary, the evidence indicates that they were mostly laid down on dry land, the exceptions being in those cases, such as at Pejark, where they may have been deposited in swamps or shallow lagoons.[6]

The direct deposition in these shallow and stagnant waters does not in any way affect the age of the tuffs; that question only arises where there is good and sufficient reason to believe that the tuffs have been, by the natural agency of wind or water, removed from their original places of deposition to others at a perhaps much later period.

The few facts gathered with regard to the Pejark tuff certainly seems to negative the idea that there has been any re-disposition of the material, and one of them is found in the numerous cavities it contains; a somewhat unusual feature in a rock of its character.

These cavities are of varying size and form, some being extremely regular, more especially the smaller ones, which are also generally spherical, but others again most irregular in shape. An examination in situ shows that the cavities are not all due to one cause. Some, the larger and mostly irregular ones, have a brownish coloured lining, and are found only near the bottom of the bed with the leaf impressions. These are undoubtedly the

4. Proc. Roy. Soc. Vict. Vol. XX., pt. I., 1909, pp. 20, 21.

5. Mem. Geol. Surv. of Vict., No. 9, 1910, p. 13. Geology of the Camperdown and Mt. Elephant Districts.

6. A specimen of tuff from Pejark Marsh, examined by F. Chapman, is stated by him to "show carbonized and iron-stained impressions of vegetable stems. When wax squeezes of these were taken they were seen to be triangular in section, and under the microscope show a structure exactly matching that of the surface in the living Victorian Marsh-loving *Cyperus lucidus*. The tuff specimen referred to also show excellent cross bedding disposed at a high angle to the plant-stems, thus indicating the formation of this deposit from gentle showers of volcanic dust."

result of the decay, and removal of vegetable remains. Higher up in the bed, where there is no sign of those remains, the smaller and more regular cavities occur in horizontal zones, and these likely enough have arisen through air entangled in the showers of ashes being carried with them to the bottom of the swamp, and there unable to escape.

In neither kind of cavity is there the slightest indication that it was formed by the gases given off by the decomposition of vegetation in the swamp in which the ashes fell. The presence of cavities due to air or other gases entangled in the shower of ashes, if it be a correct interpretation of the phenomenon, in itself sets at rest any doubts about the tuff not being in its original site, because such cavities could not have been retained during a re-distribution either by wind or water.

Mahony and Grayson,[7] in describing the microscopic characters of the Hampden tuffs, mention that a deposit at Blind Creek, about which some uncertainty exists as to whether it has been re-deposited or not, is similar to the tuffs occuring elsewhere in their original position. The same may be said of the Pejark tuff, as its character does not seem to differ from that of the beds of fine texture undoubtedly in situ. The Pejark bed is also sharply defined from both the underlying and overlying deposits, and there has been no mingling with extraneous material in any part of it. There are, then, no features in connection with the occurrence which might be held to indicate that it was laid down under conditions inconsistent with primary deposition.

The facts as they are, point not only to a sudden change in the nature of the deposited material, but to great rapidity of deposition with slight intervals of rest, during which the fine sediment suspended in the water of the lagoon or swamp settled, forming thin, impalpable seams in the tuff.

The whole bed was no doubt laid down in a comparatively short time, then earlier conditions again prevailed, and the present alluvial soil was deposited.

Regarding the origin of the tuff in question, there are three possible sources within the immediate neighbourhood of the place where the excavations were made, viz., Mt. Noorat, three miles to the north, Lake Keilambete, about two miles to the west, and Lake Terang, one mile due south.

The first of these sources and the most distant from the position mentioned, while leaving no question of its crater origin, has not

7. Loc. supra cit., p. 19.

yet supplied evidence of a sufficiently definite nature to prove that the tuff emanated from it. Mahony and Grayson[8] say that tuff was proved in wells sunk through the basalt to the north of the Mount, and they verbaly informed the writer that there was also evidence of tuff underlying the lavas in other directions.

This merely introduces the possibility of Mount Noorat having contributed to the Pejark tuff, but one of the other suggested places of origin is accompanied by evidence quite sound enough to fix it as the main source.

Lakes Keilambete and Terang, although surrounded by accumulations of tuff, have not been generally accepted as the sites of old volcanic vents.

Mr. A. R. C. Selwyn[9] thought they were more probably accidental depressions due to other causes, and Professor J. W. Gregory[10] is confident that they, as well as Lakes Bullemerri and Gnotuk, are not crater lakes, but occupy basins formed by subsidences in bedded volcanic tuff, which were probably caused by the eruptions of neighbouring volcanoes.

Mahony and Grayson,[11] on the other hand, hold that all these lakes are directly due to volcanic explosions, and with this view the writer is in accord. Their paper is a most valuable one, not only on account of the interesting matter it contains, but also because it is the only systematic account of the geology of the district yet published. As these notes must necessarily be brief, and only of a general nature, reference should be made to that paper.

The part of Lake Keilambete visited by the writer, like nearly the whole of its banks, was hidden by a luxurious growth of grass, with the exception of some outcrops of soft, tertiary, fossiliferous limestone underlying the superficial tuffs.[12]

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8. Loc. supra cit., p. 6.
9. Intercolonial Exhibition Essays, Melb., 1866.
10. The Geography of Victoria, Melb., 1903, p. 130. Revised Ed., 1913, pp. 131-136.
11. Loc. supra cit., p. 13.
12. Mr. F. Chapman, Palæontologist to the National Museum, who was good enough to examine all the fossiliferous material collected, determined the Lake Keilambete forms from the limestone as follows:—
   Foramnifera.—*Truncatulina lobatula*, W. and J. sp. Also others indet.
   Polyzoa.—Indet.
   Echinidermata.—*Echinocyamus (Scutellina) patella*, Tate sp, Eupatagus (?) laubel, Duncan.
   Brachiopoda.—*Magellania insolita*, Tate sp., and *M.* (?) *pectoralis* Tate sp.
   Pelecypoda.—*Pecten yahliensis*, Tate.
   Pisces.—*Lamna apiculata*, Ag. sp.
   Mr. Chapman places the limestone bed in the Janjukian series.
   Oyster shells of fossilized appearance occur on the beach of the lake, and it may be useful to record the fact here given to the writer by Mr. H. Quiney, of Mortlake, that many years ago an attempt was made to acclimatize oysters in the lake, but without success. It is to this source that the presence of the shells may be attributed.

The lake has an area of two square miles,[13] and is situated about two and a-half miles north-west of the township of Terang. Its circular form and low banks of volcanic tuff gently sloping into the surrounding plains on all sides, are very suggestive of volcanic origin. The fact that the banks are raised at all, unless they are of aeolian origin, makes it difficult to understand how they could have been formed if the lake is occupying a depression resulting from the withdrawal of material from below through the activity of neighbouring volcanoes.

It seems more reasonable to expect a gradual slope towards the lake by a sagging of the strata, instead of the reverse. Again, the symmetrical shape, which has been assumed, in place of one more or less irregular, as in the case of lakes situated in areas where the evidence supports an origin by subsidence, is more consistent with a volcanic origin. There is no evidence that this lake basin was formed in a depression in volcanic tuff. The tuff appears to have been deposited on a comparatively level land surface, through which the volcanic forces burst an opening. Mahony and Grayson[14] point out with regard to Lake Bullenmerri, which has only an area of a little over two square miles, is bounded by steep sides, and has its floor lying 700 feet below the highest part of the rim, that the formation of such a basin by the sinking of its floor has never been actually observed, but that there are instances of the production of similar depressions by paroxysmal explosions.

If it can be proved that the accumulations of tuff round the lake in situ thinned out as they receded from the lake itself, a strong piece of evidence would be established in favour of the basin being an explosion vent.

With regard to this, and several other points, Mr. A. J. Merry very kindly went to considerable trouble to ascertain what data were known from well sinkings in the neighbourhood. The result of his inquiries went to show that the well sinkings near Lake Keilambete all indicated a gradual reduction in the thickness of the tuff away from the lake, thus supplying the important evidence required. It is not certain, however, if this tuff extends to, and is continuous with, the Pejark bed. On the geological quarter sheet, buckshot gravel is seen to be the superficial deposit intervening between the former and the Pejark Marsh, and the nature of the underlying beds is not disclosed.

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13. Intercolonial Exhibition Essays, Melbourne, 1866.
14. Loc. supra cit., p. 13.

While there may be certain characteristics absent from the formation of Lake Keilambete, they do not put nearly such a barrier in the way of ascribing its origin wholly, or in part to a volcanic explosion, as the presence of other characteristics do to the acceptance of the explanation that the lake basin is a simple subsidence in the land surface.

The site of Lake Keilambete may, therefore, be considered on good grounds the source from which the tuffs surounding it were derived, but evidence has not yet been collected to show that it has contributed to the Pejark Marsh tuff, although quite likely enough it has done so to some extent. Lake Terang has an area of one square mile,[15] or half that of Lake Keilambete, and, strangely enough, although it is without an apparent outlet, the water in it is fresh, unlike that of Keilambete. It also lacks the conspicuous circular form of Keilambete, and its irregularity, which is really not by any means marked, is emphasised by the varying height of the surrounding hills. The township of Terang is situated along the northern slope of these hills, but also spreads on to the level country, both eastward and northward. At the east end of the lake the hills are low, forming a gradual rise from the country beyond. Following along the township the elevation increases right to the west end of the lake, where the greatest prominence is attained, and is deemed worthy of the title of Mount Terang. From Mt. Terang, tapering hills extend further to the westward. Continuing round the lake the land rapidly falls away until a gap, forming the lowest part of the ring, is reached, and this is succeeded again on the south by somewhat prominent hills extending to another gap at the east end.

The greatest depth of water, which is in the centre of the lake, at the time of the Author's visit (1909) was said to be three feet. In this respect it differs much from Lake Keilambete, which, according to the geological quarter sheet, had a depth of 96 feet in the year 1888. It is also said that when the early settlers came to Terang there were 30 feet or more of water in Lake Terang, and that it even flowed out through the gap on the south-west side. As the surface of the water has not been lowered to this extent, it is believed by local residents that the bottom has risen.

The growth of peaty vegetation has given some foundation for this belief, but it does not explain the reduction in the volume of water. This can only be accounted for by its draining away along

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15. Intercolonial Exhibition Essays, Melbourne, 1866.

some subterranean passage. As already mentioned the water is fresh, and it would require a considerable access to bring the level up to the gap, which is said to have been reached in the past. There is no doubt that there has been a large diminution in the quantity of water in the lake within recent years, and if this is caused by the supply, either superficial, or superficial and subterranean combined, as the case may be, being exceeded by the loss due to evaporation, it would be noticed in the salinity of the water. Keilambete has also been lowered in level to some extent during the same time, but the saltness of its waters is very marked.

A suggestion might here be made with regard to this difference in the water of the two lakes which in other respects seem to have much in common. It has been mentioned that in another paper[16] that at Pejark Marsh, in driving a crowbar through the yellow clay, on the top of which cut fragments of bone were found, the bar entered a softer stratum, and water flowed freely from the hole so made, showing that probably the water-bearing bed from which the local residents obtain their supplies, had been tapped. It is also thought that this might be the porous fossiliferous limestone of Tertiary age exposed along the shores of Lake Keilambete for some feet above the present water level.

On the shores of this lake wells have been sunk for some twenty or thirty feet in the limestone, it is said, and fresh water obtained, although the lake water itself is so saline from the absence of an outlet that it is unfit for consumption by stock. It, therefore, seems evident that the limestone bed is a channel by which the supply of water to Keilambete is augmented to some extent. Now at Lake Terang conditions are apparently different, and the process is reversed. In this case the water is either being forced out through the porous stratum into the surrounding country, where numerous wells are drawing it away more rapidly than before the stratum was tapped, and more rapidly than it can be naturally replenished, or else underground supplies, which were sufficient to balance the loss by subterranean outlets, have been intercepted. Mahony and Grayson[17] mention this as a probable factor in the desiccation going on at Lake Terang.

The sides of the lake, or ring of hills enclosing it, are composed principally of bedded tuffs. An extremely good exposure occurs

16. Spencer and Walcott, "The Origin of Cuts on Bones of Australian Extinct Marsupials." Proc. Roy. Soc. Vict., Pt. I., 1911, p. 93.
17. Loc. supra cit., p. 10.

just at the back of the Mechanics' Institute, where they have been quarried for building stone, and a clean vertical fcae about ten feet in height has been left. The beds here are of much coarser texture than at Pejark Marsh, and scattered through them are small lumps of white, indurated clay, which impart the effect produced by splashes of whitewash. An interesting feature was noticed here near the top of the beds, giving evidence that a volcanic vent was not far distant. This was the characteristic bend in the bedding of the tuff caused by impact of a falling body, and occurred under a cavity at one time occupied by a bomb or ejected block.

At Mt. Terang, where the tuff is being quarried just to the north of the summit, the beds are seen to be dipping, as far as can be made out, with the outward and northward slope of the hill. They are capped by a thin flow of scoriaceous basalt, which seems to form the cover of the hills extending to the west. Clay enclosures are also noticed here, but not so abundantly, and in one place the lava has intruded the tuff in the form of a small dyke now largely decomposed.

Just south of the summit of Mt. Terang, where a cutting for a road has been made, from what can be seen, the beds generally show a dip towards the lake, but as they have here been disturbed and become almost vertical within a short distance, where they abut on a coarse agglomerate or mass of volcanic ejectamenta, it is not quite certain whether this is the true direction of dip or not. It may be that this agglomerate is occupying a vent, and that the disturbance and rapid change in dip of the bedded tuffs has been caused by the downward drag of the volcanic material during its settlement. Enclosed in the agglomerate are lumps of flesh-coloured clay, reaching up to the size of a man's head. They are indurated by the heat to which they have been subjected, and mostly exhibit an imperfect prismatic structure from the same cause. These enclosures are of considerable interest on account of the fossils some of them contain, bearing witness of the presence of the marine tertiary beds underlying the volcanic deposits of the district, and from which they have been derived. Mr. F. Chapman identified these fossils as belonging to two Polyzoan genera—*Adeona* and *Lepralia*, and a brachiopod, doubtfully referred to the genus *Crania*. If then, we have here no evidence that the site of an old vent lies within the limits of Lake Terang, from whence came the various materials forming the mount and the surrounding hills? The ejected lumps of the older underlying rocks alone testify to the presence of a not distant source. On the eastward outward slope of the lake near the cemetery, a well put down passed through about 80 feet of tuff before striking water, but half a mile or so further east, poor "buckshot" country is encountered resting on, it is said, a clay bed. Again, near the summit of Mount Terang, another well was sunk, and a still greater thickness of tuff was met with. Mr. Merry also says that to the west and south of the lake the good volcanic country is succeeded by "buckshot" and clay lands. The geological quarter sheet shows what is called the "older volcanic series," giving place to "buckshot" gravel to the west, but to the north extending to the limits of the quarter sheet. The title given to this series is badly chosen, and misleading, as it does not refer to the older basalts, known as such since the time of the first geological survey of Victoria, but to a section of the newer volcanic rocks belonging to a much more recent period. Apart from the confusion occasioned thereby, "older" is an inappropriate term to employ, as the basalt it is applied to, is in part superficial, and at Lake Terang mapped right up to its side, so that it must be younger than the tuffs there, and Mahony and Grayson state that the basalts belong to one cycle of activity, no sharp line of demarcation separating them. These authors[18] have very properly in their paper substituted the terms "earlier" and "later" for the older and newer volcanic series of the quarter sheet. To the north of Lake Terang we know that at the Pejark drain, distant about a mile, there is at the most only two feet of tuff, and Mr. Merry ascertained that between the drain and the lake the tuff or "sandstone" had been encountered in every well sinking and cellar excavation, increasing in thickness as the lake was approached. The actual thickness of the tuff bed on that side of the lake could not be found out. The section behind the Mechanics' Institute shows a face of 10 feet. This establishes the continuity of the Pejark and Lake Terang tuffs, and makes it probable enough that they originated from the same point, although of course, as already stated, they may have blended to some extent to the west and north with the tuffs which emanated from the site of Lake Keilambete and from Mt. Noorat.

As the tuffs of Lake Terang are unquestionably occupying their original place of deposition, and are continuous with, and thin out into, the Pejark beds, there seems no reason to attribute the

18. Loc. supra cit., p. 4.

occurrence of the latter to re-deposition. If Lake Terang does not represent an ancient centre of volcanic activity, it is inconceivable how a mass of volcanic ashes and coarser ejectamenta, covered with lava for the greater part, and undoubtedly in situ, came to be piled up there where there is no evidence whatever to connect its presence with any other possible source of origin.

It is possible, however, that the crater basin ocupied by the lake may have been enlarged by subsidence through the withdrawal of material from below.

In view of the facts given it may fairly safely be taken that any works of man discovered beneath the tuffs of the areas under consideration would at least put his history back to the last great epoch of volcanic activity in south-west Victoria, and make him the contemporary of our giant extinct marsupial fauna.

[Proc. Roy. Soc. Victoria, 32 (N.S.), Pt. I., 1919].

Art. II.—*New or Little-known Victorian Fossils in the National Museum.*

Part XXIV.—On a Fossil Tortoise in Ironstone from Carapook, near Casterton.

By FREDERICK CHAPMAN, A.L.S.
(Palæontologist, National Museum, Melbourne.)

(With Plate I).

[Read 8th May, 1919].

Note on the Matrix.

Bog iron-ore, known mineralogically as a form of Limonite ($2Fe_2O_3 + 3H_2O$), is a common preservative of fossil plants and animals, in which their remains are usually found as casts and impressions. In Victoria we have numerous instances of such occurrences of beds of ironstone; as for example, the deposit on the Parwan Creek, and other exposures near Bacchus Marsh, which contain leaves of Laurel, Cinnamon and Beech.

Of terrestrial or freshwater (lacustrine) origin, these bog iron-ores contain the remains either of the organisms which were living in the swamps and lakes, as the ostracoda and shells; or remains of animals as bones and feathers, which were washed into the deposit off the land.

In the case of the Swedish lake iron-ores, the higher bacteria have played a prominent part in separating the iron oxide from the water, and such may have been the case with the beds of iron-stone near Casterton in which the above fossil tortoise was found. The iron was in all probability derived from the vast outpourings of lava during late Tertiary times in Victoria, being dissolved out by meteoric waters and re-deposited in pans on the bottoms of swamps and lakes.

Description of Specimen.

The practically unique fossil now under consideration was found in a bed of ironstone at Carapook, north-east of Casterton. It represents a replacement in limonite of the greater part of the body cavity of a tortoise. On the dorsal surface the vertebral column is well-marked by a deep, interrupted groove. The sutures of the costal plates are faintly visible. The impressions of the bones of the pelvic girdle are also seen. On the ventral side impressions of the bones of the plastron may be made out, and also those of the epidermal plates; of the latter the most strongly marked are the grooves between the pectoral and abdominal shields.

This fossil cast is referable to the genus *Emydura*, Bonaparte,[1] to which the Murray Mud-tortoise belongs. From all appearances the fossil may be referred, with some reservation, to the same species, *Emydura macquariae*, Gray sp.[2]

The length of the fossil specimen when complete was about 28 cm. as against 27 cm. of a full-grown living specimen.[3] Breadth, about 15 cm. A living example from Wahgunyah, mentioned by McCoy, shows almost identical proportions. This fossil is slightly broader in proportion, both across the carapace and plastron, than the living specimens, but this difference seems to be due to compression.

Observations.—The Murray Mud-tortoise is common in the River Murray and its tributaries and branches, but is not found in Victoria in rivers flowing to the south. This curious point in its local distribution may indicate the once northern trend of the rivers in the Casterton district, which now join the Glenelg.

Anent the discovery of the specimen, the question arises whether this ironstone deposit bears any relationship to that occurring at Redruth, which yielded *Eucalyptus* and *Banksia* leaves, and a bird's feather.[4] Carapook is in the same district as Redruth, and

1. Arch. f. Naturgeschichte, 1838, Vol. I., p. 140.
2. *Hydraspis macquarii*, Gray, 1831, Syd. Rept., p. 40.
   Platemys macquariae, Gray sp., Dumeril and Bibron, Erp. Gen., Vol. II., p. 438.
   Hydraspis victoriae, Gray 1842, Zool. Misc., p. 55.
   Chelymys macquaria (pars), Gray, 1844, Cat. Tort, p. 42 .
   Euchelymys sulcifera, Gray, 1871. Ann. Mag. Nat. Hist. ser. 4, Vol. VIII., p. 118.
   Euchelymys sulcifera, Gray, 1872, Proc. Zool. Soc. Lond., p. 508.
   Chelymys victoriae (pars), Gray, Proc. Zool. Soc. Lond., p. 506, pl. XXVII.
   Chelymys macquaria, Cuvier sp. McCoy,, 1884, Prod. Zool. Vict. pp. 11-14, pl LXXXII. and LXXXIII.
   Emydura macquariae, Gray sp. Boulenger, 1889, Cat. Chelonians, Rhynchocephalians and Crocodiles in the Brit. Mus., p. 230, Fig. 63.
   Emydura macquariae, Lydekker, 1889, Cat. Foss. Rept. and Amphibia. Brit. Mus., p. 169.
3. Prod. Zool. Vict., Vol. I., 1884, p. 12.
4. See Proc. Roy. Soc. Vict., Vol. XXIII. (N.S.), pt. I., 1910. pp. 23-26, pls. IV., V.

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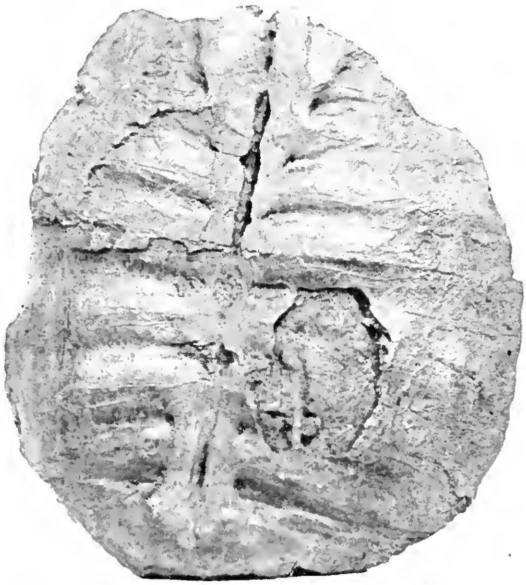

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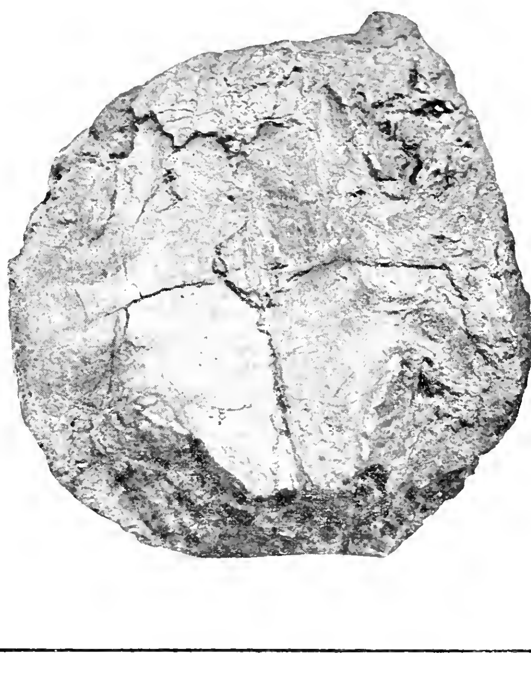

F.C. photo.

circ. ½ nat. size.

Fossil Cast of Emydura, cf. Macquarie, Gray sp., Carapook.

lies 20 miles to the N.W. The probable age of the Redruth ironstone was, in my original description, put down as Miocene, but it is possible that it may be of later age. This can only be proved in conjunction with more precise field evidence than we have at present.

Occurrence.—In an ironstone bed, three feet from the surface, at Carapook, N.W. of Casterton. Presented by Mr. James S. Macpherson.

Age.—Probably Pleistocene.

Previous records of Fossil remains of EMYDURA MACQUARIAE.—R. Lydekker has recorded[5] two fragmentary specimens of the above species from the collection at the British Museum (Natural History), London. One of these is "An imperfect eighth marginal bone of the right side, belonging either to this or an allied species." Its locality is doubtful, but "apparently from the Pleistocene cave-deposits of New South Wales.

The other is "An imperfect right tenth marginal, probably referable to the same species as the preceding; from the Pleistocene cave-deposits of the Wellington Valley, New South Wales. This specimen appears to include part of the eighth costal."

EXPLANATION OF PLATE I.

Fig. 1.—*Emydura* cf. *macquariae*, Gray sp. Dorsal surface of cast in ironstone. Carapook, near Casterton. About half natural size.

Fig. 2—Lower surface of the same specimen. About half natural size.

5. Cat. Foss. Reptilia and Amphibia in the British Museum (Nat. Hist.), pt. III., 1889, p. 169.

[Proc. Roy. Soc. Victoria, 32 (N.S.), Pt. I., 1919].

Art. III.—*On the Essential Oil of Boronia pinnata, Sm. and the presence of Elemicin.*

By HENRY G. SMITH, F.C.S.
(Sydney Technological Museum).

[Read 10th July, 1919].

The Boronias (N. O. Rutaceae) are plentifully distributed in Australia, and constitute a genus the flowers of which are often strongly perfumed.

The essential oil, the subject of this communication, was distilled by Mr. P. R. H. St. John, in Melbourne, from material collected, towards the end of the year 1917, in the Longwarry District of Victoria. The plant at that time of the year was in full bloom.

Very few species of Boronia have so far been worked for their oil, and consequently little is at present known concerning the constitution of their odoriferous products.

In this case it is particularly interesting to know that almost three-fourths of the oil consists of the trimethoxy-phenol ether, Elemicin.

This substance which is 4-allyl—1.2.6, trimethoxy-benzol; $C_{12}H_{16}O_3$, occurs in the higher boiling portion of the oil of Manila Elemi, and it was from this oil that it was first isolated, and its characters and composition determined.

The constants given for Elemicin are:—boiling point 144-147° C. at 10 millimetres pressure; density at 20° = 1.063, refractive index 1.5284; also that it occurs in the fraction of the oil boiling at 277-280° C.

The oil of *Manila Elemi*, distilled from the oleo-resin of *Canarium commune*, L., is thus derived from plants belonging to the Burseraceæ, a natural order somewhat far removed, systematically, from the Rutaceæ, to which Boronia belongs, and it is thus interesting to find this rare plant constituent so widely distributed.

The slight fluorescence of the oil is also worthy of remark, because it seems very probable that this was wholly or partly due to the presence of a small quantity of the methyl-ester of anthranilic acid, which constituent it was possible to extract from the oil by agitating with dilute sulphuric acid. As the plant was in flower at the time of distillation, it is probable that this ester was derived from the flowers, and it may be found not to occur in the leaves. Although the fluorescence of the oil was apparently considerably diminished after agitation with dilute acid, yet it was not entirely removed in this way.

A considerable amount of work has been carried out on elemicin, and iso-elemicin, by Semmler (Ber. 1908, 41, 1768, and other references in the same volume), the material worked upon having been derived from Elemi oil.

This is the first time elemicin has been detected in the oils of Australian plants.

My thanks are due to Mr. F. W. Byrne, of the Chemical Department of the Museum, for assistance in this investigation.

Experimental.

The total yield of oil was equal to 0.383 per cent. The crude oil, which was heavier than water, was of a light amber colour, and had a mild aromatic odour, suggesting the presence of geraniol and geranyl-acetate. It also had a slight fluorescence. When dissolved in absolute alcohol the secondary odour was pleasant, and it appears that the oil of this species of Boronia will be found a useful addition to the perfumery products of Australia.

The crude oil had :—

Specific gravity at 15°C. = 1.0197.

Rotation $\alpha_D = +3.8°$.

Refractive index at 20° C = 1.5125.

Soluble in 1 vol. 70 per cent. alcohol (by weight).

The dextrorotation of the oil was due to the activity of a small quantity of pinene; this is shown later.

The saponification number for the esters was determined both by boiling and in the cold.

(a) 1.5252 grams boiled for half-an-hour with alcoholic potash, required 0.0308 gram KOH. S.N. = 20.2.

(b) 1.528 grams treated with alcoholic potash in the cold with two hours' contact required 0.028 gram KOH. S.N. = 18.3.

This result is important, and, together with the odour, indicates that the chief ester in the oil is geranyl-acetate, and that it occurs to the extent of 6.4 per cent.

That free geraniol was also present is suggested from the results of acetylation. A portion of the crude oil was boiled with acetic anhydride and anhydrous sodium acetate in the usual way.

(a) 1.5144 grams of this esterised oil, when boiled with alcoholic potash, required 0.056 gram KOH. S.N. = 36.9.

(b) 1.5162 grams, when treated with alcoholic potash in the cold, with two hours' contact, required, 0.042 gram KOH. S.N. = 27.7.

To confirm this result some cold saponified oil was steam distilled. Besides the terpenes an aromatic alcohol came over, which was strongly indicative of geraniol.

Although the chief alcohol may be considered to be geraniol, yet it is evident that other alcohols were also present.

Determination of Combined Acids.

A portion of the crude oil was boiled for two hours with an aqueous solution of sodium hydroxide. The alkaline solution was separated and acidified with sulphuric acid. The clear filtered solution was distilled until volatile acids ceased to come over. The distillate was neutralised with Barium hydrate solution, evaporated to dryness and treated in the ordinary way.

(a) 0.1868 gram Barium salt gave 0.1580 gram $BaSO_4$ = 84.58 per cent.

(b) 0.2306 gram Barium salt gave 0.1958 gram $BaSO_4$ = 84.91 per cent.

On treating the Barium salt with sulphuric acid the odour of butyric acid was noticeable; it is thus assumed that butyric acid was also present. The results obtained are equal to 59.8 per cent. of Barium acetate, and 40.2 per cent. Barium butyrate. The acetic acid was evidently in combination with the geraniol as geranyl-acetate.

The amount of free acid in the crude oil could not be satisfactorily determined for several reasons, and although a small amount of a solid acid was eventually isolated, yet the saponification number was under 2.

Phenol and Free Solid Acid.

A portion of the oil was shaken with dilute sodium hydroxide until extraction was complete. The aqueous solution was separated, shaken with ether to remove adhering oil, acidified, and again shaken with ether. The ether extract thus obtained was equal to 0.198 per cent., and was semi-crystalline, due to the presence of the solid acid.

The product was dark coloured, and had a strong phenolic odour. It was dissolved in ether, and the acid removed from the phenol by shaking with a solution of Sodium carbonate. The small quantity of acid when finally purified, was crystalline, and melted at 159-160°C. It was not cinnamic acid, and perhaps consisted of trimethylgallic acid, which is formed by oxidation of elemicin.

The ether solution of the phenol after removal of the acid was evaporated to dryness. The residue had a strong phenolic or creosote-like odour, was not crystalline, and when dissolved in alcohol gave a purplish-brown colour with ferric chloride, which colour remained persistent.

Tests for some of the well-known phenols gave negative results, and as the amount was small, its identity could not be determined.

The oil, after the removal of the phenol and free acid, was repeatedly shaken for some days, with a saturated solution of sodium bisulphite, but no combination took place. Aldehydes were thus absent.

Distillation of the Crude Oil.

100 c.c of the crude oil were submitted to distillation under atmospheric pressure. A few drops of an acid water with a little oil came over below 160°C. (uncorrected). Between 160-250° only 16.5 c.c. came over as first fraction, 10 c.c. of which distilled below 180°.

Thes temperature rose rapidly to 259°, and distillation then proceeded as follows:—

259-265° = 18 c.c.
265-270° = 50 c.c.
270-274° = 63 c.c.
274-280° = 70 c.c.

This fraction was then separated, and although 3 c.c. of an oil came over on continued heating, yet the temperature did not rise beyond 280°. The residue in the still was a dark hard pitch-like substance, which powdered readily when cold.

The first fraction gave the following results:—

Specific gravity at 15°C. = 0.8657.
Rotation $a_D = +15.9°$.
Refractive index at 20° = 1.4639.

Cineol was not present. The oil of this fraction was fluorescent.

15 c.c. of the first fraction were again distilled, when 7.5 c.c. came over below 158°C., and 5.5 c.c. between 158-190°. The

portion distilling below 158° had

Specific gravity at 15° = 0.8596.
Rotation $^{a}D = +21.2°$.
Refractive index at 20° = 1.4569.

and formed a nitrosochloride, which melted at 104°C.

The lower boiling constituent in the oil was thus shown to be dextrorotatory pinene.

Possibly limonene was also present in the intermediate portion, as the specific gravity was only 0.8590.

The second, or large fraction, gave the following results:—

Specific gravity at 15°C. = 1.0519.
Rotation $^{a}D = +0.4°$.
Refractive index, at 20° = 1.5230.

Soluble in 0.5 volume of 70 per cent. alcohol, remaining clear on further addition.

After removal of any phenol which might be present in this fraction, it was again distilled under reduced pressure, the first 15 c.c. being discarded. The remainder boiled fairly constant at 191°C. under 47 millimetres pressure. The product gave the following results:—

Specific gravity at 20°C. = 1.0705.
Inactive to polarised light.
Refractive index at 24°C = 1.5283.

It was thus considered that the bulk of the oil consisted of this constituent. When freshly distilled, it was practically colourless, had a slight fluorescence, and a delicate aromatic odour, reminding somewhat of linalool. It darkened slightly on keeping.

Analysis gave the following:—

(a) 0.1688 gram gave 0.1196 H_2O; and 0.4222 CO_2 : H = 7.87 and C. 68.22 per cent.

(b) 0.1332 gram gave 0.0932 H_2O; and 0.3362 CO_2 .H = 7.8 and C. 68.85 per cent.

$C_{12}H_{16}O_3$ requires H. 7.75 and C. 69.1.

Methoxy Determination.

(a) 0.2872 gram gave 0.9498 AgI equal to 43.6% OCH_3.

(b) 0.3144 gram gave 0.9939 AgI equal to 41.8% OCH_3.

It is thus evident that the molecule $C_{12}H_{16}O_3$ contains three methoxy groups.

That the molecule was unsaturated was shown by the action of Bromine, when the substance was dissolved in carbon tetrachloride, although a satisfactory bromide was not obtained. At first the bromine was absorbed without evolution of hydrobromic acid, but later the evolution of HBr. was pronounced, the solution becoming dark purple.

Formation of the Acid.

A portion was oxidised by Potassium permanganate in alkaline solution; considerable heat was evolved. After completion of the reaction, the remaining colour was removed by sulphurous acid, filtered, evaporated to small bulk, and acidified with dilute sulphuric acid. A solid acid separated at once. This was purified from boiling water, from which it crystallised in needles. It melted sharply at 169°C (corr.) without decomposition. The acid was titrated with decinormal sodium hydroxide; 0.13 gram dissolved in absolute alcohol required 6.15 c.c. $\frac{1}{10}$ NaOH to neutralise, thus 40 grams would neutralise 211.4 grams of acid, $C_{10}H_{12}O_5 = 212$.

It was thus evident that the acid was trimethylgallic acid $C_{10}H_{12}O_5$, the characteristic acid formed by the oxidation of elemicin.

That a small quantity of iso-elemicin was also present was indicated by the formation of a minute quantity of acetic acid on oxidation by Potassium permanganate. This was shown by distilling over the free acid and forming with it the Barium salt. This on ignition gave 91.6 per cent. $BaSO_4$. Theory requires 91.37 per cent.

The above investigation shows that the principal constituent in the oil of *Boronia pinnata* is the trimethoxyphenol-ether, Elemicin, (4 allyl—1,2,6 trimethoxybenzol) and that it occurs in the oil of this species to the extent of about 70 per cent.

[PROC. ROY. SOC. VICTORIA, 32 (N.S.), PT. I., 1919].

ART. IV.—*On the "Clawing" Action of Rain in Sub-Arid Western Australia.*

BY J. T. JUTSON

(With Plate II.).

[Read 10th July, 1919].

Introduction.

In sub-arid south-central Western Australia, which is portion of the great plateau of that country, erosion presents results different in many ways from those obtained in areas possessing a "normal" climate. This is partly due to the difference in degree, and to some extent in kind, of the erosional agents, and partly to the surface alteration that rocks and soils have in many parts sustained. There are certain minor features which are peculiar to the area, and therefore of interest. Such are the miniature soil-terraces described in this paper, the formation of which is associated with the "clawing" action of rain, and with the gravitational drift of rock debris.

Summary.

The "clawing" action of rain on gentle soil-covered slopes with a firm surface produces terraces with tiny cliffs, which are termed "miniature soil-terraces," and at the same time gradually removes the soil to lower ground. By the formation and recession of these terraces, drifting rock debris is undermined, and topples forward down the slopes. Thus a decided aid is given to the slow, gravitational drift of rock debris from higher to lower parts.

Description of the Processes.

In sub-arid south-central Western Australia there is a widespread tendency to form hard caps at the surface, owing to water being drawn there by capillary attraction, and to evaporation then taking place with deposition of the contained salts.

Soils are no exception to this process, although the cap is in places but a mere film of slightly firmer material than that below. This film, however, is quite sufficient to influence the transporting action of the rain. On many gentle soil-covered slopes, especially those covered by a sandy loam, the rain passes over the film in thin sheets or rills without furrowing the ground, despite the latter having many spaces bare of vegetation. Where the film becomes broken by any means, miniature waterfalls occur, due to the flow of water over the film to the softer soil beneath. Tiny cliffs are thus formed.

These tiny cliffs may be only from an inch to six inches in height, but they may extend laterally—that is, approximately at right angles to the direction of water-flow—for many yards, and thus form a miniature soil terrace on the slope. Other similar terraces may form above and below; and thus on a gentle slope several such terraces may be seen rising one above another, separated by varying distances, but usually fairly close together.

The actual outline of a terrace (see Plate II., Fig. 1) may be described as a series of gentle curves or scallops, mostly concave to the ground at the foot of the "cliffs," and each curve usually presents a minutely crenulated edge. This appearance suggests some force that has gently clawed away the soil, and hence the writer terms the rain action "clawing," Tiny furrows may run from the "clawed" edges, indicating the directions of the minute rills. These furrows usually tend to unite within a few feet from the edges into a larger one, but within a few more feet this larger furrow dies out, owing to the action of the water in depositing the transported fine sand and soil as a series of minute, flat alluvial fans or "lobes." The surface of the lower ground by reason of such deposit becomes levelled off, thus illustrating, on a very small scale, one result of rain action in this country. Another general result is the slow transportation by rain of soil from higher to lower ground.

Extensive areas of rock fragments slowly drifting from higher to lower ground form one of the commonest surface features in sub-arid south-central Western Australia; but only the most resistant rocks, such as quartz, jasper and ironstone, travel any distance. On the soil-covered terraces, such loose pieces of rock often occur; and, as "clawing" proceeds, these fragments are seen in course of being undermined. Eventually they topple over to the lower level, and by repetition of this process their migration down the slope is largely accomplished.

[Proc. Roy. Soc. Victoria, 32 (N.S.), Pt. I., 1919].

Art. V.—*A Striking Example of Rock Expansion by Temperature Variation in Sub-Arid Western Australia.*

By J. T. JUTSON.

(With Plate II.).

[Read 10th July, 1919].

A rather remarkable example of rock expansion, due to temperature-variation, having come under the writer's notice in sub-arid Western Australia, its record may be of value. It occurs about ten miles to the north-north-west of Comet Vale, a mining township about sixty miles north of Kalgoorlie, on the Kalgoorlie-Laverton railway line. It is, therefore, situated well in the interior of Western Australia, in an area of low rainfall and of great temperature variations.

The rock is a biotite granite, which outcrops as a bare rounded hill rising to an inconsiderable height above the surrounding plain. This rock is, therefore, constantly exposed to the weather; and, owing to the great variations in daily and nightly temperature, it peels off in layers or bands of various thickness, with the result that the rock assumes the well-known rounded appearance characteristic of granite. This peeling or flaking off is the "desquamation" of Richthofen.[1]

The particular occurrence referred to is a surface slab of granite, on the lower slope of the hill, abutting a "gnamma," or natural rock-hole. This slab is 10 feet long, two feet six inches wide, and ranges from one and a half to four inches in thickness. It is separated from the parent mass, except at its ends (which here mean the terminations roughly at right angles to its length). These ends pass into rock of similar character, but the slab rises in a gentle curve towards the centre, where it is not resting on anything (except possibly at one point on a loose boulder that has drifted into the cavity). On the uphill and downhill sides of the slab, at the centres of the respective sides, the height of the lower face of the slab from the surface of the solid rock below is seven inches and four and a-half inches respectively. The slab is cracked

1. Hume, W. F., "Professor Walther's Erosion in the Desert Considered." Geol. Mag., Decade VI., Vol. I., Nos. 595-6 (1914), p. 21.

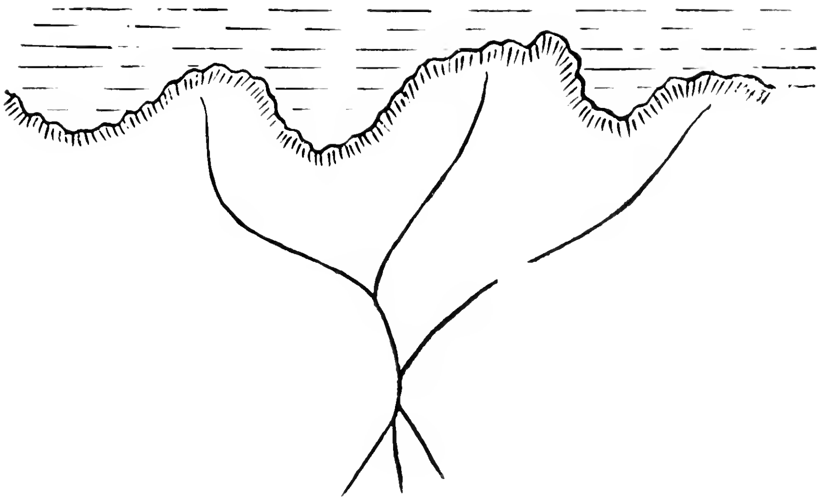

Fig. 1—The figure shows the tiny rain furrows running from the foot of the "cliffs," uniting, and then dying out as "distributaries."

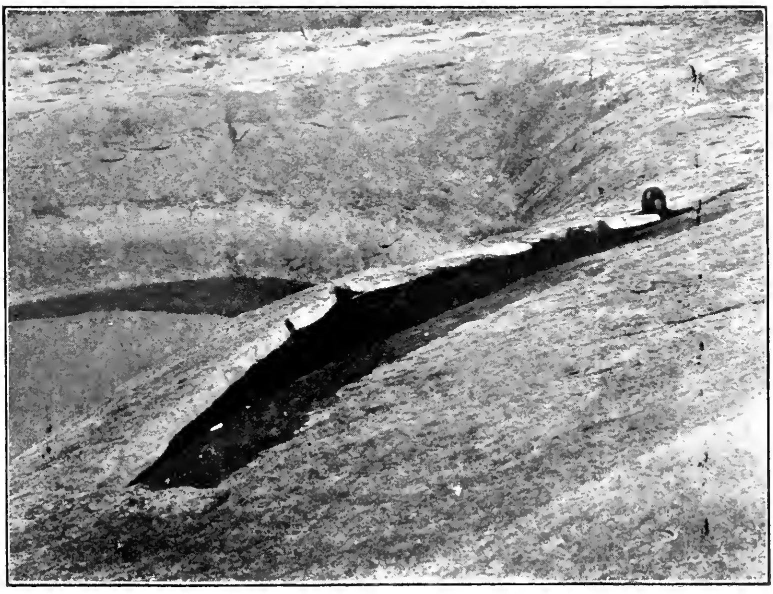

Fig. 2.

right through (vertically and horizontally) across the centre, and the portion on one side of the crack has sunk one half of an inch to an inch below the other portion.

This slab of rock has, therefore, been bent and raised to a maximum height of seven inches above the solid rock below; and its bending power was so great that it attained this height before breaking. Temperature variation appears to be the only cause of this phenomenon.

The accompanying photograph (Plate II., Fig. 2), illustrates the features here described.

[Proc. Roy. Soc. Victoria, 32 (N.S.), Pt. I., 1919].

Art. VI.—*On an Ostracod and Shell Marl of Pleistocene Age from Boneo Swamp, West of Cape Schanck, Victoria.*

By FREDERICK CHAPMAN, A.L.S., F.R.M.S.

(With Plates III. and IV).

[Read 10th July, 1919].

Description of Deposit.

The dried marl is of a whitish-grey colour, but when wet is grey to smoke-brown. It is light in weight and cavernous in places, the holes being due to the roots and stems of plants, which have been enclosed in the deposit.

The molluscan shells are mainly of freshwater types, belonging to the genera *Bullinus* and *Coxiella*, but the marine genus, *Erycina*, is also well represented.

Ostracoda are chiefly of aquatic character, as *Cypris* and *Candonopsis; Limnicythere* is a genus which is usually found in streams and lakes, draining high land, and in close proximity to the sea; *Cythere* (*C. lubbockiana*), though rare in this deposit, is a true marine ostracod.

Under a high power of the microscope the fine washings are seen to consist of minute rounded particles mingled with fragments of ostracoda, and a few freshwater diatoms (*Cymbella*). This genus of diatomaceae has been previously recorded from several Victorian localities of Pleistocene age, in deposits of a freshwater or lacustrine nature, as those of Mickleham (det. by author), Eglinton, Amherst, Coralulup, Splitter's Creek, Rodborough, Belfast and Talbot.[1]

The material is almost purely calcareous. On testing it for phosphoric acid, no reaction was obtained.

1. See Mahony, D. J. Bull, Geol. Surv. Vict., No. 26. 1912, pp. 12, 15 and 16.

Description of Fauna.

PHYLUM MOLLUSCA.

Class PELECYPODA.

Fam. LEPTONIDAE.

Genus ERYCINA, Lamarck.

Erycina helmsi, Hedley. (Plate III., Figs. 1, 2.)

Erycina helmsi, Hedley, 1915, Proc. Linn. Soc., N.S. Wales, vol. XXXIX., pt. IV., p. 701, pl. LXXX. Figs. 37-39. Chapman and Gabriel, 1917, Proc. R. Soc. Vict., vol. XXX. (N.S.), pt. I., p. 6.

Observations.—It is interesting to meet with this little bivalve in these sub-fossil deposits, in which the majority of forms are of freshwater habitat. The localities where it is found living are Dee Why Lagoon, New South Wales; and in Victoria, at Port Melbourne, Corio Bay, Altona Bay, Port Albert and Lakes Entrance. Mr. C. J. Gabriel and the author also recorded it (loc. supra cit.) from the Pleistocene deposits underlying volcanic tuff near Warrnambool, where it occurred abundantly in association with many marine shells and a few brackish water forms. Some specimens from Lake Connewarre, near Geelong, in the Dennant collection, labelled "*Pisidium etheridgei,*" also belong to the above species. At first glance, this small form might easily be mistaken for the aquatic genus, *Pisidium*, but an examination of the hinge-line is sufficient to show the difference.

Occurrence.—Common in the Boneo Swamp deposit.

Class GASTEROPODA.

Fam. TRUNCATELLIDAE.

Genus COXIELLA, E. A. Smith.

Coxiella striatula, Menke sp. (Plate III., Fig. 3.)

Truncatella striatula, Menke, 1842, Moll. Nov. Holl., p. 9.

Blanfordia pyrrhostoma, Cox, 1868, Mon. Austr. Land Shells, p. 95, pl. XV., Fig. 14.

Pomiatopsis striatula, Menke sp. Tenison Woods, 1876, Proc. Roy. Soc. Tas. for 1875, p. 78.

Coxiella striatula, Menke sp., E. A. Smith, 1898, Proc. Malac. Soc., vol. III. p. 75.

Coxiella confusa, E. A Smith, 1898, Ibid. p. 76.

Coxiella striatula, Menke sp., Hedley, 1916, Prelim. Index. Moll. W. Austr., p. 189.

Observations.—Some of the shells of this freshwater or brackish lacustrine species have as many as six whorls. The periostracum having been removed by natural decay, the ornament is clearly seen as a longitudinal striation with occasional stronger varicial striae, crossed by finer lineations. The young examples of about three whorls are not decollated, the protoconch showing as a smooth depressed spiral of about one and a-half whorls.

The cleaned surfaces of the shells point to a slight age for this deposit, although it should be borne in mind that the margins of some swamps where this species abounds are covered with layers of the shells in this condition.

C. striatula is a very widely distributed form in Australia.

Occurrence.—Common in the Boneo Swamp deposit.

Fam PLANORBIDAE.

Genus BULLINUS, Oken.

Bullinus acutispira, Tryon, sp. Plate III., Fig. 4.

Physa acutispira, Tryon, 1866, Amer. Journ. Conch. vol. II. p. 9, pl. II., Fig. 10. Tate and Brazier, 1881, Proc. Linn. Soc. N.S. Wales, vol. VI., p. 557. Smith, 1882, Journ. Linn. Soc. Lond. Zool., vol. XVI. p. 282, pl. VI., Fig. 16. Clessin, 1885, Conch. Cab., vol. I. pt. 17, p. 242, pl. XXXIV., Fig. 1.

Bullinus acutispira Tryon sp., Hedley, 1917, Rec. Austr. Mus., vol. XII., No. 1, p. 5, pl. I., Figs. 11-13.

Observations.—The present speciments of these freshwater shells from Boneo Swamp are of thicker build than the var. *yarraensis*, T. Woods.[2] and are therefore referred to the type species.

Bullinus tasmanicus, T. Woods sp.[3] closely resembles the above species, but the apex is not so acute, nor is the aperture so open. The species and variety have been recorded from Horsham, Cape Grant, near Portland, Yan Yean Reservoir, Bunyip River, and Carrum Creek, Frankston. One of the Boneo Swamp specimens has an elongated spire, and resembles the figured specimen of Hedley's, from Horsham.

Occurrence.—This specimen is fairly numerous in the Boneo Swamp material.

2. *Physa yarraensis*, T. Woods, Proc. Roy. Soc. Vict. Vol. XIV., 1878, p. 64. *Bullinus acutispira*, Tryon, sp., var. *yarraensis* T. Woods var. Hedley, 1917, Rec. Austr. Mus., Vol. XII., No. 1, p. 5, pl. II., Fig. 16.

3. *Physa tasmanica*, T. Woods, Proc. R. Soc. Tasmania, for 1875 (176), p. 74. *Bullinus tasmanicus*, T. Woods, sp. Chapman, Mem. Nat. Mus., Melbourne, No. 5, 1914, p. 58, pl. I., Figs. 5, 5*a*.

Class CRUSTACEA.

Super-order OSTRACODA.

Fam. CYPRIDAE.

Genus CYPRIS, Müller.

Cypris mytiloides, G. S. Brady. (Plate III., Figs. 5, 5*a*.)

Cypris mytiloides, G. S. Brady, 1886, Proc. Zool Soc. Lond. p. 89, pl. IX., Figs. 1-3.

Observations—This species was first described from Kangaroo Island, S. Australia. It is a well known living form in Victorian swamps and lakes, and I have examples from the Yering Flats, near Lilydale.

The carapace of *C. mytiloides*, seen laterally, appears to be generally rather broader than in the majority of living specimens, but this difference is only sub-varietal. Average length of carapace, 3.2 mm.; breath, 1.4 mm., The type specimen of Dr. Brady, supplied by Prof. Tate, has a length of 5 mm.

Occurrence.—In the Boneo Swamp deposit this species is very abundant.

Cypris sydneia, King. Plate IV., Figs. 6, 6*a*.

Cypris sydneia, King, 1855, Proc. R. Soc. Tasmania, vol. III., pt. I. p. 65, pl. X. Fig. M.

Cypris ciliata, Thomson, 1879, Trans. N.Z. Inst., vol. XI. p. 253, pl. XI. Fig. A, I*a-g*.

Cypris sydneia, King, G. O. Sars, 1894, Vidensk, Selsk, Skrifter. I. Math. Nat. Kl. No. 5, p. 27, pl. IV., Figs, 2*a-c*. Id., 1896, Freshwater Entom. from neighbourhood of Sydney, Kristiania (Alb. Cammermeyers Forlag), p. 50.

Observations.—*C. sydneia* was originally described from specimens taken in a swamp near Woolloomooloo Bay, Sydney, and Mr. Whitelegge collected it from Bourke Street, Sydney. The New Zealand localities are—lagoons in the neighbourhood of Dunedin; a pond at Eyreton, North Canterbury district; ditches at Kaitaia, N. Island.

The present examples are quite typical, and the shape and position of the muscle-spots agree with the figures given by Sars, of the New Zealand specimens. The surface of the shell is sparsely punctate, and from each punctum there is a faint stria directed posteriorly.

Occurrence.—This freshwater species is fairly abundant in the Boneo Swamp deposit.

Cypris tenuisculpta sp. nov. (Plate IV., Figs. 7, 7*a*, *b*.)

Description.—Valve seen from the side, subreniform, highest in front, narrowing slightly to the posterior. Edge view subovate, moderately tumid, more compressed anteriorly. Valves slightly unequal. Dorsal margin roundly angulate near the middle, directly sloping to the extremity. Both ends evenly rounded. Ventral margin incurved at the middle, and curving outwards to meet the evenly rounded anterior border; the latter having a narrow depressed margin. Surface of shell finely but distinctly sculptured with closely set longitudinal and anastomosing raised lines.

Length, 1.3 mm.; greatest width, 0.77 mm.

Observations.—This species closely resembles *Cypris lateraria*, King,[4] especially in the figures given by G. O. Sars[5] from the Sydney examples. The chief difference lies in the superficial sculpture, which in the present species is finely lineate, *C. lateraria* having a granulose surface with scattered tubercles.

Occurrence.—Common in the Boneo Swamp deposit.

Candonocypris assimilis, G. O. Sars. Plate IV., Figs. 8, 8*a*.

Candonocypris assimilis, G. O. Sars, 1894, Contrib. knowledge Freshwater Entom. N, Zealand, Vidensk, Selsk, Skrifter, I. Math. Kl. No. 5, p. 36, pl. V., Figs. 2*a-c*.

Observations.—In outline, seen from the side and above, the fossil specimens perfectly agree with Sars' New Zealand species, which is a freshwater form. The valves are slightly unequal, as seen in at least one of the complete carapaces in the present collection, and the muscle-spots number 7, with 2 arranged slightly forward and below the others. The surface of the shell is marked with excessively fine, elongate reticulae and a few punctations.

The writer would be inclined to place under the above genus Brady's *Cypris viridula*,[6] of which the above appears to be a fuscous variety. The straight dorsal border figured by Dr. Brady

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4. *Cypris lateraria*, King, Proc. R. Soc., Tasmania, Vol. III., pt. I., 1855, p. 65, pl. X., G. G.
5. G. O. Sars, 1896. On Freshwater Entom., from the neighbourhood of Sydney, partly raised from dried mud, Kristiania, p. 53, pl. VII., Figs. 3*a-c*.
6. Proc. Zool. Soc. Lond., 1886, p. 88, pl. VIII. Figs 1, 2.

is not always represented, and in other ways, as in the thicker carapace, it seems to be distinct from *Ilyodromus*, in which genus G. O. Sars has more recently placed it.

Sars' specimens were hatched from dried mud taken from lagoons in the neighbourhood of Dunedin. A female measures 1.6 mm. in length. The present examples have a length of about 1.4 mm.

Occurrence.—Abundant in the Boneo Swamp material.

Fam. CYTHERIDAE.

Genus CYTHERE, Müller.

Cythere lubbockiana, G. S. Brady. Plate IV., Fig. 9.

Cythere lubbockiana, G. S. Brady, 1880, Rep. Chall. vol. I. pt. III. Zool. p. 68, pl. XIV., Figs, 6*a-d*. Chapman, 1914, Proc. R. Soc. Vict. vol. XXVII. (N.S.), pt. I. p. 36, pl. VII., Fig. 17.

Observations.—The present example of this marine ostracod appears to be typical in all essentials as form, outline and ornament, with a minor exception that the pittings are replaced by smaller punctuation, as in *C. acupunctata*, Brady.[7] As a living species, it is recorded from Booby Island, Torres Strait, in 6-8 fathoms.

Fossil specimens have been recorded by the writer from the Miocene and Pliocene of the Mallee bores, the deepest being 542 feet from the surface; these Miocene deposits, by the way, have been formed in about 100 fathoms.

It is interesting to note the above species under such widely differing circumstances as to age, depth and geographical position. Although not yet recorded from coastal dredgings round Victoria, *C. lubbockiania* probably occurs in its shallow depths; and in times not far distant, this and its allies, along with the marine bivalve, *Erycina helmsi*, were washed in by tidal currents.

Occurrence.—One left valve found in the Boneo Swamp deposits.

Limnicythere sicula, sp. nov. Pl. IV., Figs. 10, 11.

Description.—Valves very small; seen from the side, subrectangular, expanded anteriorly. Hinge-line long and straight; ventral border incurved in the middle. Anterior margin depressed,

7. *Cythere acupunctata*, Brady, Rep. Chall. Vol. I., Pt. III. Zool. 1880. p. 68, pl. XIV., Figs. 1*a-h*.

with a broad border marked with radial lines; posterior with a narrow depressed margin. Seen from above, carapace ovate, compressed at the extremities, with a hooked process prominent in the median area. Rising from the middle of each valve, a little in front and towards the ventral margin, the hooked process is seen to curve towards the dorsal border. Below this, nearer the ventral margin, is a rounded prominence or tubercle, and near the dorsal margin, anteriorly and medially are two others, Superficial ornament consists of fine reticulae or pittings scattered closely over the larger part of the valves.

Length, .38 mm.; greatest width, .3 mm.; thickness of carapace, .27 mm.

Observations.—None of the northern species very closely approach the above form, the nearest being *L. monstrifica*, Norman sp.,[8] found living round England, and Pleistocene in the Lincolnshire Fens. This has two large spinous processes, with several smaller spines and ridges. Undoubtedly the nearest allied species is the *Limnocythere mowbrayensis*, Chapman,[9] which the writer recently described from Mowbray Swamp, near Smithton, N.W. Tasmania. In this species, the lateral processes are not so produced, the tubercles differently spaced, whilst the anterior border is not so deep nor broad. Moreover, it attains a larger size than the present species.

Occurrence.—This very minute species is excessively abundant in the Boneo Swamp deposit.

General Remarks and Summary.

An examination of the swamp deposit from this locality in the Schanck Peninsula affords some interesting points for comment. Probably in late Pliocene times, and on to Pleistocene, this area was connected with Tasmania. The immediate progenitors of the freshwater mollusca and ostracoda found in the Boneo deposit must have been living in dune and swamp country, which no doubt extended across Bass Strait. We can conceive this country then connected by way of a chain of swamps running from the

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8. *Cypris monstrifica*, Norman, Ann. Mag. Nat. Hist., Vol. IX., 1862, p. 45, pl. III., Figs. 4, 5. *Limnicythere monstrifica*, Norman sp. Brady, Mon. Rec. Brit. Ostrac., 1868, p. 420, pl. XXIX., Figs. 9-12.
9. Mem. Nat. Mus., Melbourne, No. 5, 1914, p. 60, pl. II. Figs. 8*a*-*c*.

N.W. corner of Tasmania passing northwards to the east of King Island, and joining with the Cape Schanck area.[10]

That there is a slight antiquity to be ascribed to the Boneo deposit seems to be shown by the presence of marine shells, for the existing conditions would appear to preclude their penetration so far inland, unless perhaps by an abnormally high tide. No doubt the actual conditions at the time of deposition were those of tidal swamps, such as may be seen in the coastal lakes of the Ninety Mile Beach in Gippsland.

This marl is not phosphatic, as might be supposed from the abundant remains of ostracoda. An explanation of this may be found in the fact that those forms which do occur are all thin-shelled, and of the more purely calcareous type of freshwater genera.

The organic remains found in this marl are:—

Pelecypoda.	*Erycina helmsi*, Hedley.
Gasteropoda.	*Coxiella striatula*, Menke sp.
	Bullinus acutispira, Tryon sp.
Ostracoda.	*Cypris mytiloides*, G. S. Brady.
	,, *sydneia*, King.
	,, *tenuisculpta*, sp. nov.
	Candonocypris assimile, G. O. Sars.
	Cythere lubbockiana, G. S. Brady.
	Limnicythere sicula, sp. nov.

EXPLANATION OF PLATES.

Plate III.

Fig. 1.—*Erycina helmsi*, Hedley. Left valve. × 10.

,, 2.—*E. helmsi*, Hedley. Interior of left valve of another specimen. × 10.

,, 3.—*Coxiella striatula*, Menke sp.

,, 4.—*Bullinus acutispira*, Tryon sp. × 5.

,, 5.—*Cypris mytiloides*, G. S. Brady. Right valve. 5*a*, ventral edge view of the same. × 26.

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10. In Dr. F. Noetling's paper on the Antiquity of Man in Tasmania (Proc. R. Soc., Tasmania, 1910), that author, on plate I., Fig. 6, shows the Tasmania-Victorian coastal contours, as would appear from an uplift of 40 fathoms of the present sea bottom in the Strait. The tongue of land thus brought up would form a direct connection from the Smithton (N.W. Tasmania) district to the Boneo (Cape Schanck) locality, and this view helps considerably to explain the theory here advanced, that the Boneo fluviatile fauna was, in part at least, derived from a Tasmanian one.

Plate IV.

Fig. 6.—*Cypris sydneia*, King. Right valve, showing muscle-spots, 6*a*, ventral edge view. × 26.

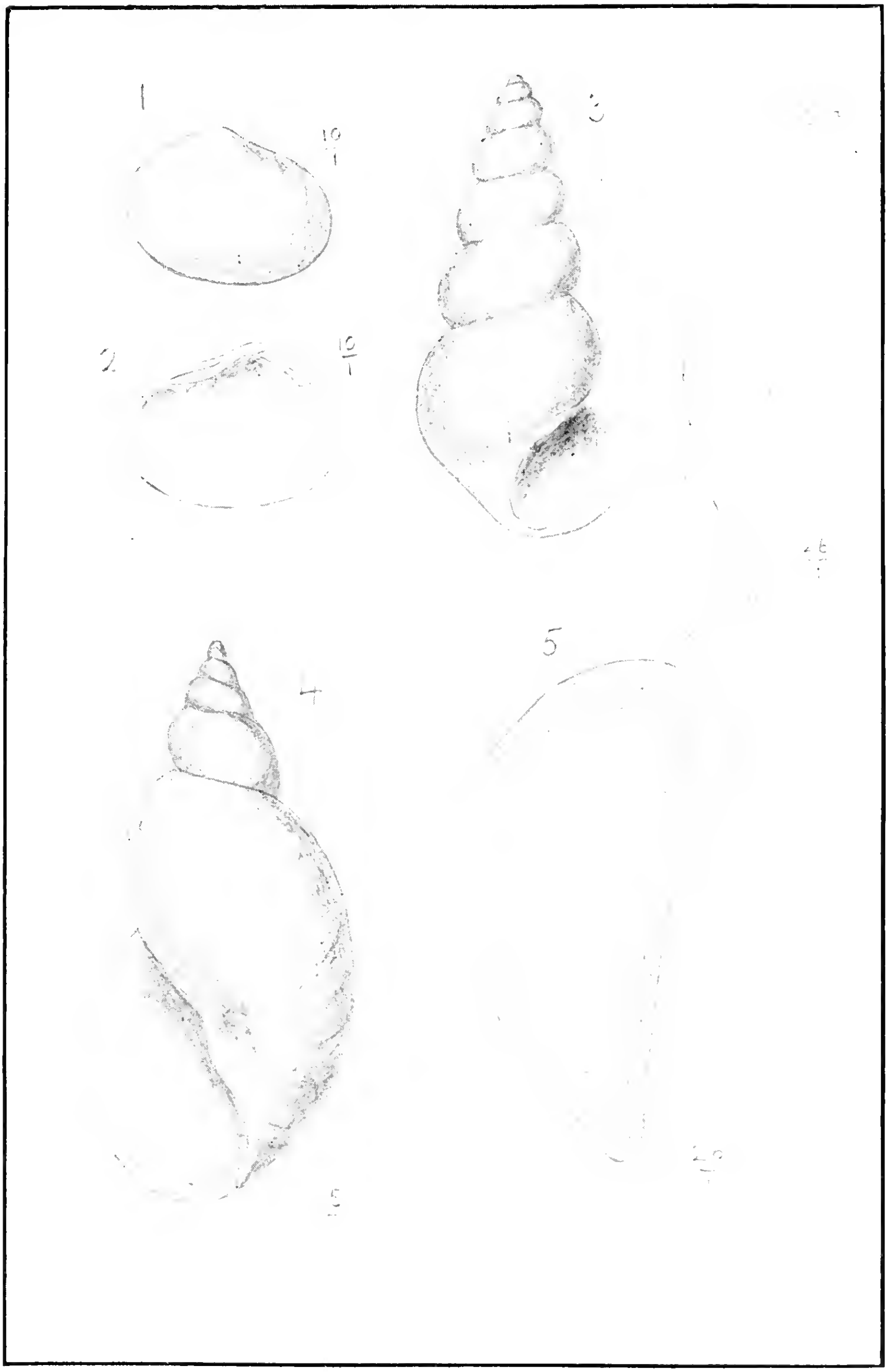
,, 7.—*Cypris tenuisculpta*, sp. nov. Right valve, × 26. 7*a*, ventral edge view of carapace, × 26. 7*b*, magnified view of ornament. × 78.

,, 8.—*Candonocypris assimile*, G. O. Sars. Left valve, showing muscle-spots. 8*a*, ventral aspect of carapace. × 26.

,, 9.—*Cythere lubbockiana*, G. S. Brady. Left valve. × 52.

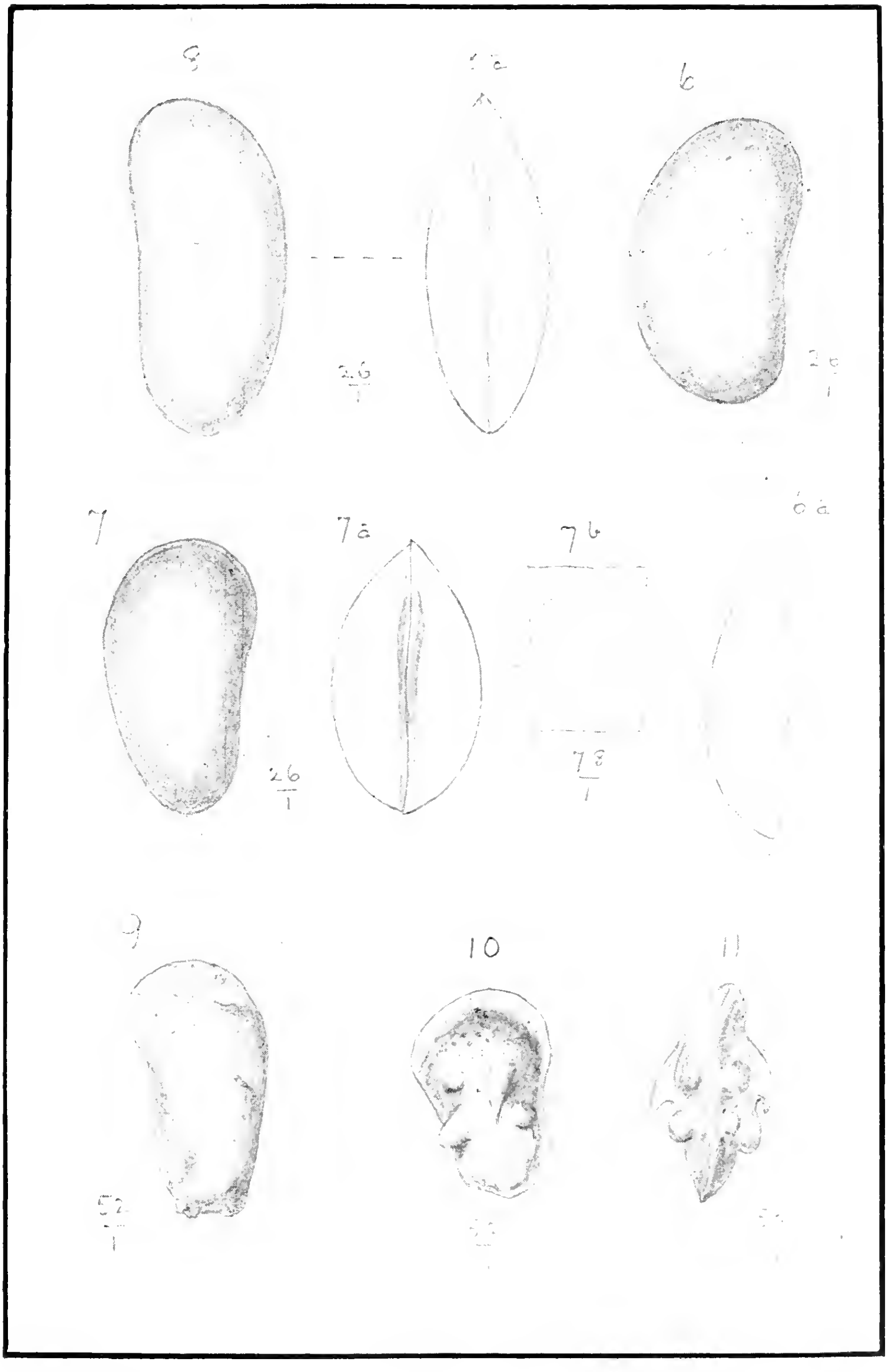
,, 10.—*Limnicythere sicula*, sp. nov. Right valve. × 52.

,, 11.—*L. sicula*, sp. nov. Edge view, dorsal aspect. × 52.



F.C. del. ad nat.

Pleistocene Fossils: Boneo Swamp, C. Schanck.



F.C. del. ad nat.

Pleistocene Ostracoda: Boneo Swamp, C. Schanck.

[Proc. Roy. Soc. Victoria, 32 (N.S.), Pt. I., 1919].

Art. VII.—*The Diabases and Associated Rocks of the Howqua River near Mansfield, with reference to the Heathcotian Problem in Victoria.*

By E. O. TEALE, D.Sc., F.G.S.

With an account of the Petrography of the Diabases by Prof. E. W. Skeats.

(With Plate IV., 4 Text Figures and Map).

[Read July 10th, 1919].

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7. Summary and conclusions.

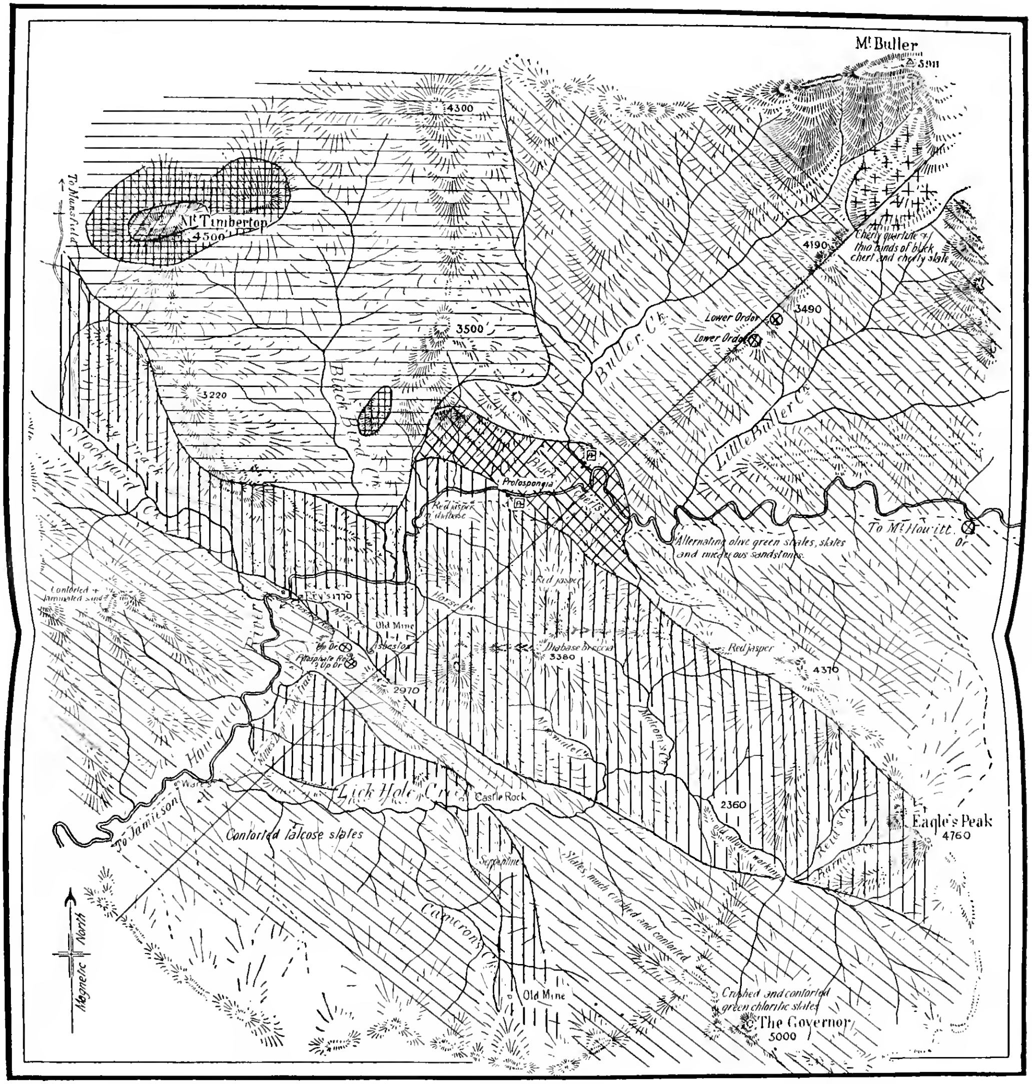
1.—Introduction.

The existence of serpentine and associated basic igneous rocks in the Howqua River to the south-west of Mount Buller was first referred to by Mr. A. M. Howitt,[1] in 1907, in the Records of the Geological Survey in a short note with an accompanying sketch map. Mr. Howitt's visit was an extremely short one, allowing only about a day in the field, and his main object was to report on the supposed occurrence of phosphate of alumina similar to that found near Mansfield. He, however, was able at the same time to note the outcrop of a considerable extent of basic igneous rocks and black cherts. The latter he regarded as probably Heathcotian, on account of their resemblance to similar cherts at Heathcote, which had then been recently placed in that group by Professor Gregory.[2] The igneous rocks he described as amphibolites, which he regarded as intrusive into the Lower Palaeozoic and of Devonian age. He also obtained a graptolite from the Palaeozoic slates which the late Dr. T. S. Hall referred to as a Monograptus,[3] thus indicating Silurian strata. The amount of information collected by Mr. Howitt in a short time, and in such rough and mountainous country, is remarkable. The writer having spent considerable time in the Mount Wellington district in Gippsland, examining the area where serpentine and associated Upper Cambrian limestones occur, came to the conclusion that an important axial line existed in the Wellington region. The extension of the line to the north passes through inliers of closely similar rocks on the Howqua, and at Dookie.

When, therefore, Professor Skeats suggested that I should take up the study of the Howqua region, with the assistance of a Government Research Scholarship, I was very glad to avail myself of the opportunity. I would like at this stage to specially express my indebtedness to Professor Skeats for his interest and assistance in this work. He not only visited the out of the way region on the Howqua, spending about a week in the field with me, but very kindly conducted me over the Lancefield and Heathcote areas, which may be looked upon as the type occurrence of the much debated Heathcotian series.

This work has been invaluable for comparative purposes in dealing with the Howqua region. In the Geological Laboratory of the University, too, I have had advantage of full access to the numerous slides and hand specimens from these regions. It is very helpful

GEOLOGICAL SKETCH MAP, HOWQUA HILLS
SOUTH EAST OF MANSFIELD



LOWER PALÆOZOIC

DIABASE	Heathcotian.	
CHERT ⊡ *Protospongia*		
SLATE AND SANDSTONE	Cambrian ? to Silurian. ?	⊗ *Graptolites, L.Ordov. to Silurian?*
GRANO-DIORITE	Devonian	

UP. PALÆOZOIC

DACITE-PORPHYRY	Devonian
RHYOLITE	Lower Carboniferous
SANDSTONE, CONGLOMERATE AND PURPLE SHALE	Lower Carboniferous

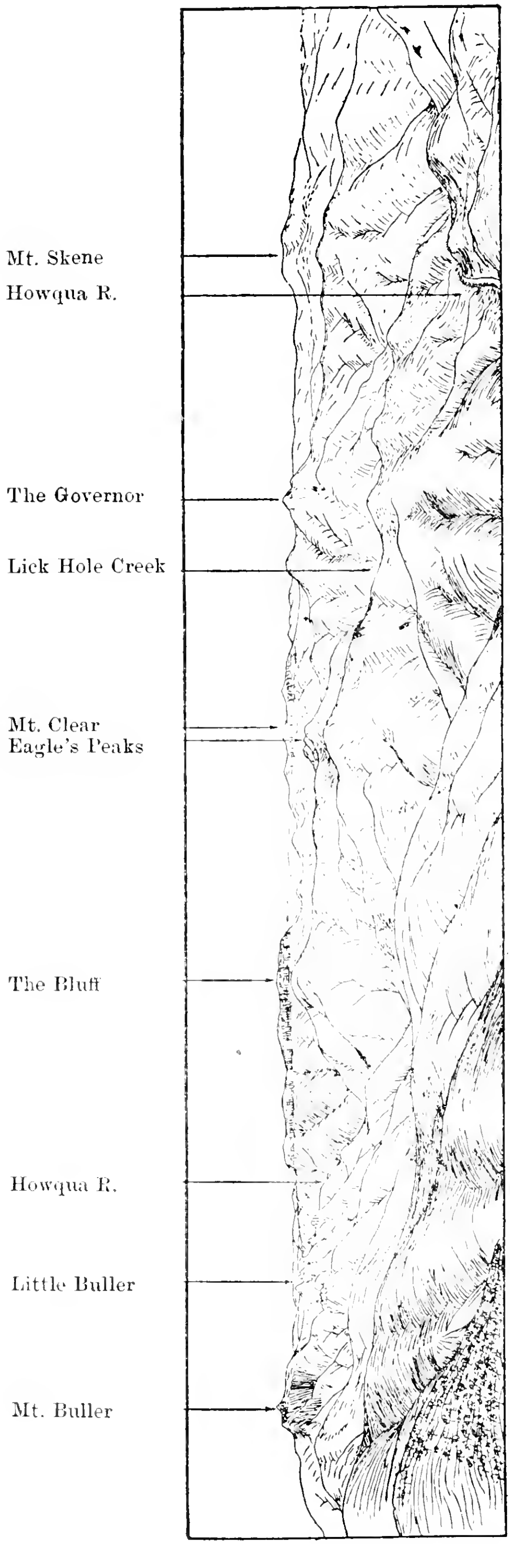
Scale: 40 30 20 10 0 40 80 120 — *Chains* —

therefore to be able to treat the new area in a comparative manner with the better known regions. While there are certain gaps and differences in the Howqua region, as compared with Lancefield, Heathcote and the Dolodrook, near Mount Wellington, many of the comparisons are strikingly similar. It is possible to match many of the special rocks of Heathcote so closely that were the specimens not labelled, it would be impossible to distinguish them from each other.

The problems of the Heathcotian series and the controversial questions wherein Professor Skeats, Mr. E. J. Dunn, Professor J. W. Gregory, and the late Dr. A. W. Howitt either agreed with or differed from each other, have been ably set out by Professor Skeats ([4] and [5]), so that it will only be necessary to enumerate here in due place those special aspects which call for consideration in conjunction with the Howqua area. Many important features in the Lower Palaeozoic history and structure in Victoria are dependent on the elucidation and interpretation of the origin, age and relationships of the various rocks in the scattered inliers of diabases and cherts, now generally included in the Heathcotian series. Regarding this series, field work proves that the Heathcotian conformably underlies graptolite bearing Lower Ordovician rocks, and on field evidence therefore it might be Lower Ordovician or Cambrian. It is on the reconsideration of the Dinesus material on which the original claim for a Cambrian age, subsequently abandoned, is now reasserted, and appears to be established, that it becomes necessary to include the lowest beds generally known as Heathcotian in the Cambrian.

2.—General Location of the Howqua Region.

The area under consideration lies to the south-east of Mansfield just within the rough mountainous region of the central highlands of Victoria. It is distant by road from Mansfield about 22 miles. For 12 miles, as far as Merrijig, on the Delatite River, the road is good, thence the route follows an old track little used, and in a very poor state of repair. By this a steep ascent is made over the shoulder of a ridge overlooked by Mount Timbertop, to drop down into the deep mountainous valley of the Howqua, a striking contrast in its rugged and almost uninhabited character from the open park-like grazing and farming district of Mansfield.



CENTRAL VICTORIAN HIGHLANDS,
HOWQUA REGION.
Sketch from M'Timberlop from east to south showing stage of dissection and remnants of overmantle of horizontal or relatively flat lying rocks.

Fig. 1.

3.—Physiographical Features.

Physiographically, the Howqua area is in an interesting position. It lies near the northern edge of the great central highland belt of Victoria, close to the wide and striking sunkland of the Mansfield district, the development which has had such a remarkable and interesting effect on the history of the river system of this region, the details of which have been ably discussed by Fenner.[6]

Standing on the commanding viewpoint of Mount Timbertop, at about 4500 feet, the general survey of the physiography is particularly interesting, and is scenically both grand and varied. (See Fig. 1.) To the south and east especially the view is most imposing, looking out over the deep Howqua Valley, across the fretted and dissected northern portion of the central plateau, the highest portions of which rise to close on 6000 feet. Mount Buller, the nearest, about four miles to the east, at 5911 feet, present a precipitous front to the west, and forms, with its basalt capped summit, a striking remnant of the old plateau, with the valleys of the Delatite and the Howqua on either side 4000 feet deep. At Timbertop the observer is standing in a small outlier of the flat lying Upper Palaeozoic strata, with the frequently associated rhyolite at the base. To the east and south-east he looks over a vast extent of deeply dissected country, from which the great overmantel of hard, almost horizontal, rocks has been removed, exposing the underlying highly inclined Lower Palaeozoic rocks, chiefly slate and sandstone. The central watershed of the State, known as the Main Divide, lies about 20 to 30 miles distant in this direction, and presents a precipitous and ledged front, due to the same more or less horizontal strata as those on Timbertop. Mounts Magdala, Clear and Macdonald, are the most noteworthy points, while the Bluff of similar structure, distant about ten miles, adds to the rugged character of the scene. Should these mountains be snow-covered, as they frequently are in the winter, the ledged character is generally emphasised.

The whole view in this direction, and as far round as Mount Torbreck to the south-west, about 25 miles away, overlooks the basin of the Upper Goulburn and its tributaries. It may be described as a mountainous region of high relief in an advanced stage of dissection. The original plateau character has been almost obliterated, only restricted ridges within the basin, which rise to about 5000 feet, remain to indicate its former features. The old

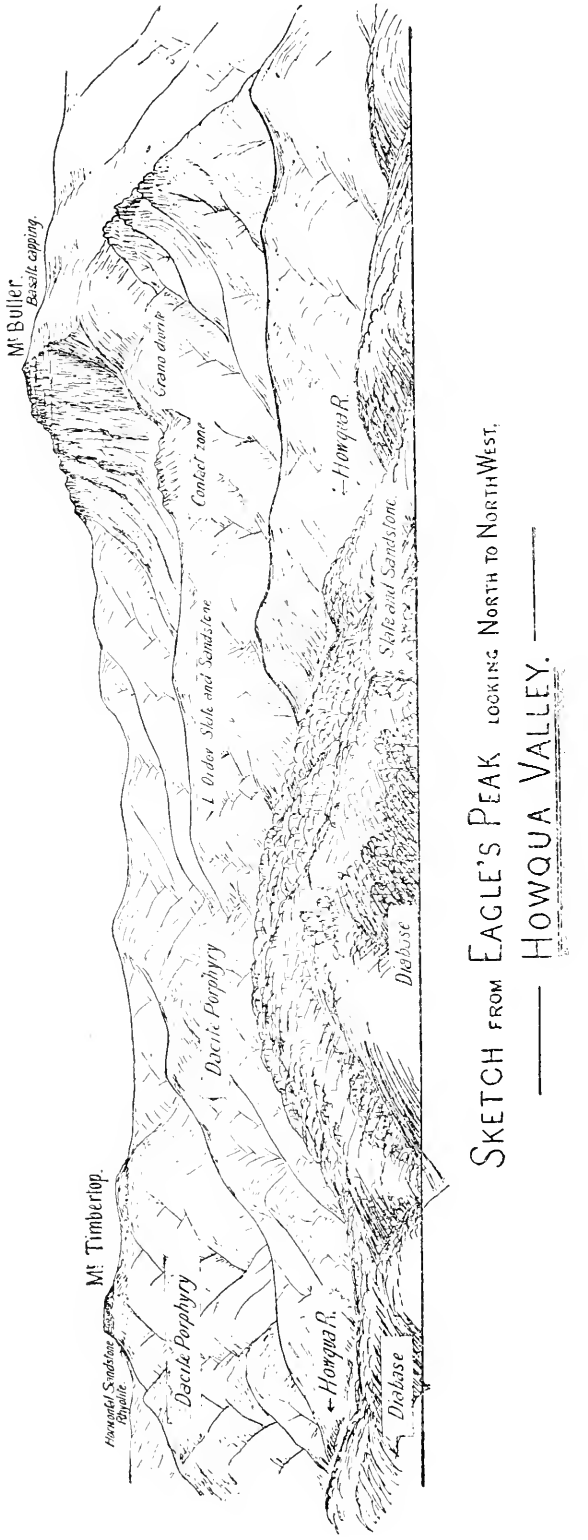

Mt Buller.
Basalt capping.
Grano diorite
Contact zone
Older Slate and Sandstone
Howqua R.
Slate and Sandstone
Diabase
Dacite Porphyry
Mt Timbertop.
Horizontal Sandstone
Rhyolite
Dacite Porphyry
Howqua R.
Diabase
Sketch from Eagle's Peak looking North to North West,
Howqua Valley.

Fig. 2.

plateau is best preserved round the margin along the main Divide. These relatively flat, elevated areas at 5000 feet and over are locally known as snow-plain country. They form summer feeding grounds for cattle during a few months of the year. The Howqua valley is one of the main cattle routes to these summer grazing areas from the low country. A bridle track follows its course towards the headwaters, where it rises to the open grassy plain near Mount Howitt. The economic value of the region does not lie in its possibilities from a point of view of settlement. Both from an agricultural and pastoral point of view its capabilities are almost negligible, but it forms an important collecting ground and store-house for water supply. It is here that the Goulburn gathers its waters, the value of which for irrigating its fertile alluvial plains is now being widely recognised.

4.—General Geology.

The area specially considered from a geological point of view lies on either side of the Howqua River, with Mount Buller in the north-eastern corner, and comprises about 60 square miles of country. The diabases and associated rocks, which are specially referred to in this paper, cross the tract from north-west to south-east, which is the general trend or grain of the structure as a whole.

One great handicap to investigation in this region apart from its uninhabited and mountainous character was the absence of any map suitable for the work in hand. A surveyed traverse of the Howqua River was kindly supplied by the Lands Department, and with this as a basis, the rest of the topography was sketched in by means of prismatic compass methods, which was the best that could be done under the conditions.

The rocks of this region, with the exception of a small outlier of Kainozoic basalt on the summit of Mount Buller referred to by Fenner[7] are entirely Palaeozoic, but they range in age, probably from Cambrian to Lower Carboniferous, and include both sedimentary and igneous rocks. They may be conveniently considered first in chronological order, starting with the oldest. (See Fig. 2.)

5.—Lower Palæozoic.

This includes rocks which range from Cambrian to Silurian, covering more than three-fourths of the area under consideration, but the exact mapping of the boundaries is rendered very difficult on acount of the intense folding and crushing to which the series as a whole has been subjected, together with the sporadic and apparently erratic distribution of the fossils, which are mainly graptolites in poor state of preservation, and *Protospongia*. The only fossils obtained from the Cambrian in this region are *Protospongia*, and possibly radiolaria from black cherts similar to those of Heathcote.

Cambrian (Heathcotian Series).

The rocks of this series fall into two groups :—

1. Basic igneous rocks (diabases in part), and associated tuffs, with their alteration products.
2. Protospongia cherts.

A.—The Diabases.

1. The basic rocks referred to here form an important central occurrence in the area under consideration. There are two belts, more or less parallel, but of unequal size, both, however, with a general north-west to south-east direction. The largest and longest starts outside of the area at least a couple of miles to the north-west, and passes out of the map in the south-east, where its extension has not been examined. Its greatest width is about $1\frac{3}{4}$ miles; the outline is somewhat irregular along portion of its north-eastern side, where it comes in contact with the dacite porphyry, but otherwise the junction and trend conform closely with the general strike of the enclosing sediments.

The smaller belt is shorter and narrower, and ends bluntly on the Howqua, as shown on the map. It would appear to diverge somewhat in direction from the larger belt towards the south in the Cameron's Creek area, which has, however, been only imperfectly traced.

In general, the boundary of these rocks is readily traced in the field, on account of the sharp soil change from the rich dark red of the diabase to the poorer slaty soil of the surrounding rocks. The open, park-like and grassy slopes of the diabase, too, are often in striking contrast to the closer forest with scrub undergrowth of the sedimentary rocks, so that from suitable vantage points the general bearing and limits of the two formations can be distinctly observed from a considerable distance. This is quite analogous to the "clear country," of the serpentine area in the Dolodrook.

The *Protospongia* cherts bound the diabase along the eastern side of the main mass, forming a well-defined belt, about half a mile wide. Numerous specimens, showing the characteristic cruciform spicular arrangement of *Protospongia*, were found in the field in these cherts, and a microscopic section, No. 78, from this belt of cherts, displays well the abundance of the sponge spicules embedded in a dark, largely chalcedonic ground mass. (See Microphoto Plate I., Fig. 3.)

In the Heathcote area Dr. Howitt held that the silicification of corresponding rocks was a metamorphic effect, due to the intrusion of the diabase, an interpretation which is dissented from by Professor Skeats, who shows good reasons for regarding them in part as altered submarine tuffs, silicified by metasomatic action, the adjacent igneous rock being considered as mainly contemporaneous lava flows.

The features are closely analogous here, where the *Protospongia* cherts are found. These fossiliferous cherts have not been recognised along the western boundary nor along the contact of the smaller diabase occurrence. In general, the western junction of the main mass is marked by much crushing and shearing, with other accompanying alterations in both the igneous and the sedimentary, but nothing attributable to contact alteration has been noted. Shistose talc rock is abundant in the valley of the Stockyard Creek, and elsewhere, close to the junction. An important section is exposed in the bed of the Howqua at the foot bridge, where the old dray track from Merrijig ends. The diabase crosses the river in a north-west direction, just above the bridge, forming a bar, and an interesting series of intensely crushed rocks of somewhat varied character can be traced more or less continuously from within a few yards of the contact down stream for about three chains. A short break of about two chains intervenes, where the exposure is masked, and then crushed black slate follows, forming a conspicuous cliff, at the bend of the river. The crush zone here is at least five to six chains wide. A noteworthy feature is that the rock adjoining the diabase shows not the slightest contact alteration at a distance of less than a yard from the junction. Intensely crushed and contorted rocks are the general rule along the contact. This feature, together with lithological and fossil differences of this zone compared with that in the eastern edge are worthy of note, and will call for further comment later, when dealing with the sedimentary rocks and general structural considerations.

(*a*). *Normal Diabase.*

The diabasic rocks show some variation in character from a somewhat doleritic type to that of a dense basalt, the latter being the dominant type. The dense forms are almost identical in features with those of Heathcote.

Though the sections at the Howqua do not show so clearly the same interbedded succession, the character and occurrence of the diabase, and that of the associated cherts are so similar that the assumption is reasonable that here, too, they represent similar submarine lavas, and tuffs, or interbedded cherts.

CHEMICAL ANALYSES OF DIABASES
By E. O. Teale

	Howqua		Heathcote
	No. 15	No. 25	No. 630
SiO_2	46.44	58.17	55.77
Al_2O_3	15.71	13.15	11.23
Fe_2O_3	.53	3.18	1.82
FeO	11.21	8.61	10.11
MgO	8.61	0.91*	7.94
CaO	12.3	6.7	4 64
Na_2O	2.5	7.00	4.91
K_2O	.21	0.41	.73
H_2O +	.21	0.33	.55
H_2O –	2.54	1.34	1.91
TiO_2		0.8	0 22
	100.46	100.61	99.80

* Note low MgO content

NO. 25.—SODA, RICH TYPE.

Mineral.	Norm. %	Group.	%
Quartz	.72	Q.	Salic. 65.17
Orthoclase	2.22	F. 64.45	
Albite	59.21		
Anorthite	3.07		
		L.	
Diopside	28.0	P. 31.56	Femic 4.55
Hypersthene	3.56		
Magnetite	4.4	M. 4.55	
Ilmenite	.15		

Class $\frac{\text{Sal.}}{\text{Fem.}} = \frac{64.45}{31.56} < \frac{7}{1} > \frac{5}{3}$ = Class 2. Dosalane.

Order $\frac{\text{Q.}}{\text{Fem.}} = \frac{.72}{64.45} < \frac{1}{7}$ = Order 5. Germanare.

Rang. $\frac{K_2O + Na_2O}{CaO} = \frac{117}{120} < \frac{5}{3} > \frac{3}{5}$ = Rang. = Alkali Calcic. Ilmenose.

Sub-Rang. = $\frac{K_2O}{Na_2O} = \frac{4}{113} < \frac{1}{7} >$ = Sub-Rang. = Persodic. Beerbachose.

(b) The petrography of the diabases, including soda-rich types.

(By Professor E. W. Skeats.)

Reference to the chemical analyses shows that diabases of fairly normal composition are present. The analysis of No. 15 shows that as regards the alkali content, it is normal, but has a high content of the alkaline earths, especially of lime. No. 25, however, on analysis proves to have a very high soda content, and is unusually low in lime. It evidently has suffered albitization, and shows that the spilite type of magma is represented among the Howqua diabases, and the analysis of a diabase from Heathcote is also relatively rich in soda.

The petrographic descriptions which follow show that albitization, silicification, chloritization, the production of secondary hornblendes from augites, the formation of carbonates, and the development of the mineral lawsonite, are features of fairly common occurrence among the Howqua diabases, which in hand specimen, may not appear to be specially altered.

The term diabase, used to describe these rocks, has been found useful to retain, although it is now clear from their field relations and principal petrographic characters that they are mainly submarine lava flows and ashes.

No. 11.—Diabase from the ridge between Howqua River and Lick Hole Creek. The rock consists of pale-coloured augite to the intent of about 3-5th, and a very kaolinized felspar to the extent of about 2-5th of its volume. The augite is diallagic in part. Both augite and felspar seem to have started crystallizing simultaneously, as each in places is porphyritic, and in other places is moulded on the other. The felspar is too cloudy for specific determination, a little ilmenite, altered to leucoxene and of chlorite after augite, is also present. Some secondary clear to cloudy chalcedony is also present, partly replacing felspar.

No. 12.—Locality east of No. 11, but on the same ridge. The rock is moderately coarse-grained; about two-thirds consists of felspar, mostly as relatively large rectangular phenocrysts, with a small amount of later micro-spherulitic felspars moulded on them. The phenocrysts are mainly albite, or Ab_{90} An_{10}, having a refractive index as low as the mounting balsam, which is less than 1·53. Some felspars are untwinned, possibly 010 sections, with extinction angles, ranging from 3°-19°. Others show carlsbad or albite twinning, or both. Symmetrical extinction angles of 15°-18° occur on the albite lamellae. Some of the felspar is saussuritized to granules of epidote and zoisite. The bulk of the felspar slightly preceded the augite in crystallizing, but in one place augite and felspar are in micrographic intergrowth. A fair quantity of ilmenite occurs in elongated crystals, and is more or less altered to leucoxene. Clusters of radiating, brown, green or bright red micaceous products occur. In one place crystals of a secondary red micaceous mineral product radiate from the ilmenite at right angles and granular epidote is also associated with it. A little pleochroic aegirine-augite, with extinction angle of 29°, is also present. The rock may be described as an albite diabase.

No. 15.—Compact diabase, from Four Mile Creek (analysed). (See Plate I., Fig. 2.) There is very little felspar present, and this consists of lath-shaped crystals and larger areas now altered to zoisite and minute secondary mica flakes. The rock consists mainly of granular augite, with some areas of chlorite, a fair quantity of ilmenite altered to leucoxene, and some granular pale brown sphene.

This mineralogical content is in agreement with the high lime and magnesia, and low alkali content of the analysis.

No. 16.—Spotted diabase from Four Mile Creek. In the hand specimen light circular spots are noticeable, but are much less prominent under the microscope. However, slightly lighter areas can be seen, and appear to be due to the relative crowding of minute more or less altered lath-shaped felspars, while a relatively smaller amount of augite and chlorite occur in these areas than in the rest of the rock. One large phenocryst of plagioclase now consisting mainly of chlorite and secondary felspar, was noticed, and minute granular oxide of iron, with a little carbonate, occurs. The augite is mostly granular in habit, with undulose extinction.

No. 17.—Compact diabase from smaller diabase outcrop on the track to Ware's, and south of Fry's.

In this rock much recrystallisation under pressure has occurred. Most of the augite has recrystallized as fibrous secondary hornblende, with light to dark green pleochroism, and extinction angles ranging from 11° to 21°. The felspar has recrystallized to water clear secondary felspar, with enclosures of secondary hornblende needles. Ilmenite in large skeleton rhombohedra altered to leucoxene, is fairly abundant. Some interstitial secondary calcite is present. The extensive recrystallization of the rock is no doubt referable to its occurrence in a crushed zone, south of Fry's, and it resembles some of the recrystallized diabases of Heathcote and Mt. William, near Lancefield, but is hardly so altered as the epidiorites of Ceres, near Geelong, since some relic structures in the form of original augite and felspar are still noticeable.

No. 18.—Diabase, south-east of No. 17.

A diabase which has suffered fairly complete recrystallization to fibrous hornblende, and secondary water clear felspar. In the process a considerable amount of granular and dusty magnetite has separated out.

No. 22.—From main diabase mass, Lick Hole Creek, and east of isolated crushed diabase mass. A relatively coarse-grained type with no signs of recrystallization under pressure. Coarse plates of augite and cloudy felspar form the bulk of the rock, with chlorite and clear felspar as secondary products.

No. 25.—Soda rich diabase (analysed), Lick Hole Creek, one mile north of the Governor, and near the south-east end of the main diabase mass. (Micro. Photo., Plate I., Fig. 1.)

About 2-3rds of the rock consists of felspar in large and small prismatic, quadrate or irregular crystals. Simply twinned and untwinned crystals are abundant, and some show lamellar twinning. The low refractive index, positive sign, and biaxial figure show that albite or albite-oligoclase predominates. All the felspars are clear, and some contain secondary hornblende and chlorite, suggesting recrystallization. Some original augite remains, but much is altered, either to normal hornblende or green pleochroic fibrous actinolite. Sphene, epidote and zoisite occur in granules. Brown clusters of radiating biotite crystals occur, and some calcite, a little quartz, and a few elongated prisms of apatite are present. The high albite content of the rock is confirmed by the chemical analysis, but it is difficult to reconcile the relative abundance of ferro-magnesian minerals with the strikingly low magnesia content recorded in the analysis.

No. 40.—Diabase on spur, east of Blackbird Creek, north of Howqua River, and about one mile E.N.E. of Fry's. A rock type in which augite and its alteration product chlorite predominate and felspar is in subordinate amount. Some of the felspar probably preceded the augite in crystallizing, and recrystallization of felspar, with resulting inclusion of chlorite has probably occurred. Ilmenite granules have changed to sphene.

No. 41.—Diabase from Castle Rock, Lick Hole Creek. A diabase which has suffered much secondary albitization. Augite is altered to pale and to brown secondary hornblende. The original felspar is now quite cloudy, chlorite is developed, and an irregular vein of secondary albite or albite-oligoclase traverses the section. It looks like quartz in ordinary light, but is identified by the presence of some lamellar twinning, by its refractive index, which is less than 1·53 and by biaxial figures with positive signs. Ilmenite, more or less altered to sphene, and hematite, are present. The albite in the vein occurs in clear interlocking crystals, associated with calcite, and with fibrous secondary hornblende.

No. 42.—Diabase, near No. 41. A rock similar to No. 41, but with only a minute vein of secondary albite, traversing the section.

No. 72.—Silicified fine-grained diabase from Four Mile Creek, near the massive black bedded cherts at the north-east margin of the main diabase mass. In the fine-grained diabase area a little augite remains, but most of it is altered to chlorite and secondary hornblende. Lath-shaped, water clear felspars, with chlorite inclusions occur. Sporadic secondary quartz occurs in granules in the mass of the diabase, but in over half the section the diabase has been completely replaced by a radial and granular aggregate of chalcedonic silica, with some coarser grained quartz crystals. The rock has a spotted appearance, due to greater concentration of felspar laths in roughly circular areas.

No. 73.—Diabase from Four Mile Creek, near to 72. This rock is rather coarse grained. Brown unaltered augite and large lath-shaped albite or albite-oligoclase, many with chlorite inclusions, form the bulk of the rock. Opaque iron oxide is fairly abundant, and large areas of chlorite, apparently not derived from augite, occur.

No. 107.—Diabase from spurs south of Barney Creek, at south-east end of main diabase mass. The rock may be described in its present condition as a micrographic quartz-diabase. Some original augite remains, but most of it has changed to secondary hornblende. Chlorite is abundant, ilmenite altered to sphene is prominent, porphyritic crystals of albite or albite-oligoclase, one or two prismatic crystals of apatite, and some relatively large irregular quartz crystals occur. The background is a beautiful micrographic intergrowth of quartz and albite, the latter showing lamellar twinning in places, and a refractive index lower than quartz. The micrographic background and the larger quartzes both appear to be of secondary origin.

No. 108.—Diabase from spur south of Barney's Creek, Upper Lick Hole Creek Valley, at south-east end of main diabase mass. A diabase of moderate grain size, in which very complete secondary alterations of the original minerals, augite, felspar and ilmenite have occurred. A little original grey brown augite remains, but most of it has been changed to secondary hornblende, some of it prismatic to tabular, some to fibrous actinolite, some to vivid green chlorite in clusters of radiating fibres. Quartz occurs in scattered granules, and in micrographic intergrowth with augite and with chlorite. This quartz may be primary or secondary. Much secondary quartz occurs, more or less completely replacing the lath-shaped felspars which, however, still show the outlines of the crystals and the positions of the twin lamellae in a remarkable way. An irregular vein, about $\frac{1}{8}$ inch wide, traverses the rock, and consists partly of quartz, but mainly of colourless to cloudy prismatic and radiating crystals of lawsonite, a hydrated silicate of lime and almuminium. The mineral is recognised by its positive sign, and biaxial character, its high refraction and polarization colours up to second order, whereas the quartz shows low neutral tints. The lawsonite is a secondary mineral derived mainly from the alteration of the felspar, but in places is seen to develop from altering ferromagnesian minerals in the mass of the rock. Ilmenite is partially altered to leucoxene, and a little secondary calcite and epidote are also present. No secondary albite was recognised in the rock, and the original felspars are so altered either by becoming cloudy, through incipient saussuritization or replaced by quartz, that their original character is unrecognizable.

No. 109.—Diabase from same locality as No. 108. A moderately coarse grained rock which is free from quartz, but otherwise has suffered much the same changes as has No. 108. The large platy albite or albite-oligoclase felspars have chlorite inclusions. Some augite has developed a diallagic structure, and there is a considerable development of secondary lawsonite, principally in clear to cloudy minute radiating crystals.

No. 118.—Diabase from Upper Lick Hole Creek, one and a-half miles N.N.W. of The Governor.

A diabase in which albitization is a marked feature, resulting in the formation of clear secondary platy crystals, and raditaing lath-shaped crystals. The augite is mainly converted to secondary hornblende, some of which is normal, while some is fibrous, pleochroic actinolite. A good deal of calcite occurs, but neither quartz nor lawsonite have been recognised.

No. 119.—Diabase from same locality as No. 118. A coarse-grained type, with cloudy felspars, pale augite, partly replaced by hornblende, and a little quartz.

No. 121.—Diabase from Lick Hole Creek, quarter mile west of No. 118. A rock similar to No. 119, but with an abundance of large opaque crystals of magnetite or ilmenite.

No. 122.—Diabase from same locality as No. 121. A rock almost identical in characters with No. 118.

(c) *Platy and Splintery Diabase.*

Some forms of platy diabase appear to be due to a special development of jointing in the diabase. This form was favoured by the natives for making their stone axes, and several small quarries occur close to the road, about half a mile north of the old road terminus. More often they appear to represent altered tuff beds. Rocks of this nature occur at intervals throughout the area, but the outcrops are not readily traced. The most characteristic and tuff like occur on Lick Hole Creek, about a mile above Malcolm's Creek. Here they are somewhat banded, and suggest stratification. The rock is dark green, and of very fine texture in hand specimens, and under the microscope (section 24) shows a very fine textured fragmental structure of minute angular fragments in a matrix which cannot be resolved. Section 23 is a basic platy rock with coarse and fine banding, but is altered, and in parts serpentinized so that its original character is not recognisable, but the probability is that it represents a tuff. The splintery diabase is a fine-grained green variety, which splits readily into long slender splinters, or pencils with angular edges. It is found in contact with massive diabase at the north-western extremity of the small diabase area, a little less than a mile in a straight line south of Fry's.

It can be matched exactly with a similar occurrence at Heathcote south of Photograph Knob, where Professor Skeats regards it as an altered tuff.

B. *Agglomerate.*

A well-marked breccia occurs on the east-west ridge between the Howqua and Fry's, and the Lick Hole Creek. It forms one of the prominent points, and is marked Breccia Knob on the map. This rock is a typical breccia, made up largely of igneous fragments, but contains also some banded chert. Sections of the chert examined suggested strongly altered tuff, and were of coarser texture than the *Protospongia* chert. Under the microscope a thin section of the breccia (Section 14) shows it to be made of fragments so dense as to be almost opague, but small pyroxenes present indicate that the material is igneous and represents rapidly cooled lava. If the eruption were submarine, as it is believed the general evidence indicates, the rapid chilling of parts of the lava would be expected.

C. *Alteration Features of the Diabase.*

(*a*) *The Red Jasper.*

The bright red colour of this rock together, with its hardness and durability make it rather a conspicuous and characteristc rock in the recent river gravels in the diabase region, and also an easily recognizable pebble in some of the Upper Palaeozoic conglomerates.

It occurs in situ in the diabase as apparent inclusions,[1] for which they have have been mistaken, but it is clear in the Howqua, as in the Heathcote region, as shown by Professor Skeats, that it represents one of the phases of metasomatic replacement of the diabase. A good section can be studied in the bed of the Howqua River at low water, about one and a-half miles above Fry's, as shown on the map. The irregular shape is typical of patchy replacement areas, and miscroscopic sections occasionally show relic structures of the original igneous rocks, though in general the action has gone so far that all that is seen is an aggregate of secondary quartz and iron oxide stain.

These jaspers occur at intervals along a definite line, bearing from north-west to south-east, that is, coinciding with the general trend of the diabase.

They vary from small aggregates of jasper patches to larger masses of perhaps 50 to 100 square yards in extent. Associated with the normal red jasper there are often other varieties of quartz varying both in colour and texture, milky quartz and granular quartzitic forms being frequently present.

The linear arrangement of these outcrops suggests the occurrence of a shear or fracture zone along this line, which favoured at recurring intervals the access of silicifying solutions. The jasper which is a definite alteration product of the diabase is distinct in character from the black bedded cherts, which are altered stratified deposits.

(b) *The Siliceous-Carbonate Rocks.*

These rocks form a very striking and characteristic alteration product in the diabase area, and are identical in character with similar rocks occurring in Heathcote. In appearance the rock has a somewhat schistose structure due to fine and contorted banding. (Sec. 51.) It has a prevailing brown colour, with greenish streaks due to a substance allied to selwynite or green chalcedony, which also occurs in lenticles and patches. Numerous sections examined by Professor Skeats from Heathcote indicate that this was originally a diabase or diabase tuff which has suffered alteration in two stages. First it was subjected to a carbonating solution, which produced a mixture of iron, lime and magnesian carbonates, and, later, siliica bearing solutions invaded the rock, replacing in part the original carbonate.

Four separate outcrops of this rock have been noted. One is in the bed of the Howqua, at the pack horse bridge, near Fry's—(specs. 51-54); a second about a mile farther down the river, associated with the smaller diabase area; the third is on the track to Cameron's Creek—(Spec. 44)—about a quarter of a mile south of Lick Hole Creek; and the fourth is about half mile to the south-west of this spot—(Spec. 113). The two lastnamed occurrences are in close proximity to a serpentine outcrop, and the first is on a fracture line leading to another serpentine area. It may be, therefore, that the concentration of carbonates in one place may be casually connected with mineral redistribution, which took place during serpentinization.

C. *The Talc Rocks.*

These rocks vary from massive talc rock and talc schist, undoubtedly altered diabase to talcose sediments, which may be altered tuff beds. The latter will be referred to again, when dealing with the lower Palaeozoic sediments. Talc rock is abundant at the north-western end of the diabase area, in the valley of Stockyard Creek, and its greasy nature adds to the difficulty for horse traffic on the steep graded track to the Howqua from Timbertop

Gap, especially in the present bad state of repair of the road. In general it occurs at intervals along the western margin of the large diabase area, and round the edges of the smaller one. Though sometimes massive it is generally schistose and iron-stained. The crushed margins of the diabase appear to have been most favourable for its development. At Cameron's Creek about a mile and a-half south of Lick Hole Creek, a schistose talc rock with very little iron stain appeared to be slightly auriferous. Some prospectors at work during the writer's examination obtained a fair prospect of very fine gold from a trench entirely in this rock.

(*d*) *Serpentine and Chrysotile.*

Three outcrops of serpentine, all of fairly limited extent, have been noted. The largest occurs on a ridge about half a mile south of Lick Hole Creek, in the track to Cameron's Creek. It is of the usual dark green type, and varies from massive to schistose. Isolated grains of chromite have been detected in it, but no quantity of this mineral has yet been found, nor has any corundum been observed in this district, as in the case of the Dolodrook and Heathcote regions. A thin section shows the rock to be completely serpentinized, and it possesses the platy structure of antigorite, and is, therefore, probably due to the alteration of a pyroxene rock.

The second outcrop is about a mile south-east of Fry's, on the western margin of the diabase; its extent is masked here by much surface soil and hill slip material.

This outcrop is noteworthy, because it contains chrysotile asbestos. The increased demand for asbestos during the war, both locally and abroad, has induced much searching after local supplies, and this occurrence has been taken up by Mr. Fry with a view to opening it up to prove its worth. At the time of my visit only shallow hillside cuts had been made. These revealed thin veins of chrysotile traversing the serpentine along numerous joints and slip planes forming a network which at some of the intersections developed into knots or centres of chrysotile. All the material noted was of a slip fibre type—that is, it consisted of somewhat overlapping fibres lying parallel to the joint and slickenside planes. None of the cross-fibre type was observed. With regard to the origin and development of chrysotile veins in serpentine, the subject has been discussed by Graham in Economic Geology.[9] His inquiry leads him to favour the idea that the agents of change for the Canadian occurrences were magmatic siliceous waters derived from neighbouring granitic intrusions.

Twelvetrees,[10] in describing the asbestos occurrence in serpentine at Anderson's Creek, near Beaconsfield, Tasmania, also postulates a causal connection of the origin of the asbestos with a neighbouring granitic intrusion.

At Heathcote and Howqua the rocks have certainly been invaded by siliceous solutions, and in each case granitic intrusions are present in close proximity. It is reasonable, therefore, to suggest at any rate that the vicinity of an acid magna may have provided conditions which were favourable for the remarkable selective metasomatic and other changes, which were wrought along favourable lines and zones in both of these areas. At Howqua, grano-diorite occurs on the southern slopes of Mount Buller, and a mass of dacite porphyry of related age is actually in contact with the diabase between the Howqua and Timbertop.

(e) *Mineralization of the Diabase.*

Another phase in the alteration of the diabase is shown by the siliceous sulphide occurrence at the abandoned gold mine, about a mile south-east of Fry's. The occurrence is an interesting one, and it has been known under different names during its chequered career as a mining venture, but perhaps its best known title is the Great Rand Mine. No accurate survey of this deposit has been made so far as the writer is aware, but like many sulphide occurrences its shape would appear to be irregularly lenticular, consisting of a metasamotic replacement in a fracture zone. The quartz is tough, and very finely granular, and the sulphides are abundantly distributed through it. Iron sulphides, pyrite and pyrrhotite, predominate, but, galena, sphalerite, chalcopyrite and arsenopyrite were noted in small quantity. During my last visit to this region, the mine was being tested by a small syndicate, with the view to determining whether it was possible to treat the ore profitably. The deposit was systematically sampled under the direction of Mr. W. A. T. Davis, of Melbourne, and through the courtesy of Mr. Cottingham, one of the syndicate, I was able to note hurriedly the character of the deposit, as far as the old workings would permit. These reveal a mineralized zone about 300 feet long, in a north and south direction, by nearly 200 feet from east to west.

The mineralization is irregular, and sulphides are found in varying quantities throughout the rock from considerable masses to a mere impregnation. The examination was too short to determine whether any definite system or plan of arrangement for the mineral material could be recognised, but the observations suggested two sets of fracture lines, or planes, one set about east and west, another approximately at right angles. Along the former especially, mineral solutions have been very active, replacing the original rock with sulphides associated with quartz or calcite. Two active processes accompanying the sulphide formation appear to have been silicification and carbonation. Much of the original rock in places appears to be almost completely carbonated, as is shown in a slide (No. 102), from the southern end of the working. From Mr. Cottingham I have since heard that the result of the sampling indicated an average value for the deposit of about 8 dwts. per ton, which they did not regard as sufficeintly encouraging under the circumstances to lead them to undertake further work.

It is interesting to note that if a north-west to south-west line through this mine be produced in either direction, it follows the trend of the diabase and includes other auriferous occurrences at intervals. The old alluvial workings in Stockyard Creek lie at the north-western end. Another abandoned mine occurs to the south-east, on Malcolmn's Creek, while still further in this direction extensive alluvial workings, long since worked out, are found in the upper portion of Lick Hole Creek. Nothing to suggest a continuous line of lode has been noted along this line, but a probable fracture zone is suggested which provided at intervals favourable access to mineralizing solution. This is in conformity with another parallel line to the east previously referred to, along which siliceous replacements have taken place chiefly resulting in the formation of red jasper.

The Cameron's Creek gold occurrences appear to be of the more normal reef quartz type; at any rate, the adit examined in this area revealed a quartz lode with well defined walls, of decomposed diabase. This is on the southerly portion of the smaller diabase outcrop. A section of the igneous rock (No. 50) showed much chloritization, but traces of an original hornblende were recognizable by cleavage lines preserved in iron oxide; triclinic felspar was recognizable, and secondary calcite was moderately abundant.

A brief report on the mine was made by the late James Stirling[11] in 1888, in which he described the Cameron's Creek reef as consisting of quartz segregations in intrusive diorite.

D. *Lower Palaeozoic Sediments.*

These are found enclosing the diabase on all sides, except where later dacite porphyry or Upper Palaeozoic sediments overlie it at the northern extremity. These rocks are mapped as Silurian on the 8 inch Geological Map of Victoria, and until the writer's examination the only fossil recorded from this region was a *Monograptus* obtained by Mr. A. M. Howitt, and indentified by the late Dr. T. S. Hall.

The present field work has brought to light other graptolites, ranging from Lower to Upper Ordovician and *Protospongia* in cherts identical with those of Heathcote now included in the Cambrian, and possibly also radiolaria in the same cherts. The fact that the graptolites are poorly preserved, and separated by large intervening barren areas, makes the working out of the correct stratigraphical succession in this area very difficult. In fact it would be unwise in the present state of our knowledge in this region to attempt to mark boundaries between the different members of the Lower Palaeozoic. We can only note that the succession probably ranges from Cambrian to Silurian, and no unconformability has with certainty yet been recognised in this region.

At Heathcote no certain line of division can be drawn between the lowest beds of the Ordovician and the uppermost of the Cambrian. The Dinesus trilobite beds form a bench marking the Cambrian, but above them there is a great thickness of unfossiliferous sediments which seem to pass comformably into the Ordovician.

In the area above mentioned, and in the Howqua region, it would appear that there has been a continuous sedimentation from Cambrian, through Ordovician, and possibly, too, into Silurian in the last area. The fossil record is, however, unfortunately very imperfect.

(a) *Lithological Features of the Sediments and Apparent Relationships.*

There are certain broad lithological distinctions which are apparent, and features also with regard to the general distribution which call for discussion.

First, there is a marked lithological contrast on either side of the main diabase area.

On the western side only Upper Ordovician and, possibly, Silurian graptolites[1] have been noted, and these come from a very restricted area. Slaty rocks often somewhat talcose and chloritic prevail, sandstones and quartzites being subordinate. The rocks are frequently intensely contorted, particularly at the "Governor," and a long line to the north west of this.

The unweathered slates were often black, as at the outcrop below the pack-horse bridge at Fry's. By oxidation and leaching, however, they are often almost white.

They only show slight local chertification, and no *Protospongia* has been noted in these cherts.

On the eastern side, however, the black *Protospongia* cherts are well developed, forming a continuous belt up to half a mile in width, directly in contact with the diabase. These cherts stop suddenly to the east and give place to a dark, micaceous and slightly felspathic sandstone, which appears to be quite conformable and then follows a thick succession of olive green phyllitic slates, alternating with sandstone and quartzite. Traversing these rocks across the strike in a north-easterly direction towards Mount Buller, at about one and a-half miles from the cherts, thin black slate bands begin to occur interbedded with the olive green slates and sandstone. Two of these bands have yielded *Tetragraptus* and *Didymograptus*, thus indicating a Lower Ordovician horizon. Continuing still further to the north-east, and approaching the Mount Buller grano-diorite, these sediments give place to belt of dark cherty slates, and fine grained quartzite, often veined with quartz. Microscopic sections of these rocks indicate contact phenomena attributable to the proximity of the plutonic intrusion. These indurated rocks form a very jagged outcrop, to which the rough outline of Little Buller is due.

Following up the valley of the Howqua, the direction is in general easterly, and, therefore, crosses the strike of the same series of sediments in an oblique direction. The Lower Ordovician strata, yielding *Tetragraptus* and *Didymograptus*, have not been noted, but at a few chains west of Eight Mile Creek, indistinct graptolites were found in black cherts. These were too poorly preserved for certain identification, but they suggested *Diplograptus*

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1. The writer has spent days searching along the restricted area where Mr. A. M. Howitt obtained a graptolite, identified by Dr. T. S. Hall as a *Monograptus*, but did not find a single specimen of this genus, though hundreds of specimens of less restricted range were obtained, chiefly *Climacograptus* and *Diplograptus*, with probably *Glossograptus* and other doubtful forms.

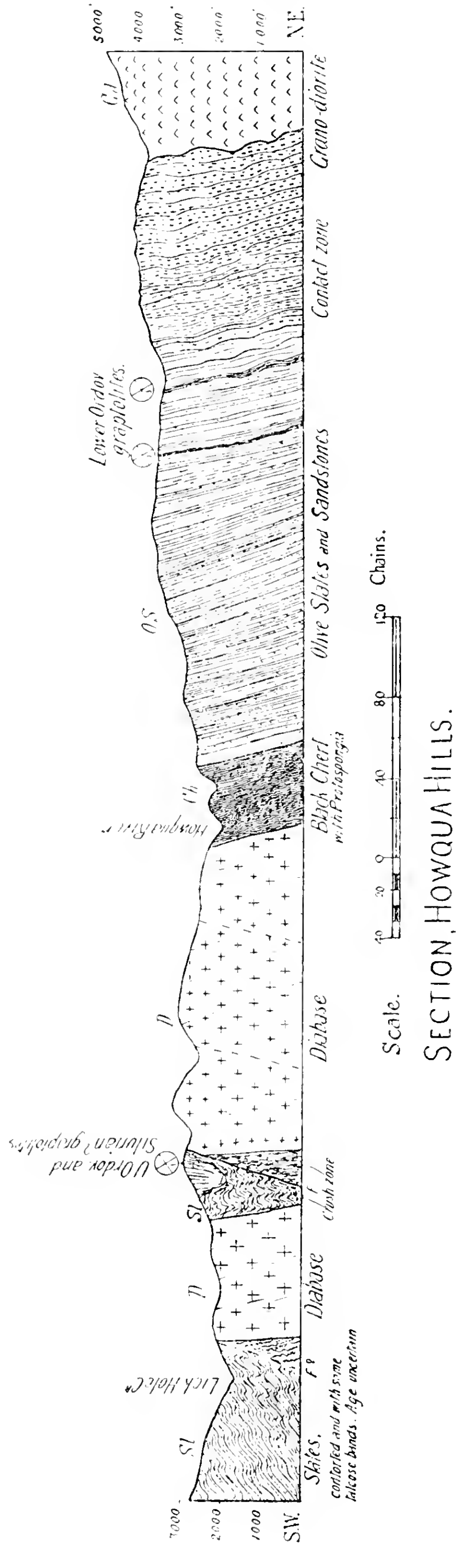
SECTION, HOWQUA HILLS.
Scale.
Chains.
N.E.
S.W.
Grano-diorite
Contact zone
Olive Slates and Sandstones
Black Chert with Protospongia
Diabase
Crush zone
Diabase
Slates, contorted and with some felspar bands. Age uncertain
Lower Ordov graptolites.
U Ordov. and Silurian? graptolites
Howqua River
Lick Hole Cr

Fig. 3.

and *Climacograptus*. If this is correct, they probably are of Upper Ordovician age. These sporadic occurrences of imperfectly preserved fossils are tantalizing, but they indicate that great caution is necessary in interpreting the stratigraphy of the region.

(*b*) *Structure of the Lower Palaeozoic Area.*

In general, the prevailing dip on the eastern side of the main diabase, as far as observed, appears to be consistently easterly, while on the western side it is to the west. The structure, however, is clearly not that of a simple anticline, for the evidence of the fossils on either side, together with the lithological discordance excludes the possibility of such a view.

A faulted anticline, with the fault approximating to the western margin of the main diabase, is suggested, but this requires an enormous down throw on the western side to bury the great thickness of Lower Palaeozoic sediments represented on the eastern side. The Upper Ordovician, and possibly Silurian fossils on the western side close to the diabase, would appear to demand this view, in the absence of any recognised unconformity to afford any other explanation. The presence of the second diabase occurrence to the west offers certain difficulties, however, in the way of this interpretion.

Another alternative would be to assume that the Upper Ordovician, with possibly Silurian, is but a small fragment that has been nipped in by the intense folding to which the area has been subjected. The fossiliferous area is very restricted, further search may extend it, but the writer has spent much time without success looking for fossils in the surrounding strata. It may, therefore, be that the bulk of the rocks which, so far, have proved unfossilferous, are very much older, and may be Lower Ordovician, or even Cambrian. With the present evidence at hand the matter must be left an open question. (See Fig. 3.)

(*c*) *Phosphate Deposits.*

While searching diligently to obtain graptolites to confirm, if possible, the presence of Silurian, as indicated by a reported *Monograptus* found by Mr. Howitt, Professor Skeats and the writer discovered a phosphatic breccia. This was of considerable interest, because it was the report of phosphatic rock from this district that led to Mr. A. M. Howitt's flying visit. The piece shown to Mr.

Howitt was a loose block, which had been brought to the old mine. As no more could be found in the neighbourhood, it was suggested that it might have come from Mansfield.

The position of the present occurrence is shown on the map. It is only about a mile in a straight line, south-east from Fry's, and less than half a mile south-west from the old mine.

The rock is light-coloured, creamish, earthy fragments predominating, but dark, almost black pieces sometimes somewhat cherty, also occur. Rough stratification is noticeable, and the bed has a defined dip and strike conforming with the enclosing rocks. The outcrop is not continuously exposed at the surface, and has the appearance of being broken and dislocated. The rocks in general in this zone are much disturbed. The phosphatic breccia, however, can be traced at intervals along a distance of about 130 yards, in a north-west to south-east direction.

Wavellite is abundant in thin seams along some of the joint planes, and an analysis of the surface rocks shows that it is an impure aluminous phosphate, containing only about 7% of P_2O_5. This may represent leached material; at any rate, it would be unwise to say that it represents the composition of this rock at a depth. Lithologically, the material does not resemble the Mansfield phosphate rock, which is not a breccia. The organic remains are imperfectly preserved crustaceans of the character of phyllopod-like forms, while those of Mansfield have been referred to as probably Salterella, thus differing also organically. An account of this phosphate deposit has recently been published.[2]

Since *Tetragraptus* has been recorded at Mansfield, it would appear that both Lower and Upper Ordovician graptolite-bearing rocks are closely associated. At the Howqua, the only fossils in the associated beds are graptolites and occasional brachipods, which may be either Upper Ordovician or Silurian, and the phosphate deposits are definitely interbedded with these.

In order to test the relationship of the phosphate deposit to the surrounding sediments, the writer and his father spent a couple of days with pick and shovel putting a trench across the outcrop, the result of which was to prove conclusively that the phosphate breccia is interbedded with the surrounding graptolite-bearing strata. The accompanying section illustrates the relationship.

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2. Ernest W. Skeats and E. O. Teale, Aust. Inst. of Mining Engineers, Proc. New Series, No. 32, 1918, pp. 155-165. Fig. 4 is from a block lent by the Aust. Inst. of Mining Engineers.

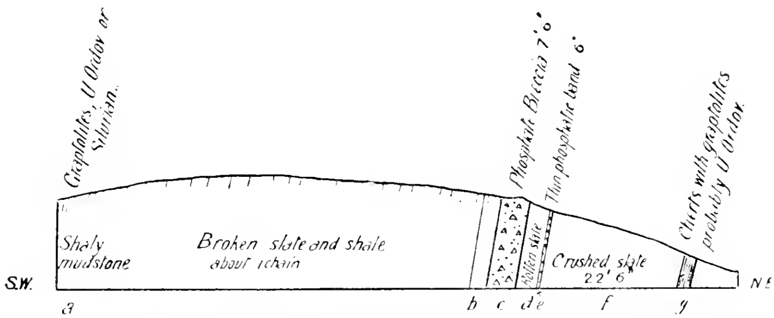

Fig. 4.—Section across outcrop of phosphate breccia.

E. *Concerning the Age of the Diabase and the Cherts.—A Comparative Review.*

These rocks from stratigraphical considerations appear to be the oldest rocks in this region, which necessarily places them low down in the older Palaeozoic series, but on the evidence available in this region alone it would be difficult to assign a definite horizon to them.

The view in this direction, however, is strengthened, and much uncertainty as to age is removed, when a comparative review is made of other closely similar occurrences in the State. Various gaps in the evidence, which make any one area in itself incomplete disappear when all are taken in conjunction. The other areas which call for special consideration in this direction are:—

1. Heathcote.

2. Dolodrook River, near Mount Wellington, Gippsland.

The fossil evidence of the *Dinesus* beds with associated *Protospongia* cherts, at Heathcote, established the age of the rocks as Cambrian.

There would seem to be little doubt that the Howqua rocks are on an extension of the Dolodrook line, where the age is definitely fixed by the tribolite limestone. The absence of this evidence at the Howqua, however, is counterbalanced to some extent by the presence of *Protospongia* cherts and overlying Lower Ordovician rocks, containing such graptolites as *Tetragraptus* and *Didymograptus*. At the Dolodrook, Upper Ordovician rocks come directly in contact with the Cambrian. Again, as an offset against the paucity of direct fossil evidence at the Howqua, we have the very complete lithological resemblances and mineral changes which match the typical Heathcote occurrences. There would seem little doubt, therefore, that the diabases and cherts of the Howqua belong to the Heathcotian series, and must be regarded as Cambrian. Whether also some of the adjoining sediments are to be included in this series must at present be left an open question.

6.—The Upper Palæozoic Rocks.

The present investigation was principally concerned with the relationships of the older rocks, but some of the later geology is not without interest, and as rocks of this age are found in the northern portion of the area under consideration, where they come into contact with the diabase, a little time was devoted to roughly demarking their boundaries and noting their main features. The rocks of this series fall into the following groups:—

A.—Devonian.

1. Dacite, porphyry,
2. Granodiorite.
3. Diorite.

B.—The Lower Carboniferous.

1. Basal conglomerates.
2. Rhyolite.
3. Conglomerates.
4. Sandstones.
5. Purple shales

1. *Dacite Porphyry.*—This rock covers a considerable tract of country between Mount Timbertop and the Howqua, and extends easterly towards the Buller Creek, where it gives place to Lower Palaeozoic strata. It is also found to the north outside the region of this map on the fall towards Merrijig. Rock of this nature is widely distributed in the King River Valley, as indicated by Kitson.[12] In both localities it underlies the basal conglomerates of the Lower Carboniferous beds, in which pebbles of the porphyry are not uncommon. In the Howqua area this feature was noted in the Timbertop conglomerates. Professor Skeats[5] has referred to the King River porphyry as related to the Dacites. In hand specimens the rock has a general dark colour, on account of a dark, fine-grained base. It inclines to red, where oxidized and weathered. Phenocrysts of felspar and quartz are abundant, the former predominating, and show up on the dark base, imparting a typical porphyritic appearance. Garnets are frequently recognizable. Under the microscope in thin sections chemical alteration in all the specimens examined has proceeded too far for satisfactory determination.

The structure is typically porphyritic, the base is fine grained and felstic, often showing flow phenomena. The phenocrysts in order of abundance would appear to be, felspar, ferromagnesian mineral, quartz and occasional garnets. The felspars are more or less decomposed, but in general the twinning and cleavage can be recognised. There appears to be about an equal amount of repeated and untwinned forms, but undoubted orthoclase has not been recognised for the refractive index is invariably higher than that of the canada balsam.

The quartz is often rounded, cracked and embayed. The ferromagnesian minerals have been almost completely chloritized, but their outlines are marked by black outlines due to iron oxides. Biotite is indicated, and hypersthene and hornblende are also suggested. The amount of ferromagnesian mineral indicates a rock related to the Dacites (Slides 29, 30, and 32.)

2. *Granodiorite.*—This rock is very abundant in the boulders of the Howqua, but it is only found in situ within the area mapped in the extreme north-eastern corner on the slopes of Mount Buller. Its intrusive character is shown by the contact alteration of the adjoining Lower Palaeozoic strata. All the sections prepared were from boulders in the Howqua, as these were the freshest specimens obtainable, and their source was known with fair certainty. The prevailing rock has a typical granitic structure, and is of a grey colour, but very fine grained varieties are not uncommon, showing a tendency to porphyritic structure.

It is worth recording that a small splash of molybdenite was noted in one of the boulders.

Hornblende, biotite and triclinic felspar are readily recognizable in hand specimens. In thin sections, felspars appear to be slightly more abundant than quartz. Twinned and untwinned forms are about equal in amount. The repeated twinning is very minute, with occasional fine cross twinning, suggesting anorthoclase.

Biotite and hornblende, both green in colour, are invariably present, but in varying quantities in the different slides. In the basic segregation patches, the hornblende predominates, and the nature of the rock approaches that of a normal diorite. In general the character of the rock compares closely with that of the normal granodiorites of the State, and its association with the rocks of a dacite type is also similar. This intrusion, therefore, is probably to be correlated with the general and extensive one affecting eastern and south-eastern Australia, and regarded as Lower Devonian in age.

3. *Diorite.*—This rock has not been observed in situ yet, but fresh specimens are abundant in the river gravels, and, judging from the most basic segregation patches in the granodiorite, it is most probably that the diorite is magmatically related to the granodiorite, and is no doubt associated with it in its occurrences, The rock in hand specimens is medium grained, crystalline, of dark colour, showng abundant hornblende and felspar. In thin sections the structure is holocrystalline, inclining to panidiomorphic, but the ferromagnesian minerals are imperfect in this direction. The felspars are most abundant and appear to be almost entirely triclinic. Quartz is rare, being present only as odd grains. Ferromagnesian minerals are abundant, but bulk less than the felspars. They consist of typical green hornblende and greenish brown biotite.

B. *Lower Carboniferous.*

The age of these rocks is determined from the evidence of the fish remains found in the Mansfield area, with which these beds can be seen to be continuous. They form part of an extensive series of sediments extending from Mansfield south-easterly into Gippsland.

1. *Basal Conglomerates.*—These are not largely developed within the area mapped, but small remnants are found directly overlying the dacite porphyry on the slopes between Timbertop and the Howqua, and one small outcrop in the track near the top of Timbertop Gap rests in the decomposed diabasic rocks. It contains pebbles both of this rock and of the porphyry. Quartz and quartzitic rocks are perhaps the most abundant generally, but porphyry, red jasper, and diabase can generally be recognised.

2. *Rhyolite.*—This is a well-defined sheet of variable thickness which at Timbertop amounts to about 600 feet. It generally rests on the conglomerate, but occasionally this bed appears to be absent, and it rests directly on the porphyry, as on the spur east of Blackbird Creek. Upon it is found almost invariably either conglomerate or pebbly sandstone.

The rock is distinct from the porphyry. It is more felsitic, with fewer phenocrysts, which are entirely felspar and quartz. Flow structure is generally apparent. The colour is generally red and the rock is decidedly more siliceous than the porphyry.

Thin sections show it to be typical rhyolite, but the specimens examined are more ferruginous than those of Mount Wellington, and the felspar phenocrysts, all orthoclase, are more abundant than the quartz. Secondary silicification is apparent in some sections. No ferromagnesian minerals were noted. (Slides 26, 28, and 34.)

3. *Conglomerates.*—This bed often passing into pebbly sandstones generally overlies the rhyolite almost everywhere in this series. It is well developed at Mount Timbertop, where it passes up into the normal sandstone.

4. The sandstones are generally of a coarse texture, often flaggy and micaceous, and with a reddish colour. They form as a rule thick beds which alternate with a purplish to chocolate coloured shale, which sometimes has the appearance of an oxidised ash bed. The shales generally provide good grazing country. The colour, texture and generally low angle of dip of these rocks render them readily distinguishable from the older rocks in the field. Their influence on the topography, too, is distinct.

The alternation of hard and soft beds more or less horizontally disposed gives the hills in general a table topped and ledged character, so well shown in the neighbourhood of Mansfield.

Summary and Conclusions.

The area examined covers about 60 square miles of mountainous country, previously unmapped. It lies about 20 miles to the south-east of Mansfield, and forms a portion of the central highland region of Victoria. Physiographically it consists of an area of high relief in an advanced stage of deep dissection. The original plateau character is almost completely obliterated. Deep valleys with permanent streams separated by steep narrow ridges occupy the whole of the region. Small remnants of an overmantel of flat-lying rhyolite and sediments are preserved, providing a topographic contrast to the outline of the highly folded older rocks.

The area lies in the drainage basin of the Upper Goulburn, and the development of this river system as a whole is intimately connected with interesting tectonic and structural questions.

The main problem dealt with in the area concerns the occurrence of diabasic rocks and cherts closely similar to those of Heathcote, and their relations generally with reference to the Heathcotian problem in Victoria.

The lithological resemblances are most striking, both with regard to the diabase and its alteration products. The cherts occupy a similar relationship, and in each case contain *Protospongia*. Contact alteration features are absent, and the rocks for the most part have the character of altered lavas and tuffs of submarine origin.

The trilobite rocks which at the Dolodrook and Heathcote provide evidence of the Cambrian age, are absent in the Howqua, but the field evidence shows that the diabases and cherts are low down in a series of sediments, in the higher portions of which Lower Ordovician fossils have been discovered.

At Heathcote the succession from Cambrian to Lower Ordovician appears to be conformable, the diabases and cherts being on an undoubted Cambrian horizon. It appears reasonable here to include the similar rocks of the Howqua in the same period.

With regard to the associated Lower Palaeozoic sediments, a lithological and fossil discordance on the western and eastern sides of the main diabase is noted and discussed. Upper Ordovician and possibly Silurian fossils are restricted to a small area on the western side, close to the diabase. The rest of the sediments on this side have so far yielded no fossils. They consist largely of slates, sometimes black, often talcose and chloritic, and usually highly contorted. Chertification is slight. On the eastern side the *Protospongia* cherts appear to be conformably in contact with the diabase. They form a well defined zone, which is followed by a series of alternating sandstones and olive green phyllitic slates so far unfossiliferous over a great range of thickness. Higher in the series, thin bands of black slate carrying Lower Ordovician fossils are interbedded with strata of this type. No Silurian fossils have yet been obtained on this side. Some which are possibly Upper Ordovician occur.

The general structure of the area is somewhat obscure, but a faulted anticline with the Upper Ordovician or Silurian included as a small nipped-in piece, is suggested, as illustrated in the sketch section.

The upper Palaeozoic rocks are briefly referred to:

The rocks of Devonian age are:—

1. Dacite Porphyry.
2. Granodiorite.
3. Diorite.

Those of Lower Carboniferous age are:—

1. Conglomerates.
2. Rhyolite.
3. Pebbly and flaggy sandstones.
4. Purplish shales.

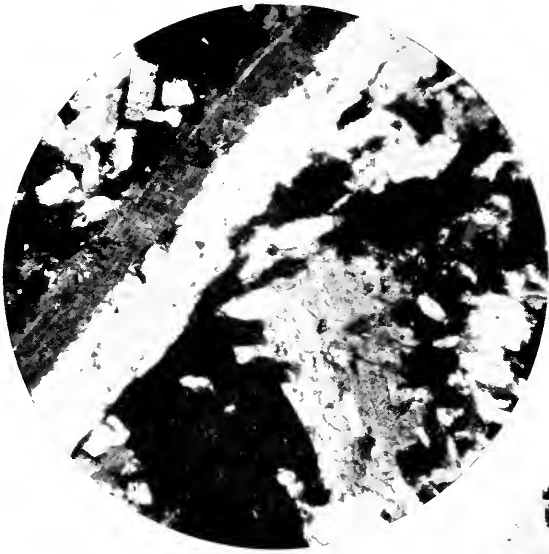

Fig. 1. × 35 diam.

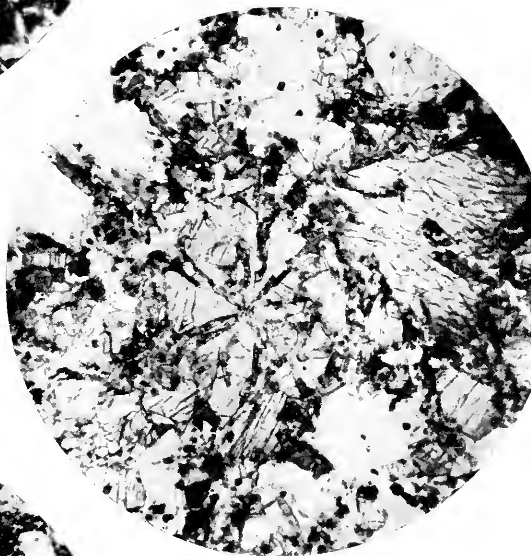

Fig. 2. × 35 diam.

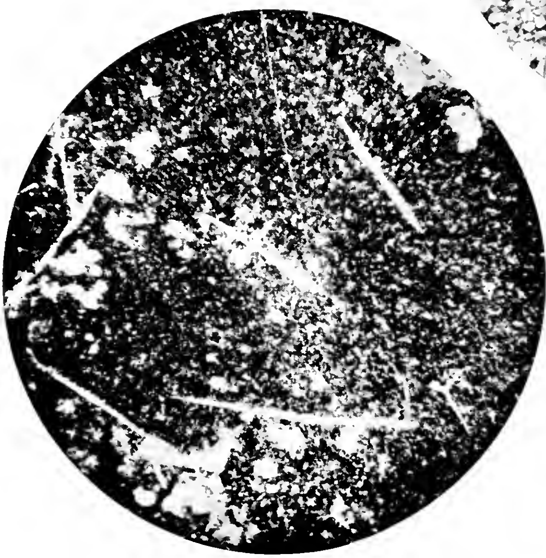

Fig. 3. × 24.5 diam.

Acknowledgements.

I have previously referred to willing help and criticism afforded by Professor Skeats, who has now come to the rescue at the eleventh hour by kindly offering to deal with the petrological description of the more typical forms of diabase. This work was postponed pending the completion of chemical analyses by the author, but the necessity of leaving at short notice for West Africa would have meant leaving this section in a very incomplete form had it not been for this friendly offer. I am also greatly indebted to my father for constant companionship in the field, where the roughness and inaccessibility of the country would have added considerably to the difficulty of the work had it been necessary to do it alone.

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DESCRIPTION OF PLATE V.

Fig. 1.—Rock section, No. 25. Soda-rich diabase from Lick Hole Creek, one mile north of the Governor, and near the south-east end of the main diabase mass. Section × 35 diameters. Polarized light. A large simple twin of albite is seen with smaller quadrate and irregular crystals. The dark areas are principally interlocking fibres of actinolite with augite.

Fig. 2.—Rock section, No. 15. Compact diabase from Four Mile Creek. Section × 35 diameters. Ordinary light. Abundant augite, showing its cleavages with a few radial penetrating felspar laths are seen. Black ilmenite is noticeable, and the clear areas are pale chlorite.

Fig. 3.—Rock section No 78 Bedded black chert, Howqua River, on north-east side of main diabase mass. Section × 24.5 diameters, ordinary light. The black background consists mainly of chalcedony. Numerous spicules of *Protospongia* either as straight rods or in triradiate or cruciform arrangements are seen in the field of view.

END OF VOLUME XXXII., PART I

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Art. VIII.—*A contribution to the Palaeozoic Geology of Victoria, with special reference to the Districts of Mount Wellington and Nowa Nowa respectively.*

By E. O. TEALE, D.Sc.

(with Plates VIII., IX.).

[Read 14th August, 1919.]

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Notes on the Maps.

Wellington District, Map 1.

The area contained in Map 1 comprises about 90 square miles of mountainous country in a region previously unmapped geologically, except for a sketch map by Reginald Murray, issued in 1884, scale, 2 miles to an inch. Though the topography was roughly sketched in by him from main vantage points, very little of the area included in this map was examined geologically, hence as the margins of this region were mainly Upper Palaeozoic, he assumed that these rocks probably covered the whole area. A land survey was made some years ago of a limited portion centring round the serpentine rocks. The blocks were not permanently taken up, and only about one boundary fence was ever put up, so that very few points or lines other than parts of the Wellington and Dolodrook river courses could be definitely recognised in the field. These, however, were made use of, and formed the basis from which the existing map was constructed.

The important central portion, which includes the Cambrian and Ordovician inliers, has been accurately traced and mapped. The outlying topography has been determined approximately by a combination of rapid compass traverses, assisted by plane table methods from suitable vantage points.

Hickey's Creek Region, Map 3.

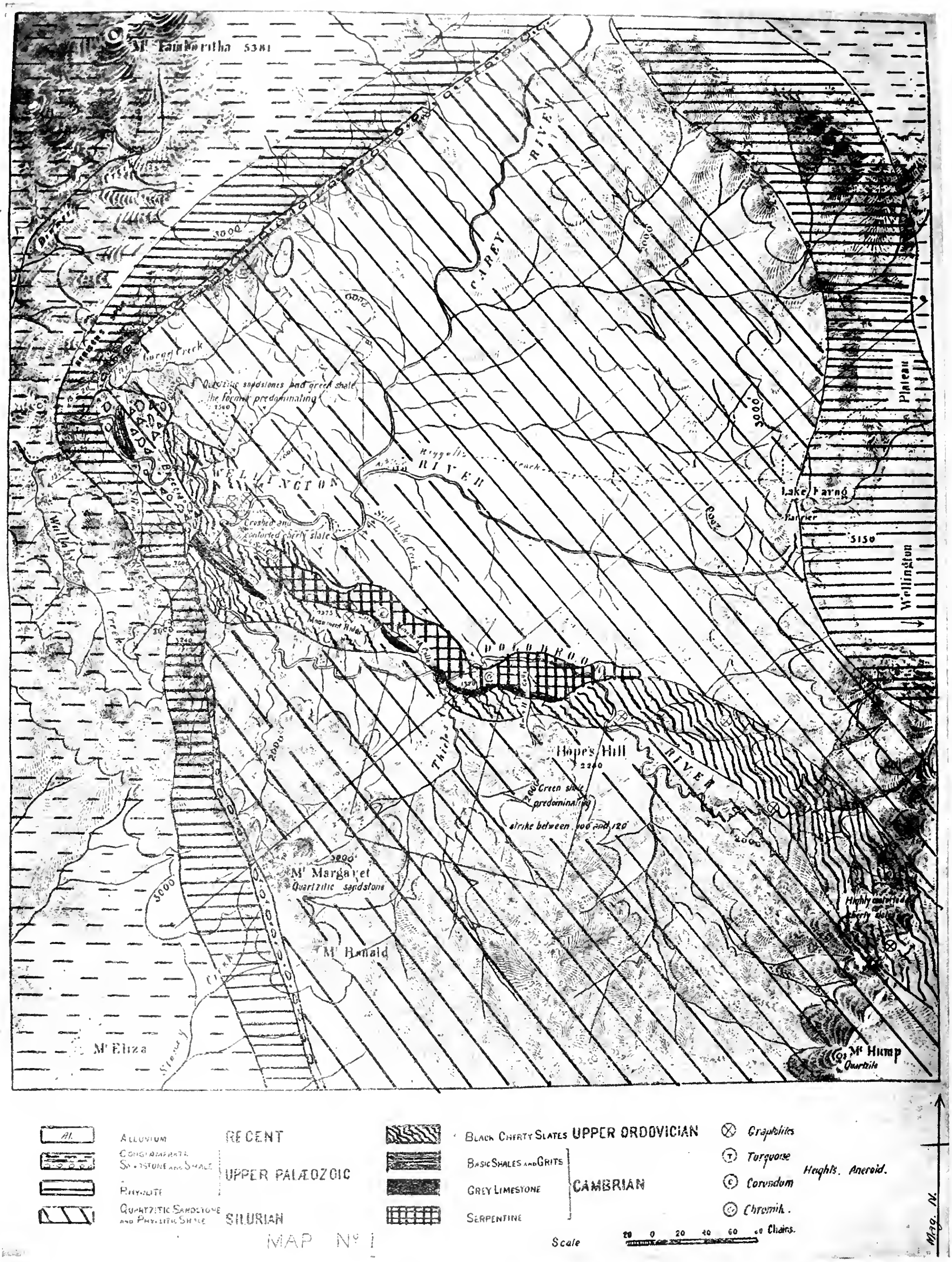
The only topographical basis for this map was the position and course of the Macallister River, obtained from the county map. The road was traversed by myself, and the rest of the features sketched in—in part by plane table methods and rapid compass traverses. Murray's Sketch Map also included this district, but no details concerning important structural features were shown.

Nowa-Nowa—Buchan District, Map 4.

This is another area little known geologically, with a very imperfect topographical basis to work upon. The main streams, such as Boggy Creek, Ti-Tree Creek, Yellow Water Holes Creek and Tara Creek, have been definitely located by Government surveys, and the roads and settler's blocks as indicated provide some fixed points from which to work, but practically the whole of the Tara Range, from its termination in the S.E., near Mt. Nowa-Nowa, to where it passes out of the map in the N.E., has only two fixed points shown in any of the existing maps, namely, the two trigonometrical stations of Mt. Nowa-Nowa and Mt. Tara.

The only other geological map which includes this area is the general map of Victoria, 8 miles to an inch. I understand there are some unpublished sketch maps in the hands of the Geological Survey of Victoria, upon which this portion of the general map was based, but I have not seen them.

The author spent about five weeks in this district, which covers an area of about 200 square miles. It was traversed on foot, single handed, so that though the boundaries indicated are all my own, they are necessarily only very approximate.



Map of Mt. Wellington Area.

Introduction.

The following observations and conclusions are the result of field work which was started in the vicinity of Mount Wellington, in North Gippsland, about fifteen years ago. It was the existence of a small, imperfectly known mountain lake, close to Mount Wellington, which first attracted the writer to this region. Lake Karng, as it has been named, had been visited by the late Dr. Howitt about fourteen years previously, but the question of its origin was not definitely settled. Of the two views discussed by Howitt (1 and 2), namely, glacial and landslip origin, the glacial was most favoured.

No other scientific observer had visited the lake until the writer's examination in December, 1904. A report of the excursion appeared in the "Victorian Naturalist," 1905 (11). The landslip origin of the barrier which forms the lake is there upheld, and several subsequent visits by the writer have greatly strengthened this conviction.

Incidentally, the first excursion showed that the whole region was full of interest, both geologically and physiographically, and during the years 1904 to 1908 (11, 12, 13), four short vacation expeditions were made into various parts of this district. The most important result of this preliminary work was to show that to the west of Mount Wellington there was an extensive and complex inlier of Lower Palaeozoic rocks in an area previously regarded as Upper Devonian. In this region, along the Wellington and Dolodrook Rivers, extensive outcrops of black cherty slates were discovered, yielding abundant and beautifully preserved Upper Ordovician graptolites. Serpentine containing Corundum and Chromite was also found to occur along a belt within the Ordovician area, but its age and relationship to the surrounding rocks had not yet been worked out. Several outcrops of grey crystalline limestone intimately associated with the slates and serpentine were next discovered, and these proved later to be some of the most important and interesting rocks of the district. At first a small brachiopod was the only fossil obtained, which Mr. Chapman regarded as a Silurian form, but later another outcrop of limestone yielded abundant trilobites, which Mr. Chapman confidently recognised as Upper Cambrian (13 and 15). This came as a surprise, for though the field observations were limited, they had not suggested the marked stratigraphical break which the palaeontological evidence now demanded. Shortly previously to this discovery, Mr. E. J. Dunn (16), late Director of the Geological Survey, in company with

Professor E. W. Skeats, made a flying visit to this region, spending only about four days there. Mr. Dunn's attentions were specially directed to the examination of the Serpentine, with the associated occurrence of the Corundum and Chromite, but the observations of both these geologists on the relations of the limestone to the surrounding rocks, though hurried, led them also to receive with some surprise the possibility of their being regarded as Cambrian.

A few years previously, in 1902, Professor Gregory, from a study of several Lower Palaeozoic areas in Victoria, but particularly in the vicinity of Heathcote, claimed that a Pre-Ordovician series of probable Cambrian age existed; and to which he gave the name Heathcotian. Professor Gregory's conclusion was not, however, accepted with full confidence by all the Victorian geologists, and later, Professor Skeats (18) examined carefully the Heathcote rocks, and in 1908 published a very comprehensive review of the situation, concluding that the evidence in favour of a Pre-Ordovician series at Heathcote was not conclusive. He therefore for the time being favoured the inclusion of the doubtful rocks in the basal Ordovician.

The Cambrian problem in the Wellington district was therefore of more than local interest since the existing knowledge concerning the occurrence of Cambrian generally in Victoria was in an unsatisfactory state. It was clearly the chief among many interesting and important questions awaiting solution in this region.

At this stage in May, 1908, the writer's departure to undertake geological exploration in Africa under the direction of the Imperial Institute, postponed indefinitely these interesting researches.

A paper was therefore written, embodying the conclusions arrived at, and stating also the more important unsolved problems (13).

Early in 1915, while in Melbourne, on a short holiday from Africa, the effect of the war led to the suspension of the African Exploration, and it was suggested by Professor Skeats and Dr. Summers that I should resume in the meantime the Wellington researches. The University offered encouragement and assistance in the form of a Government Research Scholarship, and the opportunity, therefore, to renew the work was gladly availed of.

The foremost aim of the expedition was to endeavour by careful survey to map and work out the relations of the various limestone outcrops to one another, and to the surrounding rocks. It was soon found, however, that the work grew in scope, for the mapping showed a succession of inliers ranging from Cambrian to Silurian, surrounded by a ring of Upper Palaeozoic sediments with associated acid and basic lava flows. Important broad structural and tectonic considerations involving palaeozoic geology generally therefore, became involved.

On the first expedition of renewed exploration in April, 1915, I was accompanied by my father, Mr. A. O. Thiele, who had been a constant helper throughout the numerous field trips to this area. Mr. Herman, Director of the Geological Survey, also kindly arranged for Mr. J. Caldwell, one of the officers of the Survey, to join the party as a field assistant, and I am greatly indebted to the willing and able help rendered by both these persons.

Various unavoidable difficulties, due partly to the season and partly to the rough nature of the country, prevented the completion of the work before the wet season set in, and as the district was unsuitable for winter field work, it was decided to choose another region in the meantime, offering unsolved problems likely to bear in some way with those of the Wellington region.

The district, therefore, between Nowa Nowa at the head of Lake Tyers and Buchan, was chosen, for it included two occurrences believed by Mr. Dunn to be of Heathcotian age, one in Boggy Creek and the other in the Tara Range (19), south-east from Buchan.

In Boggy Creek, just north of Nowa Nowa, Mr. Dunn had stated that diabases associated with cherts occurred and in the Mount Tara goldfields he had recognised cherts. Both these occurrences had been included in the Heathcotian on purely lithological grounds, but the relationship to the surrounding rocks had not been worked out. This district further offered an opportunity of studying a portion of the important belt of igneous rocks known as the "Snowy River Porphyries," thus affording scope to discuss the Palaeozoic volcanic history generally, of which the Wellington series form an important chapter.

These various journeys through Gippsland provided also some interesting physiographical studies, so that the extent of the work has gradually grown until it includes a number of distinct problems which will now be considered in turn.

WELLINGTON DISTRICT.

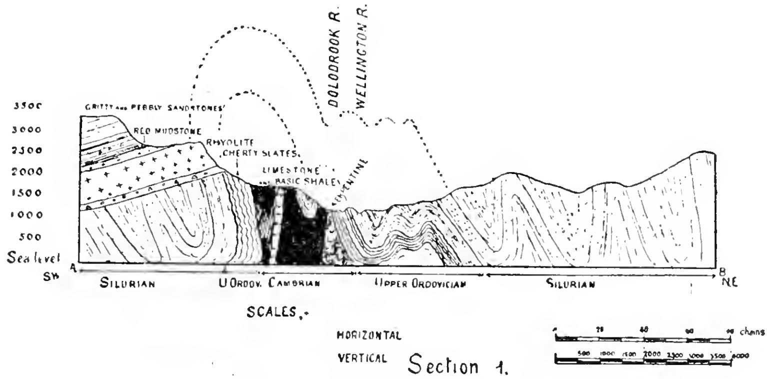
The Palaeozoic Geology.—The Wellington region forms part of one of the important major tectonic and structural zones of Victoria, which may be conveniently termed the Mansfield-Wellington zone. This belt bears the record of a long succession of tectonic volcanic and sedimentary events ranging practically throughout the Palaeozoic period, starting with Cambrian and closing with Lower Carboniferous. There are probably three distinct periods of igneous activity represented, namely, Cambrian, Lower Devonian and Lower Carboniferous. A succession of powerful fold and fault movements along a line varying between N.N.W. and N.W. acting at intervals throughout this period, has impressed especially in the older formation, some marked structural features in the form of intense folding, crumpling and crushing. A general parallelism in strike as a rule exists between the different formations, and the evidence of unconformities has to be considered very carefully. The problems of any portion of this extensive and mountainous belt should take note of the general features of the whole area as far as possible, but, unfortunately, much of the region is still very imperfectly known, and some of it has never been examined geologically. The Wellington area forms the southern end of the belt, and rises abruptly from the northern edge of the great Gippsland Plains, a little to the north of Heyfield, and forms a part of the great Central Highlands of Victoria.

The Mansfield region lies near the northern end, across the Main Divide, not far from the border of the Highlands with the northern plains. The length of the whole belt is about 100 miles, with a width up to about 40. Much of it is covered by Upper Palaeozoic sediments and igneous rock, but extensive denudation has in places stripped off this covering, and laid bare the older rocks, notably near Mansfield, in the Howqua Valley, and also in the Wellington and Dolodrook Rivers. The need for further work in the first and second localities will be explained later. The particular features of the Palaeozoic rocks of the Wellington area will now be taken in order and some reference made to related occurrences elsewhere in Victoria.

Pre-Ordovician Series (Heathcotian).—Under this division there are three distinct groups of rocks:—

(a) Serpentine	Pre-Upper Cambrian.
(b) Trilobite Limestone	Upper Cambrian
(c) Garvey Gully series of Sediments	

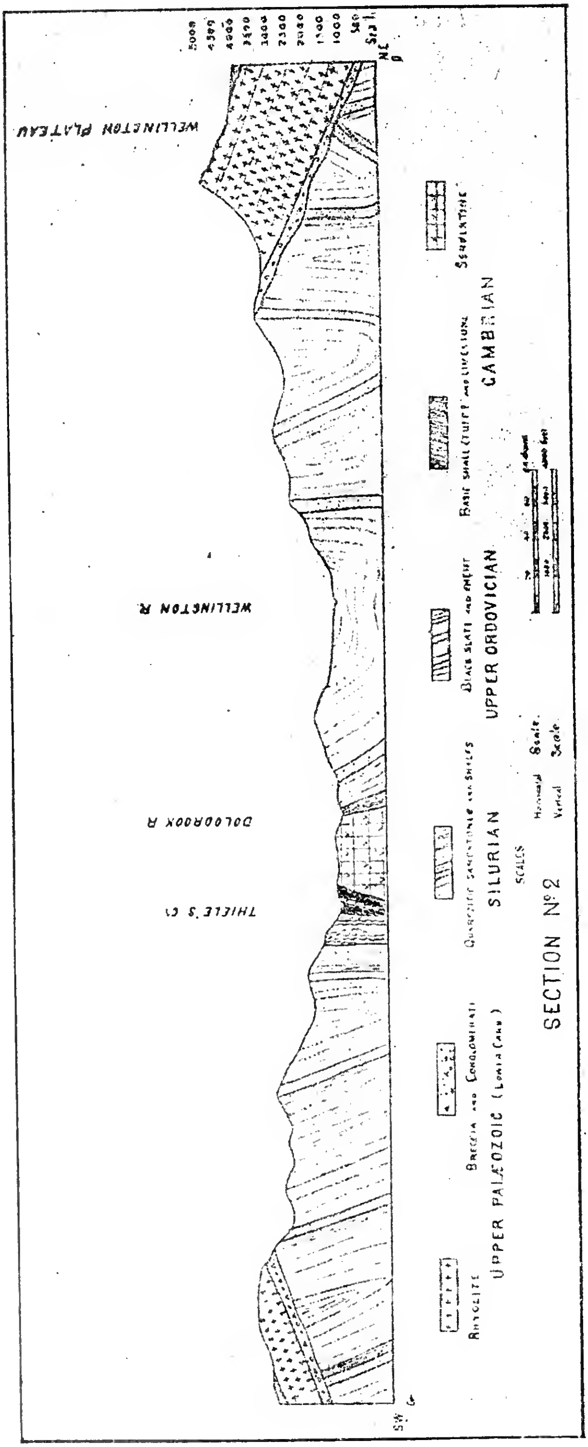
The general occurrence of this series is shown on the map of the Wellington region, and the accompanying Sections (Map No. 1 and Sections 1 and 2). It will be seen that the rocks of this series occur as a long, narrow curved inlier striking generally in a north-westerly direction, which is the grain or trend of the whole structure of the area. A narrow, incomplete ring of black cherty graptolite slates of Upper Ordovician age almost surrounds the inlier, but on the northern side along a portion of the contact the Silurian sediments rest directly against the Serpentine. The whole series is intensely crushed and contorted, and so are the Upper Ordovician



Section showing relation of Cambrian Inlier to surrounding Rocks Dolodrook River

rocks. As all the successive formations have been subjected to periods of folding and compression along a north-westerly direction, they have a similar strike, and small vertical sections of contacts do not yield conclusive evidence of unconformity. The mapping, however, of the boundaries gives more satisfactory information in this direction, and everywhere the lithological and palaeontological break is quite sudden.

The Serpentine.—The extent and general features of this rock with its associated minerals, Chromite and Corundum, were described in a previous paper (13), but the age and relationship to the surrounding rocks had not been definitely established. The Serpentine was then regarded by me as the oldest rock occurring in this region, and was put down as Pre-Upper Ordovician. This view is still upheld, but it is now possible to further restrict its age to Pre-Upper Cambrian. The Serpentine was shown previously (13) to be of the nature of an altered intrusive rock, originating from both pyroxenites and peridotites. Various rocks are found directly in contact with it, for example, serpentinous grits, conglomerate and finer sediments derived from the denudation of the serpentine, also associated diabase tuffs in which there are definitely interbedded lenticular limestone deposits of Upper Cambrian


WELLINGTON PLATEAU
WELLINGTON R.
THIELE'S CK
SW
NE
RHYOLITE
BRECCIA AND CONGLOMERATE
UPPER PALÆOZOIC
QUARTZITE SANDSTONE AND SHALES
SILURIAN
BLACK SLATE AND CHERT
UPPER ORDOVICIAN
CAMBRIAN
SERPENTINE
SCALES
Horizontal Scale
Vertical Scale
SECTION No 2

age; elsewhere Upper Ordovician slate or Silurian sandstone and shale directly overlie the Serpentine. Nowhere has there been observed any rock showing contact alteration. The conclusion, therefore, is clear that not only is the Serpentine the oldest rock but there is a stratigraphical break between it and the next oldest rock, the Upper Cambrian, sufficient to allow of considerable denudation previous to the deposition of the Upper Cambrian. The intense shearing and foliated character of much of the Serpentine has been previously referred to (13). It is generally recognised that a certain amount of such structure frequently found in Serpentine is due to intense expansional forces generated by the increase in volume, which accompanies the mineralogical change from pyroxene and olivine into Serpentine. Additional stresses, however, of an intense character due to general compressional earth movements have further deformed these rocks, and have largely contributed to their schistose character.

A very useful and comprehensive summary of the state of our knowledge concerning the Heathcotian Series is given by Professor Skeats in the "Volcanic Rocks of Victoria" (18). It includes references to various Serpentines and associated rocks in Victoria, some of which have been doubtfully referred to by various geologists as Pre-Ordovician. Further interesting information and statements concerning Cambrian occurrences generally in Australia are discussed by Professors David and Skeats in the Federal Handbook, in the section dealing with the geology of the Commonwealth (20). Serpentine has been shown to occur in a number of widely-separated localities frequently associated with cherty and diabasic rocks, notably at Waratah Bay, near Casterton and the Limestone River, Benambra. These rocks have been doubtfully included by some authorities in the Pre-Ordovician Series, but though little is known concerning the relationship to the surrounding rocks, the definite fixing of the age of the Wellington Serpentine adds a little more weight to the conjecture that these other occurrences may be correlated with the Pre-Ordovician.

It is interesting to note as previously referred to by Professor Skeats (18) that near Heathcote the diabase at its margin passes into a rock allied to Serpentine, known as Selwynite, containing chromite and corundum, an association also found in the Wellington area.

The Garvey Gully Series.—These rocks were recognised in part in my previous paper (13), under the heading of "Sediments composed largely of Serpentine Detritus, and were doubtfully included in the Upper Ordovician. A more extended examination, however, has shown that they are distinct lithologically from the black slates; the junction is always a sharp one, and further the limestone deposits which have yielded definite Cambrian fossils are interbedded with them. Chemically, these rocks are distinct from the adjacent cherty graptolitic slates. Their analysis shows a low silica percentage and relatively high iron, lime and magnesia content. The soil, therefore, derived from their weathering is of a noticeable red colour and clayey character, supporting a richer growth of grass and other vegetation than the rather stony and sterile soil of the slates. The belt is further marked by a rather striking feature of the weathering of some of the fine grained sediments, which petrological examination proves to be tuffaceous. These rocks weather into striking elongate spheroids with a succession of spheroidal shells similar to the well-known structure of partly decomposed basalt and other igneous rocks. Their field occurrence and petrological examination, however, leave no doubt as to their sedimentary origin.

There are two separate occurrences of this series, both of limited extent. The largest and most important is a long narrow belt along the Dolodrook Valley. It starts about a quarter of a mile northwest of Garvey's hut, and extends south-easterly on the southern side of the Serpentine as far as Roan Horse Gully, a distance of three and a half miles. The greatest width is never more than a few chains. The other occurrence is a small outcrop of highly contorted basic sediments exposed in the bed of the Wellington River, roughly on the line of strike, about a mile and a quarter northwest from the termination of the first-named inlier.

At its north-western extremity, the Dolodrook inlier passes out of sight under the Upper Palaeozoic rocks, but along its southern or south-western boundary it is directly in contact with the Upper Ordovician slates. The character of the sediments varies from coarse serpentinous conglomerate through grits to fine greenish diabasic tuffs. Several sections merit special attention.

Locality A, (Dolodrook River).—This position is shown on the map extending from the junction of the Black-Soil Gully, in a south-westerly direction, for about twenty chains. The succession and relationship are represented in Section No. 1. At the junction of Black-Soil Gully with the Dolodrook, there is a small inlier of Serpentine with contorted black cherty slates in contact on the north side. The junction appears to be a fault, and obscure but recognisable Upper Ordovician graptolites can be traced in the cherts almost up to the junction. Following the river bed upstream, the Serpentine about one chain in width passed serpentinous and ferruginous shale of the Garvey Gully type, highly ferruginous here on account of weathering. The rock continues for about eight chains, when a hard cherty band of contorted slates is encountered. It is about two chains wide and definitely Upper Ordovician, from which characteristic graptolites have been obtained. At first sight, the band has the appearance of being interbedded with the Cambrian sediments, but palaeontological evidence supported by petrological differences and comparison with similar small outliers of Upper Ordovician in the vicinity, shows that the occurrence is due to intense folding which has nipped portions of the overlying Ordovician into the Cambrian. Continuing with the section, the cherts are followed again by a belt of about 10 chains of typical greenish basic tuffs with interbedded Cambrian limestone about one chain wide and beyond this to the south-west, these rocks are bounded by a belt of contorted Upper Ordovician cherts.

The contact between the two series is shown in a small gully which enters the Dolodrook at the limestone outcrop. It is situated about five and a half chains from the junction in a south-west direction. The passage from basic tuffs to cherty slates is sharp, with about two feet of gossany material in between, probably occupying a fault. The rocks are highly inclined and disturbed on either side.

A chemical analysis of the tuff is appended, showing its basic character.

	I.		II.
SiO_2	50.09		48.11
Al_2O_3	12.69		13.30
Fe_2O_3	5.30		3.70
FeO	12.01		8.10
TiO_2	2.12	MnO	1.43
CaO	5.08		8.48
MgO	5.60		9.51
H_2O-	0.40	Loss on Ignition	4.21
H_2O+	2.72		
Na_2O	2.54		1.96
K_2O	1.32		1.57
CO_2	0.80		—
	100.67		100.37
S.G.	2.86		

(I.) Green banded tuff—Garvey Gully series Dolodrook River (Teale.)

((II.) Purple and green tuff between Pen-Maen-Melyn and Pen-Maen-Foel, South Wales, Cambrian, (Wilson), British Petrography, Teall, page 223.

The principal differences to be noted in comparing the Dolodrook tuff with the Cambrian one of South Wales are the greater percentage of iron and smaller amount of lime and magnesia present in the former. No other analyses have yet been made of similar rocks of supposed Heathcotian age in Victoria.

Thin sections of the fine grained tuff (No. 44), from the Dolodrook, show a banded and somewhat schistose structure, with numerous small sub-prismatic and irregular grains of basic plagioclase felspar, many of which are orientated with their longer axes parallel with the planes of schistosity, but many also lie at any angle, frequently across the planes of foliation. Much chloritic and some serpentinous material is present between the felspar grains, but no fresh pyroxenes were distinguished. Magnetite is abundant, and several small grains of quartz were noted. The fragmental structure, together with the chemical and mineralogical composition seems to indicate the nature of an altered subaqueous diabase tuff.

The secondary silicification, which is one of the marked features of the diabase tuffs and allied rocks at Heathcote, is absent.

Locality B.—The next section of importance is about two and a half miles in a south-easterly direction, at the junction of Thiele's Creek with the Dolodrook. Here within a relatively small area there are good exposures of the Serpentine, the basic sediments with interbedded limestone, the Upper Ordovician graptolite bearing slates; and the Silurian sandstones and shales (Map 2).

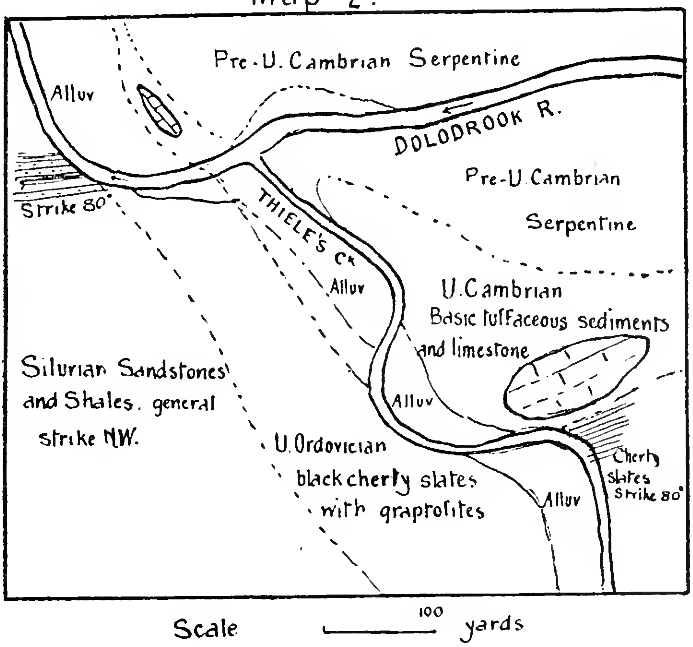
The actual contact of the Cambrian sediments and the Serpentine is shown in the bed of the Dolodrook River, at Thiele's Creek Junction. Here the sediments are of the nature of serpentinous and chloritic conglomerates, grits and finer bands.

A section of this is given by Mr. Dunn (16), who describes the rocks as post-Ordovician, on account of the presence of dense darker rock fragments, which he regarded as Ordovician slate, but which microscopic evidence shows to be a basic igneous rock. The fine dark bands described by Mr. Dunn as slate, prove to be tuffaceous, and similar in character with the basic sediments associated with the Cambrian limestone in every case.

In this vicinity there are two limestone outcrops associated with the basic sediments. Additional thin sections of both the coarse and fine material indicate their tuffaceous character, and support the view also that they belong to the Garvey Gully Series.

The contact and section generally are important, as they show clearly that the Serpentine is a pre-Upper Cambrian rock, the denudation of which in part contributed to the Cambrian sediments.

Map 2.



The remaining portion, consisting largely of diabasic pyroclastic material, indicates an Upper Cambrian volcanic phase.

This section shows also an interesting structural twist in the strike, post-Silurian in age, for the whole series, including the enveloping Ordovician and Silurian rocks, are locally bent round from a north-west strike to one varying between 80° and 100°. This continues for more than a mile easterly, the strike then gradually swinging back to a more normal north-west direction.

Locality C. (Roan Horse Gully).—A traverse from a few chains on the north side of the Dolodrook, opposite the Roan Horse Gully junction, in a S.S.W. direction, across the Dolodrook, and along the bed of Roan Horse Gully, shows well the relative position of the various rocks, and illustrates the typical structure of the inlier.

The limestone is again associated with the same basic sediments, which rest against the south side of the Serpentine. The enveloping Upper Ordovician rocks are found as a very thin belt on the north side of the Serpentine, and repeated just to the south of the limestone. All the strata are highly inclined, being almost vertical, but an overthrust from the north, or north-east, causing a fault in the vicinity of the Ordovician contact, has placed the limestone locally above the graptolite slate, as shown in the sketch section, No. 3. This movement is probably to be correlated with the general overthrust of post-Silurian date, affecting a considerable part of the Dolodrook area, for a fine example of overfolding of the Silurian rock is shown in the Dolodrook, about one mile and a quarter in a straight line below Thiele's Creek junction (Photo. 2).

The Silurian sandstones and shales outcrop at each end of the section forming the next enveloping zone of the complex inlier. The general ge-anticlinal structure is therefore complete along this line.

The Dolodrook Limestones.—These form one of the most important series, for they have provided the definite palaeontological evidence without which it would have been impossible to discover the complete key to the structure of this region.

Previous to resuming the field work in this region, the fossils, chiefly trilobites which Mr. Chapman had definitely concluded to be Cambrian, came from the limestone outcrop No. 1, at the north-west end of the belt.

The first fossil obtained in the district from the limestone, originally regarded by Mr. Chapman as Silurian, came from Roan Horse Gully outcrop, about three and a-half miles to the south-east, but no trilobites had yet been found in this occurrence. The recent field work, however, has been successful in discovering similar trilobites in four separate outcrops, including the Roan Horse Gully limestone, and the mapping generally shows clearly that all the limestone outcrops, of which there are nine, belong to the same series. The additional fossils obtained, Mr. Chapman states, give further convincing evidence of the Cambrian age, and his supplementary palaeontological description will be given later.

Upper Cambrian Fossils.—The following are the fossils described by Mr. Chapman (15) from the Dolodrook:—

Plantae—

Class, Algae. Girvanella Sp.

Animalia—

Class Crinoidea

Crinoid stems, joints and ossicles.

Class Brachiopoda

Lingulella

Orthis (Plectorthis) platystrophioides.

(Originally confused with Platystrophia biforata.)

Class Gasteropoda.

Scenella tenuistriata, Chapman.

Related to Stenotheca—Cambrian of South Australia.

Class Crustacea, Sub. Class Trilobita.

Agnostus australiensis, Chapman.

Ptychoparia thielei, Chapman.

Ptychoparia minima, Chapman.

Crepicephalus etheridgei, Chapman.

The limestone has a pleasing grey colour, is crystalline, and, when polished, would make an attractive ornamental stone, but in its present inaccessible position there is no immediate prospect of it being available for use. No quantitative analysis of its composition has been made, but a qualitative test showed that it was relatively pure, with only a small percentage of magnesium carbonate. All the outcrops are of lenticular character and small extent, the two largest being No. 1 Dolodrook, and that at Roan Horse Gully. The latter can be traced along the strike for about three hundred yards, and shows a good face towards Roan Horse Gully of about a chain in width.

Upper Ordovician.—These rocks, consisting of black slates, with highly cherty bands frequently intensely contorted, have been referred to in a previous paper (13), but their extent and relationship to the other rocks in the vicinity had not been fully traced. It had been recognised in general that they wrapped round the central inlier of Serpentine and associated rocks, but the outer boundary had not been followed. The result of additional field work makes it now possible to indicate these features on the map presented; showing that the Ordovician rocks are in turn enveloped by an outer ring of later sediments, with a distinct lithological and palaeontological break. The slates are everywhere readily distinguished in the field from the less indurated shales and sandstones of the next series. Graptolites are abundant throughout even in the most highly cherty representatives, but naturally the best preserved specimens are obtained from the less altered bands. The forms represented are uniformly Upper Ordovician types. The first graptolites were obtained by the writer in 1905, and were described by the late Dr. T. S. Hall (14). Since then other forms have been collected from various parts of this area, and numerous other collections have been made by various members of the geological survey throughout Eastern Victoria.

Of these occurrences, the best collections have come from (1) Matlock, (2) the Thomson-Jordan Valley, (3) the Black River Belt, and (4) the Wellington area. These four localities consist of parallel strips of Upper Ordovician rock, separated by belts of Silurian sandstone and shale. The fossils show that these outcrops, if not identical in horizon, are at any rate, very closely allied; and owe their reappearance to successive intense folding along lines of N.N.W. axes, resulting also in the folding of the overlying Silurian rocks in a similar way. Subsequent denudation during the present cycle of erosion has exposed some Ordovician as inliers. They are generally narrow, elliptical belts, conforming to the general strike, but disappearing along the strike under the Silurian, often to reappear, however, at varying intervals along this line. This is due mainly to a very general development of pitch, sometimes north and sometimes south. This structure, common throughout the older rocks of Victoria, has been clearly brought out in the Wood's Point and Walhalla district by the excellent field work of Mr. O. A. L. Whitelaw and Mr. W. Baragwanath respectively.

Up to the present no definite graptolite zones have been recognised in the Upper Ordovician in Victoria. It is probable that the vertical range in the Upper Ordovician is not so great, but it is likely that systemate work would yield some definite results in favourable areas.

The following is the complete list of graptolites recorded from the Wellington region:—

Diplograptus foliaceus, Murchison.
Diplograptus thielei, T. S. Hall.
Diplograptus (Orthograptus) quadrimucronatus, J. Hall.
Diplograptus (Orthograptus) calcaratus, Lapworth.
Leptograptus flaccidus, J. Hall.
Climacograptus wellingtonensis, T. S. Hall.
Climacograptus bicornis, J. Hall.
Climacograptus bicornis, var. tridentatus, Lapworth.
Climacograptus tubuliferus, Lapworth.
Dicellograptus elegans, Carruthers.
Dicellograptus morrisi, Hopkins.
Dicellograptus gurleyi, Lapworth.
Cryptograptus tricornis, Carruthers.

Dicranograptus nicholsoni, Hopkinson.
Dicranograptus hians, T. S. Hall.
Nemagraptus gracilis, J. Hall.
Lasiograptus margaritatus, T. S. Hall.

Most of the above species are widespread and abundant in their occurrence throughout the area, but Orthograptus calcaratus has only been found at one spot in the north-western extremity of the Ordovician, marked G, where it is associated with abundant Climacograptus bicornis and another rare form, C. tridentatus. The last-named species was also found at another locality, marked $G._2$.

Splendidly preserved specimens were obtained, and it is the first undoubted record for Victoria, a doubtful instance has been recorded from Cravensville.

Nemagraptus gracilis has only been found in Roan Horse Gully.

Dicellograptus gurleyi is also rare, and has only been recorded from the Wellington area.

See comparative table, showing general record of Ordovician graptolites in Victoria.

It is interesting to note that a small amount of turquoise was observed in several places, chiefly as very thin veinlets in the joints of the cherty rocks and, occasionally, also associated with white quartz.

The mineral is evidently widespread in its occurrence in the Upper Ordovician rocks in Victoria. The best known localities are Ryan's Creek, Myrrhee (31), and Mt. Avis, Edi, King Valley. Mr. Caldwell tells me that he found it in black slate on the Black River, and I found it myself in light-coloured chert in the Tara Range.

A certain amount of white powdery phosphatic material also occurs irregularly distributed along joints and fractures. One sample of altered siliceous rock yielded an analysis 8% of P_2O_5.

Some phosphatic deposits of promise from an economic standpoint occur in the vicinity of Mansfield. They are associated with Ordovician rocks, but their true relation is still the subject of controversy.

The cherty nature of the Ordovician rocks of the Wellington district is a noteworthy feature. The prevailing colour is black, and the most completely altered bands are of the nature of lydianite or black jasper. All grades of silicification occur, and though in general the cherts run in bands with intervening belts of more normal slate, instances are common showing slightly chertified slate a few inches wide between beds of jasper. There has clearly been a selective action in the process of silicification, probably controlled mainly by primary differences in composition existing in the original strata. Thin sections, however, of the slates and cherts have so far not revealed what these differences were.

The alteration is not attributable to the direct contact action of igneous intrusion, but would appear to be explained by a selective metasomatic replacement due to aqueous solutions permeating the rock.

Instances of this type of chertification are found throughout the Palaeozoic rocks. It is natural, therefore, to find cherts of very different ages resembling each other somewhat closely, and this has led to considerable confusion on account of some geologists having correlated numerous cherty outcrops with the "Heathcotian" on purely lithological grounds.

Professor Skeats (18) has discussed the origin and occurrence of the cherts of the Heathcote area, and has shown that they are largely due to metasomatic replacement of diabase and diabase tuffs. The age is left an open question, but their inclusion in the basal portion of the Ordovician was favoured on the then known palaeontological evidence.

Dr. Summers (21) has described cherts and associated rocks at Tatong, where they are interbedded with fairly normal sediments, which he regards as Upper Ordovician.

In the Wellington area and in the Tara Range, near Buchan, I have found Upper Ordovician graptolites actually in the cherts. It is therefore clear, as Dr. Summers points out, that the occurrence of cherts as characteristic of the Heathcotian Series loses its significance.

Up to the present no radiolaria have been noted in thin sections of the Wellington cherts which have been examined.

Reviewing the important structural points brought out by a study of the Lower Palaeozoic geology of the Wellington area, it is clear that the axis of this complex inlier marks an important structural line, the direction of which is parallel with the main Palaeozoic trend lines, along which a succession of important tectonic movements have been renewed many times. We therefore find the zonal arrangement of successive formations bearing in a prevailing N.N.W. to N.W. direction very marked, exposing in this case within a remarkably small area, narrow, parallel but unconformable belts from Cambrian to Silurian.

With this in mind, it is natural to look expectantly along the continuation of the strike of this belt.

UPPER ORDOVICIAN GRAPTOLITES.

	Mt Wellington District. E.O.T	Turquoise Mine, Ryan's Ck, Myrrhee. A.M.H.	" " Mt Avis, Edi	North slope, Mt Easton, 3 miles from Thomson-Jordan Junc. W.Bd	Dingo Ck, 290° 2 mls Thomson-Jordan Junc.	Main Divide between Mt Selma and Spring Hill. O.A.L.W.	Black R, near junction with Ten Mile Ck.	Two miles NW of Mt Easton.	Three quarters of a mile NE of Mt Easton.	Matlock 1¼ mls SW Kelly's Hill. EOT and Geol Surv.	Sandy's Creek Mitchell R.	Cravensville.	Dark R.	Tungamah.	Snowy R, Mt Deddick.	Accommodation Ck Deddick.	Walwa Ck.	Wombat Ck.	Mt Deddick (river pebbles)	Cabanandra.	Thoona.	McLaughlan's Ck.	Two miles east of Myrtleford. E.J.D	Kerrie ? U Ordovician	Myrtleford, 10ch NE Allot 2 (W Clemens)	Nowa Nowa. O.A.L.W	Tara Range. E.O.T	Parish of Newham, Sec V.A. E.W.S & H.S.S.	S of U Macedon, Loc 51	Emu Creek, Allot 48A Kerrie	Kevington. O.A.L.W	Jordan R, 2½ miles above Jericho. O.A.L.W.
Diplograptus sp.	⊕	⊕	⊕		⊕	⊕	⊕																					⊕	⊕		⊕	
D. cf tamariscus, Nicholson										+																						
D. foliaceus Murchison.	+			+	+		?		+	+		+				+			+		?									+		
D. thielei, T.S Hall.	+																															
D. carnei, T.S Hall.								+									+	?				?										
D. ingens, T.S Hall									+																							
D. pristis																		?														
D. cf aculeatus, Lapworth									+																							
D (Orthograptus) quadrimucronatus, J. Hall	+								+																							
D. angustifolius, J Hall.																										+						
D. tardus, T.S Hall.																																+
D. calcaratus, Lapworth.	+															+																+
Leptograptus sp.																															⊕	
L. flaccidus, J. Hall.	+							+	+																							
Climacograptus sp.			⊕	⊕	⊕		⊕	⊕																⊕		⊕	⊕					
C. wellingtonensis, T.S. Hall.	+																															
C. bicornis, J Hall.	+			+					+			+							+													+
C. bicornis, var peltifer, Lapworth.																																+
C. tridentatus, Lapworth.	+											?																				
C. baragwanathi, T.S. Hall.									+																							
C. hastatus, T.S Hall.										+																						
C. tubuliferus, Lapworth.	+			+						+							+			?												
C. cf innotatus, Nicholson.										+																						
C. caudatus, Lapworth.																+																
C. mensoris, T.S. Hall.								+																								
Dicellograptus sp								⊕				⊕					⊕		⊕				⊕								⊕	
D. affinis, T.S Hall.				+	+					+									+													
D. elegans, Carruthers.	+			+					+									+		?										+		+
D. morrisi, Hopkinson.	+									+										+												
D. gurleyi, Lapworth.	+																															
D. cf anceps.																		+				?										
D. sextans, J Hall.																																+
D. complanatus, Lapworth var *ornatus*, Ellis and Wood								+																								
D. aff forchammeri, Geinitz.					+																											
Cryptograptus tricornis, Carruthers.	+								+							+																+
Dicranograptus sp.							⊕																								?	
D. nicholsoni, Hopkinson.	+								+																							
D. hians, T.S Hall.	+								+							+																
D. ramosus, J. Hall.									+		+			+	+																	+
D. var. *semispinifer* T.S Hall																?																
D. var *longicaulis* T.S H.																										?						+
D. furcatus, J. Hall.																																+
Nemagraptus gracilis	+																															
Lasiograptus margaritatus, T.S H.	+			⊕				+	+																							
Glossograptus sp.	⊕		⊕	⊕					⊕																		⊕				⊕	
G. fergusoni, T.S Hall.				+																												
G. hermani, T.S Hall.		+	+								+	+	+	+							?					+						?
Clathrograptus geinitzianus, J. Hall																										+						
Dendrograptus sp		⊕							?	?																						
Didymograptus cf caduceus, Salter.			⊕		⊕									+												+		?				
D. ovatus T.S Hall											+																					
Dichograptus, sp			⊕																						⊕	⊕						

NOTE – ⊕ indicates that the genus only has been recorded.

It may be of some significance, therefore, that we find in this line other complex Lower Palaeozoic inliers, whose structural details and relationships are still a subject of controversy, and provide promising scope for further work.

The phosphatic deposits at Flannery's, near Mansfield, and the associated sedimentary rocks form one of the most interesting inliers in question.

Some very fragmentary fossils were obtained some years ago from the phosphatic material, consisting chiefly of Salterella, and obscure trilobite remains. The fossils were very unsatisfactory, but were regarded by Professor Gregory as probably Cambrian. Professor Skeats and Dr. Summers have obtained both Upper and Lower Ordovician, and Mr. A. M. Howitt Lower Ordovician graptolites in such close proximity to the spot from which the trilobite remains were found that the geology is clearly complex, and the results of more detailed work should be of considerable interest.

Another area requiring further attention is in the Upper Howqua Valley, at such a position that the extension of the Cambrian axis of the Wellington region might be expected to appear.

Mr. A. M. Howitt (22) made a flying visit to this region about eleven years ago, and recorded the occurrence of cherts, which were regarded as Cambrian, phosphate rock, amphibolites and serpentine of undetermined age, also Silurian slates and sandstones.

The relationship of these rocks has recently been discussed by the author in the Proc. Roy. Soc., Vic.

Silurian.—The rocks of this series consist chiefly of alternating quartzitic sandstones and greenish sandy shales. Some of the latter have a marked rubbly to splintery mode of weathering, and by oxidation are frequently rusty brown near the surface. They dip at high angles, and have been folded along numerous axial lines in a general N.N.W. to N.W. direction. Though they have been subjected to much folding and even overfolding, as shown in the Dolodrook, below Thiele's Creek junction (Photo. 2), the intense contortion which is such a marked feature of the Ordovician is as a rule absent.

The actual contact between the Ordovician black slates can be seen at several outcrops. Three of these are worthy of mention. One is in Blyth's Gully (Loc. D.), about 20 chains N.N.W. from the Wellington-Dolodrook Junction. Another is in the bed of a steep tributary gully of the Wellington, about a mile N.W. of the abovenamed junction (Loc. E.), and the third is in Thiele's Creek, about

30 chains south from its junction with the Dolodrook (Loc. F.). In all these instances, conformity of strike and similarity of dip are shown, but the horizontal extent of the exposure is limited, and when the general boundaries of the contiguous formations are traced the evidence in favour of an unconformity is more marked. The lithological break is a sharp one in every case, and the graptolites are abundant in the slates to the junction when they stop suddenly.

Unfortunately, no distinctive fossils definitely recognisable as Silurian were obtained, but a grit containing crinoid impressions was noted at Locality D, and a similar crinoid bearing grit was noted in the Dolodrook valley close to the outer boundary of the Ordovician, confirming the ge-anticlinal interpretation of the structure.

Mr. Chapman states that the material, though not conclusive, is lithologically similar to fossiliferous grits of Silurian age collected by Mr. Whitelaw in the Wood's Point Belt, where they bear a similar relation to the underlying slates.

This series is of great extent, wrapping round the Ordovician and older rocks, and forming a wide area of hill country.

From its furthest limit, in the north of the Carey River, where it disappears under the Upper Palaeozoic rocks, southwards to the vicinity of Glenmaggie, where it passes under the Tertiary plains, is a distance of more than thirty miles in a straight line.

It is the outer zone or ring of the complex Lower Palaeozoic inlier and the Upper Palaeozoic cover is found continuously along its eastern limits, approximating to the Avon watershed.

On the west denudation has been more effective, so that the Upper Palaeozoic over-mass is wanting between Hickey's Creek and the plains, a distance of about twelve miles.

The rocks, therefore, regarded as Silurian, can thus be traced continuously to the Macallister Valley to the south of Hickey's Creek, and thence westerly to the Wood's Point-Walhalla zone, included in the surveys of Messrs. Whitelaw and Baragwanath, respectively.

Within the area mapped several of the prominent elevated points rising to well over 3000 feet, are due to the superior resistance to weathering of some of the hard quartzitic sandstone of this series. The three most conspicuous and noteworthy are Mts. Hump, Margaret and Ronald.

Upper Palaeozoic.—The rocks here considered form a portion of the most extensive occurrence of this age found in Victoria. The extent of the whole belt from its southern border, where it is contiguous with the Gippsland plains to the northern limit toward Benalla, is about 100 miles, and the greatest width is about forty miles. The general trend of the belt is about N.N.W. It is composed in part of sedimentary rocks, consisting chiefly of thick conglomerates, coarse sandstone and chocolate shales and mudstones, with in places interbedded acid and basic lava flows. The sedimentary series in the vicinity of Mansfield contains fossil fish of Lower Carboniferous types, associated with Lepidodendron.

The strata of the southern portion are very similar lithologically to those of the Mansfield area, but with the exception of an imperfect fish scale, the only fossils obtained were those of Lepidodendron, found in widely separated localities in the Macallister valley, and also that of the Avon. The Geological Survey Map shows this series as Upper Devonian, and the Mansfield region as Carboniferous, but the evidence in favour of their separation is inconclusive, and they are here all regarded tentatively as Lower Carboniferous.

In addition to the above group of rocks, there is a great development in the northern portion of the belt, and particularly in the valley of the King River, of acid porphyritic rocks, which, according to Professor Skeats (28), appear to be related to the dacites, suggesting their correlation with the dacites of the Strathbogies and elsewhere, which are generally regarded as of Lower Devonian age. This is in conformity also with the field evidence of A. E. Kitson (10), who interprets them as being uncomformably overlaid by the Upper Palaeozoic sediments.

Along the western margin of the Upper Palaeozoic belt is the Barkly Valley, notably on Fullarton's Spur. O. A. L. Whitelaw shows in his map the occurrence of porphyritic rocks, some of which Professor Skeats has recognised as altered andesites, distinct from the acid lavas of the Wellington area, and comparable most probably with some of the Lower Devonian volcanics, typically known as the "Snowy River Porphyries."

Another interesting feature is brought out by a study of the geological map of Victoria, with reference to the eastern and western adjoining formations. On the eastern side the older rocks are Upper Ordovician; no Silurian has yet been recognised.

To the west, and continuing to the vicinity of the meridian of Melbourne, Silurian rocks, prevail, with only relatively narrow inliers of Upper Ordovician.

Should more detailed work later fail to discover any Silurian rocks to the east of the Upper Palaeozoic belt, it would seem to point to the possibility of an old eastern shore line of the Silurian sea, which is now buried beneath the latter rocks of this area.

The whole Palaeozoic history of this belt, with its succession of sedimentary and volcanic events emphasises that it has represented a major tectonic and structural zone throughout Palaeozoic times.

The two areas where the Upper Palaeozoic rocks have received most attention from me are the vicinity of Mt. Wellington and the Macallister valley, at Hickey's Creek. These two areas will be considered separately.

Wellington Area.—The position and extent of these rocks within the area discussed is shown on the map, and their relationship to the underlying rocks is indicated in sections, numbered 1, 2, 3 and 4. It will be seen that they rest unconformably on the Silurian and older rocks, and in general the beds dip at low angles with a marked absence of the sharp repeated folds of the older series.

On the western side of the map it is seen that the beds dip uniformly westerly (W.S.W.), and on the Wellington side the dip is easterly. These two directions have been proved to form part of a large anticlinal fold at least fifteen to twenty miles in width. The axis has a direction of about N.N.W. and lies between Mt. Tamboritha and Mt. Wellington. The southern portion has suffered much denudation, with the result that within the area examined, the crown of the fold has entirely gone, revealing the underlying older rocks, which have, in turn, been much dissected during the present cycle of erosion. The two limbs of the folds are preserved with their steep scarp slopes opposing one another, forming, especially in the case of Mt. Wellington, bold and precipitous cliffs. (Photo. 3.)

The rock succession is very constant over the whole area, though the thickness of the individual beds is subject to some variation, and in general the observations of Murray (9) and Howitt (4) in other portions of this region, indicate the same succession and features.

The basal beds almost everywhere consist of reddish conglomerates, breccias, or breccio-conglomerates, with pebbly sandstone and red shaly bands developed locally. The pebbles and boulders consist chiefly of quartz and quartzite, with some indurated shale and cherty slate.

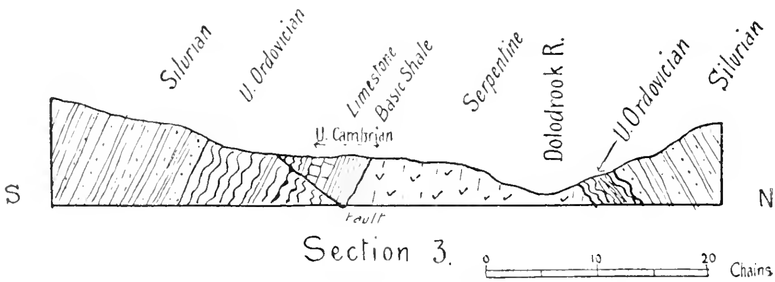
One feature of importance is the occurrence also of acid igneous fragments and boulders. Some of these are exactly similar to the rhyolites and rhyolitic porphyries of the Wellington series which overlie these beds. Others are too decomposed for definite comparison.

No outcrop of Lower Devonian igneous rock has been recognised in the area, but as indicated previously rocks probably of this age occur about ten miles to the N.N.W. at Fullarton's Spur and about forty miles to the N.N.W. in the King River District.

From a comparative microscopic examination of numerous thin sections of Lower Devonian porphyries with those from the Wellington area, the details of which will be given later, it appears probable that a satisfactory distinction may be made microscopically between the two series.

If this feature is proved by wider investigation to enable a generalisation to be made, it may be possible to recognise in these conglomerates and breccias, porphyries of two distinct periods representing material derived from a Lower Devonian source, and also later rocks belonging to the first products of the outbreak of the Lower Carboniferous volcanic activity.

A considerable thickness of acid lavas and tuffs succeeds these basal beds over wide areas, and it seems likely that though the main outburst and effusion slightly succeeded the deposition of the conglomerates, some of the earliest outbursts were practically contemporaneous, contributing some of the admixed igneous material which suggests the nature of volcanic ejectamenta.



Section 3.
Roan Horse Gully

One of the best sections showing the basal beds where the breccia character predominates is at Locality G, Wellington River, about three-quarters of a mile below the Wellington-Dolodrook junction. The beds are of a coarse nature, and contain both angular and water-worn rocks, consisting largely of black cherty slates, quartzites and quartz; stratification is visible, and the beds are here inclined at a much higher angle than usual, dipping to the W.S.W. at about 70°. They are seen to rest against the Upper Ordovician cherty slates, which are much contorted, and the junction suggests a fault line, striking north-westerly. The same beds show a marked discordance in strike at another outcrop, about fifteen chains to the north-west, where there appears to be a short north and south fault. The strike on one side is about N.E., and on the other N.W .

The belt as a whole, however, is traceable almost continuously without any noteworthy break, below the overlying rhyolite sheet, and these disturbances in dip and strike, though striking, are only of limited extent.

Another deposit with some special features is exposed in the bed of the Wellington River, still further to the north-west at Locality H. Its exact nature and relationship is not clearly understood, but it may be an extreme lithological variation of the basal beds under discussion. The extent is about 20 chains over about a width of one chain along the bed of the river.

Its character is that of a coarsely fragmental deposit, composed very largely of fine grained diabasic rock, the interstices being filled up with granular quartz and calcite. A few angular inclusions of quartz porphyry similar to that of the Wellington series were noted.

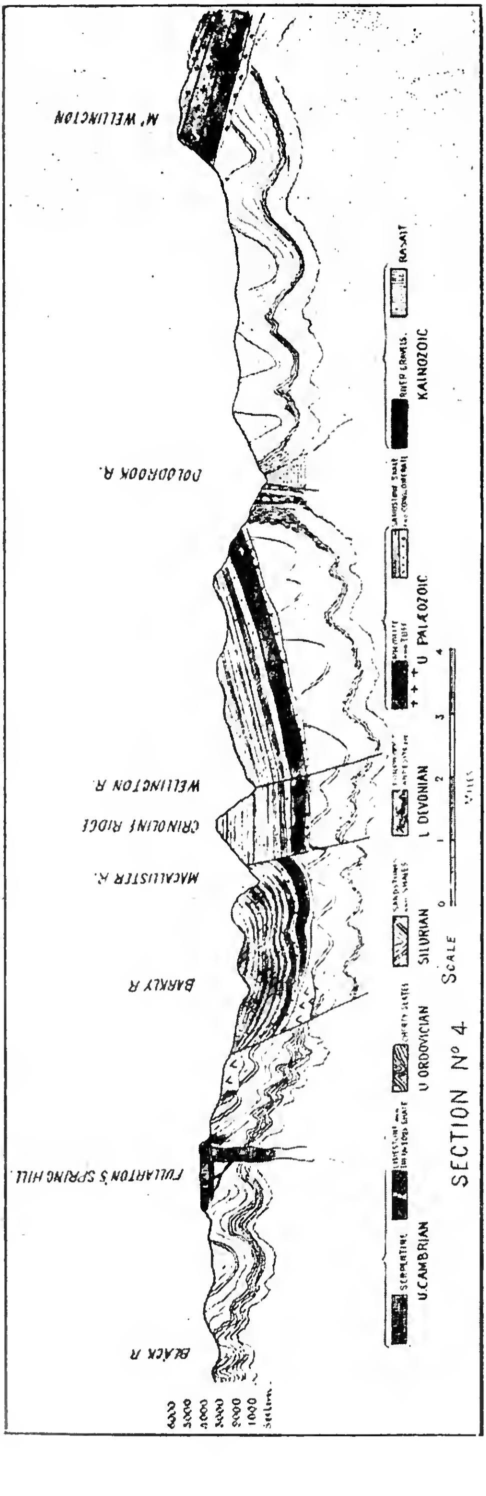
A number of thin sections from various parts of this deposit were examined.

The diabasic material is fine grained, and much altered. Fine plagioclase laths and magnetite are recognisable, but there is much chlorite and calcite. The interstitial material is siliceous and calcareous, consisting of a coarse to fine grained mosaic of quartz and calcite.

Secondary silicification affecting both the diabase and the interstitial material is recognisable, but an original fragmental character can be recognised in some sections, showing altered fragments of shale and diabase, irregular grains of quartz, showing secondary growth and an occasional fragment of orthoclase.

The porphyry inclusion shows a fine microcrystalline siliceous base, with corroded and embayed orthoclase phenocrysts, showing some kaolinization and secondary silicification.

These acid igneous inclusions suggest possibly a Lower Carboniferous source, and though the relationship of the deposit to the


M^t WELLINGTON
DOLODROOK R.
WELLINGTON R.
CRINOLINE RIDGE
MACALLISTER R.
BARKLY R
FULLARTON'S SPRING HILL
BLACK R
SERPENTINE
U.CAMBRIAN
U ORDOVICIAN
SILURIAN
L DEVONIAN
U PALÆOZOIC
RIVER GRAVELS
KAINOZOIC
BASALT
SECTION N^o 4
SCALE
0 1 2 3 4
MILES

surrounding rocks is not clear, the occurrence is included tentatively with the basal beds of the Upper Palaeozoic.

The Rhyolites and Associated Tuffs.—These rocks occur as a well-defined sheet of great extent. They are readily traced in the field, consistently near the base of the series along either limb of the main anticlinal fold. They vary in thickness from less than 1000 to over 2000 feet. In the thinnest portions they would appear to represent a single flow, but in Mt. Wellington where they form a bold escarpment on the western face, they are composed of successive beds of pyroclastic material and rhyolitic flows.

These rocks, under the name of quartz-porphyries and felsites, were recognised by Howitt and Murray, in widely separated areas in this region, and they were invariably found occupying a position towards the base of the series. Howitt recognised the volcanic nature of the rock, and that there were both effusive and pyroclastic representatives. One of the finest sections, that of Snowy Bluff in the Moroka Valley, to the north of Wellington, has been carefully described by both Murray (9) and Howitt (4).

The rhyolitic rocks there rest on conglomerates, and are estimated at about 100 feet in thickness. One of the striking features of much of the igneous material in the vicinity of Wellington is that rocks of the outward appearance of quartz-porphyries, are often crowded with water-worn pebbles of quartz and quartzite, often producing quite a conglomeratic appearance. Numerous inclusions of indurated slate and shale are also common.

Thin sections of some of these rocks have shown that the igneous material of which they are in part composed, is pyroclastic. One particularly fine example from the northern shore of Lake Karng, Mt. Wellington, showed the tuff character remarkably well (microphoto.). It contains angular and broken fragments of quartz and felspar set at all angles in a fine microcrystalline base, containing beautifully preserved tubes of irregular outline so characteristic of tuffs, but seldom so well preserved. Their bent and twisted shapes and broken cusp-like forms are particularly striking in the section.

The fact that material of this nature is often admixed with waterworn pebbles of the old rocks, points to the conclusion that explosive volcanic action was practically contemporaneous with the deposition of part at any rate of the basal conglomerate beds.

Another section from the southern shore of the lake has been referred to in a previous paper (13). It has the character of a rapidly-cooled lava and shows very fine perlitic structure.

The rock on the summit of the plateau is a typical banded rhyolite, the flow lines being very conspicuous.

The detailed succession of igneous material building up the Wellington mass has not been worked out, but there is a noteworthy thickening in the vicinity of Lake Karng. In the southern bluff of Wellington the thickness is not more than 1,000 feet, but in the vicinity of the Lake it is more than double that amount. This is probably accounted for mainly by the presence of marked irregularities of the Palaeozoic surface on which the volcanic beds were laid down.

It is perhaps strange that no undoubted vent or fissure by which the volcanic material reached the surface, has yet been definitely recognised, nor have any dykes, acid or basic, been noted in this region. Considering the high melting point of rhyolite, its viscous nature, the deep dissection of the rocks, and the wide extent of the lava flows in this region, it is perhaps remarkable that some channel by which it reached the surface has not yet been recognised.

No undoubted intrusive quartz-porphyries have yet been noted in this region.

A fine section of the rhyolite, showing its relations to the basal conglomerates and over-lying sandstones, is shown in the course of the Wellington, just north of Shaw's Gap, or one mile and three-quarters in a straight line north-west from the Wellington Dolodrook junction. (Loc. 1.) Here the river has cut a tortuous canyon for about half-a-mile through the rhyolite, forming precipitous cliffs, showing fine columnar structure. (Photo. 4.)

The remaining portion of the series, amounting to some thousands of feet in thickness, consists largely of alternating beds of conglomerate, passing into pebbly sandstone and normal gritty sandstone, separated by beds of varying thickness, of purple shales and mudstones, with, in places, interbedded sheets of altered basalt. (Melaphyre of Howitt.)

Fossils are rare throughout the series. The first obtained came from the sandstones of the Avon River, and were described by Sir Frederick McCoy as Lepidodendron Australe. The writer has since noted Lepidodendron at four localities in the Macallister basin. They are as follow :—

(1) Roadside cutting near Basin Flat.
(2) Roadside cutting, Macallister R.—Target Cr. Junction.
(3) Reid's Selection, near Barkly R.
(4) Near Glencairn (Mr. Sweetapple's).

The only other fossil obtained was a fish scale, from near the Wellington-Dolodrook junction, regarded by Mr. Chapman as probably belonging to the rhizodont genus Strepsodus (23)

The general nature of the beds, together with the contained fossils, indicate a freshwater or lacustrine origin, and the shape of the basin appears to have been that of a long relatively narrow trough, at least a hundred miles in length, with a general N.N.W. direction.

The Melaphyres.—These have been referred to briefly in a former paper (13), and two analyses by G. Ampt were included. Reference is also made to Howitt's description of the melaphyres of Snowy Bluff, where at least eight distinct flows separated by beds of sandstone and shale have been recognised, but they are never of any great thickness (7).

Until last year, no melaphyre had been noted within the area under consideration, but one occurrence can now be recorded in Wallaby Gully, towards its head.

The section forms a small fall in the channel of the creek, showing a bed of melaphyre twelve feet thick resting on red shaly mudstones, with a thin band of mudstone on top followed by sandstone. The flow is distinctly amygdaloidal at the top and bottom with the usual secondary quartz, calcite and epidote. The central portion is a dense fine grained rock. A thin section of this shows under the microscope a distinct flow structure due to the parallel arrangement of the felspar laths. These have a low extinction angle, and appear to be oligoclase; they are ophitically enclosed in chlorite into which all the augite has passed. Analyses of this rock are not very satisfactory on account of the great amount of alteration which has taken place. The one here submitted is from the central portion. The low amount of lime and magnesia is probably due to secondary leaching, for calcite amygdales are common in the upper and lower portion and thin sections of these parts also show calcite.

For comparison the two analyses by Ampt of samples from the basin of the Moroka are repeated. No. 2 was the freshest sample and, therefore, probably the most normal.

The Melaphyres are clearly subaqueous basic lava flows, and are always found considerably higher in the series than the Wellington Rhyolites.

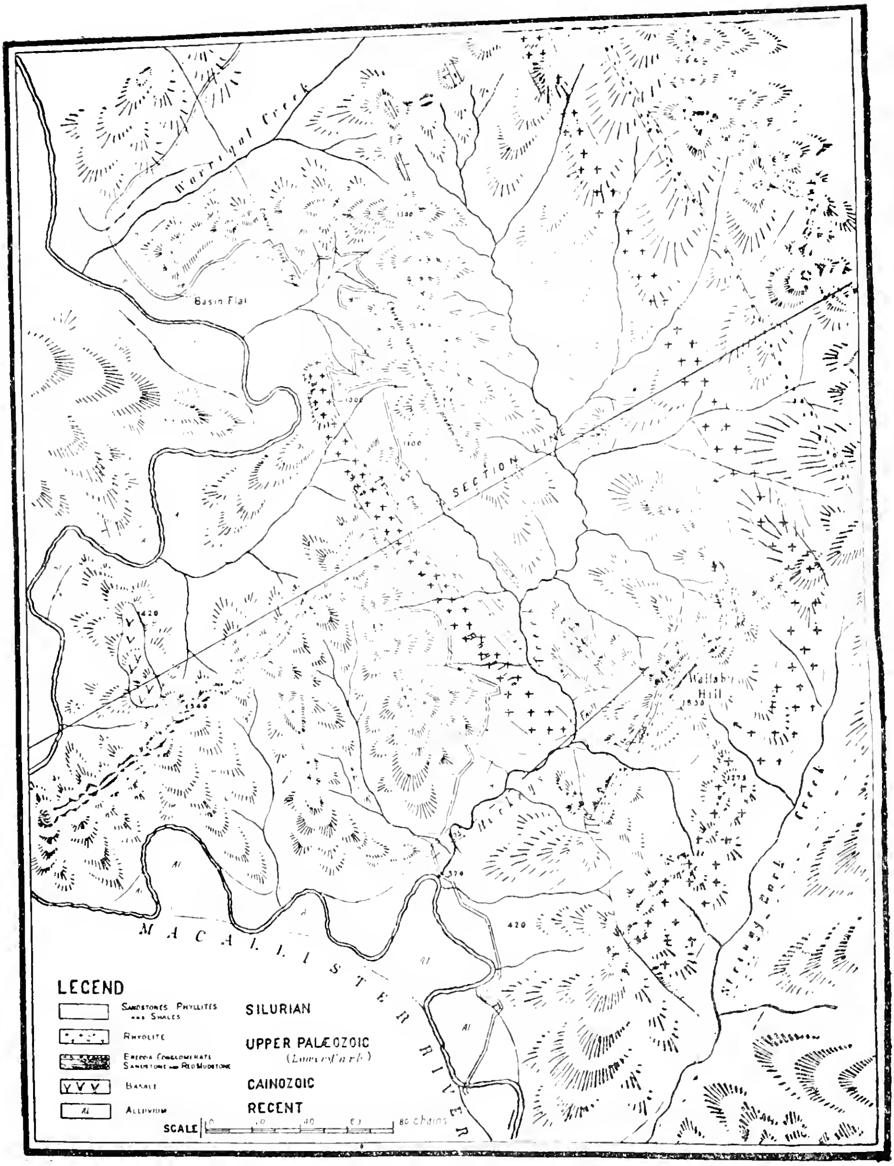
	1	2	3
SiO_2	47.84	49.35	43.88
Al_2O_3	16.17	17.61	16.58
Fe_2O_3	9.28	1.50	5.83
FeO	8.64	9.72	9.11
CaO	4.70	7.71	9.60
MgO	2.62	3.17	5.77
Na_2O	4.47	3.10	2.02
K_2O	0.08	1.56	1.06
P_2O_5	tr.	tr.	tr.
H_2O	0.06	0.65	0.64
H_2O	2.51	2.56	2.22
TiO_2	2.68	2.83	3.52
MnO	0.30	0.07	tr.
Pyrite FeS_2	—	0.34	
	99.35	100.17	100.23
S.G.	2.82	S.G. 2.918	

1. Melaphyre (No. 177), Wallaby Creek, Wellington Valley. —Analyst E. O. Thiele.
2. Melaphyre, Moroka Snow Plain; fairly fresh sample. —Analyst G. Ampt.
3. Melaphyre, Bad Spur, Moroka Valley; altered specimen. —Analyst G. Ampt.

HICKEY'S CREEK DISTRICT.

This is a relatively small area on the eastern side of the Macallister valley, at Hickey's Creek junction, about twelve miles from Glenmaggie (see Map 3). It lies on the route from Heyfield to Mount Wellington, via the Macallister Valley, and therefore had been frequently traversed during the journeys to and from the Wellington region.

Here particularly, as well as at other points further north in the Macallister Valley, the Upper Palaeozoic rocks had been noted to be very highly inclined, with dips ranging up to nearly vertical, and sometimes in the reverse direction to the normal one. It was therefore decided to give a little time to a more detailed study of the features, with the result that some interesting structural points are brought out, marking a powerful tectonic line running approximately N.N.W., and probably continuing for a great distance in this direction, coinciding very closely with the western boundary of the Upper Palaeozoic series. A new road for vehicular traffic in place of the old pack track has recently been made as far as the junction of Target Creek with the Macallister, about thirty miles from Glenmaggie. At Hickey's Creek, this road leaves for a time



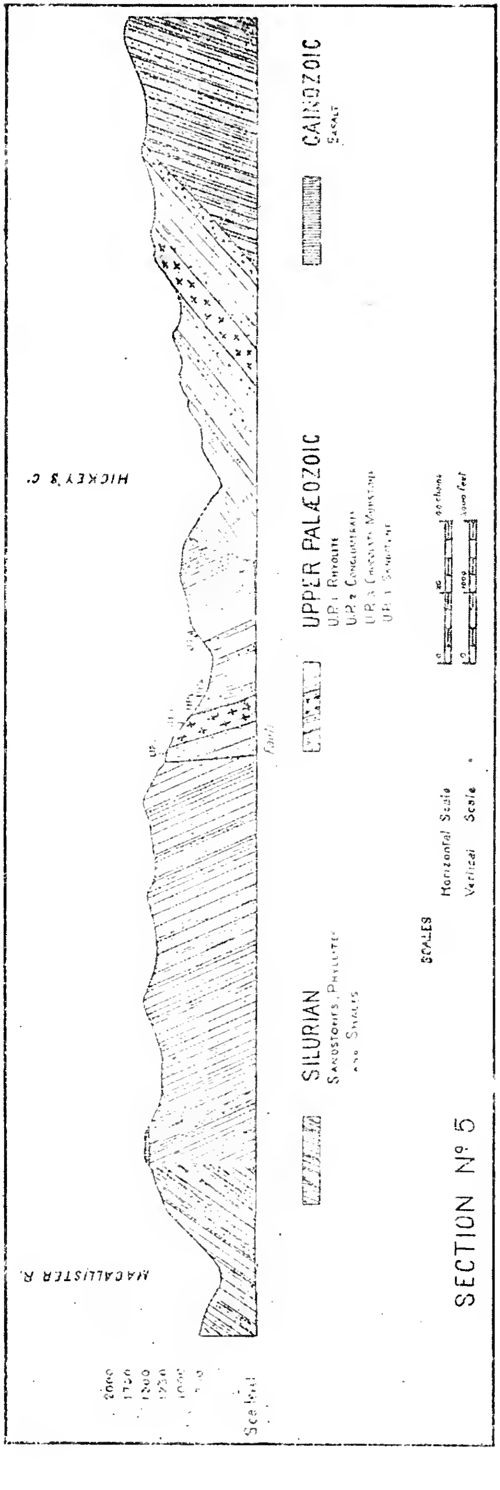
MAP N° 3

the Macallister, and rises by a long sidling grade more or less parallel with the valley of the creek to a saddle, thence descending to the Macallister again at Basin Flat by a similar winding grade cut out of the steep hillside. This part of the road affords a succession of fine sections of the highly inclined Upper Palaeozoic rocks, including the basal beds, rhyolite, conglomerates, sandstones (in one place containing Lepidodendron), purplish shales and mudstones. The area mapped includes this part of the road, and the Hickey's Creek Basin essentially, most attention being given to the Upper Palaeozoic rocks, and their contact with the older rocks. The only other formations noted are the Silurian sandstones, phyllites and shales, and a small remnant of a Kainozoic basalt flow.

Silurian.—The usual alternation of quartzitic sandstones with phyllites and shales is found in this area, but the phyllites and shales predominate over the sandstones. They are generally greenish in colour, due to a certain amount of chlorite, and are fairly arenaceous. The whole series is intensely folded and frequently crushed. Small quartz veins are very abundant either along joints, shear planes, bedding planes, or fracture lines.

Upper Palaeozoic.—The rocks belonging to this series are identical in character and succession with those described in the Wellington area, but their high angle of inclination is a striking feature.

The prevalence of thick beds of conglomerates, and coarse pebbly sandstone, and the general red colour of most of the beds, especially the shales, combine to form a striking contrast with the Silurian rocks. The boundaries as a rule are, therefore, readily traced in the field, and also certain characteristic beds within the series can be easily followed for considerable distances, and these are of great assistance in working out the structure. In this way the rhyolite and associated conglomerates were found in following across the strike to be repeated on account of a marked synclinal structure, but as the mapping shows it is not of a simple character, for one limb is bent round in such a manner in the vicinity of Wallaby Hill as to bring the strike of similar beds at right angles. This point is perhaps the most striking feature in this area, for it forms a precipitous rocky crag rising on the eastern side of Hickey's Creek. It is composed of beds of coarse conglomerates dipping at 50 degrees to the N.W. and striking N.E. The beds are cut through towards the southern end by a small tributary of Hickey's Creek causing a rocky cleft, which isolates another rocky crag of slightly lower elevation, and composed of the same conglomerate. Following these beds along the strike in a N.E. direction, they soon swing round to N.N.W., and the same feature is noted with regard to the underlying rhyolite and basal conglomerate. The same rhyolite and conglomerate can be noted on the western side of Hickey's Creek, dipping in the opposite


HICKEY'S C.
MACALLISTER R.
Fault
CAINOZOIC
BASALT
UPPER PALÆOZOIC
U.P. 1 RHYOLITE
U.P. 2 CONGLOMERATE
SILURIAN
SANDSTONES, PHYLLITES AND SHALES
SCALES
Horizontal Scale
Vertical Scale
SECTION No. 5
Sea level

direction at a high angle. Fine sections are shown in the road cuttings, about two miles northerly from Hickey's Creek junction (see 12). From about this point, also looking south-easterly across the deep valley of Hickey's Creek, there is an interesting view of Wallaby Hill, showing on the upper portion bare dip faces of the conglomerate striking at right angles to the direction of view. At the same time, in the lower slopes, there are conspicuous outstanding ribs of conglomerate and sandstone dipping at a high angle to the north-east, and whose strike therefore is at right angles to the rocky face forming the summit.

Faults.—Reference to Map 3 and Section 5 of this area shows that an intense compressional movement at right angles to a N.N.W. axis has nipped in and folded a belt of the Upper Palaeozoic sediments in a trough of older rocks. Along the western contact, at several places, the rocks are disturbed and often much crushed. A fine example of crushed rock is seen in Hickey's Creek, close to the old pack track, and about three-quarters of a mile from the Macallister junction. Here a portion outcrops as a conspicuous monolith, about thirty feet high. It consists of broken Silurian quartzite, forming a rough breccia, but distinct from the basal breccias and conglomerates of the Upper Palaeozoic, which are clearly of a detrital nature. Tracing the contact along in a north-north-westerly direction, it is found that in addition to the crush features a portion of the basal beds is cut out, the features in general therefore indicating a persistent fault along this line.

Transverse sections across the Macallister valley at intervals to the north, beyond the area included in this map, would seem to indicate similar structural conditions. The western limb of the broad anticlinal fold has been bent back to form a minor syncline, and faulted against the older rocks on the west. This same feature is recognisable still further north along this line in the map, and section of Woods' Point sheet by O. A. L. Whitelaw, and a generalised section compiled from that map and extended to the east from my own observations seems to provide a probable interpretation of the structure (Section 4). A minor fault with a north-easterly direction intersects the major one, and corresponds in position with the lower portion of Hickey's Creek, but it is the other direction which is of greatest importance.

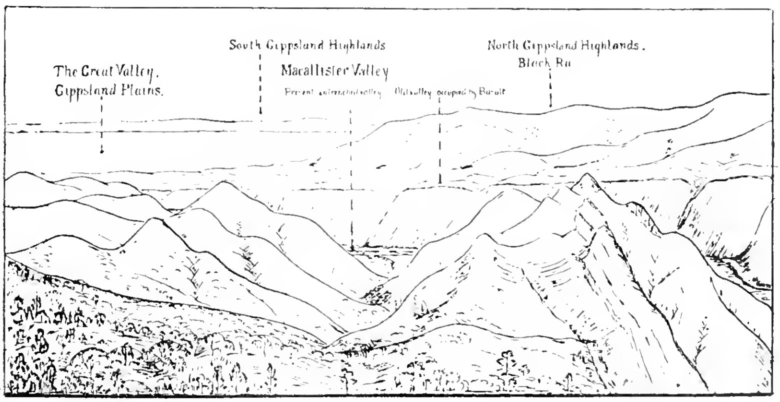
The age of this tectonic movement cannot be fixed closely. It is clearly post Lower Carboniferous, but may still be Palaeozoic, though it seems probable that renewed differential movement may have taken place along this line at successive intervals during the late Kainozoic uplift, which produced the existing highlands. The position and general direction of the Macallister valley coincides in part with this line, and some of the physiographic features suggest at any rate that its course has been controlled to some extent by this feature.

Kainozoic Basalt.—The extent of this rock is small, it is but a remnant of an extensive flow which once occupied the valley. It is about a thousand feet above the present stream bed, and was at one time clearly continuous with other more extensive fragments, which are to be found chiefly to the south in the vicinity of Blanket Hills, where the basalt forms a striking shelf about 800 feet above the existing stream, which is now entrenched to that amount along the eastern margin.

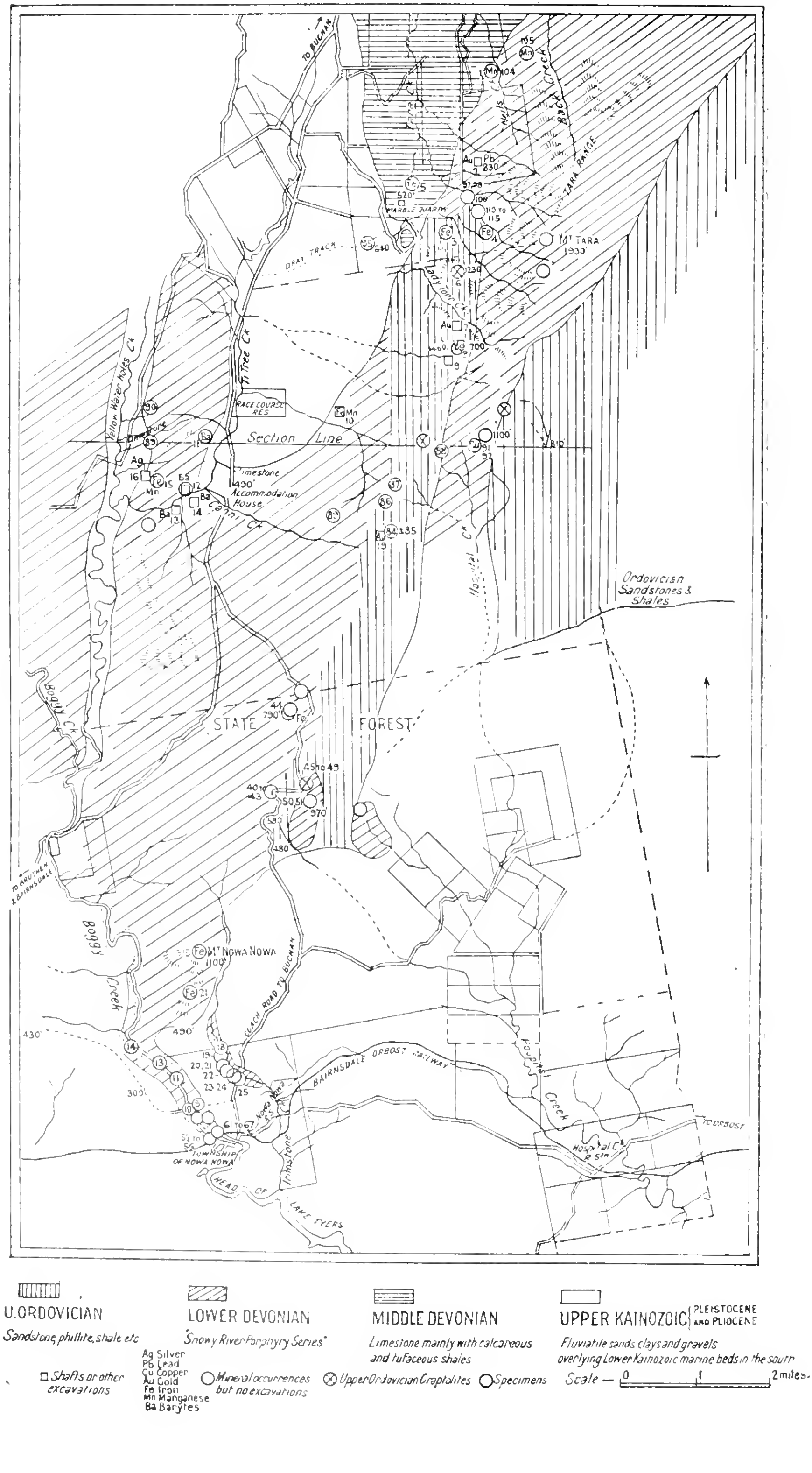
A fine view of this feature is seen from Wallaby Hill, showing also the sudden termination of the Highlands in the south, a portion of the plains of the Great Valley of Victoria, and the Southern Highlands in the distance. (See Sketch A.) The basalt of Gippsland generally is usually regarded as the Older Basalt, and may, therefore be at least pre-Miocene. There is no satisfactory petrological distinction, by which the various Kainozoic basalts can be recognised.

It is, therefore, often very difficult to correlate many of the lava flows in even adjacent areas. For instance, the high N. and S. ridge to the west of the Macallister, from Mount Useful in the south, where it forms the divide between the Thompson Valley, to Connor's Plains in the north, where it is part of the Main Divide, is capped at intervals with basalt resting on river gravels. These

SKETCH A



Map 4



TO BUCHAN
Back Creek
Tara Range
Mt TARA
1930'
MARBLE QUARRY
DRAY TRACK
Lady Tom Ck
Yellow Water Holes Ck
Ti Tree Ck
RACE COURSE RES
Section Line
Limestone
490' Accommodation House
Cairn Ck
Hospital Ck
Ordovician Sandstones & Shales
Boggy Ck
STATE
FOREST
TO BRUTHEN & BAIRNSDALE
Boggy Creek
Mt NOWA NOWA
1100'
COACH ROAD TO BUCHAN
BAIRNSDALE ORBOST RAILWAY
TOWNSHIP OF NOWA NOWA
HEAD OF LAKE TYERS
Trinstone
Hospital Ck
R Stn
Creek
TO ORBOST
U.ORDOVICIAN
Sandstone, phillite, shale etc
LOWER DEVONIAN
"Snowy River Porphyry Series"
MIDDLE DEVONIAN
Limestone mainly with calcareous and tufaceous shales
UPPER KAINOZOIC
PLEISTOCENE AND PLIOCENE
Fluviatile sands clays and gravels overlying Lower Kainozoic marine beds in the south
Shafts or other excavations
Ag Silver
Pb Lead
Cu Copper
Au Gold
Fe Iron
Mn Manganese
Ba Barytes
Mineral occurrences but no excavations
Upper Ordovician Graptolites
Specimens
Scale — 0 1 2 miles.

form some of the highest points of the surrounding highlands.

The Mount Useful Basalt is only eight miles in a straight line to the west of the outcrop here described, and yet it is 3300 feet higher. It apparently marks the line of an old valley parallel with the present Macallister, and one question that at once suggests itself is to account for this great difference in altitude. The two alternatives which seem to be most worthy of consideration are, first, that the two basalts represent flows of totally distinct periods in Kainozoic times, and, second, that if of the same age, there has been most extensive differential movement parallel with this line in late Kainozoic times; which view is correct it is impossible to say, but on physiographic grounds I am inclined to favour at any rate a certain amount of differential movement. This will be referred to again later.

In this section the rock is seen to be a typical olivine dolerite, with a well-developed ophitic structure, violet brown titaniferous augite enclosing oligoclase. Olivine and magnetite are abundant. The section from the Hickey's Creek area is similar to that from Blanket Hills, but is of a slightly finer grain, and contains more olivine. The specific gravity of the latter is 2.81.

The District of Nowa Nowa. (Map 4.).

The region here described extends from Nowa Nowa, at the head of Lake Tyers, northward to within about four miles of Buchan, a distance of about sixteen miles. It lies to the west of the Snowy River, and includes the southern termination of the great belt of volcanic rocks known as the "Snowy River Porphyries."

As previously indicated, this region was chosen for examination mainly for two reasons:—(a) To examine certain outcrops of cherty rocks, which had been briefly referred to by Dunn (24) as "Heathcotian," and (b) to study some of the features of the Lower Devonian volcanic rocks.

The late Dr. A. W. Howitt (3 and 5) described the latter series as consisting of accumulations of acid lavas and associated pyroclastic deposits, built up round a line of ancient volcanoes occurring along a meridianal fissure. Certain quartz porphyry occurrences were regarded as probably representing the stumps of some of these old volcanoes.

Since Howitt's contribution, about forty years ago, giving a general description of this interesting and important belt of rocks, there have been no important additions to our knowledge of the region.

Later field work by Murray (25), Ferguson (26), and O. A. L. Whitelaw (27), has added a little to the details concerning the distribution and boundaries in a few localities, but no further petrological work has been done, nor had any chemical analysis ever been made of rocks from the "Snowy River Porphyries."

Professor E. W. Skeats (28), in his paper on the Volcanic Rocks of Victoria, gives a summary of Howitt's description of the "Snowy River Porphyries," dealing with their distribution, geological relations and petrological character. Briefly, they form a north and south belt up to about thirty miles in width, and extending southwards for sixty miles from near the head waters of the Murray, where the highest points rise to over 6000 feet, to the head of Lake Tyers, where they pass under fluviatile and marine Kainozoic deposits at less than thirty feet above sea level. Some doubt has been expressed as to the exact age of these rocks. It has been shown clearly that they are pre-Middle Devonian, but there is some uncertainty as to the lowest limits of the series. Mahony and Griffith Taylor (29), in dealing with the geology of the Federal Territory, compare certain quartz-porphyries of that region with the "Snowy River Series," but they claim that they represent in the Federal area, an Upper Silurian volcanic activity, which continued into the Lower Devonian. In Victoria, the beginning of this important volcanic outburst cannot yet be fixed so certainly, as Upper Ordovician graptolites are the only definite fossils obtained from the older sediments, on which the volcanoes rest unconformably.

Howitt's petrological examination of this rock was of a preliminary nature, and he describes them as quartz-porphyries (in which orthoclase prevails over plagioclase, a point to be referred to again later), felstones (acid lavas), ash and agglomerates.

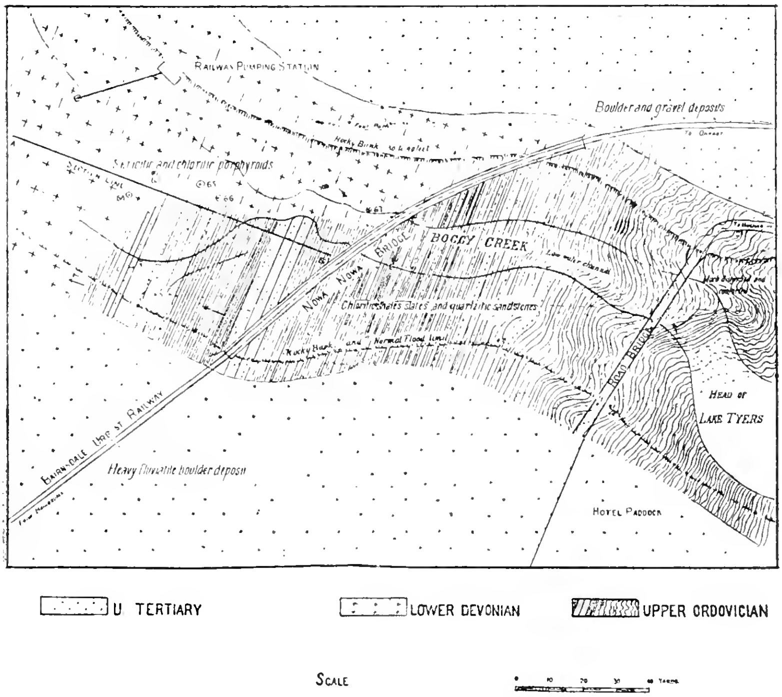
General Surface Features.—The physiography of the area under consideration will be discussed separately under the section devoted to that purpose. It will only be necessary here to mention a few salient points.

The southern portion is part of a low coastal plain of soft rocks, rising, as a rule, not more than several hundred feet above sea level. The uppermost beds consist of fluviatile grits, sands, gravels and boulder deposits, which, in the south, overlie marine Kainozoic limestones and marls, but further north than about twelve miles from the coast, they rest directly on the older rocks.

The rest of the region forms a low portion of the Victorian Highlands, most of which is below 1000 feet in altitude, and its southern border is less sharply marked off from the coastal plain than usual. Hard rocks of a varied nature have controlled largely the main irregularities of the present surface, and the principal feature is the Tara Range, which runs obliquely across the area in a N.N.E. direction. Starting towards the S.W. corner of the map, at Mount Nowa Nowa (about 1100 feet), the range continues as a rocky forest clad ridge to the N.N.E., rising in Mt. Tara to nearly 2000 feet. The rocks composing it consist of quartz porphyrite and Upper Ordovician slates and sandstones.

The most important streams are Boggy Creek and its tributary, Yellow Water Holes Creek. The former enters the head of Lake Tyers at the township of Nowa Nowa, after passing for several miles through a rocky gorge entrenched in the Porphyry Series, and exposing some of the best sections to be seen in this area. A few of the gullies on either slope of the Tara Range also provide some good exposures, but most of the area is covered with the scrub and forest, and the relationship and boundaries of the rock formations are rather difficult to follow. The task of mapping several portions was further hampered by the want of maps of any kind. The sketch

Map 5



map therefore accompanying this paper is in many places only a very rough approximation. Most attention was given to the lower portion of the Boggy Creek, and the slopes and gullies of the Tara Range.

General Geology.

The following formations are included within the area, and will be dealt with in turn:—

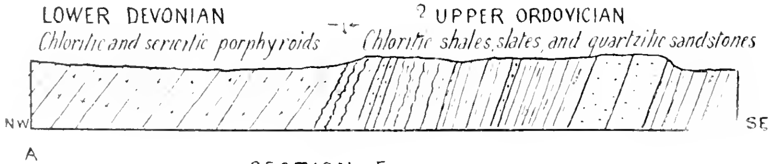
1. Upper Ordovician, consisting chiefly of highly inclined quartzitic sandstones and slates, the latter chertified in parts.
2. "Snowy River Porphyry Series"—probably Lower Devonian in age, and consisting of volcanic rocks, both effusive and pyroclastic, ranging from andesites to acid lavas.
3. Middle Devonian, comprising crystalline limestone and calcareous shales.
4. Kainozoic, ranging from Lower Kainozoic to Pleistocene.

Observations were confined mainly to the first two series.

Upper Ordovician.—This Series consists chiefly of alternating thin beds of quartzitic sandstones, mudstone, shale, phyllite and some cherty slate. There is a marked absence of the black graptolite slates, which are so characteristic a feature of the Ordovician rocks in the Wood's Point and Wellington districts.

Fossils are rare, and frequently imperfectly preserved, but all the recognisable forms have been Upper Ordovician graptolites.

The first record is due to O. A. L. Whitelaw, who obtained graptolites in a road cutting at 5 miles 50 chains from Nowa Nowa, in the Buchan Road. These were examined by the late Dr. T. S. Hall (30), and the forms identified are tabulated in the list given elsewhere. (Table 1.) Three additional occurrences found by myself are marked on the map.



SECTION E

BOGGY CREEK NOWA NOWA

Scale, 1" = 22

Five separate areas have been observed within the region here discussed, where rocks regarded as Ordovician have been observed.

Three of these are quite small inliers, two occurring in the bed of Boggy Creek (Secs. C. and E.), and the third in Ironstone Creek (Sec. D.) The relationship to the "Snowy River Porphyry Series" can be studied at all these sections, but its best seen at Section E, Nowa Nowa railway bridge. (See Maps 4 and 5, and Section E.)

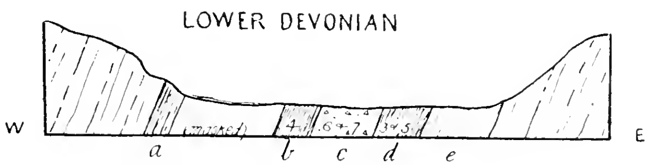
Though the strike and dip of the two series are similar in direction, the junction is seen to be unconformable.

No fossils have been obtained from any of these inliers, but the outcrops at both sections, E and D, appear to be on an extension of the strike of a larger belt to the north, where graptolites have been obtained, and the rocks are lithogically similar. All that can be said, therefore, with regard to the age of the succeeding igneous series is that it is post Upper Ordovician.

The two remaining occurrences are of larger extent, and their position will be seen by reference to Map 5. One occurs as a narrow strip about a mile in width, and nine miles long, with a general bearing a few degrees east of north. It is almost surrounded by the "Snowy River Porphyries." Its southern continuation is masked by the Upper Kainozoic sands and gravels.

These deposits also border it for about two miles along the north-western boundary.

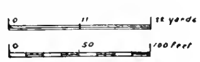
About two-thirds of the length of the belt coincides with the crest of the Tara Range, but at the northern end it lies a little to the west of the watershed.



SECTION A. BOGGY CREEK.

a. Light green chloritic shale. b. Purple shale with sericitic markings.
c. Porphyry breccia. d. Chocolate shale similar to b.
e. Light coloured sheared felsite

Horizontal Scale
Vertical



6.

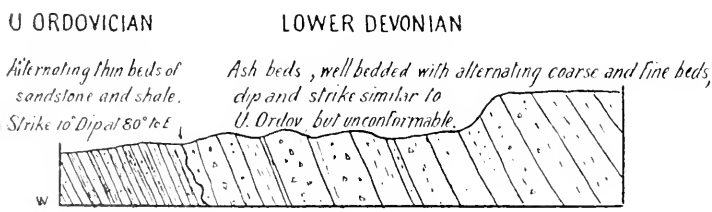
BOGGY CREEK REGION

Mount Tara Goldfield.—It is in the northern half of this Ordovician area, extending over a distance of about four miles, that the now abandoned Tara goldfield is situated (24 and 25). Numerous old prospecting shafts and open trenches occur at intervals throughout the field, but most work has been done at the northern end, in the vicinity of Lady Torr Creek, where there are a number of adits and shafts.

All the accessible adits were examined, and roughly sectioned. These observations, together with those above ground, show clearly that the rocks are very much disturbed, faulted and sheared. The line of crushing and shearing lies between N. and S. and N.N.E., and coincides roughly with that of the old mines. Though some quartz occurs, it does not appear to be in the form of a defined quartz reef, and the lode formation seems to be of the type of a fracture zone of crushed rock with some quartz and gossany material.

The strike of the rocks is generally N. to N.E., but at the northern end of the field there is much variation, north-westerly and even westerly strikes being observed close to the normal direction. This is well shown in some of the adits, where numerous faults with a generally northerly trend are revealed. Most mining appears to have been done at the "Orbost Tunnel" (Au. No. 9 on Map 4), where there are two adits and some stoping has been done along a fault line, striking 10 degrees east of north and dipping W.N.W. at about 65 degrees.

The auriferous occurrences are in general confined to the Ordovician belt, but gold has also been obtained in the porphyry, about half a mile to the north of the termination of the Ordovician. This was at the "Tara Crown," (Au. No. 2 on Map 4), where it was associated with galena. This is probably a continuation of the fracture zone, which intersects the Ordovician.



SECTION C. BOGGY CREEK

Scale

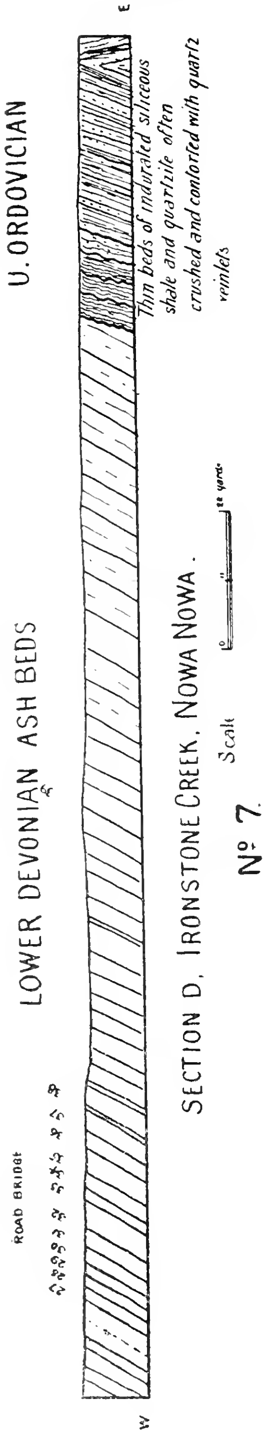
The rocks throughout the gold field, in addition to their sheared features, are frequently somewhat cherty, and on the whole are light-coloured, varying from whitish to creamish, with some superficial ironstaining along the joints and bedding planes. This light colour may be due to extensive bleaching within the zone of oxidation, for occasional loose fragments of black chert are to be found, and there is one occurrence of black chert in situ in the bed of Lady Torr Creek.

Special attention was given to the region of the old gold mines, because it was here that Mr. E. J. Dunn described the occurrence of "Heathcotian" (24), as well as Ordovician. Mr. Dunn observes that "the Tara Range is remarkable that within a mile of the Micawber lease there are three distinct series of rocks carrying auriferous vein-stones."

The three series referred to are Heathcotian, Ordovician and Lower Devonian, and the separation of the first two series appears to be based on lithological differences only, particularly the supposed significance of cherts and jasperoid rocks as a distinctive characteristic of Heathcotian; but here again, as in the Wellington district and elsewhere, this feature loses its significance, for at locality 6, north of Lady Torr's Creek, the author found Upper Ordovician graptolites in light coloured cherty rocks, and in general these rocks are so intimately associated with the more normal sediments, which also yield Upper Ordovician graptolites (locality 18), that there is no valid reason for separating them.

Turquoise.—A little turquoise was found in an old adit in the basin of Lady Torr's Creek. It occurs chiefly along the joints, irregularly distributed in a light-colored felspathic sandstone, and though of interest as another example of its wide distribution in the Ordovician, the specimens obtained did not afford much promise from a commercial point of view.

Gossany Ironstone.—Towards the northern end of the area under consideration (Fe 6 on map), there is an ironstone outcrop, consisting chiefly of limonite. It is roughly elliptical in shape, measuring about 3 chains in a north and south direction, and $1\frac{1}{2}$ to 2 chains across. Much of the limonite is hard and massive, but some contains quartz, and broken up sedimentary rock. The limits are rather indefinite, the deposit passing out into ferruginous shale much crushed and jointed. The strike of the strata is about N.N.E., and the dip appears to be easterly at a high angle. Another similar outcrop occurs about 30 chains to the S.S.W., on the fall to


E
U. ORDOVICIAN
Thin beds of indurated siliceous shale and quartzite often crushed and contorted with quartz veinlets
LOWER DEVONIAN ASH BEDS
SECTION D, IRONSTONE CREEK, NOWA NOWA.
Scale
No. 7.
ROAD BRIDGE
W

Lady Torr Creek. These occurrences are distinct from the iron deposits in the porphyry, to be referred to later, the latter consisting largely of hematite, while the former appears to be the type of gossany cappings, which may develop into sulphides at a depth. No work, however, has been done with a view to testing these deposits.

Another Ordovician area still remains to be referred to. It forms part of a large region which extends to the Snowy River, and beyond into Croajingolong. Along its western boundary it is in contact with the Snowy River Porphyries. The line of junction has not been accurately traced, but it bears in a general N.N.E. direction. My own explorations here have been very limited, and were confined principally to the vicinity of the Orbost bridle track, and to a rapid reconnaisance along the now disused track to Bete Bolong, on the Snowy River. Some obscure graptolites were found close to the western boundary, with the porphyry, and are probably Upper Ordovician. The general strike as far as observed lies between N. and N.E., and it is worthy of note that this direction is characteristic of nearly all the features in this region as a whole. It is not confined merely to the strike of the strata. The belts of Ordovician, of porphyry and Middle Devonian limestone, also the longer axes of many of the granite batholiths, the major faults, and the trend of the various ore deposits, all conform approximately in this direction. It is in contrast to a north-westerly trend, which is a marked feature over a wide area to the west, and it would appear to be a continuation of the important trend lines of this direction so well developed in New South Wales.

The Snowy River Porphyry Series.—The distribution of the rocks of the series within the area here considered is shown on the map in which the characteristic N. and S. to N.N.E. trend is well shown.

Porphyritic rocks of an acid type and general pinkish to brown colour prevail on the rocky ridges, the highest point in the region culminating in Mt. Tara, about 1930 feet in height.

These rocks being of a relatively hard and resistant nature, naturally form exposures, while large intervening areas are so masked with soil that little idea can be obtained as to the nature of the underlying rock. The spoil heaps, however, of some of the now abandoned mining shafts and other excavations frequently suggest some types, showing considerable variation from the acid porphyries, and allied rocks of the ridges, and the sections in Boggy

Creek reveal the existence of bands of altered andesitic and trachytic rocks.

The fragmental character of much of the rock is frequently apparent macroscopically, and thin sections show clearly that much of the finer material too, though often much altered and silicified, is of a pyroclastic origin.

An alternation of coarse and finer-grained material, with slight indication of bedding, appears to be the general rule, definitely stratified beds being rare. Howitt (3) observes that he had only noted at one place, near Buchan, a section which suggested aqueous assortment and deposition, which he regarded as of limited extent and purely local. Though this appears to be true in the main, in the area under consideration, the outcrops in the southern extremity afford an exception, for at Section A, Boggy Creek, and Section D, Ironstone Creek, particularly, the character and regularity of the bedding are such as to strongly suggest aqueous deposition. In this region also two other exceptional features are worthy of note: the beds are highly inclined, and intensely sheared, the latter agency having converted the rocks into typical porphyroids. These are best developed at Section E, Nowa Nowa railway bridge. The schistose character is marked along the Boggy Creek Gorge for nearly a mile above the railway bridge, but gradually disappears beyond this. The direction of schistosity corresponds with that of the strike of the different beds, being in a general N. to N.N.E. direction. As the course of the stream bed is here about N.W., it is a favourable one for exposing a good line of Section. For general and petrological description, it wil be convenient to group the rocks as follow:—

(a) Porphyroids.
(b) Stratified ash beds.
(c) Trachytic and andesitic rocks.
(d) Acid porphyritic and pyroclastic rocks.
(e) Ceratophyres.
(f) Granitic rocks.

The Porphyroids.—These rocks form a rather striking group, for their schistose structure, and often also a sheen or lustre due the development of sericite give them a distinct lithological character. Their junction with the underlying sediments, presumably Upper Ordovician in age (Section E, Boggy Creek), is sharp and unconformable. They are again exposed in the bed of Ironstone Creek (18-22), and still further to the N.E. towards the head of one of the branches of Bill's Creek (below No. 68).

In general these rocks are usually light in colour, varying from light cream to pale green. Sometimes their fragmental character can be recognised macroscopically. In Section A, No. 6 specimen represents a coarse crushed porphyry breccia, with red jasper shale and chloritic inclusions. The mechanical stresses have developed a considerable amount of sericite and thin sections show in addition secondary silicification. The red jasper has the appearance of an altered igneous rock, possibly a diabase or andesite; traces of felspar can be recognised, and hematite is disseminated through it. Fragments of fine grained acid igneous rocks are also present.

On the other hand, many of the rocks of this group have a very fine texture, with their original character so altered that even thin sections may not give any satisfactory evidence concerning their primary nature, but, on the whole, the microscopic examination clearly points to the fact that they are dynamically altered acid porphyrites and ash beds.

Specimen 1, Boggy Creek, is a hard schistose rock, which in the thin section, shows a distinctly fragmental character. There is a fine micro-crystalline base of quartz and felspar, in part sericitic, and set with irregular fragments of plagioclase and quartz, the former predominating. The felspar is probably an oligoclase-albite. Vivid green chlorite is abundant as well as sericite.

No. 2 is a light grey porphyroid, the thin section showing abundant sericite and no chlorite. Small fragments of plagioclase felspar are present.

No. 18, Ironstone Creek, is a sericitic rock of similar type, with recognisable granular quartz, but all trace of the felspar has been obliterated.

No. 19, Ironstone Creek, is a coarse-grained sericitic rock, with a definite schistose structure. Occasional plagioclase fragments are recognisable, and some chlorite is present. Among the inclusions one fragment may represent an altered andesite. The result of intense stress is well shown.

A belt of these porphyroids, 10-12 feet wide, in the bed of Boggy Creek (No. 63, Map 5), is highly pyritic, and micaceous hematite is widely distributed, frequently sparsely disseminated and associated with red jasper and ordinary quartz, but occasionally moderate outcrops of fairly pure hematite can be observed. More often, however, the ore is highly siliceous and lenticular in occurrence. The iron ores, however, are not restricted to the porphyroids, but the micaceous variety appears to be the characteristic form occurring in these rocks, and the stresses to which they have been subjected may have been favourable to the production of the micaceous form of the ferric oxide.

One feature worthy of some reference, and well shown at Section E, is the fact that the porphyroids appear to have been more affected by dynamical stresses than the underlying older sediments, consisting of chloritic shales, slates and quartzitic sandstones. They therefore frequently approach typical schists in character, while the adjoining older beds still preserve the appearance of normal sediments. It is probable, however, that the two series may have been subjected simultaneously to stresses of the same order of magnitude, but the nature of the mineral composition of the porphyries and ash beds from which the porphyroids have been derived made them more susceptible to the development of new structures and mineralogical rearrangement.

Stratified Ash Beds.—These beds are best studied at Section A and C, Boggy Creek, and at Section D, Ironstone Creek. The stratification is regular, with an alternation of coarse and fine material, the dip being at a high angle, westerly in sections A and D, and easterly at C. It is well known that a sub-aerial deposition of volcanic ash may result in remarkably regular deposition, and in the absence therefore of definitely aqueous sediments interbedded with the ash beds or of the association of fossils in sedimentary material with the pyroclastic, it may not be possible to decide whether the beds in question are really sub-aqueous or not. The fine, purple shales, beds b and d, Section A, however, resemble very closely true sub-aqueous sediments, and may, in fact, be such. No. 16, Section C. may be taken as one typical example of the normal bedded ash beds, though the degree of coarseness naturally varies from bed to bed. This example is a light greenish grey granular rock. A thin section shows well the fragmental structure, with abundant chlorite, angular quartz, and some triclinic felspar and magnetite set in a micro-crystalline base of quartz and felspar, with some secondary silicification.

At Section D the beds are exposed more or less continuously for about 8 chains, and sometimes show a slight amount of schistosity. A good exposure is to be seen under the road bridge. The colour is in general grey, but darker and lighter bands with slight variations in texture bring out the thin regular character of the bedding. Numerous thin sections (27-39) show a general similarity mineralogically. No. 28 is a finely granular grey rock, with a little felspar recognisable macroscopically. In the thin section the base is seen to be slightly schistose, and micro-crystalline, consisting of felspar and quartz, and showing some secondary silicification. It is set with angular fragments of triclinic felspar, showing fine repeated twinning after the albite type, and occasionally carlsbad twinning also. Extinction measurements on several of the most suitable sections indicate that the felspar is probably oligoclase-albite. A little sericite and chlorite are also present. No. 38 is somewhat coarser in grain and of a light green colour. The fragmental character and slightly schistose structure are revealed in the thin section; angular quartz fragments are abundant, also altered felspar, and probably some scapolite. Dark, green chlorite and calcite are present as alteration products, and some fine-grained fragments probably represent altered shale.

One feature worthy of mention in connection with the microscopic examination of the above rocks is that all the identifiable felspar fragments noted are triclinic.

Trachytic and Andesitic Rocks. — In contrast to the light coloured siliceous rocks just described, another group of darker and more basic types is met with in Boggy Creek (Specimens 9-14), and so far they have not been traced or recognised beyond the restricted area, in the region here examined. They occur in definite bands, and appear to represent both effusive and pyroclastic beds. Most of the rocks of this type are very much altered, and the original ferro-magnesian minerals are almost invariably altered to chlorite.

No. 11 is a fairly typical example of the andesitic type. It is a dark rock, with pink felspar phenocrysts.

Thin sections under the microscope show phenocrysts of triclinic felspar, slightly cloudy through decomposition, of stumpy habit and with broad twin lamellae. No very satisfactory extinction measurements were obtained, but it may be oligoclase. The ferro-magnesian mineral was probably augite, but it is completely decomposed to chlorite. Magnetite is common. The base is cloudy and altered, but small felspar laths are abundant in it. The rock is regarded as an altered augite-andesite. No. 9 is more altered, showing some serpentinization, and much chlorite. The felspars are abundant and similar in habit to 11, but are kaolinized and carbonated.

No. 12 is a dark, dense rock, slightly porphyritic, with patches of red jasper. The thin section shows a distinct trachytic structure, with abundant felspar laths in a brownish devitrified base.

The largest felspar phenocrysts are inclined to be of rather stout habit, showing somewhat broad twin lamellae, and generally low extinctions, suggesting oligoclase.

The numerous felspar laths, which bulk most largely in the slide, and show simple twinning, are probably sanidine, as also are a number of definitely prismatic forms of intermediate size. Magnetite is abundant, but almost all trace of the original ferro-magnesian mineral has disappeared. Veins and patches of secondary quartz and chlorite are present, and one portion of the slide has been almost completely silicified, showing the quartz both as a mosaic and microcrystalline form stained by patches of hematite and some chlorite.

The rock appears to represent an interesting type of altered trachyte or trachytic andesite.

No. 14 is a dark grey, finely porphyritic rock macroscopically, but the thin section shows a distinct fragmental structure, with abundant angular fragments of triclinic felspar (probably an albite of the type Ab_{19} An_1). Smaller felspar laths are present, some of which are triclinic, with low extinctions, and, maybe, oligoclase, also magnetite and fragments of altered rocks similar to 12; much chloritized. The base is finely granular in part, due to secondary silicification. There are no recognisable original ferro-magnesian minerals, but chlorite is abundant. The rock probably represents an altered andesitic ash.

Acid Porphyritic and Pyroclastic Rocks.—Rocks of this type are very abundant, and show considerable variety of colour and texture. In general a prevailing red to brown colour is most common, but various shades of green to grey are also found.

Flow structure is not common, and was only noted in one place, namely, in the ridge between Ti-Tree Creek and Yellow Water Holes Creek, and W.N.W. from Beecher's.

Quartz and felspar either as fragments or phenocrysts are usually apparent macroscopically, and in thin sections the rocks of this division can generally be readily separated into two groups—

(1) Those definitely fragmental, representing altered pyroclastic material.

(2) Those of the more normal quartz-porphyrite type, probably partly hypabassal, having solidified in the fissures, or vents, through which the more superficial material reached the surface.

Both these types are well represented along the Tara Range.

(i.) *Fragmental Type.*—Sections of this type show all the larger minerals and inclusions as broken and angular fragments, with no embayment. The base is siliceous and finely granular, and among the larger fragments felspar is often more abundant than quartz, and the triclinic form distinctly predominates, orthoclase being rare.

The secondary minerals most abundant are chlorite, and occasionally calcite.

(ii.) *Acid Porphyrites (Non-Fragmental).*—The rocks of this type have perhaps a higher silica percentage than normal porphyrite, and this may in part be due to a certain amount of secondary silicification and alteration.

The fine grained base of the rock is generally affected to some extent in this way. All the recognisable felspars, however, are dominantly triclinic, orthoclase being more or less rare.

No. 100 is a medium grained porphyritic rock of a red brown colour.

In the thin section the phenocrysts have rather irregular outline, the quartz is partly rounded, and occasionally embayed. The felspars are more abundant than quartz, and occasionally have a regular prismatic outline, but more often are broken and irregular. Twinning after the albite law prevails, but occasional pericline and carlsbad types are represented. The twin lamellae vary from moderately broad to fine bands. Different kinds of felspars appear therefore to be represented. Only a few were satisfactory for determination by extinction angle. These gave readings up to 20 degrees, and are probably therefore andesine.

The optical features of several examples suggest anorthoclase, and the chemical analysis further points to some potash felspar, which, however, has not been definitely recognised microscopically. Magnetite is only moderately abundant. The base is micro- to crypto-crystalline, with some evidence of recrystallisation and silicification. Minute laths and fragments of felspars and quartz are scattered through it.

Chlorite is sparsely distributed through the rock, and calcite is present in moderate amount.

This rock is regarded as a quartz porphyrite. No. 105 is a greenish porphyritic rock, but the chemical analysis corresponds closely with that of the previous example.

The thin section is very similar. Quartz phenocrysts are a little more abundant, and some are beautifully embayed. The felspars show a similar range and variety. One example has very minute pericline twinning, and may be anorthoclase.

Iron oxides are a little more plentiful; some occur as very minute grains abundantly scattered through the rock. Corroded xenoliths of both fine grained igneous and altered sedimentary rocks are moderately numerous. There is an occasional flake of muscovite, and little chlorite but no calcite was observed.

No. 93 may be portion of an agglomerate. It contains numerous xenoliths, apparently all of igneous origin. One is an altered andesite, the others are red, fine grained felsitic rocks, stained with hematite, and showing small, partly kaolinised felspar phenocrysts. The rest of the rock is generally similar to the previous examples. Some of the quartz is rounded, but only slightly embayed.

No. 91 is a specimen from the Dominion copper mine, now abandoned. It is similar in grain, but lighter in colour than the other examples described, but on exposure suffers a superficial red discolouration, which appears to be due to the presence of some carbonate of iron. Otherwise the minerals present are similar. A little copper pyrites is present in the dump, but as the shaft is full of water, nothing could be seen as to the occurrence of the copper.

Quartz-Ceratophyre.—No. 68.—This rock is of medium grain, porphyritic, but inclined to be granular in hand specimens, and has a general grey colour. The analysis show a silica percentage of 72.41, very similar to that of the acid rocks generally of this district, but in the alkalies there is a marked difference in that soda is 6.86 and potash only 0.13.

It is very closely comparable with certain rocks, described from Navigation Creek, Noyang, by Howitt (32), under the names of quartz-mica-porphyrite and quartz-porphyrite.

Reference to the table with analysis will show the close resemblance.

Professor Skeats, in reviewing the volcanic rocks of Victoria (28, p. 187), quotes Howitt's analyses and gives some additional remarks on these rocks, describing them as quartz-ceratophyres. Referring to one example, he says, "This rock shows a microcrystalline granular ground mass of quartz and felspar, with minute microliths of chlorite, replacing probably amphibole. The porphyritic constituents are as follows:—

Oligoclase of an acid variety, showing both albite and carlsbad twinning. Quartz in corroded and fractured crystals and chlorite pseudomorphs after magnesia-iron-mica."

The above description also concisely describes the features of No. 68. The occurrence of this rock is shown in Map 4, near the head of one of the branches of Ironstone Creek. The outcrop, however, is very limited, being partly surrounded by late Kainozoic sands and gravels.

The relationship to the igneous rocks of the district is not shown, but it is almost certainly later than the earliest members of the Snowy River Series, which show here various stages of shearing with the development of porphyroids. Some of these outcrop in the stream bed a short distance below the ceratophyre.

From the chemical analysis of No. 68, applying the American Classification, it is interesting to note that it falls into the persodic Subrang, noyangose, of liparase, the per-alkalic Rang (1) of britannare, the quardofelic Order (4) of persalane. Class 1.

ANALYSIS AND MOLECULAR RATIOS AND CLASSIFICATION.

SiO_2	72.41	1.207	Quartz	29.28
Al_2O_3	14.38	0.141	Orthoclase	0.55
Fe_2O_3	2.94	0.018	Albite	58.16
FeO	0.85	0.012	Anorthite	3.33
MgO	1.18	0.029	Corundum	2.84
CaO	0.87	0.015	Hypersthene	2.90
Na_2O	6.86	0.110	Magnetite	2.32
K_2O	0.13	-	Ilmenite	0.45
H_2O+	0.67	-	Hematite	1.28
H_2O-	0.04			
CO_2	-		Class	1
TiO_2	0.26	0.003	Order	4
P_2O_5	0.17	0.001	Rang	1
MnO	0.09	0.001	Sub rang	5
Total	100.85			
S.G.	2.63			

Magmatic Name, Noyangose.

Granite Rocks.—Only one small occurrence of granite has been noted in the area included in the map. It is limited to an exposure of a few chains extent along the bed of one of the branches of the Tara Creek, No. 98. On the west it is in contact with the fragmental igneous rocks of the Snowy River Series. No evidence of contact alteration of these rocks was noted, nor have any dykes or offshoots of granitic rocks into them been observed. It is probable, therefore, that the granite is the older rock. A much more extensive outcrop of granite closely similar macroscopically, and in thin sections also, occurs a few miles to the east of the Tambo River, and the Bairnsdale-Orbost railway line intersects the southern end of the mass, showing some good sections in one of the cuttings a few miles east of Bruthen. The rock is of medium grain and pink colour, closely resembling the better known Gabo Island granite, with which it is most probably to be correlated genetically. At the locality east of Bruthen, the granite intrudes sedimentary rocks, presumably of Upper Ordovician age.

There is, therefore, no opportunity to study the relationship to the volcanic rocks of the Snowy River Series.

Another occurrence lies to the east of the Tara Range in the vicinity of the now deserted district of Bete Bolong. The granite here takes the form of two elongate elliptical masses more or less parallel, with their longer axes striking north easterly across the Snowy River. The surrounding rocks are entirely sedimentary, again presumably Upper Ordovician. This area was only very hurriedly visited, at one place on the western margin. Two types were noted, one a fine grained aplitic variety, and the other a distinctly hornblendic form without the prevailing pink colour of the types previously mentioned. Distinct contact alteration is shown in the sediments in the vicinity, characteristic hornfels being common. As the area examined at Bete Bolong was very limited, it is impossible to say whether or not the position seen is typical of the whole of the area.

Thin sections of the granite from all the above localities were examined.

No. 98, Tara Range, and that from near Bruthen, most nearly resemble each other, but hornblende is most abundant in the Bete Bolong example.

They all agree in having at least three types of felspar—orthoclase and two triclinic forms; much of the felspar is partly kaolinised, and, therefore, unsuitable for determining accurately the relative proportions, but approximately the monoclinic and triclinic forms appear to be about equal in amount. One triclinic form is well zoned with moderately broad twinning, while a less common type has exceptionally fine twinning, often of the pericline type, and with undulose extinction, indicating probably anorthoclase. The ferro-magnesian mineral is sparsely represented in No. 98, and in the Bruthen type. It is partly chloritized, but in the former it is green hornblende, and in the latter it appears to be a greenish brown biotite. No analyses have been made of these rocks, but it is probable that they would correspond fairly closely with that of Gabo Island, falling therefore into the group of Victorian alkali granites in contrast to the more calcic type of the granodiorites. An analysis of the Gabo Island granite is included in the table for general comparison with those of the quartz-porphyrites of the Tara Range, and the similarity chemically is very noteworthy.

With regard to the Snowy River Porphyries generally, much more field work combined with chemical and petrological research is necessary before any satisfactory conclusions and generalisations can be made concerning many interesting petrological problems in this area. It is a region which offers splendid scope for future research, and it is perhaps remarkable, as Professor Skeats has already observed, that the late Dr. Howitt having done such valuable preliminary work in this series, never returned to it. Fortunately, the collection of his rocks and thin slices, together with his field notes, are in the possession of the University of Melbourne, and it has been of considerable help in connection with certain petrological points, to be able to compare my own slides with some of those of Howitt's from adjacent areas.

It is clear, however, that compared with the very careful detailed work, both chemical and petrological, given by Howitt to such areas as Noyang, Swift's Creek, Omeo, etc., this region received very scanty petrological attention, and most of the slides would seem to be among some of his very earliest work in this direction, and are often too thick or too much altered for very satisfactory determination.

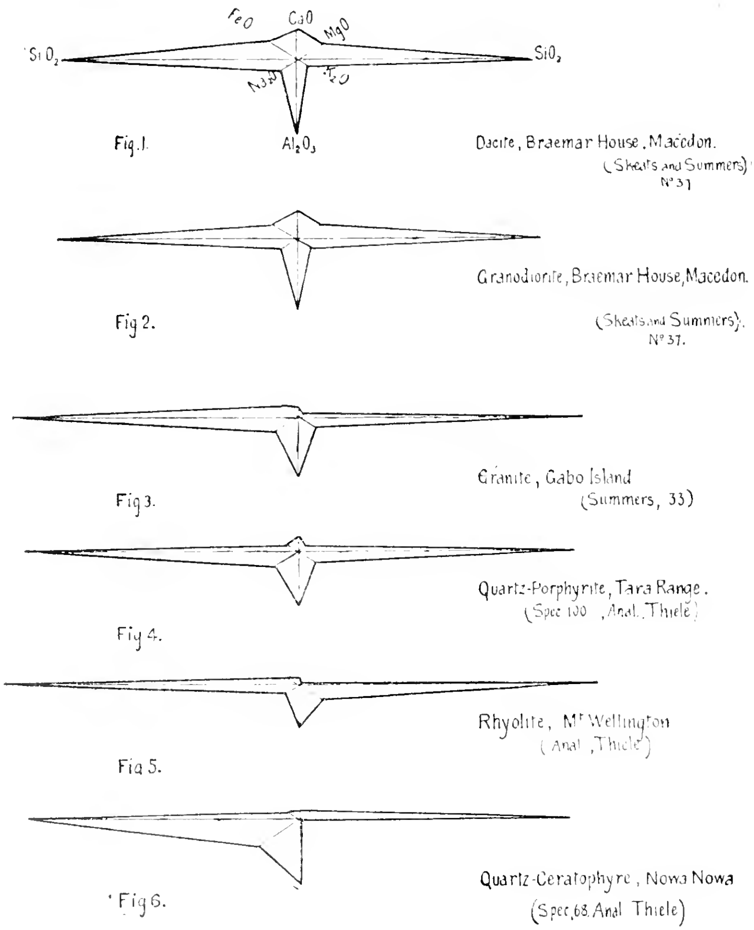
One of the most interesting points, brought out as my own petrological study of these rocks proceeded, was the predominance of triclinic felspar among the phenocrysts of the acid porphyritic rocks, especially as Howitt had emphasised the reverse, namely, that monoclinic felspars prevailed. On referring, therefore, to the particular slides, which he had mentioned in this connection, it was clear that these early determinations of his required some correction and qualification for all the identifiable phenocrysts were certainly plagioclase. On account, however, of the decomposed state of the rock, some of the felspars were too kaolinized for determination. An important point, therefore, is raised, as to whether this feature concerning the felspars applies to the porphyries of this series as a whole. If so, then it may be possible to distinguish petrologically between these and certain other porphyries, macroscopically similar, but belonging to the Upper Palaeozoic of the Wellington Series.

Here again, however, many more sections require to be examined in order to determine whether in their case, as it would seem to be, the orthoclase felspar predominates.

Chemical Characters and Petrographical Relationships.—Only a few analyses are available, and from a limited area. These are all of the acid rocks; none have yet been made of the andesitic types. Making use of the instructive variation tables given by Summers (33, Fig. 3, p. 270), it is seen that the important types of Devonian

N° 8.

BROGGER DIAGRAMS



igneous rocks, plutonic and volcanic, conform closely to the graphs with the Dacites at the least acid end, and the granites of Gabo, Woolamai, etc., at the other end.

The quartz porphyrites of the Tara Range are found to occupy a position corresponding very closely with that of the Gabo Island granite, and as has been shown petrographically, it is with a granite of this type that they appear to be associated.

It would appear, therefore, that the acid rocks of the Snowy River Series belong to an acid alkali province, in contrast to the acid sub-alkali province, to which the dacites and grano-diorites belong, but all conforming to a normal variation curve.

It would be further interesting to consider the position and relationship of the andesites, but these rocks are much altered and decomposed, and, so far, no specimens suitable for analysis have been obtained.

It is worthy of note also that porphyries and rhyolites of the Wellington Series form again a more acid series than those of the Snowy River.

	1	2	3	4	5	6	7
SiO_2	72.55	73.41	71.68	70.51	72.41	72.39	72.49
Al_2O_3	11.74	12.30	13.57	14.36	14.38	14.42	13 48
Fe_2O_3	2.54	2.09	1.28	0.33	2.94	0.56	1.16
FeO	0.46	2.13	1.94	1.95	0 85	0.30	2.09
MgO	0.68	0.14	1.37	1.08	1.18	1.85	0.49
CaO	1.85	1.08	1.88	2.98	0.87	0 85	1.31
Na_2O	3.46	3.71	2.22	3.17	6.86	5.93	3 38
K_2O	4.41	4.04	3.87	3.15	0.13	1.23	4.06
H_2O+	0.41	1.51	1.24	1.18	0.67	1.13	0.76
H_2O-	0.06	0.10	0.29	—	0.04	—	0.18
CO_2	1.80	—	0.08	nil	nil	—	tr.
TiO_2	0.175	0.16	0.33	1.20	0.26	—	0.46
P_2O_5	0.14	tr.	0.03	0.12	0.17	tr.	—
NiO	—	—	—	0.08	—	—	—
MnO	—	—	0.13	—	0.09	0.01	0.13
	100.27	100.67		100.11	100.85	98.67	99.99

1. Quartz Porphyrite, No. 100, Mt. Tara Range. —Analyst E. O. Teale.
2. Quartz Porphyrite, No. 105, Mt. Tara Range. —Analyst E. O. Teale.
3. Quartz Porphyry, Federal Territory. —Analyst A. G. Hall.
4. Quartz Porphyrite, Violet Town, Strathbogie Range. —Analyst G. Ampt.
5. Quartz Ceratophyre, No. 68, Nowa Nowa. —Analyst E. O. Teale.
6. Quartz Ceratophyre, Navigation Creek, Noyang. —Analyst A. W. Howitt.
7. Granite, Gabo Island. —Analyst J. Watson.

Economic Minerals.—The following minerals are known to occur in the rocks of this region :—

1. Gold.
2. Copper Pyrites.
3. Argentiferous Galena.
4. Iron minerals (Hematite and Limonite).
5. Manganese Minerals (Pyrolusite, etc.)
6. Barytes.

Most of the mining has been done in connection with gold. With most of the others only a few shallow excavations, with an occasional shaft have been opened up. Very little can be said with regard either to their geological occurrence or economic possibilities, for the reason that most of the shafts are inaccessible, and in other cases the opening up has been far too limited to enable any reliable opinion to be formed.

The position of these occurrences is shown on the map. Hematite would appear to be chiefly if not entirely restricted to the "Snowy River Porphyries." Two forms have been noted, a micaceous variety, widely distributed in the southern portions, and a massive hematite. The largest outcrop of this nature was at locality Fe 20, about six and a quarter miles north from Nowa Nowa.

Analyses of some of these ores are given in some of the Annual Reports of the Mines Department, some of them indicating ore of good quality, but insufficient work appears to have been done to determine even approximately the quantity of ore available. The same observation holds with regard to the manganese ores. These occur at the northern end of this region (Loc. M, Specimen 104), and are at the junction of the porphyry, with the overlying limestone series, and from the material exposed in the dump it would appear that they occur in the calcareous and ferruginous shales associated with that series.

Barytes is widely distributed in the porphyry, and is very common in the hills close to Beechers, Canni Creek, where there are a few shallow excavations. Most of it is iron-stained, but some good white material can be seen at Ba 11. (Specimens 13 and 74.) A small open cut here shows an irregular occurrence of Barite in thin veins and small masses replacing the decomposed porphyry.

Argentiferous galena occurs both in the limestone series and in the porphyry. Some prospecting work was in progress at the "Tara Crown," during the time of my visit, where there appeared to be a well-defined fissure lode traversing decomposed felsitic rocks in a N.N.E. direction.

Locality A, 19.—Yellow Water Holes Creek is the position of the long-abandoned "Good Hope Silver Mine." The shaft here penetrates calcareous fossiliferous middle Devonian shales.

Middle Devonian.

The Limestone Series.—Very little time was devoted to this series. An important area, however, composed of these rocks, occurs in the northern portion of this region, and is continuous with that in the vicinty of Buchan. The general features of these rocks have been well described by Howitt (3, 4 and 5), and the age is definitely fixed by the fossils as Middle Devonian.

Associated with the limestones are calcareous shales, and the whole series is in general gently folded, though some instances of high dip are to be noted. Howitt described these limestones as being laid down in troughs and basins in the Snowy River Porphyries, into which they have in many cases been further let down by trough faults. General erosion of the present cycle, and probably also that of an earlier period acting unequally on the limestones and surrounding porphyries has resulted partially in developing important basins, more or less conciding in position with some of those of Palaeozoic times in which the Middle Devonian limestones were laid down. Two basins of these types occur in this region. One is the wide, flat valley of the Ti Tree Creek, surrounded by ridges of porphyry and older rocks, save on the northern side, and the other is a narrower valley to the west, that of the Yellow Water Holes Creek.

It is interesting to note that small residual Devonian limestone occurrences outcrop in both these valleys partly buried beneath gravels sands and clay of late Kainozoic age. These are represented in Section 9. The trough faulting is assumed as probable from general considerations.

It is on the southern end of the large limestone area on a branch of the Tara Creek, in Mr. A. McRae's property, that the new Commonwealth Marble Quarry is situated.

Kainozoic.

These deposits are of considerable interest in that they throw some light on physiographical cycles preceding the present one. Their features will only be briefly referred to here. They are broadly divisable into three groups—

(a) A lower series of marine beds.

(b) An upper series of fluviatile beds.

(c) Basalt.

Both (a) and (b) are to be seen in some fine sections in the cutting of the new Bairnsdale-Orbost railway line.

The Marine beds so far noted consist of cream coloured sandy limestones and marls similar to the Bairnsdale Series, and probably Janjukian in age. These deposits can be traced from the coast to the head of Lake Tyers, where they are ferruginous, but further south along the lake cliffs the characteristic limestones are well developed. Several small outcrops are exposed in the railway line between Nowa Nowa and the Snowy River. But it is at the latter locality along the cliffs overlooking the river flats from the western side, that the finest sections are exposed. The railway cuttings here reveal cream coloured horizontally bedded limestones underlying heavy fluviatile gravels and beds of water-worn boulders.

The various sections have not been closely studied in order to determine whether or not the later marine beds of Kalimnan age are represented, but there are some coarsely bedded ferruginous grits, probably of shallow water marine origin, which may belong to this series. They appear to be unconformably overlaid by the later fluviatile beds.

So far as is known, all the marine beds in this region occur at less than 200 feet above sea level, and do not extend inland more than about twelve miles in a straight line from the coast. This limit approximately marks the position of the early Kainozoic coast line, and corresponds closely to the southern margin of the Highlands in this region.

Fluviatile Deposits.—These overlie the uppermost marine beds, and are therefore late Kainozoic, but as no fossils have been found in them, their age cannot be definitely fixed. They are generally regarded, however, on physiographical grounds as representing an important Pleistocene cycle of erosion. It is almost certain though, that some of these deposits are older, particularly those which occupy ancient drainage lines in the Highlands, beneath lava flows of basalt. In general, however, most of these fluviatile deposits may probably safely be regarded as Pleistocene.

They form an extensive superficial sheet of material, ranging from fine gravels and sandy clays to deposits of large water-worn boulders, the latter providing a very interesting miscellaneous collection of igneous and sedimentary rocks, among which various kinds of porphyries are abundant. They range in height from fifty to several hundred feet above the present river beds, and are found rising in the southern portion of the highlands to at least 800 feet above sea level.

They are to be correlated with a very general period of great fluviatile activity in Pleistocene times in Australia.

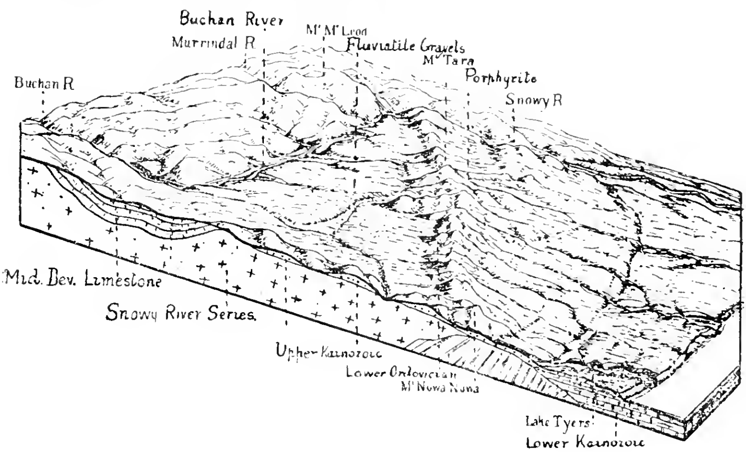
Immediately to the west of the Tara Range in the northern part of Map 4, there is an extensive basin drained partly to the south by Ti-Tree Creek, and to the north into the Buchan River, by the Tara Creek. (See Block Diagram, No. 10.) Remains of a partly-denuded sheet of Upper Kainozoic sands, grits and gravels are here preserved at altitudes rising to about 800 feet above sea level, and resting on a floor varying from Ordovician sediments to Devonian porphyry and limestone.

In general, however, they would appear to have filled in a basin corresponding in position to an ancient Devonian one, in which the Middle Devonian limestones were laid down, almost entirely burying them. Erosion of the present cycle has again partly laid bare the limestones, especially in the basin of the Tara Creek.

Basalt.—This rock has been observed only in the north-western corner of this region, in the vicinity of South Buchan, while passing along the coach road to Buchan, but its extent and character have not been observed. It is most probably to be correlated with the basalt referred to by Howitt, as occurring at Gelantipy and the Buchan River, further north, and classed by him as "Newer Volcanic."

Palaeozoic Earth History.

From the descriptive sections now concluded, dealing with two widely separated areas in Gippsland, which, however, are but very small fragments of the whole region, it will be seen that the Palaeozoic history provides a long succession of events, full of interesting structural, petrological, and other problems about which, however,



our knowledge is so fragmentary that at the best, our ideas can only be largely conjectural. It may, nevertheless, be stimulating to further research to attempt to formulate some picture of the earth history of this ancient era.

It will be seen that the same area along the Mansfield-Wellington belt, marks the site successively of marine deposition in Upper Cambrian, Upper Ordovician and Silurian times, with probable intervening periods of sub-aerial denudation. The Cambrian rocks also indicate contemporaneous volcanic action of a basic nature, the extent of which is unknown. Devonian times were ushered in with the outbreak of great igneous activity, the greatest volcanic period of Palaeozoic times in this part of Australia. Rocks of this age, however, are better developed in certain other parts of Victoria. This region was then mainly a land area, for the volcanic accumulations appear to have been almost entirely sub-aerial. Whether marine conditions supervened here as they did along the Snowy River belt is not known, for no Middle Devonian limestones have yet been recognised, but in late Devonian or early Lower Carboniferous times, a large trough, at least 100 miles long and possibly fifty miles wide was developed and occupied by a fresh water lake. The early lacustrine sedimentation which was thus initiated was accompanied in its early stage by energetic volcanic activity, both effusive and explosive, and of a highly acidic nature. Long after this rhyolitic outburst had ceased, and as deposition proceeded, there were successive outpourings of basic lavas, mostly of no great thickness, and these in turn became covered with later sediments belonging to the same period.

The succession along the Snowy River is less complete. No Cambrian, Silurian, or Lower Carboniferous sediments are known, but the volcanic accumulations of Lower Devonian times indicate very great igneous activity, which was succeeded by marine invasion in Middle Devonian into basins and troughs in the "Snowy River Porphyries."

The history recorded in these zones implies a sequence of powerful earth movements of various kinds to be discussed later. Even a casual look at the geological map of Victoria reveals a general subparallelism of the Palaeozoic formations, with a prevailing northly trend, and a little closer investigation indicates that certain belts have had a more varied history, therefore implying zones of greater unrest or instability, along which movements, also in some cases, igneous activities, have been periodically repeated. It has been shown that the Mansfield-Wellington belt has had a particularly varied history, and it contrasts strongly with the belt to the east, which is almost entirely Upper Ordovician, and which we may call the Dargo-Ovens zone. To the west, on the other hand, the rocks are chiefly Silurian, overlying Upper Ordovician. With regard to the eastern limits of this area, it is perhaps significant that it corresponds closely with the Cambrian outcrop in the Wellington district, and also the Howqua-Mansfield and Dookie localities farther north, in the vicinity of which rocks doubtfully referred to as the Heathcotian Series occur; while on the western side forming the boundary in part, between a Lower Ordovician region to the west, there is the important Mt. William-Colbinabbin line of Heathcotian rocks. These boundaries, or geological frontiers, may, therefore, represent certain critical lines in the past earth history, along which the struggle for mastery between conflicting earth forces has been repeatedly renewed and fought out.

Successive Distribution of Land and Water.

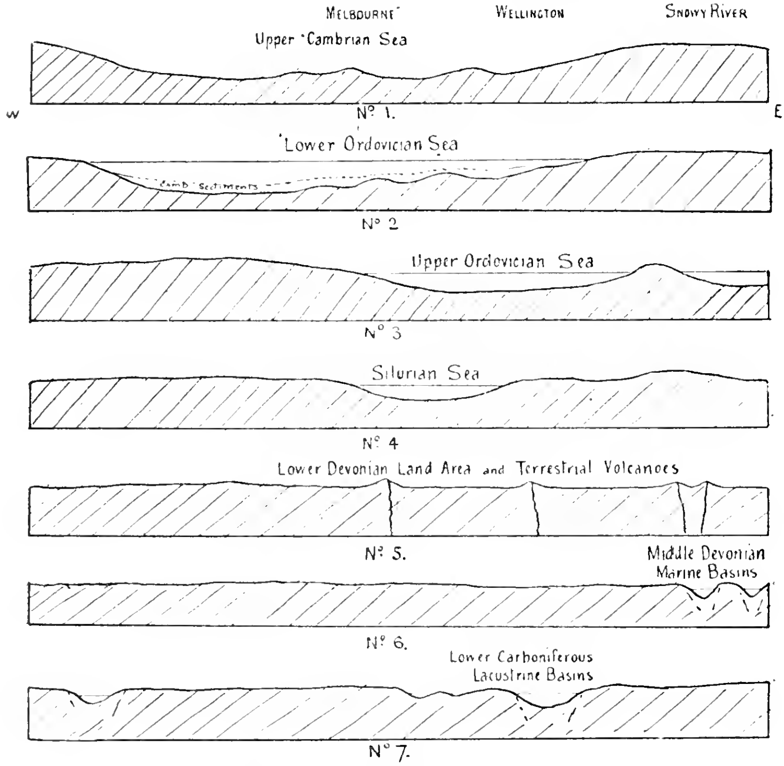
In considering the probable distribution of land and water throughout Palaeozoic times, we can only be guided by the known outcrops of the various formations, and fresh discoveries at any time are liable to modify our views, but the sub-parallel arrangement and the restriction of particular formations to certain belts or areas strongly suggest a successive alternation of land and water, which might be brought about by a long continued progressive wave-like undulation of the earth's crust.

If we consider a succession of east and west sections through Victoria during the Palaeozoic history, representing them diagrammatically to show the relative position of land and water, certain interesting features are brought out. (Diagram No. 11.)

With regard to the Cambrian times, our knowledge is far too fragmentary to enable us to form any reliable conception of the area of the sea of that period, but the pre-Cambrian rocks of Western Victoria may have formed the western limit, while on the east it may have been the belt of crystalline rocks of the Omeo zone, though there is some doubt as to whether these rocks are really Archaean or altered Ordovician.

At any rate, a probable view that seems reasonable would represent a wide Cambrian sea, occupying the greater part of the now dry land of Victoria, with ancient land masses in the east and the west (Diagram No. 11, Fig. 1).

Practically all the Cambrian rocks of Victoria so far known represent accumulations of submarine volcanic material of the nature of basic lavas and tuffs, the latter often admixed in part with fine normal sediment. The nature of the deposits, while not suggesting specially deep-water conditions, would favour the view that they accumulated over a sea floor at some distance from a shore line. The cherts and tuffs are of a uniform and fine nature, possessing none of the special features expected in those deposited under lit-



No. 11.
Diagram of Successive Palaeozoic Basins

toral conditions. The advent of Ordovician times does not appear to have been marked by any break in deposition, but the sediments, still of a fine uniform nature, became more normal, for submarine volcanic activity had come to an end. The distribution of land and water remained much the same, and the succession on the whole, therefore, is probably a conformable one, but local gaps in the record appear to occur, notably in the Wellington area, where Upper Cambrian is in contact with Upper Ordovician. Elsewhere —as at Lancefield and Heathcote—it is impossible to determine closely where Cambrian ends and Ordovician begins.

The existing geological map of Victoria shows a striking restriction of Lower Ordovician rocks to a region lying to the west of a line approximating to the meridian of Melbourne, which would suggest an important contraction of the sea at the close of Cambrian times. Later investigations, however, indicate that this is more apparent than real.

Prof. Skeats (40) has shown that a large area in the Mornington Peninsula, originally regarded as Silurian, must now be included in the Lower Ordovician.

Several inliers of Lower Ordovician rocks are now known in the heart of the Silurian region as far east as the Mansfield district, approximately ninety miles to the east of the Melbourne meridian, and as very large tracts of the mountainous country in the eastern highlands of Victoria are very imperfectly explored geologically, it is probable that other occurrences may be revealed in the future. It is unsafe, therefore, in the light of our imperfect knowledge to generalise too positively on the distribution of land and water in early Palaeozoic times. In general, however, it would appear that there was a progressive restriction of the marine basin through Lower Palaeozoic to the close of Silurian.

In the sections therefore (Diagram 11), the relative position and extent of the successive basins are merely represented tentatively, summarising our existing knowledge of the palaeogeography of this region.

In Upper Ordovician times a marked narrowing of the Palaeozoic basin appears to have taken place, for no Upper Ordovician rocks have yet been found to the west of the Melbourne meridian. The sea may have then occupied two basins partly separated by the Omeo crystalline belt. (Diagram 11, Fig. 3.)

The next event was again a considerable restriction of marine area, drawing the Silurian Sea into a central basin corresponding to the western part of the Upper Ordovician Sea. It is not clear whether complete land conditions intervened before the Silurian Sea reoccupied the site of the western portion of that of the Upper Ordovician. The evidence of uncoformability is not conclusive everywhere. (Diagram 11, Fig. 4.) The advent of Lower Devonian times was marked by the disappearance of marine conditions altogether, and the outbreak of extensive terrestrial volcanic activity, accompanied also by widespread plutonic disturbances and earth movements. The dacites, porphyrites, granodiorites, and "Snowy River Series," and possibly also the normal granites belong to this period. The sea never again transgressed in Palaeozoic times to the extent of the early marine basins. (Diagram 11, Fig. 5.) In Middle Devonian times, the last marine deposits were formed in the restricted basins or troughs in Eastern Victoria, which were depressed below sea level, and were partly filled by limestone and calcareous shales.

The region of the depression coincided closely with that occupied by the volcanic zone of the Snowy River Series (Diagram 11, Fig. 6). The conditions of late Devonian and early Carboniferous were essentially terrestrial, but were accompanied by the development of several lacustrine basins, the greatest of which was the great Mansfield-Wellington trough, and as previously indicated, the early sedimentation was accompanied by rhyolitic effusions, and, later, by basic lava flows. (Diagram 11, Fig. 7.)

Types of Earth Movements.

The general trend of all these Palaeozoic basins appears to have been northerly, and the type of crust movement which most reasonably explains the succession of basins, parallel, but laterally shifted or restricted, is the conception of a slow wave-like undulation of the earth's crust, the basin being reciprocal feature of the adjacent land mass. It is possible to picture a prolonged progressive movement of this type to proceed with or without marked compressional or tangential movement. In the first case, the beds of each successive formation would become highly folded, and in the latter only slightly so. The idea does not preclude the possibility of periods of a much augmented rate, with important fractures and displacements.

An alternative view would be to consider the formation of a succession of basins such as here described, as being due mainly to the differential movement of great blocks or earth segments along fault planes, certain areas being alternately lifted and lowered. The whole structure of the Palaeozoic rocks, however, favours the first view, but it does not exclude the possibility and even the probability of a certain amount of faulting and block movement as well, and it would seem that as the Palaeozoic era drew to a close, after the great Devonian convulsion, though the fold movement still predominated, that of the block type became more pronounced, and finally prevailed throughout Mesozoic and Kainozoic times.

If the regional distribution of calcic and alkali igneous rock is definitely related to fold and fault movement respectively as Harker has contended, then in areas where both these types may have acted either successively or simultaneously, it would be reasonable to expect complex and apparently anomalous results with regard to the associated igneous activity. Summers (33) has reviewed the relationships of igneous rocks to earth movements in Victoria, and has opened up an extremely interesting, but very debatable subject. He has, however, shown that it is impossible to apply Harker's generalisation. It is practically certain that if the various geologists who are sufficiently familiar with the local geology were to attempt to make out a picture of the Palaeozoic history with special reference to the associated earth movements, they would differ considerably in important details. One or two events, however, stand out very clearly, and it is probable that all would agree with the view that the opening of the Devonian epoch was marked by most energetic earth folding, which intensely crumpled all the already folded pre-existing formations.

As Summers pointed out, the dominant movement was of the pacific type along north and south fold lines, but was it accompanied by great volcanic and plutonic activity, as has generally been believed? It would rather appear that the igneous phase, though related with this great crustal disturbance, lagged behind somewhat, otherwise, we might reasonably expect to find a definite linear arrangement or relationship of the igneous rocks, with some of the major fold lines. This is far from the general rule, however, in fact it is only in the case of the "Snowy River Porphyries" that a meridional arrangement is apparent. All the other occurrences appear to be distributed in a very irregular manner. Further, the volcanic deposits would appear to rest unconformably on the upturned edges of the older rocks. It appears to be the exception that the ash beds are intensely folded with the older beds.

Summers (33) has also discussed the question of the Heathcotian diabases and earth movement, and favours the idea that the basic eruptions and submarine tuffs of the Heathcotian Series are more easily explained as accompanying fault action rather than fold movement. It must be admitted, however, that the evidence is very scanty and indefinite, and is open to be interpreted in either way. The area exposed is far too limited, and the structure too imperfectly known to enable any satisfactory criticism to be made.

The Granite Batholiths and their Relation to Palaeozoic Structure.

No account of Palaeozoic history would be complete without some special reference to the abundant granite masses which penetrate the Lower Palaeozoic sediments.

Petrologically, they fall into two groups—(1) the sub-alkali group of granodiorites, (2) the group of alkaline granites. Regarding their age, they are here on petrological grounds all considered as Lower Devonian, but the alkaline granites have been sometimes referred to as probably older, mainly because they have nowhere yet been noted intruding Silurian sediments. All attempts so far to correlate the occurrence and distribution of these rocks with definite structure lines have been unsatisfactory.

The various masses are very irregular, both with regard to outline and distribution. When elongate or elliptical in shape, their longer axes just as often as not, are at right angles to the fold lines of the ancient rocks. Their contacts have not been exhaustively examined, but in many of the important instances they truncate the strata they invade, and no satisfactory linear or other distribution of the various outcrops has been recognised.

Professor Gregory, in his Geography of Victoria (34), attempted to link up certain granite masses to form the roots of what he termed the Primitive Mountain Chain, having a general east-north-east trend; and a still more fragmentary line to the south, more or less parallel, he named the Bunurong Range.

The grouping of the granite areas in this way appears to have little to support it, even from a linear arrangement, and far less from any structural consideration, as T. S. Hart has already pointed out (35).

Howitt (32) long ago recognised the importance of the factor of the assimilation of sediment and other rocks by a plutonic magma, a view which has received special emphasis and elaboration more recently by Daly.

This idea has received some support with regard to Victorian granite and allied rocks, from the observations of Howitt (32), Hart (35), Skeats and Summers (27), and Junner (38).

The petrological evidence in support of the idea is still very scanty, but structurally and otherwise it seems to provide the best conception of the great development of granite batholiths and their distribution in Victoria.

Pitch Along Anticlinal Lines.

This structural feature is one of great importance in the consideration of Palaeozoic geology in Victoria. Every area that has been closely studied has emphasised the importance of its bearing on the general structure, and it frequently also demands careful consideration in connection with the development of mining operations on the gold fields. The systematic work of the Geological Survey has added much to our knowledge concerning this feature in practically all the important goldfields, but little is known with regard to it in most other regions.

There are various questions which arise when it is made a subject for careful consideration, and two of these perhaps, stand uppermost—

(1) The age or geological epoch, when it was impressed upon the Palaeozoic formation.

(2) The dominant factor or factors contributing to its development.

Very few opinions have been expressed concerning this subject.

The late Dr. T. S. Hall (39) apparently associated its development with the movements which led to the uplifting of the existing highlands and formation of the Main Divide. This would imply a very late Kainozoic age. Its direction, however, appears to be too inconsistent and variable to be associated fundamentally with a movement which was essentially that of block movement.

T.S. Hart (35) has discussed the question and suggests a number of probable causes which are worth tabulating :—

(1) The making and dying away of individual folds.

(2) Local disturbances as a fault affecting a small area.

(3) Varying intensity of folding from place to place.

(4.) Transverse folding, simultaneous or subsequent to the main folding.

(5) Settlement of an imperfectly supported area over an invading granite.

(6) Subsequent tilting or transverse warping of folded blocks.

The above factors are all clearly competent to produce the results under discussion, and when it is considered that they may all have repeatedly contributed towards this end through past geological history, it becomes a complex problem to endeavour to apply anything approaching a definite statement with regard to its age and origin.

Hart, however, would apparently restrict the main period of development to Palaeozoic times, and this is a view most consistent with general tectonic considerations. It is unsafe to lay down any hard and fast conclusions with regard to this feature generally; each area will have to be considered carefully in detail with due regard to local and general tectonic disturbances, but one cannot help being impressed with the possible favourable conditions produced by the great batholithic disturbances of Devonian times, especially if Daly's conception of magmatic stoping and associated down-warping of overlying areas be regarded, as the most favourable explanation of the mechanism of such an important petrogenic phase in earth history.

The Relation of the Dyke Rocks and Quartz Reefs to Structure and Earth Movements.

It has long been recognised in Victoria that many of the important gold-bearing reefs can be grouped along certain more or less parallel zones, with a northerly trend, and separated by other belts of non-productive reefs or marked by the absence of reefs altogether. Most of the Victorian reefs (excepting the Bendigo and Castlemaine fields) occupy definite fissures, or are associated with igneous dykes which have intruded fracture lines. The bearing of these occurrences in general is northerly, parallel with axial lines of folding.

The age of the great reef formation is generally believed to have been Devonian, and genetically associated with the granitic intrusions of that epoch.

One belt in particular, is worthy of mention, illustrating very well the features above mentioned; namely, the Walhalla-Woods Point Zone. The prevalence of dykes, frequently of a diorite type, and auriferous reefs along this zone, is in contrast to their absence in the country to the west and east. Other such instances might be mentioned. There are also non-auriferous zones, where fractures, faults or dykes are common, about which, however, little is known with regard to their age and distribution. Many of these may not be Palaeozoic, and these are therefore not included in the present discussion.

It would appear from the consideration of the above that one phase of the great Devonian tectonic and igneous disturbance found expression in the development of lines of fracture, with a definite northerly trend along certain zones, and their infilling with igneous dykes and quartz reefs. The geological study of these areas has so far not revealed anything to suggest that these fracture lines can be regarded as planes of great differential movement on either side of which important earth blocks or segments were dislocated. They would appear rather to indicate zones of tension due to crustal adjustment, accompanying the folding and batholithic intrusion of that period.

The Fracture Line of the Snowy River Porphyries.

As indicated previously, this zone is the only one where the occurrence of certain igneous rocks other than dykes of the Devonian period corresponds closely with the general direction of the Palaeozoic trend lines. This arrangement led Howitt to postulate the idea that the volcanoes of this epoch were disposed along a meridional fissure, and though the actual position of the sites of these ancient volcanic vents still remains to be located, the view certainly offers the most probable explanation of the features as a whole.

This zone would appear also to have been successively fractured at later periods. The occurrence of the iron ores appears to be associated with one of these lines. The marked shearing resulting in the production of porphyroids is another phase, and the origin of the basins in which the limestones occur, though perhaps referable mainly to warping and erosion, may possibly be associated also with some trough faulting. Howitt has also referred to certain persistent features along the eastern side of the Snowy River Porphyries, coinciding with the valley of the Snowy River, suggesting the existence of a powerful meridional fault. Other parallel faults coinciding with the Limestone Creek and Buchan River are also suggested. (3, p. 189.)

The age, however, of these fault and fracture lines, and, in fact, their exact position also, is very indefinite. Some may be post-Palaeozoic, and it is even probable that if not originating in Kainozoic times, the plateau building period that produced the existing highlands has caused renewed movement along some of these major faults.

The undulations and gentle folding of the Middle Devonian limestones show that the fold movement, though less intense than in earlier times, still continued, and the same feature is shown by the structure of the Upper Palaeozoic rocks of the Wellington region.

Summary.

The principal features to be emphasised as a result of the consideration of the areas under discussion may be briefly enumerated as follows.—

1. *Wellington District.*

(1) The general structure of the Wellington-Dolodrook region is anticlinal, passing from a broad, simple fold in the case of the uppermost rocks to complex repeated folding in the case of the underlying old rocks.

(2) The periods of folding have been renewed from time to time, possibly on four successive occasions, but the trend of all the fold lines has persisted in a tolerably constant direction, varying between north-west and north-north-west.

(3) Denudation of the existing cycle has developed to such an extent that a complex inlier is exposed, consisting of a core of Cambrian rocks enveloped successively by Upper Ordovician, Silurian and Upper Palaeozoic sediments.

(4) The Upper Palaeozoic strata are of lacustrine origin, and those of the other periods are marine. The Cambrian limestones have yielded a definite series of trilobites, and are interbedded in basic tuffs. The Upper Ordovician rocks are black slates, chertified in part, and they contain abundant typical graptolites. The Silurian rocks have so far only yielded crinoid remains.

(5) Igneous activity is represented in two and probably three, distinct periods if we consider the district as a whole, including the Upper Palaeozoic rocks as far as Mansfield. The Cambrian series contains a pre-Upper Cambrian serpentine, with chromite and corundum derived from peridotite and pyroxenite rocks, and the Upper Cambrian contains basic tuffs. Volcanic rocks of the nature of porphyrites allied to dacites occur in the King River Valley, and others, mainly of an andesitic nature, on Fullarton's Spur, in the Macallister Valley. These are probably Lower Devonian. The basal portions of the Upper Palaeozoic (Lower Carboniferous), contain thick beds of rhyolite, and acid pyroclastic deposits. Higher up in the series there is a succession of basaltic flows (melaphyres) interbedded with the sediments.

(6) Special structural features are noted along the Macallister valley, where the Upper Palaeozoic rocks, normally dipping at a low angle, are here frequently highly inclined, and an important fault line is recognised, approximating in position to that of the Macallister Valley, and bearing, therefore, in a N.N.W. direction.

2. *The District of Nowa Nowa.*

(1) The cherts and jaspers of the region have been examined with regard to age and the origin. All the cherts observed are altered slates, and are regarded as Upper Ordovician. Definite graptolites have been found in some of them. The red jaspers are often associated with micaceous hematite, and are found chiefly in the porphyroid belt of the "Snowy River Series," and are

therefore Lower Devonian. They appear to be metasomatically altered igneous rocks, varying from andesitic to more acid types. Though widespread in their distribution, each occurrence appears to be small in extent.

(2) The oldest sediments in this region are regarded as Upper Ordovician. Definite graptolites were found in four distinct localities, and there does not appear to be any valid reason, structural or lithological, to justify the separation of any of the non-fossiliferous portions from those yielding graptolites.

(3) The igneous series known as the Snowy River Porphyries, is regarded as Lower Devonian, and rests uncomformably on the Upper Ordovician sediments. The chief additions to previous knowledge concerning this extensive igneous belt are:—

(a) The recognition of porphyroids.

(b) Finely stratified ash beds.

(c) The occurrence of trachytic and andesitic rocks.

(d) The fact that the so-called quartz-porphyries are really quartz-porphyrites, triclinic felspar predominating. Two analyses of this type are given.

(e) A soda rich type is described as a quartz-ceratophyre. Both microscopically and chemically it is shown to be closely similar to certain rocks described by Howitt from Noyang, as quartz-porphyrites, and later referred to by Skeats as ceratophyres.

(f) The chemical characters and petrographical relationships of the igneous rocks are discussed, and it is shown that the porphyrites are genetically related to the alkali granites, which are characteristic of this part of Victoria.

Making use of a variation diagram to compare the various acid igneous rocks of Victoria, it is seen that the quartz-porphyrites of the Tara Range, and the alkaline granite of Gabo Island, etc., conform closely to the graphs occupying the opposite end to that of the dacites and granodiorites. It would appear, therefore, that the acid rocks of the Snowy River Series belong to an acid alkali province, in contrast to the acid sub-alkali province to which the dacites and grano-diorites belong, but conforming to a normal variation curve.

3. Under the heading of Palaeozoic Earth History, the following features are discussed :—

(1) Successive distribution of Land and Water.
(2) Types of Earth Movements.
(3) Granite Batholiths and their Relation to Palaeozoic Structure.
(4) Pitch along Anticlinal Lines.
(5) Relation of Dyke Rocks and Quartz Reefs to general structure and Earth Movements.
(6) The Fracture line of the "Snowy River Porphyries."

A succession of Palaeozoic basins of sedimentation, with a general northerly trend appears to be recognisable. These have varied in position and extent from period to period.

They have overlapped in certain instances, while in others they appear to have been laterally shifted, a land area taking the place of the basin of an earlier period, and vices versa.

The resultant formations have nevertheless a general parallel arrangement.

This succession of basins, parallel, but laterally shifted or restricted, is thought to be best explained by the conception of a slow wave-like undulation of the earth's crust, the basins being the reciprocal feature of the adjacent land mass. The basin would, therefore, be regarded as of the type of a geo-syncline. Block movement, though not excluded entirely, is regarded of minor importance during this era. The most intense folding was pre-Devonian. The great granite batholiths, though belonging to the active Devonian period of tectonic and igneous disturbances, show much irregularity of shape and distribution, and also a discordance with strike and fold lines. It is considered that their features generally are best explained by the conception of "magmatic stoping."

The consequent disturbance of surrounding and over-lying blocks of sediments may have been one of the most important agencies inducing the features of "pitch," so common throughout the Lower Palaeozoic formations. Certain zones appear to have been subjected more frequently during Palaeozoic times to tectonic and volcanic disturbance than other regions.

The Wellington-Mansfield Belt is one of these areas, the zone of the Snowy River Porphyries represents another.

The general trend of both fracture and fold lines throughout the Palaeozoic era appears to have been between north-west and northerly.

Acknowledgments.

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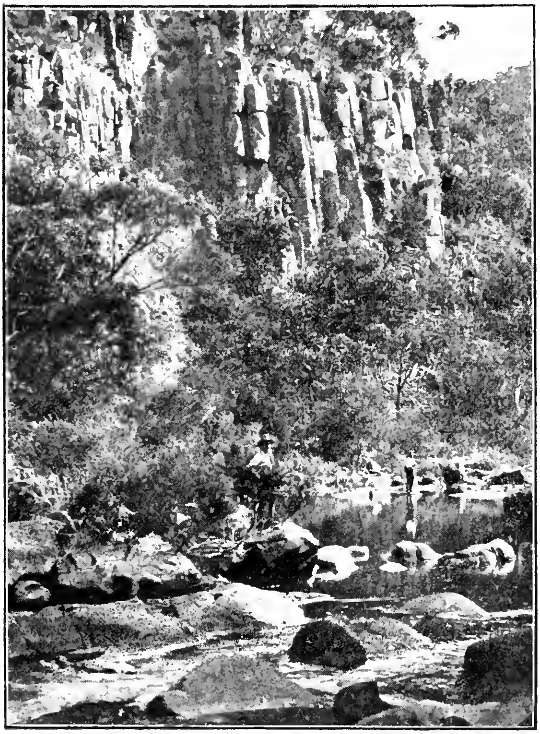
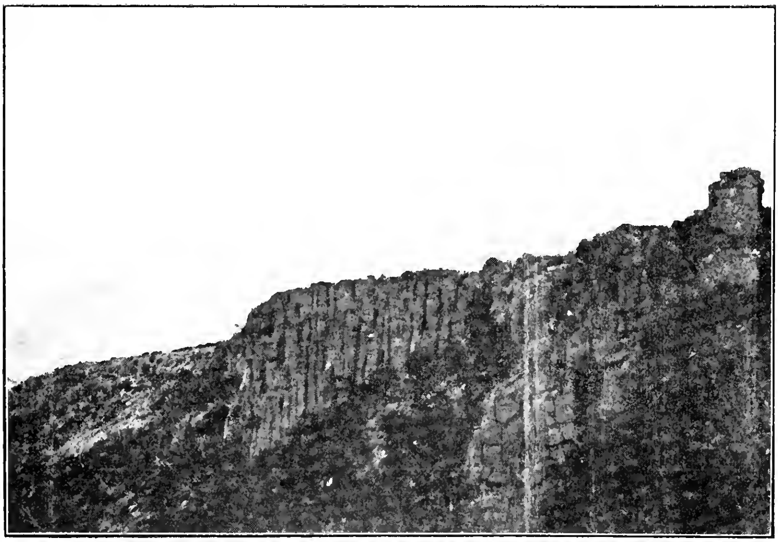
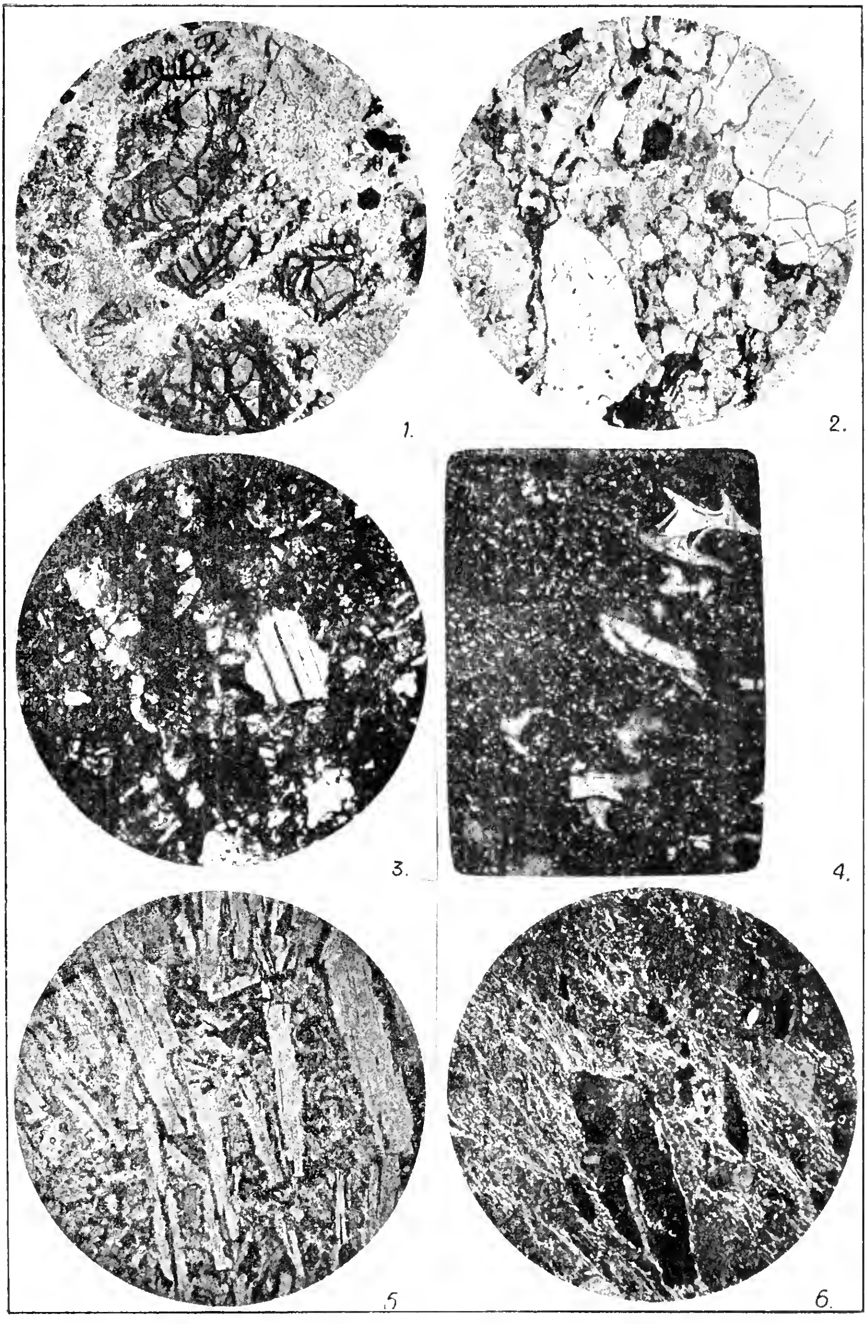


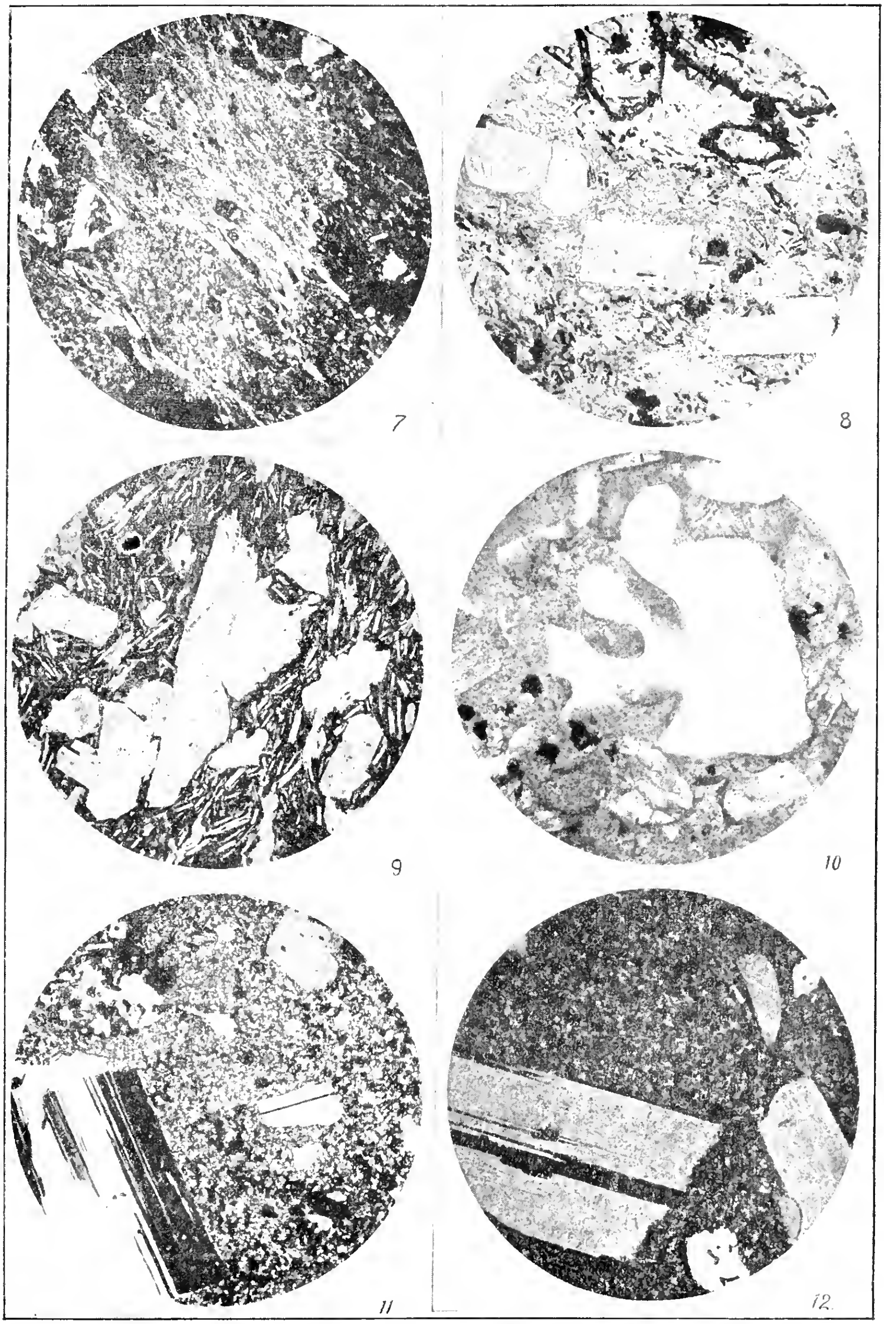
Columnar Rhyolite, Wellington Gorge, and weathered Garvey Gully Tuffs



Overfolding of Silurian, Dolodrook R., and
Columnar Rhyolite, Mt. Wellington



Rocks of Mt. Wellington and Nowa Nowa



Rocks of Nowa Nowa and of Mt. Tara (10).

[Proc. Roy. Soc. Victoria, 32 (N.S.), Pt. II., 1920].

Art. IX.—*Note on the Correction for Chronometer Rate.*

By J. M. BALDWIN, M.A., D.Sc.

[Read 14th August, 1919.]

The following very easy way of applying the correction for chronometer rate has been in use at the Melbourne Observatory for some years. As I find that many who have often to use the correction are unaware of the method, it seems worth while, although the method is probably not new, to call attention to it.

Let T be the period of a vibrating system in seconds
T′ the period as shown by a chronometer
r the daily rate of the chronometer, + if losing, so that the chronometer indicates $(86400 - r)$ seconds in a day,

$$\text{and 1 chronometer second} = \frac{86400}{86400 - r} \text{ seconds.}$$

$$\therefore \qquad T = T' \cdot \frac{86400}{86400 - r}$$

$$\text{and } \log.T = \log.T' - \log.\left(1 - \frac{r}{86400}\right)$$

$$= \log.T' + .43429 \times \left\{\frac{r}{86400} + \tfrac{1}{2}\left(\frac{r}{86400}\right)^2 + \cdots\right\}$$

The value of the right hand side is nearly

$$\log.T' + \frac{r}{2} \times 10^{-5}$$

so that, *to obtain log.* T, *add half the daily rate in seconds to the fifth decimal place of log.* T′. The value of T so obtained will be within one part in a million for values of r up to 15 seconds. If a siderial chronometer is used, $r = -236{\cdot}56$, and even in this case the accuracy attained is 1 part in 100,000.

The expression

$$\log.T = \log.T' + \frac{r}{2} \times 10^{-5} + \frac{1}{190} \cdot \frac{r}{2} \times 10^{-5}$$

gives a value of T correct to one part in a million, provided r is not greater than 120, while the addition of the extra term

$$+ \frac{r}{900} \cdot \frac{1}{190} \cdot \frac{r}{2} \times 10^{-5}$$

gives more than sufficient accuracy in every case.

[Proc. Roy. Soc. Victoria, 32 (N.S.). Pt. II., 1920].

Art. X.—*A New Method of Determining the Mechanical Equivalent of Heat.*

BY

Professor T. H. LABY, M.A.

AND

J. K. ROBERTS, B.Sc.

(Natural Philosophy Department, University of Melbourne).

(With Plates X. and XI. and 1 Text Figure.)

[Read 11th September, 1919.]

Introduction.

It appeared to the writers that an additional direct determination of the mechanical equivalent of heat would be of value, and might, in view of the progress of precise measurement, attain higher accuracy than that previously realised, and, incidentally, information might be obtained as to the accuracy of the electrical units.

After a long series of preliminary experiments, a method, in which a copper cylinder is heated by a rotating magnetic field, has been devised, possessing the characteristics—(1) of accurately stationary temperatures, and (2) that a small fraction of the heat developed is lost. This method is being carried out so as to attain, if possible, an accuracy of 1 in 10,000 in J, the mechanical equivalent of heat.

Previous Determinations.

There have been five determinations[1] of the mechanical equivalent of heat, to which it is necessary to refer—namely, those made by Joule, Rowland, Misculescu, Reynolds and Moorby and Rispail. Of these experiments only those of Rowland and of Reynolds and Moorby appear to possess high accuracy, and they are not immediately comparable, as the values of J, which they give, are in terms of different heat units. Several determinations have been made of what may be called the electrical equivalent of heat. If the mechanical equivalent, J, were known to an accuracy of 1 in 10,000 (which should not be beyond attainment), the degree of its

1. Joule, Phil. Trans., Vol. CXL. p. 61 (1850); Rowland. Proc. Amer. Acad., Vol. XV., p. 75 (1879); Miculescu. Journ. de Phys., Vol. I., p. 104 (1892); Reynolds and Moorby, Phil. Tran. Vol. CXC., p. 301 (1897); Rispail, Ann. Chim. Phys., Vol. XX., p. 417, (1910).

agreement with the electrical equivalent would be an indication of the accuracy with which the practical electrical units realise their intended values.

Principle of the Experiment.

The method to be described, we believe, has not been previously applied. Baille and Féry[2] proposed to generate heat, not by stirring water, but by placing a copper cylinder in a rotating magnetic field produced by polyphase currents. Their proposal is open to the objection that the lines of magnetic force would probably have a component of motion in the direction of the axis of the copper cylinder. Heat would then be generated to which there was no corresponding couple. We have obtained a rotating magnetic field with a known and fixed axis, A, by the rotation of an electro-magnet. A copper cylinder is mounted (see Figs. 1 and 2) so as to be capable of rotation about a vertical axis, B, and is

2. Comptes Rendus., Vol. CXXVI., p. 1494 (1898).

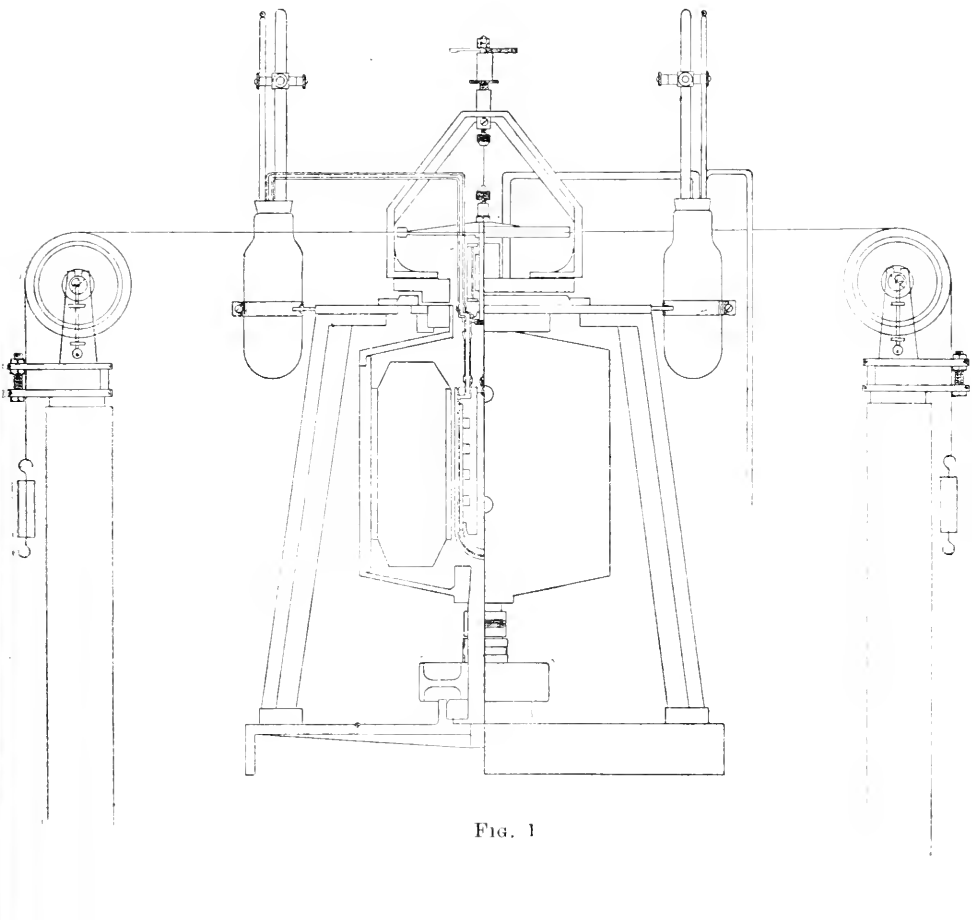


FIG. 1

placed in the rotating field. The axes A and B are brought into coincidence. The determination of J then becomes a question of finding the work done on the copper cylinder, and the heat developed in it. The work is found as in Rowland's experiment. The copper cylinder is attached to a vertical axle and wheel (diameter, D cm); and the whole is suspended by a torsion wire. Two wires pass round the circumference of the wheel over pulleys to two masses of m gm. The couple mgD dyne.cm. produced by these weights balances the couple arising from the rotating magnetic field. The torsion wire gives stability to the system.

The heat developed is measured by a continuous flow method. Water flows past a platinum thermometer, then it circulates round the copper cylinder and out past a second platinum thermometer. The heat developed is $M(\theta_2 - \theta_1)$ calorie, where M gm. is the quantity of water flowing in an experiment, and $(\theta_2 - \theta_1)$ degree is the rise of temperature. To eliminate the heat losses, L calorie, from the expression for J, two experiments are made—a heavy and a light one—in which the inlet and outlet temperatures θ_1 and θ_2 are the same. The heat developed in the former is about ten times that in the latter. We then have for the heavy experiment

$$\pi Dnm_1g = J(\theta_2 - \theta_1)M_1 + L$$

and for the light

$$\pi Dnm_2g = J(\theta_2 - \theta_1)M_2 + L$$

and therefore

$$J = \pi Dng(m_1 - m_2) / \{ (M_1 - M_2)(\theta_2 - \theta_1) \}$$

where n is the number of revolutions of the field magnets for the period of an experiment, which is the same for the light and heavy experiments.

The heat developed in the light experiment is made less than in the heavy experiment by reducing the strength of the magnetic field.

In the above relation it is assumed that the loss of heat, L, is constant for a given value of the inlet and outlet water temperatures. The text-book accounts of Callendar and Barnes' experiments[3] lay inadequate stress on the conditions which those observers showed must be fulfilled for this assumption to be justified. In our preliminary experiments the loss of heat, L, bore little relation to the inlet and outlet water temperatures, θ_1 and θ_2. With θ_1 and θ_2 fixed, L would vary widely with the rate of flow of the water through the copper, which was then in the form of a hollow copper ring. After the factors which determined the heat losses in this form of the apparatus had been determined by a number of experi-

3. Callendar, Phil. Trans., Vol. CXCIX., 1902, pp. 112, 114, 115, 122; Barnes, Phil. Trans., Vol. CXCIX., 1902, pp. 224-228.

ments, the apparatus now being described was designed so that the inlet and outlet water temperatures would determine the surface temperatures of the calorimeter, and so for a given temperature of the surroundings of the calorimeter, determine the loss of heat, L, independently of the rate of development of heat in the calorimeter.

The equation we have given assumes that three axes are parallel, namely, the axis of rotation of the magnetic field, the axis about which the copper cylinder is free to rotate, and the axis of the couple produced by the two masses m. This condition is fulfilled to the required accuracy in the apparatus as we are using it.

In another paper,[4] the theory of the electrical device, which we have used in these experiments, is given. It is there shown that the couple ψ dyne.cm. acting on the stator is given by the expression

$$\psi = \pi\rho N\phi^2 / \{ \rho^2 + 4\pi^2\lambda^2 N^2 \}$$

where N revolution per sec. is the speed of the rotor, ϕ maxwell is the flux crossing the copper cylinder, ρ is proportional to the resistance from end to end of the cylinder, and λ cm. is a certain inductance.

Design and Operation of the Apparatus.

It will be convenient to call the rotating field magnets, the rotor, and the copper cylinder and the iron cylinder which it encloses, the stator.

The rotor (see Figs. 1, 2, 3 and 4) is mounted on ball bearings, with its axis vertical. The field magnet windings are connected through slip rings to a lead storage battery. The rotor is belt-driven by a shunt motor, and the speed of the former is determined by means of a worm gear, which, at the completion of every 100 revolutions (that is, about every four seconds), moves a pen writing on a chronograph; the pen also indicates seconds, as given by a standard clock. In this way, the rate of rotation and number of revolutions is recorded.

The rotor is pierced with eight sighting holes (see Figs. 3 and 4) for adjusting the axis of the stator parallel to that of the rotor. These holes, if fully open, thoroughly ventilate and cool the field magnets.

The lower bearing of the rotor is rigidly held by an iron bed plate bolted to a brick foundation. In order to prevent vibration in the plate, which carries the upper bearing of the rotor and the

4. J. K. Roberts. The Design of a Motor with Large Air Gap and Rotating Field Magnets. Proc. Roy. Soc. Vict., XXXII., 1920, p. 156.

bearing of the stator, the rotor was balanced. Suitably illuminated points situated on the plate in question were observed with a microscope, carried by a support free from vibration, and the rotor was balanced until the amplitude (i.e., diameter of circumscribing circle) of the vibration of the plate was reduced to .001 cm.

The field magnets have two poles, and there are two windings on each pole. These windings can be connected in series so that the turns reinforce one another, and the maximum flux for a given current produced. They are so connected for the heavy experiment. The windings can also be connected in series so as to oppose one another in their magnetising effect. They are so connected for the light experiment. In this way the flux can be reduced to one-tenth without changing the current in the windings and, therefore, without changing the temperature of the rotor in the light and heavy experiments.

The Stator and Calorimeter.—The construction of the stator is shown in Figs. 5, 6 and 7. Fig. 5 shows copper and iron cylinders. The iron cylinder increases the magnetic flux, and supports the copper cylinder. The channels on the external surface of the iron, and the axial hole, carry the water in its circulation through the apparatus. The iron cylinder is attached to a glass tube (see Fig. 6) filled with eider down, in order to reduce loss of heat by conduction. The glass tube in turn is attached to a steel shaft which passes through a ball-bearing, and, at its upper end, is suspended by a steel torsion wire. The wire supports the whole weight of the shaft and calorimeter.

A thin sheet cylinder encloses the copper cylinder, and a Dewar flask encloses the steel, copper, and iron cylinders, which to prevent corrosion are all silver plated.

The water enters the calorimeter (see Figs. 5, 6 and 7) through a rubber tube, flows downwards between the inside wall of the Dewar flask and the thin steel cylinder, turns upwards and flows between the steel and the copper, then down between the copper and iron, and finally out of the calorimeter through the axial hole in the iron armature. The object of this somewhat elaborate circulation is—(1) to bring the water into thorough contact with the copper and iron in which the heat is generated, (2) to break up stream lines, and so ensure that the inlet and outlet water temperatures determine the heat losses of the calorimeter.

The ball bearing which maintains the shaft vertical was very carefully made, and is used without oil lubrication, which was found to increase the friction. The angular amplitude of the stator when set in torsional oscillation decreases by 10 per cent. per vibration, from which it can be shown that the friction is very small. A mirror is attached to the shaft of the stator, and its movement observed by lamp and scale. With the apparatus arranged for a determination of the mechanical equivalent, the stator oscillations are not critically damped; frictional resistance arising from the viscosity of water is added, till the damping is critical.

Couple.—Two thin wires (see Fig. 1) pass from the circumference of the wheel over two other wheels (see Fig. 2), and then to the weights. With the axis of the stator vertical (which it is to within 12′ of angle) these wires should be parallel and horizontal, conditions which are readily fulfilled.

The design, construction and testing of the wheels shown in Fig. 8 has required a great deal of attention. Ball, roller, and cone bearings were tested, and found to possess far too much friction to be suitable for these wheels, and so a knife edge was used. While this bearing is quite free from friction, and practical in use, it is necessary to locate the position of the knife edge relative to the centre of the wheel, a test which is not so easily made as might be expected.

Measurements.

The relation

$$J = \pi D n g (m_1 - m_2) / \{ (M_1 - M_2)(\theta_2 - \theta_1) \}$$

indicates what degree of accuracy is necessary in the various quantities in the right hand member, if J is to be correct to 1 in 10,000.

D, the diameter of the wheel, is 20 cm., and can be measured to the necessary accuracy. The revolutions, n, are counted. The acceleration of gravity, g, is accurately known for Melbourne. The masses, m_1 and m_2 gm., are readily found to the required precision.

With $\theta_2 - \theta_1 = 10°C$. it is necessary to determine this difference to 1/1000°C, which is about the limit of accuracy obtainable with a platinum, or, in fact, any thermometer. The water flows past the platinum thermometers contained in Dewar flasks, as shown in Fig. 2.

The water, after passing through the calorimeter is collected in a copper can. A two-way tap turns it into this can at the beginning of the experiment, and at the same time starts the chronograph record; at the end of the experiment turning the tap causes the water to flow to a different vessel, and also stops the chronograph record. The water collected is weighed.

Distilled water contained in two thermally insulated tanks, so arranged as to give a constant head of about 240 cm. (8 feet) is used in the experiments.

The precision of the experiments will be limited (1) by the steadiness in the rate of generation of heat, and (2) by constancy of the loss of the heat, L, in the heavy and light experiments. The first of these has been satisfactory in the preliminary experiments, and if necessary, could be improved. The principal loss of heat, no doubt, occurs through the walls of the vacuum jacket of the calorimeter, and is proportional to the excess of the temperature of the inner wall (that is, the temperature of the inlet water θ_1) above the outer wall (that is, the air temperature θ_a). This difference $(\theta_1 - \theta_a)$ degree can be determined, it is expected, with sufficient accuracy to attain the desired precision.

Only preliminary determinations of J have so far been made, further experiments are now in progress.

We have to thank Mr. R. Berryman for the care he has taken and the success he has achieved in constructing the apparatus shown in the figures.

DESCRIPTION OF PLATES.

Plate X.

Fig. 2.—General view of apparatus.
,, 3.—Rotor with top removed, showing pole pieces and windings.
,, 4.—Rotor mounted.

Plate XI.

,, 5.—The two parts of the stator, on the left the iron cylinder in the channels for water, on the right the copper cylinder fitting over it.
Fig. 6.—Stator attached to torsion wheel with flask removed.
,, 7.—Stator with flask attached, showing plate with levelling screws resting on the top plate of Fig. 5.
,, 8.—Knife edge bearings.

[Note added 10th March, 1920 :—Improvement in the brush contacts on the rotor has led to greater steadiness in the rotor field magnet current and therefore in the couple; this has made the water damping device mentioned in the text unnecessary.

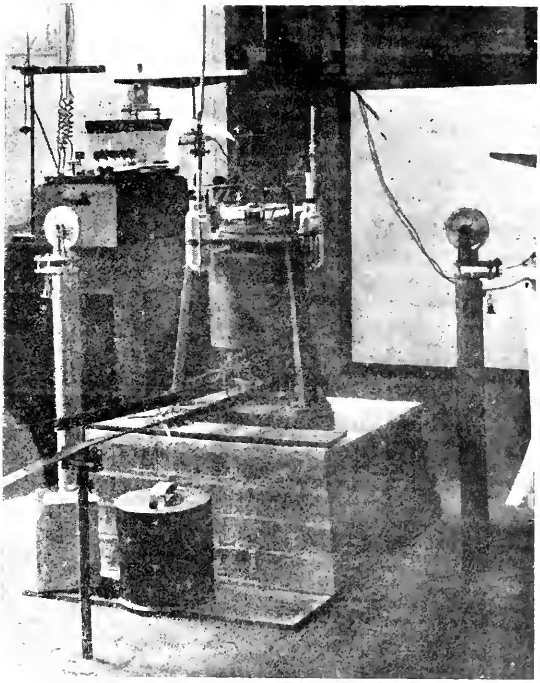


Fig. 2. General View of Apparatus.

Fig. 3. Rotor with top removed, showing pole pieces and windings.

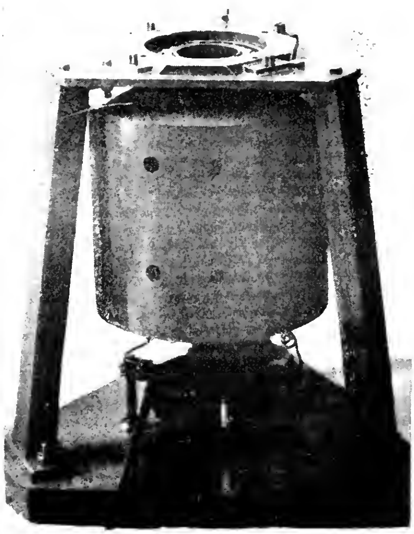


Fig. 4. Rotor mounted.

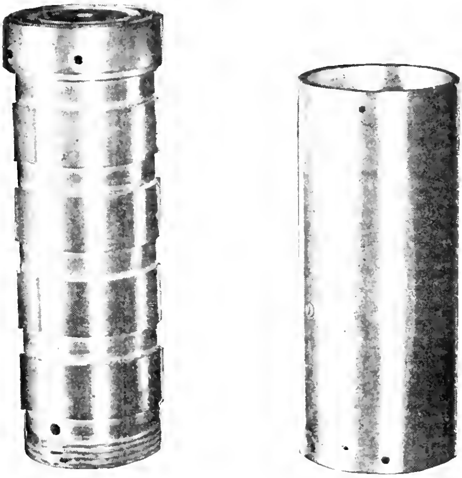


Fig. 5. The two parts of the stator, on the left the iron cylinder in the channels for water, on the right the copper cylinder fitting over it.

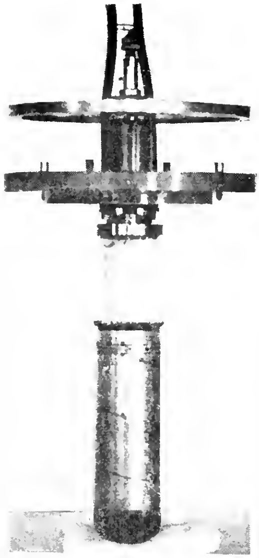


Fig. 6. Stator attached to torsion wheel with flask removed.

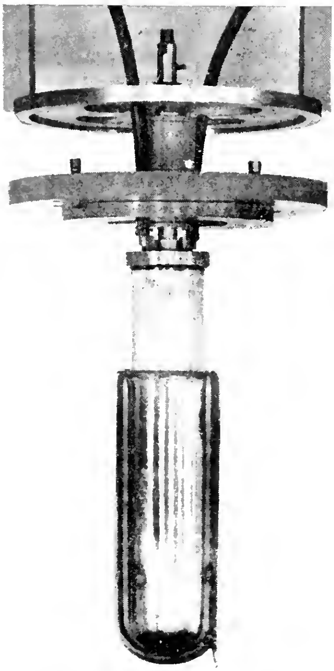


Fig. 7. Stator with flask attached, showing plate with levelling screws resting on the top plate of Fig. 5.

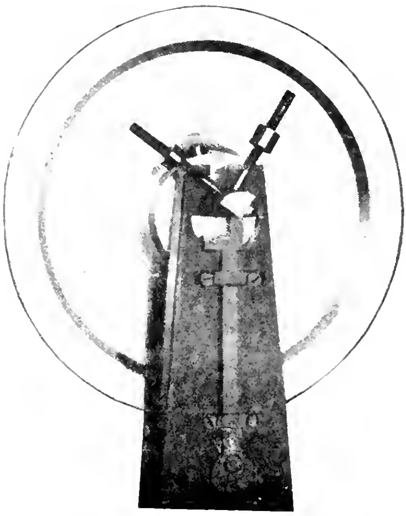


Fig. 8. Knife edge bearings.

It has also been shewn that the heat losses take place mainly from the tubes which lead the water into the flask and not from the flask itself. For a fixed rate of generating heat the loss of heat is proportional to the excess of the mean of the inlet and outlet water temperatures over the air temperature. The rate of loss of heat varies with the rate of generation of heat for fixed temperatures and has been shewn to be a linear function of it. This will enable the heat losses to be allowed for. J.K.R.]

[PROC. ROY. SOC. VICTORIA, 32 (N.S.), PT. II., 1920].

ART. XI.—*The Design of an Induction Motor with large Air Gap and Rotating Field Magnets.*

BY J. K. ROBERTS, B.Sc.

(Natural Philosophy Department, University of Melbourne).

(With 2 Text Figures.)

[Read 11th September, 1919.]

It will easily be seen that the apparatus described in another paper[1] in these Proceedings is an induction motor, with the following peculiarities:—

1. The field magnets are magnetised by direct current, and are rotated to produce the rotating magnetic field. This is necessary in order that the axis of rotation of the magnetic field may be accurately determined, and that there may be no movement of the magnetic field along the axis of rotation.

2. The armature consists of a hollow cylinder of solid copper with a soft iron core.

3. The machine works at 100% slip, i.e., the armature remains at rest.

4. The air gap is very much larger than usual to permit of the insertion of the Dewar flask.

The problem of designing the instrument was similar to that of designing an induction motor. A first approximation to the behaviour of the instrument may be made by supposing the copper armature replaced by another armature of the same size, consisting of very narrow strips of conducting material insulated from each other, the resistance of all the strips in parallel being equal to that of the copper cylinder from end to end, and each strip being connected at either end with that diametrically opposite to it by a perfect conductor.

If this armature be placed in a uniform magnetic field of strength H, which rotates at the rate of N revolutions per second, the usual theory of the induction motor gives the torque as:—

$$\psi = \pi N H^2 l^2 c^2 R n (R^2 + 4\pi^2 N^2 L^2)^{-1}$$

where l cm. is the length of the armature, c.cm. is the diameter of armature. R. E.M. units is the resistance of each of the circuits (i.e., twice the resistance of one strip), n total number of

1. Laby and Roberts. A New Method of Determining the Mechanical Equivalent of Heat, page 148.

circuits (i.e., one-half the number of strips), and L.cm. the inductance of each of the circuits.

The quantity Hlc is the magnetic flux threading the armature, and is denoted by ϕ. Thus we have

$$\psi = \pi N n R \phi^2 (R^2 + 4\pi^2 N^2 L^2)^{-1}$$

We may write $R = \rho n$ where ρ is a constant depending on the resistance of the original copper cylinder.

Thus

$$\psi = \pi N \rho \phi^2 (\rho^2 + \frac{L^2}{n^2} 4\pi^2 N^2)^{-1}$$

Let $L = \lambda n$ where λ is a constant

$$\psi = \pi N \rho \phi^2 (\rho^2 + 4\pi^2 N^2 \lambda^2)^{-1} \qquad \ldots\ldots (1)$$

It should be noticed that writing $L/n = \lambda$ (a constant) takes into account the mutual action of the induced currents on one another. For suppose that we replace the original copper armature first by one consisting of n circuits and second by one consisting of $2n$ circuits where n is large. The currents flowing in adjacent circuits will be nearly the same both in magnitude and in phase, and since the circuits are near together the mutual inductance of two adjacent circuits will be practically equal to the self-inductance of either of them. Thus the flux threading a circuit when a certain current flows in it will, in the case of the armature of $2n$ circuits, be approximately twice what it is for the same current in the armature of n circuits. Writing $L = n\lambda$ we assume that it is exactly twice the value.

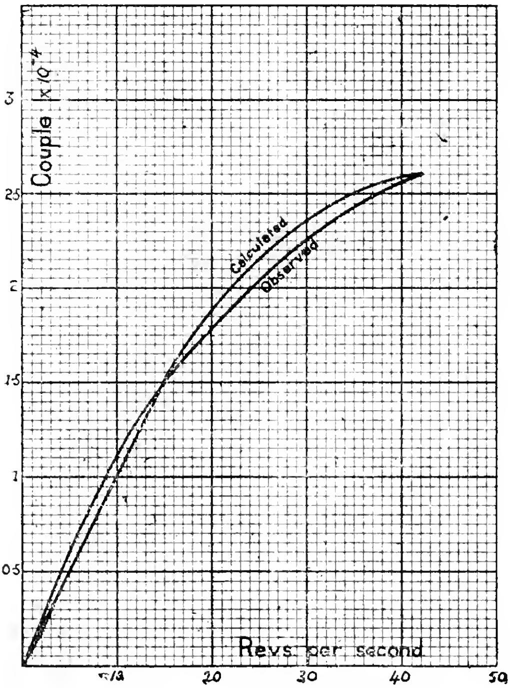
In order to determine ρ and λ for particular cases, the following experiments were carried out :—

Experiment (a).—A U-shaped permanent magnet was weighed and suspended by means of a bifilar suspension so that the poles hung downwards. An armature, consisting of a cylinder of copper with an iron core was placed midway between the poles and attached to a spindle, by means of which it could be rotated, a revolution counter was attached to the spindle. The couple acting when the spindle was rotated was measured by observing the deflection of a spot of light, which was reflected from a mirror attached to the magnet. The couple was measured for different rates of rotation of the armature. The value of ϕ was determined by winding the exploring coil of a Grassot fluxmeter around the armature and rotating it through 180°. This of course gives twice the value of $2.\phi$ The result obtained was $\phi = 6.23 \times 10^3/2$ Maxwell. Mass of magnet, 2870 gm. Distance from mirror to scale, 54.5 cm. Length of suspending wires, 44.2 cm. Distance between suspending wires, 2 cm.

The couples obtained were the following :—

Revolutions per second.	Deflection of light on reversing direction of rotation of copper.	Couple (absolute)
43.96	97.7 cm.	2.69×10^4
33.48	94.5 cm.	2.26×10^4
21.98	76.2 cm.	1.93×10^4
13.6	49.35 cm.	1.35×10^4

These results are plotted in Figure 1.



Using the values at two points we may determine ρ and λ from equation (1). From the graph when

$N=42$, $\psi=2{\cdot}6 \times 10^4$, and when $N=15$, $\psi=1{\cdot}5 \times 10^4$,

We have therefore

$$\left.\begin{array}{l}\rho=2{\cdot}772 \times 10^4 \text{ E.M.U.} \\ \lambda= 92{\cdot}5 \text{ cm.}\end{array}\right\} \cdots\cdots(2)$$

Substituting these values in equation (1) we calculate the couples ψ for different values of N, with the following results :—

$N=20$, $\psi=1{\cdot}87 \times 10$

$N=30$, $\psi=2{\cdot}36 \times 10^4$

These values are plotted in Figure 1, in the "calculated" curve.

Experiment (b).—Further experiments of the same nature were carried out by removing the armature from a series wound "Immisch" motor, and replacing it by a hollow copper cylinder with an iron core. The pole pieces were built up with cast iron so as to clear the copper by about one millimetre. The whole was mounted on a cradle dynamometer, and arranged so that the copper cylinder could be rotated at different speeds by means of a belt and pulleys of different sizes.

Current was passed through the field coils and the torque produced on rotating the copper measured in the usual way.

The value of ϕ was measured by making and breaking the current in the field coils, and noting the deflection of a fluxmeter with an exploring coil, wound around the copper. In each case the couple with zero flux was measured to eliminate the frictional couple. The following results were obtained :—

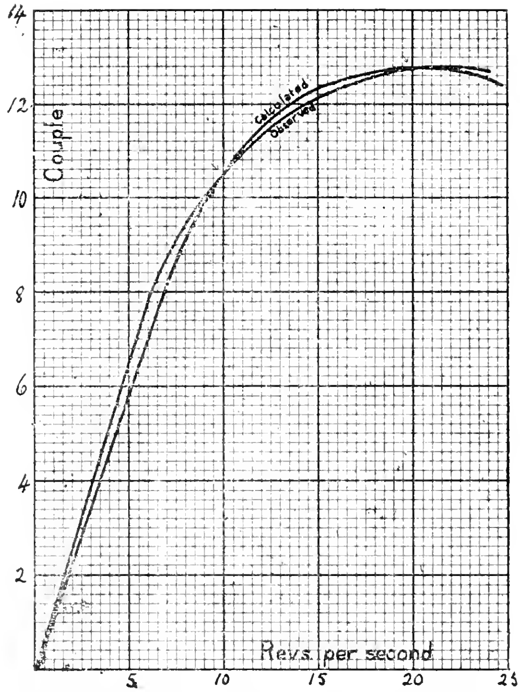
Revolution per second.	Value of 2ϕ	Mass of balancing rider.	Distance of rider from Centre.	Couple due to Eddy Currents.	Couple corrected to $\phi = 2{\cdot}79 \times 10^5/2$
6.65	0 2.72×10^6	100 200	29 cm. 52.5 cm.	7.45×10^6	7.84×10^6
11.0	0 2.74×10^5	100 200	10 cm. 60 cm.	1.08×10^7	1.12×10^7
16.1	0 2.79×10^5	100 200	14 cm. 70 cm.	1.23×10^7	1.23×10^7
20.2	0 2.79×10^5	100 200	16 cm. 73 cm.	1.27×10^7	1.27×10^7
24.0	0 2.79×10^5	100 200	10 cm. 70 cm.	1.27×10^7	1.27×10^7

In order to correct the observed couples for variations in the value of ϕ it was assumed that the couple is proportioned to ϕ^2. To verify this, two experiments were carried out at the same rate of rotation with values of ϕ in the ratio of 1 to 2. The couples were measured as before. The values of the ratio Couple : ϕ^2 were found to be

$$6.07 \times 10^3 \text{ and } 6.04 \times 10^3.$$

This justifies the assumption made.

The values of the couples corrected in this way are given in the last column of the table, and are plotted against revolutions per second in Fig. 2.



In order to compute the values of ρ and λ of Equation (1) for this case two points on the graph are used.

When $N=10$, $\psi=10.4\times10^6$, and when $N=20$, $\psi=12.7\times10^6$

In the same way as before we get

$$\left.\begin{array}{l}\rho=4.63\times10^4 \text{ E.M.U.}\\ \lambda=382 \text{ cm.}\end{array}\right\}\ldots\ldots (3)$$

Using these values of λ and ρ the couples which should correspond to different values of N can be calculated from formula (1) to be :—

$$N=15,\ \psi=12{\cdot}33\times10^6 \text{ and } N=25,\ \psi=12{\cdot}29\times10^6$$

These are plotted in Fig. 2 in the calculated curve.

In order to apply these results to the design of a new apparatus, it is necessary to compare the values of ρ as calculated above with the values of the resistances from end to end of the two cylinders which were used. If we do this we get the following :—

ρ/Resistance of copper cylinder =(a) 17·6 and (b) 24·2......(4)

The values of λ obtained were λ=(a) 92·5 and (b) 382......(5)

The reason for the fact that ρ is about twenty times the resistance of the copper from end to end, which we may call σ, is that if r is the resistance of each of the $2.n$ strips by which the copper is replaced,

$$R=2n\sigma$$

The resistance R of each of the circuits formed by joining a pair of strips in series by two perfect conductors will be

$$R = 2r = 4n\sigma$$

$$\text{But } R = n\rho \text{ and } \therefore \rho = 4\sigma$$

That is, if the ends of the conducting strips were joined by perfect conductors, we would have ρ equal to four times the resistance of the copper from end to end. The remaining factor of five is due to the fact that the effective resistance of the paths joining the strips is not zero.

The large increase in the value of λ in the experiments with the Cradle dynamometer is probably due to the fact that in these experiments the air gap between the copper and the pole pieces was smaller than in the case of the permanent magnet.

Another point, which must be determined, before it is possible to design a new apparatus, is the extent to which the magnetic resistance of a magnetic circuit can be inferred from the dimensions of the apparatus.

To do this, the "Immisch" motor was used, and the flux threading the iron core was measured for different diameters of the core, and different magneto-motive forces, with the following results:—

Average area of air gap.	Length of air gap (both sides).	Magnetic resistance of air gap.	Magneto Motive force.	Magneto Motive force. Resultant Flux.
60.43	0.73	0.0121	3.47×10^3	0.0251
,,	,,	,,	6.01×10^3	0.0301
39.4	1.03	0.0261	3.70×10^3	0.0380
,,	,,	,,	6.61×10^3	0.0418
28.8	1.87	0.0650	3.71×10^3	0.0595
,,	,,	,,	6.84×10^3	0.0630

The numbers in the last column give the effective magnetic resistance of the Circuit.

Comparing these values with the values of the resistance as calculated from the dimensions, it will be noticed that for small air gaps, the effective resistance is larger than the calculated, and also that the value increases with increasing flux density. This means a higher magnetic leakage at higher flux densities. But when the air gap is 2.cm. long, the calculated and effective magnetic resistances are practically the same, and also the value of the effective resistance is almost independent of the flux density.

Certain dimensions in the new apparatus are fixed:—

(i.) The external diameter of the rotor is limited to 30 cm.

(ii.) The internal diameter of the pole pieces must be not less than 7.3 cm.

(iii.) The external diameter of the armature must not exceed 5.5 cm.

(iv.) The length of the armature must not exceed 13 cm.

(v.) Rough calculations shewed that the thickness of the copper should be 3 or 4 mm.

The copper was made 3.3 mm. thick, and 5.45 cm. in external diameter.

This makes the electrical resistance from end to end 4.46×10^3 E.M. unit.

From equation (4) we multiply this by 20 to obtain the value of

$$\rho = 20 \times 4.46 \times 10^3$$

Calculating the magnetic resistance from the dimensions we obtain the value

$$\text{Magnetic resistance} = 0.040.$$

Since the air gap is 1.9 cm. long it can be inferred from the experiments carried out that this will be the effective value of the magnetic resistance.

The flux obtainable is therefore given by

$$\phi = .4\pi(ni)/0.04 = 10\pi(ni)$$

where ni is the number of ampere turns.

It is proposed to run the apparatus at 1500 revolutions per minute, i.e., $N = 25$.

$$\text{Power} = 2\pi N\psi$$
$$= 2\pi^2 N^2 \rho\phi^2(\rho^2 + 4\pi^2 N^2 \lambda^2)^{-1}$$

Since $\frac{1}{2}$-Horse Power is required we have

$$3.73 \times 10^9 = 1{\cdot}086 \times 10^{12}(ni)^2(7.95 \times 10^9 + 2.47 \times 10^4\lambda^2)^{-1} \text{.......(6)}$$

If $\lambda = 92$ and 382 as in Equation (5) we obtain respectively

$$ni = 5.38 \times 10^3 \text{ and } 5.86 \times 10^3 \text{.......(7)}$$

The inductance term should not be greater than 356, as the air gap is nearly ten times as large as in the Experiment (b).

The heat generated in a winding of given size depends on the number of ampere turns.

It is, therefore, necessary to discover whether it is possible to dissipate the energy which would be generated in a winding of the size required by the dimensions of the apparatus. In making calculations it can be safely assumed that .05 watt can be dissipated per square cm. of the area of winding. With this assumption the possible number of ampere turns on each coil comes out to be 4500—that is, a total of 9000, which is more than is required. As only a limited voltage is available it is necessary to choose wire of such a gauge that the resistance will be low enough to allow the requisite number of ampere turns.

The poles were wound with 4720 turns of 24 gauge copper wire.

An experiment was carried out to determine the power of the apparatus so designed. It was found that when the apparatus was generating one half horse-power the current in the field winding was .575 amperes; since there are altogether 9440 turns this gives for magnetising current,

$$5.43 \times 10^3 \text{ ampere turns.}$$

This value lies between the predicted limits, viz.,

$$5.38 \times 10^3 \text{ and } 5.86 \times 10^3 \text{ as in equation (7).}$$

The rise of temperature of the winding was found from its resistance, the temperature coefficient of a sample of the wire having been measured. The temperature rose 47° with all the vents in the apparatus closed. Thus the apparatus realised the power for which it was designed. The ventilation caused by the vents was large, and with them open the rise was much smaller.

[Proc. Roy. Soc. Victoria, 32 (N.S.) Pt. II., 1920].

Art. XII.—*Australian Phlebotomic Diptera:—New Culicidae Tabanidae and Synonymy.*

By. FRANK H. TAYLOR, F.E.S

Communicated by J. A. Kershaw.

[Read November 6th, 1919.]

The following paper contains descriptions of three new species of Diptera, which are contained in the genera *Uranotaenia*, *Silvius* and *Tabanus*.

Philalomyia is substituted for the generic name *Elaphromyia*, as the latter is preoccupied, and two species of Tabanidae are sunk as synonyms.

Family CULICIDAE.

Uranotaenia albofasciata, sp.n.

Head clothed with bluish-white scales; antennae brown, plumes brown; palpi and proboscis brown.

Thorax brown, with blackish-brown, narrow scales. There is a broad band of white, small, flat scales on the lateral and anterior margins; prothoracic lobes white sealed; scutellum pale with black flat scales.

Abdomen covered with dusky scales, first segment white scaled, remaining segments, except the apical, with prominent white apical bands; venter apparently pale scaled.

Legs brown, femora pale beneath, last three tarsi of hind legs pale scaled.

Wings black scaled, base of wings white scaled, also apex of costa and the subcostal vein above the cross-veins, anterior basal cross-vein longer than and about twice its length from the anterior cross-vein, first fork-cell slightly narrower and shorter than the second fork-cell, base of latter nearer the base of the wing.

Length, 2.5 mm.

Habitat.—Northern Territory, near Darwin (G. F. Hill).

Abundantly distinct from other Australian species, and a well-defined member of the genus.

Type in Coll. Hill.

Family—TABANIDAE.

Sub-Family—Pangoninae.

Phibalomyia, nom. nov.

Elaphromyia, Taylor, *nec* Bigot.

Proc. Linn. Soc., N.S. Wales, 1916, XLI., p. 749 (1917), op. cit., XLII., p. 517 (1917).

I am indebted to Prof. Dr. Bezzi for informing me that the name *Elaphromyia* has already been used by Bigot in 1859 (Dipt. Trypaneidae), thus invalidating its use in the Tabanidae. I therefore propose the above alteration.

Pseudotabanus queenslandi, Ricardo.

Corizoneura kurandae, Taylor.

Ann. Mag. Nat. Hist., (8), XVI., p. 273 (1915); Taylor, Proc. Linn. Soc., N.S. Wales, 1916, XLI., p. 748 (1917).

I am indebted to Mr. Kershaw, Curator, National Museum, Melbourne, for the courtesy of examining the Tabanidae contained in the Museum Collections, where there is a specimen of this species named by Miss Ricardo, thus establishing the identity of the two names.

Silvius distinctus, sp. nov.

Length, 10-13; length of wing, 9-11; width of head, 2.5-4 mm.

♀ *Head.*—Face and cheeks black, tomentum dirty grey, pubescence grey; beard grey; palpi black, slender; antennae black, base of third joint with a shallow angle, pubescence black on first two joints; front narrow, parallel, pubescence grey, black round the ocellar triangle, frontal callus as broad as the front; eyes black, bare.

Thorax chocolate-brown, pubescence black, prominent on sides; scutellum black with black pubescence; pleurae black with grey pubescence.

Abdomen, black, segmentations creamy, very broad on first segment, absent on penultimate and apical segments, segmentations narrowed in the median line, giving the abdomen the appearance of having a median black stripe; first two segments of venter with pale pubescence, penultimate and apical black, remainder with creamy segmentations.

Legs black, pubescence black.

Wings.—Basal half grey, rest clouded with black; veins black; stigma black; no appendix.

Habitat.—Northern Territory, Bathurst Island (G. F. Hill),

A very distinct and easily recognised species belonging to the *nigrapennis-fergusoni* group.

Type in Coll. Hill, paratype in Coll. Taylor.

Sub-Family TABANINAE.

Genus **Tabanus.**

Group VII. Abdomen, with one or more stripes, usually continuous.

Tabanus geraldi, sp. nov.

Length, 17; length of wing, 14; width of head, 5.75.

♀ *Head.*—Face and lower half of cheeks covered with grey tomentum, upper half of cheeks and subcallus, with dull golden tomentum; beard grey; front parallel with creamy tomentum and pubescence; vertex dusky; frontal callus small, pear-shaped, lineal extension reaching the middle of the front; first joint of antennae reddish-brown, pubescence grey, long, second joint black, very short, third joint black, base with a small, prominent tooth; palpi creamy-yellow, stout, ending in a blunt point, pubescence short, black mixed with pale at the base.

Thorax black, tomentum dirty grey, grey above wing roots, pubescence black and golden, grey above wing roots, black on sides; scutelum black, pubescence black, grey on posterior border; pleurae grey with grey pubescence.

Abdomen black, with dense black pubescence, with a median grey stripe terminating on the penultimate segment, lateral margin with dense, grey pubescence, sides of segments three to five yellowish; venter slate coloured with grey pubescence.

Legs black, basal third of fore tibiae reddish, mid and hind tibiae, except the apices, pale reddish-brown, pubescence grey on femora and tibiae, black on tarsi and apex of tibiae.

Wings clouded with yellowish on the veins except on the marginal cells; veins black, stigma reddish; no appendix.

Habitat.—Northern Territory, Bathurst Island (G. F. Hill).

A beautiful and very distinct species, quite unlike any other known Australian *Tabanus*.

Type unique in Coll. Hill, to whom it is dedicated.

Tabanus strangmanni, Ricardo.

Tabanus mastersi, Taylor,

Ann. Mag. Nat. Hist., (8), XIV., p. 393 (1914); Taylor, Proc. Linn. Soc., N.S. Wales, 1916, XLI., p. 754 (1917).

This appears to be a variable species, as both names refer to the same species.

[PROC. ROY. SOC. VICTORIA, 32 (N.S.), PT. II., 1920].

ART. XIII.—*On the Synthesis of Sugar from Formaldehyde and its Polymers, its Quantitative Relations and its Exothermic Character.*

By ALFRED J. EWART, D.Sc., Ph.D.
(Professor of Botany and Plant Physiology in Melbourne University, and Government Botanist).

[Read 6th November, 1919].

In 1861 Butlerow found that on treating trioxymethylene trimolecular formaldehyde) with hot lime water, a sweet yellow, unfermentable syrup, "methylenitan," was obtained. Loeb[1] obtained an unfermentable "formose" syrup by the prolonged action of lime water on dilute formaldehyde, and by using magnesia obtained a "methose" syrup containing fermentable sugar. Fischer[2] showed that all three syrups were complex mixtures, containing α acrose and obtained this sugar, and β acrose from Barium hydrate and acrolein bromide. The α acrose is optically inactive fructose, and the β acrose is inactive sorbose.

The methods used for the preparation of sugar are mostly slow ones, involving incomplete reactions, and no attempts appear to have been made to determine any precise quantitative relations of the reacting materials.

In a previous paper[3] a method was described of rapidly polymerising formaldehyde to sugar by running dilute caustic soda into a boiling weak solution of formaldehyde, containing calcium formate. The advantages of this method are that there is a definite end reaction, so that quantitative estimations are possible, that the process is very rapid, requiring only a few minutes for completion, and that the amount of formaldehyde polymerised is very large. The residual products are calcium and sodium formates and sugars, mainly pentoses and hexoses, any methyl alcohol formed boiling off.

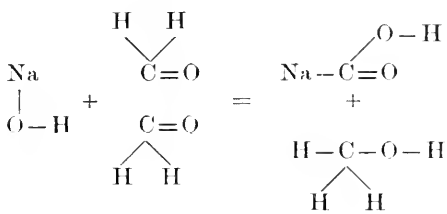
At low temperatures the reaction is extremely slow, and but little sugar is formed, while when strong caustic soda (35-40%) is

1. Loeb, Ber. D. Chem. Ges. 1887, Vol. 20, 142, 3039; 1888, Vol. 21, 270; 1889, Vol. 22, p. 470.
2. Fisher, Ber. d. Chem. Ges. 1894, seq.
3. Ewart, Proc. Roy. Soc. of Vict., 1919, Vol. XXXI., p. 379.

boiled with concentrated formaldehyde mainly sodium formate and methyl alcohol are produced.

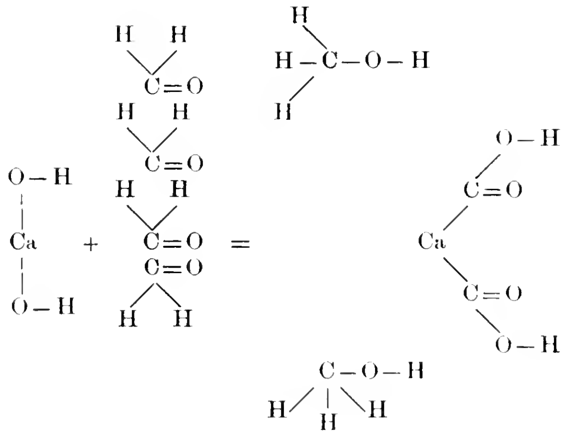
The purpose of the following investigation was to determine more closely the conditions determining the reaction, and bringing about the maximum polymerisation. The nature of the reaction appears to be as follows :—The sodium hydrate first reacts with the calcium formate, producing calcium hydrate, and sodium formate. The calcium hydrate has a more energetic polymerising action than sodium hydrate, and as this action takes place, it is converted into calcium formate, and methyl alcohol is produced. The amount of free alkali present at any given moment is, therefore, small in proportion to the amount of formaldehyde. If any free caustic alkali is present the sugar produced is caramelised on boiling, and the liquid turns brown. A drop or two of free alkali added in excess produces this change at the end of the reaction.

The polymerising action of an alkali appears to depend partly upon its valency. Thus the divalent Mg, Ca, Sr and Ba, hydrates appear to produce more polymerisation than the monovalent Na. and K, hydrates, the relative order being Ca, Sr, Ba, Mg, K, Na. Hence in the presence of a calcium salt, much more polymerisation takes place than if sodium hydrate is added directly to the boiling formaldehyde solution. We might picture the reaction with formaldehyde when no polymerisation takes place as follows :—



The sodium displaces hydrogen in the first CH_2O molecule, which together with the HO radicle of the sodium hydrate, displaces oxygen from the 2nd molecule. This is transferred to the first one, producing sodium formate and leaving methyl alcohol.

With calcium hydrate the reaction would take place similarly, but with four molecules of formaldehyde.



It is not easy at first to see why under any conditions this reaction should lead to a production of sugar, nor would it in all probability if it were a simple matter of a reaction between formaldehyde and an alkali. Bearing in mind the fact that when a previously measured quantity of dilute alkali is run into boiling dilute formaldehyde, the reaction is completed, and sugar is produced within two or three minutes, or even more rapidly if an excess of soda is used, whereas the same solutions kept at 12 to 15°C. for two months or more develop little or no sugar, it seems probable that this difference can hardly be due wholly to the influence of temperature on the rate of chemical reaction.

If a strong solution of formaldehyde is boiled down to $\frac{1}{5}$ or $\frac{1}{6}$ its bulk, and cooled, it solidifies to a white waxy mass of the polyhydrate of formaldehyde. None appears while the liquid is boiling, because of its low melting point. When a litre of 1 or of 2% formaldehyde is boiled nearly to dryness, and then cooled, it leaves a considerable solid residue of the polyhydrate of formaldehyde. Hence, in spite of the loss of formaldehyde vapour, a dilute solution can be concentrated by boiling. If the solution is evaporated at a lower temperature, or under reduced pressure all, or nearly all the formaldehyde escapes, and no residue is left. Presumably therefore, in boiling water, the substance exists mainly as the polydrate of formaldehyde, or as paraformaldehyde, which, on cooling, partially dissolves and partially dissociates to formaldehyde, so long as it has not separated out in mass. Hot water poured into paraformaldehyde or the solid polyhydrate soon acquires a smell of

CH_2O, and the solid slowly disappears in excess of hot water. In cold water a large part is still present, undissociated, after three days.

Paraformaldehyde, or the polyhydrate, dissolves in a few hours in excess of cold 2% NaHO, the liquid smelling of CH_2O, but also containing a little sugar. In cold, strong 35% NaHO, solid paraformaldehyde at once dissolves, forming a yellow liquid smelling of CH_2O, and containing sugar. It blackens and gives a caramel smell, with sulphuric acid, gives Molisch's test (α naphthol) for carbohydrates, and yields furfural on boiling with hydrochloric acid.

Hence, paraformaldehyde and the polyhydrate yield sugar immediately in contact with cold, concentrated soda, whereas formaldehyde does not.

If hot, 35% NaHO is added in slight excess to melted paraformaldehyde, there is a sudden evolution of methyl alcohol, and the resulting brown liquid contains sodium formate and reducing sugar.

Hence it may be concluded that in boiling water the formaldehyde exists mainly as paraformaldehyde or the polyhydrate, and that the alkali produces sugar, methyl alcohol and sodium formate, when it reacts with paraformaldehyde or the polyhydrate, but only or mainly sodium formate and methyl alcohol when it reacts directly with formaldehyde.

Suppose three molecules of di-molecular formaldehyde react with one of Barium or calcium hydrate, as follows :—

$$\begin{matrix} C_2H_4O_2 \\ C_2H_4O_2 \\ C_2H_4O_2 \end{matrix} + Ba\begin{matrix} HO \\ HO \end{matrix} = \begin{matrix} CH_3OH \\ Ba\begin{matrix} COOH \\ COOH \end{matrix} \\ CH_3OH \end{matrix} + \begin{matrix} CHO \\ CH_2HO \end{matrix}$$

The upper and lower molecules may be supposed to separate into CO and CH_3OH, the latter separating as methyl alcohol and the former combining with the BaH_2O_2 to form barium formate. In some manner not understood one of hydrogen is by a kind of enzymatic action transferred from one portion to the other of the central dimolecular formaldehyde

$$\begin{matrix} CH_2O \\ CH_2O \end{matrix} = \begin{matrix} CHO \\ CH_2HO \end{matrix}$$

yielding biose or glycollic aldehyde. This would represent a maximum percentage polymerisation to sugar of 33%, and if tetroses or hexoses were formed directly from biose produced in this way, the percentage polymerization by weight would be the same. If, however, pentoses and hexoses were formed by the direct linking of formaldehyde to the glycollic aldehyde, without further production of formates and methyl alcohol, the polymerisation ratio for pentose would be 9 :5 (45%), and for glucose would be 10 :6 (60%). If a dissaccharide were produced, the maximum ratio would be 16 : 12, i.e., 75%.

A monovalent alkali such as sodium hydrate can react with single molecules of $C_2H_4O_2$, producing sodium formate and methyl alcohol, and will only produce a biose when 2 of sodium hydrate react with 2 of $C_2H_4O_2$, with a third molecule interpolated. The chance for this grouping is not more than half what it is in the case of a divalent alkali, where a single molecule reacts with not less than 2 molecules of $C_2H_4O_2$.

Methods.—The same result is not produced when the liquids are mixed cold, and then heated, as when the sodium hydrate is run into the boiling liquid. Thus 250 c.c. of water, with 5 c.c. of 10% calcium formate and 4 c.c. of 25.2% formaldehyde, after raising to the boiling point required, 7.2 c.c. of 3.5% NaHO to complete the reaction. If mixed cold with 7 c.c. of sodium hydrate, on raising to the boiling point a further addition of 0.4 c.c. of NaHO was required to complete the reaction. If mixed cold with 7 c.c. NaHO, and kept for 15 days at 15° C., on raising to the boiling point, the addition of a further 1.2 c.c. of NaHO is required to complete the reaction, and remove all CH_2O. Hence at low temperatures more formate is produced and less formaldehyde is polymerised to sugar, so that more soda is required to remove all the formaldehyde.

In carrying out estimations, a preliminary test was in each case carried out in an open beaker. The amount of sodium hydrate required was less than the full amount by the amount of CH_2O lost during the boiling. The same amounts of CH_2O, water and calcium formate, were then placed in a flask fitted with a condensing apparatus, so that the condensed steam washed back the escaping formaldehyde. The amount of sodium hydrate previously noted was then run in from a burette fitted to the cork, as rapidly as was possible without causing too violent ebullition.

The yellow tinge which indicates the completion of the reaction appears slowly with very dilute solutions, and the preliminary test must be checked by smell as well as colour. With strong solutions the yellow colour is produced before the reaction is completed, if the soda is added more rapidly than the formic acid is produced. With a little practice these two sources of error are easily avoided.

A solution containing 250 c.c. of water, 5 c.c. of 10% calcium-formate, and 5 c.c. of 31.5% of formaldehyde required 9.6 c.c. of 3.5% sodium hydrate, and required 25.8 c.c. of soda when no calcium formate was present. If no polymerisation had taken place, then the equation would be—

$$2\ CH_2O + 2NaHO = CH_3HO + Na\ CO\ OH$$

i.e., 60 grams of formaldehyde are required to neutralise 40 grams of sodium hydrate (or 38 grams of calcium hydrate).

3 grams of CH_2O are contained in $\frac{3 \times 100}{31.5}$ c.c. of 31.5% solution.

3 grams of NaHO are contained in $\frac{2 \times 100}{3.5}$ c.c. of 3.5 solution.

$\therefore$ 1c.c. of 31.5% CH_2O = 6c.c. of 3.5% NaHO.

In the experiment 9.6 c.c. of soda were required, which represents 1.6 c.c. of CH_2O. Hence of the 5 c.c. of formaldehyde used 3.4 c.c. were theoretically polymerised to sugar. In this way, the apparent percentage polymerisation can be calculated under varying conditions, and with various concentrations, as thus :—

Water	c.c. of 10% $CaCO_2$	c.c of 31.5% CH_2O	c.c. of 3.5% NaHO required	Per cent. of CH_2O polymerized
250 c.c.	5.0	5.0	9.6 c.c.	68
250 c.c.	0.0	5.0	27.8 c.c.	8

In addition to sugar, however, small amounts of by-products may appear. Thus perceptible amounts of dihydroxyacetone are produced when formaldehyde is polymerised to sugar by boiling with calcium carbonate.[4] Allowing for this possibility, the percentage polymerisation to sugar is between the theoretical maximum of 75% for the disaccharide and 60% for hexose.

The influence of the concentration of calcium formate present was found by varying the amount added, while keeping the water and formaldehyde constant. Five c.c. of 31.5% CH_2O were added to 250 c.c of calcium formate and water.

The soda first reacts with the calcium formate, forming calcium hydrate and sodium formate. The calcium hydrate reacts with the

4. H. and A. Culer, Ber.d. D. Bot. Ges. 1905, 39, pp. 36, 39.

Water		c.c. of 10% $Ca\ CO_2$		c.c. of 3.5% Na HO required		Per cent. of formaldehyde polymerized
250	-	0.0	-	27.7	-	8
250	-	0.1	-	23.9	-	20
250	-	0.2	-	19.8	-	34
249.5	-	0.5	-	17.5	-	42
249	-	1.0	-	14.1	-	54
248	-	2.0	-	11.6	-	62
247.5	-	2.5	-	11.2	-	62
246.5	-	3.5	-	10.1	-	66
245	-	5.0	-	9.8	-	68
240	-	10.0	-	9.8	-	68
235	-	15.0	-	9.8	-	68
230	-	20.0	-	9.7	-	68
210	-	40.0	-	9.7	-	68

formaldehyde, forming calcium formate and polymerising a portion to sugar. No sugar condensation is produced by boiling formaldehyde with either calcium or sodium formates.

From the equation $2\ NaHO + Ca(COOH)_2 = CaH_2O_2 + 2\ NaCOOH$ 80 grams of soda = 130 grams of calcium formate $\therefore$ 10 c.c. of 3.5% NaHO = 5.7 c.c. of 10% calcium formate or 9.8 c.c.% of NaHO = 5.5 c.c. of 10% calcium formate. Hence maximum polymerisation is reached at a point where the soda and calcium formate are approximately equivalent. After that point an excess of calcium formate causes no increase in the percentage polymerisation. When still less calcium formate is present, the amount of soda required rises, more sodium formate being produced and less sugar.

An addition of 20 c.c. of 10% calcium formate causes an appreciable rise of the boiling point, and may be responsible for a slight loss of formaldehyde either as vapour or in the form of by-products other than sugar, and not involving any reaction with the calcium hydrate. Hence the slight decrease in the amount of soda required, which is in fact easily within the limits of error of the method used. In a further series of tests, the percentage of calcium formate was kept constant, and the amount of formaldehyde varied, 245 c.c. of water and 5 c.c. of 10% $CaCO_2$ were used in each experiment.

c.c. of 31.5 per cent. CH_2O		c.c. of 3.5 per cent. NaHO required		Per cent. of CH_2O polymerized
1	-	4.8	-	20
2	-	5.3	-	55
3	-	5.7	-	68
4	-	7.9	-	67.5
5	-	9.8	-	68
5.5	-	14.3	-	56
6	-	18.0	-	50
7	-	29.0	-	31

Apparently an excess of calcium formate interferes with polymerisation, when the formaldehyde is very dilute, while with the strong solutions since the 5 c.c. of 10% calcium formate requires 8.9 c.c. of 3.5% to convert it all into CaH_2O_2, portion of the 5.5, 6 and 7 c.c. of CH_2O has to be neutralised directly by the soda, and hence the percentage polymerization decreases.

Starting with 0.25 c.c. of 10% $CaCO_2$ and 0.5 c.c. of 31.5% CH_2O, and increasing or decreasing each proportionately, the following results were obtained :—

Water		c.c. of 10 per cent. $Ca(COOH)_2$		c.c. of 31.5 per cent. CH_2O		c.c. of 3.5 per cent. NaHO required		Per cent polymerization of CH_2O
249.55 c.c.	-	0.62	-	1.25	-	5.1	-	32
248.75 c.c.	-	1.25	-	2.5	-	6.4	-	56
247.5 c.c.	-	2.5	-	5.0	-	13.0	-	58
245.5 c.c.	-	5.0	-	10.0	-	27.9	-	54
242.5	-	7.5	-	15.0	-	49.0	-	46

On the basis that 1 molecule of CaH_2O_2 reacts with 9 molecules of CH_2O, then 1 c.c. of 10% $Ca(COOH)_2$ represents 0.66 c.c. of 31.5 CH_2O.

Hence the amount of calcium formate present is below that theoretically required, and a large portion of the CH_2O reacts directly with the soda, giving a low percentage polymerisation. Further, two standards were taken, namely, (A) 5 c.c. of 10% $CaCO_2$ to 3 c.c. of 31.5% CH_2O, and (B) 5 c.c. of 10% $CaCO_2$ to c.c. of 31.5% CH_2O. The amounts of each were increased or decreased proportionately to one another in the two sets of tests, A and B, and added to 250 c.c. of water.

A

c.c. of 10 per cent. $Ca(COOH)_2$		c.c. of 31.5 per cent. CH_2O		c.c. of 3.5 per cent. NaHO required		Per cent. polymerization of CH_2O
1.6	-	1.0	-	4.8	-	20
3.3	-	2.0	-	6.2	-	50
5.0	-	3.0	-	6.5	-	63
6.6	-	4.0	-	8.6	-	65
8.2	-	5 0	-	10.1	-	66
9.8	-	6.0	-	13.2	-	63
11.4	-	7 0	-	15.6	-	63
13.1	-	8.0	-	19.2	-	60

B

c.c. of 10 per cent. Ca $(COOH_2)$		c.c. of 31.5 per cent. CH_2O		c.c. of 3.5 per cent. NaHO required		Per cent. polymerization of CH_2O
1.88	-	1.5	-	7.1	-	20
2.5	-	2.0	-	6.4	-	45
3.75	-	3.0	-	7.4	-	60
5.0	-	4.0	-	8.2	-	62
6.25	-	5.0	-	9.4	-	68
7.5	-	6.0	-	11.0	-	70
8.75	-	7.0	-	16.1	-	61
10.0	-	8.2	-	18.5	-	61

A, contains very nearly the theoretical amount of Ca formate required for the production of pentose sugar (1 mol. Ca formate = 9 molecules CH_2O). If any hexose or disaccharide is formed, less calcium formate would be required for optimal polymerisation. The higher polymerization in B indicates that some hexose or disaccharide is produced. With the intermediate concentrations, the results are very consistent, varying less than 1 % in duplicate tests. At the extremes, however, the results obtained particularly at the lower extreme are apt to vary somewhat, however, carefully the tests are performed.

Evidently, too great an excess of calcium formate interferes slightly with polymerisation at the higher concentrations, whereas in lower concentrations the opposite effect appears to be exercised. The maximum polymerisation is given with concentrations corresponding to 0.62% to 0.75% solutions of formaldehyde.

When strong solutions of alkali are used , or when the formaldehyde is concentrated, portion of the alkali is apt to attack the sugar produced, decreasing the apparent polymerisation.

When calcium formate is present, however, and the soda is added gradually, the percentage polymerisation decreases less rapidly with increasing concentration.

Thus, adding 10% c.c. of 31.5% CH_2O to 50 c.c. of 10% $CaCO_3$ (6.3% CH_2O), 28.8 c.c. of 3.5% Na HO was required to complete the reaction, and an abundance of sugar was formed. In this case 52% of the 6% CH_2O was polymerised. Using a mixture of 50 c.c. of 10% $CaCO_3$, and 20 c.c. of 31.5% CH_2O, and running in 35% NaHO, it is necessary to obtain an approximately accurate result to keep the temperature below boiling point, and to shake vigorously after each addition of soda until the precipitated lime dissolves as formate. Even then the liquid becomes distinctly brown before all the formaldehyde has been removed. The amount of soda averaged 6.6 c.c., and 1 c.c. of CH_2O equalling 0.6 c.c. of soda, the percentage polymerisation was 45.

Polymerisation by other divalent alkaline metals

In the previous paper it was found that the presence of neutral barium, strontium or magnesium salts in boiling formaldehyde, to which caustic soda was added, increased the amount of polymerisation, and decreased the amount of soda required to neutralise the formaldehyde. Barium and strontium were not quite so effective as calcium, and magnesium had comparatively small effect. In these preliminary tests the importance of having a slight excess of the neutral formate present was not realised, and hence further estimations were carried out in the same manner as for calcium.

It is, however, difficult to obtain exact quantitative determinations owing to the delay in the completion of the reaction after each addition of soda. If the latter is added too rapidly, so that any precipitate forms, this only dissolves very slowly, and any undissolved precipitate represents so much neutralised caustic soda. If, however, the boiling is very prolonged, the liquid turns yellow, while still containing formaldehyde, and when the reaction is completed the liquid appears to contain more by-products other than sugar. At least the liquid from a reaction completed in two hours boiling contained from 5 to 10% more reducing sugar, as determined by the Pavy method, than one completed by six hours' boiling, and the latter required slightly less caustic soda, although all other conditions and quantities were the same.

For these tests it was found best to use a simple type of condensing flask, with the burette passing through the cork, and with an open upright tube 4 ft. long as the condensing column. Of the 500 c.c. of water used 100 c.c. was allowed to trickle slowly down this tube during the two-hour period over which the boiling, and addition of soda, were spread when strontium and barium salts were used. As the soda burette becomes slightly warmed during the boiling, its final reading must be checked after it has cooled to the original temperature.

Strontium.—Crystallised strontium formate was used as a 10% solution. The proportions used were 20 c.c. of strontium formate, 500 c.c. water, and 70 c.c. of 31.5 formaldehyde. The amounts of 3.5% sodium hydrate required varied from 20.8 c.c. to 21.2, representing an apparent polymerisation of formaldehyde of 65%.

Barium.—In the presence of barium formate, using similar quantities, the reaction was slighly more rapid. The amounts of soda required to neutralise all the formaldehyde varied from 20.4 to 20.9, representing a percentage polymerisation of formaldehyde of 65 to 66%.

Magnesium.—Owing to the highly insoluble character of the hydrate, its polymerising action is extremely slow, and quantitative estimations are difficult to obtain. A preliminary estimation was made, using an excess of the hydrate precipitated in the liquid by caustic soda. In this case the only advantage of using caustic soda is that the hydrate is precipitated in a more bulky and flocculent form than if the dry hydrate is used. From the amount of magnesium hydrate, remaining after all the fomaldehyde had been polymerised, the approximate amount required was estimated.

Using these proportions more exact estimations were made. The condensing flask was provided with a condensing tube 4 ft. long, which was sealed at the upper end as soon as the liquid had been brought to boiling point, and allowed to blow out to a thin safety bulb. The liquid was then kept just at the boiling point for several days. The liquid became brown before the end of each experiment.

In the presence of magnesium formate, 500 c.c. of water and 10 c.c. of 31.5% formaldehyde, after the addition of 23 c.c. of 3.5% sodium hydrate, a small amount of a white insoluble solid still remained after several days. This was not Mg H_2O_2, and was insoluble in dilute acid, the liquid was faintly acid, and still contained a small amount of CH_2O.

Using 750 c.c. of water, 15 c.c. of 31.5% CH_2O, a slight excess of magnesium formate and 40 c.c. of 3.5% NaHO, all the formaldehyde was removed, after boiling for 22 hours, the liquid was faintly acid, and contained a small amount of white solid, inconspicuous when suspended, but not consisting of Mg H_2O_2. This represents a percentage polymerisation of 58. A further test gave a polymerisation value of 57. As a small amount of the magnesium hydrate appears to form an insoluble compound, and as during prolonged boiling a trace of the formaldehyde is oxidised directly to formic acid, which represents a further direct removal of magnesium hydrate without producing any polymerisation, the polymerisation value of 57 to 58 for the divalent Mg corresponds fairly well with that of 65-68 for the divalent Ca. Ba. Sr, and contrasts sharply with the values for the monovalent K and Na of 8 to 14%.

Potassium.—On the basis of the conclusions given above, that the relative efficiency of calcium and sodium as polymerising agents depends upon the former being divalent, and the later monovalent, we should expect to find equivalent solutions of the monovalent metals, sodium and potassium, exercising a very much inferior polymerising action, and that in the presence of calcium formate it should be a matter of indifference whether sodium hydrate or an equi-molecular solution of potassium hydrate was used to bring about polymerisation.

As a matter of fact the correspondence is even more exact than might have been expected. Thus, using 250 c.c. of water to the proportions given the following were the results :—

c.c. of 10 per cent. calcium formate		c.c. of 31.5 per cent. CH_2O		c.c. of 3.5 per cent. NaHO required		Per cent. polymerization
10.0	-	5	-	9.8	-	68
0.0	-	5	-	27.7	-	8
0.0	-	4	-	22.6	-	6
				c.c. of 4.9 per cent. KHO required		
10.0	-	5	-	9.6	-	68
0.0	-	5	-	26.1	-	14
0.0	-	4	-	20.9	-	12

Non-reducing sugar.

In order to determine whether any non-reducing sugar was formed, to 50 c.c. of calcium sugar concentrated to a thick syrup, BaH_2O_2 solution was added. A small amount of white precipitate was formed. This was filtered, washed, and treated with CO_2. The filtrate contained a non-reducing sugar, giving reduction after boiling with a drop of H_2SO_4, and pink with resorcin and HCl., but no reaction with phenylhydrazin. Hence a small amount of disaccharide resembling cane sugar is formed, but the percentage is much less than 1%, and is greater if the boiling is prolonged during the production of sugar.

In sugar synthesis by Ba and Sr, a small amount of ppt. always forms, which does not dissolve even if boiled with excess of CH_2O. It yields sugar after treatment with CO_2, and is apparently a compound of a disaccharide with BaH_2O_2, or Sr H_2O_2. The amount is always small if the sugar condensation is carried out under proper conditions.

Fischer has shown that in the presence of acids condensation of disaccharides from mono-saccharides, particularly from levulose, is possible, and it seems probable that any disaccharides formed are not produced by directly polymerisation from CH_2O, but indirectly from the monosaccharides. Hence their appearance would not necessarily increase the apparent polymerising action of the alkali.

Reducing power of sugar syrup.

Although the synthetic syrup contains a mixture of sugars, it is of some interest to determine its reducing power in glucose equivalents.

The syrups were formed by running 4.9% potassium hydrate into boiling formaldehyde, containing calcium formate.

	Water		10 per cent. Ca formate		31.5 per cent. CH_2O		Amount req. of 4.9 per cent. KHO
A—	750	-	15 c.c.	-	15 c.c.	-	27.6 c.c.
B—	750	-	25 c.c.	-	15 c.c.	-	29.5 c.c.

10 c.c. of A were diluted to 50 c.c. with 10% NH_4HO, and titrated against 50 c.c. of Pavy's solution (8.316 grams copper sulphate per litre).

34.7 c.c. neutralised 50 c.c. of Pavy. There was no increase in the reducing power after boiling with citric acid.

After heating with 1 drop of HCl., 34.5 c.c. reduced 50 c.c. of Pavy

After heating with 5 drops of HCl., 35.4 c.c.=50 of Pavy.

After heating with 10 drops, 44.5 c.c. decolorised 50 c.c. of Pavy.

Hence a trace of non-reducing sugar may be present capable of inversion by HCl, but excess of HCl causes the decomposition of some of the sugar.

Repeating A and B several times, the maximal reducing action obtained was 33.5 c.c.=50 c.c. Pavy=0.025 gram glucose, and, therefore, the total bulk of 805 c.c. of syrup had a total reducing power equivalent to 1.348 gram of glucose. Since 15 c.c. of 51.5% CH_2O were used; in terms of glucose this would represent a sugar polymerisation of 29%.

In a test with caustic soda alone, 35% caustic soda was run into boiling 31.5% CH_2O. A yellow tinge appeared at once, but to neutralise all the formaldehyde 25 c.c. of 31.5% CH_2O required 14.8 c.c. of 35% NaHO. As 14.8 c.c. are equivalent to 23 c.c. of CH_2O, this represents a theoretical polymerisation of 8%. The liquid contained reducing sugar equivalent to 0.13 gram of glucose, which represents a polymerisation in terms of glucose of 2%. Owing to the strength of the alkali used, however, much of the sugar formed is caramelised.

The action of alkalies on the polymers of formaldehyde.

The concentrated aqueous solution of CH_2O is supposed not only to contain volatile CH_2O, but also hydrates such as $CH_2\begin{matrix}-O-H\\-O-H\end{matrix}$, and $(CH_2)_2O(OH)_2$. The latter is a non-volatile polyhydrate which leaves a waxy solid on complete evaporation, supposed to be diformaldehyde, "paraformaldehyde" $(CH_2O)_2$. The better known triformaldehyde or metaformaldehyde $(CH_2O)_3$ is stated to be distinguished from diformaldehyde by its subliming just over 100°C., whereas its M.P. is 171-172°C., and by its insolubility in water, alcohol and ether.

In contact with peroxides of Ba or Sr, and water, polymerised formaldehydes are catalytically changed into the simple form, and much heat evolved.

There appears to be some uncertainty as to the real nature of "paraformaldehyde," and as to how best to obtain it in pure form.

If a saturated solution of formaldehyde is evaporated by rapid boiling to $\frac{1}{5}$ its bulk, or a 30% to $\frac{1}{6}$ its bulk, and then allowed to cool, it sets as a white waxy solid. A solution containing 175 90°C., then giving off water and CH_2O, recondensing as a solution grams of CH_2O yielded 122 grams of this solid. It melts at of CH_2O, or escaping as gases. In a desiccator or in air it slowly loses water and CH_2O; after three weeks in a desiccator, losing 36% of its weight. If heated to just over 100° c.c. it boils, and after all the water has been driven off the residue sets to a harder waxy solid, with a specific gravity slightly greater than the hydrate (1.2). This gives off CH_2O vapour when heated.

Apparently the first solid obtained is the polyhydrate. This is, however, unstable. After two to three weeks in a dessicator, frequently exhausted by a Geryck pump, a considerable loss of water and CH_2O takes place (nearly 40%), and the residue sublimes on heating. The solid lost on the average 0.8% of its weight daily, until 38% has been lost, by which time the daily loss had fallen to 0.2%.

Both the polyhydrate and the "paraformaldehyde," when in mass, remain incompletely dissolved in cold ether, alcohol or water, even after three days, but in hot water or alcohol dissolve rapidly. On cooling the alcoholic solution, a larger proportion of white solid separates out, which blackens and gives a smell of ether, with warm strong H_2SO_4, and decomposes on heating. It is apparently a compound of CH_2O, with alcohol.

In the intermediate condition between hydrate and $C_3H^6O_3$. changes to CH_2O when heated in water to 130°C. Samples of $C_3H_6O_3$ prepared in various ways, were all found to dissolve slowly, after prolonged heating in excess of boiling water, when in the form of a fine powder. Large pieces, however, give for a considerable time the appearance of being insoluble.

In the intermediate condition between hydrate and $C_3H_6O_3$, it dissolves more readily in hot water than $C_3H_6O_3$, melts partially before subliming, and sublimes into oily drops, which set to a white wax on cooling. When conversion is complete the C_3H_6O, sublimes without melting, and deposits as a white solid.

The production of sugar from solids.

If dry $(CH_2O)_3$ is mixed with crystalline Barium hydrate (BaH_2O_2 8 H_2O) and ground intimately in a mortar, a pasty mass is obtained, smelling of CH_2O. If this is gently warmed at one point a sudden and violent exothermic reaction spreads through the mass, CH_2O, water vapour and methyl alcohol are given off, and the temperature rises to 100° C. or 110° C. if a large mass is used, with an excess of barium hydrate. The resulting brown, gummy residue contains no formaldehyde, but reducing sugar appears.

Similar reactions are given with strontium hydrate, but with dry calcium hydrate the reaction is imperfect. "Paraformaldehyde" and the solid polyhydrate may be used instead of metaformaldehyde. In the latter case the temperature does not rise beyond 100° C., owing to the large escape of steam.

Metaformaldehyde and alkali.

The solid was ground with dry barium hydrate in varying molecular proportions, and the pasty mass weighed out to contain in each case 0.45 gram $(CH_2O)_3$. After warming, the residue was dissolved in warm water, the Barium formate and any excess of Barium hydrate precipitated as sulphate, and the filtrate tested by the Pavy method. Any $(CH_2O)_3$ remaining is filtered off with the Barium sulphate, and if any CH_2O is present, the ammonia used the Pavy method. (Any $(CH_2O)_3$ remaining filtered off with the affect the tests foı reducing sugar. Similarly the formic acid is converted into ammonium formate. As a matter of fact the reaction is a very complete one, and with the proper proportion of barium hydrate every trace of formaldehyde is removed.

The following proportions were used :—

A and B.	1	Barium hydrate (0.85 gram)	to 1.8 $(CH_2O)_3$	(0.45 gram)
C	1	,, ,, (0.42 ,,)	to 3.6 $(CH_2O)_3$	(0.45 gram)
D and E.	1	,, ,, (0.28 ,,)	to 5.4 $(CH_2O)_3$	(0.45 gram)

with the following results—

Proportion	Final reaction	Loss of weight after warming	Mass	Reducing equivalent in glucose
A. 1 : 1.8	Strongly alk.	0.21	Brown	0.075 gram
B. 1 : 1.8	,, ,,	0.23	,,	0.074 ,,
C. 1 : 3.6	Less ,, ,,	0.23	Yellow	0.073 ,,
D. 1 : 5.4	Weakly alk.	0.17	White or	0.061 ,,
E. 1 : 5.4	,, ,,	0.14	pale yellow	0.066 ,,

In B and E the separated ground solids were mixed lightly but thoroughly, and then warmed. In E the mass was mixed and ground with a glass pestle, while the reaction was taking place.

Further investigation showed, however, that to obtain maximum polymerisation, with a minimum loss, quantities totalling not less than 2 grams must be used. Otherwise the reaction is not so complete, and hence the low production of sugar above. The results of three tests are given, the second with a sample of $(CH_2O)_3$ obtained from the Chemistry School, the first and third with samples prepared from a bulk sample supplied by Cuming, Smith's, and purified by sublimation. The proportions used were approximately 4 of $(CH_2O)_3$ to 1 $Ba\ H_2O_2$. In all three cases the residue was brown, contained no formaldehyde, and was weakly alkaline.

CH_2O_3		BaH_2O_2		Loss of weight		Reduction equivalent of residue in terms of glucose
1.25 gram	-	0.78 gram	-	0.38 gram	-	0.37 gram
1.25 ,,	-	0.78 ,,	-	0.33 ,,	-	0.39 ,,
2.5 ,,	-	1.56 ,,	-	0.78 ,,	-	0.72 ,,

This represents a polymerisation equivalent in terms of glucose of 30 to 32%. The maximum polymerisation in terms of glucose obtained when using boiling dilute formaldehyde was 29 to 30%. That is, in spite of the loss of formaldehyde vapour, more sugar is obtained from solid metaformaldehyde and crystalline barium hydrate than when the reaction is carried out with dilute solutions in water.

The last experiment (with 2.5 grams) was carried out in a small distilling flask. The distillate weighed 0.45 gram, so that apparently at least $\frac{1}{8}$ of the formaldehyde is lost as vapour. This would increase the actual polymerisation value in terms of glucose to 36%.

Even if an excess of Barium hydrate is used, so that no trace of formaldehyde remains in the residue, the filtered extract gives distinct aldehyde reactions, and hence presumably contains the biose sugar, glycollic aldehyde.

Paraformaldehyde and the polyhydrate.

The former was prepared by melting the latter and heating till water vapour ceased to escape. Similar results were obtained, but the production of sugar was less, and the hydrate gave off more water vapour during the strongly exothermic reaction.

$(CH_2O)_2H_2O$	Alkali		Loss of weight	Glucose equivalent of reducing sugar	Per cent. polymerization in terms of glucose
2.09 gram	SrH_2O_2	0.8 gram	0.63 gram	0.35	17%
1.53 ,,	BaH_2O_2 = 1	,,	0.55 ,,	0.34	22%
1.69 ,,	NaHO 0.5	,,	0.74 ,,	0.08	5%
$(CH_2O)_2$ 1.25 ,,	BaH_2O_2 1	,,	0.41 ,,	0.33	26%

In each case the amount of alkali was sufficient to remove all the formaldehyde. When sodium hydrate and the polyhydrate are pounded together, the reaction starts spontaneously, and is very violent. There is a heavy loss of formaldehyde vapour, and much of the sugar is caramelised. For this reason the percentage polymerisation is less than when a boiling dilute solution of formaldehyde is neutralised with dilute sodium hydrate.

If the reaction is started by locally warming several grams of the mixture in a small distilling flask, a large amount of distillate is obtained without applying further heat. This consists in the case of the polyhydrate (and crystalline Ba H_2O_2) of water, methyl alcohol and formaldehyde.

If a slight excess of the polydrate is used, the whole of the BaH_2O_2 is converted into barium formate. This can be obtained by dissolving the residue in a little water, and adding an equal bulk of alcohol. A large part of the sugar slowly settles out with some barium formate. On filtering after 48 hours standing, and doubling the bulk in the alcohol, a second ppt., mainly of barium formate, is produced, which can easily be washed and purified.

A point worth noting is that if the finely ground polyhydrate is mixed thoroughly with finely ground crystalline barium hydrate, the mixture smells strongly of formaldehyde, and its temperature falls 15°C. for some time. The temperature then slowly rises, but not appreciably above that of the room. The mixture slowly develops traces of reducing sugar, but does not undergo any complete reaction even after days in contact, until this is started by heating one point of the mixture.

A similar preliminary fall of temperature is shown with di- and tri-molecular formaldehyde. If, however, these are mixed with freshly slaked dry quicklime, or with powdered calcined barium or strontium hydrates, the mixture remains dry, the fall of temperature is hardly noticeable, and on heating the mixture locally the reaction does not spread. Only the parts heated turn brown, and methyl alcohol distils over (yielding methyl iodide with Iodine and red phosphorus). The residue contains an abundance of reducing sugar, but the reaction is imperfect, and is difficult to complete without overheating portion of the mixture, or volatilising much of the formaldehyde.

It is the presence of water of crystallisation in the crystalline barium hydrate which enables its reaction with solid polymers of formaldehyde to progress, and be completed throughout the whole mixture. Some of this water of crystallisation is liberated by mere contact with solid formaldehyde.

Summary of Results.

Cold dilute solutions of formaldehyde yield with alkalies, formates and methyl alcohol, sugar polymerisation being inappreciable. The reaction is incomplete after months in contact.

Maximum sugar production is given with boiling liquids, and the reaction is completed almost instantaneously.

The maximum sugar polymerisation varies from 68% (Ca), 66% Ba, 65% Sr. to 58% Mg. for divalent alkalies, and from 14% (K) to 8% (Na) for monovalent alkalies. The high polymerisation value (68%) estimated from the amount of alkali required for neutralisation indicates either that the pentoses and hexoses are produced directly, or that glycollic aldehyde is produced by the reaction yielding formates, and 3 or 4 of formaldehyde added to it without further decomposition of formaldehyde. This is also indicated by the appearance of pentoses. Polymerisation of biose would yield tetroses or hexoses, but not pentoses.

The greatly increased polymerisation when soda is run into a solution of formaldehyde containing calcium formate is merely due to the fact that calcium hydrate becomes the polymerising agent, and as a divalent metal exercises a greater polymerising action. There is no evidence of any katalytic action, as was formerly supposed.

In terms of glucose, the reducing sugars produced represented a polymerisation of 29% for calcium, and 2% for sodium. Apparently the sugars have half the reducing power of glucose.

The solid polymers of formaldehyde yield sugar readily, and abundantly, when in contact with solid alkalies. The most complete reaction is shown with the powdered crystalline hydrates of Ba and Sr. A feeble endothermic reaction precedes the violent exothermic one. The production of sugar is greater than with solutions, the polymerisation equivalent in terms of glucose being 30-32%.

In all cases the sugar is a by-product in a reaction, yielding formates and methyl alcohol. The alkali is used up and the amount of sugar formed is proportionate to the amount of alkali consumed. The reaction is, therefore, widely different from an enzymatic one. No mode of enzymatically polymerising formaldehyde to sugar is known, such as might occur in plants.

Conclusions.

The foregoing research was undertaken in order to elucidate certain points of interest to the plant physiologist concerning the possible modes in which plants could synthesize sugar from formaldehyde, which the purely chemical researches available did not appear to answer. It has led me to the conclusion that a production of formaldehyde does not form a stage in the synthesis of sugar by plants, and that it would be a very wasteful, indirect way of producing sugar.

The reasons on which this conclusion are based are as follow :—

(1) In 1908 I showed that when chlorophyll was oxidised in the presence of light, and in the absence of carbon-dioxide, one of its decomposition products was formaldehyde, and that this was the explanation of the appearance of traces of formaldehyde in green leaves exposed to light. This result has been confirmed by Schryver and by Jorgensen and Kidd.* Schryver stated that more formaldehyde was produced when carbon dioxide was present, but as the results of experiments extending now over ten years, there can be no doubt that the process is purely one of photo-chemical oxidation, and is not increased by the presence of CO_2.

(2) There are strong reasons for concluding that alkalies do not polymerise formaldehyde to sugar, or only to a very slight extent, but instead produce methyl alcohol and formates. Pronounced sugar formation only takes place when the alkali acts on a polymer, such as paraformaldehyde, the polyhydrate, or metaformaldehyde. The production of sugar from a solution of formaldehyde mainly depends on the presence of the polyhydrate in the solution. With cold dilute solutions the production of sugar is almost negligible. For a complete reaction and high polymerisation a temperature of 90°C. to 100°C. is necessary. Even then the polymerisation is only partial, and formates and methyl alcohol are formed in large amount. These are not known to accompany photosynthesis in plants.

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* Ewart, Proc. Royal Soc. Lond., B 1908, Vol. 80, p. 30; Schryver, *ibid.* 1910, 82, p. 226; Jörgenson and Kidd, *ibid.* 1917, 89, p. 342.

(3) Every method of polymerising formaldehyde to sugar yields a mixture of sugars, in which pentoses are included, and often form the main yield. Pentoses are not direct products of photosynthesis in plants, but instead hexoses and their 6 or 12 carbon derivatives, starch and polysaccharides.

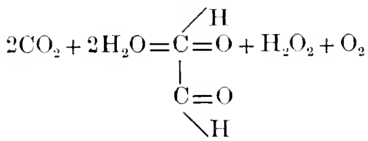
(4) It is as easy for the plant to produce sugar directly as to produce formaldehyde. Thus taking the process in three stages—

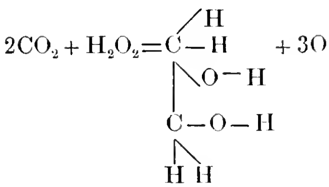
$$\left\{\begin{array}{ll} CO_2 + H_2O & = CHO + HO + O \\ CO_2 + HO + H_2O & = CH_2HO + 3O \\ CHO + CH_2HO & = \begin{array}{l}CHO\\ CH_2HO\end{array} \end{array}\right. \quad \text{Biose sugar.}$$

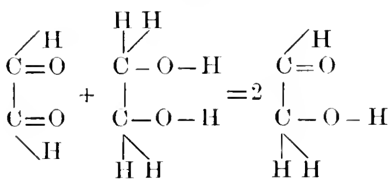
or in one stage:—

$$2CO_2 + 2H_2O = \begin{array}{l}CHO\\ CH_2HO\end{array} + 2O_2$$

The equation could also be represented as in 1, 2, 3.

(1) 

(2) 

(3)  Biose.

(5) This Biose sugar (glycollic aldehyde) is readily polymerised by sodium carbonate to acrose, a hexose sugar.

(6) This mode of producing sugar would be endothermic, as in the plant. The production of sugar from the polymers of formaldehyde involves an exothermic reaction which, under appropriate conditions, is very violent.

(7) Magnesium hydrate has a slower polymerising action on formaldehyde than any other metallic alkali. Since the presence of magnesium in chlorophyll is hardly accidental, its relations to glycollic aldehyde when it is in organic combination merit future

investigation. For it to be able to act as a polymeriser in the plant, it must act in ferment fashion without itself being altered or brought permanently into different combination. That is the polymerising action must differ widely from that of alkalies on formaldehyde and its polymers.

(8) If photosynthesis involves an actual combination of chlorophyll and carbon dioxide, which combination is distintegrated by light into chlorophyll and carbohydrate, hexoses would be formed as readily directly as through the intervention of biose and the chlorophyll would act as a lytase or carboxidase enzyme.* Its mode of action in producing glycollic aldehyde would also be that of an enzyme.

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* Proc. Royal Soc. of Vict. 1918, Vol. xxx. p. 208.

[Proc. Roy. Soc. Victoria, 32 (N.S.), Pt. II., 1920].

Art. XIV.—*Contributions to the Flora of Australia, No. 28.*

BY

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AND

J. R. TOVEY,

(Assistant, National Harbarium, Melbourne).

(With Plate XII.)

[Read October 9th, 1919.]

Acacia dawsoni, R. T. Baker. (Leguminosae).

Mitta Mitta, Mr. Clinton, Nov., 1918.

New for Victoria.

Acacia leprosa, Sieb. "Leper Acacia." (Leguminosae).

Between Eaglehawk and Sydney Flat, Victoria, David J. Paton, August 23rd, 1919. An unrecorded locality in Victoria for this plant.

Adriana, Gaud. (Euphorbiaceae).

Pax in Engler's Pflanzenreich, IV., 147-II., pp. 17 to 21 (1910) practically agrees with Bentham's arrangement of the genus *Adriana*. Maiden, in his Census of New South Wales Plants, follows them.

Distribution of Adriana.

A. glabrata, Gaud. V., N.S.W., Q., N.A.

A. glabrata, var. acerifolia, Pax. (A. acerifolia, Hook). V., N.S.W., Q.

A. glabrata, var. Cunninghamii, Müll. Arg. V.

A. glabrata, heterophylla, Müll. Arg. V.

A. tomentosa, Gaud. W.A., N.A.

A. Hookeri, Müll. Arg. (incl. 2 varieties). V.

A. quadripartita, (Lab.) Gaud. W.A., T., V.

A. Klotzschii, (F. v. M.) Müll. Arg. S.A., V.

In Mueller's Second Census, the foregoing species are reduced to two, but as they are all readily distinguished from one another they must be kept separate.

AGROSTIS LACHNANTHA, Nees. (Gramineae).

Dookie, Victoria, W. D. Wilson, February, 1911. Canterbury and Mitcham, Victoria, R. Ardagh, December, 1918.

This useful pasture grass, a native of South Africa, is now apparently establishing itself as a naturalised alien in Victoria.

AIZOON ZYGOPHYLLOIDES, F. v. M. (Aizoaceae).

This species was recorded in the Victorian Naturalist, Vol. XVII., p. 203 (1901), as being new for Victoria. This was evidently an error, as the specimens from Corio Bay, Geelong, Jan., 1901, on which the record was founded, proved on examination to be Mesembryanthemum angulatum, Thunb., a native of South Africa, which has been recorded as an introduction at Coode Island, in Victoria. (Collected by J. R. Tovey, 1908.) Aizoon zygophylloides is only found in West and South Australia, New South Wales and Queensland.

ALHAGI CAMELORUM, Fisch. "Camel Thorn" (Leguminosae).

Tongala Irrigation District, Victoria. E. Kendall, 13/1/1920.

This plant, a native of Central Asia and the Orient, was previously recorded as growing wild in Victoria from the North-eastern district. It is now evidently spreading westward.

AMARANTHUS DEFLEXUS, L. (Amarantaceae).

Elwood, Victoria, E. J. Semmens, November, 1917.

Another locality in Victoria for this weed. It is a native of Europe, and is now apparently in the process of naturalisation in this State.

ARUNDO PHRAGMITES, L. (Phragmites communis., Trin.)
"Common Reed." (Gramineae).

Daly River, Northern Territory, May, 1919.

Probably fairly common in the Northern Territory, but only previously recorded from Port Darwin, M. Holtze, 1889. It may possibly in some cases be included under the name Arundo Roxburghii, F. v. M. The plant is used for thatching hay ricks and sheds in Victoria. It has a certain fodder value when young, and may have other economic uses.

BASSIA QUINQUECUSPIS, F. v. M. var. villosa, Benth. (Anisacantha muricata, Moq.) var. villosa, Benth. "Spear-fruited Saltbush". (Chenopodiaceae).

Sedgwick, near Bendigo, E. J. Semmens, 24/10/1919; Numurkah Shire, per Department of Agriculture, Nov., 1919.

This plant is now evidently spreading eastward in Victoria, having been previously recorded from the North-West District only.

BRACHYCOME MICROCARPA, F. v. M. (Compositae).

Ti-tree Creek to Orbost, Mr. Sayer, 1887, Cann River, H. B. Williamson, Jan., 1918.

New for Victoria.

BROMUS CEBADILLA, Steud. "Chilian Brome Grass" (Gramineae).

East Caulfield, Geo. Seymour, 17/12/1919.

This grass, a native of Chili, may be classed as an exotic not yet sufficiently established to be considered naturalised.

BUCHANANIA OBLONGIFOLIA, W.V. Fitzg. Royal Society of W.A., III., p. 65, 1918. (Anacardiaceae).

A specimen from Robinson River, King's Sound, 1888, G. Poulton, was identified by Mr. Fitzgerald as B.oblongifolia before this species was published. It agrees with the specimens quoted in the Flora of the Northern Territory, pp. 171-172, as Buchanania Muelli var pilosa. The specimens hardly appear to be sufficiently distinct from the forms of Buchanania Muelleri to justify raising a new species, B. oblongifolia, W. v. F.

CALEANA MINOR, R. Br. "Small Duck Orchid" (Orchidaceae).

Sperm-whale Head, South-east of Lake Victoria, Gippsland, T. S. Hart, 12/12/1919.

This orchid has not been previously recorded so far east in Victoria.

CALOCHILUS CUPREUS, R. S. Rogers. "Copper Beard." (Orchidaceae)

A new orchid from South Australia, described by Dr. Rogers in the Proceedings of the Roy. Soc. of South Australia, collected for the first time in Victoria near Boronia Peak, Grampians, by J. W. Audas, 2/11/1918.

CALOSTEMMA PURPUREUM, R.Br. "Garland Lily."
(Hydrocharitaceae).

Lake Hattah, J. E. Dixon, April, 1919.
A definite locality in Victoria for this plant.

CASSYTHA. (Lauraceae).

In regard to the germination of seed of Cassytha, Mr. C. C. Brittlebank writes as follows:—

"About eleven or twelve years ago, at Myrniong, I obtained numbers of young seedling plants in all stages of growth from seeds just sprouting, rooted seedlings, and even plants, which had become fixed to young gum twigs. In several seedlings, which had reached this stage, the lower part had withered, but in some cases the plant had broken at the base. As to the conditions prevailing prior to and during the observations. A bush fire had passed through the stunted gum scrub, which was heavily loaded with Cassytha. Both host and parasite had been destroyed by the fire. Heavy rain fell shortly after, and continued to do so at intervals. The burnt gums sent out sprouts from their bases, and it was upon these young suckers that the more mature seedlings had become attached. This was the only time that I ever saw the seedlings of this plant, and it was due to this that I so carefully observed them." Evidently the germination of Cassytha is rare, owing to its hard seeds, and in this case the heat of the bush fire softened the seed coats and hence caused the absorption of water and germination of the seeds. The duration of the seeds in the soil is not known, but some buried in the soil of a pot for three years were found to be capable of germinating after being filed.

Mr. T. S. Hart has also forwarded me seedlings of C. melantha, found growing wild near Bairnsdale, in October, and apparently germinating naturally. It is possible that the difficulty of finding seedlings may be due to the fact that germination only takes place naturally during one month in the year, and that the rooted attachment is soon lost.

CASUARINA HELMSII. Ewart and Gordon, n.sp. (Casuarinaceae).

Gnarlbine, W. Australia, R. Helms, 12/11/91. Eucla, W. Australia, J. D. Batt, 1886. (See Plate XII.).

This plant was named C. humilis by Helms, but has terete instead of angular branches. The following is the description:—

A small tree from 5-8 feet in height. Branchlets are from 4-4½ in., and branches slender. The sheath-teeth vary from six to seven in number.

Fruit cones are cylindrical, and very regular, about ½-in. in diameter, and 1-in. long. The valves do not protrude beyond the surface, which is nearly smooth, and quite glabrous.

The seeds are small and red. They are much more pointed than those of C. humilis, and smaller.

Deviations from C. humilis.

(1) Branches.—These are much more slender, and the branchlets are about twice as long, though with shorter internodes and smaller diameter; they are also less angular than C. humilis. The colour of the branchlets is more greenish than grey.

(2) Fruits.—The cones are shorter and less rugose, the valves and markings are more regularly arranged, and the valves do not open as widely. The seeds are small, red and pointed, while those of C.humilis are larger, black and blunt.

COLLOMIA COCCINEA, Lehm. ex Benth. "Scarlet-flowered Collomia." (Polemoniaceae).

Mandurang, Hintiraecku (without date), Bendigo, E. J. Semmens, Nov., 1919.

This plant, a native of Chili, is an exotic, found growing wild, but not yet sufficiently established to be considered naturalised.

CREPIS SETOSA, Hall, f. "Hairy Crepis." (Compositae).

Ballarat, Victoria, E. J. Semmens, March, 1913.

This plant, a native of Europe and Asia Minor, may be classed as an exotic, not yet sufficiently established to be considered naturalised. It is a weed of cultivated and waste places, and takes up the place of useful vegetation, and should be suppressed.

CROWEA SALIGNA, Andr. (Rutaceae).

Pine Mountain, Upper Murray River, Vic., C. Walker, Oct., 1891.

CYTISUS LINIFOLIUS, Lam. "Flax Broom." (Leguminosae).

Roadsides, at Ararat, E. J. Semmens, October, 1918. Another locality in Victoria for this introduced plant.

ECHIUM VIOLACEUM, L., or Echium plantagineum, L.
"Paterson's Curse." (Boraginaceae).

After the last visit of the British Association some doubt was raised as to the correct name for the above plant, and it was even suggested that it might be Echium italicum. The latter suggestion was, however, merely due to the plant having been seen in fruit only. To decide the former question specimens were submitted to Dr. Lacaita, who has been specialising on the genus Echium. In his reply given beneath, the decision is made that the name given to the plant by Bentham in 1869, and under which the plant was proclaimed, is not correct, and that the name should be Echium plantagineum. As the point is one of some importance, Dr. Lacaita's reasons are given in full:—

"As to Echium plantagineum and Echium violaceum, the plant often called violaceum, especially by English botanists, is, as you rightly say, identical with E.plantagineum, but it is not E.violaceum,L. The violaceum of Sp. Pl. is a muddle of two species, quite unlike each other, neither of which is E.plantagineum. The synonyms all refer to E.rubrum, Jacq., a very distinct species. It is the only Echium with a clubbed instead of a trifid stigma. The definition of the genus both in Bentham and Hooker, and in Engler, requires modification in that respect. But the observation describes a plant cultivated in Hort. Uppslana, which is represented by the specimen in the Linnean Herbarium. This plant is neither rubrum, nor, as pointed out by Moris in his Flora Sardoa long ago, is it E.plantagineum (E.violaceum auctt. plur.). Moris says it is very like the Sardinian (and Italian) plant known as E. pustulatum S. and S. It is very like it, but as far as I can form an opinion without dissection of the corolla, which is inadmissable in Linnean type specimens, it is more probably the Portuguese and Spanish E. rosulatum, Lange, which, to this day, is grown at Kew, and taken under the misnomer of "E. plantagineum," or "E. creticum."

It is curious that Linneaus should never have recognised E. rubrum, for there are three fine examples of it in his herbarium, two sheets being loose, but the third is pinned to the sheet of E. italicum. None of these three sheets bears any writing of Linneus, who left them undetermined.

E. plantagineum is always easily recognised by—

1. Plantain-like basal leaves.
2. Amplexicaul upper leaves.
3. Peculiar thin texture of corolla in dried plant.

4. Corolla glabrous, with long hairs on the nerves and ciliate, not velvety pubescent all over, as in all species for which it could be mistaken.
5. Leaf indumentum homogeneous; the tubercle at base of hairs conspicuous or inconspicuous, but no carpet of close short pubescence beneath them.

It appears, therefore, that the name E. violaceum, under which Paterson's Curse was originally proclaimed, must now revert to E. plantagineum L.

EUCALYPTUS MITCHELLIANA. Cambage. Willow Gum. (Myrtaceae).

Near Chalet, Buffalo Mountains. An addition to the Flora of Victoria. The plant was originally named E. Mitchelli, but this name is already pre-empted for a fossil Eucalyptus (Journ. Royal Soc. of N.S. Wales, Vol. LII., p. 57, 1919.)

EUCALYPTUS WOOLLSIANA, R. T. Baker. (Myrtaceae).

About seventeen miles east of Nowingi Railway Station, North-West Victoria. (L. G. Chandler, 24/9/1919.)

This Eucalypt has not been previously recorded as growing indigenously in Victoria.

FICUS MACROPHYLLA, Desf. "Moreton Bay Fig." (Moraceae).

From the base of a large tree in the University grounds, in November, 1914, the bark was removed, and two inches of the outer wood. The tree attempted to send down roots from the cut surface at one point. These were cut off. During the first two seasons the foliage of the tree was quite normal. Later the leaves began to fall more rapidly than new ones were produced, and branch after branch died. During the first season the amount of latex increased markedly, after the second season it steadily decreased. The tree was not entirely dead until the declaration of Peace in May, 1919. It, therefore, lasted four and a-half years after being rung. During this time the wood remained moist and sappy to the heart of the tree, and it continued to grow on the upper part of the tree, above the ringing, but ceased to grow on the basal portion of the trunk. At the end of the four and a-half years the roots were found to be entirely dead, whereas above the ringing, the bark at one or two points still shewed signs of life. On examining the wood it was found that although the apparent rings are regular and well defined, they are not annual rings. The tree could not have been planted more than fifty-five years ago, probably not more than fifty years ago. On some of the projecting buttresses the rings totalled from 220 to 263. The smallest number between the buttresses was 121. The tree can, therefore, form two to four rings in one year. These narrow rings are formed of alternate layers of wood fibres mixed with vessels, and of thin walled, rounded, almost parenchymatous cells resembling somewhat tangential medullary rays. If the cross section is examined from a distance sufficient to obscure the narrow rings, the broader annual rings can be distinguished. The number of these was 46, and in the buttresses they were broader and included more of the narrower rings.

The death of the tree was due not to any interruption of the water supply, but to the starvation and death of the roots. The wood of the Moreton Bay fig apparently retains the power of conducting water indefinitely, or at least, up to an age of 40 or more years.

Gleichenia Hermanni, R.Br. = G. linearis, Clarke. (Filicales).

As there are no Victorian specimens of this plant, it cannot be retained in the Flora of Victoria.

Gleichenia laevigata (Willd), Hook. (Filicales).

There appears to have been some confusion regarding the nomenclature of this fern. In "Hooker's Synopsis Filicum," G. laevigata is given as a synonym to G. flagellaris, Sprengl., but in Christensen's "Index Filicum," they are kept distinct. See also "Domin. Prod. Farnfl. Qld. 205, Rosenburgh, in his Handbook of Malayan Ferns, adopts G. laevigata, Hook, for the Malayan specimens. The typical G. flagellaris, Spreng. is a native of Mauritius only, whilst G. laevigata is a Malayan fern extending to Australia. Some specimens of G. laevigata have also been confused with G. flabellata, R. Br. — those labelled G. flabellata and given in Bentham's Flora Australiensis, Vol. VII., p. 698 (1878) under Victorian localities, proved to be G. laevigata, Hooker.

The distribution of G. laevigata, Hook, and G. flabellata, R. Br., in Australia, appears to be limited to the Eastern and Northern portion—i.e., Tasmania, Victoria, New South Wales, Queensland, and Northern Australia.

GNAPHALIUM INDICUM, L. "Indian Cudweed." (Compositae).

Near Station Peak, Victoria, without collector's name or date. This species has not been recorded previously for Victoria.

GOODENIA ARTHROTRICHA, F. v. M., ex Benth. Fl. Austr. IV. 62 (1869) =G. Bonneyana, F. v. M., Fragm. VI. 226 (1868), t. LIII.. (Goodeniaceae).

The above is given by Krause in Engler's Pflanzenreich IV., 277, p. 63 (1912).

The description of G. Bonneyana was published a year earlier than that of G. arthrotricha, hence G. Bonneyana has priority, and is therefore a valid species, with G. arthrotricha as a synonym.

Distribution.—Western Australia.

GOODENIA GENICULATA, R.Br. (Goodeniaceae).

K. Krause, in his Monograph of the Goodeniaceae, in Engler's Pflanzenreich IV., 277, pp. 52, 3, 4 (1912), divides the above species into five different species, i.e., G. geniculata, R. Br., G. primulacea, Schlechtd., G. robusta, Krause, G. affinis, De Vriese, G. lanata, R. Br. Of these some of the forms of G. primulacea cannot be readily distinguished from some of those of G. geniculata, hence G. primulacea can only be considered to be a variety of G. geniculata, i.e., G. geniculata, R. Br. var. primulacea, Benth, as given in Benth, Fl. Aust. IV., p. 63 (1869).

Krause gives the distribution of G. primulacea from South Australian localities only, but we have specimens from Victorian and New South Wales localities, which agree exactly with the above, and must be placed under the variety primulacea.

The distribution of the foregoing species are :—G. geniculata, R. Br., South Australia, Tasmania, Victoria, New South Wales, and Queensland.

G. geniculata, var. primulacea, Benth, South Australia, Victoria, New South Wales.

G. geniculata, var. heterophylla, F. M. Reader, Victoria.

G. robusta, Krause, South Australia, Victoria.

G. affinis, De Vriese, Western Australia.

G. lanata, R. Br., Tasmania, Victoria, New South Wales.

GOODENIA GRANDIFLORA, Sims. (Goodeniaceae).

In Engler's Pflanzenreich IV., 277, p. 75 (1912), Krause reduces G. albiflora, Schl., G. Chambersii, F.v.M., G. Macmillanii, F.v.M., and G. Nicholsonii, F.v.M., to varieties of G. grandiflora, Sims.

G. albiflora and G. Chambersii seem to be fairly distinct, and may for the present be classed as valid species.

G. Macmillanii and G. Nicholsonii may be placed as varieties of G. grandiflora, thus adding this species to the list of Victorian Flora.

Distribution.

G. grandiflora, Sims, Western Australia, South Australia, New South Wales, Queensland, Northern Australia.

G. grandiflora, var. Macmillanii, Krause, Victoria.

G. grandiflora, var. Nicholsonii, Krause, South Australia.

GREVILLEA RAMOSISSIMA, Meisn. "Branched Grevillea." (Proteaceae).

Buchan, East Gippsland, Miss Margaret McRae, 15/12/1919.

This plant has only been previously recorded from the North-Eastern districts.

GREVILLEA ROSMARINIFOLIA, Cunn. "Rosemary Grevillea." (Proteaceae).

Whipstick Scrub, Neilborough Road, north of Eaglehawk, Victoria, David J. Paton, 7/9/1919.

This species has usually reddish flowers, but the flowers of the above specimen were of a greenish yellow colour, but turned a dark colour when drying.

HAKEA FLEXILIS, F. v. M. "Flexile Hakea" (Proteaceae).

This is a valid species, and is a native of Victoria, New South Wales and South Australia.

HAKEA SERICEA, Schrad. (1795). (H. ACICULARIS, R.Br., 1809).

Hence H. sericea has priority over H. acicularis.

HELIPTERUM MICROGLOSSUM, Maiden and Betche. (Compositae).

As there are no Victorian specimens of this species, the name must be deleted from the Flora of Victoria.

HYBANTHUS FILIFORMIS, F. v. M. "Slender Violet." (Violaceae).

Mitta Mitta, S. F. Clinton, October, 1919.

Not previously recorded for the North-Eastern district of Victoria.

HYPOLEPIS TENUIFOLIA, Bernh. "Soft Hypolepia." (Filicales.)

Raymond Creek, near bridge of Old Cann Road, East Gippsland, George E. Harrison, 1/1/1917.

This is a definite locality in Victoria for this plant.

INULA GRAVEOLENS, Desf. "Stinkwort." (Compositae).

Nowa Nowa, Gippsland, Victoria, Hon. James Cameron, April, 1919. This proclaimed pest is gradually extending eastward in this State.

ISOPOGON ANEMONIFOLIUS, Knight. "Tall Conebush." (Proteaceae).

Near Providence Ponds, West of Fernbank Railway Station, Gippsland, Victoria, T. S. Hart, 15/11/1919.

A definite locality in Victoria for this plant. Although the plant is given in F. v. Mueller's Census, there were no specimens in the Herbarium, and Bentham gives it as from New South Wales only.

JASMINUM LINEARE, R.Br. "Desert Jasmin." (Oleaceae).

North-east of Lake Hattah, Vic., J. E. Dixon, April, 1919. A definite locality in Victoria for this plant.

LASIOSPERMUM RADIATUM, Trev. "Royal Down Flower." (Compositae).

Near Ballarat, H. B. Williamson, Feb., 1914.

This plant, a native of South Africa, has now apparently established itself as a naturalised alien in the above district.

LORANTHUS (Loranthaceae).

Hill's Northern Territory specimens No. 303 and 421, which were labelled Loranthus dictyophlebus, are considered by Mr. Maiden to be Loranthus Exocarpi, Behr, var. spathulata, Blakely; also Hill's No. 539, labelled L. longiflorus, Desr., he considers to be L. odontocalyx, F. v. M.

LORANTHUS LONGIFLORUS, Desr. "Long-flower Mistletoe." (Loranthaceae).

Genoa, Victoria, Rev. A. J. Maher, Nov., 1918.

New for Victoria.

LOLIUM SUBULATUM, Vis. "Wimmera Rye Grass." (Gramineae).

Nhill, January, 1919, A. J. Mullett.

This is a new record as a naturalised alien in Victoria. It is stated to have spread from a patch planted near a dam twenty-three years ago at Minyip, and now covers several hundred acres. It has been found at various localities in the Wimmera, including Nhill, Warracknabeal, and has apparently been confused with some of the numerous forms of English Rye Grass, Italian Rye Grass, Western Wolths, etc.

It is a native of South Europe, but it does not appear to be common, or to have been investigated economically. Mr. Mullett informs me that it has a high carrying capacity for stock, maintains itself readily by seed, but is injurious to wheat cultivation. The grass appears to be more vigorous and larger in the Wimmera than in its native home. Hence specimens were sent to Professor Hitchcock, United States Agrostologist, who confirms the above identification.

It is possible that forms might be raised from this grass suitable for Central Australian regions, as a drought resistant grass. Information in regard to the properties of this grass is given by Mr. Mullett in the May number of the "Agricultural Journal of Victoria," 1919.

Lonicera japonica, Thunb. (Caprifoliaceae).

Ararat Creek, Narnargoon, Victoria. J. W. Audas, Nov., 1919

A garden escape spreading along the creek and possibly in the process of naturalisation.

Microcala filiforms, Hoff. and Link. "Slender Microcala."

Langwarrin, Victoria, Ed. E. Pescott, Oct., 1919.

A native of Europe, previously recorded as naturalised in the Western District of Victoria only.

Microcybe pauciflora, Turcz. (Rutaceae).

Localities.—Western Australia, Drummond, 5th Collection, n 209, South Coast, R. Brown, East Mount Barren, G. Maxwell.

South Australia.—Near Lake Hamilton, C. Wilhelmi; Port Lincoln, C. Wilhemi; Port Lincoln, S. S. Browne; Venus Bay, Col. Warburton; Kangaroo Island, O. Tepper.

Victoria.—N.W. of Lake Albacutya, C. French, senr.; Murrayville, H. B. Williamson.

Microcybe multiflora, Turcz. (Rutaceae).

Localities.—Western Australia, Drummond 5th Collection n. 211. North of Sterling Range, and west of Blackwood River, Muir; between Dundas Hills and Lake Lefroy, J. D. Batt; between Eucla and Fowler's Bay, Miss S. Brooke; Eucla, W. Webb, also J. D. Batt.

South Australia.—Moonta, Beythien, Kangaroo Island, O. Tepper; Sedan, Rothe.

Victoria.—Nhill, St. Eloy D'Alton; N.W. of Lake Albacutya and beyond Lake Hindmarsh, C. French; Mallee, C. Walter; Wimmera, C. S. Sutton, C. French, junr.

M. MULTIFLORA, var. baccharioides.

Near Fowler's Bay, W.A. E. Giles; near Port Eucla, W.A., Forrest; Gawler Ranges, S.A., Dr. Sullivan.

MICROCYBE ALBIFLORA, Turcz. (Rutaceae).

Locality.—Western Australia; Drummond, 5th Collection, n. 210.

The foregoing species were associated together by Baron von Mueller, under the heading of Eriostemon capitatus. The distinction of Microcybe from Eriostemon is not only a convenient one, but is based upon clear and definite scientific distinctions. Of the three forms included by Baron von Mueller under E. capitatus, all are valid as distinct species under Microcybe.

MURALTIA HEISTERIA, D.C. "African Furze." (Polygalaceae).

Norton's Summit, about eight or nine miles from Adelaide, Sth. Australia, per A. G. Edquist, July, 1919.

This hardy evergreen shrub, native of South Africa, is evidently a garden escape, and may become a pest if allowed to spread.

MYOSOTIS AUSTRALIS, R.Br. "Austral Forget-me-not." (Boraginaceae).

Wedderburn, Victoria, W. W. Watts, October, 1918.

A new locality in Victoria for this plant.

NOTHOSCORDUM FRAGRANS, Kunth. "Wild Onion or Scented Nothoscordum." (Liliaceae.)

Cawley's Creek, Timboon, per W. A. N. Robertson, 23/10/1919.

This plant, a ative of North America, recorded as a garden escape in the Vict. Nat., XXIV., p. 193 (1905), may now be considered to be established as a naturalised alien in this State.

OXALIS PURPURATA, Jacp. (Oxalidaceae).

Drouin, Victoria, Nov. 1919, C. French, Junr.

Recorded previously as a garden escape, and now reported as common at Drouin. This plant, a native of South Africa, is evidently in process of naturalisation.

PANICUM PARVIFLORUM, R.Br. (Gramineae).

As there are no Victorian specimens of this plant, it must be deleted from the Flora of Victoria. Its original admission was due to an error. (See Vict. Nat. XXIV., p. 87, 1907.)

PHEBALIUM OBCORDATUM, Cunn. (Rutaceae).

Whipstick Scrub, Neilborough Road, North of Eaglehawk, Victoria, David J. Paton, 7/9/1919.

This species has only previously been recorded from New South Wales. There is a specimen in the National Herbarium labelled in the late Baron von Mueller's handwriting as Eriostemon Mortoni, from Sandhurst, Victoria, September, 1877, without collector's name. E. Mortoni, F.v.M., is a synonym to Phebalium obcordatum, Cunn. The Baron apparently neglected to record it for Victoria.

PHORMIUM TENAX, Forster. "New Zealand Flax." (Liliaceae).

Cawley's Creek, Timboon, per W. A. N. Robertson, 23/10/1919.

This plant, a native of New Zealand, which is often cultivated in gardens, is stated to be growing wild at the above locality.

PIMELEA FLAVA, R. Br. (Thymelaeaceae).

Bentham gives the flowers as being male and female. In Moore's Flora of New South Wales, this character is used in diagnosis in the Keys. In a large number of specimens recently examined in class it was noticed uniformly that each head contained a number of male flowers, and a few fruiting flowers, but that all the latter contained two well developed and apparently fertile stamens. The flowers may, therefore, be either male or hermaphrodite. There appears, however, always to be a larger number of male flowers in the head than of the "female," or hermaphrodite, flowers.

PLAGIANTHUS MONOICA (R. Helms M.S.). Ewart, n.sp. (Malvaceae).

Near Lake Deborah, West Australia. Collector, R. Helms. 1891.

This undescribed plant had the above MS. name, without any author, attached. It is a shrubby plant, covered with a pale, close, short tomentum, easily rubbed off or scraped off, leaving a brown surface on the branches. The leaves are long, narrow, sessile, nearly linear, with ventrally inrolled edges, 3-5 centimetres long, averaging about 2 mms. broad. The flowers are in terminal leafy cymes, usually of 3-6 flowers. Carpels, 3, rarely 2, one-seeded. Styles 3 (or 2) forking dichotomously into 6 (or 4) (Ureneae). Flowers male and female. Staminal column bearing anthers to the summit (Malveae). In the female flowers the petals are stiff, scarious scales covered with hairs. In the male flowers the petals are normal.

Although the character of the styles is peculiar, the plant appears to belong to Plagianthus, and it may be placed next to P. squamatus.

POLYPOGON LITTORALIS, Sm. "Perennial Beardgrass." (Gramineae).

Fisherman's Bend, Port Melbourne, Victoria, A. O'Brien, 18/11/1919.

This species is a native of Europe; has been recorded as introduced in Queensland and West Australia. It has now made its appearance in Victoria for the first time. In its native home it grows in salt marshes along the sea coast. It is not likely to prove of much value as a pasture grass.

PULTENAEA POLIFOLIA, Cunn. "Dusky Bush Pea" (Leguminosae).

Mitta Mitta, S. F. Clinton, Nov., 1918.

New for Victoria.

PULTENAEA PROCUMBENS, Cunn. "Curl-leaf Bush Pea." (Leguminosae).

Mitta Mitta, S. F. Clinton, Nov., 1918.

New for Victoria.

RANUNCULUS MUELLERI, Benth. "Felted Buttercup." (Ranunculaceae).

"Flourbag," Bright-Omeo Road, 4600 ft., Nov. 20, 1918, D. J. Paton.

In Mr. Williamson's paper on doubtful Victorian Plant records, it was pointed out that Ranunculus Muelleri was only represented in the Herbarium from the doubtful locality, Munyang Mts., which might mean a New South Wales locality. Mr. D. J. Paton forwards specimens collected on the Omeo side of Mt. Hotham, which belong to Ranunculus Muelleri, and, therefore, give an undoubted Victorian record for this plant.

SETOSA ERECTA, Ewart and Cookson. (Flora of the Northern Territory, 1917, p. 33) = SETOSA HORDEACEA, Ewart. (Chamaeraphis hordeacea, R.Br.)

The characters on which the distinction from Chamaeraphis are based are:—

Setosa:

Inflorescence a spike
Spikelets single to each awn
Glumes rigid
"Awn" very long and rigid
Styles free to the base
Staminodia 3 in female flower.
Outermost small glume callous and truncate

Chamaeraphis:

Inflorescence a panicle.
Spikelets two or more to each awn, very rarely one.
Glumes lax.
"Awn" short and soft.
Styles shortly united at the base.
Staminodia 2 in female flower.
Outermost small glume thin and membranous.

Setosa represents the highest development of the peculiar mode of developing an awned spikelet, of which the beginnings are shown in Chamaeraphis, and in Setosa the spikelet, with its basal branch "awn," disarticulates very readily and in one piece. In Chamaeraphis the spikelets disarticulate less readily and separately.

Setosa is strongly xerophilous, though usually growing near water. Chamaeraphis is semi-aquatic.

SOLANUM VIOLACEUM, R.Br. "Violet Nightshade." (Solanaceae).

East Gippsland, Rev. A. J. Maher.

New for Victoria.

TRICHINIUM ALOPECUROIDEUM, Lindl. "Long Tails." (Amarantaceae).

"Lorquon" received from State School, No. 2590, 5/5/1919.

A definite locality in Victoria for this plant.

TRICHOMANES PARVULUM, Poir. (Filicales).

There are no Victorian specimens of this fern. The plants on which the original record was made proved on examination by the Rev. W. W. Watts to be *Umbraculum flabellatum*, Gottsche (Hepaticae) the two plants having an extraordinary external resemblance. T. parvulum must be deleted from the list of the Flora of Victoria.

TRIGLOCHIN CENTROCARPA (Hook) var. longicarpa. (Naiadaceae).

Watheroo Rabbit Fence, W.A., M. Koch, September, 1905.

According to Ostenfeld, in Dansk Botanist, Arkiv. Bd. 2, page 35, 1918, the above was included under Triglochin centrocarpa, Hooker, in the collection by Max Koch.

ULMIS CAMPESTRIS, L. "Common Elm." (Ulmaceae).
(Rate of growth.)

In the last number of the Contributions to the Flora of Australia, some data were given in regard to the growth of this tree. One curious feature was an apparent contraction taking place during autumn and winter, after the cessation of growth in circumference, followed by an expansion during a wet winter period (June-July). In these observations the bark was left untrimmed around the measurement line, and the tape used was standardised only at the commencement and close of the observations. According to Trowbridge and Weil (Science N. Series 48, 1918, pp. 348-550), trees vary both in length and in breadth according to the temperature. Thus stems of Tilia europaea and Platanus orientalis increase in diameter slightly with a rise of temperature above 32 deg. F., but undergo marked transverse contraction with a fall of temperature below 32 deg. F. They conclude that the diameter of a tree is less when frost cracks are open than when they are closed, and that the cracks are due to this contraction and not to the expansion of the frozen water. The question naturally arises whether full precautions were taken to ensure that the measurements taken were adequately standardised. Trowbridge and Weil mention that the changes in circumference lag six to twenty-four hours behind the changes of temperature. The temperature at the centre of the trunk of a large leafless tree is not, however, affected appreciably by daily variations of temperature, and only responds slowly to a change in the average mean temperature.

In the measurements of the Elm taken in 1917-18, it was found that an apparent growth contraction took place in winter, and that slight variations in circumference were shown from time to time during the non-growing period. These measurements were taken with a tape around a partially smoothed line.

To obtain more accurate measurements a girdle of bark was removed, leaving a smooth surface close to the cork cambium. A standard length of 6 ft. 9 in. was marked by Dr. Baldwin, Government Astronomer, on the stone basement. After each measurement with a waxed tape it was extended over the standard, the increase over the standard giving the actual increment of growth. The tape was thus merely used to transfer the circumference of the stem to the standard length, and not to measure it.

The tape was kept in a dry room, and from November, 1918, to April, 1919, 6 ft. 9 in. on the tape corresponded to 6 ft. 9 in. on the standard. The tape then began to shorten, and most rapidly during May, until 6 ft. $9\frac{4}{16}$ on the tape covered 6 ft. 9 in. on the standard, and on June 15th, 6 ft. $9\frac{5}{16}$. By July 2nd the tape had shortened a further $\frac{1}{32}$ of an inch. A similar tape kept in a damp cellar for a month shortened $\frac{1}{4}$ inch per 8ft. in this time, although the temperature was fairly constant. The effect is, therefore, due to the gradual absorption of moisture, the humidity of the air increasing greatly in Melbourne during winter.

The deepening of the girdle on the tree reduced the circumference from 6 ft. $11\frac{1}{4}$ in. to 6 ft. $8\frac{3}{4}$ in.

In the previous year's measurements growth did not become perceptible until the first week in November, but here it began during the first week of October. This was the same time as when the cambium began to divide in the previous years measurements, so that the removal of the cork ring allows the actual growth to become sooner perceptible externally. In 1918 growth ceased at the end of February, but in 1919 it continued until the middle of March. This was probably, however, the result of the exceptionally mild and favourable autumn experienced in 1919. The total growth in 1917-1918 was $1\frac{1}{4}$ in., and in 1918-1919 $1\frac{1}{2}$ in.

Date.			Corrected Girth.				Rate of Growth per month of 30 days in $\frac{1}{16}$ in.
			Ft.	in.	$\frac{1}{16}$ in.		
July 26, 1918	-	-	6	8	12	-	nil.
August 16, 1918	-	-	6	8	13	-	nil.
September 21, 1918	-	-	6	8	13	-	nil.
October 10, 1918	-	-	6	8	14	-	
October 18, 1918	-	-	6	8	14	-	1.5
October 30, 1918	-	-	6	8	15	-	2.5
November 7, 1918	-	-	6	9	1	-	7.5
November 26, 1918	-	-	6	9	5	-	6.3
December 3, 1918	-	-	6	9	7	-	8.6
December 14, 1918	-	-	6	9	9	-	5.5
December 26, 1918	-	-	6	9	11	-	5.0
January 17, 1919	-	-	6	9	14	-	4.3
January 30, 1919	-	-	6	10	0	-	4 6
February 20, 1919	-	-	6	10	3	-	4.3
March 13, 1919	-	-	6	10	5	-	2.9
March 28, 1919	-	-	6	10	5	-	nil.
April 25, 1919	-	-	6	10	5	-	nil.
May 21, 1919	-	-	6	10	5	-	nil.
August 1 1919	-	-	6	10	5	-	nil.

Throughout the autumn and winter there was no evidence of any expansion or contraction with changes of temperature within a range of 45°F., (34 F.-79°F.), the static measurement being 6 ft. $10\frac{5}{16}$ in. On several occasions after rain had fallen and saturated the bark, corrected readings of 6.10 $\frac{6}{16}$ were given (May 23rd, June 2nd, June 15th, June 30th, etc.), but between these times the measurement reverted to 6 ft. $10\frac{5}{16}$ in. It would be of interest to know in detail the method of standardization adopted by Trowbridge and Weil, and also what precautions were taken to distinguish between variations of girth due to moisture and those supposed to be due to temperature. A variation of $\frac{1}{16}$ in. in 6 ft. $10\frac{5}{16}$ in. is approximately 0.07%, and if it were due to temperature, with a range of 45°F., it would represent 0.0017% per 1°F., which would in any case be negligable in dealing with a material like the trunk of tree. The view put forward by Trowbridge and Weil that frost cracks are due to the pronounced contraction of the diameter of the tree and not to the expansion of frozen water merits further investigation.

Verbascum Blattaria, L. Spurious or Twiggy Mullein. (Scrophulariaceae).

In J. M. Black's Naturalised Flora of South Australia Ver-
In J. M. Black's Naturalised Flora of South Australia, Ver-
ralised aliens in South Australia, whereas in Victoria the only two

recognised are V. Thapsus and V. Blattaria. There has always been some confusion between V. Blattaria and V. virgatum. Thus Verbascum virgatum, Spreng. (Syst. 1, 621) = V. Blattaria.

Verbascum Blattaria, Vell = V. virgatum.

The true V. Blattaria is that of Linnaeus Sp. Pl. 178, a native of Europe and Asia, whereas V. virgatum was described by Stokes (With. Bot. Arr. Brit, Pl. ed. 11, 227), and appears to be originally a native of Europe only.

In Bentham's British Flora, V. virgatum is distinguished from V. Blattaria by (1) the more abundant glandular hairs, (2) the pedicels of the flowers are shorter than the calyx, whereas in V. Blattaria they are longer; (3) there are usually 2-6 flowers to each bract.

If the Victorian specimens of V. Blattaria are sorted out into those with long and those with short pedicels, it will be found that the glandular pubescence varies in both series, and that there are as many specimens of "V. virgatum," with one flower to each bract, as with two or more flowers. If the specimens are sorted into "1 flowered," and 2, or more, flowered specimens, the long stalked and short stalked characters are completely mixed in both sets. Although V. virgatum is called the "Twiggy Mullein," branching specimens otherwise typical of V. Blattaria are quite common.

The only satisfactory conclusion is to regard V. virgatum as a variety of V. Blattaria, differing in one constant feature, the length of the pedicel, as thus—

V. Blattaria, L.	V. Blattaria, L. var. virgatum.
Flowers 1 to each bract Pedicels longer than calyx or bracts.	Flowers 1 or 2 rarely up to 6 to each bract. Pedicels usually shorter than calyx or bracts.

The variety virgatum is the commoner form in Victoria, but in Europe is of more restricted range than the typical V. Blattaria.

VICIA SEPIUM, L. "Bush Vetch." (Leguminosae).

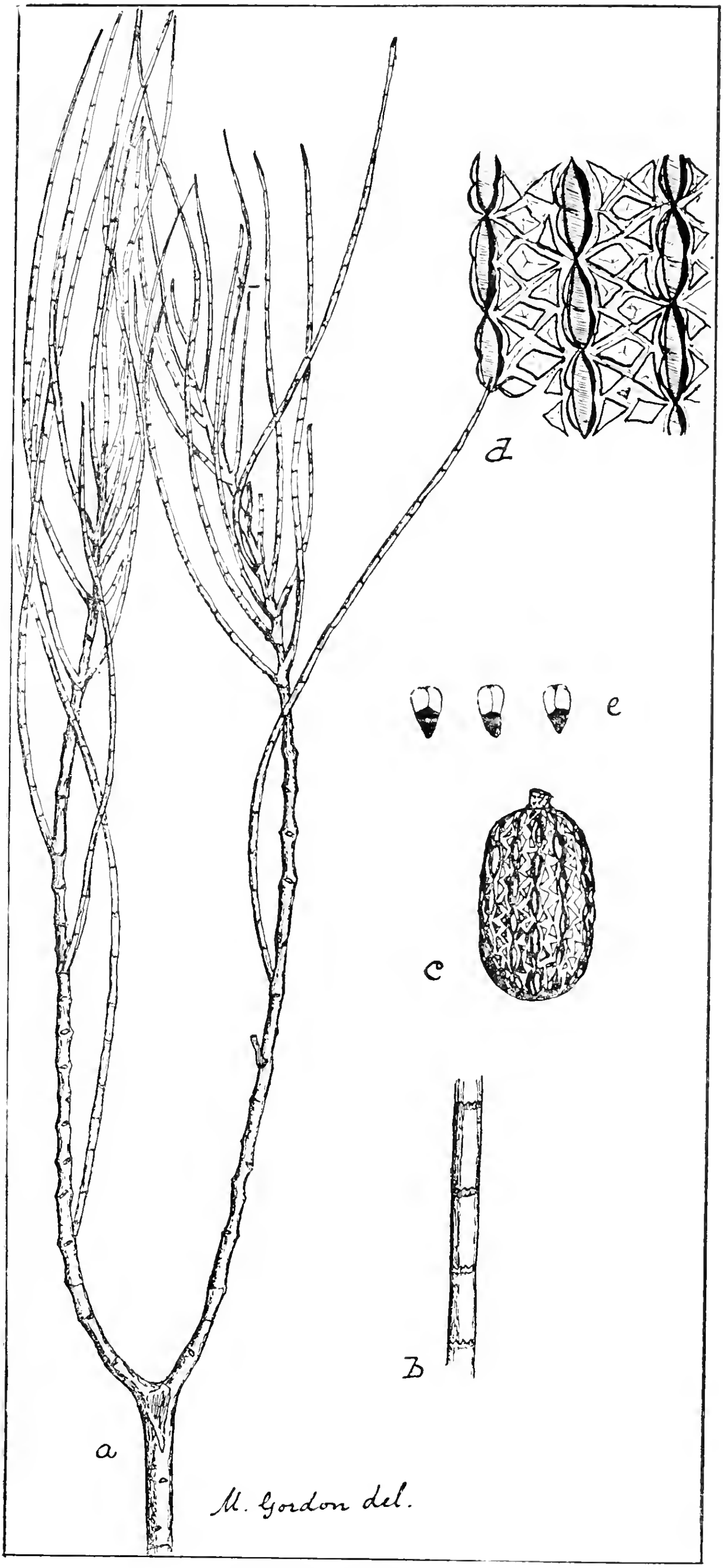
Alston's Farm, S. Wycheproof, Vic., W. W. Watts, Sept., 1918.

Not previously recorded as a naturalised alien in Victoria, but probably often confused with Vicia sativa. Vicia sepium is naturalised in South Australia.

ZYGOPHYLLUM BILLARDIERI, D.C. "Coast Twin Leaf." (Zygophyllaceae).

Wahgunyah, Murray River, G. H. Adcock, Sept. 11, 1919.

In the preparation of phylloxera resistant vines by grafting on



Casuarina Helmsii, n sp

to resistant stocks, the grafts are at one stage packed in seaweed trucked from the coast, and washed at Wahgunyah. This has caused the appearance of several coastal plants at this inland locality, including the above, as well as Melilotus parviflorus and Salsola Kali.

DESCRIPTION OF PLATE XII.

CASUARINA HELMSII, Ewart and Gordon.

(a) Portion of branch.
(b) Branchlet with leaf-sheaths.
(c) Fruiting cone.
(d) Portion of same, magnified.
(e) Seeds.

[Proc. Roy. Soc. Victoria, 32 (N.S.), Pt. II., 1920.]

Art. XV.—*A revision of the genus Pultenaea, Part 1.*

BY. H. B. WILLIAMSON.

(With Plates XIII., XIV. and XV.).

[Read November 6th, 1919].

It is only natural that in large genera more confusion is likely to occur than in small ones, and some time ago Professor Ewart advised me that a general revision of the genus Pultenaea would probably yield profitable results, and was indeed urgently necessary. The results of the first part of this investigation, based on the examination of the material at the National Herbarium, Melbourne, and of specimens received from the Government Botanists of the other States, are here given.

The genus Pultenaea is confined to Australia, and comprises 92 acknowledged species. Seventy-five species are described in Bentham's Flora Australiensis, two of which have been transferred to other genera, and one reduced to a variety. The species since described number 20, comprising those set up by Mueller (3), Tate (2), Black (2), Maiden (3), Maiden and Betche (2), Bailey (1), Baker (2), Scott (1), Andrews (1), Pritzel (1), and Regel (1). No labelled specimen of either of the last three is in the Herbarium.

The approximate distribution is—Queensland, 11 species; New South Wales, 45; Victoria, 37; Tasmania, 13; South Australia, 22; and Western Australia, 22.

About half of the species are confined to one State; about 20 are recorded for two States, 10 for three States, and 6 species are widely spread—four States. As with other genera, few of the Western Australian species—two—occur east of the limits of that State, one of which extends to South-West Victoria. It is worthy of note that in the Flora of the Northern Territory, Ewart and Davies, 1917, the genus is not mentioned, and that very few records of Pultenaea exist for Western Australia outside the south-western district of that State.

While attempting a revision of the genus in which, judging by evidence of labelled and unlabelled specimens in the National Herbarium, much confusion exists, it is not claimed that finality can now be reached with regard to certain groups, for the occurrence of forms that seem to connect the members of those groups presents much difficulty. Considering the varying forms for example, of the group known under Eupultenaea, an advocate for reduction of species could place five or six, including P. stricta, P. retusa, P. Gunnii, under one species name, and cultural experiments may yet prove that they are not all valid species, but few would be bold enough to make such a drastic reduction.

Even if it were proposed to unite, say, the three mentioned, which certainly are very close as regards floral structures, the work of the great systematists, Bentham, Smith, Hooker, Mueller and others, would be discredited, and their ideas of what constitute a species set at naught. While recognising most of the species set up by these great workers, one's aim must be to realise their system, and to follow it in the light of later discoveries of forms unknown to them. At the same time it is inevitable that in all such revisions of large genera, additional species must be set up, consisting for the greater part of certain forms which have in error or for convenience been placed as varieties, but which, if they had been more fully considered by the pioneers of systematic botany, would have been given specific rank. The author, recognising the fallacy of multiplying species unnecessarily, has in doubtful cases allowed the varietal rank to stand. It is known that species may show variations according to climatic and soil conditions, and it may be conceded that the variations will be greatest or most likely to occur in the first named, and least in the last-named of the following:—Habit; colour of flower; size, shape and texture of leaf; size and shape of stipules; arrangement of flowers; size and shape of bracts, bracteoles, calyx, ovary and seeds. So that in the case of Pultenaea a variation of ovary, whether stipitate or sessile, villous or glabrous, shape of calyx, position and shape of bracteoles and bracts, are of more importance in determining a species than the habit, the shape and size of the leaves, or the colour or size of the corolla. In other words, if ovary, calyx, bracteoles and bracts are similar, a good deal of variation in habit or in leaf can be allowed within the limits of a species, whereas if habit, leaves, corolla and stipules are similar, a marked difference in the reproductive organs just named will justify the setting up of a species.

In the diagnostic drawings this has been kept in view, and they include besides sketches showing shape and size of leaves and stipules, drawings showing only the shape, size and relative position of calyx, bracteoles and bracts. No attempt is made to show the marginal curving of the leaf, or the nature of the indumentum.

Regarding the corolla, one has only to read in descriptions the oft-repeated "Standard twice as long as calyx," or "nearly twice," "lower petals shorter"—this, by the way, is included in the description of the genus—"keel dark coloured," etc., to feel how unimportant these parts are in determining a species of the genus. The fact that so many species of Pultenaea have been described in the absence of pods seems to show that these are non-essential, though in the case of a plant without stipules, and with the bracteoles well away from the calyx tube, the examination of ripe seeds would be necessary to determine the genus.

Section EUPULTENAEA.

Pultenaea daphnoides, Wendl.

Varies much in foliage, the normal plant having leaves cuneate-oblong, with a fine straight point. Flowers in dense terminal heads, and bracteoles well up on the calyx

var. obcordata Bth. has truncate leaves with a prominent point. Victoria, Tasmania, South Australia.

var. parviflora, n.v.

This has been placed under daphnoides and retusa, and among doubtful forms. It differs from the type in having cuneate-oblong leaves 4 to 6 lines long without a point, margins flat or slightly incurved, mid-rib obscure above.

Upper Murray district, C. French, Junr., 1886. Wildflower Show, 1919, no loc.

Pultenaea stricta, Sims.

A smaller shrub than P. daphnoides, with smaller leaves, ovate-oblong, with recurved margins, and a small recurved point. Bracts numerous, glabrous, deciduous, with rounded point, outer ones bifid and shorter. Bracteoles high on the calyx, usually glabrous. I can find no constant variation from the type in var. incurvata, Ewart, from Frankston.

Pultenaea Maidenii, Reader.

This differs from P. stricta in its long-pointed hairy bracteoles, fixed near the base of the calyx. The lower lobes are narrow, longer than the tube, and almost setular pointed. The leaves are cuneate, thin and often conduplicate. Its nearest affinity is P. largiflorens, F.v.M.—the broad-leaved form from South Australia—from which it differs in having narrower cuneate leaves and a very different calyx. It should retain specific rank.

Pipe Head Waterworks, Hamilton, Vic., Collected by the writer, 11/1904.

Pultenaea capitellata, Sieb.

A species bearing a remarkable general resemblance to P. pycnocephala, F.v.M., and variously placed with that species, or with P. stricta, in which latter Bentham wrongly included it.

Its minute stipules and high-adnate bracteoles place it right away from Mueller's species, although there is a specimen labelled by him "P. pycnocephala F.v.M." From P. stricta it can be separated by its flower heads, solid and almost globular, and very persistent bracts, broadly ovate, densely covered with silky hairs, except at the margin, bifid, with a narrow median point. Calyx lobes and bracteoles are setaceous. Leaves cuneate, slightly pointed. The specimen, "Port Jackson, Sieb, n. 313," Fl. Aust., p. 113, is this species, and not the plant figured by Sims, Bot. Mag. Sieber's name should be retained for it.

Braidwood District, Twofold Bay, N.S.W., and East Gippsland, Vic.

Pultenaea pycnocephala, F. v. M.

A remarkable species, with broadly-ovate coriaceous leaves, silky below, and with flowers in dense globular heads, covered with imbricate, silky villous, persistent bracts. The bracteoles are long, very silky, villous, and are fixed quite under the calyx.

Bluff Mount, Poverty Point, Tenterfield, N.S.W.

Pultenaea retusa, Smith.

A species with calyx and bracteoles like those of P. stricta, but with shorter bracts, more falcate upper calyx lobes, and leaves linear to cuneate, sometimes emarginate.

Var. linophylla, Benth, with longer leaves and longer calyx. Port Jackson.

Var. longifolia, F.v.M., with leaves up to 1½ inches.

Specimens from E. Gippsland, with cuneate leaves, almost bilobed, 2 or 3 lines long, seem to be included under the description in Bentham.

Specimens from Hazelbrook, N.S.W., Hamilton, and from Twofold Bay, show leaves cuneate-oblong to obovate.

Queensland, New South Wales and Eastern Victoria.

Pultenaea Benthami, F.v.M.

Recorded only from the Grampians, Vic., with calyx, bracts and bracteoles like those of P. daphnoides, but with rigid, almost linear, acute, or pungent leaves.

Pultenaea Millari, Bailey.

A species with silky cuneate-ovate leaves, and flowers solitary in the upper axils.

Stannary Hills, Herberton, Qld.

var. *angustifolia*, n.v.

From Eidsvold, Qld., Dr. Bancroft, are specimens, which differ only from the type in having leaves narrow-lanceolate, with a more prominent point.

Pultenaea myrtoides, Cunn.

With leaves like those of P. Millari, but nearly glabrous. Flowers are in dense terminal, globular heads, with boat-shaped bracteoles fixed rather low on the calyx.

New South Wales, Queensland.

Pultenaea polifolia, Cunn.

A Queensland species, with hairy linear leaves, and remarkably long petioles, and with bracteoles linear-subulate, fixed about the middle of the calyx tube. Flowers in dense terminal heads.

Pultenaea petiolaris, Cunn.

A species with leaves linear to lanceolate, with a point slightly recurved. Its calyx lobes are fringed with silky hairs, as are also the keeled bracteoles fixed well up on the calyx tube.

Pultenaea mucronata, F.v.M.

=*P. polifolia*, Cunn, var. *mucronata*.

This plant was described from specimens from Ovens River, Vic., and differs from P. polifolia only in having broader leaves, more villous branchlets, and less keeled bracteoles set rather lower on the calyx tube. Bentham says, "This may possibly prove to be a broad-leaved form of P. polifolia." In the light of evidence of intermediate forms, including those from Batlow and Nungatta, N.S.W., the species name, mucronata, can be suppressed, and all the forms included under P. polifolia.

Specimens from Blackheath, N.S.W., with cuneate mucronate leaves, and setaceous bracts, stipules and calyx lobes, can provisionally remain under var. mucronata.

Pultenaea Gunnii, Benth.

Although very variable in foliage, the small size of the calyx, bracts and bracteoles, and the constantly recurved edges of the leaves, keep it quite distinct from P. stricta. "The larger leaved forms can always be distinguished from P. striata (stricta?) by the very much smaller bracts," (Bentham). These are scarcely ever longer than the very short pedicels, and the bracteoles are minute, of a dark colour, and set well up on the calyx. As regards flowers, it is nearest to P. microphylla, but that species has cuneate to linear-cuneate leaves.

var. planifolia, F.v.M., a broad leaved form from Badger Head, Tas.

var. flava, Ewart, from Wandin, Vic., has light yellow flowers.

One or two forms which seem to connect this with P. stricta remain for further study.

Pultenaea microphylla, Sieb.

A species from New South Wales, with linear-cuneate leaves, and a smaller calyx than the last-named species. Tenterfield specimens have almost linear leaves, with lower face almost closed.

var. cuneata, Benth; leaves are cuneate-truncate, 3 to 4 lines long, bearing some resemblance to P. largiflorens, F.v.M., which latter may be distinguished by the large upper lip of its calyx.

New South Wales, Queensland.

Pultenaea cinerascens, Maiden and Betche.

=*P. microphylla* var. *cinerascens*.

As the only difference between this plant and P. microphylla, Sieb. is that of habit and foliage, it should not have received specific rank. Specimens of P. microphylla from Tenterfield show almost linear leaves. In Proc. Roy. Soc., N.S.W., XXXIII. 310, the authors admit that there is no marked difference of flowers or inflorescence, and that Gilgandra and Scone specimens are links connecting the two alleged species. All these forms can now well be grouped under Sieber's species name.

Warialda, N.S.W.

Pultenaea Drummondii, Meiss.

A Western Australian species, with shining yellowish scarious bracts, and a peculiar calyx, with upper lobes rounded, and united into a broad emarginate lip.

Pultenaea Skinneri, F.v.M.

A Western Australian species, with recurved mucronate leaves, reversed on the stem, and with a large calyx 4 lines long, with bracteoles nearly as long, fixed well below the calyx tube.

Pultenaea Hartmanni, F.v.M.

A Queensland species, with leaves between those of P. scabra and P. retusa, but with minute stipules, remarkably small bracteoles fixed at the base of the calyx, and with longer calyx lobes than those of P. retusa.

Pultenaea pinifolia, Meiss.

A Western Australian species, with narrow linear leaves, spreading stipules, and very deciduous bracts and bracteoles, the latter being long, and fixed well below the calyx tube.

Pultenaea pedunculata, HK.

A prostrate shrub often matted, with flowers on filiform pedicels, often half inch long—in some Port Lincoln specimens one inch long. The calyx is almost glabrous, with acuminate lobes, and the bracteoles are nearly as long, linear and below the calyx tube.

South Australia, Victoria, New South Wales, Tasmania.

[As there is some discrepancy between the description of this species in Bentham's Flora, and that given in the Botanical Magazine, the matter will be discussed when dealing with Pultenaea Ausfieldii, Regel, one of the forms that appear to have been included under P. pedunculata].

Pultenaea conferta, Benth.

A Western Australian species, with short, linear, crowded leaves, and a remarkable calyx, with the upper lobes large and free, and the lower ones very much smaller.

Pultenaea pauciflora, Scott.

A Western Australia species, with long white hairs on the young foliage, and with incurved leaves linear-lanceolate, flat, but with thickened or slightly recurved margins, with mid-rib scarcely prominent below, fine pointed. The calyx has equal lobes, and the bracteoles are free from the calyx. It belongs to section Empultenaea, near P. Drummondii.

Narrogin Exp. Farm, Stoward.

Pultenaea scabra, R.Br.

Three very divergent forms have been united by Bentham in this species:—

(a) R. Brown's P. scabra, from the Blue Mountains (Sieb, n. 286), with narrow-cuneate, truncate leaves, with a fine seta terminating the mid-rib, and with setaceous, spreading stipules, sometimes 3 lines long.

(b) Lindley's P. montana—P. scabra var. montana Bth.—the common Victorian form, with minute stipules, and leaves obcordate or obvate, with no point, often with much recurved margins.

(c) R. Brown's P. biloba—P. scabra var. biloba, Bth.—with leaves dilated and two lobed, with a short recurved point.

Brown's scabra and Lindley's plant are very distinct, but as there is no marked difference in the flowers they may be kept under P. scabra, especially as the varying forms of the var. biloba present graduated intermediates.

Section ACIPHYLLUM.

This section—3 species—is confined to Western Australia, and is distinguished by peculiar transversely reticulate leaves.

Pultenaea aciphylla, Benth—(P. recticulata Bth.)—with leaves ovate to linear-lanceolate, pungent. *Pultenaea aspalathoides*, Meiss, with leaves narrower than those of P. aciphylla, with a smaller calyx, larger bracteoles, and flowers crowded round with leaves.

Pultenaea ochreata, Meiss, distinguished from the two former by having shorter and broader leaves, with no point, and nearly orbicular bracteoles.

Section EUCHILUS.

This section contains those species which have ternate or opposite leaves.

Pultenaea obcordata, Benth.

A West Australian species, with obcordate, ternate, or opposite leaves, and a remarkable calyx, with its upper lobes almost orbicular, and its lower lobes linear and much shorter.

Pultenaea rotundifolia, Benth.

A West Australian species, with minute opposite leaves, rarely crowded, and flowers like those of P. obcordate, but on filiform pedicels often half-inch long.

Pultenaea calycina, Benth.

A West Australian species, with opposite or ternate leaves, like those of P. retusa, and with a calyx resembling that of P. obcordata, but with larger, more separated upper lobes.

Pultenaea acuminata, R. T. Baker.

A New South Wales species, with opposite leaves resembling those of P. Gunnii, with a very large calyx—about 4 lines—with a short tube, and long linear bracteoles fixed below the calyx tube.

Byalong Creek, N.S.W.

Pultenaea spinulosa, Benth.

A West Australian species, with opposite, crowded pungent leaves, reticulate below, and with a calyx having large, almost free, upper lobes, having subulate points, and with very narrow lower lobes.

Pultenaea tenella, Benth.

An Alpine species, with the habit and appearance of P. paleacea var. sericea, but having ternate, concave leaves, and a long calyx with lobes longer than the tube.

Alps of Victoria.

Pultenaea Luehmanni, Maiden.

A slender trailing plant, remarkable for its filiform, opposite branchlets, and distant leaves. Its terminal, head-like inflorescence distinguishes it from all other species of the section. Its nearest affinity is P. tenella, but that species has axillary flowers, and a larger and a differently shaped calyx.

Pipe Head, Hamilton Waterworks, Vic., Collected by the writer, Nov., 1904.

Pultenaea cymbifolia, J. M. Black.

A South Australian species, with small, decussate, convex mucronate leaves, rather crowded, and a silky calyx like that of P. calycina, with large upper lobes, united below the middle, and very small subulate lower lobes.

Kangaroo I., Andrews. A specimen was sent to the Herbarium in 1886 by Miss Brookes, Mt. Rugged to Victoria Springs, but was set aside by Mueller for determination later.

Section COELOPHYLLUM.

This section includes those species with alternate leaves, flattened, concave or terete.

Pultenaea flexilis, Smith.

An almost glabrous shrub with flat, or slightly concave leaves, glabrous calyx, with scarcely pointed lobes shorter than the tube, flowers axillary on rather long pedicels, with lanceolate, pointed bracteoles fixed on the tube at the base, and ovary glabrous with a few long hairs at the top.

Victoria, New South Wales.

Specimens from Clarence River, Beckler, are labelled "P. flexilis var. mucronata," p. 135, Fl. Aust. They exactly match specimens from Giggo Range, and the Dandenongs, Vic., since determined by Mueller as a variety of P. juniperina. These, as well as specimens from Pine Mount, N.E. District, Walter, having pubescent ovary, and bracts and bracteoles of P. juniperina, must be referred to that species.

Pultenaea altissima, F.v.M.

A species which has been wrongly united with P. flexilis, from which it differs in having its bracteoles ovate and free from the calyx, in which characters it agrees with P. obovata Benth., its nearest affinity. It has also its flowers in terminal umbel-like racemes, not axillary as in P. flexilis, and its leaves are linear-cuneate without points, and rarely over half-inch long. From P. obovata it differs in having a much smaller calyx with shorter lobes, and leaves narrower. We should follow Bentham in keeping it a distinct species.

New South Wales, Twofold Bay, and Upper Genoa River; probably occurs in East Gippsland.

Pultenaea obovata, Benth.

A New South Wales species, like P. flexilis, but with broad-ovate or broadly-cuneate leaves, two or three lines long, on rather long petioles, concave, light green above. Calyx, with lobes longer than the tube, which distinguishes it from P. altissima, and with small ovate-orbicular bracteoles fixed below the calyx.

Moona River, Walcha, N.S.W.

Pultenaea paleacea Willd.

A species with linear leaves, long, scarious stipules, and dense terminal heads much covered with long imbricate bracts. The calyx is silky, and bracteoles are ovate, and are fixed on the calyx tube. Port Jackson, var. obtusata, Benth, has broader cuneate, leaves; var. sericea, Benth, the form common near Melbourne, has long, silky, white, scarious stipules and bracts.

Var. robusta, n.v. from Queensland (Gympie, Wellington Point), is a robust plant, differing only from var. sericea in having much larger leaves and flowers.

Pultenaea Williamsoni, Maiden.

= *P. paleacea*, var. *Williamsoni*.

This plant must now be referred to P. paleacea. It is of stronger and more robust growth, though of the same habit. The bracteoles are certainly wider and longer than in P. paleacea, but they are not constantly fixed at the very base of the calyx, being often just above the base. There are specimens from Wellington Point, Q., J. Wedd, which match the Victorian specimens in every respect, except that the bracteoles are smaller, and are fixed rather higher on the calyx tube.

From P. stricta this plant is far removed by its habit, its remarkably large stipules, its large leaves, its large persistent bracts, and the shape and position of its bracteoles.

Strathbogie, Vic., A. W. Vroland, Nov., 1904.

Wellington Point, Q., J. Wedd.

Pultenaea stipularis, Smith.

A showy New South Wales species, easily distinguished by its straight, linear leaves, and very long stipules, calyx lobes, bracts and bracteoles, the two last-named being hirsute with long hairs.

Port Jackson, Blue Mountains, N.S.W.

Pultenaea glabra, Benth.

A New South Wales species, with leaves like those of P. dentata, and with few bracts. It can readily be distinguished by its peculiar calyx, and the absence of all hairs. The calyx has nearly equal lobes, acute and spreading, as long as the tube. Bracteoles broad-lanceolate fixed at the middle of the calyx tube.

Blue Mountains, N.S.W.

Pultenaea dentata, Labill.

A widespread species, with narrow-lanceolate concave leaves, and imbricate bracts, covering the dense heads in bud. The species is easily determined by its bracteoles, which are ovate or oblong, bifid, with a central subulate lobe, giving the summit a dentate appearance.

New South Wales, Victoria, Tasmania.

Pultenaea subumbellata, HK.

A species with heads more capitate than subumbellate, and flat or slightly concave leaves, and a small hairy calyx, with hairy bracteoles well under the calyx. This last character, along with the absence of stipules, makes it a connecting link between Pultenaea and Latrobea diosmifolia, Bth. It has, however, strophiolate seeds.

New South Wales, Victoria, Tasmania.

Pultenaea incurvata, Cunn.

Like P. subumbellata in the absence of stipules, and the position of bracteoles, but distinguished from that species by its generally larger leaves, incurved at the tips often wrinkled below. Its bracts and bracteoles also are larger. Brown's specimens from Port Jackson are not incurvata, as labelled, but subumbellata.

New South Wales only.

Pultenaea selaginoides, F.v.M.

A Tasmanian species allied to P. subumbellata, having very minute stipules, shorter, thicker, and more concave leaves, almost imbricate. The calyx is small and glabrous, with blunt and almost equal lobes. Bracteoles are lanceolate, concave, fixed under the calyx. Flowers axillary, not capitate, as in P. subumbellata.

St. Paul's River, Tasmania.

Pultenaea euchila, D.C.

A plant that looks like a large form of P. flexilis, having larger flowers and leaves, and longer pedicels. It differs from P. flexilis in bracteoles, and calyx, the former being linear-subulate, and inserted close under the calyx, and the latter being larger, with lobes longer than the tube, with the upper ones falcate.

Port Jackson, Hunter River, Clarence River, N.S.W.

Brisbane, Ipswich, Qld.

Pultenaea densifolia, F.v.M.

A South Australian species, with very small, obovate concave leaves, with recurved tips, and flowers in axillary, sessile tufts, near the summit of the branches. Broad scarious bracts and bracteoles conceal the calyx, which is nearly three lines long, and has pungent-pointed lobes.

South Australia, Port Lincoln, Encounter Bay; doubtful from Victoria, "Murray Desert, F. Mueller."

Pultenaea Campbelli, Maiden and Betche.

A New South Wales species, near P. glabra, but with smaller and straighter leaves, and a slight pubescence on the small branches. It is easily distinguished from P. glabra, by its very small stipular bracteoles, fixed at the base of the calyx tube. These being all reddish brown, have the aspect of trifid bracteoles.

Walcha, N.S.W., J. F. Campbell, October, 1898.

Pultenaea aristata, Sieb.

A New South Wales species, with calyx and bracteoles like those of P. humilis, but its leaves are narrower, more concave, and are armed with a straight bristlet. The flowers are in dense terminal heads, unlike those of P. humilis, and are surrounded by reddish bifid bracts. The general aspect is that of P. plumosa.

Port Jackson, Appin, N.S.W.

Pultenaea plumosa, Sieb.

A species with narrow, concave leaves, without a bristle point. The broader leaved forms resemble P. humilis in foliage, and flower structure. The flowers are, however, in terminal heads, and the bracteoles are provided with broad stipules, are longer and broader, and are set under the calyx tube.

Port Jackson, Clarence River, Blackheath, N.S.W.

Pultenaea Baeuerleni, F.v.M.

A New South Wales species, near P. aristata, but with leaves filiform, channelled above, granular rough, and with no bristle point.

The petioles are conspicuous, and the stipules are long, appressed, and somewhat downy. Upper calyx lobes are much united, and and bracteoles are larger, oblong, mucronate, and fixed below the calyx tube.

Braidwood District, N.S.W., Bæuerlen.

Pultenaea elliptica, Smith.

A New South Wales species, with leaves elliptical to ovate, the upper ones being long-petiolate. Stipules broad, appressed, the upper ones being ciliate with long hairs. Flowers are crowded in upper axils like those of P. humilis, having bracteoles under the calyx, reddish, scarious with small point; var. thymifolia, Bth. has leaves smaller and narrower, and slightly smaller flowers.

Pultenaea rosea, F.v.M.

A species with terete leaves, and linear lanceolate bracteoles fixed under the calyx tube. It is, however, quite unique among its congeners in having pinkish or mauve-coloured flowers.

Summits of Grampians (Mt. William).

Pultenaea largiflorens, F.v.M.

A plant with obovate to linear-cuneate leaves, more or less concave or folded, and recurved at the ends, silky below, with flowers with a silky calyx with much falcate upper lobes, which give the buds a hooked aspect. Bracteoles are lanceolate to ovate, slightly hairy on the back, and are fixed well up on the calyx tube.

Grampians and North-Western District, Vic.

var. latifolia, n.v. To this may be referred the South Australian forms, which have much wider leaves, generally ovate-oblong, flat or slightly folded, and sometimes obcordate emarginate (Clare, S.A., Tate). In some of these, where the leaves are crowded, they appear almost ternate.

From Wedderburn, W. W. Watts, and from New South Wales, per W. Baker, comes a form differing from the normal only in having calyx, bracts and bracteoles larger, the last-named being fixed rather lower on the calyx tube, near its base. It is exactly similar in habit and general appearance to the Wimmera forms of P. largiflorens, and can scarcely rank as a variety.

EXPLANATION OF PLATES XIII., XIV., AND XV.

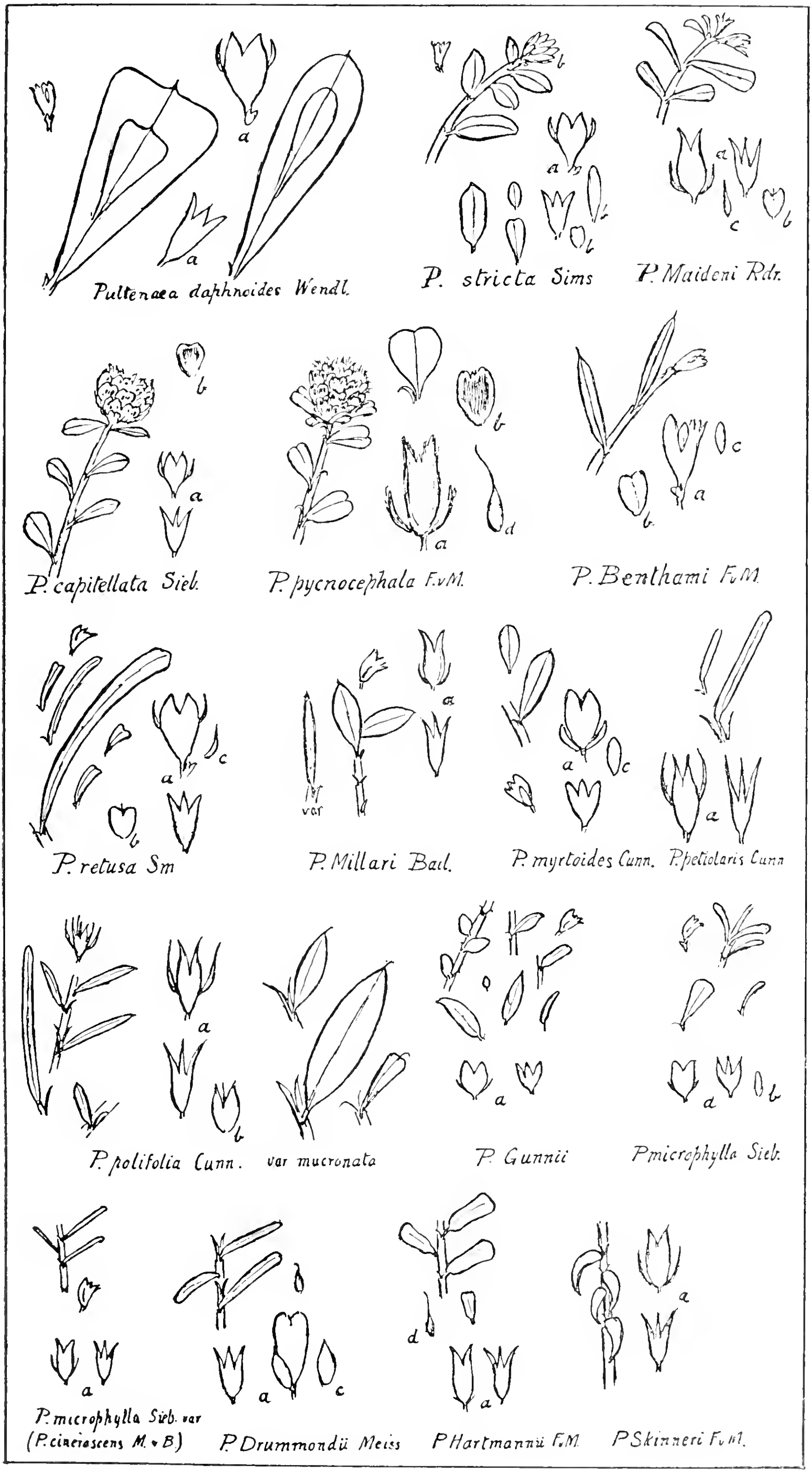
All drawings of leaves are natural size. Where the calyx is shown without reference letter it is natural size.

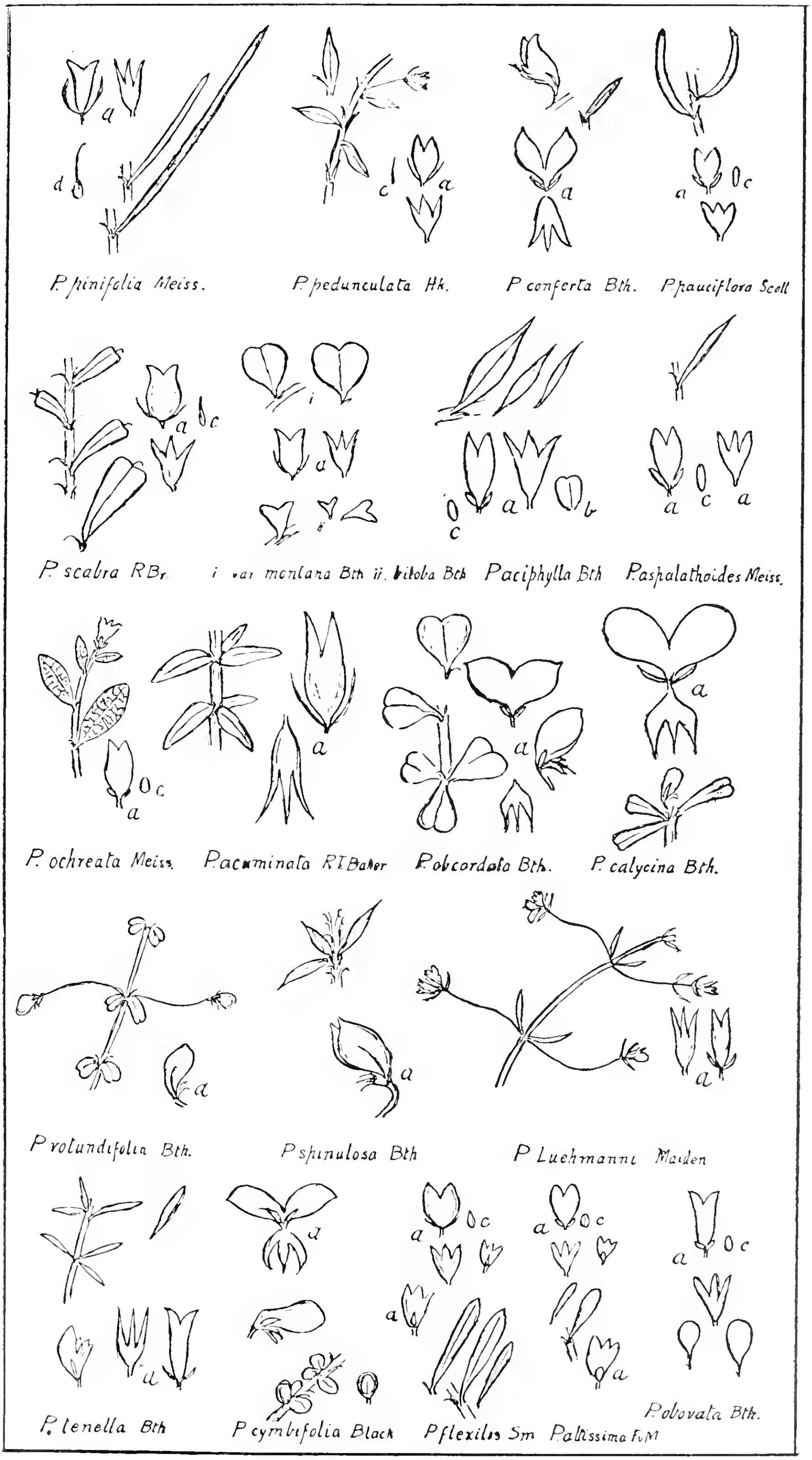
a. Upper and lower calyx lobes × 2.

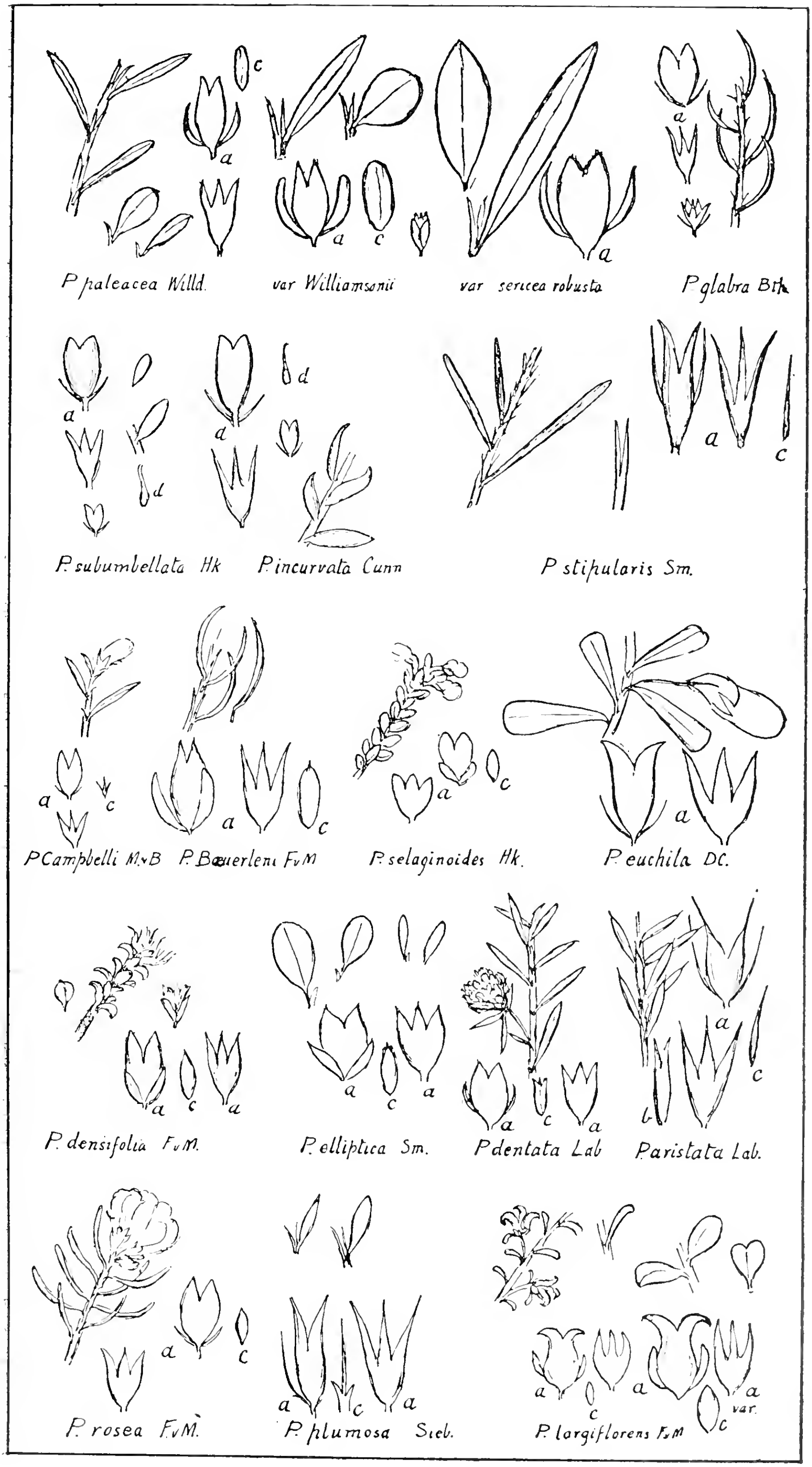
b. Bract × 2.

c. Bracteole × 2.

d. Ovary and style × 2.


Pultenaea daphnoides Wendl.
P. stricta Sims
P. Maideni Rdr.
P. capitellata Sieb.
P. pycnocephala F.v.M.
P. Benthami F.v.M.
P. retusa Sm
P. Millari Bail.
var
P. myrtoides Cunn.
P. petiolaris Cunn
P. polifolia Cunn.
var mucronata
P. Gunnii
P. microphylla Sieb.
P. microphylla Sieb. var
(P. cinerascens M. & B.)
P. Drummondii Meiss
P. Hartmannii F.v.M.
P. Skinneri F.v.M.


P. pinifolia Meiss.
P. pedunculata Hk.
P. conferta Bth.
P. pauciflora Scott
P. scabra R.Br.
i var montana Bth ii. biloba Bth
P. aciphylla Bth
P. aspalathoides Meiss.
P. ochreata Meiss.
P. acuminata R.T.Baker
P. obcordata Bth.
P. calycina Bth.
P. rotundifolia Bth.
P. spinulosa Bth
P. Luehmanni Maiden
P. tenella Bth
P. cymbifolia Black
P. flexilis Sm
P. altissima F.v.M.
P. obovata Bth.


P paleacea Willd.
var Williamsonii
var sericea robusta
P glabra Bth
P subumbellata Hk
P incurvata Cunn
P stipularis Sm.
P Campbelli M.v.B
P Bæuerleni FvM
P selaginoides Hk.
P euchila DC.
P densifolia FvM.
P elliptica Sm.
P dentata Lab
P aristata Lab.
P rosea FvM.
P plumosa Sieb.
P longiflorens FvM
var.

[Proc. Roy. Soc. Victoria, 32 (N.S.), Pt. II., 1920.]

Art XVI.—*Notes on a Collection of Tertiary Fossils from Ooldea and Watson, South Australia.*

BY

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Hon. Palaeont. Geol. Surv. Vict.

(With Plates XVI., XVII. and Text Figure.)

[Read 11th December, 1919.]

Introductory.

On account of the scarcity of information regarding fossils occurring in the area traversed by the construction of the Transcontinental Railway from Port Augusta to Kalgoorlie, it seems advisable to put on record some notes of the specimens now in the National Museum.

The fossils under consideration were collected by Messrs. F. A. Cudmore, R. C. Chandler and Dr. T. Griffith Taylor, B.E., B.A., F.G.S. Mr. Cudmore obtained a large collection of Miocene fossils, mainly as casts and moulds, in his recent trip to Ooldea and Watson, and a selection of these he has given to the Museum. I am also indebted to him for the photographs here reproduced, and for detailed information of the various fossiliferous exposures north and south of the railway.

Mr. R. C. Chandler was successful in obtaining a number of fossils in this locality during the early history of the line's construction, when engaged in acquiring natural history specimens for the Museum.

Dr. Griffith Taylor also collected a few fossils during his recent journey to Central South Australia, and has kindly donated the coral specimens—one of which is here figured—to the State collection.

Localities of Collection.

The Ooldea Soak[1] has been known to travellers from Fowler's Bay for many years. It is situated on the Nullaboor Plains, west of the sand-hill country, about 100 miles N.W. of Fowler's Bay, and about three miles north of the railway line. Various outcrops of

1. See S. A. White. The Emu, Jan. 1919, p. 189.

granite appear in this area, having a general north-westerly trend, and there are indications of the superimposed Tertiary beds having been displaced in that direction. This, indeed, may account for the occurrence of the Soak in this desert country, far away from any other visible water-hole, except some salt lakes, as Lake Tallacootra, to the south, and which are evidently due to a similar cause. It is just possible that sub-artesian water is tapped here, and remains held up by the heavier or impervious shell-marls of the Pleistocene deposit.

The collection made by Mr. Chandler comprises both Janjukian, or Miocene fossils (mainly as casts), and some Older Pleistocene material, cemented together or in loose specimens.

The small but interesting collection made by Dr. Griffith Taylor was from Janjukian beds. The specimens include a hard limestone with *Chlamys* cf. *murrayanus*, Tate sp., and two examples of a Janjukian coral, *Orbicella* (olim *Heliastraea*) *tasmaniensis*, Duncan sp., which had rarely before been found outside of Tasmania. This *Orbicella*, Mr. Cudmore informs me is abundantly scattered over various parts of the Plains.

The collection made by Mr. Cudmore comprises more than a hundred specimens. They are chiefly preserved in a hard ochreous and white limestone, generally as casts and moulds, although some still retain the shell structures, as *Chlamys murrayanus*. Mr. Cudmore's specimens came principally from the Ooldea Well (not used), 300 yards west and 200 yards south of Ooldea railway station, though a few of similar kinds were obtained from the half-mile cutting at Watson, next to Ooldea, on the road to West Australia. The limestone country is well shown by photographs here reproduced, taken by Mr. Cudmore.

On glancing at the geological map of this district, one sees that Ooldea is situated on the later Tertiary bed, but close to the boundary of outcrop of the Miocene series. From the disposition of the two Tertiary beds, as mapped, it would appear probable that the Pleistocene deposit represents a fairly shallow marine bed laid down upon, and flanking a Miocene limestone, which extended south-eastward as a promontory, as far as long. 133°30' at the present time, as now seen exposed in the elevated plains. From the fact that the Ooldea Soak is fresh, it is highly probable that the water is deep-seated, and has its origin in or below the mass of Miocene limestone, which must here be faulted, as seems to be indicated by the sporadic but linear arrangement of inliers of deep-seated rocks, and is not an ordinary soak in an impervious bed. In fact, this theory of the presence of faults along this particular trend line is supported by the parallel system of fractures re-entrant along the coast, stepped in the same direction from the Head of the Bight to Anxious Bay, and even beyond.

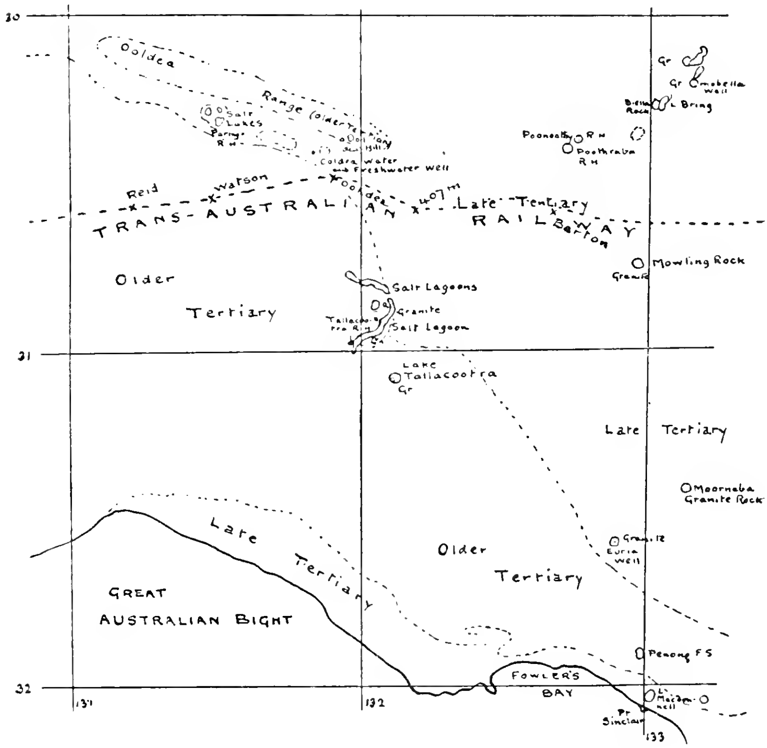

Fig. 1. Sketch Map of South Australian area including Fowler's Bay and the Ooldea Soak. Main details taken from the geological map of South Australia, by H. Y. L. Brown, 1899.

This shows the trend, in a north-westerly and south-easterly direction, of probable fracture zones, involving the Miocene and Pleistocene rocks. The direction of sand-ridges are also seen to be influenced by the underlying structure, since, as Mr. Henry Deane, M.A., informs me, they generally run in a similar way. These fracture lines would also appear to have a considerable bearing on the disposition of water holes, lagoons and soaks in this part of the country.

Areas in this map marked Granite may also include Metamorphic rocks, as Gneiss, Hornblende and Mica Schists; also Diabase dykes and mineral veins.

The Older Tertiary can be referred to the Miocene, to which the older fossiliferous beds of the Ooldea Soak belong.

The late Tertiary includes the Older Pleistocene of the Ooldea Soak and all subsequent stages, as Sand-dune rock and Concretionary limestone.

OLDER PLEISTOCENE FOSSILS FROM THE OOLDEA DISTRICT.

Order FORAMINIFERA.

Genus **Orbitolites,** Lamarck.

Orbitolites complanata, Lamarck.

Orbitolites complanata, Lamarck, 1801, Syst. Anim. sans Vert., p. 376. Carpenter, 1856, Phil. Trans., p. 224, pls. IV-IX. Chapman, 1913, Proc. R. Soc. Vict., vol. XXVI. N.S. pt. I. p. 170.

This species ranges from the Balcombian (Muddy Creek), through Janjukian (Mallee Bores) to Werrikooian and Pleistocene (Well borings, Murray Flats, and Croydon Bore, near Adelaide).

A fine sample of limestone, largely composed of the above fossil, together with mollusca (*Clanculus* and *Brachyodontes*) was presented to the National Museum by Mr. R. H. Matthews, who obtained it from Yorke Peninsula, six miles N.W. of Yorketown.

O. complanata occurred in the Croydon Bore as far down as 450 feet, and was there associated with *Laganum* and *Glycimeris*. At 395-415 feet the associated fauna was *Ostrea angasi*, *Glycimeris obliquus*, *G. convexus*, *Limopsis tenisoni* (recorded as *L. belcheri*), *Crassatellites oblonga*, *Mesalia provisi* and *Cassis fimbriatus*. This fauna contains some archaic forms, as *Mesalia provisi* and *Glycimeris convexus*, and the age of the deposit is certainly Werrikooian or Upper Pliocene. In the present sample, as in the raised beach at Yorke Peninsula, the beds are slightly younger, and may be referred to the older raised beach stage, or Lower Pleistocene.

Chandler Collection.

Class PELECYPODA.

Fam. ARCIDAE.

Genus **Arca,** Lamarck. Subgenus **Anadara,** Gray.

Arca (Andara) trapezia, Deshayes.

Arca trapezia, Deshayes, 1840, Mag. Zool., p. 21, 3 figs.

The shell attains a large size in this bed, and vies with similar large specimens in the Pleistocene of the West Melbourne Swamp. They reach a length of 104 mm., and a height of 81 mm.; the shells are embedded in a fine calcareous mud. Although the abundance of this species might suggest estuarine influence, the remainder of the associated mollusca are of the ordinary open water type.

Chandler Collection.

Fam. PINNIDAE.

Genus **Pinna**, Linné.

Pinna intermis, Tate.

Pinna zeylanica, Angas (non Gray), 1865, Proc. Zool. Soc., p. 655.

Pinna inermis, Tate, 1886, Trans. R. Soc. S. Austr., vol. IX., p. 71, pl. IV., Fig. 5.

Prof. Tate records this species from St. Vincent's Gulf, and generally from Eucla to the south-east coast of South Australia. It is found "partially buried vertically in mud or sand in a few fathoms water."

In some respects the fossil shell resembles the earlier portion of *P. virgata*, Menke, a West Australian living form, but is distinguished by the feeble radial ridges, which in the living species are very distinct.

Chandler Collection.

Fam. PECTINIDAE.

Genus **Chlamys**, Bolten.

Chlamys bifrons, Lamarck, sp.

Pecten bifrons, Lamarck, 1819, Anim. sans. Vert., vol. VI. pt. I., p. 164, No. 4.

Chlamys bifrons, Hedley, 1914, Biol. Results Endeavour, vol. II., p. 73.

This species is recorded from the shores of New South Wales, Victoria and South Australia. The related form, *Chlamys undulatus*, Sow. sp., is noted as living in Western Australia. The fossil specimens are typical of *C. bifrons.*

Chandler Collection.

Fam. MYTILIDAE.

Genus **Brachyodontes**, Swainson.

Brachyodontes hirsutus, Lamarck, sp.

Mytilus hirsutus, Lamarck, 1818, Anim, sans Vert., vol. VI. pt. I. p. 120, No. 5.

Brachyodontes hirsutus, Lam. sp., Hedley, 1917, Journ. R. Soc. New South Wales, vol. LI. Suppl. p. 11.

This species is abundant on the South Australian, Victorian and New South Wales coasts, but seems to be unrecorded from Western Australia.

Chandler Collection.

Fam. VENERIDAE.

Genus **Marcia,** H. and A. Adams. Subgenus **Katelysia,** Römer

Marcia (Katelysia) strigosa, Lamarck, sp.

Venus strigosa, Lamarck, 1818, Anim. sans Vert., vol. V., p. 605.

This common shell is found on muddy and sandy beaches at low tide.

Chandler Collection.

Class GASTEROPODA.

Fam. TROCHIDAE.

Genus **Clanculus,** Montfort.

Clanculus dunkeri, Koch sp.

Trochus dunkeri, Koch, 1843, in Philippi, Abbild, und Beschr. neuer Conch., vol. I, pt. III. p. 67, pl. II. Fig. 5.

Clanculus dunkeri, Koch sp., Pritchard and Gatliff, 1902, Proc. R. Soc., Vict. vol. XIV. (N.S.), pt. II., p. 121.

This species is found living in South Australia and Western Australia, and is recorded from Westernport, Victoria.

Chandler Collection.

Fam. TURRITELLIDAE.

Genus **Turritella,** Lamarck.

Turritella clathrata, Kiener.

Turritella clathrata, Kiener, 1843, Icon. Coq. Viv., p. 33, pl. XIV., Fig. 1, Reeve, 1849, Conch. Icon., vol. V., pl. VIII., Fig. 37. Pritchard and Gatliff, 1900, Proc. R. Soc. Vict. vol. XII. (N.S.) pt. II., p. 202.

This is a well known South Australian species, and is also recorded from the south-west coast of Victoria.

Chandler Collection.

Fam. CERITHIIDAE.

Genus **Bittium,** Leach.

Bittium cerithium, Quoy and Gaimard sp.

Turritella cerithium, Quoy and Gaimard, 1834, Voyage Astrolabe, vol. III. p. 139, pl. LV. Figs. 27, 28.

A common form in Victorian waters; apparently absent from lists of other States.

Chandler Collection.

Fam. COLUMBELLIDAE.

Genus **Columbella,** Lamarck.

Columbella aff. semiconvexa, Lamarck sp.

Buccinum semiconvexa, Lamarck, 1822, Anim. sans Vert., vol. VII. p. 272.

Pyrene semiconvexa, Lam. sp., Hedley, 1917, Journ. R. Soc. New South Wales, vol. LI. Supp. p. 90.

This is a common shell, frequent in most shallow sands round the Southern Australian coasts.

Chandler Collection.

Fam. FUSIDAE.

Genus **Fusus,** Lamarck.

Fusus australis, Quoy and Gaimard.

Fusus australis, Quoy and Gaimard, 1833, Voy. Astrolabe, vol. II. p. 495, pl. XXXIV. Figs. 9-14. Tryon, 1881, Man. Conch. vol. III., p. 55, pl. XXXIV., Figs. 113, 116, 118.

A common shore-living shell in South Australia and Victoria.

Chandler Collection.

Genus **Fasciolaria,** Lamarck.

Fasciolaria australasia, Perry sp.

Pyrula australasia, Perry, 1811, Conchology, pl. LIV., Fig. 4.

Fasciolaria australasia, Perry sp., Hedley, 1903, Mem. Austr. Mus., vol. IV., p. 373.

A well-known south coastal species. Recorded from the Western Bight in 100 fathoms; the species also ranges to shallower depths.

Chandler Collection.

Fam. VOLUTIDAE.

Genus **Mitra,** Lamarck.

Mitra pica, Reeve.

Mitra pica, Reeve, 1845, Proc. Zool. Soc. Lond., p. 49, Idem, 1845, Conch. Icon., vol. II., pl. XXXI. Fig. 247. Pritchard and Gatliff, 1899, Proc. R. Soc. Vict., vol. XI. (N.S.) pt. II. p. 188.

This species is found living in South Australia, and it also occurs along the Victorian coast from Westernport to Warrnambool.

Chandler Collection.

Fam. BULLARIIDAE.

Genus **Bullaria,** Rafinesque.

Bullaria botanica (Hedley).

Bulla australis, Gray, 1825, Annals of Phil., N.S. vol. XXV. p. 408.

Bullaria botanica, Hedley, 1918, Journ. R. Soc. N. S. Wales, vol. LI. Suppl. p. 104 (nom. mut. for *B. australis*, Gray non Ferussac).

A well distributed species in littoral waters round the southern parts of Australia.

Chandler Collection.

MIOCENE FOSSILS FROM THE OOLDEA DISTRICT.

Order FORAMINIFERA.

Orbitolites complanata, Lamarck.

Genus **Orbitolites,** Lamarck.

This discoidal foraminifer, here also recorded from the Older Pleistocene (see antea page 228) reaches a diameter of 1½ inches. The present occurrence of this large variety is interesting, since the older, Oligocene form in Australia is much smaller, and the younger, early and late Pleistocene, specimens are not quite so large. It is fairly common here.

Cudmore Collection.

Class ANTHOZOA.

Fam. TURBINOLIIDAE.

Genus **Placotrochus,** Edwards and Haime.

Placotrochus deltoideus, Duncan.

Placotrochus deltoideus, Duncan, 1864, Ann. and Mag. Nat. Hist. vol. XIV., p. 164, pl. V. Fig. 5.

Casts only. Cudmore Collection.

Fam. STYLOPHORIDAE.

Genus **Stylophora,** Schweigg.

Stylophora sp. nov.?

Numerous moulds and casts of a branching form. Cudmore Collection

Fam. ASTRAEIDAE.

Genus **Montlivaltia,** Lamaroux.

cf. *Montlivaltia*, sp.

A species with a large discoidal, depressed calyx.

Cudmore Collection.

Genus **Orbicella,** Dana.

Orbicella tasmaniensis, Duncan sp. Plate I. Fig. I.

Heliastraea tasmaniensis, Duncan, 1876, Quart. Journ. Geol. Soc. vol. XXXII. p. 342, pl. XXII., Figs. 1-3.

Astrangia tabulosa, Tate, 1893, Journ. R. Soc. N. S. Wales, vol. XXVII. p. 145, pl. XIII. Fig. 2.

Two species of the above named coral were presented by Dr. Griffith Taylor. They occur in the hard, reddish limestone of the Tertiary series, and were found on the surface of a salt lake east of Ooldea. One of them is preserved in hard, semi-crystalline limestone, in which the coral structure is much obscured; whilst the other is weathered and whitened, so that it has the appearance of a living coral. The structure of the weathered specimen is, however, none the less perfect, for this process has simply picked out the calcareous infilling. A large number of wind-worn pieces of this coral was also secured by Mr. Cudmore, who states that they occur scattered over the limestone plains. By their blackened and polished surfaces the fragments appear to have been exposed to the weather for a long time.

The species, living and fossil, formerly referred to the genus *Heliastraea*, are now relegated to *Orbicella* by Verrill and Quelch[2] by reason of priority.

There is a close agreement of these specimens from Ooldea with those from Tasmania, though the former have the calices rather larger in diameter (9 :8). The weathered specimen shows that, although the dissepiments are, as a rule, curved downwards, this is by no means invariable. This specimen has the mesenteric pouches filled with a pale glauconite, thus showing, in common with other organic marine bodies, a tendency for the body cavity to act as a receptacle for the deposition of the hydrous silicate of iron, alumina and potash to form that mineral.

Orbicella tasmaniensis has, up to the present, been unknown from any locality outside Tasmania, excepting Flemington, Victoria.

Taylor and Cudmore Collections.

2. Rep. Chall., Vol. XVI., Zool. 1886, p. 106.

Class ECHINOIDEA.

Fam. CLYPEASTRIDAE.

Genus **Laganum**, Gray.

?*Laganum sp.*

A fragmentary test shows a portion of the sub-angulately contoured ambitus and internal supporting pillars. The genus was previously recorded by Tate from the Tertiary of St. Vincent Gulf, South Australia. (*L. platymodes.*)

Cudmore Collection.

Class PELECYPODA.

Fam. PARALLELODONTIDAE.

Genus **Cucullaea**, Lamarck.

Cucullaea corioensis, McCoy.

Cucullaea corioensis, McCoy, 1876, Prod. Pal. Vict. Dec. III. p. 32, pl. XXVII. Figs. 3-5*b*. Tate, 1886, Trans. R.S.S. Austr., vol. VIII. p. 144. Harris, 1897, Cat. Tert. Moll. pt. I. Australasia. (Brit. Mus.) p. 336.

Numerous casts of this widely ranging species (Oligocene to Werrikooian), occur here.

Cudmore Collection.

Fam. ARCIDAE.

Genus **Glycimeris**, Da Costa.

Glycimeris maccoyi, Johnston sp.

Pectunculus laticostatus, McCoy non Quoy and Gaimard, 1875, Prod. Pal. Vict. Dec. II. p. 26, pl. XIX. Figs. 10-14.

Pectunculus maccoyi, Johnson, 1884, Papers and Proc. R. Soc. Tas., p. 199, Id., 1888, Geol. Tas, p. 225, pl. XXX. Fgs, 1, 1*d*.

Casts and moulds of this common Tertiary species occur in the hard limestone.

Cudmore Collection.

Fam. PECTINIDAE.

Genus **Chlamys**, Bolten.

Chlamys murrayanus, Tate sp.

Pecten murrayanus, Tate, 1886, Trans. Roy. Soc. S. Australia, vol. VIII., p. 105, Pl. VII., Figs. 5, *a*, *b*.

One of the specimens found four miles west of Ooldea by Dr. Griffith Taylor, is a cast in hard cream coloured limestone. Others collected from near the same locality (Watson cutting), by Mr. Cudmore, show a denuded shell, the riblets being devoid of ornament except in one case, where the structure is seen to be that of *C. murrayanus;* the appearance is misleading, and the shell might easily be mistaken for one of the Amusium type, like *A. yahliensis*, T. Woods sp.

In the Miocene seas *C. murrayanus* attained a large size, some examples measuring as much as 3½ inches in length.

Previously recorded from South Australia in Miocene beds of the Lower Murray River.

Taylor, Chandler and Cudmore Collections.

Chlamys aldingensis, Tate sp.

Pecten aldingensis, Tate, 1886, Trans. R.S.S. Austr., vol. VIII., p. 109, pl. VII., Figs. 1*a-c*. Chapman, 1912, Mem. Nat. Mus. Melbourne, No. 4, p. 48.

Previously recorded from South Australia in the Miocene glauconitic limestone of Aldinga Bay. Dennant notes it from Stansbury, South Australia, and the present writer from the polyzoal limestone of Seal River, King Island. Cudmore Collection.

Fam. SPONDYLIDAE.

Genus **Spondylus**, Linné.

Spondylus cf. *gaederopoides*, McCoy.

Spondylus gaderopoides, McCoy, 1876, Prod. Pal. Vict., Dec. IV. p. 27, pl. XXXVIII. Figs. 1-1*d*.

Spondylus gaederopoides, McCoy, Tate, 1886, Trans. R. Soc. S. Austr., vol. VIII. p. 121.

Two casts of united valves occur here. They are solidly built, and of the general form of the above species, which, by the way, is a restricted Miocene fossil. Cudmore Collection.

Fam. LIMIDAE.

Genus **Lima**, Bruguière. Subgenus **Limatula**, Wood.

Lima (Limatula) jeffreysiana, Tate.

Lima (Limatula) jeffreysiana, Tate, 1886, Trans. R.S.S. Austr. vol. VIII. p. 119, pl. IV., Fig. 8.

A well preserved shell is found here. Cudmore Collection.

Fam. CRASSATELLITIDAE.

Genus **Crassatellites,** Kruger.

Crassatellites cf. *oblonga*, T. Woods sp.

Crassatella oblonga, T. Woods, 1875, Papers and Proc. R. Soc. Tasmania (1876), p. 25, pl. II., Fig. 11.

This internal cast closely resembles the Table Cape form specified above, especially in the anterior position of the umbones.

Cudmore Collection.

Fam. CARDITIDAE.

Genus **Cardita,** Bruguière.

Cardita cf. *tasmanica*, Tate.

Cardita tasmanica, Tate, 1886, Trans. R. Soc. South Austr., vol. VIII. p. 154, pl. XII. Fig. 13.

The species appears to be represented here by an internal cast, judging by the shape and number of riblets, with impressions of some still preserved, it is in all probability referable to the above

Cudmore Collection.

Cardita scabrosa, Tate.

Cardita scabrosa, Tate, 1886, Trans. R. Soc. South Australia, vol. VIII., p. 152, pl. II., Fig. 4.

A good internal mould of this species occurs here.

Cudmore Collection.

Fam. LUCINIDAE.

Genus **Lucina,** Bruguière.

Lucina planatella, Tate, 1886, Trans. R. Soc. S. Austr., vol. VIII., pl. XII. Fig. 11, Idem, 1887, ibid, vol. IX. p. 146.

Both moulds and casts, showing ornament and internal form are found in some frequency. The species was originally described as a Table Cape fossil. I have since identified it amongst fossils from Maude.

Cudmore Collection.

Fam. CARDIIDAE.

Genus **Cardium** Linné.

Cardium victoriae, Tate.

Cardium victoriae, Tate, 1887, Trans. R. Soc. S. Austr. vol. IX. p. 151, pl. XIV. Figs. 1*a*, *b*. Harris, 1897, Cat. Tert. Moll. Australasia (Brit. Mus.), p. 367.

Several examples showing typical surface ornament are found here.

Cudmore Collection.

Subgenus **Protocardium**, Beyrich.

Cardium (Protocardium) antisemigranulatum, McCoy.

Cardium (Protocardium) antisemigranulatum, McCoy, 1877, Prod. Pal. Vict., Dec. V. p. 16, pl. XLIV. Figs. 2, 3.

Represented here by an internal cast.

Cudmore Collection.

Fam. VENERIDAE.

Genus **Venus**. Subgenus **Chione**, Megerle.

Venus (Chione) cainozoicus, T. Woods sp.

Venus (Chione) cainozoica, T. Woods, 1877, Papers and Proc. R. Soc. Tas. for 1876, p. 113.

Chione cainozoicus, T. Woods sp., Tate, 1887, Trans. R. Soc. S. Austr. vol. IX. p. 156, pl. XVI. Figs. 3*a*, *b*.

Two examples. Cudmore Collection.

Venus (Chione) ? hormophora, Tate, sp.

Chione hormophora, Tate, 1887, Trans. R. Soc. S. Austr., vol. IX., p. 155, pl. XV. Figs. 1*a*, *b*.

A cast and also an impressed mould of the shell was found. The former shows the straight ventral region, and the latter the ornamentation, of the above typical Table Cape species.

Cudmore Collection.

Genus **Dosinea**, Scopoli.

Dosinea johnstoni, Tate.

Dosinea johnstoni, Tate, 1887, Trans. R. Soc. S. Aust., vol. IX. p. 161, pl. XIV. Figs. 9 and 12.

A mould of a shell of a *Dosinea* in white limestone shows by a wax squeeze the characteristic costation of the above species. The concentric ridges measure 20 in a breadth of 10 mm. and are elevated rather than depressed and rolled over to become almost confluent, as in *D. densilineata*, Pritchard.[3] The length of the present example, if complete, would measure about 50 mm. *D. johnstoni* has a long vertical range, from Balcombian to Kalimnan (Balcombe Bay, Table Cape, Upper Muddy Creek).

Chandler and Cudmore Collections.

3. Proc. Roy. Soc. Vict., Vol. VIII., 1896, p. 135, pl. IV., Figs. 5-7.

Fam. TELLINIDAE.

Genus **Tellina,** Linné.

Tellina, aff. *albinelloides*, Tate

Tellina albinelloides, Tate, 1887, Trans. R. Soc. S. Austr., vol. IX. p. 164, pl. XVI. Figs. 4*a*, *b*.

A large shell-impression was found here, which agrees in the main characters with the above species. *T. albinelloides* is a Kalimnan form, so that this occurrence, if it be correctly assigned, is unique as a Miocene fossil.

Cudmore Collection.

Tellina, cf. *cainozoica*, T. Woods.

Tellina cainozoica, T. Woods, 1877, Papers and Proc. R. Soc. Tas. for 1876, p. 113. Tate, 1887, Trans. R. Soc. S. Austr., vol. IX., p. 164, pl. XVIII. Fig. 5.

A solitary specimen, doubtfully referred to the above species occurs here.

Cudmore Collection.

Fam. CORBULIDAE.

Genus **Corbula,** Lamarck.

Corbula pyxidata.

Corbula pyxidata, Tate, 1887, Trans. R. Soc. S. Austr., vol. IX. 117, pl. XVII. Figs, 12*a*, *b*.

A well defined cast in white limestone occurs here

Cudmore Collection.

Corbula ephamilla, Tate.

Corbula ephamilla, Tate, 1887, Trans. R. Soc. S. Austr., vol. IX. p. 176, pl. XVII., Figs. 13*a*, *b*. 14.

A mould of this widely distributed species was found here.

Cudmore Collection.

Fam. TEREDINIDAE.

Genus **Teredo,** Linné.

Teredo directa, Hutton, sp.

Cladopoda directa, Hutton, 1877, Trans. N.Z. Inst., vol. IX. p. 597, pl. XVI. Fig. 13.

Teredo directa, Hutton, sp., Suter, 1914, Rev. Tert. Moll. N. Zealand, pt. I. (Pal. Bull, 2, N.Z. Geol. Surv.), p. 54.

Two casts of Teredo tubes found here correspond with the almost straight small tubes of the above species which came from the Miocene of Canterbury, N. Zealand.

Cudmore Collection.

Class GASTEROPODA.

Fam. TROCHIDAE.

Genus **Astele**, Lwainson.

Astele sp.

Several casts and moulds of a form referable to the above genus occur in the white limestone. It has rather smooth, flat whorls, and a thread-like ornament round the base. It resembles an undescribed species from the Miocene of Victoria.

Cudmore Collection.

Fam. NATICIDAE.

Genus **Natica**, Scopoli.

Natica substolida, Tate, var. *grandis*, *nov.*

Description.—Shell of the type of *Natica substolida*, Tate,[4] but of much larger dimensions and heavier build, the length being more than twice that of the specific form (54 mm., as compared with 25 mm. in the species).

A large specimen of *Natica*, somewhat deformed, but evidently belonging to the new variety, has been figured by Mr. C. J. Gabriel and the writer from the Mallee Bores, under the name of *N. subinfundibulum*, var. *crassa*, Tate.[5]

This large variety is fairly common in the limestone of the Ooldea district, and its large size (over 2 inches in length), makes it a conspicuous fossil.

Cudmore Collection.

Natica cf. *hamiltonensis*, Tate.

Natica hamiltonensis, Tate, 1893, Trans. R. Soc. S. Austr., vol. XVIII. pt. 2, p. 319, pl. X. Fig. 6.

A cast referred with slight doubt to this common Tertiary fossil was found here.

Cudmore Collection.

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4. *Natica (Neverita) substolida*, Trans. R. Soc. S. Austr., Vol. XVII., p. II, 1893, p. 323, pl. VI. Fig. 3.
5. Proc. Roy. Soc. Vict., Vol. XXVI. (N.S.) pt. II., 1914, p. 321, pl. XXV., Figs, 15*a*, *b*,

Genus **Euspira**, Agassiz.

Euspira cf. *effusa*, Tate sp.

Ampullina effusa, Tate, 1893, Trans. R. Soc. S. Austr., vol. XVII. pt. 2, p. 327, pl. X. Figs. 2, 2*a*.

A cast of a globosely whorled naticoid shell was found, of which there is very little doubt as to its relationship. *E. effusa* was recorded by Tate from the Miocene glauconite sands of the Adelaide Bore, whilst Dennant notes it from Brown's and Hamilton Creeks, in Victoria, in beds of Miocene age.

Cudmore Collection.

Fam. CERITHIIDAE.

Genus **Cerithium**, Bruguière.

Cerithium pritchardi, Harris.

Potamides semicostatum, Tate (non Deshayes), 1885, Papers and Proc. R. Soc. Tas. for 1884, p. 226.

Cerithium pritchardi, Harris, 1897, Cat. Tert. Moll. Australasia (Brit. Mus.) p. 225, pl. VII., Fig. 3.

Numerous pieces of this strongly built shell are included in the collection, some of which had been weathered. They were found accompanied by *Orbicella* in the exposed rubble of the plains. It is a restricted Miocene fossil.

Cudmore Collection.

Genus **Newtoniella**, Cossman.

Newtoniella sp.

A hollow mould of a shell referable to this genus, and probably new, occurs here.

Cudmore Collection.

Fam. CYPRAEDIAE.

Genus **Cypraea**, Linné.

Cypraea spp.

These are casts, fairly common, related to the typical forms *C. subsidua*, Tate, and *C. murraviana*, Tate.

Cudmore Collection.

Fam. VOLUTIDAE.

Genus, Lyria, Gray.

Lyria acuticostata, sp. nov.

Description.—Shell long-ovate, volutiform; apically pointed, anteriorly truncated; whorls moderately high, entirely costate, the acute riblets numbering about 18 on the body whorl. Protoconch small, as compared with *L. semiacuticostata*, Prichard,[1] and consisting of two volutions.

The above description is completed from an example in the Dennant collection, from Bird Rock, Torquay, Victoria.

Dimensions.—The limestone specimen measured when complete, circ. 60 mm.; the Torquay marl specimen, 42 mm.

Comparison.—In general shape and acute apex this species is related to *L. semiacuticostate* from Table Cape, but differs essentially in having continuous costation. It is clearly an ancestor of the living *Lyria mitraeformis*,[2] from which it differs in the more numerous costae and slightly narrower shell.

Cudmore Collection.

Genus Voluta, Linné.

Voluta validicostata, Tate.

Voluta alticostata, Tate, 1889, Trans. R. Soc. S. Austr., vol. XI. p. 122, pl. V. Fig. 7.

Voluta validicostata, Tate (nom. mut.), vide Dennant and Kitson, Cat. Cain. Foss., 1903. p. 100.

Several casts of young and median grown shells are found here. Although occurring in the Balcombian, in Victoria, it is more typical of Janjukian strata, both there and in South Australia.

Cudmore Collection.

Voluta cf. *ancilloides*, Tate.

Voluta ancilloides, Tate, 1889, Trans. R. Soc., S. Austr., vol. XI. p. 126, pl. III., Fig. 7.

A cast of a shell of the above specific type occurs in the hard limestone from Ooldea. *V. ancilloides* is a well-known Table Cape fossil.

Chandler Collection.

Fam. OLIVIDAE.

Genus **Ancilla**, Lamarck.

Ancilla sp.

A cast of a shell occurs in the limestone, of the type of an *Ancilla* found at Spring Creek and Table Cape (Nat. Mus. Coll.), but of very large dimensions. It must have attained a length of about 50 mm. when complete, whereas the Spring Creek specimens rarely measure more than 20 mm., a difference accounted for by the variation in sedimentation.

Fam. TURRITIDAE.

Genus **Clavatula**, Lamarck.

? *Clavatula* sp.

This is an internal cast of the apical portion of a large conical species, with the earlier whorls faintly costate and medially ridged.

Cudmore Collection.

Fam. CONIDAE.

Genus **Conus**, Linné.

Conus spp.

Probably several species are represented here, but they are all internal casts. So far as can be seen, the commonest form is related to *Conus ligatus*, Tate.[6]

Chandler and Cudmore Collections.

Class CEPHALOPODA.

Fam. NAUTILIDAE.

Genus, **Nautilus**, Linné.

Nautilus sp. cf. *geelongensis*, Foord.

Nautilus geelongensis, Foord, 1891, Cat. Foss. Cephalopoda (Brit. Mus. pt. II. p. 332, woodcut, Fig. 69. Chapman, 1915, Proc. R. Soc. Vict. vol. XXVII (N.S.), pt. II. p. 354, pl. IV. Figs. 7-9).

The present example is a large specimen (a fragmentary cast), having an approximate diameter of about 6 inches when com-

6. Trans. Roy. Soc. S. Austr., Vol. XIII., pt. 2, 1890, p. 196, pl. VII. Figs. 4, 4a, b; pl. VIII., Fig. 9.

plete. In its broad contour it is nearest to *N. geelongensis*, a Janjukian species from the polyzoal rock generally.

Cudmore Collection.

FOSSIL LISTS.—OOLDEA DISTRICT.

Older Pleistocene.

Orbitolites complanata, Lam.
Arca (Anadara) trapezia, Desh.
Pinna inermis, Tate.
Chlamys bifrons, Lam. sp.
Brachyodontes hirsutus, Lam. s.p.
Marcia (Katelysia) strigosa, Lam. sp.
Clanculus dunkeri, Koch sp.
Turritella clathrata, Kiener.
Bittium cerithium, Q. and G. sp.
Columbella aff. *semiconvexa*, Lam. sp.
Fusus australis, Q. and G.
Fasciolaria australasia, Perry sp.
Mitra pica, Reeve.
Bullaria botanica, Hedley.

Miocene.

Orbitolites complanata, Lam.
Placotrochus deltoideus, Dunc.
Stylophora, sp. nov.
cf. *Montlivaltia*, sp.
Orbicella tasmaniensis, Dunc. sp.
?*Laganum* sp.
Cucullaea corioensis, McCoy.
Glycimeris maccoyi, Johnst. sp.
Chlamys murrayanus, Tate, sp.
Chlamys aldingensis, Tate sp.
Spondylus cf. *gaederopoides*, McCoy.
Lima (Limatula) jeffreysiana, Tate.
Crassatellites cf. *oblonga*, T. Woods sp.
Cardita cf. *tasmanica*, Tate.
Cardita scabrosa, Tate.
Lucina planatella, Tate.
Cardium victoriae, Tate.
Cardium (Protocardium) antisemigranulatum, McCoy.
Venus (Chione) cainozoicus, T. Woods sp.
Venus (Chione) ?hormophora, Tate.
Dosinea johnstoni, Tate.
Tellina aff. *albinelloides*, Tate.
Tellina cf. *cainozoica*, T. Woods.
Corbula pyxidata, Tate.
Corbula ephamilla, Tate.
Teredo directa, Hutton sp.
Astele sp.
Natica substolida, Tate, var. *grandis*, nov.
Natica cf. *hamiltonensis*, Tate.
Euspira cf. *effusa*, Tate sp.
Cerithium pritchardi, Harris.
Newtoniella sp.
Cypraea spp.
Lyria acuticostata, sp. nov.
Voluta validicostata, Tate.
Voluta cf. *ancilloides*, Tate.
Ancilla sp.
Clavatula sp.
Conus spp.
Nautilus geelongensis, Foord.

Episodes in the Formation of the Beds of the Great Bight Area.

In pre-Miocene times the area abutting on the Cretaceous of the Lake Eyre district to the north-west, to Charlotte Waters on the north, to Albany, on the west, and to the Adelaide Plains on the east, and far to the south on what is now the Southern Ocean, was probably dominated by an estuarine or generally base-levelled country. This area also extended through the Riverina as far as Wagga, in New South Wales, and occupied a large part of the Wimmera and Mallee districts of Victoria. The underlying (fundamental) rocks of this area consist mainly of granite,[7] chloritic slate, felspathic quartzites, slaty rocks and sandstones, all excepting the granite possibly referable either to the Ordovician, Cambrian or metamorphic series, including Algonkian. The deposits laid down on these basal rocks were river, estuarine, swamp and lake accumulations, consisting of sands and clays with carbonaceous and lignitic material.

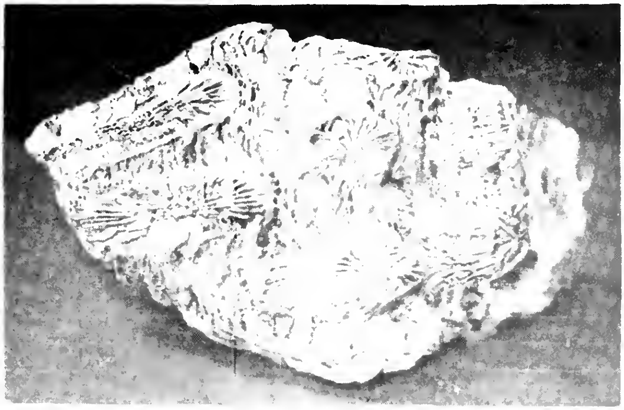
Following the deposition of these beds, which, by the way, were not uniformly spread over the entire area mentioned, there were occasional oscillations which brought them below sea-level, causing an interstratification of marine beds with the terrestrial. Later, the oscillations ended in a steady to quick downward movement until a depth of at least 100 fathoms below sea-level was reached. In this sea-bed a rich deposit of calcareous mud was formed, filled with debris of polyzoa, echinoids, mollusca and foraminifera. These beds can be referred to the Janjukian series of Victoria, and are homotaxial with the Miocene of Europe.

In Lower Pliocene times (Kalimnan series) the sea-bed rose to within a few fathoms of the surface, with fine sandy deposits, upon which flourished molluscs as *Ostrea*, *Natica*, *Turritella* and the sea-urchin, *Laganum*, amongst many other organisms. In places there were huge oyster banks, and in the more rocky parts vast deposits of mollusca peculiar to such conditions, as *Mytilus*, *Barnea*, *Venerupis*, *Arca*, *Cucullaea* and *Glycimeris*, a few species of which facies are still living. Possibly a part of the Miocene limestone of which the fauna is here discussed, may have persisted into the Lower Pliocene, as evidently a few forms, such as *Tellina* cf. *albinelloides* and *Laganum*, seem to indicate.

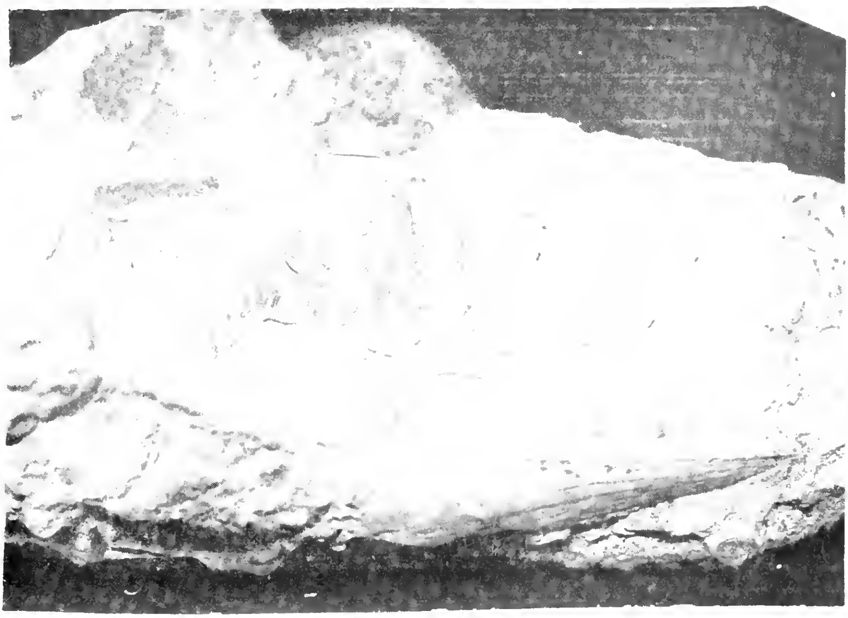
In the later period of the Pliocene this sea-bed again deepened, and a shell deposit with many existing species was laid down.

7 In the Albany district these older limestones = Plantagenet Beds) have been shown by J. T. Jutson and E. S. Simpson (Journ. and Proc. Roy. Soc. W. Australia, Vol. II., 1917, p. 48) to have been laid down on the granite.

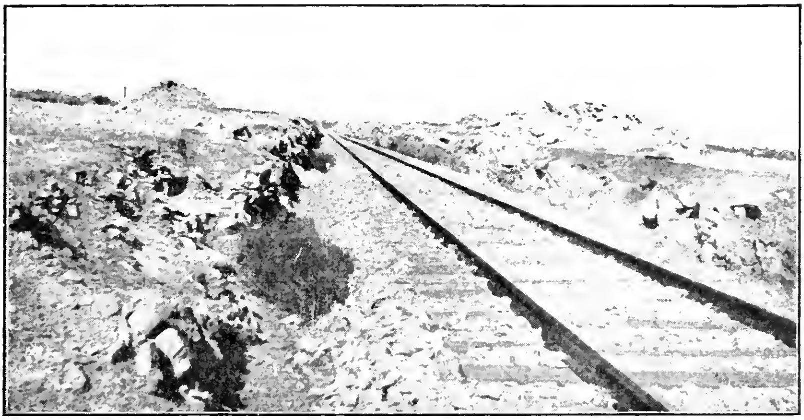
1

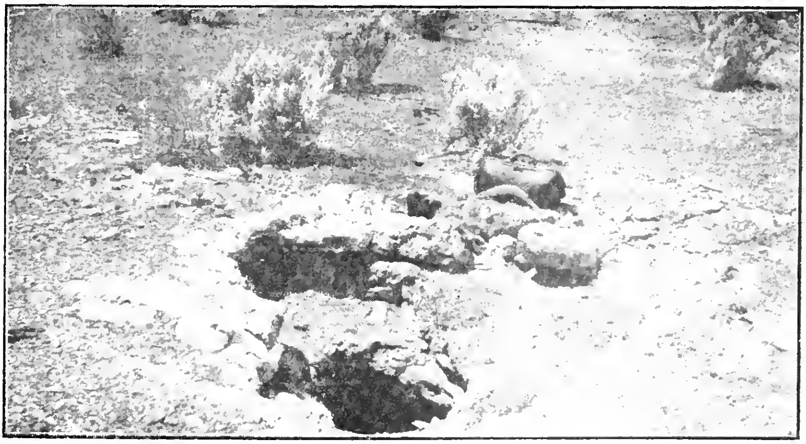


2



Fossils of Ooldea





Tertiary Limestone Plains near Ooldea

This deposit can be referred to the Werrikooian, as it is geologically comparable with the Glenelg upraised marine beds. It also occurs in the upper part of the Croydon Bore, near Adelaide, to about 400 feet. One of the commonest fossils in this bed is *Orbitolites complanata*. This foraminifer is now living on the Australian coast, but at lower latitudes. For example, on the west coast, at Shark's Bay (lat. 25 S.), and on the east coast at the Barrier Reef (from about lat. 23 S.). The occurrence of *Orbitolites* at the higher latitude of 32 S. denotes a warmer climate in Werrikooian and Older Pleistocene times. During the Weerikooian a number of the molluscan species became extinct, whilst others, along with *Orbitolites*, persisted.

In the next period, the Older Pleistocene, the bed of shells and foraminifera emerged from the sea, and was raised to a height of about 381 feet between that time and the present; it is found to-day overlying the Janjukian limestones at the Ooldea Soak, 100 miles inland. Upon the present coast line, in late Pleistocene times there was laid down an ordinary beach deposit with shells, and this is now found forming ledges and raised beaches at protected places along the southern coast, denoting the continuance of the uplift along the shores of the Great Bight even to the present time.

EXPLANATION OF PLATES.

Plate XVI.

Fig. 1.—*Orbicella tasmaniensis*, Duncan sp. Miocene (Janjukian). From surface of Salt Lake, W. of Ooldea, South Australia. Circ. nat. size.

,, 2.—Fragment of Raised Beach, of Older Pleistocene age; showing *Pinna inermis*, Tate (shell at base), *Bullaria botanica*, Hedley, and *Bittium cerithium*, Q. and G. sp. Ooldea district, South Australia. Three-fifths nat. size.

Plate XVII.

Fig. 1.—Cutting with fossiliferous Tertiary limestone (Miocene); half mile east of Watson.

,, 2.—Blowhole in Miocene limestone, near Ooldea. (Photographs on this plate by Mr. F. A. Cudmore.)

[Proc. Roy. Soc. Victoria, 32 (N.S.), Pt. II., 1920].

Art. XVII.—*The Longevity of Cut Flowers.*

By ELLINOR ARCHER, M.Sc.,
(Secretary of the Seed Improvement Committee).

[Read 11th December, 1919.]

This work was carried out in the Botanical Department of Melbourne University, as Government Research Scholar.

In studying the question of the longevity of cut flowers, the first thing to be taken into account is the reason or reasons which cause cut flowers to die, or to lose their characters as flowers by passing into the fruiting condition.

That is, flowers may undergo either:—

(1) Withering of the sepals and petals due to passage from the flowering to the fruiting stage.

(2) Falling of the sepals and petals due to the same cause.

(3) Abnormal premature withering.

The last cause is naturally the only one to be considered when dealing with the longevity of cut flowers.

Abnormal withering may be caused in various ways:—

(1) By the blocking of the vessels preventing the rise of sap and, as transpiration continues, resulting in a loss of turgor, followed by drooping.

(2) By self-poisoning, owing to an exudation of poison from cells near the cut surface.

In the work that has been done up to date no actual case of premature withering due to poisoning has been proved. The manner in which cases of possible poisoning were tested was as follows:—Some of the suspected material was thoroughly ground and squeezed, and an extract made, in one case by boiling in water, and in the other by soaking for a considerable period in cold water. Fresh flowers were then placed in the extract, which should contain the poison in concentrated form, but in every case the material in the extract lasted just as well as the control, proving that there cannot have been much, if any, poison present in the extract.

The most frequent cause of abnormal withering is, therefore, some form of blocking of the vessels with a resultant loss of turgor. That blocking does actually take place can easily be seen by sectioning the stem at short distances from the cut ends, and examining the vessels under a microscope.

This blocking may be caused by external factors, or by factors within the plant itself. The most common external cause is the development of bacteria in the water surrounding the stem. This is especially likely to happen if flowers are placed in dirty vessels, or vessels in which the water has been left standing for some time. The bacteria enter the vessels of the stem at the cut end, the sap being an attraction, and after a time form a complete block, preventing the ascent of water. This may happen to practically any plant, and the most effectual remedy is to change the water frequently, and by so doing the accumulation of bacteria is checked.

Internal causes of blocking are a great deal more difficult to discover and define. There may be an exudation of wound gum into the vessels, or the parenchyma cells surrounding the vessels may develop outgrowths which push their way into the lumina, and finally form a parenchymatous tissue completely blocking the vessels, and very effectively retarding the ascent of sap. This condition is known as the formation of a tylosis.

In order to prevent withering in these cases, it will be necessary to keep the vessels clear, either by preventing the exudation or the abnormal growth taking place, or by dissolving it as rapidly as it is formed. This will have to be done by placing the stem in some solution which will perform the required action without at the same time having any harmful effect on the living tissues of the plant.

The work was commenced with any plants that happened to be blooming at the time, and various well known household methods for preserving flowers were tested. Placing the stems in boiling water, removing the bark for some distance up the stems, and charring the stems, all proved equally unsuccessful with the flowers used. The only one found to be of the slightest use was in the case of dahlias, which, if inclined to droop, would when placed in boiling water, very often completely revive.

Chrysanthemums and wattles are very inclined to show sudden abnormal drooping, and in one or two cases this was proved to be due to the present of masses of bacteria blocking the vessels, while in others what seemed to be a gummy precipitate could be seen in the vessels by examining a section of the stem. Since the blocking and consequent withering take place very rapidly, it is most probably caused by an internal secretion of a gummy nature. If this is the case it should be able to be prevented by placing the stems, either in a solution which will cause a precipitation on the walls of the vessels of the gummy substance directly it is formed and so prevent further exudation, or in a solution which will dissolve the exudation as fast at it enters the vessels.

Various tests were attempted to try and discover the solubility of the blocking material, but without success. If the material should be wound gum, which appears most likely, it ought to be able to be detected by testing with phloroglucin and hydrochloric acid, with which it should give a bright red colour, but no colour change was observable. A special stain for wound gum which should stain it in contrast to the surrounding tissues known as Hanstein's mixture, composed of equal parts of concentrated alcoholic solution of Fuschin and Methyl Violet, also gave no result.

Numerous tests for showing the presence of tannin were also attempted, especially on sections of Acacias, but although the presence of extensive tannin was shown in the cortex, medullary rays, and pith, the actual blocking substance in the vessels gave no definite tannin reaction.

The exact nature of the substance exuded from the surrounding cells into the vessels and causing blocking, therefore, remains doubtful, although it is most probably a form of wound gum which will not react to the colour tests.

Although the chemical nature of the substance exuded into the vessels remains undiscovered, an effective means was found of preventing the blocking in Acacias. It was found that if fresh specimens of Acacias, soon after being taken from the trees, are placed in a dilute solution of the non-poisonous heavy metals, no blocking occurs, and the flowers remain nearly perfect for a considerable period. The metal which proved most successful was lead, the nitrate, and the acetate being the salts most used, as they are the only two lead compounds easily soluble in water. Silver nitrate in dilute solution also proved fairly effective, but owing to its power of rapid decomposition it is somewhat unsuitable. Soluble mercury salts, presumably owing to their poisonous properties, proved rapidly harmful, while the other members of the group were not suitable for use.

The following tables give some idea of the effect that immersion of the stems in a weak solution of lead nitrate has on various species of wattle. It would be difficult to say exactly which day a certain mass of wattle flower actually died, therefore in the following tables the condition of the flowers at intervals of two, six, and fourteen days was noted. In a good many cases the flowers did not shrivel and droop at all; apparently, if it had not been for other causes, they would have kept indefinitely, but in every case, after from ten to fourteen days, the specimens would become discoloured. This discolouring would commence with the part of the stalk actually immersed in lead nitrate, and gradually spread until it affected the whole stalk, leaves, and, lastly flowers, so that in no case could the flowers really be called fresh for more than fourteen days.

In many cases the articulation between the pedicels of the capitula and the stems become loosened, with the consequence that the capitula fall off very easily, although remaining quite fresh.

It will be seen that the exact effect of the lead nitrate varies with the different species; for example, no experiments with Acacia armata succeeded, and the effect on other markedly xerophytic species, such as juniperina and verticillata, was very slight. A good deal of variation is noticeable in the effect of the lead nitrate on different specimens of the same variety. In some experiments the control and the specimens in lead nitrate have lasted for an equally short period, whereas another experiment with the same variety will give a good result. In all cases where rapid withering has taken place detailed sectioning and examination of the stem shows blocking. There is presumably some undetermined factor which controls the extent of the exudation, and the effect which immersion of the stem in lead nitrate will have on this. It is possible that the length of time intervening between the time that the blossom is picked, and the time that it is placed in the solution will have a considerable influence on its longevity. Accurate experiments to determine this point have not yet been carried out; but it was noticed that in any case where the blossom had been kept for some time, and had begun to wither, the lead nitrate did not exert a reviving effect, but the specimen would remain in a drooping condition for a long time, whereas the control would completely wither. That is, the lead nitrate does not dissolve blocking already formed, but prevents any further exudation taking place. Another possible factor influencing the amount of blocking shown in the stem might be the age of the wood forming the vessels at the cut part. This point was also undetermined.

Tables to show the influence of varying strengths of lead and silver salts on the longevity of the blossoms of varying species of Acacias.

[The number of days quoted under each column indicates the number of days that the specimens remain fresh.]

Species.	Control. Days.	Lead nitrate .5% Days.	Lead nitrate 1% Days.
A. saligna	2	6	6
A. salicinia	2	2	2
A. montana	2	6	6
A. prominens	2	6	6
A. stricta	2	14	14
A. fimbriata	2	14	14
A. diffusa	2	14	14
A. neriifolia	6	14	14
A. leprosa	6	14	14
A. longifolia	6	14	14

	Control. Days.	Lead nitrate 1% Days.
A. rubida	6	14
A. pycnantha	2	14
A. longifolia, var. sophora	2	14
A. decurrens var. normalis	2	6
A. cultriformis	2	14
A. myrtifolia	6	14
A. dodonaeifolia	6	14

	Control. Days.	Silver nitrate 1% Days.	Lead nitrate 1% Days.
A. sclerophylla	2	6	6
A. venulosa	2	6	14
A. spectabilis	2	6	14
A. saligna	2	14	14

	Control. Days.	Lead nitrate 1% Days.	Lead acetate 1% Days.
A. retinodes	6	14	14
A. lophantha	6	14	14
A. armata	2	2	2
A. juniperina	2	6	6
A. verticillata	2	6	6
A. acinacea	2	2	2
A. neriifolia	2	14	14
A. melanoxylon	2	6	6

In order to prove that the solution of lead nitrate did actually prevent blocking in the vessels, and allowed a freer passage through the stems the following experiment was performed.

Two short stems of as nearly as possible the same length and diameter were fixed in a perpendicular position. To the upper end of each was attached a small rubber tube connected with a small reservoir, while to the lower end a small graduated flask was also connected by a rubber tube.

Reservoir A, attached to Stem A, was filled with water, and Reservoir B, attached to Stem B, was filled with a 1% solution of lead nitrate. The reservoirs, which were the same size, provided an equal pressure on each stem, and should force an equal amount of liquid through the stems into the graduated flasks. The stems being of equal diameter, they should have approximately the same number of vessels, and unless blocking occurred in one and not in the other, the same amount of water and lead nitrate should pass through in the same time.

Experiment 1.—Time, one hour.

Stem A, water only, amount collected	.25 ccs.
Stem B, lead nitrate, amount collected	5 ccs.

Experiment 2.—Time, 45 minutes.

Stem A, water only, amount collected	.5 ccs.
Stem B, lead nitrate, amount collected	5 ccs.

Experiment 3 (with same stem as Experiment 2).—Time, one hour 15 minutes.

Stem A, amount collected	.7 ccs.
Stem B, amount collected	7 ccs.

Experiment 4.—Time, two hours.

Stem A, water only, amount collected	.5 ccs.
Stem B, lead nitrate, amount collected	3.5 ccs.

Experiment 5.—Time, three hours.

Stem A, water only, amount collected	.5 ccs.
Stem B, lead nitrate, amount collected	5 ccs.

These experiments show that the vessels are more open to the passage of lead nitrate solution than water. The viscosity of the lead nitrate solution is slightly greater than that of water, but its density is greater, and the greater head balances the higher viscosity largely. Neither factor would cause more than a 5 to 10% difference in the rate of flow, whereas the differences observed amount to 700 to 1000%, and this fact can only be explained by presuming that some form of blocking of the vessels intervenes to prevent the passage of water, but this is not developed when lead nitrate is passed through instead of water. This is proved by microscope examination of sections of the stems which have been used in the experiments. Stem A showed extensive blocking, whereas the vessels in Stem B were quite empty and with open lumina.

This method of preserving wattle blossom could be quite easily carried out in the household. A few crystals of lead nitrate to a quart of water should make a solution of a sufficient strength to preserve the blooms without having any harmful effect.

[Proc. Roy. Soc. Victoria, 32 (N.S.), Pt. II., 1920].

Art. XVIII.—*The Endophytic Fungus of Lolium, Part I.*

BY

ETHEL McLENNAN, B.Sc.,

(Lecturer on Botany in the Melbourne University.)

(With Plates XVIII. to XXVI. and 8 Text Figures.)

[Read Dec. 11th, 1919.]

Historical Introduction.

The fact, that grains of *Lolium temulentum*, L. (Darnel) contain a layer of fungal hyphae, situated between the aleurone layer and the fruit and seed coat, was demonstrated by Vogl (1) in 1898. In the same year Guérin (2), Hanausek (3), and Nestler (4), published papers dealing with this subject.

These earlier workers drew attention to the fact that the presence of the fungus in the grain is a fairly constant feature. Guérin examined samples of *Lolium temulentum* from South America, Asia, Africa, and Europe, and recorded that only three showed the absence of hyphae. He failed to note their presence in the embryo, although they were observed in the ovary before the fertilisation of the ovum. *Lolium arvense*, With., and *Lolium linicolum*, Sond., were also found to be fungal-containing, but he reported only one example of *Lolium perenne*, L., with the fungus. He suggested that the presence of the fungus in the Darnel grains is probably an example of symbiosis rather than one of actual parasitism.

Hanausek's results confirmed those of Guérin, and, in addition, he noted the presence of the hpyhae in the nucellus of the young ovary, where, he stated, it produced knots. This fact, he suggested, indicates a possible affinity of the fungus in question with the *Ustilagineae*.

Hanausek never examined a Darnel grain without finding hyphae in the usual position, but all samples of *L. perenne*, L. examined showed the absence of hyphae.

Nestler working along the same lines traced the distribution of the fungus in the seedling, and in the growing plant right up to the formation of the grain. He, in addition, tried to cultivate the fungus in artificial media with negative results. Only a few grains were found to be devoid of the fungus. He examined several of the species of *Lolium*, including *Lolium perenne*, *L.*, but found that the hyphae were absent in all cases. It was suggested that possibly Woronin's "Taumelroggen" and the fungus of Darnel bore some relation one to the other, on account of their somewhat similar physiological action. At the same time, however, he called attention to the many differences which might be cited between the two.

Hiltner's (5) attention was drawn to the work of Hanausek and Nestler, and in 1899 he published a paper dealing with the function of the fungus found associated with Darnel. This he stated to be of a nitrogen fixing nature, and proceeded to verify the statement by experiment. He recorded that *Lolium temulentum* grew equally well in nitrogen-free and nitrogen-containing sand, and he was thus drawn to the conclusion that the above statement as regards its function is the correct one. The methods employed by Hiltner are open to criticism, and I shall refer to his work in a later part of this paper (pp. 284-285.)

Micheletti (6), 1901, worked mainly on the chemical side of the question. A paper, "The Seed Fungus of *Lolium temulentum*, L., the Darnel," by Freeman (7), appeared in 1902. Freeman found that samples of Darnel from various localities showed wide differences in the proportion between fungal containing and fungal free seeds. He correlated the absence of the fungus with certain morphological characteristics, viz., colour and shape, although he indicated that in a few cases this correlation was not evident. Perhaps the chief point in his paper deals with the mode of entry of the fungus into the embryo. He described an isolated patch of hyphae at the base of the groove on the inner side of the grain. This patch he called the "infection layer" and he stated that it was from this layer that infection of the embryo took place. The course of the hyphae, according to his observations, was always intercellular, and penetration of the aleurone layer by the infecting hyphae took place at the junction of several cells. In all grains examined where hyphae were present in the embryo they were also found in the grain, and all the evidence was negative as to the possibility of their presence in the embryo and absence in the grain. However, he cited one doubtful case as regards this converse statement.

The distribution of the fungus in the growing plant was noted, and in dealing with the inflorescence and ovary he described in detail the development of his "infection layer."

All attempts to cultivate the fungus in artificial media were unsuccessful.

In conclusion he pointed out that Guérin considered the relation between the two organisms, one of true symbiosis; he agreed with this idea, but added, "the large hyphal layer of the grain, and the occasional penetrations of the endosperm, suggest vestigial indications that the action of the fungus is, or has been, at times injurious to the endosperm of the plant. Otherwise the fungus seems ordinarily to exert an almost stimulating influence on the host."

Freeman examined 30 grains of *Lolium perenne* L., and found only 5 contained the fungus. Of 59 grains of *Lolium italicum*, Braun, 2 alone showed the second organism, while of 25 grains of *Lolium linicolum*, Br., the full number gave positive results.

Another paper by Nestler (8) appeared in 1904, but it throws little further light on the problem. Fuchs (9), 1911, viewed the subject from the chemical standpoint, and finally, in 1912, a research by Buchet (10) was published, but, unfortunately, I have been unable to obtain this paper in Australia.

The erratic occurrence of the fungus in both *Lolium temulentum* and *Lolium perenne* recorded by these investigators does not tend to support the idea of a symbiotic association, but rather stresses the probability of its parasitic nature. The investigations described in the following paper were carried out in order to test these results for those grasses grown in Australia, and also to attempt to elucidate the actual relation between the two organisms. In attempting to further our knowledge of the relation between the grass and its associated fungus, I have limited myself mainly to a study of *Lolium perenne*, as practically no work has been done on this grass, and, in addition, it is a much more convenient form for obtaining embryological material. As far as time permitted I have compared this form with *Lolium temulentum*, and the results recorded in this paper are true for both forms. Perhaps a few minor differences may be determined later, but the main points are undoubtedly true for both grasses.

Methods.

Microtome sections were employed in the examination of the mature grains. The grains were soaked in distilled water for several hours, and then placed in a fixing fluid. During the early part of this work, Carnoy's fixing solution was used. Owing to the starchy nature of the endosperm, it was difficult to get good results, but if a paraffin with a fairly low melting point be used, it was found quite possible to obtain good and serial sections, after using this fixing reagent. At a later stage Bouin's fixative was employed, more particularly when dealing with the later stages in the development of the grain. It was quite easy to obtain absolutely entire sections after the specimens have been fixed in this way. The disadvantage lies in the fact that the starch in the endosperm was not well preserved, and also after this fixative the staining reactions, with the stains employed, do not seem to be as brilliant as they are following upon Carnoy's fixative.

The ether-freezing microtome was not satisfactory, owing to the difficulty in obtaining serial sections, and it was generally necessary to do this. Again, it was impossible to obtain as thin sections in this manner as with the paraffin method.

Hand sections were practically useless. They can only confirm the presence of the hyphae in the grain, but evidence as to their absence cannot be drawn from them.

The stain most generally employed, in fact, solely, as regards the mature grain, was aniline gentian violet.[1] In using this stain care must be taken to see that it is always fresh, as it does not keep well. Its staining capacity diminishes rapidly after several days. This stain was washed out with Gram's iodine water, then with absolute alcohol. Sections were next cleared in clove oil, and mounted in balsam.

Excellent results were obtained with this stain, the hyphae for the most part being stained a brilliant bluish purple, and the endosperm reacting to the iodine.[2] It far exceeded any other stain I have tried, among them being Haidenhain's haematoxylin, aniline safranin, erythrosin, aniline blue, etc. The aleurone cells for the most part and the cells of the scutellum and embryo do not stain, so that the hyphae present in these tissues stand out in striking contrast to the colourless cells around them.

This stain, used by itself, was only useful when dealing with the mature grain. In studying the embryology of the grasses in question it was necessary to counter-stain. Sections of the ovary before, and at the time of fertilisation, were stained with Bismarck

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1. One Soloid tabloid of gentian violet dissolved in 7 ccs. of abs, alc, and 63 ccs. of water containing 2.8 ccs. of aniline solution.

2. The colourisation of the endosperm by the iodine is, of course, not permanent, although the hyphae retain the violet stain well. This is certainly a drawback to the method, but it is more than compensated for by the excellent results obtained, which, indeed, are not approached by any other method.

brown, followed by aniline gentian violet; later stages were also treated in the same way. In addition, some of the later sections were stained with congo red. These were first stained with aniline gentian violet, followed by Gram's iodine water, and finally by congo red. This stain washes out very readily in the alcohols, so it was found necessary to use a watery solution of congo red, and to wash away excess with water, then to drain off as much of the water as possible, and transfer immediately to clove oil. If the sections be left on the water oven at a temperature of 45-50°C., they will clear perfectly well in from 1-2 hrs., and they can then be mounted in balsam and prove to be quite permanent.

The mature grain.

My aim at first was to make a record of the grains of both *Lolium temulentum*, and *Lolium perenne* examined, and to note the number of fungus-containing and fungus-free seeds.

After examining a large number of grains, I have been forced to the conclusion that it is impossible to distinguish macroscopically grains containing the fungus from those devoid of it (if any). The colour difference cited by Freeman cannot be regarded as a distinguishing feature.

Nine grains were chosen from a sample of Darnel obtained from Northam, Western Australia. Of these 4 were very dark in colour, 2 more or less intermediate, and 3 a pale straw yellow, but all of the nine showed a dense hyphal layer situated between the aleurone layer and the outer testa and pericarp. This is but a single example of many similar series. As the work proceeded it became more and more evident that both colour and size of grain were quite independent of the fungal constituent.

When commencing this record hand sections were used, as it was possible to handle a large number of fruits in a comparatively short time, by this means. Sometimes these hand sections revealed a grain apparently fungus-free—i.e., no definite layer of hyphae could be seen in the usual position in the grain. These, when obtained, were frequently microtomed, and fine but distinct fungal hyphae were found penetrating the scutellum, so it seemed impossible to decide whether a particular grain was devoid of the fungus unless serial sections were obtained sufficiently thin to enable these fine threads to be demonstrated. Although hand sections are useful in demonstrating the presence of the fungus, they cannot be accepted as evidence in regard to its absence.

The following results show that *Lolium perenne* is just as striking an example of a fungus-containing fruit as *Lolium temulentum*, and that the number of either grains devoid of the fungus is remarkably small. In fact, they suggest that probably all grains of Darnel and English rye grass contain this second organism, and failure to discern it in some grains is due to the fact that it is present in such minute quantities in the mature grain that it needs special care and staining to bring the hyphae out, or, as this paper proceeds, a second alternative will be considered (p. 293).

Lolium temulentum, L.

Locality	No. of grains examined	Fung. pres.	Fung. abs.
Victoria	93	93	—
Northam, W. Aust.	9	9	—
Katanning, W. Aust.	27	27	—
Kew, England	31	31	—
Cambridge, England[3]	9	9	—
Total	169	169	

Lolium perenne, L.

Locality	No. of grains examined	Fung. pres.	Fung. abs.
Victoria	53	53	—
Cowra, N.S.W.	12	12	—
New Zealand	4	4	—
South Africa	18	18	—
Scotland	11	11	—
Ireland	17	17	—
Total	115	115	

Although former workers have recorded the presence of the fungus in *Lolium perenne*, previously it has been thought to be very sparingly distributed in this species. The above results show that this is not actually so. It has also been suggested that the toxicity of Darnel is due to its fungal component, but since English rye grass shows a regularly occurring hyphal layer as well as Darnel, this suggestion

3. The "seeds" of this Cambridge sample were much smaller than those of any of the Australian samples. Frequently also on hand-sectioning no hyphal layer was evident, but several of the grains were microtomed, and further examination then showed distinct hyphae in the scutellum and embryo. Possibly the plants yielding the grain were grown under conditions which did not favour the luxuriant development of the fungus, so that the absence of the extra-cellular hyphal layer was more common in this sample than is usually the case. Only these grains which were actually microtomed are included in the above list.

does not seem to be a feasible one. Of course it might be argued that the two grasses contain different species of fungi, one of which might be toxic, the other harmless. The actual identity of the fungi obtained from the grains can only be established when they are grown artificially, and the sporing stage obtained, but as far as one can judge by comparing the two forms, they are very similar, and are certainly very closely related if not actually identical. Seemingly the explanation of the cause of the poisonous nature of Darnel must be looked for elsewhere, and is not to be furthered by a study of the fungus found inhabiting it.

Freeman, when discussing the fungus in the embryo of the grain, records some experiments which were undertaken in order to investigate the function of the nucellar layer of hyphae, although it is not quite clear what bearing they have on this point. He grafted embryos of *Lolium temulentum* on endosperms of *Lolium perenne*, and vice versa, the grains having previously been sterilised, and all manipulations carried out under sterile conditions. Thirty-four grafts of *Lolium perenne* embryos on *Lolium temulentum* endosperms were made, and of this number eighteen germinated. He examined two of these seedlings, and found both contained hyphae, from this he argued it was very probable that "hyphae from the *infection layer* of the *L. temulentum* grains were able to gain entrance to the embryos of *Lolium perenne*." These experiments really lead nowhere, for the hyphae are already in the rye grass embryos before grafting on any foreign endosperm, and their presence cannot possibly be due to infection from the nucellar hyphal layer or from his localised *infection area*.

Distribution of the fungus in the grain.[4]

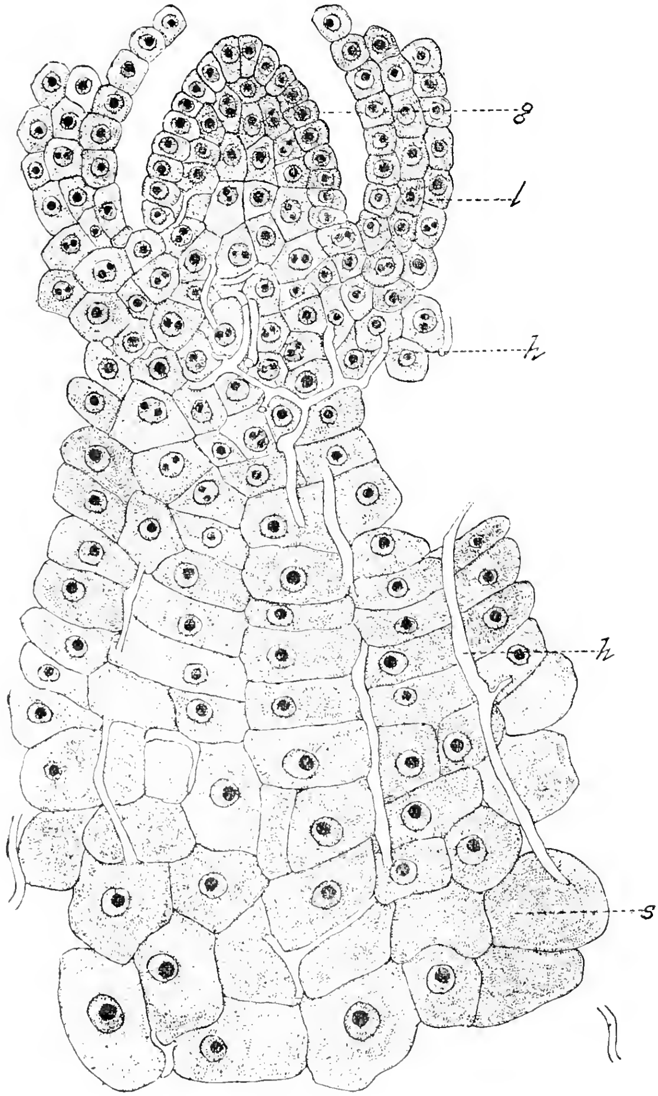
Many grains of *Lolium perenne* were sectioned with a view to determining the distribution of the fungus in the fruit. Transverse sections taken at different levels are shown in Plate XVIII., Figs. 1-3. The yellow line illustrates the distribution of the fungus. A transverse section at the distal end of the grain, Fig. 1, shows the hyphal distribution to be co-extensive with the aleurone layer. A

4. Following upon Brown and Morris (11), I have adopted the following terminology in describing the grain. The furrowed side of the grain is the *ventral* surface, the side opposite to this the *dorsal*. The embryonic end is called *proximal*, while the stigmatic end, or that portion remote from the embryo, is *distal*. A section passing through the ventral and dorsal surface is a *sagittal section*, while the longitudinal section at right angles to this is a *coronal* section. The sagittal plane which divides the grain into two equal halves is the *median sagittal plane*. A section at right angles to both sagittal and coronal planes is *transverse*.

transverse section nearer the proximal end of the grain, as is shown in Fig. 2, would cut through the scutellum. Such a section shows that the hyphae occur between the endosperm and the scutellum wherever the tissues are in contact, and hyphal penetrations into the scutellum may and do take place at any point over this area. The hyphae in addition extend even past the limits of the aleurone layer, and penetrate the scutellum on its outer exposed dorsal surface. A transverse section at the extreme proximal end of the grain, Fig. 3, passes through the embryo, but the starchy endosperm is no longer included in the section. Even at this level the hyphae surround the scutellum, as is indicated by the yellow line in the figure. The coronal plane is perhaps the best for demonstrating the distribution of the fungus in any one section (Plate XVIII. Fig. 4), the occurrence of the fungal layer between the scutellum and endosperm at all points of contact and the extension of the fungal tissue on the dorsal proximal surface is clearly seen.

Plate XVIII, Fig. 5, shows a median sagittal section illustrating the same points and, in addition both of these latter sections shew the distribution of the hyphae in the embryonic area. The scutellum is often very richly traversed by fine fungal threads, and they are not restricted to any special area, but occur more or less uniformly right through the tissue. Some grains show these threads more readily than others, but a study of the embryology of the grain will suggest that this might often be the case. The hyphae are readily discernible in the growing cone; their presence here has been pointed out by the earlier workers. (Text-figure 1.). The above facts are also true of *Lolium temulentum*, but it is much rarer in this case to obtain a scutellum so markedly inhabited as in *Lolium perenne*, and in any case the threads are generally finer. In several examples of *Lolium perenne* I have found hyphae present in the radicle, but they are not generally evident in this region.

Freeman raises the question—How does the fungus obtain entrance to the embryo? As an answer, he devoted a large part of his paper to a description of a localised patch of hyphae, which he termed "*the infection layer*," and to its mode of origin. He says that on the ventral proximal end of the grain there occurs an isolated patch of hyphae which penetrates between the aleurone cells and cells of the scutellum, and thereby gain entrance to the embryo when it is fairly advanced in its development. He states that on the dorsal surface of the grain the hyphae do not extend to the end of the aleurone layer. To



Text-Figure 1.

Growing point of an embryo from a *Lolium perenne* grain. The section was cut obliquely and includes only the growing point =g ; young leaves=l ; and scutellum=s ; hyphae=h. × 850 diam.

quote directly: "It is not impossible perhaps that infection may, in exceptional cases, take place from this side of the scutellum (dorsal); but, if so, it occurs very seldom. I have seen no evidence either in the mature grain or in the developing ovary to indicate that such an infection is ever accomplished."

My observations permit of a different answer to this question. Hyphae occur at the junction of the scutellum and endosperm, not only near the ventral surface (Freeman's infection layer), but wherever these tissues are in contact I was unable to demonstrate the existence of an isolated patch as described by Freeman. Furthermore, it is impossible to agree with the statement that the hyphal layer does not reach the end of the aleurone layer on the dorsal side of the grain. As is shown in Plate XVIII. Figs. 2-5, hyphae can and do occur right round the periphery of the embryonic area.

These facts in themselves are interesting, but they do not answer our question. At a later stage, in this paper, it will be shown that *infection* of the embryo takes place at a very early stage in development, and that the distribution of hyphae in the mature grain has no bearing on this point, but is a result of the special function carried out by this partner in the development of the grain.

It is only fair to emphasise the fact that Freeman dealt only with *Lolium temulentum* when working out his idea of an infection layer, and that this criticism is based *mainly* on work done on *Lolium perenne*. However, if the facts demonstrated in the embryological section (pp. 267-281) are true, they apply equally well to both forms, and it becomes abundantly clear that the distribution in the adult grain is not associated especially with the *infection* of the embryo as Freeman suggests.

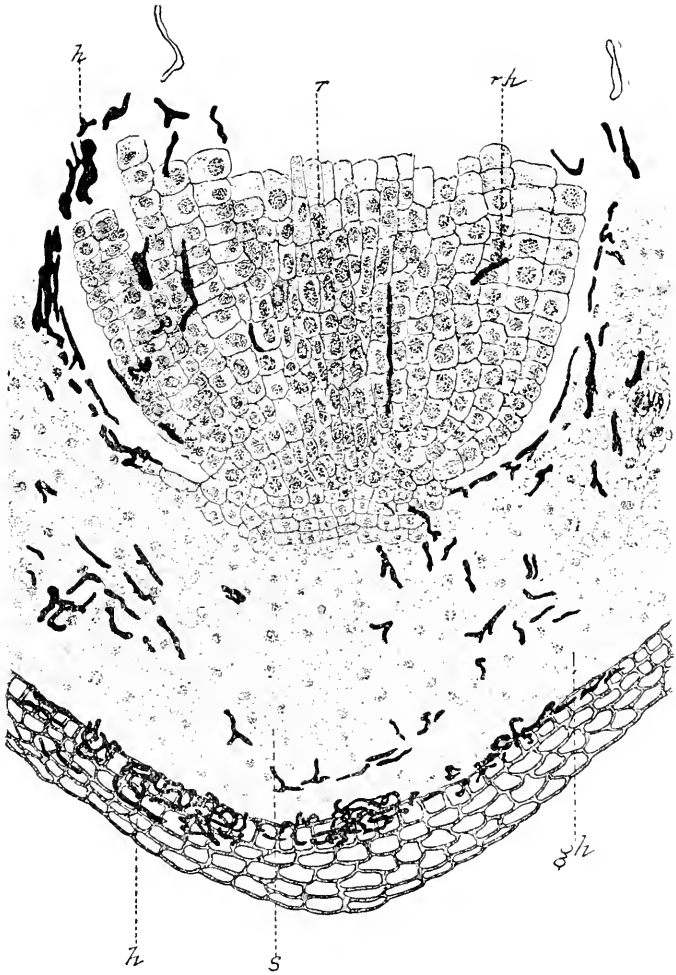
Previous workers have described the hyphal layer itself in detail. Australian grown grains of either grass seem to shew a very rich growth of hyphal tissue. Some grains of Darnel grown in the University grounds, Melbourne, had an average layer of 31.6 u. Grains of English rye in many cases showed a layer quite as broad as that shown by an average Darnel, but in both the width or extent of the layer is extremely variable, depending largely on the activity of the fungus during the period between fertilisation and formation of the seed. Aniline gentian violet, followed by Gram's iodine water, was used solely for staining the adult grains. The hyphal layer does not stain uniformly, however, with this stain, some portions of the hyphal threads reacting to the violet colour, other parts remaining colourless. This variation in the staining properties was displayed by different parts of the same hyphae, the coloured portions being interrupted by colourless, in a very irregular manner. In order to ascertain whether these unstained segments contained protoplasm or were devoid of contents, and thus remained unaltered by the stain, sections were submitted to a second stain following upon gentian violet. Congo red was chosen, as it stains the cell walls, and also the protoplasm The result was that the former uncoloured sections were stained with the red, and displayed dense contents just as is the case with the coloured segments The difference in the staining capacity is probably due to the presence of ferments in certain parts of the hyphal network wherever the ferment is present in any quantity, then will the "blue" stain be evident. Colour is lent to this idea by the fact that the aleurone layer shows the same staining reactions as the hyphal layer. The majority of the cells do not react to the violet stain, but certain of them stand out markedly from the rest, for they stain densely and form very striking portions of the section. The number of such coloured cells varies in each individual grain. In addition, the scutellum repeats the above phenomenon. In this case, the "blue" cells are generally restricted to the epithelial layer of this tissue.

Brown and Morris (11) have shown that in *Hordeum vulgare* the secretion of diastase is located in the absorptive epithelium, and in a later paper Brown and Escombe (12) that in addition, the aleurone layer is capable of bringing about marked changes in the endosperm when this is separated from its embryo, and placed under favourable conditions.

The distribution of the active ferment-secreting cells therefore, agrees with the staining reactions described above, and supports the view that the coloured segments of the hyphae contain either an enzyme or its fore-runner, and this conjecture is further strengthened by the later embryological work.

When examining a sample of English rye grass from Ireland, a specimen was occasionally found showing hyphae (which for the most part stained with gentian violet) invading the starchy endosperm. Freeman records a similar distribution for grains of *Lolium temulentum* from Ghent. A careful examination of the aleurone layer of such a grain showed that the hyphae were also running riot here. Instead of the usual inter-cellular course, many hyphae could be made out actually passing into the cells, and in many cases a single hypha could be traced entering and leaving as many as three cells. As is well known, the cell walls of this layer are thick, and also pitted. The hyphae enter through these pits, and thereby gain access to the cell (Plate XIX. Fig 5). Sometimes the opening in the wall of the aleurone cell was smaller in diameter than the penetrating hypha; when this was the case a conspicuous narrowing was noticed at the point of entrance, but on the far side of the pit the hypha again attained its previous size. In addition the scutellum showed an extraordinarily large amount of the fungus. Here the intra-cellular course was also very evident (Plate XIX. Fig. 4). Many of the scutellar cells stained vividly; such cells were seen to be fungal containing. The entrance to the cells was gained through pitted walls, as is the case in the aleurone layer. The remaining cells of the scutellum were normal, and the grains did not seem to be any the worse for this exceptional behaviour on the part of the fungus. In such abnormal grains the hyphal layer was present as usual. There is no doubt that the hyphae invading the cells are the same as those composing the extra cellular layer.

These phenomena were not confined to the sample from Ireland, one of English rye grass from South Africa also contained certain grains showing an extraordinary distribution and growth of the fungus. As before, both the aleurone layer and the scutellum were permeated by intra-cellular hyphae. In one particular case the scutellum, which normally is packed with aleurone grains, appeared to consist of a dense sclerotial-like mass of threads. The bulk remained colourless, and they resembled "ghosts," or casts, of former more virile hyphae (Text figure 2). They are represented in the text figure as dotted lines, and they completely filled the whole of the scutellar tissue, although the cells composing it were not distorted or enlarged in any way. This section cut in the coronal plane) and the others accompanying it, were later stained with congo red; it was then easier to decipher these ghost-like contents of the scutellum. Many were cut transversely, but owing to a large amount of twisting some were seen running lengthwise through the tissue for a short distance. They probably represent fungal hyphae, which were numerous at certain stages in the development of the grain, carrying a special food supply to special parts, and in giving this up to the host-plant they have undergone a partial dissolution, which was not completely carried out in these few exceptional cases by the time the grain reached maturity.



Text-Figure 2.

A longitudinal section through the radicle, and a portion of the scutellum of a grain of *Lolium perenne* (Ireland). This was an abnormal grain. r = radicle, rh = hyphae in radicle, s = Scutellum, gh = ghost-like hyphae forming a sclerotial like growth in the scutellum which was nevertheless perfectly formed; h = hyphae staining with gentian violet. × 103 diam.

Text-figure 3 illustrates the stigmatic end of the same grain (a coronal section not cut in the median line shows portion of the

Text-Figure 3.

A section of the stigmatic end of the same grain as text fig. 2. a=aleurone cells, the outlines of which are distorted by abnormally large intercellular hyphae; h=intercellular hyphae, h = intra-cellular hyphae, w=wall of aleurone cell. × 1000 diam.

aleurone layer at this end of the grain cut tangentially, and therefore it does not appear as a single layer of cells.) Interpolated between the aleurone cells, lying in the inter-cellular spaces, altering their whole contour, are outlines of hyphae, which seem to be swollen, somewhat gelatinised, and in a state of disorganisation. Similar bodies were also visible in the matrix of the cells themselves.

These occurrences lead me to believe that at some stage in the life of the grain the hyphae were intra-cellular, and that in the few aberrant cases met with this embryological condition persisted in the mature grain.

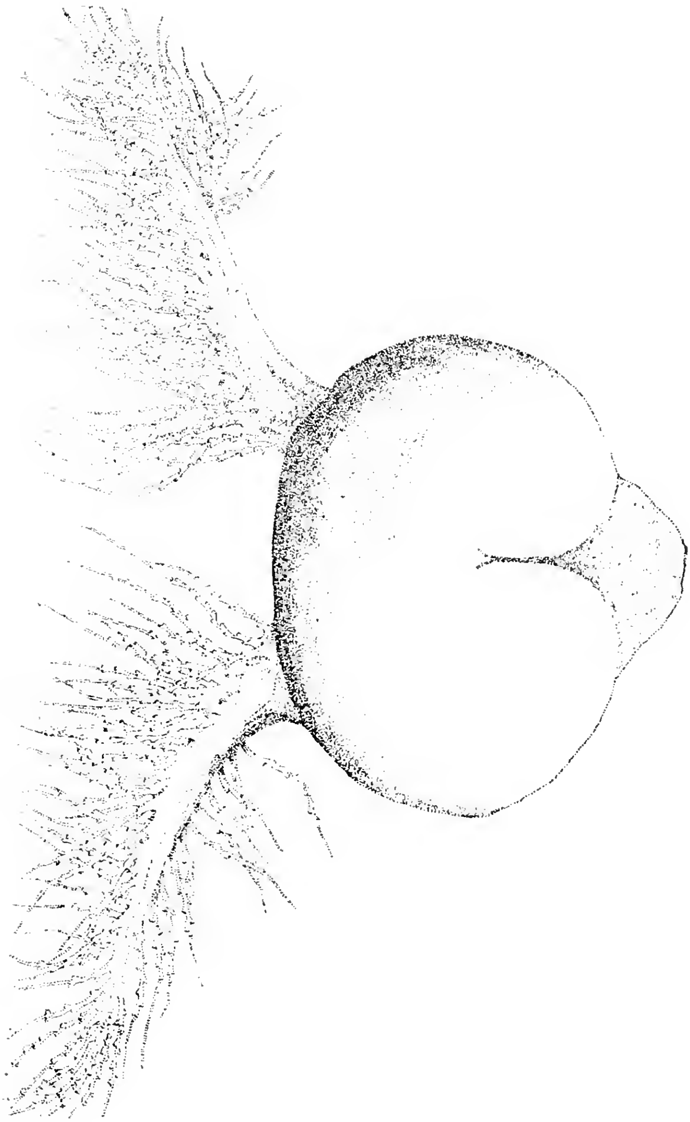
Development of the Ovary from the Flowering to the Fruiting Stage.

It is convenient to divide this portion of the paper into sections, and to consider the relation of the fungus to the grain, at certain definite stages in its formation. This relation becomes very pronounced and characteristic, either just about the fertilisation period or immediately afterwards, and from here to the final stages is most intimately associated with the changes taking place, resulting in the formation of the endosperm, with its aleurone layer, and the various parts of the embryo.

Stage A.

Text-figure 4 illustrates the external appearance of the ovary at the flowering stage just prior to fertilisation. It is drawn from the ventral surface, and shows the stigmas arising from the dorsal side, the bi-carpellary nature of the fruit is indicated in the figure. The ovum lies directed towards the proximal end of the ovary. I have designated this period Stage A.

Hyphae are present in the carpels from their earliest inception, but it is only at about this stage that their intimate relation with the ovarian tissues of the grass is evident. They enter the ovary at the stalk end, and branch through the carpellary wall. They are generally more abundant during the earlier stages at this end than at the distal stigmatic end. These hyphae characteristically accompany the vascular tissue of the stalk, and are to be seen in very close proximity to the annular and spiral vessels running in this area. (Plate XXI. Fig. 4.) In many of the sections numerous small lateral buds on the hyphae suggested haustoria, but they may be minute lateral branches just being caught in the section. The



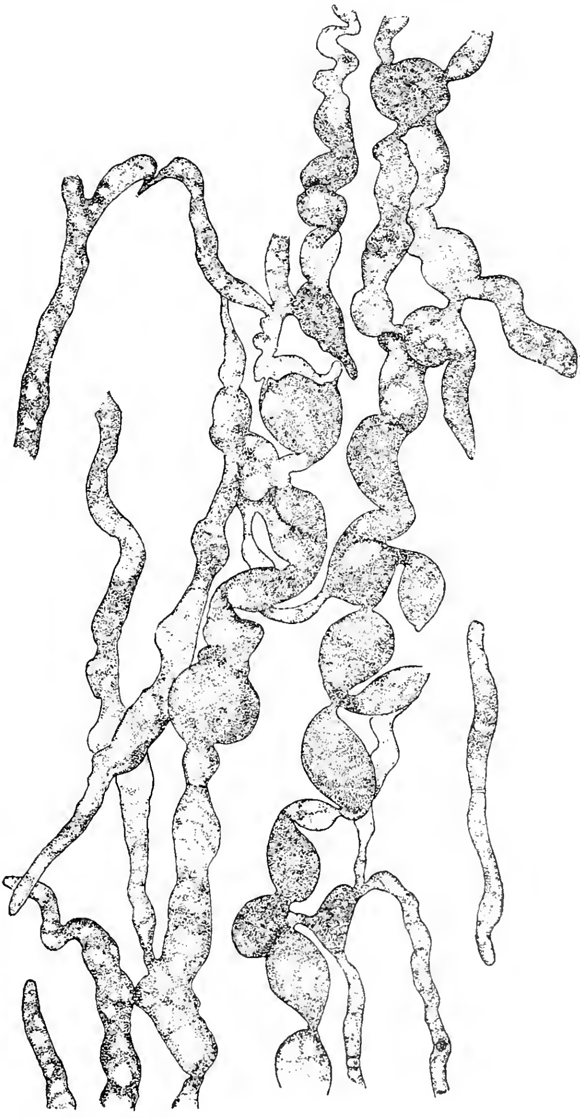
Text-Figure 4.

External appearance of the ovary of *Lolium perenne* at Stage A. × 15 diam.

cells of the carpellary stalk do not contain starch, and many of them stained deeply with the gentian violet after counter-staining the sections with bismarck brown. These blue cells were always plentiful in this region; such cells have been invaded by the fungus, and their contents probably used for its own nutrition. They always stain deeply, and the hyphae in their vicinity do likewise. If the cells do not stain too darkly, it is possible to observe fungal threads forming a network in the lumen of the cells, many of the threads being exceedingly fine. The position of these cells is shown in Plate XX. The cells are not enlarged, and apparently only differ from those around them by their different staining properties. The cell walls in this area are pitted; whether this is the normal condition or whether the pit has resulted from a secretion of the fungus is a debatable point.

The lateral walls of the carpel are packed with small compound starch grains, and in this region the hyphae only occur between the cells. They run in all directions, but are, as far as I have observed, strictly inter-cellular in this position, at this stage. However, when the stigmatic region is reached they seem to get the upper hand, and a large number of cells become their prey. These cells are also starch-containing, and when so intruded upon they immediately react to the violet stain. Sometimes the whole of this area will appear a dense violet colour, for the great majority of the cells in this part are attacked at this period. When the cell is first invaded, the starch is seen to become swollen and disorganised, and loses its power of reacting to the iodine wash used in preparing the sections (Plate XXI., Figs. 2 and 5). The fine hyphal threads wrap round the starch groups, and even enter between each individual grain (Plate XXI. Fig. 5), apparently digesting them. There is no doubt that these cells are suffering at the hands of the fungus, and that their contents are being transferred to this fungal system. Some of the cells show an entire absence of starch; they appear to be practically empty, and somewhat collapsed. These have been invaded at an earlier stage, and yielded their contents in a similar way. The stigmatic tracts present in the carpel wall generally show hyphae in abundance; they extend right into the stigmas, and even here become intra-cellular, but do so probably only after fertilisation has taken place, when the function of the stigmas has been completed.

Occasionally, the base of a staminal filament remained attached to the ovary during sectioning, and hyphae were found to extend into this region. One or two examples were obtained, showing such hyphae in a much convoluted condition. Parts of the thread were swollen and bladder-like, with sharp constrictions at intervals. The contents, however, were the same throughout the length of the thread, showing no signs of spore formation. (Text-figure 5.)



Text-Figure 5.

Hyphae from a staminal filament shewing sharp constrictions occurring at intervals along their length. × 1700 diam.

While these changes are proceeding in the carpel wall, the hyphae in the developing ovule are not quiescent. They keep pace with the growth of the ovule, and until the embryo-sac is at the 8-celled stage they simply run between the cells of the nucellus, ramifying in every direction. They extend right through the nucellar tissue completely surrounding the embryo-sac. Freeman, when discussing the ovary of *Lolium temulentum* at this stage, states that hyphae are completely wanting on the outer dorsal surface towards the embryo-sac end, stopping at about the level of the antipodal group. If this is so, it is difficult to see how hyphae come to be present in this position in the mature grain. As far as I have observed they are uniformly distributed through the inner layers of the nucellus, but do not generally extend into the very outer layers until later in development. The dual staining properties are shown by these hyphae, but the great majority of them will pick up the purple stain.

The first indication of any change in the relation between the fungus and the cells of the ovule at this stage is the tendency for the hyphae to form knots (Plate XXI. Fig. 3). These are especially striking if the sections are cut rather thicker than those to be used for detailed high power examination. Hanausek described the occurrence of knots (Knäuel) in the ovary of Darnel, and figured them. I have been unable to obtain his original paper, only abstracts without figures being available. He offered the occurrence of these knots as evidence in favour of the fungus being related to the *Ustilagineae*. Freeman says: "I have found no such knotting of hyphae to indicate the commencement of Ustilagine spore formation." These knots undoubtedly do occur, but are rather to be regarded as the first stages in the penetration of the nucellus cells. The hyphae arch round all sides of the cell before entering it, and as they generally invade two or three adjacent cells simultaneously, this arching gives the knot-like formations above described. I do not think they afford any clue to the actual systematic position of the fungus in question. Since they are just on the point of attacking a cell they are rich in ferments and always stain vividly.

Cells showing a later stage of invasion are also present in such an ovule. Lateral branches arise from these enfolding hyphae, which penetrate the cell wall and pass into the substance of the cell itself. It soon becomes filled with a dense network of threads, and in this condition forms a most striking part of the section, for such cells are the only members of all the nucellar tissue, which will stain in the same way as the fungal system. (Plate XXI. Fig. 1). They stand out in contrast to the background of normal, unattacked nucellar cells.

It is difficult to determine whether the hyphae actually apply themselves to the nuclei, but it is readily seen that the nuclei do undergo a definite change, becoming large and somewhat distorted, and at this stage will stain uniformly with the violet dye. These fungal-containing cells may occur in any position in the nucellus, but at this stage they are few in number, and are generally to be found at the end of the ovule furthest from the micropyle. They become more abundant after fertilisation occurring in any part of the nucellar tissue.

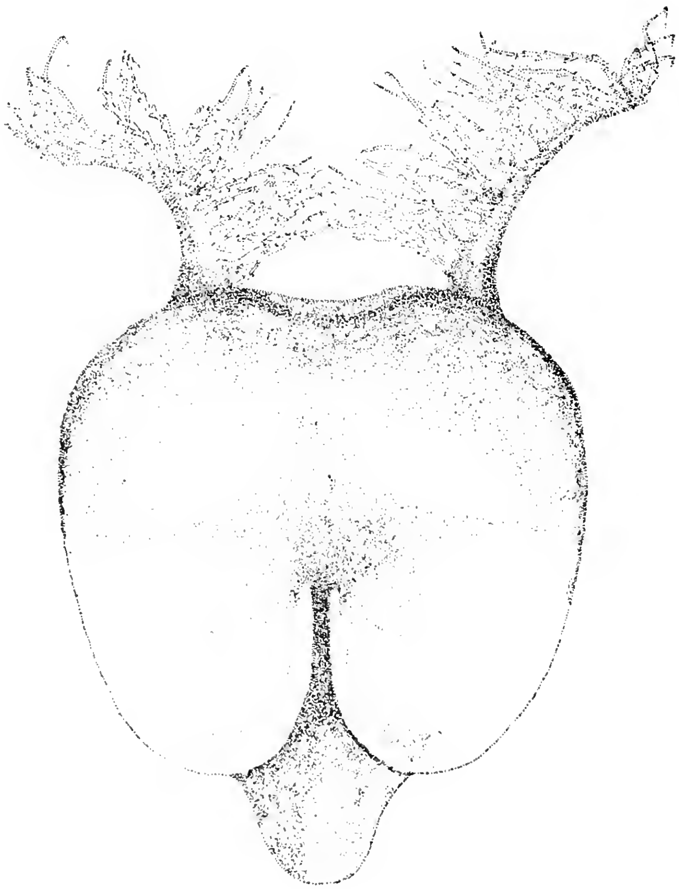
The embryo-sac at this stage is ready for fertilisation, and it agrees with the rest of the ovule in containing the fungus. The protoplasmic lining of the sac carries the hyphae. They run rather sparingly along the sides, and at the distal end of the embryo-sac, but are more abundant at the proximal end in the vicinity of the ovum. They are in close connection with both the synergidae and the egg-cell, and enter into the substance of the latter at this early point in the development of the grain. (Plate XXI., Fig. 6.) Previously it has been thought that "*infection*" took place at a much later stage, after the differentiation of the growing cone, when the formation of the embryo was fairly advanced. It has been suggested that the entrance of the fungus into the embryo was due to the chemotactic influence of the growing apex. My observations show that the fungal constituent is present in the ovum before any divisions have taken place, and that the formation of a special layer in the grain for the purpose of infecting the embryo at any specified period is not necessary.

Stage B.

Text-figure 6 illustrates the external appearance of the ovary after fertilisation, and at the commencement of endosperm formation. The elongation of the ovary which accompanies this change is beginning to be apparent. As in Stage A, it is drawn from the ventral surface, and shows the same features as before.

If an ovary be sectioned at approximately this stage, our knowledge of the relation of the fungus to the grass is considerably augmented.

The hyphae are still active in the carpel wall. The cells composing the distal area of this wall are attacked by the fungus, their



Text-Figure 6.

The external appearance of the ovary of *Lolium perenne* at Stage B. × 15 diam.

starchy contents are disorganised and absorbed into the hyphal system. The collapse of these cells enables the ovule to encroach on the space formerly occupied by them, and elongation of the developing grain thereby results. At this period the ovule does not increase markedly in breadth, and so the cells composing the side walls of the carpel are not yet invaded, the activity of the fungus is, as in Stage A, more evident in the distal region.

The most noticeable change occurs in the ovule itself. The fungus is responsible for the disorganisation of the nucellus.

Thriving on the nutriment obtained from these cells, and also on that obtained from the carpellary wall, it increases tremendously in amount, invading and attacking every portion of this tissue. (Plate XXII. Fig. 1.) This figure represents the hyphae massed together in this area. For the most part it is difficult to discern the outlines of the disorganising cells, except at the edge of the ovule, where they are still intact, although, unlike the previous stage, the hyphae have spread now into these outer layers. The nuclei of the cells of the nucellus persist for some little time after invasion, but they become enlarged, and stain uniformly, as shown in the figure.

The type of branching of the hyphae is very characteristic. (Plate XXII. Fig. 2.) The branches are given off almost at right angles to the main thread, and at their point of origin a slight swelling generally occurs. They are strongly septate, and rich in protoplasmic contents, and they show numerous vacuoles and well marked nuclei. If the sections are stained only with gentian violet, followed by Gram's iodine solution, the majority of the hyphae in these regions stain deeply, but the colourless portions noticed both in the adult grain and in the ovary prior to fertilisation are still present. In order to stain these segments sections at this stage were subjected to congo red, after staining in the above manner. Such treatment made the study of the endosperm much simpler.

The embryo-sac as a result of the stimulus of fertilisation has enlarged considerably, the enlargement being accompanied by the appearance of endosperm. The formation of this tissue is at first most active at the proximal end of the sac, in the vicinity of the ovum. On the dorsal proximal surface it forms a complete plate of tissue, the distal extremities of which are separate and considerably narrowed. These dip towards the ventral surface, and in section appear as two bands of tissue, from one to two cells in width, each being surrounded by nucellus.

The cells of which the endosperm is composed are highly protoplasmic, and contain large nuclei. Starch has not, as yet, been laid down in them. The endosperm is formed at first by a process of free cell formation. This soon ceases, and further growth takes place by the repeated division of the outer layer of cells, and thus the tissue grows, and gradually assumes its mature condition. This mode of growth is more easily followed at a later stage, so further reference will be made to it when dealing with Stage C.

Until the endosperm commences to be formed, the fungus has been increasing in amount at the expense of the nucellus, etc. This increase is only a temporary one, for the hyphae now grow in close contact with the endosperm cells. They enter them when the cells are young and not fully formed, and are here seen to become disorganised. The food material thus gained by the grass is used in the preparation of the reserve store of food, which is later to be deposited in this tissue. Plate XXII., Fig 3, shows a portion of the endosperm and the accompanying hyphae. This section was stained with congo red, and the hyphae and protoplasm stain in the same way. Plate XXII. Fig. 4, also shows the close union between the fungus and the grass. This section was stained only with gentian violet, and the hyphae could be traced more readily in the cell itself. Many of the disorganising threads running in the host cells stained blue, and are shown in the figure, the cells themselves remaining unstained. Plate XXII., Fig. 5, repeats the structure shown in the two previous figures, but in addition it shows extremely well, lateral branches, which arise from a hypha running parallel to the length of the endosperm, and which enter adjacent cells of this tissue, yielding up their food to the embryo grass plant.

The fungus is most abundant in the region of the ovum, due probably to the fact that the lumen of the embryo-sac begins to fill first around the embryo. In this region the cells are long and crescent shaped, and have very dense contents.

The synergidae are still present, and their absorption is no doubt the result of the activity of the fungus, a fact which may help to explain the pronounced growth of hyphae always present in this position.

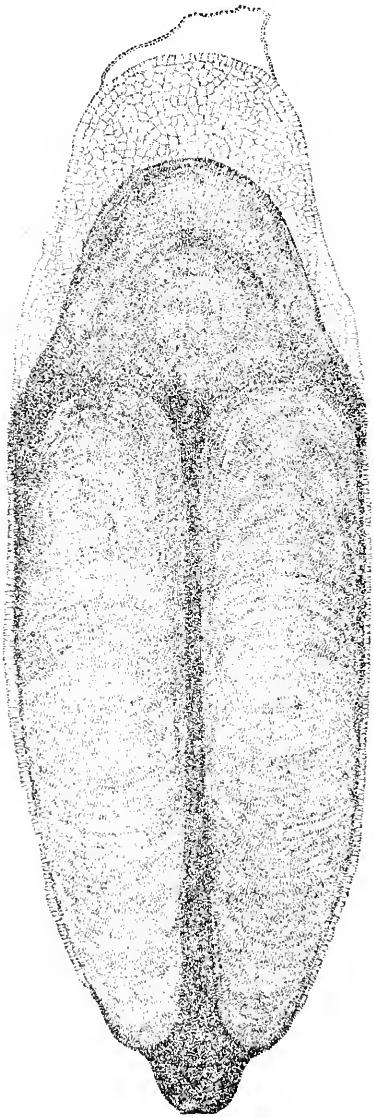
The ovum is still undivided, although it has increased in size and the cytoplasm has become vacuolar.

In the intermediate stages between B and C, the division of the ovum and the subsequent growth of the embryo are points of interest. The first division of the egg is generally transverse, at right angles to the pro-embryo, and each cell usually contains a well-marked vacuole. The fungus ramifying in the nucellus in this part of the sac comes into direct contact with the endosperm, which forms a lining to the pocket in which the embryo grows. The hyphae are unusually abundant, and are actively transferring food-material from the various parts of the carpel to the endosperm in this area. (Plate XXV., Fig. 1.) These cells are later absorbed by the growing embryo, which, therefore, ultimately benefits by this concentration of hyphae. The cells of the pro-embryo also receive hyphae directly. Plate XXV., Fig. 3, shows a more advanced embryo. The dermatogen has just been cut off, and the hyphae are seen to enter right into the substance of the embryo. The endosperm cells at the extreme micropylar end are disorganising as a result of the presence of the fungus, and are also included in the figure.

Stage C.

Text-figure 7 illustrates the external appearance of the ovary when it is approaching maturity. A considerable amount of endosperm has been formed; the shadowed portion of the diagram indicates the extent and distribution of this tissue. As in the two previous stages, the ovary is drawn from the ventral surface. The furrow is noticeable at the proximal end, but as yet, is not well developed at the distal extremity. The dorsal proximal end projects beyond the rest of the ovary in the form of a pocket, in which the embryo develops.

Sections taken at this stage emphasise the facts already disclosed. The great bulk of the nucellus has disappeared, whilst the endosperm has increased in a well-marked and definite manner. The hyphae are still abundant, but owing to their absorption by the endosperm they are not as plentiful as in Stage B. The disorganisation which takes place all round the periphery of this layer keeps the growth of the hyphae in check, and, consequently, they never over-run the developing grain, but tend to decrease in amount after the first appearance of endosperm. (Plate XXIII.) The food-supply made available to the grass by the digestion of the hyphae is utilised by the young actively growing endosperm cells. This is rendered possible, for the growth in size of this tissue takes place from the outer surface. The outermost layer of the endosperm may be regarded as a cambium, which is active only on its inner surface. This meristematic layer divides in the usual manner, and the cells so formed are at first more or less brick-shaped, but gradually assume an approximately spherical form, and attain their adult size. Growth is carried on in this manner until the fruit is practically mature, then this outermost dividing layer ceases its activity, but persists in the grain as the aleurone layer, the cells of which serve as a store of nitrogenous material. This idea of an *endospermic cambium* is supported by the fact that the nuclei of this layer remain large and intact, even when the cells are



Text-Figure 7.

The external appearance of the ovary of *Lolium perenne* at Stage C. × 15 diam.

packed with reserved food, and also the walls of the aleurone cells become thickened, showing pits or points of communication at intervals. It is a well-known fact that cambial cells embarking on a period of rest show considerably thickened cell walls. The thickenings are usually removed wholly or in part, when such a layer recommences its activities.

If the stamens, before they ripen, are removed from a spikelet and cross-pollination is also prevented, the ovary remains small, but the fungus will grow rapidly in the nucellus, and ultimately forms a sclerotial-like mass of hyphae, occupying the main part of the ovule. Freeman records this fact for Darnel, and I have had similar results with English rye grass. Since, by preventing pollination, endosperm formation does not take place, this dense growth is only to be expected, for even in a fertilised ovary the fungus is parasitic on the nucellus, and for a short period tends to increase in amount. The prohibiting factor is the endosperm, which destroys the hyphae as fast, or faster, than they are being formed, hence removal or absence of this factor favours the development of the fungal organism, and the attempt towards sclerote formation is the result.

The primary tissues have been cut off in the embryo. It has elongated considerably in length at the expense of the endosperm cells adjacent to it. (Plate XXV., Fig. 3). These no longer form a close investment to the embryo, but have disappeared at the micropylar end, and the embryo now lies free in the embryo-sac. The attachment of the suspensor to the microple is broken at this stage. Hyphae still run in close association with the embryo, and in section it shows the hyphae running in its tissues.

Transition from Stage C to the Mature Grain.

Externally, the only changes which are evident during this transition are the elongation of the ovary, accompanied by an increase in breadth, and the development of the embryonic area, which becomes more pronounced as the scutellum develops and the embryo reaches maturity.

Sections taken at any stage during this period show features common to the earlier stages. The increase of endosperm, resulting from the continued activity of its outer layer, tends to crush the hyphae, which are ramifying in the remnants of the nucellus, into a layer running round the periphery of the seed. This layer becomes more pronounced as the endosperm reaches its adult size, and fills the space formerly occupied by the nucellus, the outer parts of which are the last to disappear. Starch cells continue to be formed until the seed is almost ripe, and the hyphae nourish these young starch cells, just as they did the inner, now mature, starch cells, in the younger stages already described.

When the endosperm attains its full size, the outer dividing layer ceases to function, and becomes the young aleurone layer. The cells, which constitute it, retain their embryonic form, as regards both their size and shape, in their adult condition. They eventually thicken their walls considerably, and their contents become packed with aleurone grains, so that finally the nitrogenous layer characteristic of the endosperm of cereals is formed.

Plate XXIV. illustrates a section of the endosperm taken at the stigmatic end of a grain, at a stage when the aleurone layer is not yet adult. The hyphae, which by this time are in the form of a layer, take part in the nourishment of the aleurone cells. Just, as in the case of the starch cells, they actually enter into the cell cavity by penetrating the cell-wall, and become absorbed by the protoplasm which converts the nourishment so obtained into the aleurone grains which are present in great abundance in the adult layer. This plate shows several hyphae passing through the walls and disappearing into the cell-contents.

The aleurone cells figured are young. They show a well-marked nucleus, and are filled with protoplasm, in the meshes of which aleurone grains are being formed. The absorption of the hyphae continues until the cells are packed with grains, and the seed is nearly ready for ripening. A section of a fully mature normal endosperm shows, however, no signs of the endophytic nature of the fungus.

It is interesting to note that Peklo (16) suggested that the aleurone layer was probably fungal in origin in all cereals. The suggestion arose as a result of an incidental examination of some *Lolium temulentum* grains. In order to carry the investigation further he decided to examine grains of *Triticum*, *Secale*, and *Hordeum*. He recognised the necessity of examining rust-resistant types, and stated fully in his paper the varieties he proposed to examine. With the forms chosen he obtained negative results. Not deterred, he next examined material he already had embedded in paraffin, but he did not state its origin, or given any information regarding its rust-resistant capacities.

Examination of such material revealed fungal hyphae occupying the lumen of the aleurone cells, from which densely stained bodies were budded off. Peklo believed them to be aleurone grains. It seems highly probable that the grains used for sectioning were mouldy, and that the aleurone grains figured are in the process of digestion. This is accentuated by the fact that some grains were found actually embedded in the hyphae themselves, and also by the fact that Peklo suggests that the fungal threads found bear a resemblance to those of *Mucor Rouxianus* (*Amylomyces Rouxii*), although the actual identity of the two was not established. The point of interest as far as this paper is concerned lies in the fact that Peklo probably found the fungus in the aleurone cells of young *Lolium temulentum* grains, and from this isolated case he attempted to generalise, stating that such was the origin of the layer for all cereals.

The breadth of the hyphal layer found in the grain is dependent on two factors—

(a) The activity of the fungus.

(b) The absorbing power of the endosperm.

If the fungus is strong and luxuriant in its growth, and can keep pace with the activity of the endosperm, a thick hyphal layer would result, for even at maturity the endosperm will not have used, as food-material for itself, all the available hyphae.

If, however, the growth of the mycelium is inclined to be weak, the absorbing power of the endosperm will be greater than the growing power of the fungus, and the result will be a very small layer in the mature grain, or even perhaps the complete absence of such a layer.

In the earlier part of this paper (p. 256) I emphasised the fact that absence of the fungus in hand-sections, or in any individual microtome section could not be taken as evidence of the total absence of the fungus in the grain. The reason for this statement should now be clear. The presence or absence of a definite layer in the grain is dependent on the activity of the fungus, and the absorbing power of the endosperm. Even if a grain does not exhibit a definite layer, hyphae may still be present in the embryo in sufficient amount to ensure the appearance of the fungus in quantity at the desired stage in the development of the next generation of Lolium.

We are also in a position to discuss the significance of the distribution of the fungus in the grain. Freeman attributed it mainly to the result of the method of infection of the embryo, but I am led to the conclusion that it is a result of the part played by the fungus during the development of its host. The grass so controls and subjugates the mycelium during the changes which take place after fertilisation, that the embryo-sac, as its increases in size, pushes the fungus closer and closer to the periphery, until the mature condition is reached. Not only is the hyphal layer found between the endosperm and the testa, but, if the fungus is active, remnants may be found all round the periphery of the embryonic area, in fact, in any position occupied by them during the later embryological stages. (Plate XVIII. Figs. 1-5.)

The embryo during this period follows the usual course of development. At Stage C it was an undifferentiated club-shaped body, and hyphae were in close association with its micropylar end.

The next marked period of growth results in the appearance of the stem apex (Plate XXV., Fig. 4.) This is followed by differentiation of the radicle and elongation of the cotyledon. When all the parts of the embryo are thus marked off from one another, growth continues until the embryo is fully developed. The fungus, in the meantime, can generally be seen at both the micropylar end, and also, between the developing scutellum and endosperm. It is generally pronounced in the region of the plerome cells of the cotyledon.

Further investigations of the development of the embryo have been commenced in order to determine more exactly the relation of the fungus to its later development, as it is possible that the fungus plays a role in the formation of the scutellum comparable to the one it plays in the formation of the endosperm.

The hyphae, already in the very young embryo, follow the development of the stem-apex, and remain localised in their growth until germination takes place.

The Fungus in the Plant.

The growth of the fungus keeps pace with that of the plant, the hyphae, however, are mainly restricted to the growing apex, but can be seen extending for a short distance down the stem. They show the dual staining property already described (pg.

Even at this stage the intra-cellular nature of the fungus can be demonstrated. Some of the parenchymatous cells of the grass are invaded, and used as a food supply by the hyphae. Such cells always stain with gentian violet, and they show a dense network of hyphae. They may occur near the vascular tissue, and also towards the periphery of the stem.

When the inflorescence is formed, they are especially abundant at the base of the carpels. The cells so affected do not increase in size, and are only to be distinguished from a normal unaffected cell by their different staining properties. It is not till the ovule is well advanced that any great increase in the fungal partner takes place, when the phenomena already detailed follow in their natural sequence.

Cultivation of the Fungus in Artificial Media.

All attempts by previous workers to obtain a pure culture of the fungus have been unsuccessful. Their work has been limited mainly to the nucellar hyphae. So far I have been no more successful than Nestler and Freeman in endeavouring to get the fungus to grow outside its host. As further work is being done in this direction, it has been thought advisable to give a short account of the methods employed, and the results so far gained.

Since hyphae isolated from the hyphal layer of the grain had not yielded any result, and as they represent the dormant stage of the fungus, I thought greater success might be attained if the cultures were made from a more active stage in its life-history. Accordingly, the ovary was thought to be a suitable starting point, and stages ranging from A-C in the development of the grass have been used for infecting the culture media.

For the most part the culture medium has been made up in the following way:—

A decoction of *Lolium perenne* in water was autoclaved, then filtered and cleared with egg albumen. The liquid so obtained was made into a 1% agar solution, and autoclaved. It was subsequently filtered, titrated, tubed and sterilised.

Other media have been tried, e.g., honey agar, starch agar, etc., but with no better results.

The ovaries were treated in various ways, before using them for infecting the plates.

(1) Some were washed for one minute in equal parts of a 1% mercuric chloride solution and 45% alcohol, followed by a thorough washing in sterile distilled water.

(2) Others were washed in ether for varying lengths of time, from five minutes to one minute.

(3) Others, again, were shaken for some time in sterile distilled water.

After this preliminary treatment they were crushed with sterile forceps and introduced into the mouth of the agar tube, and then immediately plated. A drop of lactic acid solution being introduced to eliminate the growth of bacteria.

(Crushing the ovaries brings the fungal hyphae into direct contact with the medium used, and it was though that this might induce growth).

Some of the plates were left at room temperature, others were incubated at 23°-25° C. As a rule the plates were found to remain remarkably free from external contamination, and exhibited no growth at all. Occasionally some superficial fungus, mostly *Penicillium*, developed from the surface of the ovary, more especialy from the stigmas.

Probably the preliminary treatment to which the ovaries were subjected may have acted detrimentally on the fungus, even killing it. Further work, however, requires to be done to decide this point.

One plate infected with an ovary, which had previously been immersed in ether for four minutes, exhibited a fungal growth which seemed to arise from the ovary as a centre and which could not be attributed to any of the commoner superficial forms.

The first signs of growth appeared on the third day after infection. The hyphae were extremely septate, and their tips seemed to divide into two, the resulting branches growing equally. At this time there were no signs of spore formation. On the thirteenth day signs of fruiting bodies were noticed. When young they appeared salmon pink in colour, becoming very dark when old. They were irregular in size and shape, and appeared to be of the nature of pycnidia.

I have to thank Mr. C. C. Brittlebank (Government Plant Pathologist) for identifying the growth so obtained. He had no hesitation in placing it as a *Coniothyrium*, probably closely related to *C. olivaceum*, Bon. The ovary from which the felt was obtained was fixed, along with a portion of the felt, in Fleming's weak solution, and afterwards microtomed. The sections showed that the tissues of the ovary remained intact during the growth of the mycelium, and hyphae similar to those composing the felt were found running in its tissues.

This may or may not be the fungus found in the *Loliums*, but its close affinity to *Phoma* is rather suggestive, for many mycorrhizal forms have been found to belong to this latter genus.

The ovary used in this plate was obtained from a plant growing in the Melbourne University grounds. It was apparently the product of a second flowering resulting from heavy early autumn rains. Since all attempts to obtain this form again have been unsuccessful, it might be argued that it cannot be the fungus found associated with *Lolium perenne*. This may be so, but it is just probable that since the ovary represented a second flowering the fungus may be growing more actively than the developing grain, the grass being naturally weakened by its previous flowering, so that the fungus may have been in a suitable condition to grow on the artificial medium provided.

Concerning the Function of the Fungus.

It has been suggested that the fungus associated with Darnel grass possesses the power of nitrogen-fixation. Hiltner (5) was the first to formulate this idea, and after testing it by experiment, he concluded that *Lolium temulentum* grew as well in nitrogen-free sand, as in sand to which nitrogen, in the form of potassium nitrate, had been added as a fertiliser. As a control he grew *Lolium italicum* under similar conditions. This species, at the time of Hiltner's work (1899), was regarded as being fungus free. Later, Freeman (1903) found in a sample of 59 grains two contained the fungus and 57 were devoid of it. This, although it is a low percentage of infected grains, could introduce a serious error into such work when using this species as a control.

The experimental methods employed by Hiltner are also open to criticism. He planted grains of both species in pots, which were completely nitrogen-free, but he watered one set of two with tap-water, which contained 0.84 mg. of nitrogen per litre. To the other set of two he gave in addition 50 mg. of nitrogen in the form of potassium nitrate. These pots were apparently left exposed to the air, and so were subject to many sources of external nitrogen contamination, the most formidable perhaps being nitrogen-fixing bacteria.

An experiment carried out in this manner could not aim at determining whether the fungus is capable of fixing free atmospheric nitrogen in *the complete absence of combined nitrogen*. However, as several investigators have shown, Berthelot (17), Puriewitsch (18), and Latham (19), that certain fungi can fix free nitrogen if supplied with a small amount of this element in a combined form, the results given by Hiltner might have some bearing on the latter point.

The following figures are extracted from his paper :—

I.—*Without nitrogen manure.*

	Dry Weight gr.	Nitrogen absolute mg.	Nitrogen per cent.
Lolium temulentum	5.173	30.35	0.59
Lolium italicum	0.974	6.69	0.69
Root mixture	3.619	7.78	0.22
Total	9.766gr.	44.82mg	0.46%

II.—*Manured with 50 mg. of nitrogen.*

	Dry Weight gr.	Nitrogen absolute mg.	Nitrogen per cent.
Lolium temulentum	5.867	72.87	1.24
Lolium italicum	2.329	40.70	1.75
Root mixture	3.381	12.60	0.37
Total	11.577gr.	126.17mg.	1.09%

The nitrogen content of *Lolium temulentum* plants, when fertilised with potassium nitrate, is seen by the above figures to increase markedly as compared with that obtained for unfertilised plants, i.e., plants watered with tap water only. Not only is this so, but the increase is nearly as great as that obtained for *Lolium italicum.* The small difference between the percentage results for both species is not outside the limit of experimental error, especially when the sources of such error are as great as in the experiment in question.

Rayner (20) when dealing with the symbiotic relation of an associated fungus in *Calluna vulgaris*, refers to the case of Darnel grass, and says : " Some degree of symbiosis has been inferred, but the experiments of Hiltner to establish nitrogen fixation for this fungus are inconclusive."

In describing the distribution of the fungus (a peculiar mycorrhizal form) found in *Calluna vulgaris*, Rayner draws attention to the fact that in many points it resembles the fungus in Darnel. The fungus from *Calluna* was isolated and grown in pure culture, and was found to be closely related to the genus *Phoma;* nitrogen-fixation was suggested as its function. Duggar and Davis (21) showed that *Phoma Betae*, when grown on mangel or sugar beet decoction, produced a nitrogen gain of from 3.022—7.752 mg., pointing definitely to nitrogen fixation for this particular fungal species. In fact, it was the only definite positive result obtained from all the forms experimented with.

Although many mycorrhizal fungi are thought to aid their host plant in this way, considerable uncertainty exists concerning the determination of the species producing mycorrhiza and their actual function.

These facts suggest that it is not improbable that the fungus associated with Darnel or English rye grass might act as a nitrogen-fixer, so an experiment was devised to try and establish a definite answer to this suggestion as regards *Lolium perenne.*

Materials and Apparatus.

(1) Method of Preparing Sand.

Sand cultures were chosen, as they supply a rather more natural condition for the plant roots than water cultures, and sand has the additional advantage of being practically insoluble, and it does not interact with the nutritive compounds used in the watering solutions. In order to obtain it free from all traces of nitrogen, it was subjected to the treatment recommended by Schramm (22). A good sample of fine quartz sand was chosen. This was thoroughly washed for about two hours in running tap-water. It was next boiled in strong hydrochloric acid for about one hour, and then washed with distilled water until chlorides could no longer be detected on the addition of silver nitrate. The sand was then heated to a red heat in a furnace for eight hours. This effectively removes any organic material which may be present. The ash formed in this way and any remaining traces of nitrogen were removed by a second boiling in pure strong hydrochloric acid. A second washing with distilled water ensued, and was carried on until the sand was free from chlorides. Finally it was washed a dozen times with nitrogen free water, and then dried in a drying oven. After this treatment, on testing for ammonia, nitrites and nitrates, only negative results were obtained.[5]

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5. Nessler's reagent was used in testing for ammonia. The Lunge test (Diphenylamine) was used in testing for nitric acid. A modification of the Peter-Griess method was used in testing for nitrous acid. This test is extremely delicate, according to Anderson (25). One-thousandth of a milligram can be detected with certainty. The Griess-Ilosvay method is as follows:—

(1) Dissolve 0.5 gm. of sulphanilic acid in 150 cc. of 2-normal acetic acid.

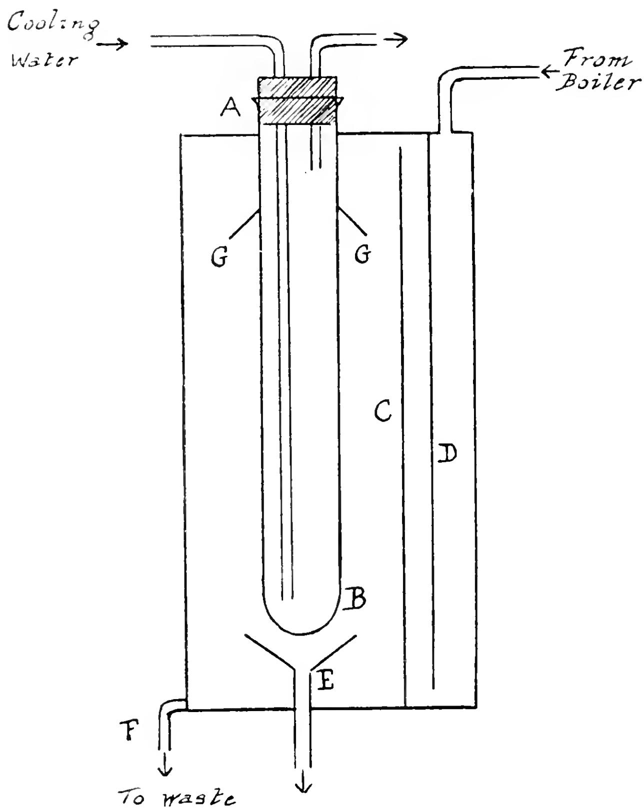
(2) Boil 0.2 gm. of *a* naphythylamine in 20 ccs. of water. Pour off the colourless solution from the violet residue, and add to the solution 150 cc. of 2-normal acetic acid. Mix the two solutions. (This mixture must be kept in a dark place.) Take 50 c.c. of the material to be tested with 2 cc. of above reagent, and allow it to stand 5 or 10 minutes; it will be coloured red if a trace of nitrous acid is present.

In using this test, the flask should be plugged with cotton wool, to prevent dust from entering the solution and disturbing the result.

(2) *Low conductivity water.*

I have to thank Dr. Rivett, of the Chemistry Department, Melbourne University, for the use of a still, the pattern of which was first described by Hartley, Poole and Campbell (28), and which readily yields water of conductivity as low as 0.4×10^{-6} mhos. The method employed is briefly as follows:—

Ordinary distilled water is boiled for about 10 mins. in a 10 litre copper vessel, open to the air, and this is connected to the apparatus shown in text-figure 8.



Text-Figure 8.

A diagram of the condenser used in preparing low condctivity water, AB = condensing tube; E = collecting funnel; C and D = Copper sheet baffles; G = tin flap welded to AB to prevent condensate from soldered junction running down A.B.

The essential part is the condensing tubes A B, which is of pure tin. Before the entering steam can reach the condenser, it must travel round two copper-sheet baffles C and D, which effectively retain liquid particles projected from the boiler. The condensate drips into the tin-funnel E, and is collected in a 3-litre Jena glass flask, with the usual guard tubes of soda lime. It is removed from the flask by siphoning. The outer cylinder is of copper, and is protected by asbestos sheeting on the outside. No water which condenses on the cylinder or the copper baffles-plates can enter the funnel E; it is drained away at F. To prevent the condensate running down A B from the soldered junction of the tube with the top of the cylinder, a tin flap is welded on, as shown at G. The drippings from this fall outside the funnel E. The middle fraction of 3 litres is the purest.

Apparatus.

Two large glass shades, fitted into a groove round the periphery of wooden stands, were used for covering the pots, in which the grains were planted. These were carefully cleaned with acid-dichromate cleaning mixture. In each case a long glass tube bent at right angles to itself was inserted through the stand into the cylinder. These were connected in turn to a series of wash-bottles. The first of these contained chemically pure sulphuric acid, giving no nitrogen reactions. This acid bottle was connected to two series of water-wash bottles, one set belonging to each cylinder. The connections were made with glass and rubber tubing. Between the last wash-bottle and each shade, a tube of wider diameter, was inserted, containing a germ-proof cotton plug. A second tube of smaller length, also bent at right angles and fitted through the wooden base into the other side of the cylinder functioned as an exit tube. These in turn were connected each to a wash-bottle, and then to a water pump. By this means a slow current of air could be kept drawn through the cylinders. Before reaching them, the air had to pass through the acid, two wash-bottles containing nitrogen-free water, and finally through the cotton plug, so all combined nitrogen in the form of dust, etc., was removed before the air reached the pots. This treatment also reduced to a minimum the chance of nitrogen fixing bacteria, present in the atmosphere, gaining access to the sand.

After the experiment had been running for some little time, it was evident that a large amount of water was being carried over by the air and condensing on the sides of the glass cylinders. In order to prevent the air from being too moist, U-tubes containing pure calcium chloride were inserted betweeen the last wash-bottle and the cotton plug.

Watering with the nutritive solutions was carried out by a siphon arrangement. A glass tube bent at an angle over each pot was connected by rubber tubing to a separating flask. This was tightly stoppered, and the stopper covered by a small inverted beaker to prevent dust from falling on it. By raising or lowering this flash the solutions flowed freely on to the pots and the quantities given could be altered at will.

The pots themselves had glazed surfaces, and were quite nitrogen free.

Before setting up the experiment, all the glass bottles and tubing were washed with the cleaning mixture, and then several times with nitrogen-free water. The open ends were plugged with cotton wool and sterilised, in a steam steriliser, on three successive days. The rubber stoppers and tubing were boiled in dilute alkali, then in dilute acid, and subsequently washed with nitrogen free water. Connections were made as soon as possible after removing the plugs.

The slot in the stand into which the cylinders fitted was sealed with putty, all the other joints were sealed with paraffin. There was every indication that the connections were air-tight.

The grains before planting were treated with a 2% formalin solution for 8 minutes, then washed thoroughly in nitrogen-free water. By previous trial it was found that this treatment did not affect the germination capacity of the seeds, and rendered them as sterile as possible.

The sand, being prepared in the manner already described, was sterilised, left to cool, moistened with nitrogen-free distilled water, and the grains planted. The shades were immediately fitted into place, the connections made, and the experiment commenced running on August 18th, 1919. It was so arranged that an equal amount of illumination was received by both pots.

The drying tubes soon became saturated with water, and it was found necessary to change them every second day. The U-tubes when not in use were kept sterilised and plugged, so that the sterility of the system was not affected by this factor. The sulphuric acid and water in the wash bottles was also changed occasionally, so as to prevent any traces of nitrogen accumulating in the last wash bottles, and thereby reaching the cylinders. During the process of changing the bottles, the rubber connections with the cylinders were clamped, so that air could not reach them.

(4) Nutritive solutions.

The control pot was watered with a nutritive solution, made up according to the following formula:—

Ammonium nitrate, 0.5 gram.
Potassium di-hydrogen phosphate, 0.2 gram.
Calcium sulphate, 0.1 gram.
Magnesium sulphate, 0.1 gram.
Sodium chloride, 0.1 gram.
Ferric chloride, 0.04 gram.
Nitrogen-free water, 1000 ccs.

The second pot was watered with a similar solution, excluding the ammonium nitrate.

The chemicals used were the purest that could be obtained. The watering solutions when ready for use gave negative results, with the nitrogen tests already described.

Results.

August 18th.—Experiment commenced.

August 27th.—Grains were germinating freely in both pots.

September 15th.—The seedlings in the control pot were taller and were showing a better colour than those deprived of nitrogen.

September 16th.—First signs of yellowing at tips of leaf in nitrogen-free seedlings.

September 19th.—All the seedlings in the nitrogen-free cylinder showed their first leaf distinctly yellow at tip, and the yellow colour was extending back along the edges of the lamina. The seedlings were all in the two leaf stage. The second leaf was quite green. The seedlings in the control cylinder looked very healthy. No signs of discolouration were evident in them.

September 30th.—The nitrogen-free seedlings were about one-third the height of the control seedlings. The first leaf was very much discoloured and withered. The second leaf was still green, showing no signs of yellowing. The third leaf just visible. The control seedlings were healthy, and of a good green colour; they showed 5-6 leaves.

October 13th.—The nitrogen-free seedlings were very unhealthy. The second leaves showed discolouration, and were dying from the tip downwards. Very much behind the control.

October 20th.—The nitrogen-free seedlings were beginning to die out. The control seedlings were exceedingly vigorous and normal.

October 30th.—The experiment was dismantled for photographic purposes, as the remaining nitrogen-free seedlings were failing rapidly.

The phenomena noted during the course of the experiment are typically those resulting from nitrogen starvation. The yellowing of the older leaves always commencing at the tip indicates that these members are being sacrificed in order that any nitrogen they possess (i.e., nitrogen obtained from the seed) may be made available for transference to the young developing leaves. This transference of nitrogen from the first-formed leaves to the actively growing centre enables the plant to exist for a certain period of time, but the lack of nitrogen manifests itself in the stunted growth and unhealthy colour and appearance of the plants.

It may be concluded from this experiment that no power of nitrogen-fixation in the absence of external supplies of combined nitrogen can be ascribed to the endophytic fungus of *Lolium perenne*.

Conclusion.

It is difficult to decide what is the actual relationship between the fungus and the Lolium plant. It could, perhaps, be regarded as a case of symbiosis, the fungus helping in the plant economy during the formation of the grain. In return for this it is housed by the grass, and its propagation is ensured by the admittance of hyphae to the embryo, so that it is able to appear in each successive generation without the intervention of a spore stage. It can only be a matter of conjecture whether this stage is entirely lost to the fungus or whether it is repressed, only as long as conditions are favourable to its transmission in the usual way, but still retains the power of sporing if in danger of extermination. The sporing stage may occur under such conditions, but up to the present it has not been recognised as belonging to the fungus normally found associated with at least two species of Lolium.

As opposed to this conjecture, Freeman (26), although he had not demonstrated the intra-cellular nature of the fungus, advocated the view that it was a smut. He was drawn to this conclusion by the idea "of the probable progression of the evolution of parasitism in smuts," from the loose smut of oats through the loose smut of wheat to the Lolium fungus. The loose smut of wheat, forming as it were, an intermediate stage between the loose smut of oat and the fungus of Lolium. It is well known that the spores of the loose smut of wheat infect the ovary at the flowering stage, and there form a mycelium, which perennates in the embryo of the grain, growing when it germinates in the manner of most smuts, and forming its spores during the next flowering stage.

The Lolium fungus could be regarded as a development from a type such as this, in which the sporing stage has been entirely suppressed, or at most occurs extremely rarely.

The points in the life-history of the fungus associated with *Lolium perenne*, which could be used to support this view, are:—

1. The behaviour of the hyphae during the growth of the plant up to the flowering stage, which closely resembles the method adopted by the *Ustilagineae*.
2. The formation of knots in the tissue of the young ovary, which, however, I prefer to explain, not as an attempt towards spore-formation, but as the preliminary to cell infection.
3. The intra-cellular course of the hyphae.

These, at first sight, undoubtedly seem to weigh heavily as evidence in favour of its relation to the smut family, the most suggestive being the behaviour of the fungus during the vegetative period of the grass.

This mode of growth in the host plant, however, is not limited to the *Ustilagineae*. Rayner (20) describes a fungus associated with *Calluna vulgaris* which grows in the tissues of the plant without any external evidence of its presence or without disturbing the normal growth of the host.

The greatest development of the fungus in this case takes place on the roots of the plants forming a mycorrhiza, endotrophic in character, but unlike most other mycorrhizal plants, the fungus keeps pace with the growing point of the stem, and after the inception of the ovary it enters this organ, and forms a mycelium in the ovary wall. The embryo remains sterile, but infection of the seed-coat is accomplished by the hyphae, so that the production of a mycorrhiza in the roots of the next generation of Calluna is not left to chance.

The fungus in the seed-coat becomes active on germination, infects the seedling, and produces the felt on the root; indeed the association is so close that the symbiosis is an obligative one, the seedlings not developing unless infected.

This is a very striking instance of symbiotic association, and, as Rayner points out, the only other plant for which a like distribution of the fungus has been described is *Lolium temulentum*. Since I have demonstrated the intra-cellular nature of the Lolium fungus it falls even more in line with the Calluna type. Although it does not form a mycorrhiza, its use to the plant is certainly demonstrated at the fruiting period. It is possible, therefore, to regard it as a case parallel to the Calluna type, the similarity to the Ustilagine mode of growth being accidental, and not of any real importance in helping us to classify it and to grasp its affinities. Since the Calluna fungus has yielded to artificial culture, and can be classed definitely as a *Phoma*, every hope can be entertained for success in this direction as regards the fungus of the Loliums.

The occasional penetrations of the endosperm, etc., already described, do not, I think, point to vestigial traces of a former parasitic habit. Even when present they do not evince any harmful results in the grain. They are probably to be explained as a luxuriant development of the fungus, resulting perhaps from good growth conditions. The endosperm has proved unable to cope with the large food supply represented by the fungus, and consequently has failed to transform it all into the usual storage form—starch and aleurone grains, so that some of the hyphae which had penetrated the tissues of the embryo, and would normally have been absorbed, remained intact. Any food-material they contained would be yielded up on germination, just as the food-material of the endosperm is changed into soluble forms, and translocated to the seat of growth.

Although I have never examined a grain of *Lolium perenne* either mature or in an embryonic condition without finding the fungus present (sometimes in minute amounts), it is quite probable that such occur.

It is conceivable that the hyphae, when growing in the young inflorescence may miss a carpel and in that case the ovule would not become infected. This would probably not prevent the formation of a fruit. The grain so formed, however, would not be so well equipped in its struggle for existence as its fungal-containing neighbour, and eventually would tend to die out. It is, therefore, unlikely that two races of both *Lolium temulentum* and *Lolium perenne* exist, one with a symbiont, the other fungus free. An occasional grain of either species may show the absence of hyphae, but this would be accidental in character, so that instead of an ever-increasing number of the latter type, they would always tend to remain at a more or less stationary minimum.

Summary.

The foregoing investigation has led to the following results:—

(1) The occurrence of the fungus in the genus *Lolium* is wider and more constant than has hitherto been demonstrated.

(2) Colour of the grain cannot be regarded as a diagnostic character in regard to the presence or absence of the fungus.

(3) The fungus is intra-cellular or endophytic in nature.

(4) The distribution in the grain is not a result of any special method of infection, but is a result of the function of the fungus during the grain's development.

(5) It is present in the embryo-sac at or immediately after fertilisation.

(6) The fungus increases in quantity at the expense of the nucellus, and the cells of the carpel wall. This is only a temporary phase. On the formation of endosperm the fungus is absorbed as a source of food-supply to the developing embryo.

(7) The endosperm is formed by the division of its outer layer. This layer functions as a kind of cambium. I have termed it the *endospermic cambium*. The cells which are cut off always to the inner side, increase in size, remain thin-walled, and become packed with starch. This outer meristematic layer is constantly receiving and absorbing hyphae, which, if present in any quantity, are finally crushed into a layer around the periphery of the endosperm. If the fungus does not keep pace with the absorbing power of the endosperm, no hyphal layer is formed in the ripe grain, but hyphae can then be found in the scutellum and embryo.

(8) The endospermic cambium after it has ceased to divide persists as the aleurone layer, which, in turn, receives a supply of nutriment from the fungal system.

(9) The ovum is infected before any divisions have taken place in it.

(10) The hyphae aggregate at the proximal end of the developing grain. They are here used by the endospermic cells in the embryonic pocket for food-supply for the developing embryo.

(11) The association of the fungus with *Lolium temulentum* and *Lolium perenne* is probably a well-marked case of symbiosis, comparable in many respects with that met with in *Calluna vulgaris.*

(12) It has been suggested that nitrogen fixation was the function of the fungus, but an experiment has been performed, and the result obtained showed that the fungus of *Lolium perenne* is unable to fix nitrogen in the total absence of external supplies of combined nitrogen.

The foregoing work was carried out in the Botanical Department of the Melbourne University during the years 1917, 1918, and 1919. I have to thank Professor Seward, Cambridge; Mr. S. F. Armstrong, Agricultural School, Cambridge; Dr. Stoward, Western Australia; Mr. Burtt Davey, South Africa; Mr. Breakwell, Sydney; Vilmorin-Andrieux and Cie, Paris; and the Royal Botanic Gardens, Kew, for forwarding supplies of grain from different parts of the world; also Mr. O'Brien, Assistant in the Botanical Department, Melbourne University, for the help he has afforded in assisting with experiments and taking photographs. To Professor Ewart I am indebted for the facilities provided for the work, and for much helpful criticism during its progress.

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EXPLANATION OF PLATES.

All figures have been drawn with the aid of the camera lucida (Zeiss).

Plate XVIII.

Figures 1-5 stained with aniline gentian violet, followed by Gram's iodine wash. They illustrate the distribution of the fungus in the grain, the position of the hyphae is indicated by the yellow line shown in the figures.

Fig. 1.—A semi-diagrammatic representation of a transverse section through the distal part of a grain of *Lolium perenne*.

(a) aleurone layer; (b) cells of aleurone layer, which stain differently from the rest, probably ferment-containing cells; (e) starchy endosperm; (h) hyphal layer; (h^1) coloured portions of hyphae (the great bulk of the layer is not stained with the gentian violet); (t) pericarp and testa.

Fig. 2.—A transverse section of the proximal end of the same grain. Letters as in Fig. 1, and (s) scutellum; (el) epithelial layer of scutellum.

Fig. 3.—A transverse section of the extreme proximal end of the grain. Letters as before, and (r) radicle; (ht) hyphae in fused pericarp and testa.

Fig. 4.—A longitudinal section of a grain of *Lolium perenne* taken in the coronal plane. Letters as in Figs. 1-3, and (g) growing point of embryo; (l) sheathing leaf.

Fig. 5.—A longitudinal section of a grain of *Lolium perenne* taken in the sagittal plane. (m) embryo; (v) vascular bundle of scutellum; (i) ligule; (ht) hyphae in fused pericarp and testa.

Plate XIX.

The following figures have been drawn from sections of a grain of *Lolium perenne* (South Africa). The fungus is especially luxuriant, its intra-cellular nature being evident in the mature grain.

Fig. 1.—A sagittal longitudinal section of a grain of *Lolium perenne*, not passing through the median line. The scutellum shows numerous hyphae, which have gained entrance to this tissue from any point on its surface.

(e) starchy endosperm; (a) aleurone layer; (el) epithelial layer; (h) hyphae in scutellum; (h^1) hyphae round periphery of the scutellum; (c) cells invaded by the hyphae. × 250 diam.

Fig. 2.—Detail of the scutellum.

(h) hyphae passing through the scutellar cells; (c) constriction of hypha during penetration of cell wall. × 1700 diam.

Fig. 3.—Aleurone cells, showing the intra-cellular course of the hyphae,

(a) aleurone cells; (w) wall of aleurone cell; (h) hypha passing from one cell to the next; (h^1) hypha lying at a different level, but drawn in the same plane in figure. × 1700 diam.

Fig. 4.—Detail of scutellum, showing the cells invaded by hyphae. × 1100 diam.

Fig. 5.—Wall of aleurone cell, showing hypha entering into cell through pit in its wall

(p) pit in wall; (h) hypha. × 1100 diam.

Plate XX.

A longitudinal section of an ovary of *Lolium perenne*, just prior to fertilisation; stained with bismarck brown, then with gentian violet, followed by Gram's wash.

(c) carpel wall; (s) starch groups in cells of carpel wall; (i) invaded cells at stalk end of section; (h) hyphae in stalk of ovary; (h^1) hyphae in distal part of wall; (h'') hyphae in distal part of wall not staining with gentian violet; (t) cells in stigmatic tract being used by the fungus as food; (ov) ovule; (hy) hyphae distributed in all parts of ovule; (ic) infected cells of ovule; (es) embryo-sac; (o) ovum; (hy^1) hyphae in embryo sac. × 103 diam.

Plate XXI.

Figures 1-6 show detail of ovule illustrated in Plate XX. (Stage A).

Fig. 1.—Three cells of nucellus, showing the intra-cellular nature of the fungus. These cells react to the violet stain, the rest of the nucellus staining with bismarck brown.

(n) nucleus; (h) hyphae; (h^1) fine ramifications of hyphae in the cells. × 1100 diam.

Fig. 2.—A cell from the carpel wall which is being attacked by the fungus and used as food-material for the fungal system.

(h) hyphae running between the cells; (h^1) fine penetrating threads; (g) starch grains being digested by hyphae; (s) septum in hyphae. × 1100 diam.

Fig. 3.—"Knots" formed by the hyphae wrapping round the cells as a preliminary to their entrance into them. The lightly-shaded portions are lying at a lower level than the darker sections of the hyphae. × 1100 diam.

Fig. 4.—A vascular element from the stalk end of the carpel wall, showing the close association of the fungus.

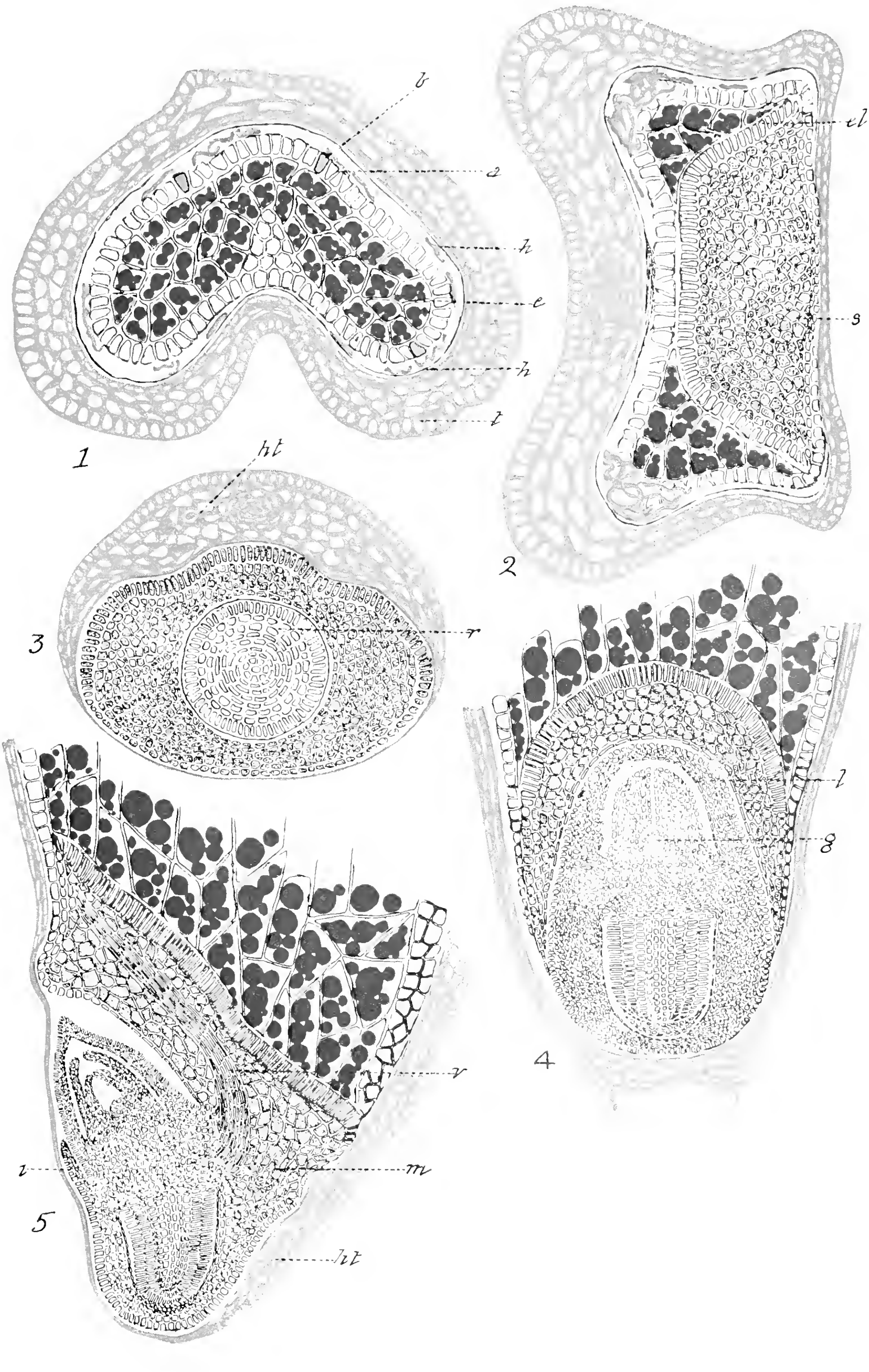
(r) thickenings on vessel; (h) hyphae. × 1100 diam.

Fig. 5.—Cells from the distal end of the carpel wall.

(g) starch groups; (h) large intra-cellular hyphae; (h^1) fine hyphal threads completely wrapping round grains prior to digesting them. × 1100 diam.

Fig. 6.—Ovum and synergidae; showing presence of hyphae in ovum before any divisions have occurred in it.

(o) ovum; (s) synergidae; (n) nucleus (nuc) nucellus; (h) hyphae. × 700 diam.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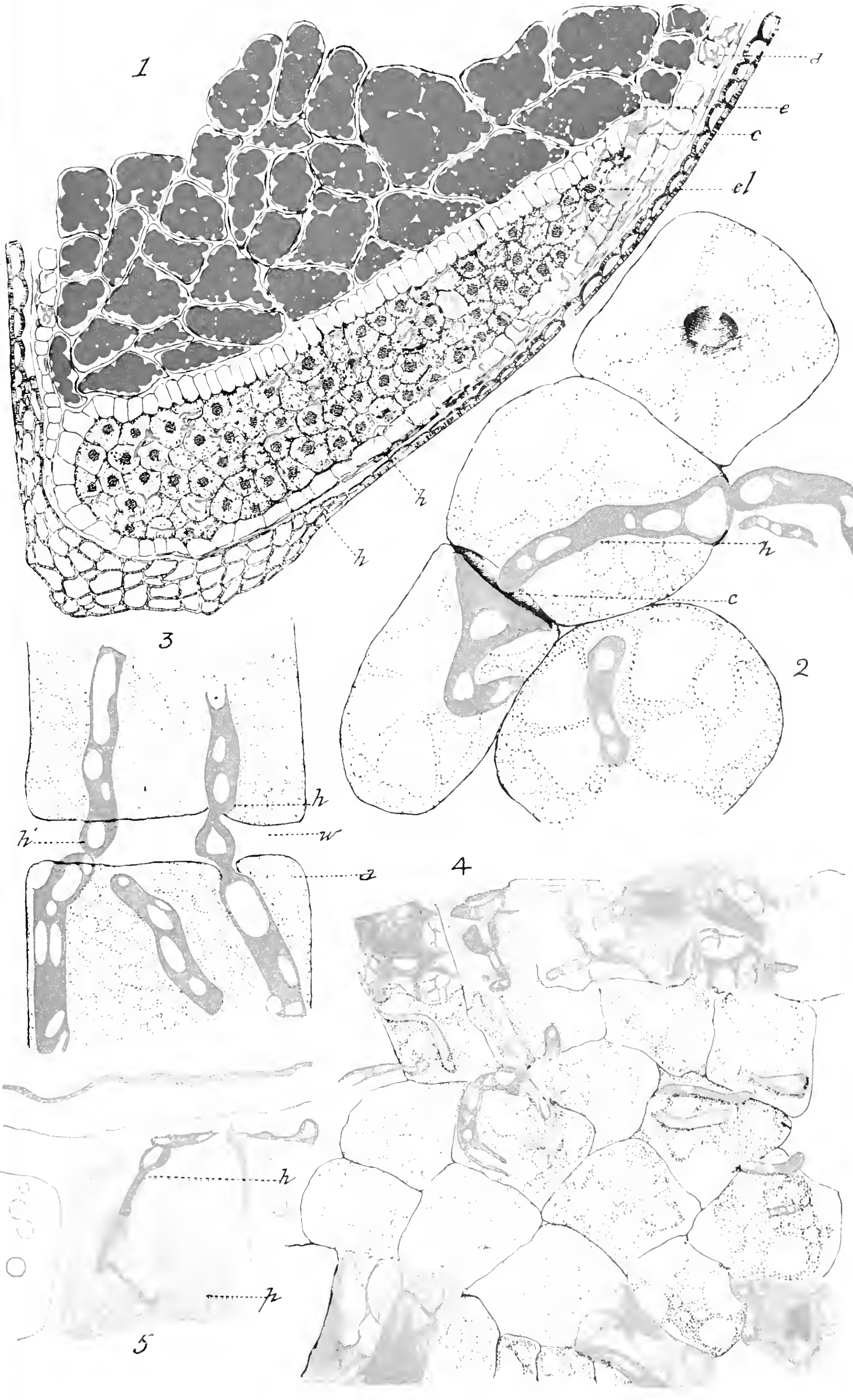
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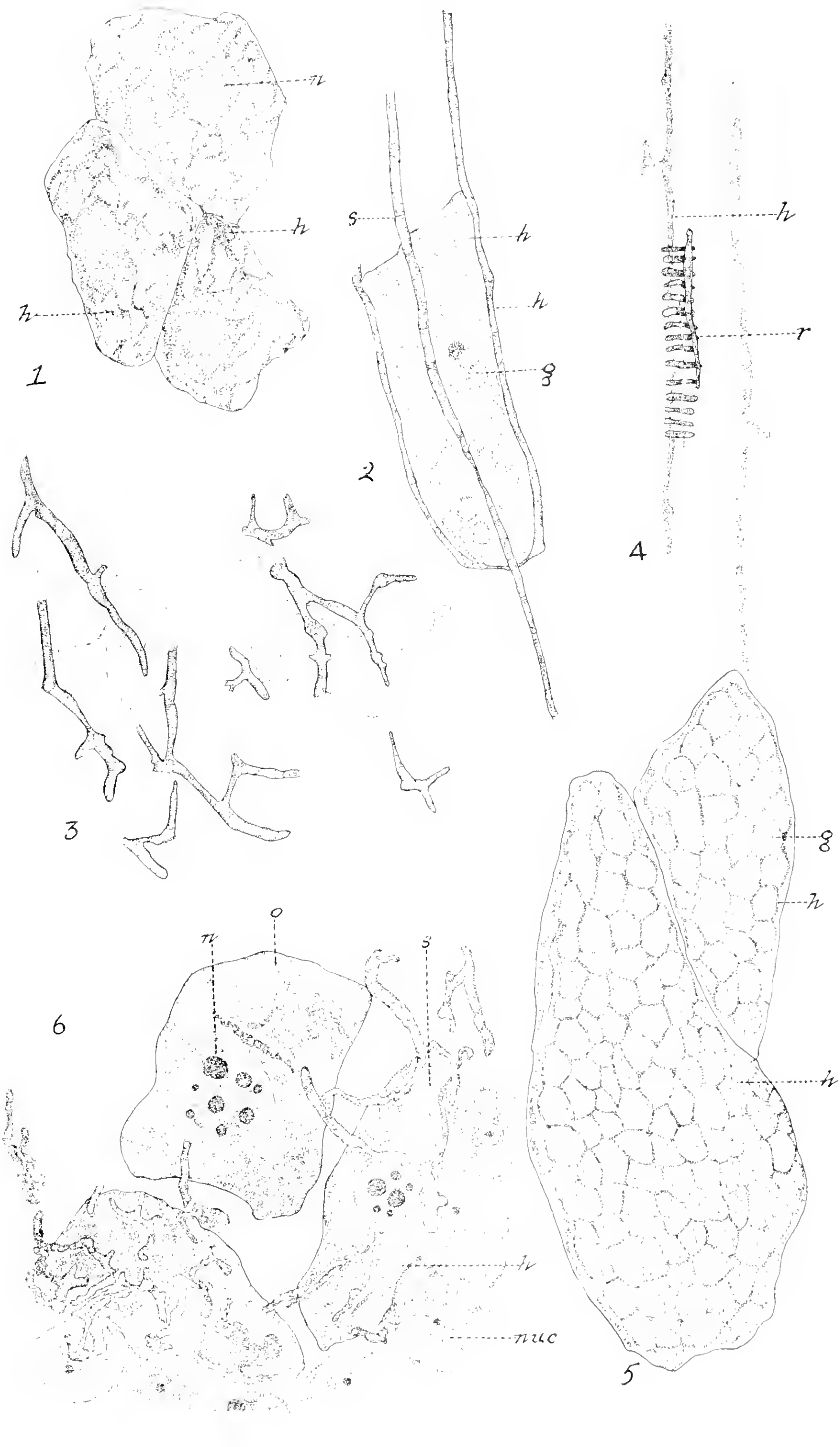
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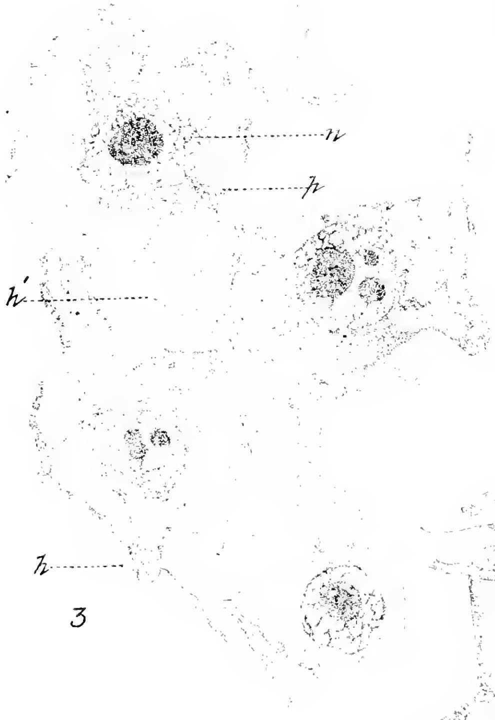

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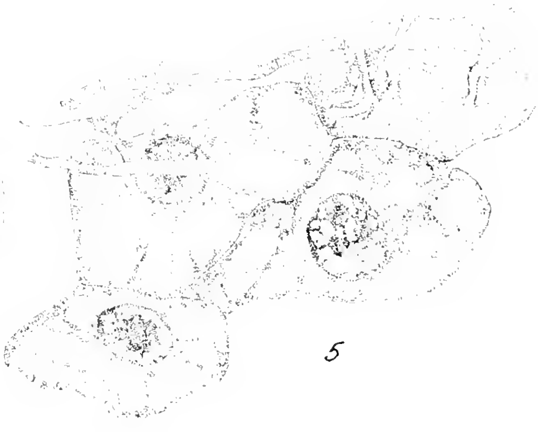

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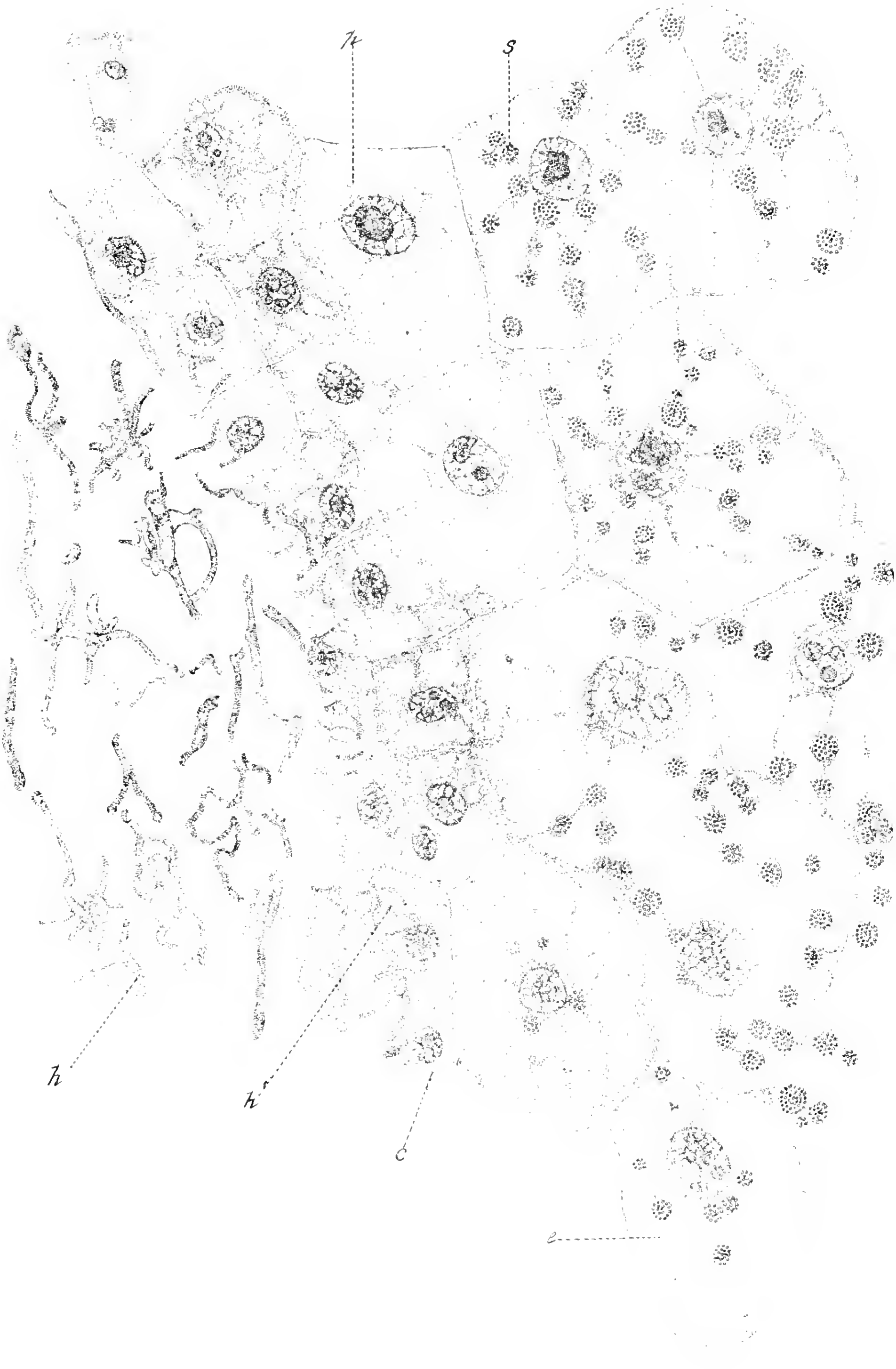
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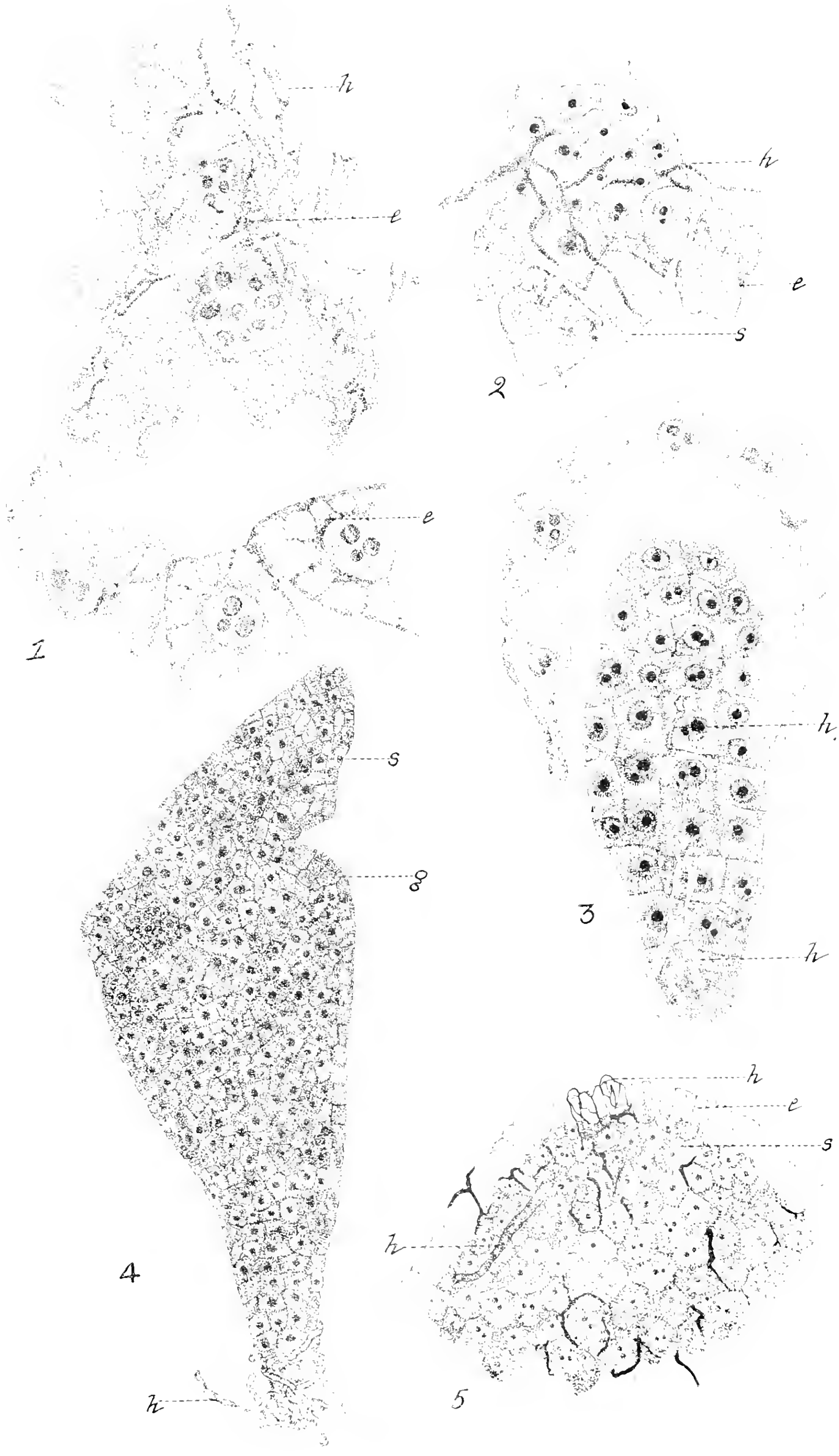
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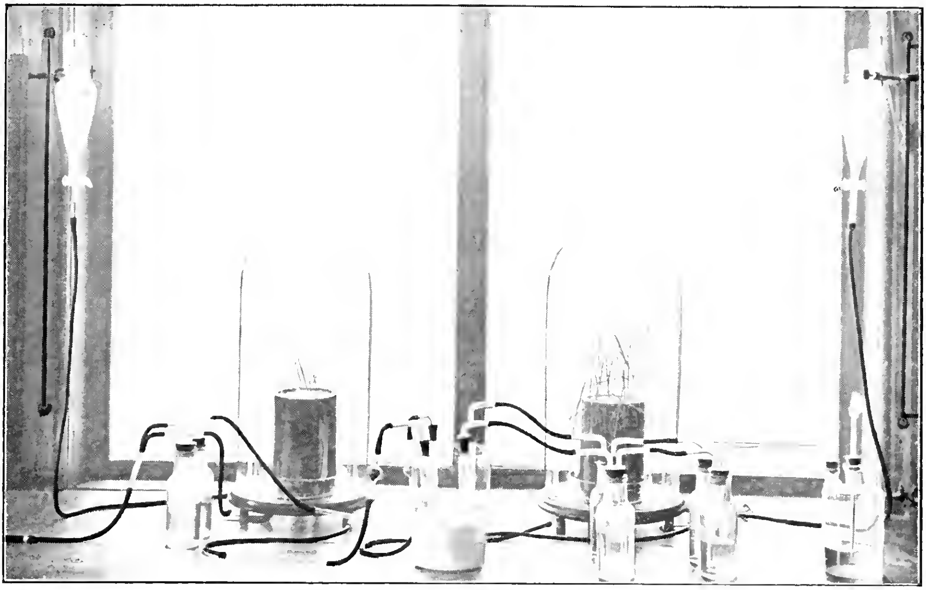
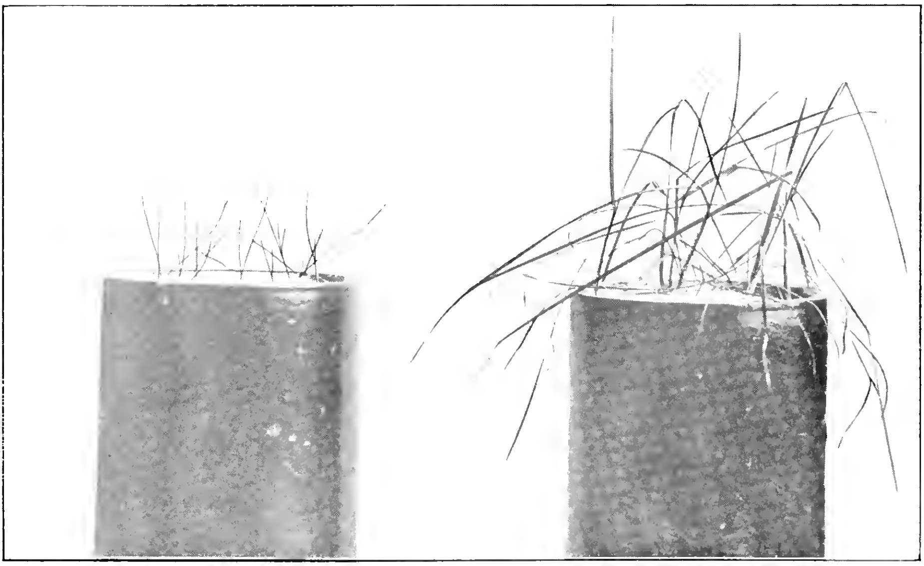


Fig. I.



A Fig. II. B

Plate XXII.

Illustrates detail of ovary at Stage B. The sections were stained with congo red, followed by gentian violet and Gram's iodine wash.

Fig. 1.—Detail of nucellus, showing network of hyphae.

(n) disorganising nuclei; (h) hyphae stained with congo red; (h¹) hyphae stained with gentian violet; (r) remnants of protoplasm of nucellar cells. × 1100 diam.

Fig. 2.—Mode of branching of hyphae in nucellus.

(n) nucleus; (v) vacuole; (b) origin of branch. × 1100 diam.

Fig. 3.—Young endosperm cells showing the hyphal threads entering and being absorbed by them.

(n) nucleus of endosperm cell; (p) protoplasm of endosperm cell; (h) hyphae; (h¹) hyphae in process of absorption. × 1100 diam.

Fig. 4.—Similar to Fig. 3, but section taken from another grain and stained only with gentian violet. The protoplasm remained unstained and the hyphae in the cells stained brightly with the violet dye.

(n) nucleus of endosperm cell; (h) hyphae entering cell; (h¹) hyphae in protoplasm of endosperm cell in process of absorption. × 1100 diam.

Fig. 5.—Same as 3 and 4, but shows the branches arising almost at right angles to main hyphal thread, and entering the endosperm cells. Lettering as before. × 1100 diam.

Plate XXIII.

A section of the endosperm taken from a grain at Stage C. It was stained with congo red, gentian violet and Gram's iodine. The outer edge of this tissue is included in the figure. The cells in this area are young, and more or less cubical, being formed by the division of the outermost layer; starch has not yet appeared in them. The older cells of the endosperm are large, and thin-walled, and starch is being deposited in the protoplasmic network. Hyphae are being absorbed by the outer dividing layer, and serve as a source of food-supply to the endosperm.

(h) nucellar hyphae; (h¹) hyphae being used by the endosperm as food; (c) young dividing layer; (e) older endosperm cells; (s) starch groups; (p) protoplasm. × 1100 diam.

Plate XXIV.

A portion of the endosperm from a nearly mature grain. The outer layer is being transformed into the aleurone layer, but even at this stage hyphae are entering the cells, and are being absorbed by them. The aleurone layer is cut tangentially in the upper part of the grain; the layer therefore, appears several cells thick at this point. The starchy endosperm cells immediately underneath the nitrogenous containing cells show well-marked nuclei, but these will disappear as the grain reaches maturity.

(a) aleurone layer; (g) young aleurone grain; (p) protoplasmic network in aleurone cells; (h) hyphae accumulating to form a layer; (et) hyphae entering aleurone cells; (n) nuclei of aleurone layer; (s) starch groups; (ne) nuclei of endosperm cells. × 1100 diam.

Plate XXV.

Figs. 1-5 illustrate the relation of the fungus and embryo at different stages in the development of the grain.

Fig. 1.—Endosperm cells from the embryonic pocket drawn from the same slide as Fig. 2. The fungus occurs in great abundance in this region at this stage. It is being used by the endosperm, which in turn hands on the food material to the embryo.

(h) hyphae; (e) endosperm cells of embryonic pocket; (e^1) ordinary endosperm cells. × 625 diam.

Fig. 2.—A young embryo.

(e) endosperm cells being used by the embryo as food; (h) hyphae; (s) suspensor end of embryo. × 625 diam.

Fig. 3.—An older embryo, the endosperm cells at the proximal end of the pocket have disappeared.

(h) hyphae present in embryo. × 625 diam.

Fig. 4.—An embryo showing differentiation of scutellum, and growing point. Stained densely with congo red, so that hyphae in growing point could not be seen.

(h) hyphae at suspensor end; (g) growing pt.; (s) scutellum. × 300 diam.

Fig. 5.—The tip of the scutellum from a grain of *Lolium perenne* (not yet fully developed), which did not contain an extra cellular hyphal layer in the usual position. Hyphae were present, however, in the scutellum and embryo.

(s) scutellum; (e) epithelial layer; (h) hyphae. × 500 diam.

PLATE XXVI.

Fig. 1.—A photograph of the apparatus used in the experiment described in the paper.

Fig. 2.—The two pots removed from the protecting shades at end of experiment.

(A) Seedlings watered with a culture solution containing ammonium nitrate.

(B) Seedlings deprived of combined nitrogen, except such as is stored in the seed. The stunted growth is evident, but the photograph does not shew the unhealthy colour and dying back exhibited by the seedlings, and which is so characteristic of nitrogen starvation.

[Proc. Roy. Soc. Victoria, 32 (N.S.), Pt. II., 1920].

Art. XIX.—*On the Structure of a New Species of Earthworm from South Australia, Megascolex fletcheri.*

By JEAN H. SHANNON, B.Sc.

(Communicated by Professor Sir Baldwin Spencer).

[Read December 11th, 1919].

(With Plates XXVII.-XXXI.)

Up to the present time, though a large number of species of earthworms has been described from Australia, more especially by Dr. Michaelsen,[1] from South-West Australia, Prof. Spencer,[2] and Mr. J. J. Fletcher,[3] from New South Wales, Victoria, Queensland and Tasmania, there has, as yet, been published only one more or less complete detailed account of one type of Australian earthworm—Megascolides australis. The species now described represents another type, differing in important respects from Megascolides, and, on the suggestion of Professor Sir Baldwin Spencer, I have attempted to describe its structure as completely as possible. The work has been carried on in the Zoological Department of the Melbourne University.

I have followed the classification suggested by Michaelsen.[4] The species evidently belongs to the genus Megascolex, as defined by him, and I propose for it the name of *Megascolex fletcheri*, the specific name having reference to the first naturalist who made a study of Australian earthworms.

Habit.

The material dealt with in this paper was collected in South Australia at a spot about ten miles due east from Kapunda, the latter being a town situated in an agricultural district.

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1. Michaelsen.—"Die Fauna Südwest-Australiens," erster Band, 1907-1908, pp. 117-232.
2. Spencer.—"The Anatomy of Megascolides australis." Trans. Roy. Soc. Vic., Vol. I., Part I., 1882. "Preliminary Notice of Tasmanian Earthworm," op. cit. 1894.
3. Fletcher.—A series of six papers, the first of which, "Notes on Australian Earthworms, Part I.," was published in Proc. Linn. Soc., Vol. I., Series 2, 1886, p. 523. The remaining five were published in the same Proceedings in 1886, 1887, 1889, respectively.
4. Michaelsen.—op. cit. p. 160.

The type of country is gently undulating, and mostly very rich clayey soil. The timbered land is isolated now, owing to cultivation.

The climate is moderate, with occasional very dry seasons, and generally a long summer with high temperatures.

These particular earthworms seem to be very peculiar and restricted in their habitat. Quite a large area of scrub land was very carefully searched, and only two small spots were found to shelter the worms. One was a somewhat low-lying, damp place beside a dam, and the other a more or less elevated spot, less timbered and sunny. In both cases the earth worms were concealed underneath cut timber for fence posts, and during the wet winter of last year were very plentiful.

Their habits were essentially moisture loving, and in the damp earth, and even in the actual timber distinct, and large holes or burrows were made, down which the worms rapidly disappeared when the post was overturned. A considerable amount of slimy, glassy material was found wherever the worms had passed, and the earth all about their burrows was well worked and divided. In some cases only a furrow was made in the earth, the lower surface of the post serving to roof it in.

When the specimens were dropped into spirit for preservation, they definitely contracted, and, as is usual with earthworms, put out a large quantity of slimy fluid through the dorsal pores all along the body.

External Anatomy.

The freshly collected worms are of a pale pink colour, and vary somewhat in size, but as a rule are from ten to twelve inches in length, and between one quarter and a-half an inch in diameter.

The clitellum is very distinct in the mature animals, and is of a paler shade than the rest of the body. It is situated about an inch from the anterior end, and is not quite regularly cylindrical, being pinched in on the ventral surface. It extends from just after the eleventh segment to the end of the eighteenth. The surface of the worm appears to be covered by a translucent and very thin membrane, but in the spirit specimens the glassy appearance is lost to a large extent, and the membrane becomes rather more conspicuous and tougher, but looses its iridescence.

There is a ring of stetae in the middle of each segment, broken at the mid-dorsal and mid-ventral lines. The most median pair on the ventral surface on each side are somewhat larger than the rest.

The segments themselves are quite distinctly marked, especially in the spirit specimens. There is a distinct median furrow around each segment, and towards the anterior end of the worm two smaller furrows may generally be found, one on either side of the main furrow.

The prostomium is normally very nearly completely dove-tailed into the peristominum.

The openings to the exterior of the dorsal pores and of the reproductive organs are mostly quite distinct, and can be seen with the naked eye.

On the dorsal surface the only openings that occur are the dorsal pores. These are situated between the successive segments in the median line, the first being between segments four and five.

On the ventral surface the most conspicuous openings are those of the vasa deferentia, on the eighteenth segment. Each is surrounded by two swollen somewhat semi-circular lips, is situated away from the median line between the third and fourth pairs of setae, and is not included in the clitellar region. (Plate XXVIII. Fig. 1. ♂) (Plate XXVII. Fig. 1. ♂).

On the fourteenth segment ventrally is a single median raised oval area, and in the centre of this is the opening of the common duct formed by the union of the right and left oviducts. (Plates XXVII and XXVII., Fig. 1 ♂).

Between segments six and seven, seven and eight, and eight and nine, are the three pairs of spermatheeal pores, opening ventrally. It is very difficult to decide whether they open in line with the fourth or the fifth seta.

In one fresh specimen that I examined there seemed to be an indication of two smaller openings, on either side of the main pore. Subsequent dissection showed the presence of accessory glands in this region in all instances.

Besides these more conspicuous openings there are certain small glands associated with the spermiducal gland, and communicating with the exterior on the ventral surface between segments sixteen and seventeen, nineteen and twenty, twenty and twenty-one, and twenty-one and twenty-two.

Internal Anatomy.

Alimentary Canal.—The living worm has very marked power of evaginating the whole crop to the extent very often of one-quarter of an inch. Upon opening up the worm one finds that the front end of the gizzard is invaginated, and appears almost urn-shaped, until the front end is pulled out, when it becomes oval.

The posterior end of the gizzard is between segments six and seven, and all the septa up to this region are considerably displaced, forming angles of about 22.5° with the body wall.

The anterior end of the gizzard is very changeable, according to the amount of evagination it has undergone.

Following on from the gizzard is a long, almost straight intestine running the length of the body, and opening to the exterior at the posterior end. It presents a bulbous expansion in each segment along its length. (Plate XXVII. Fig. 2.)

Nervous System.

There is a distinct nerve collar around the oesophageal region in segment two, with a conspicuously swollen dorsal portion slightly pinched in at the median line. On either side of the collar is given off a large nerve, which runs forwards to supply the anterior part of the oesophagus. A smaller branch supplies the crop behind on each side. After the union of the nerve ring ventrally, the fibres are collected into a very conspicuous cord, which is slightly swollen in each segment. A transverse section of the cord reveals the rather a-typical fact that there is only one large giant fibre present. (Plate XXVII. Fig 3.) (Plate XXX. Fig. 2.)

Nephridial System.

From dissection there does not appear to be a nephridial system other than very numerous micronephridia forming a fringed ring around each segment, especially towards the posterior end.

Microscopic examination of longitudinal sections taken from about the last third of the worm, reveals very peculiar structures, possibly represent a special form of nephridial organ. They are perfectly regular in position, and segmentally arranged. Each is somewhat club-shaped, and attached to the wall of the coelome by a thin stalk. Even under the very high powered objective, there appears to be little structure. The stalk is made up of almost a single chain of nucleated cells, which gradually merge into those of the outer peritoneum. They appear to have no duct, and no passage is visible from them through the muscle layers to the exterior.

The head portion of the structure has different forms, sometimes being long and regular, with a covering of small nucleated cells, and an internal longitudinal clear region, that may, perhaps, indicate the presence of a minute duct. Along the latter at intervals are rounded patches of very numerous and clearly nucleated cells. The rest of the structure seems to be almost non-cellular. Sometimes the base of the "head" is distinctly broadened, and a number of parallel ducts appear to traverse it. In yet other cases the central duct seems to follow a spiral course. In one instance the end of the structure appeared to bend towards an opening through the septum, thus seeming to indicate a relationship to the successive segments typical of meganephridia. (Plate XXIX. Fig. 4.)

The supposition that these organs are connected with the excretary function is further borne out by the development as seen in very young specimens. At an early stage the whole structure is hardly more than a chain of cells, with large nuclei, and at intervals clusters of even more regular and oblong cells. An arrangement that suggests the nephridial structure in some species of Megascolides figured by Beddard, page 51, fig. 13.

The marked similarities between this worm and certain of the Megascolides types again strengthens the idea that the mega nephridia which are generally well developed in the latter genus are represented in this animal by the peculiar structures described above. Besides this, the position of the organs at the posterior end, their segmental arrangement, and their structure also bears out the theory as to their function.

Blood Vascular System.

This system is very difficult to study, except in freshly killed specimens. Extending along the mid-dorsal line of the main length of the body is a large thin-walled dorsal vessel. Smaller lateral vessels are given off on each side in segments five, two and nine.

Just ventral to this vessel is a much smaller median one, extending between segments eight and fourteen.

A large thin-walled pair of hearts spring from either side of this vessel by a very small connection in segments ten, eleven, twelve and thirteen. A very fine pair of vessels also spring from this longitudinal vessel in each segment just anterior to the hearts, and probably are present in segments eight, nine and fourteen as well. (Plate XXVII. Fig. 2.)

There seems to be only a single median ventral vessel into which open the large hearts, but just before doing so each heart gives off a very fine vessel from the outer side, supplying the body wall. Microscopic examination of this ventral blood vessel in transverse section showed that the thickness and structure of the walls were quite peculiar. (Plate XXX. Fig. 4.)

There is a quite definite endothelial lining, with large nucleated cells, and a wall that seems to be largely composed of muscular fibres, running mainly in a circular direction. Besides these elements there are numerous very large clear nucleated cells in the walls of the vessel, and here and there between these latter are quite conspicuous spaces or holes.

Reproductive System.

Female Organs.—The paired ovaries are situated in the thirteenth segment and the two oviducts have very large funnel-shaped openings just below them. The ducts pass through the septum, dividing segments thirteen and fourteen, and then pass to the mid-ventral line, and unite as they pass through the thick muscular wall to open to the exterior. The interior of each oviduct and of the common duct is richly supplied with long cilia, the length of which seems to be about equal to the radius of the passage. (Plate XXVII. Fig. 3.) (Plate XXX. Figs. 1, 2, 3.)

Male Organs.—There are two pairs of testes, one in each of segments ten and eleven. These are peculiarly small, even in a well-matured specimen. The vasa deferentia correspond in number with the testes, and open by very conspicuous and much folded rosettes just below the testes, and then continue quite separately and slightly embedded in the ventral muscles of the body wall to the eighteenth segment. Here, still paired, they enter the muscular wall of the duct from the spermiducal gland of their own side, about the middle of its length, and run parallel with the lumen for some little distance before they enter separately.

The structure and relation of these separate vasa deferentia recalls that of the same parts in Megascolides australis. (Plate XXVII. Fig. 3.) (Plate XXXI. Figs. 1, 2, 3.) Plate XXVIII. Figs. 5, 9.)

The spermathecae are paired and situated in the seventh, eighth and ninth segments, decreasing in size from behind forwards. Each consists of an oval sac, with an equally long but finger-like diverticulum, arising from just below the junction of the base of the sac with its stalk. In the most mature worms this process often appeared to have become lobed at the tip. (Plate XXVIII.

Fig. 3.) The spermathecal sac and its diverticulum open to the exterior by a large duct through the stalk. In the last region this passage seems to be furrowed transversely. (Plate XXIX. Fig 1.)

Associated with the spermathecae are other paired glandular structures. In the sixth segment is found the first pair one on each side. The seventh and eigth each contain two pairs and in the ninth is again a single pair. Ducts from these glands open on either side of the ducts from the spermathecae—i.e., between segments six and seven, seven and eight, and eight and nine. (Plate XXVII. Fig. 3.) (Plate XXVIII. Fig. 2.) (Plate XXIX. Fig. 1.)

The minute structure of these glands is very difficult to determine. Each is decidedly floccular in nature, and the surface cells are large, nucleated, and more or less regular. Internally the cells become less granular, smaller and very irregular, but some still possess very large nuclei, converging to the base of the structure there appears to be clear channel-like spaces between the cells, and these open to the interior of the "stalk." There is no definite duct running from the cell mass, but the whole of the stalk appears to become split longitudinally in an irregular and complex manner. Finally we get a widening of the passage to form a very conspicuous flask-like opening to the exterior. The surrounding epidermal cells become greatly elongated and bow-shaped to surround this structure. In most cases the cuticle is not ruptured, and this seems to show that an opening is formed only at intervals, as the duct becomes full of secretion. Plate III., Figs. 2, 3.)

The vesiculae seminales are large, and occupy most of segments eleven and twelve.

In the eighteenth segment lying tranversely are found two very large organs, the spermiducal glands. Each is flattened dorsoventrally, and is an elongated oval shape. Passing from the inner end of each is a very stout duct, which is practically coiled upon itself on its way to the exterior. The vasa deferentia enter this duct separately about mid-way along its upper surface. The prostate itself seems to be made up of lobes in close apposition to one another.

Microscopic examination shows little definite structure other than the clusters of cells in a less dense matrix, and transverse sections reveal the fact that the whole gland is traversed by one large duct lined by conspicuously nucleated and very regular cells.

In segments seventeen, nineteen, twenty, twenty-one and twenty-two, there are additional glandular structures associated with which are even smaller glands. The detailed structure of these masses of cells is difficult to determine, but apparently each consists of a large number of very granulated, irregularly-shaped and large cells, collected together. Here and there are smaller and non-granular cells arranged in groups.

There does not appear to be a definite duct, but passing from the grandular swelling are numerous small darker cells arranged in clusters, and these follow a disjointed passage through the thick muscular wall.

Problematic Gland in the Thirteenth Segment.

Still another peculiar structure is to be found from dissection, although no indication of its presence is given upon external examination. Attached to the anterior septum of segment thirteen, somewhat ventrally, is a pair of club-shaped organs, each slightly smaller than the smallest spermathecea.

In the less matured specimens examined there were three pairs of these glands—one in each of segments thirteen, twelve and eleven.

At this early stage there is practically no development of the reproductive system, and this fact seems to render it difficult to state definitely, whether these organs are or are not connected with reproduction. From longitudinal and transverse sections of the whole structure there appears to be no definite duct. The most striking features about the organ is the very abundant blood supply, the presence of definitely radiating groups of elements, and the occurrence of numerous spaces in the interior.

Beyond these points, there seems to be little else to notice, and it is difficult to suggest what is the function of these organs.

In conclusion, I wish to thank both Professor Sir Baldwin Spencer and Doctor Georgina Sweet for their valuable assistance and many helpful suggestions during the progress of my work.

EXPLANATION OF REFERENCE LETTERS.

Acc. Glds. - - - -	Accessory glands.
Acc. Op. - - - -	Opening of accessory glands.
Bld. - - - - -	Blood.
B.V. - - - - -	Blood vessel.
B.W. - - - - -	Body wall.

C. - - - - -	Cuticle.
C. & C_2 - - - -	Cell and $Cell_2$.
Clit. - - - - -	Clitellum.
C.M. - - - - -	Circular muscle.
C. Op. O.D. - - -	Common opening of oviduct..
C. Ovd. - - - -	Common oviduct.
Cr. - - - - -	Crop.
D. - - - - -	Duct.
D.B.V. - - - -	Dorsal blood vessel.
Div. - - - - -	Diverticulum.
D. of Sp. - - -	Duct of spermiducal gland..
D.P. - - - - -	Dorsal pore.
E. - - - - -	Epidermis.
F.G. - - - - -	Opening to oviduct.
G. - - - - -	Giant fibre.
G.C. - - - - -	Granular cell.
Gb. - - - - -	Goblet, or slime cell.
Gld. - - - - -	Gland.
Gz. - - - - -	Gizzard.
H. - - - - -	Heart.
I. - - - - -	Intestine.
Inv. - - - - -	Invaginated gizzard.
K. - - - - -	Nucleus.
L.M. - - - -	Longitudinal muscle.
M. - - - - -	Tissue supporting V.B. vessel.
N. - - - - -	Nerve cord.
N.C. - - - - -	Nerve collar.
Op. - - - - -	Opening.
Op. Gld. - - - -	Opening of gland.
Op. Ovd. - - - -	Opening of oviduct.
Op. P. - - - -	Opening of spermiducal gland'
Op. S. - - - -	Opening of spermatheca.
Ov. - - - - -	Ovary.
Ovd. - - - - -	Oviduct.
P. - - - - -	Peritoneal cells.
Peri - - - - -	Peristomium.
P. Gld. - - - -	Problematic gland.
Pr. - - - - -	Spermiducal gland.
Pro. - - - - -	Prostomium.
Ps. - - - - -	Tissue supporting nerve cord..
Px. - - - - -	Smaller less granular cells.

R. - - - - - Rosettes of vasa deferentia.
Rng. - - - - - Median furrow in segment.
Rs. - - - - - Large nucleated cells on surface of possible nephridial organs.
S. - - - - - Setae.
Sac. - - - - - Sac of spermatheca.
S.C. - - - - - Spinal cord.
Sept. - - - - - Septum.
Sg. - - - - - Large granular cell.
Sk. - - - - - Sickle-shaped cells.
Spth. - - - - - Spermatheca.
Spth. Op. - - - - Opening of spermatheca.
St. - - - - - Stalk part of gland.
T. - - - - - Testes.
Vas. D. - - - - Vasa deferentia.
V.B.V. - - - - Ventral blood vessel.
V.D. op. P.D. - - - Vas deferens opening into duct from spermiducal gland.
V.D. - - - - - Vas deferens.
V. Sem. - - - - Vesicula seminalis.
X.H.P. - - - - Position of region shown in Fig 4, under the high powered objective.
X.S. - - - - - Radiating cells.
X.T. - - - - - Glandular structure on segment nine (as found in one specimen examined).
Y. - - - - - Apparent duct.
Y.C. - - - - - Space between cells.
Y.N. - - - - - Possible opening of supposed nephridal structure into adjacent segment.
Y.Z. - - - - - Interior of stalk from accessory gland in segment six, splitting to form apparent duct.

EXPLANATION OF PLATES.

Plate XXVII.

Fig. 1.—Anterior end of earthworm, to show external features (diagramatic).

Fig. 2.—Diagram of anterior end of worm, to show alimentary canal and dorsal blood vessels.

Fig. 3.—Diagram of anterior end of worm, to show reproductive organs, nervous system, and accessory glands.

Plate XXVIII.

Fig. 1.—Anterior end of worm, ventral view, to show main external features.

Fig. 2.—Diagram of longitudinal section through region of spermathecae.

Fig. 3.—Types of spermathecae.

Fig. 4.—Diagram of segment thirteen, to show relative position of associated parts.

Fig. 5.—Sketch of spermiducal gland of right side, to show general features.

Fig. 6.—Drawing of longitudinal horizontal section of problematic gland, in thirteenth segment under the low-powered objective.

Fig. 7.—Part of problematic gland from thirteenth segment, under the high-powered objective.

Fig. 8.—Tranverse section of the spermiducal gland, to show main duct.

Fig. 9.—Diagram of longitudinal vertical section of spermiducal gland, to show mode of entrance of the vasa deferentia.

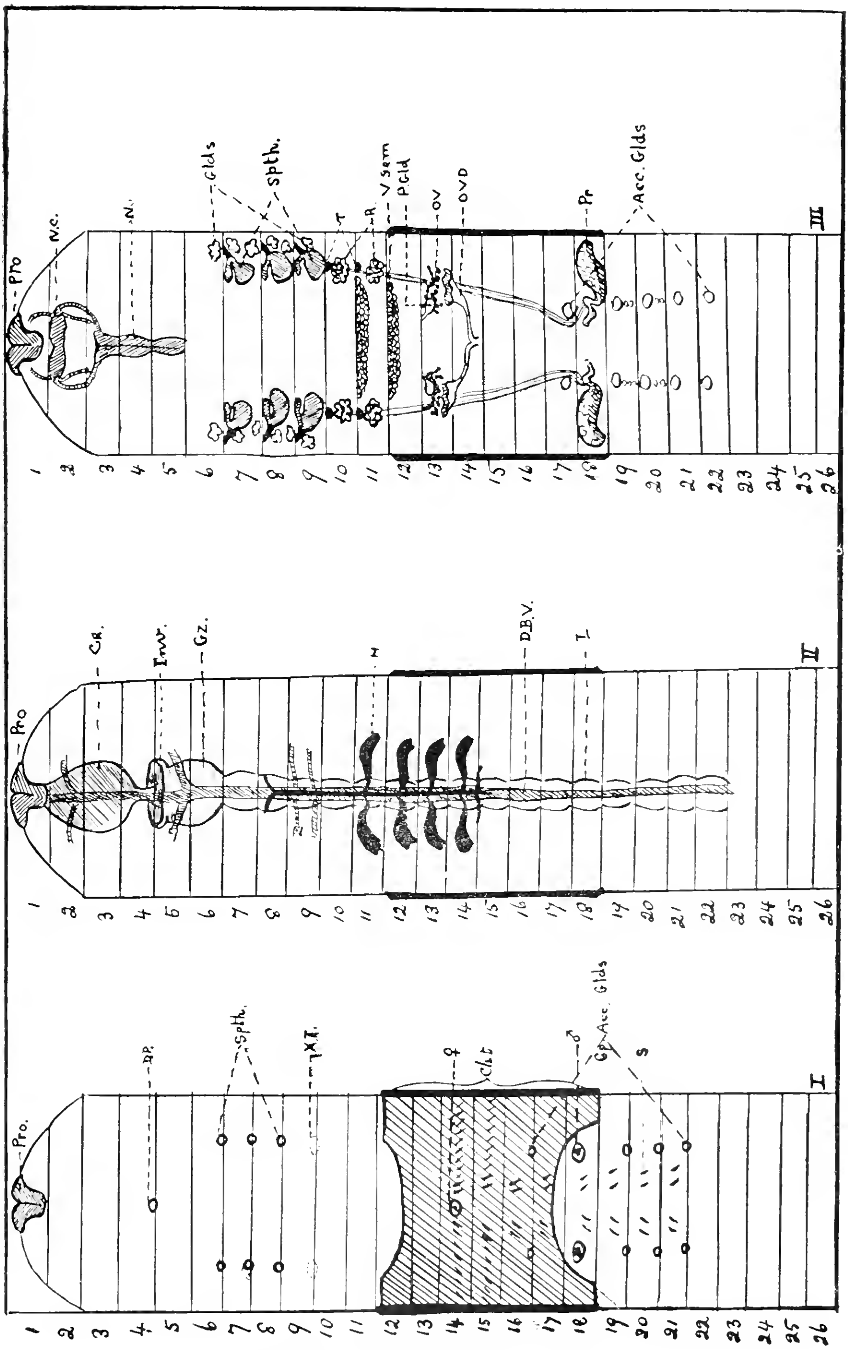
Plate XXIX.

Fig. 1.—Longitudinal section of spermathecal region.

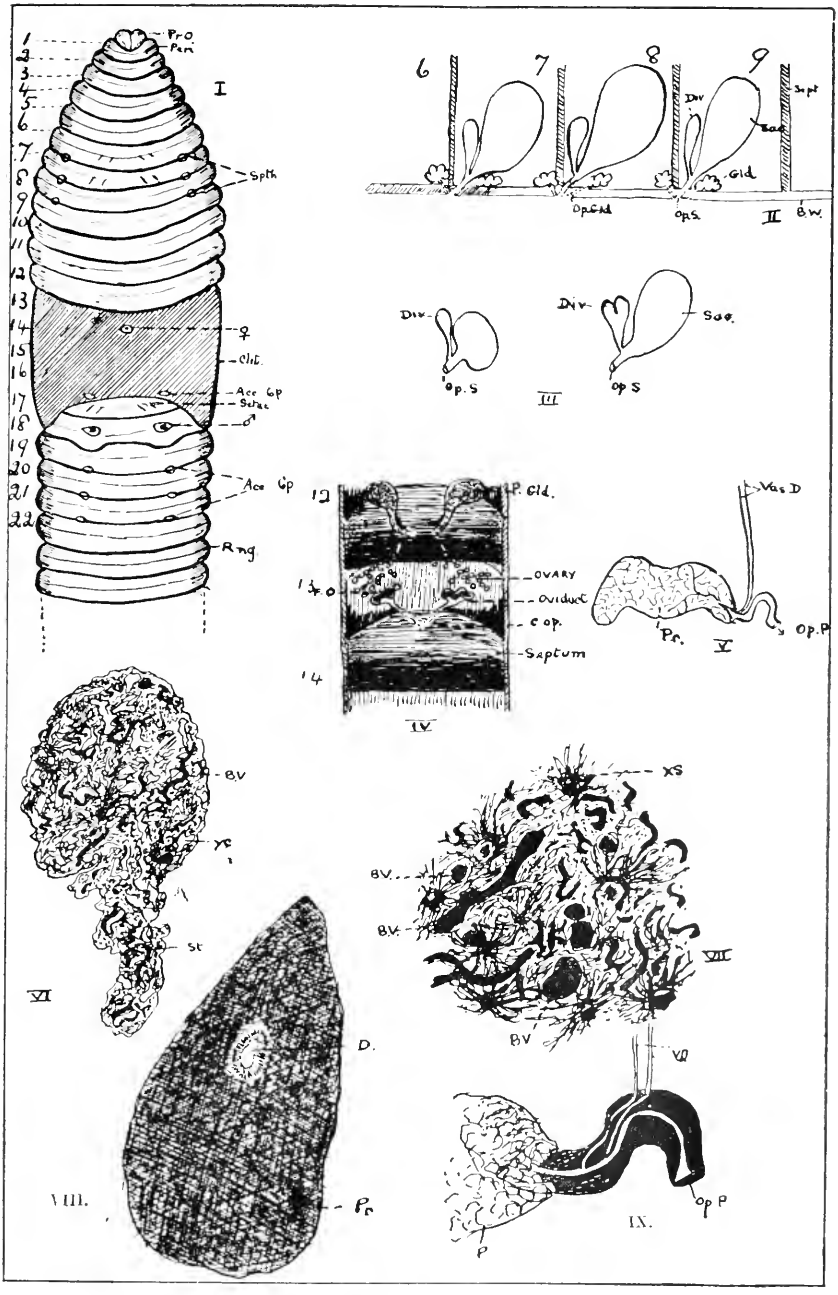
Fig. 2.—Drawing under the high-powered objective of the last part of the duct from a glandular structure associated with the spermathecae.

Fig. 3.—Drawing under the high-powered objective of a section through one of the glandular structures associated with the spermathecae.

Fig. 4.—Longitudinal section in the region of the possible nephridial organs.



Megascolex Fletcheri, n. sp.



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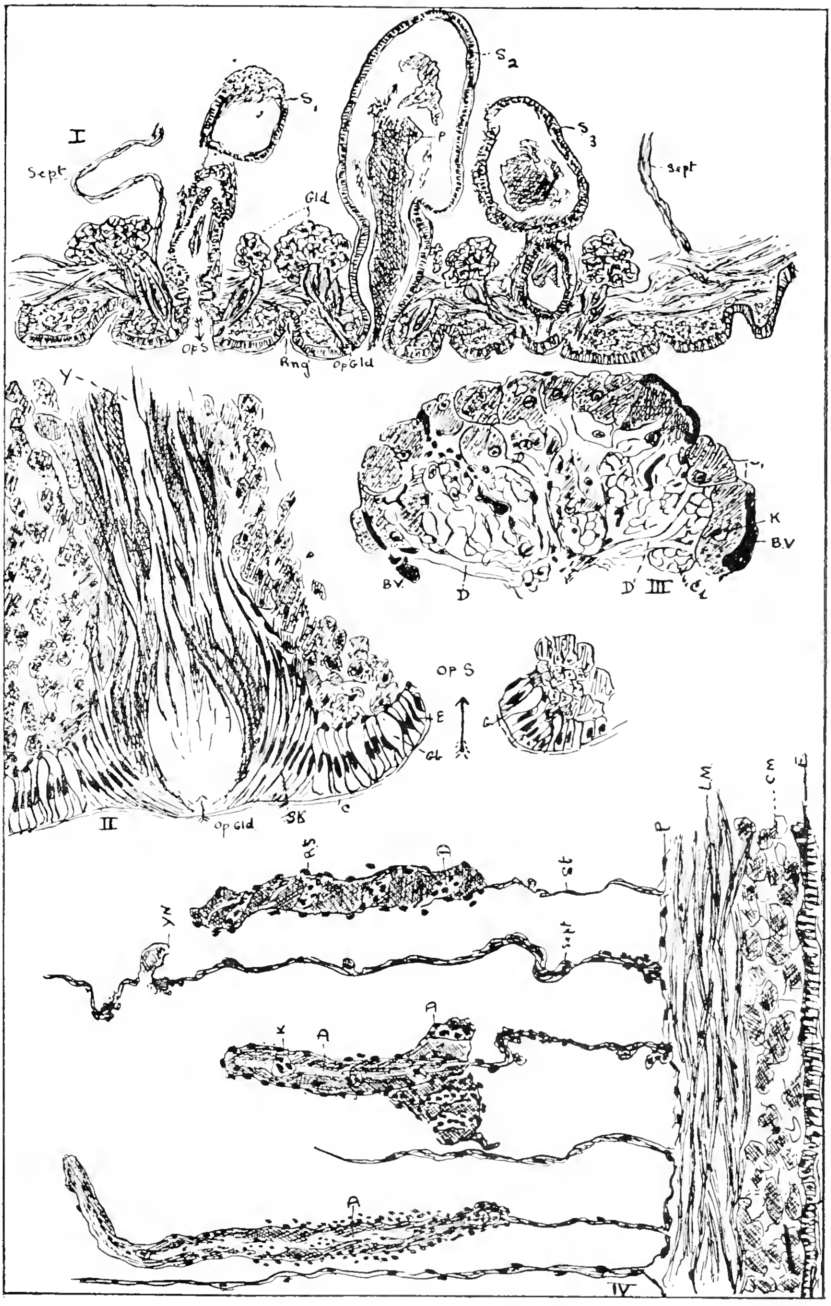

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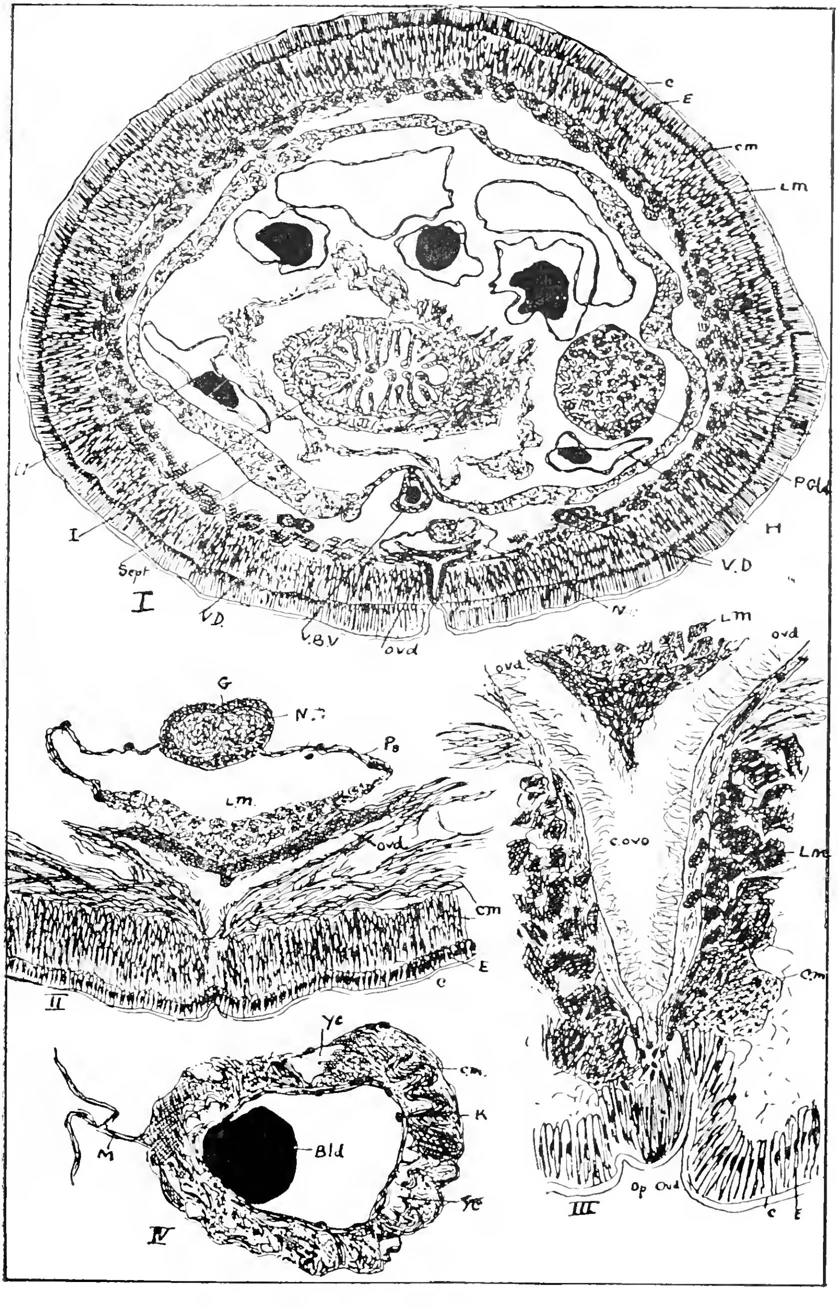

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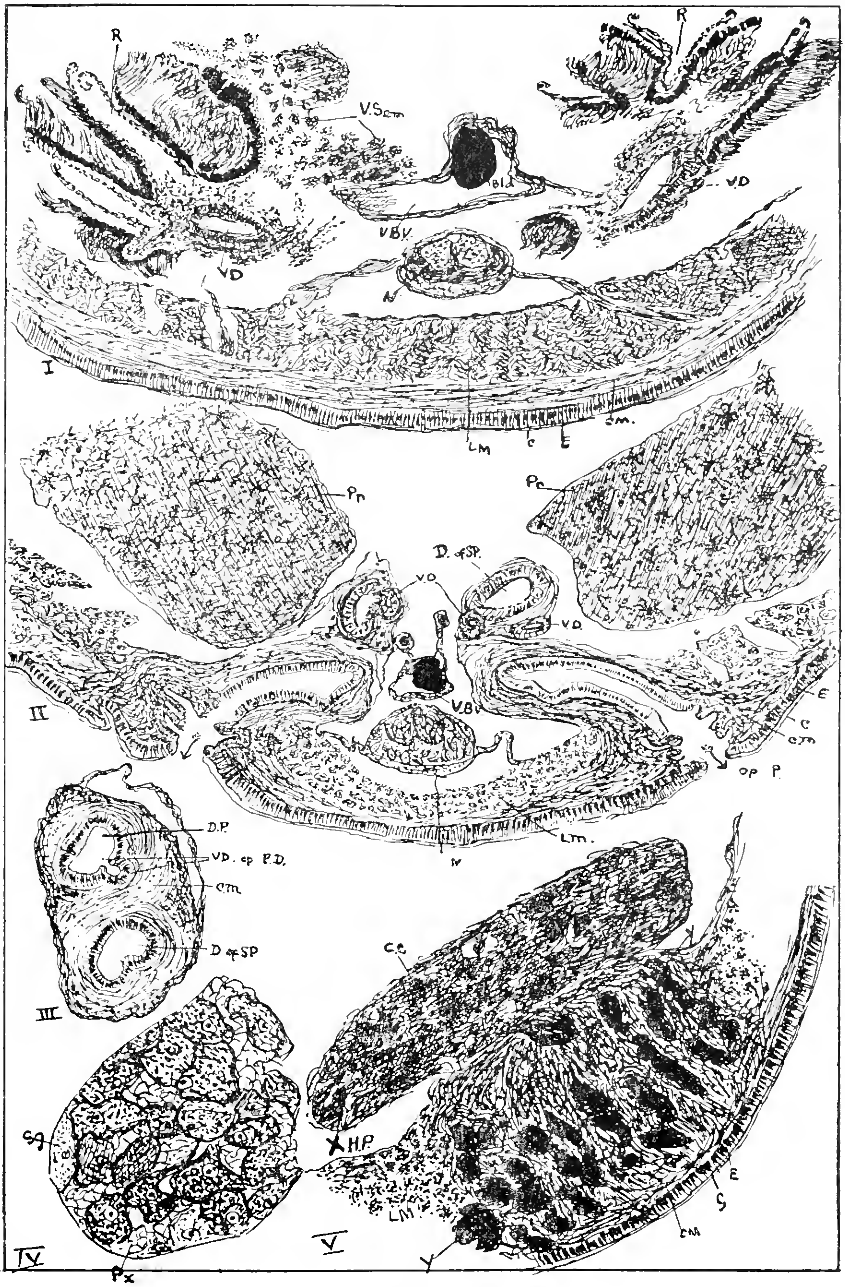

Megascolex Fletcheri

Plate XXX.

Fig. 1.—Transverse section of earthworm in region of common opening of oviducts.

Fig. 2.—Portion of body wall, with common oviduct passing through it.

Fig. 3.—Drawing under high-powered objective of common oviduct.

Fig. 4.—Transverse section of ventral blood vessel.

Plate XXXI.

Fig. 1.—Transverse section in region of opening to vasa deferentia.

Fig. 2.—Transverse section in segment eighteen, to show opening of ducts from spermiducal glands to exterior.

Fig. 3.—Transverse section of duct from spermiducal gland, showing opening of vas deferens into it.

Fig. 4.—Part of gland associated with spermiducal gland, under high-powered objective.

Fig. 5.—Transverse section of body wall to show gland associated with spermiducal gland in section.

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ART. XX.—*Notes on Dust Whirls in Sub-Arid Western Australia.*

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[Read December 11th, 1919.]

Introduction.

Dust whirls are well known phenomena in arid and sub-arid countries. They are ascending spiral air currents, which also move in a linear direction, and which carry varying amounts of dust and fine sand with them.

Dust whirls have been well described by W. M. Davis[1] and by E. E. Free.[2] Davis points out[3] that an inflow of air is begun towards the place of ascent, but as the various inflowing currents move for too short a distance to be systematically influenced by the earth's rotation, and as their irregular flow does not allow them to meet precisely at a centre, they turn a little to one side or the other, according as the stronger inflow decides, and a little whirl is then developed rotating indifferently one way or the other. Free also states[4] that the rotation seems to be indiscriminately clockwise, or contra-clockwise, as frequently one as the other.

Dust whirls are recognised to be due to overheating of particular portions of the land surface, with the result that equilibrium is disturbed, and the air rushes upwards. The surrounding air then flows inwards, and a whirl is caused.[5]

Dust whirls have been recorded from various countries, and a valuable list of the literature has been given by Free in the work already cited.

Dust whirls may reach a considerable height. Thus Davis[6] states they may reach a height of several hundred, or even a thou-

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1. "Elementary Meteorology," 1894 p. 201.
2. U.S. Department of Agriculture, Bureau of Soils, Bulletin No. 68, 1911, p. 38, *et. seq.*
3. Loc. cit.
4. Loc. cit.
5. See Free, loc. cit.
6. Loc. cit.

sand, feet; and Free[7] mentions that they are from a few feet to hundreds of feet in height. I. C. Russell remarks[8] that these columns of dust are often 2000 or 3000 feet, or even more, high. At various heights, according to atmospheric conditions, the dust tends to spread out horizontally, and so becomes invisible.

Dust columns are slender. Free remarks that they are a few inches to several feet in diameter.[9] Various observers have pointed out that when seen at a distance, they resemble water-spouts, and that they mostly occur in calm summer weather.

Previous Australian Literature.

Of Australian occurrences, the writer has found few records.

D. W. Carnegie[10] briefly refers to the occurrence of "willy-willies" in arid Western Australia, and states they are sometimes of great violence. J. W. Gregory, with regard to Central Australia, refers to the "dark whirling pillars of sand which slowly travelled up the valley"; also to "three tall columns of dust which were travelling straight towards us"; and again, to "the dust travelling chiefly in two whirlwinds."[11] D. Mawson has described[12] the "willy-willy" of the Broken Hill district, pointing out that they are of the nature of small cyclones, like water-spouts in outline, and that they are columns usually about 20 feet in diameter, rising to a height of several thousand feet. A. Montgomery has remarked[13] in connection with the Western Australian goldfields country, that "on any fine day in summer it is quite usual to be able to see several whirlwind clouds of dust dancing over the landscape at one time."

These are the only Australian records that the writer is aware of.

In sub-arid Western Australia dust whirls are locally known as "willy-willies." They are a matter of common knowledge, but no precise description has, so far as the writer is aware, ever been given of them, and still less is there any record of their mode of rotation, their height and other characters. Even in Australia

7. Loc. cit.
8. Monograph XI., U.S. Geol. Surv., Washington, 1885, pp. 9 and 154.
9. See also Mawson's estimate mentioned below.

10. "Spinifex and Sand," London, 1898, pp. 254 and 274.
11. "The Dead Heart of Australia," London, 1906, pp. 26, 120, 121.
12. "Geological Investigations in the Broken Hill Area," Mem. Roy. Soc. South Aust., Vol. II., Part 4, 1912, p. 227.
13. "The Significance of Some Physiographical Characteristics of Western Australia." Journ. Roy Soc. W. Aust., Vol. II., 1915-16, p. 83.

as a whole, the records, as noticed above, are scanty. Under these circumstances, some details, which were noted by the writer whilst engaged in geological work in the Niagara-Kookynie district, and, later, in the Comet Vale-Goongarrie districts[14] may be worthy of record. The following notes are, therefore, based on such observations, and relate only to the districts mentioned:—

General Description.

In the districts just mentioned, the climate is sub-arid, and the average rainfall is abouth 10 inches, or slightly less, per annum. Except on the surfaces of the "dry" lakes, there is generally some vegetation, but there is much bare ground between the individual plants.

The dust whirls vary much in height, and perhaps in diameter. Many are but a few feet in height and in diameter, whilst others are hundreds, and probably thousands, of feet high, and perhaps of considerable diameter. The writer, however, has no criteria as to the diameter of the high whirls, but in all instances, the diameter is small compared with the height. The dust whirls are essentially moving columns or pillars. The whirls (as the table below shows) rotate clockwise (that is, in the direction north, thence east, thence south, and thence west), and anti- or counter-clockwise. The anti-clockwise direction predominates on the records obtained. A change from one mode of rotation to the other in the same dust whirl has been noticed, and such change has taken place more than once in the same whirl.

High dust whirls may be practically vertical, or curved, or bent at a high angle to the ground. The curving, or bending, doubtless indicates varying wind velocity at different altitudes.

The dust whirls travel in different linear directions across the country. This linear movement is usually rapid in whirls that are close to the observer. It is difficult to form an opinion about the velocity of distant whirls, and no estimate has been made by the writer as to the actual velocity of near-by whirls. A low whirl, as a rule, dies out within a minute or two, but a high whirl may be visible many minutes, or possibly some hours.

A dust whirl, even a very small one, is quite violent in its action. Dust, sand, grit, and old tins and other rubbish are lifted from, or driven along the ground with great force. When taken

14. The Niagara-Kookynie area is about 115 miles, and the Comet Vale-Goongarrie area about 60 miles north of Kalgoorlie.

unawares by a small dust whirl, one at first receives the impression of the sudden and violent rising of a great wind.

Red is the predominating colour of dust whirls, owing to red being the predominating colour of the soils.

The whirls are commonest in summer, on calm days, or on days with only a gentle breeze. These facts agree with the observations of investigators in other countries. After midday is the most favourable period for the occurrence of dust whirls.

Table of Observed Dust Whirls.

The following list comprises the dust whirls recorded by the writer in the Niagara-Kookynie and Comet Vale-Goongarrie districts, with the dates of occurrence, the direction of rotation, and general remarks. Where it was impossible—mainly on account of distance—to determine the direction of rotation, a blank has been left. In some cases, the direction given is not quite certain, hence a query has been added so as to express this doubt. One gigantic whirl has been separately described below on account of its special interest. The writer is well aware that the remarks as to height and other characters of individual whirls are vague, but the phenomena do not readily lend themselves to accurate measurements, and opportunity did not always permit of more definite statements :—

Date.	Direction of Rotation.	General Remarks.
1914.		
Dec. 18. - -	Anticlockwise	These occurred in the Niagara-Kookynie district.
,, 18 - -	Clockwise	
,, 21 - -	Anticlockwise	
1915.		
Jan. 8 - -	Anticlockwise	No details, except direction of rotation were noted,
Feb. 10 - -	Clockwise	
,, 13 - -	Anticlockwise	
,, 23 - -	Anticlockwise	
Mar. 29 - -	Anticlockwise	
,, 15		Distant. In front of a ridge. From probable height of latter, the dust whirl was estimated to be 1000 feet high at the least. East of Kookynie.
1916.		
Sept. 22		Distant.
,, 22		Distant.
,, 25 - -	Anticlockwise (?)	Low.[15] On ironstone country.

15. "Low" means that the dust whirl as seen by the naked eye reached to only a small height from the surface of the ground, in some instances, not more than 20 feet, and even less.

Date.		Direction of Rotation.	General Remarks.
Nov. 11	- -	Anticlockwise	Low.
Dec. 5	- -	Anticlockwise (?)	Distant. Fairly high.
,, 6	- -	Anticlockwise	Fairly high.
,, 9	- -	Anticlockwise	Low.
1917.			
Jan. 26			Distant. Hundreds of feet high. Thin, sandy-coloured column. Rapidly changed its form and density. Quickly became invisible. Noted at 3 p.m. on very calm day.
Feb. 6			Hundreds of feet high. Soon became invisible. Day calm and hot. Noted at 1 p.m.
,, 6	- -	Anticlockwise (?)	Hundreds of feet high. Bent in the centre. Visible for a few minutes. Gradually faded away. Noted at 2.30 p.m.
,, 8	- -	Anticlockwise (?)	Distant. Very high. Very distinct, so must have been carrying much dust.
,, 8			Ditto.
,, 8	- -	Anticlockwise	Low. Raised considerable quantity of dust. Soon died out.
,, 12	- -	Anticlockwise	Low. Soon died out.
,, 15	- -	Clockwise	Low. Passed through camp. Lifted fine sand very strongly. Soon died out. About six feet in diameter.
,, 16	- -	Anticlockwise }	Each raised much dust, but soon died out.
,, 16	- -	Anticlockwise }	Diameter of each probably only a few feet.
,, 17	- -	Clockwise	Low. A few feet in diameter.
,, 17	- -	Anticlockwise	Low. A few feet in diameter. Soon died out.
,, 17			Some distance away. Probably at least 100 to 200 feet high.
,, 19	- -	Clockwise	Low. Only about two feet in diameter.
,, 19	- -	Clockwise	Low. Only about four feet in diameter.
,, 19	- -	Clockwise and Anticlockwise	Somewhat higher than last two. Rotated both clockwise and anticlockwise, the change taking place more than once in a distance travelled of 50 or 60 yards. Diameter about 15 feet.

Date.	Direction of Rotation.	General Remarks.
Feb. 19		A gigantic dust whirl. Described separately below. Note.—The 19th February was a typical day for dust whirls, being hot and sultry, with a gentle N. to N.W. breeze. Those recorded were all in the afternoon.
Feb. 20		Low.
,, 26		A gigantic distant whirl. Must have been hundreds, or perhaps thousands, of feet high. Very dark-coloured and dense-looking. Visible for about five minutes, and appeared to be moving slowly southwards. The summit of the column of dust was clearly seen to be spreading out horizontally, as such columns do.
,, 27 - -	Anticlockwise	Low.
Mar. 1		Some miles distant. High, with apparently a fairly large diameter. Travelling southwards.
,, 1		A very high thin column.
,, 29 - -	Clockwise and Anticlockwise (?)	Low. On samphire flat.
,, 29		Low. On samphire flat.
,, 29		Low.
,, 29		Low.
May 8 - -	Clockwise and Anticlockwise (?)	Rather low. Raised much dust. Travelling northwards. Travelled for a ditance of about half a mile while visible. Direction of rotation almost certainly changed from clockwise to anticlockwise, and vice versa.

Note.—The dust whirls recorded from 22nd September, 1916, onwards. occurred in the Comet Vale-Coongarrie district.

Summarising the above table records a total of 43 dust whirls. Of these 15 have no record as to direction of rotation, 15 are anti-clockwise, four are anti-clockwise with a query, six are clockwise, one is and two probably are both clockwise and anti-clockwise. The anti-clockwise rotation, therefore, predominates. This result could hardly be expected, for if, as appears to be the case, the whirls are of the nature of small cyclones, then in the southern hemispheres, the predominant rotation would be expected to follow that of the normal cyclones, that is, clockwise. Further observations, however, are required, as the records in this paper are too few to come to a definite conclusion on the point raised.

A Gigantic Dust Whirl.

The whirl now to be described has been noted in the above list, but its occurrence was so striking that a separate description is warranted.

This dust whirl was observed on 19th February, 1917, at about 1.30 p.m., in the Comet Vale-Goongarrie district, when the sun had not passed a great distance beyond the zenith. The day was hot and sultry, with a gentle north to north-west wind. The conditions were, therefore, favourable for dust whirls. This particular whirl formed a great column of dust, the top of which was above two clouds, which were at different levels in the atmosphere, the difference of level apparently being considerable. These clouds were of the cumulus type, and were such as may be commonly observed in the area after midday under the conditions mentioned. The dust column was broken by these two clouds. The column was travelling southward, or south-westwards, at a fairly rapid rate, but the rate of motion could not be determined, and in doing so, passed beyond the clouds, and showed itself as one unbroken, gigantic column, with a pronounced bend forward (i.e., in the direction of its linear movement) at the top. Otherwise it appeared to be approximately vertical. The dust whirl was close to the path of the sun's rays, and as the sun was obscured by the upper cloud, the phenomenia could be closely watched. The dust was dull, red in colour, and between the two clouds dense masses of dust could be seen by the naked eye whirling about and springing upwards. As it moved in the direction mentioned, the column became invisible within a few minutes. The direction of rotation could not be ascertained, nor could any idea be formed of its diameter, although the diameter appeared to be about the same through the whole length of the column.

The angle of elevation of the top of the column was guessed to be about 80°, but the horizontal distance of the column from the point of observation could not be ascertained, so that it is impossible to state its height, even very approximately. Judging by observation, it would certainly not be less than one mile distant, and probably much more; but if it be assumed that the distance was one mile, that the column was approximately vertical, and that the angle of elevation was 80°, the dust whirl would be not far short of six miles in height; and if it were only half a mile away (which, however, seemed altogether too short a distance), the height would approximate towards three miles.

These figures are probably far too high, due, perhaps, to the assumption that the dust column was approximately vertical. The column might appear to be vertical, and yet could perhaps be much bent towards the observer. This would materially reduce the figures.

Another means of checking the height is to ascertain the height of either of the two clouds associated with the dust columns, but no data have been obtained for this. These clouds were two of many similar scattered over, all apparently of moderate height. Again, if the general average height that these clouds form at were known, an idea of the height of the dust whirl would be obtained, but there appears to be hardly any information available as to such clouds in Australia in this connection. Records of other countries show that the upper surfaces of cumulus clouds may be over 3000 feet high.[16] There can be no doubt, however, that this particular dust whirl was of great height, reaching probably to several thousands of feet above the earth's surface, and the quantity of dust raised must have been enormous. When first viewed close to the sun's rays, the dust whirls presented a majestic spectacle.

The writer is indebted to Dr. Griffith Taylor for a reference to Mr. Quayle's Memoir on Clouds, and for some information concerning clouds, which he kindly obtained from Mr. Quayle.

Dust Whirls in Relation to Erosion.

Dust whirls must play an important part in the erosion of sub-arid Western Australia. From the preceding table it will be recognised that they are fairly numerous, even in a small area, and that they include columns of dust of great height. It must also be remembered that, unless high, numerous whirls, even comparatively close to an observer, are not seen by him. If the whole of the sub-arid portions of the State be considered, a vast amount of fine sand and dust must be displaced even in the course of one favourable day. The material is either lifted well into the air, or is dragged along or kept close to the surface of the ground. In the former case the material is chiefly fine dust, and in the latter

16. Davis. Op. cit., pp. 179 and 180.

case, which has been described as a saltatory action, fine sand. The fine dust tends to rise high into the air, and it may be some time before it settles down to the ground again. During this period it may travel far, and there can be no doubt that a considerable portion of it is carried beyond, or "exported" from the sub-arid areas.

In this way the general surface of these areas as a whole tends to be lowered.[17] The dust which falls in other portions of these sub-arid areas, tends to increase the thickness of soils locally, and also to make these soils of a more heterogeneous character.[18] Such soils are of course subject to removal by dust whirl and other aeolian action, as well as by rain action, but certain areas may receive more wind-blown material than they lose by the same agency.

The fine sand removed by saltatory action immediately settles again when the dust whirl dies out, but during its journey it would tend to collect and to remain in hollows. There is thus probably a general drift from the higher to the lower country (with some exceptions), which aids in keeping the general surface level, and thus in the formation of a vast high level plain—the "new plateau" of the writer.[19]

An interesting account of a dust-storm in south-western North America, and an estimate of the amount of dust precipitated have been recently given.[20] It has been concluded that owing to strong convectional air currents, "an enormous quantity of dust must have been eroded from these arid regions—(New Mexico and Arizona)—lifted into the upper atmosphere, and carried with the storm a thousand miles or more to the north-east, where it was brought down by the snow and sleet, which had formed at a great altitude in the air." It was calculated that not less than a million tons of organic and inorganic material fell, and probably many times that amount. The dust whirls discussed in this paper cannot of course be compared, from an erosional point of view, with such a storm, but nevertheless, the difference is but one of degree.

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17. This idea of "exportation" has of course been brought forward by earlier writers, such as von Richthofen and Davis.

18. The mixed character of soils owing to the action of the wind generally has been fully described by Free. Op. cit., p. 109.

19. Bull. 61, Geol. Surv. W. Austral., Perth, 1914, p. 525.

20. See "Geographical Review," December, 1918, pp. 514 and 515.

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Art. XXI.—*The Physiography and Geology of the Bulla-Sydenham Area.*

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[Read 11th December, 1920].

(With Plates XXXII.-XXXIV.)

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Cartography.

The area examined covers 20 square miles, and takes in the eastern half of quarter-sheet 7 S.E., and the western portion of quarter-sheet 2 S.W. There are neither dates nor compass points on these sheets.

The date of one edition of the quarter-sheet was probably 1863, but the dates of the other two editions could not be obtained. Two different copies can be seen at the Melbourne Public Library, and a third at the Geological Survey Department. One of the three editions has the Silurian conglomerate south-west of Hanging Valley (Plate XXXII.) wrongly coloured as Kainozoic.

The dips and strikes of the palaeozoic rocks on the quarter-sheet are inaccurate.

In the three editions of quarter-sheet 7 S.E., a large heart-shaped area of tree covered granite, south of Bulla, is wrongly coloured as basaltic.

In the military contour map of Sunbury two errors in road marking occur. In the extreme N.E. of the area the formed road L M (Plate XXXII.) is omitted, while the road N O in the centre west is shown as continuous across the gorge, which is called in this paper, "Column Gully."

The granodiorite boundaries in the N.E. cannot be accurately placed, owing to the gravitation of granitic detritus from the hills. It covers the lower lying basalt, and hides the junction.

Owing to the great accumulation of hill wash along the streams many outcrops are completely covered. This is probably the reason why two conglomerates marked on quarter sheet 7 S.E. are not now visible.

Attention is drawn to the names of the streams in this area, and a study of the geological quarter-sheets, the military contour maps, and the parish plans shows how loose the nomenclature has been. The names of the streams in the parish plans of 1901 differ from those of 1916, and as the names of the latter agree with those given by the local residents, the writer has accepted them for this paper. The eastern branch is Deep Creek, the western branch Jackson's Creek, and the Maribyrnong River (formerly Salt-water River); the stream from the junction of the creeks to the Yarra. The following is a table of the names given to the streams in this area in old and recent publications:—

Publication.	Western Branch.	Eastern Branch.	Combined Creeks.
Geological quarter sheet, 1863	Macedon or Saltwater River	Deep Creek	Saltwater River
Parish Plans, 1901	Saltwater River	Deep Creek	Saltwater River
„ „ 1616	Jackson's Creek	Deep Creek	Maribyrnong River
Military Contour map, 1917	Jackson's Creek	Maribyrnong River	Maribyrnong River
Donald Macdonald in *Argus*, 22/4/19	Jackson's Creek	Deep Creek	Deep Creek above tidal water. Maribyrnong River below tidal water.
Residents and nomenclature followed by writer 1919	Jackson's Creek	Deep Creek	Maribyrnong River.

Physiography.

General Survey.—The dominating feature of the area is the great basalt sheet which slopes gently from the north-west to the south-east, with a slope of 60 ft. per mile, descending from 600 ft. to 300 ft. in five miles. The Deep Creek, Jackson's Creek, and the Maribyrnong River have entrenched themselves in this low plateau to a depth of 300 ft., and they are vigorous young streams, cutting deeper and deeper into a plain that is also very youthful in character. Two granodiorite masses rise 100 feet above the lava surface.

Meanders.—Deep Creek, Jackson's Creek, and the Maribyrnong River meander in a trench about 300 ft. in depth. These streams originally flowed on the surface of the basalt plain, and the slight curves in their old courses became more and more pronounced as the streams deepened their beds. While lateral erosion was at work deepening the curves, vertical corrosion was deepening the valley, and this combined action has resulted in an alternating series of spurs and river cliffs along each stream. Waterworn pebbles of basalt, quartz, quartzite, etc., along each spur, afford evidence of the former position of the stream. This type of meander is in sharp contrast to the flood-plain meander, where only lateral erosion is active.

Several writers (1) describe an entrenched meander as one where the original meander has been preserved, and where the opposite banks of the stream make approximately equal angles with the surface of the ground. According to these geographers, the spurred meanders of Bulla and Sydenham would not be entrenched meanders. W. M. Davis, however, refers to the spurred character of the entrenched meanders of the Meuse and Seine. (2b) It is important to note that the present meanders of Deep Creek are not simply the preserved meanders of the old stream, as indicated by J. W. Gregory (3). The length of the present curves is very much greater than that of the old curves, owing to the lateral swinging of the streams, but the radii of the curves have remained approximately the same, (2a).

Down-valley Sweep of Meanders.—This sweeping movement is not so pronounced as in streams flowing through soft rock, but the effect can be definitely seen in most of the spurs along either creek and in the position of the small flood plains. The spurs are not symmetrical in section, the steeper side always pointing up-valley. This also has the effect of sharpening the spur, and the placing of the flood plain, not at the end of the spur, but on the down-valley side of it. (2a.)

Meander Belt.—In youthful streams, such as Deep Creek, the belt of wandering and the meander belt coincide with one another. The stream by lateral swinging widens its meander belt, but this tendency is checked by (a) the down-valley sweep of the meanders (which would eventually cut through the spurs), and by (b) the formation of new channels at flood time across low spurs.

Relation between Radius of Meander and Volume of Water.—W. M. Davis has shown (2a and 9), that the radius of a meander, where slope and load are equal, is proportional to the volume of water. This is exemplified in Jackson's Creek, Deep Creek and the Maribyrnong River. Jackson's Creek has a slightly smaller volume than Deep Creek, and the radii of its meanders are slightly smaller than those of Deep Creek. Similarly the radii of the Maribyrnong meanders are considerably larger than those of the creeks.

Hanging Valleys.—Excellent examples of hanging valleys are found along both Jackson's Creek and Deep Creek. In every case these tributary streams flow only after heavy rain. The best example is that to the south-west of the main granodiorite outcrop. This small stream has been formed along the junction of the basalt, and the granodiorite. At its junction with Deep Creek there is a fall 80 ft. in height. Owing to their poor supply of water the tributary streams are unable to corrode their beds as rapidly as the main streams. This is the chief cause of the lack of adjustment between the tributaries and the main streams in this area. At Hanging Valley (see Z, Plate XXXII.), this lack of adjustment is increased by the hard compact hornfels in its lower course.

Deserted Bed of Jackson's Creek.—An old accumulation of boulders can be seen in the right bank of the Maribyrnong River, a quarter of a mile south of the junction of the creeks. Some of the boulders are huge, some small, some of basalt, some of conglomerate, and others of sandstone, but none of granodiorite. It was the old bed of Jackson's Creek which deserted it when it flowed 6 ft. above its present level. If Deep Creek had contributed boulders to the conglomerate, granodiorite also would have been represented.

Corrosion.—A study of the effect of the volcanoes on that section of Jackson's Creek north of Sunbury would provide interesting matter, for it is evident that the Sunbury volcanoes in late Kainozoic times, formed an immense bar across the old Jackson's Creek, and overwhelmed the valleys to the south beneath a flood of lava.

It will be noticed that Deep Creek flows close to the boundary of the granodiorite, and the basalt. Originally it flowed along the junction. As Deep Creek deepened its bed, the granodiorite became exposed on both banks. It is probable that streams such as the Yarra and Deep Creek tend to flow at the junction of basalt and older rock because hill drainage helps to form a valley at the junction of the bedrock, and the lava sheet, and because the lava flow is probably depressed at the edges, and thus directs the drainage of the area to the line of junction.

By meandering and deepening the streams have reduced the slope from 60 ft. per mile to 18 ft. per mile. From the creek junction to the most northerly point of Deep Creek, marked on the map, is 7 miles. In this distance it falls from 280 ft. to 150 ft., giving a slope of 18 ft. per mile. It is remarkable that Jackson's Creek from the north-west boundary on the map to the creek junction flows 11 miles, and falls from 350 ft. to 150 ft., giving again a slope of 18 ft. per mile. The slopes are interesting when compared with that of the sluggish Mississippi, which has a fall of less than 1 ft. per mile. At the Bulla School the creeks are only half a mile apart, but, owing to the short distance along Deep Creek to the junction as compared with that along Jackson's Creek, the bed of Deep Creek is 60 ft. lower than that of Jackson's Creek. This illustrates the fact that in river capture the more vigorous stream may be captured by the less vigorous. Jackson's Creek and Deep Creek having the same slope, are of equal vigour, but if their valleys met Deep Creek would capture the head waters of Jackson's Creek.

Deep Creek has been superimposed along the whole of its course on the older rocks beneath. Jackson's Creek is still cutting into basalt, though it frequently carves its way across the tops of the old Ordovician and Silurian hills.

Basalt bars of greater density retard its rate of deepening by checking its velocity. In several parts Jackson's Creek resembles a series of small lakes separated from one another by basalt bars over which the water tumbles in miniature rapids.

Headward Erosion.—The extremely youthful tributary streams frequently become gorge-like, and tend to cut back across the fields. Farmers in this locality meet the problem by piling boulders at the head of the tributary and planting hardy shrubs around them in order to check the velocity of the water, and thus retard the transport of material. The early neglect to check the headward erosion of youthful streams has led elsewhere to great loss of land. A large area at Coburg has been rendered unfit for habitation within the last thirty years, and the same will occur at Aberfeldie, near the Essendon sand pits, if preventive measures are not taken soon.

Near the school at Bulla an extremely young active tributary has cut back from Deep Creek and formed a canyon in decomposed granodiorite and basalt. Apparently no effort has been made to check the headward erosion, and now it is completely out of hand, and threatens the roads north of Bulla. The canyon is about 60 ft. in depth. It is not likely to deepen further for many years, as its floor is nearly adjusted to the present level of Deep Creek. Lateral erosion is now rapidly increasing the area of destruction.

Basalt Outliers.—A small outlier is seen in the south of the large granodiorite outcrop, and another in the extreme centre-north in Ordovician sediments. They represent small basalt tongues that have been cut off from the main lava sheet by river action.

Palaeozoic Rocks.

General Description.—The bedrock of the area so far as is known consists of Upper Ordovician and Lower Silurian sediments in the form of shales, sandstones, conglomerates, quartzites, slates and hornfels. These have been strongly folded by approximately east and west pressure, and the prevalence of easterly dips suggests overfolding to the west. The folds pitch to the north, and this pitch makes the strike of the strata somewhat irregular.

Throughout the district these palaeozoic rocks have been highly fractured and faulted, most of the faults being reverse strike faults. On the left bank of Deep Creek, at the mouth of Hanging Valley, is a fault breccia altered to hornfels by the granodiorite intrusion.

If the conglomerate (C_3), near Hanging Valley, and conglomerate C_1 or C_2 on Jackson's Creek, be parts of the same stratum, lateral displacement must have taken place, and, though this is the probable explanation, yet local lenticular accumulations of conglomerate may be the reason why these bands do not appear on the same line of strike. Owing to intense pressure, well defined joint planes have been set up which tend to break the strata into small rhombohedra. These joint planes give difficulty in the taking of dips and strikes, as they closely simulate the bedding planes.

Palaeozoic Fossils.—Previous to 1918, Upper Ordovician graptolites had been found in the extreme north-west of this area (4), while Lower Silurian graptolites had been found in the extreme south-east (5), but none had been found between these localities.

In 1917 and 1918 the writer came across several fossil beds whose position is indicated on Plate XXXII. The paucity of fossils in this locality is probably due partly to dynamic and thermal metamorphism, which prevent the rock splitting along the bedding plane, and partly to the sandy nature of the sediments.

It has been suggested that the conglomerate C_1 is of glacial origin, and the absence of fossils in this neighbourhood is due to the severe climatic conditions that prevailed during their deposition. (6.) Fossils have, however, now been found in the following localities:—

(a) On the left bank of Jackson's Creek, 50 yards north of the mouth of Column Gully. (See Plate XXXII.) In a very narrow band Upper Ordovician graptolites can be obtained in abundance, Coenograptus and Diplograptus being the commonest genera. The fossils are well preserved, but are rapidly obliterated on exposure to the air.

(b) On the left bank of Jackson's Creek, half a mile south-east of the Organ Pipes. For nearly a mile along both banks of the creek, the rocks contain enormous numbers of worm impressions. On the rock face a few yards south-east of dyke D_6, the markings strongly suggest worm burrows, but Mr. F. Chapman says that they are probably the remains of the soft part of the worms. The impressions are quite different from those of Trachyderma (7). From the graptolite bed referred to in (a) to the conglomerate C_1, these impressions occur in varying numbers. The upper part of each stratum has more impressions than the lower part, and many of the most prominent markings are perpendicular to the bedding plane, and increase in diameter from below upwards.

Mr. F. Chapman has not been able to determine the age of these worms, but as there is field evidence that they are of Ordovician age, they will be called tentatively in this paper the "Ordovician worm beds."

(c) On the right bank of Jackson's Creek, at the mouth of a small gully, 30 yards east of conglomerate C_1. Here impressions of the gill plumes of the worm Trachyderma sp. occur in two very narrow bands.

(d) The best impressions of Trachyderma were found on the right bank, about 300 yards down stream from the conglomerate C_1. At this spot Trachyderma and Monograptus were obtained on the same slab. Many of the strata here yield the tubes and gill plumes of this worm, which Mr. F. Chapman has connected with the gill plumes found at South Yarra in Lower Silurian rocks. (7).

(e) On the right bank of Jackson's Creek, 30 yards north-east of the dyke D_3 (Plate XXXII). The writer found three or four species of Silurian graptolites. Graptolites from localities (d) and (e) were sent to Mr. F. Chapman. They have not been named yet, but were pronounced to be definitely Silurian.

(f) At the point x (Plate XXXII.), fossils were found about 1862 (4), by members of the Geological Survey. Mr. F. Chapman has stated that these fossils are definitely Silurian.

Junction of the Upper Ordovician and Lower Silurian.—Previous to 1918 the junction between the Silurian and the Ordovician rocks had been placed one mile S.S.E. of the junction of the creeks (6). As neither unconformity nor fossils had been found, geologists were forced to rely on the study of dips and strikes, and on this evidence alone the placing of the junction there seems to have been justified, for there the dips become lower and the direction of the strike is slightly altered. In this area it is not safe to put too much reliance on variation in strike and dip, because these are much disturbed by faulting, pitching and hill creep.

Two of the three editions of the geological quarter sheet No. 7 S.E., show the Ordovician rocks extending to the S.E. margin, while quarter-sheet No. 2 S.W. shows Silurian extending to the S.W. margin, thus making the edges of the sheets coincide with the junction between the Ordovician and Silurian sediments. A third edition of the quarter sheet 7 S.E., places the junction one-eighth of a mile to the west of this, and this is approximately the line found independently by T. S. Hart (6).

The presence of Silurian graptolites in two localities one and a-half miles west of this junction, and in another one and a-half miles N.N.W., strongly suggests that the junction shown in the quarter sheets is incorrect. There is of course the possibility that the later Silurian rocks occupy an infolded pocket of the Ordovician. In either case we are forced to look for the junction further upstream. It seems to the writer probable that the western face of conglomerate C_1 is the junction. The reasons for putting it there are as follow:—

(a) The junction is necessarily between dyke D_3 and Column Gully, for at the former, Silurian graptolites and worms are found, and at the latter, Ordovician graptolites. These two places are approximately one and a-half miles apart. No conclusive evidence is given by the dips and strikes, for though slight variations occur, up-stream and down-stream similar variations can be noted. In the Ordovician graptolite bed the dip is 84 E, and the strike exactly north and south, while in the Silurian graptolite beds the dip is 77 E, and the strike 8° west of north. Between these two beds there is no sudden change of dip or strike.

(b) The Silurian worm Trachyderma can be found in many of the strata east of C_1, but not west of it,

(c) "Ordovician worm impressions" are found in enormous numbers, from the Ordovician graptolite beds, where they are associated with Diplograptus, right up to the conglomerate C_1, but neither in it nor on the east side. The fact that these marks suddenly cease at the conglomerate strongly suggests discontinuity of conditions.

(d) The conglomerate itself is strictly conformable with the strata on the eastern side, but on the western the contact is very irregular. The one drawback to the placing of the junction at C_1 is the presence of a few pebbles in the strata on the up-stream side of the conglomerate. This suggests similarity of conditions, and though their presence is not fatal, yet it makes one hesitate to accept C_1 as a basal conglomerate.

Palaeozoic Conglomerates.—The four palaeozoic conglomerates in this area have been carefully described by T. S. Hart (5). C_4, the most northerly, is wrongly coloured tertiary in one of the three quarter sheets. It has been pointed out (6) that this conglomerate has been so indurated by thermal metamphorism that the matrix is as hard as the old quartzite pebbles, and thus the pebbles do not weather out.

The southern exposure C_3 can be picked up in a runnel on the cliff about 80 ft. above the stream. It is not altered to the extent that C_4 is.

C_2 shows the clay bands much distorted by differential pressure, as they are in the Italian Cutting, Daylesford (8).

C_1 is the largest of the four conglomerates.

T. S. Hart (6) puts forward various reasons for considering it an Ordovician glacial conglomerate. His conclusions appear incorrect. The following is a summary of the reasons given on which he based his conclusion :—

(1) A part of the conglomerate is a mixture of pebbles and fine clay.
(2) The strata are much disturbed in places.
(3) The matrix is angular.
(4) Some pebbles are facetted and striated.
(5) Fossils are absent on account of severity of the climate at that period.

The writer carefully weighed these points, but was forced to discard the theory of the glacial origin. A mixture of pebbles and clay can be formed in other ways than by glacial action, and the disturbance of the strata appears to be the unconformable junction of the Ordovician and Silurian. The presence of the striations on an insignificant percentage of the pebbles can be accounted for by the fact that when conglomerate bands are folded under pressure, the hard pebbles grind against and scratch one another. Facetted pebbles were not common in this conglomerate, and there was quite as large a percentage in the river conglomerate as in the ancient collection. On examining under the miscroscope, the matrix from conglomerate C_1, and comparing it with material taken from other strata, it did not appear to be more angular than the latter. It has been shown already that life was abundant in the seas in that age.

The direct evidence against this glacial theory is :—

(a) The general linear arrangement of the pebbles.

(b) In C_1 the pebbles lie regularly on their flat faces.
(c) Pebbly, sandy and clay bands alternate.
(d) Most of the stones are small. Not one large stone is seen. If it were glacial you would expect to find some boulders.
(e) Facetted and striated pebbles are extremely rare.
(f) Many strata contain pebbles of only one size.
(g) The conglomerate is almost certainly of Silurian age, and no other evidence of Silurian glaciation has been reported in Australia.

For the reasons above it seems more likely that the conglomerate C_1 is the basal conglomerate of the Silurian rather than an Ordovician glacial deposit.

The material of which the pebbles are composed is similar to that of the Kerri conglomerate found along Conglomerate Creek, near Macedon (10). There are quartz, quartzite, black chert, quartz porphyry, greisen and diabase pebbles. The Kerri conglomerate contains a large percentage of dimpled and squeezed pebbles, whose state it has been shown is probably due to solution under pressure (10). Many similar pebbles are found in C_1 but most of the dimples have not been made in situ, for frequently the dimples are opposed not to a pebble, but to the clay matrix. A few of the dimples may have been made in situ.

Metamorphic Rocks.

These are exposed along Deep Creek to the north, west, and south of the granodiorite. At and near the junction the sediments have been converted into hornfels, while further away they occur as spotted shales, or as indurated sandstones or shales. The width of the aureole varies considerably, probably owing to the irregular junction of the granodiorite, with the sediments beneath the surface. As far as can be judged from the bedrock exposed along the creeks the hornfels belt on the average appears to be about a quarter of a mile wide, and it gradually merges into spotted slate, which is not uniform in its distribution. The indurated sediments have abundant secondary mica.

In the hand hornfels is a hard, dense, dark rock, in which individual crystals cannot be seen with the naked eye. Under the miscroscope, however, it is seen to have abundant secondary brown biotite. Near the contact there is a considerable amount of cordierite produced, but further away andalusite, biotite, and secondary quartz predominate. The cordierite can be distinguished from the quartz by its cleavage, which is easily picked out, and by the numerous and characteristic inclusions. A little tourmaline is found in a few sections, but secondary quartz is present in abundance in all.

The hornfels close to the contact is very much coarser than that some distance away.

Owing to the quantity of sandstone which characterises the palaeozoic rocks of this area, a considerable amount of quartzite has been formed, much of it being thermal metamorphic in type.

It is interesting to note the difference between the action of running water and the weather on these metamorphosed sediments. They appear to be highly resistant to the latter, but readily succumb to the former, owing to the presence of three sets of joint planes, which divide the rocks into variously shaped rhombohedra. The result is that the stream in flood can break out the rhombs and thus deepen its bed, whereas the ordinary atmospheric agents are not so successful. The importance of jointing is shown near Hanging Valley, where a metamorphosed fault rock of the same material as the hornfels around it has more sucessfully resisted destruction by Deep Creek. The fault rock is not jointed, and the normal hornfels is, thus enabling the stream to remove it block by block.

Granodiorite.

Six outcrops are mapped, three large and three small, and they roughly form a ring round Bulla. The boundary of the north-east outcrop is hidden by later detritus, that has gravitated down from the east. The five outcrops to the north stood out as islands in the lava flood, but the most southerly was overwhelmed by it.

Chemical Character.—The material for analysis was obtained from fresh rock that had been "plug and feathered" on the main outcrop southwest of Bulla.

It was analysed by Mr. F. Watson, and the analysis is given in the following table, together with analyses of other similar rocks for comparison :—

	Granodiorite Hesket	G'diorite Pory Barringa Ck.	Granodiorite Harcourt	Granodiorite Bulla	Adamellite Ingliston	Adamellite Trawool	Adamellite Mt. Gellibrand
SiO_2	68.92	71.65	70-91	66.13	71.57	69.19	67.75
Al_2O_3	15.26	14.56	13.99	16.83	13.58	13.45	16.11
Fe_2O_3	.80	1.13	.35	1.11	1.18	2.71	.50
FeO	3.30	1.56	3.02	4.17	2.19	2.78	4.06
MgO	1.64	.84	.80	1.83	1.07	1.06	.79
CaO	3.04	1.27	2.35	3.26	1.72	2.04	2.68
Na_2O	2.71	2.76	3.94	2 25	2.79	2 89	2.60
K_2O	2.93	4.14	3.66	3.14	4.36	3 94	3.42
H_2O + 110	1.04	.15	.21	1.68	.69	.77	.96
H_2O − 110	.22	1.20	.11	.23	.11	.16	.20
CO_2	Nil	Nil	Nil	Tr.	.29	.07	Nil
TiO_2	.70	.35	.58	Tr.	.46	.51	.85
P_2O_5	.19	.12	Tr.	Tr.	.11	.18	.09
MnO	Tr.	.04	Nil	.07	.09	.14	Tr
Li_2O	Tr.	Tr.	—	—	Tr.	Tr.	—
Cl	Nil	Tr.	—	Tr.	Tr.	Tr.	—
Total	100.75	99.77	99.95	100.70	100.21	99.89	99.95
S.G.	2.688	2.630	—	2.677	2.655	2.666	2.68
	Mines Dept.	Mines Dept.	G. Ampt.	F. Watson 1918	A. G. Hall	A. G. Hall	H. C. Richards

The rather high CaO content, and the relatively low K_2O content of the Bulla rock favours granodiorite rather than adamellite, and the miscroscopical examination confirms this determination.

Megascopic Character.—It is a rather coarse grained, grey rock with many crystals, 10 mm. in diameter. Quartz, plagioclase, orthoclase, biotite and a little pyrite can be seen. The quartz has a greasy lustre, and the felspar tends to be greenish. The rock takes a fine polish, though the coarse biotite is inclined to give the surface a chipped appearance. Basic segregations with their rounded outlines are very common. The specific gravity of fresh rock is 2.677, and thus in keeping with its determination as granodiorite.

Microscopic Character.—It is a non-porphyritic, hypidiomorphic, holocrystalline rock with crystals of various sizes. It is medium to coarse in grain, with a rich assortment of minerals.

The following are present in order of decreasing abundance:—Andesine, quartz, orthoclase, biotite, chlorite, sericite, muscovite, apatite, pyrite, magnetite, arsenopyrite, calcite and zircon. The chlorite, sericite, pyrite, calcite, and arsenopyrite are secondary.

The extinction angles of the carlsbad and the lamellar twins disclose the fact that the plagioclase is basic andesine. Zoned crystals are very abundant, and the zones are seen to be more basic as the centre is approached. Certain bands of the zoned felspars were sericitized before the others, showing that felspars of that composition were not so stable in the presence of sericitizing agents. Generally sericitization took place from the centre outwards, i.e., from the basic to the acid plagioclases. In the sections studied sericite in its turn tends to be kaolinized.

Summary.—The rock from its chemical and mineral composition and its physical properties is a slightly altered granodiorite. In the hand it appears fresh, and shows no sign of weathering.

In the field it undoubtedly appears to be linked to the Gellibrand mass, which has been described by Dr. F. Stillwell as adamellite (11). Both are 500 ft. high, and have the same mineral composition, and approximately the same chemical composition. It differs from the Gellibrand stock in having a slightly higher lime content, and slightly lower silica content.

Dr. F. Stillwell found that the proportion of plagioclase to orthoclase was less than 2:1 in the Gellibrand stock, but the writer by the Rosival method found the proportion distinctly more than 2:1 in the Bulla stock, which is adjacent to it. Slight differences in mineral and chemical composition are probably local, for the two rocks are similar in all other important characters.

Granitic Intrusions.—Near Hanging Valley is a granitic dyke 20 feet wide, intruding the hornfels. Near the southern edge of the main granitic mass there are several small dykes of microgranite intruding granodiorite, while north of Bulla bridge there is a dyke of aplite and a small one of quartz, both in granodiorite.

The dyke near Hanging Valley is evidently a tongue from the main mass, but the microgranite, aplite and quartz tongues appear to have been derived from the acid residue of the magma after the outside portion had cooled and hardened. The magma evidently stoped the palaeozoic sediments so quietly that the dip and the strike are not only unaltered up to the southern contact, but are continued at the northern junction. The sediments to the west also are undisturbed.

A large number of angular and irregular rock blocks are found embedded in the granodiorite along Deep Creek, S.W. of Bulla. That they were originally blocks of sediment that were displaced by the stoping, and then sank into the molten magma, might be inferred by the angularity of the blocks, and by their close similarity to hornfels. If they were basic segregations, you would expect the outlines to be rounded.

Economics.—The best granodiorite for building purposes lies between the deep trenches of Jackson's Creek and Deep Creek, at the 500 ft. level. The expense of hauling blocks of granodiorite across these deep trenches and thence to Melbourne practically prohibits the use of this rock as a building stone.

The granodiorite, in striking contrast to the basalt of this area, is always tree-covered, and with the exception of the trees in the deep creek trenches, is the only local source of timber.

Kaolinized Granodiorite.

Location.—The granodiorite at several places round Bulla and Broadmeadows has been kaolinized. In the area under discussion there are four extensive masses of kaolinized granodiorite, and several smaller outcrops. Two of the large outcrops are being worked by Cornwells for their Brunswick pottery. The others have not yet been opened up.

Description.—At the quarry Q^1 (Plate XXXII.) one can trace the change from hard granodiorite, through the partly decomposed to the thoroughly decomposed and whitened rock. Decomposed basic segregations can also be seen in the face. Much of the mass is left the purest white by the leaching out of the iron oxide derived from the magnetite, pyrite, biotite and chlorite. In other parts the decomposed rock is deeply stained and cemented by the concentration of iron oxide.

In the smaller quarry (Q_2) near the Bulla school, there is a well-marked vein one inch thick, of bluish tourmaline and granular quartz, in a joint plane of the kaolinized granodiorite. Another vein 1½ inches thick has lately been cut out of the kaolin in Q_1.

The quartz granules of the original granodiorite persist, apparently unaltered, throughout the kaolinized mass.

Microscopic Examination.—Angular quartz is surrounded by crystallised kaolin, which appears chiefly as twinned lamellae, though often in the form of scales and aggregates. A considerable amount of sericite is still present, with earthy calcite and zircons.

Origin of the Bulla Kaolin.—Granodiorite may be kaolinized by the action of meteoric water carrying carbon dioxide in solution, which penetrating the granodiorite decomposes the biotite and felspars. Kaolin in Fiji and the Dublin Mts (Ireland) is stated by Prof. Sollas to have been formed in this way (12).

Probably a commoner process of kaolinization and the proved origin of the vast kaolin masses of England and United States (12 and 13) is that of pneumatolysis, where emanations of carbon dioxide, boron, fluorine, or chlorine, probably with steam, have decomposed the felspars and biotite of the plutonic rock.

Three investigators, E. J. Dunn, 1899 (15), R. W. Armitage, 1911 (14), and F. Stillwell, 1911 (11), have briefly discussed the Bulla kaolin. While both Mr. Armitage and Dr. Stillwell refer to the possibility of either surface water or pneumatolysis being the cause of the kaolinization of the Bulla granodiorite, the former favours the meteoric origin and the latter the pneumatolytic origin.

For the following reasons, it seems probable that pneumatolysis and not meteoric water is responsible for the kaolin of this area.

Evidence Against the Meteoric Theory.

(a) Only Isolated Outcrops Occur in Victoria.—This is strongly against the meteoric theory, for if the water and carbon dioxide were subaerial one would expect kaolin to be found in all parts of Victoria, where the old granitic surface is protected from denudation.

(b) Only Isolated Outcrops Occur at Bulla.—There are about ten outcrops at Bulla, and these are separated from one another by solid, unaltered granodiorite. Generally the surface of the granodiorite is protected by basalt and gritstone, and yet only relatively small outcrops of kaolin are found.

(c) Relation of Kaolin to the Sites of Old Valleys.—It has been stated (14) that the Bulla kaolin always underlies basalt which is situated in the sites of old pre-basaltic valleys, and that the drainage beneath and through the basalt would thus tend to be gathered along lines where it could attack the granodiorite vigorously.

In reply to this it can be stated that kaolin does not always underlie the basalt. In the largest Bulla quarry, Q_1, the kaolin is overlain by a considerable thickness of grits. The presence generally of basalt over kaolin is only what one would expect. Suppose a granodiorite mass had been converted into kaolin at various places by pneumatolysis long before the lava floods. At these places the weathering would be much more rapid than where the rock was unattacked. Depressions would be made, and, later, occupied by the lava, while the fresh and less denuded rock would stand up as a monadnock above the molten basalt.

(d) Fresh Granodiorite under Basalt.—In two places fresh, hard granodiorite was seen directly beneath basalt at a low level, while the granodiorite to the side of it had been kaolinized. At another place granodiorite was seen under basalt that had flowed into an old valley. There was no sign of kaolinization.

(e) Shape of the Outcrops.—In this area the shape of the outcrops is not very definite, but where it is shown it agrees with type (a), (Fig. 1, Plate XXXIII.) If the kaolin were of meteoric origin, it would be of type (b) (Fig. 2, Plate XXXIII.).

(f) Relation of Kaolin to Depth.—In every case the rock near the bottom of an outcrop is as much altered as that higher up the face. If the decomposition were due to surface water and carbon dioxide, then decomposition should decrease as the depth increased, for the solid rock deep under the surface stream would suffer very little from downward drainage.

(g) No Evidence of Stream Beds above the Kaolin.—If the kaolin were formed by water in old valleys draining through granodiorite, some trace of stream material above the kaolin would very likely be found. No trace of river gravels, silt or conglomerate was found above any of the kaolin masses.

(h) Kaolin Found at Many Levels.—Kaolin can be found right from the level of the stream to 200 ft. above it. One would not expect such differences in level in separated outcrops if old valley floors determined the point of attack on the granodiorite by the stream water with carbon dioxide in solution.

(i) No Evidence of Kaolin Being Formed in Present Stream.—The granodiorite along Deep Creek and on the hill sides is not kaolinized. If kaolinization be due to subaerial agencies, why has not the granodiorite in this stream bed been kaolinized?

(j) Accompanying Minerals.—Kaolinization by pneumatolysis is generally accompanied by the production of tourmaline, fluor, cassiterite or topaz, which cannot be produced by subaerial agents. A vein of tourmaline in Q_1 and another in Q_2 (Plate XXXII.) give valuable positive evidence that magmatic vapours have been present to some extent at least.

Summary.—The microscopic examination of the kaolin gives no definite evidence in favour of either theory, but the field evidence, while producing little positive evidence in support of pneumatolysis, strongly discounts the meteoric theory. The fact that no fluor, cassiterite, or topaz is found in the kaolinized rock, and only a small amount of tourmaline, rather suggests that we must turn to magmatic water and carbon dioxide as the agents causing kaolinization, as in Cornwall and in the United States (12). The earthy calcite in the sections of the kaolin supports this conclusion.

Economics.—Fifty years ago a company was formed to export this material to England, where it was bought at 18/- per ton. Owing to the heavy transport cost the company failed.

At present the kaolin in Q_1 and Q_2 is being worked by Cornwells, who use it for making fire bricks and other articles used at high temperatures. There is a growing export trade in these manufactured articles.

On account of the trace of iron in the Bulla kaolin, it has not, up to the present, been used for chinaware. The quantity of kaolin appears to be unlimited.

Kainozoic Rocks.

Older Basalt.—In the south-east of the area three lenticular outcrops were found. The most northerly is vesicular, and rests directly on Silurian sediments, and underlies a very thick cap of stratified Kainozoic grits. The best section, however, is seen in a cliff face in the extreme south-east, where very decomposed older basalt overlies a pre-older basaltic river conglomerate, about 8 ft. in thickness, which merges into sands at the sides. This sand and the sandstone conglomerate beneath the basalt are strictly local in origin, and remind one very much of the sands underlying and overlying the leaf beds two and a-half miles to the N.N.W.

In this decomposed basalt there are, in situ, several undecomposed basaltic nodules. These remove all doubt as to the identity of the outcrop. The basalt thins out at the edges, and here the underlying sand has in part been altered to quartzite, and the overlying sandy clay to a rock resembling red brick. Newer basalt more than 100 feet in thickness rests on these beds.

Pre-older-basalt River Valley.—The alignment of the three southern outcrops is indicative of an old river valley, and this conclusion is upheld by the presence of a conglomerate in the southern exposure.

No evidence of stream action in the two patches to the north was found, but this may have been hidden by the talus, which masks the surface. The northern outcrops are at a lower level than the southern one, and this suggests that the stream in this locality flowed to the N.N.E.

Basic Hypabyssal Rocks.

Along Jackson's Creek, in the south of the area, there occur at least seven basic to ultrabasic dykes. D_1 between D_1 and D_2 can be seen only when the creek is very low. In places it is sill-like. D_1 is 22 ft. wide, and is found directly beneath the "Organ Pipes," but separated from them by Kainozoic grits. D_3 contains nodules of relatively fresh material, the only unaltered mineral being apatite, though abundant augite and olivine can be recognised by the shape of the old crystals and their alteration products. Oblong outlines which may have been plagioclase laths are fairly numerous. The apatite has a vitreous to subresinous lustre. Its shape is remarkable, for it resembles a miniature torpedo. Frequently the crystals are long, but flattened. They can be obtained up to $1\frac{1}{4}$ in. in length, and down to the smallest needles. All have smooth rounded outlines, but some have small smooth depressions. The smooth outlines and depressions are evidently due to corrosion by the magma. Owing to the extreme brittleness of these crystals, it is difficult to obtain complete specimens. From carefully chosen fragments the S.G. was found to be 3.104, and the P_2O_5 content 40.3 %. A brisk effervescence is set up on dissolving the mineral in hot HCl.

Phenocrysts of olivine, augite, apatite, and felspar were set in a fine groundmass. Of these apatite is the only survivor.

The seven dykes appear to be of the same age, and of the same material, though apatite was found only in D_3. All have the same brownish yellow appearance, the same greasy feeling, the same degree of decomposition, and the same rich iron content, as shown by the iron oxide on the footwalls.

Age of the Dykes.—From their field appearance the basic dykes are all of the same age. The fact that the dykes (D_1 and D_2) are not intrusive into the overlying stratified Kainozoic grits, shows that they are older than either the Newer Basalt or the Kainozoic grits. The fact that they are intrusive into the Silurian sediments, and were not affected by the folding agencies of Lr. Devonian times (16), stamps them as post Lr. Devonian. In one dyke (D_3) a few nodules of partly decomposed rock were found, and this tells us that the dykes are not very ancient. It is, therefore, reasonable to place them with the older basalt, because rocks of this age also occasionally show undecomposed nodules, and it was at this period that vast quantities of basic magma were forced to the surface.

Kainozoic Sediments.

These will be briefly described under the following heads:—

(a) Pre-older-basaltic river conglomerates.

(b) Pre-newer-basaltic grits (Normal "Tertiary Grits.").

(c) Eucalptus leaf beds.

(d) Pre-newer-basaltic river sediments.

(e) Inter-newer-basaltic grits, conglomerates, etc.

(f) Post-newer-basaltic grits, conglomerates and alluvium.

(a) *Pre-older-basaltic river conglomerate.*—This is found in the extreme S.E. of the area, and has been described above. No fossils were found. Part of this deposit has been altered to quartzite, evidently by the older basalt.

(b) *Pre-newer-basaltic grits and sands.*—These are generally stratified. Near Keilor, about two miles to the south, the grits are stratified, and marine fossils are abundant, but no fossils have been found in the grits of this locality, with the exception of the leaf beds described in the following paragraph. A close study leaves little doubt that all these sandy deposits have been derived from the Bulla granodiorite, the stratified and unstratified deposits apparently merging into one another.

(c) *Eucalyptus Leaf Beds.*—On the left bank of Deep Creek (See Plate XXXII.) a deposit of fine sands and very fine clay bands rests above sands, which in turn rest on the upturned edges of the Silurian sediments. These clay bands are overlain by other sandy layers. The whole deposit is about 30 ft. in thickness, and is covered by more than 100 feet of basalt. The clay bands consist of two sheets about 8 ft. in thickness, light blue resting on dark brown. Both are fossiliferous, but the brown are especially rich. The fossils are leaves of eucalypts, acacias, ferns, and other plants, together with stems and fruits of unrecognised plants. The eucalyptus leaves have been described by Mr. R. Patton (17). From the delicately even strata and the fineness of the clay, the deposit is evidently a lake deposit. The old surface of the Silurian rocks rises to greater heights on all visible sides of the leaf beds, and this, together with the lithological character of the sediments, is strong evidence in favour of their lacustrine origin. There is no evidence as to whether these sands are pre-older-basaltic or post-older-basaltic. The examination of the eucalypt leaves by Mr. R. Patton threw no light on the problem of their age. From their position among the other sandy layers, with which they are conformable, it is probable that they are post-older-basaltic, like the normal Kainozoic grits.

The beds have a decided tilt to the S.E. This may be due to the compression of the loose porous sands by the great overload of new basalt, which here is about 140 ft. in thickness.

(d) *Pre-newer basaltic river sediments.*—These are shown on the map (Plate XXXII.), as areas where plant stems are very abundant. That they are river deposits is shown by their lenticular shape, by the small conglomerate that rests on the valley floor, and by the earthy nature of the matrix. They indicate the sites of pre-newer basaltic valleys.

(e) *Inter-newer basaltic grits and conglomerates.*—The lava flows of the newer basalt in this district are divided into two series—Upper and Lower. This will be explained later. Between the two series is the old soil surface of weathered rock, and in places thick deposits of grit have gravitated from the higher granodiorite in the locality into the valleys corroded in the Lower Series of the newer basalt. These grits, etc., are not stratified. They act as a simple division between the two series of newer basalt. The best occurrences are at points marked F on the map. At Column Gully a heavy conglomerate of quartz and basalt pebbles separates the two series, while in the road cutting north of Bulla an old land surface separates them.

(f) *Post-newer basaltic grits, conglomerate and alluvium.*—All these should be placed as Recent, but as they form only a later stage in the same destructive and constructive process that has been going on right through the Kainozoic, they have been placed under this head. In the neighbourhood of the heart-shaped granodiorite outcrop, unstratified grits can be seen both above and below the newer basalt. The grits have been shed from the hill. This process went on before the older basalt, before the newer basalt, and it is being continued after it. Grit covers or mixes with the basalt soil.

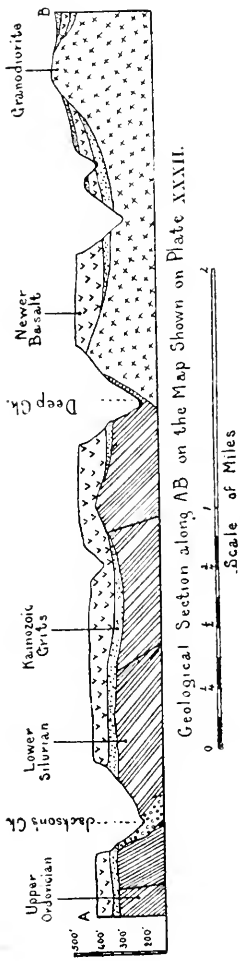
In addition to the massive conglomerates that are now being formed in the stream beds, there are conglomerates of much earlier age formed along the river spurs, especially those of Jackson's Creek, where the deposits are sometimes at least 30 feet in thickness. Generally, they are chiefly rounded quartz and basalt pebbles, and can thus be distinguished from the normal Kainozoic pebble beds which contain no basalt. These deposits have been dropped by the stream as it deepened its bed, but yet the fact should be noted that the great mass of this conglomerate occurs about 100 feet above the present stream level, i.e., when the stream had sunk its bed a little more than 100 feet below the surface. This shows that at that depth the stream cut into an old Kainozoic pebble deposit to the north, and distributed the pebbles on the convex bank of its meanders. The pebbles lower than 100 feet have probably been derived partly from the old pebble beds, and partly from the recent deposits higher up the spurs.

River alluvium, as already described under Physiography, is poorly represented in this area. It is found chiefly on the down-valley side of the spurs, and it usually passes into and overlies a heavy river conglomerate. The best deposit is found on Jackson's Creek, near its junction with Deep Creek.

Newer Basalt.

Newer basalt covers more than nine-tenths of the area mapped. It appears to consist of about seven flows that have come from Red Hill, Sunbury Hill and Bald Hill. This is shown by the contour lines on the military map, by the dominating position of these volcanoes, and by the shape and direction of the vesicles in the basalt. The points of origin of the earlier flows have not been determined. In many places the basalt has a depth of over 300 ft., but it cannot be said from this that each flow is 43 ft. in thickness, for the earlier flows are by far the deepest, since they levelled the old denuded surface. In the neighbourhood of Column Gully excellent columnar structure has been produced in the earlier flows. A description of these columns (14) and the factors producing them (18) may be found in other publications.

Upper and Lower Series.—The various flows of newer basalt in this area are divided into Upper and Lower Series by sandstone bands, river conglomerates, or thick surface soil. The places where a good junction of the Upper and Lower Series can be seen is marked F on the map. That a considerable time interval elapsed between the two series is shown by the denuded surface of the Lower, by its older appearance and more decomposed state, and by the thickness of surface soil on the Lower Series. Generally the thick scree on the valley sides masks the division line of the two series, but excellent junctions are common, especially in the N.W. of the area.



Geological Section along AB on the Map Shown on Plate XXXII.

It might be thought that the Lower Series belongs to the Older Basalt, but there is strong evidence against this:—

(1) The Lower Series rests in places on thick deposits of sand, which appear to be the normal Kainozoic grits.

(2) The river conglomerates between the two series frequently contain basalt pebbles derived from the lower series. These pebbles are only slightly decomposed. If they were older basaltic they would be thoroughly decomposed.

(3) Older basalt, three miles to the E.S.E., is thoroughly decomposed, while the lower series described above is only slightly weathered.

Scoria Cone.—Near the junction of Column Gully and Jackson's Creek is a scoria cone which was almost submerged by the youngest lava flows. A study of the sections shows that at first effusive and explosive eruptions alternated, and then gave place to a prolonged discharge of scoria and agglomerate. The uppermost of the four layers of scoria is still about 100 feet thick. Probably denudation has reduced its thickness. At one point a wall of dense basalt pierces the scoria. It is evidently a blocked up vent, or dyke.

The scoria is of the same age as the "Organ Pipes," and the columns in Column Gully, and, therefore, belongs to the Lower Series of Newer Basalt. At one point on Jackson's Creek scoria overlies and underlies the columnar basalt.

Microscopic Examination of Upper Newer Basalt.—Sections were made of very tough basalt from the small quarry on Deep Creek, north of the Leaf Beds. It proved to be a hypocrystalline rock, in which some glass was present. Large phenocrysts of olivine were set in matrix of fairly coarse labradorite. Augite and magnetite were very abundant, while iddingsite frequently replaced the olivine. The sections gave good examples of ophitic structure, for augite commonly included the labradorite laths. Flow structure was illustrated by the orientation of the labradorites, and the manner in which they "flowed" round the olivines. The rock was a coarse grained basalt.

Porphyritic Basalt.—In the triangle between Redstone Hill, Bulla and the Organ Pipes, there is a peculiar flow of dense porphyritic basalt that belongs to the Upper Series. Near the Redstone Hill, a volcano on Jackson's Creek, it is found resting directly on the sands that separate it from the Lower Series. In several places in Deep Creek and Jackson's Creek it is found in a perfectly fresh state, but above the Organ Pipes it appears in a more weathered and vesicular state. Boulders of this porphyritic basalt in the stream can readily be identified by the smooth light-brown surface spotted with black augite crystals. Under the microscope sections show that the rock contains perfectly fresh plagioclase, augite, and olivine phenocrysts up to ½ in. in diameter, set in a finer paste. The rock closely resembles the Tweed Head basalt of Queensland.

Acknowledgments.

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DESCRIPTION OF PLATES.

Plate XXXII.

Geological map of the Bulla-Sydenham Area.

Plate XXXIII.

Fig. 1.—Type of kaolin deposit due to pneumatolysis.

Fig. 2.—Type of kaolin deposit formed by the action of atmospheric water and gases.

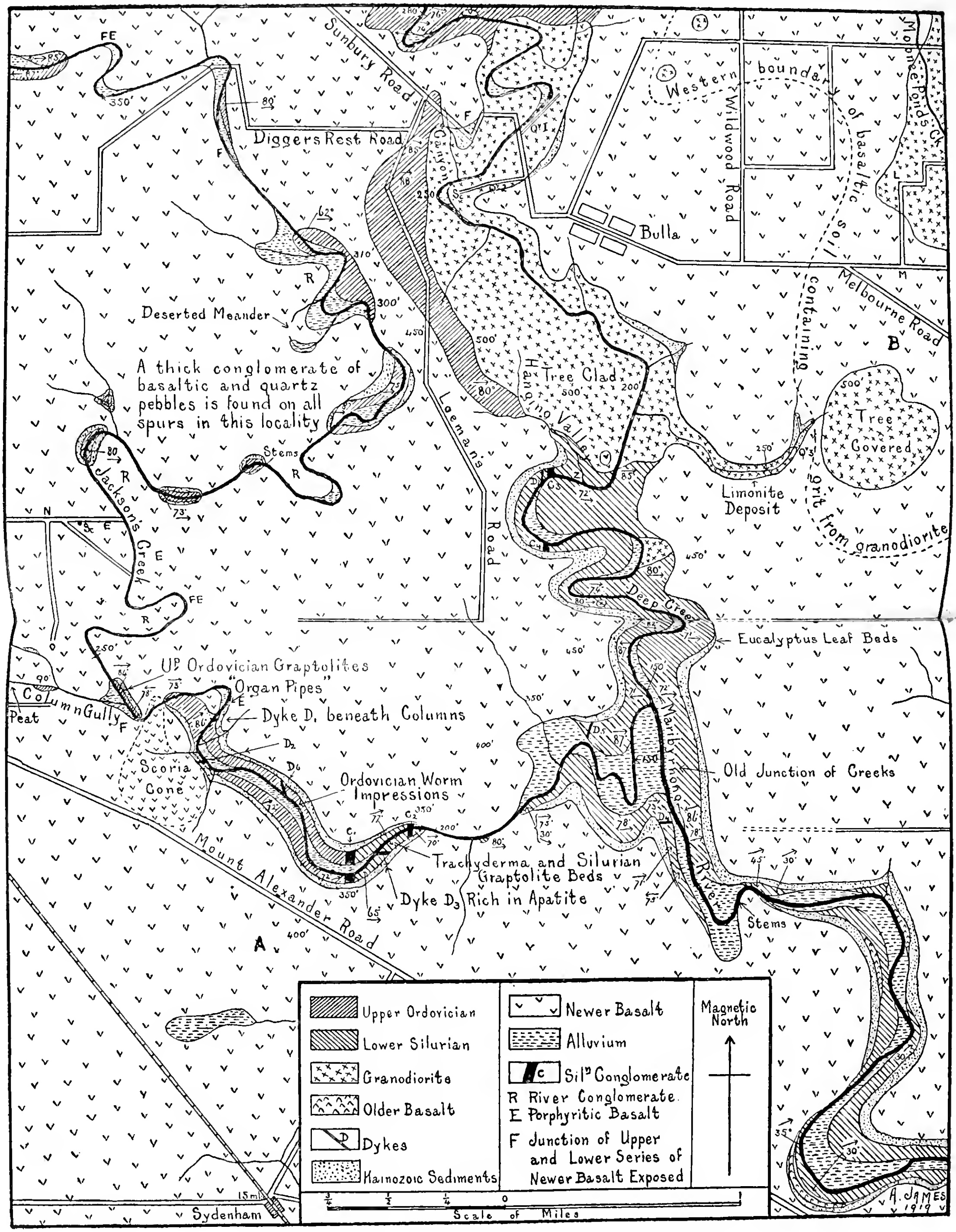
Fig. 3.—Meanders of Deep Creek. The heavy line shows the present course of the stream; the dotted line indicates the original course of Deep Creek.

Fig. 4.—Primary and secondary meanders of Jackson's Creek. The heavy line shows the present course of Jackson's Creek, with both primary and secondary meanders, while the dotted line indicates part of the original course of the stream on the surface of the basalt (with primary meanders). The large curves are primary, and are produced by the inequalities in the original land surface, but the small meanders are secondary, and are due to subsequent stream development.

Fig. 5.—This diagram shows how the bed of a stream in the spurred type of entrenched meander moves both horizontally and vertically.

Plate XXXIV.

Fig. 1.—Photograph of a spurred entrenched meander on Deep Creek. Water-worn pebbles are found along the crest of the spur. The flood plain on the down-valley side of the spur has been caused by the down-valley sweep of the meander. At the point x are the Eucalyptus Leaf Beds.



Geological Map of Bulla–Sydenham Area.

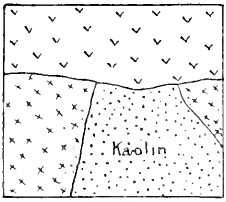
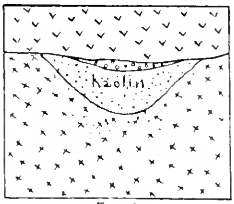


Fig. 1



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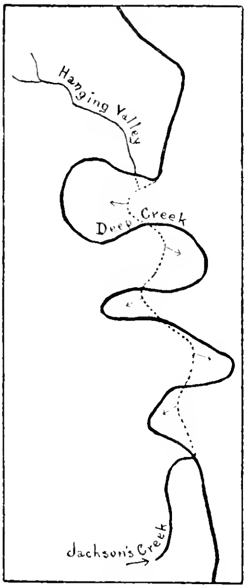

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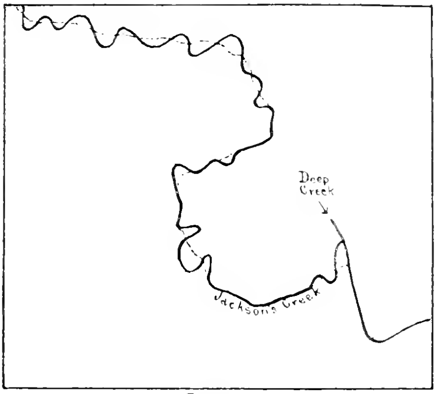

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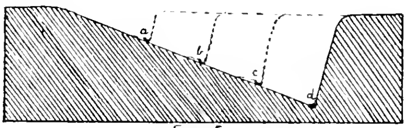
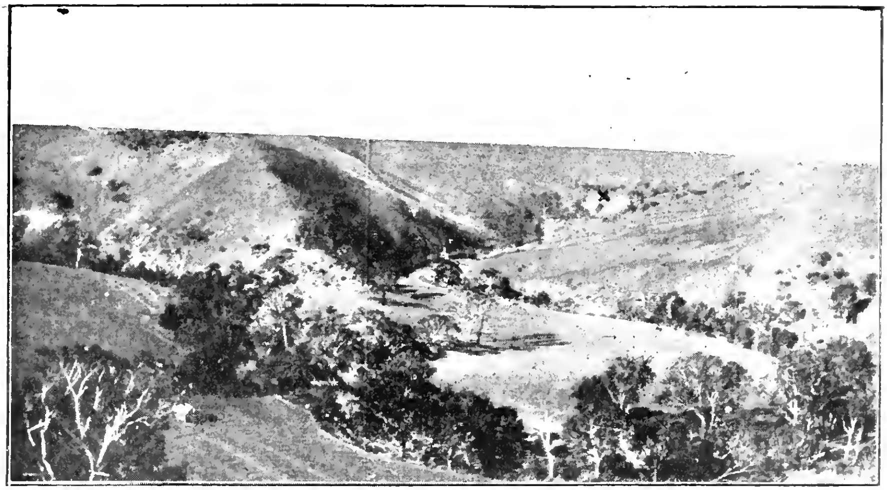
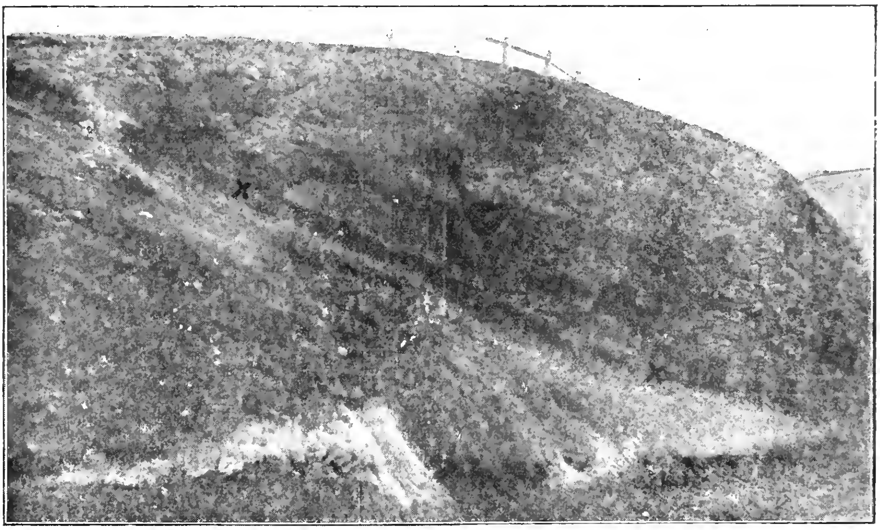


Fig. 5

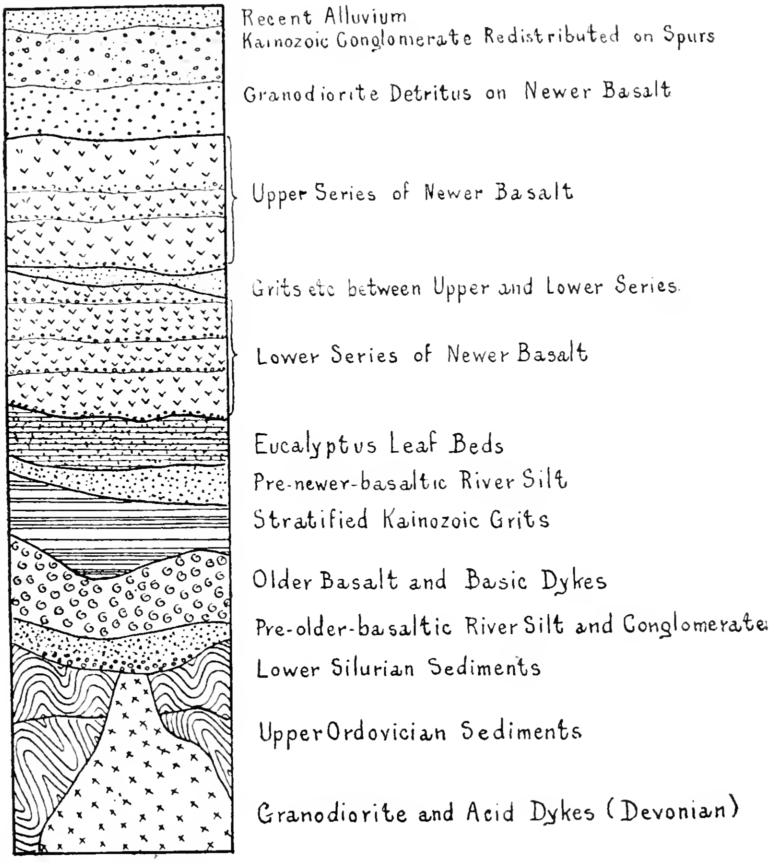
Kaolin deposits and river meanders





Spurred Meander and Junction of Upper and Lower Basalt

Fig. 2.—Photograph of the junction of the Upper and Lower Series of Newer Basalt, near the Canyon, Bulla. The Lower Series is resting on grits, which show slight step-faulting. The Upper Series is seen resting on the weathered surface of the Lower Series. The junction of the two basalts is indicated by xx on the photograph.



Rocks of the Bulla-Sydenham Area Arranged in Chronological Column.

[Proc. Roy. Soc. Victoria, 32 (N.S.), Pt. I., 1919].

Art. XXII.—*On the Seasoning of Hardwoods.*

By R. T. PATTON, B.Sc.

[Read 11th September, 1919].

The results given in this paper do not claim to settle, in any way, the question of seasoning, but are rather a record of accurate observations made on our timber when treated in various ways. In the discussions on seasoning, opinion is more often quoted than observation.

Steaming of timber, prior to seasoning, has many advocates, and this process has been given a good deal of attention. In the Botanical Laboratory, we have only been able to use 2 ft. lengths, but I do not think that this has any marked effect on the result. It may, however, since the wood vessels in the tall eucalypts are very long, and hence the steam may find its way right into the wood. If the wood be saturated with moisture, when it is put into the steam bath, it is difficult to see how the wood could dry, since the air is also saturated. On the other hand, if the wood be partly seasoned, then it ought to take up moisture. The latter case was not investigated. In the former case, however, all specimens weighed approximately the same when taken out as when put in. Steaming may, as Tiemann points out, prove a ready means of heating the wood, but the same result could probably be secured in another way. In the former experiments, the results of which are published in the Proc. Roy. Soc. Victoria, Mountain Ash (Eucalyptus regnans) was mainly used, but in this series Messmate (E. obliqua) was mainly used. The general results are the same. In the first place there is no acceleration of drying after steaming. Typical examples are given below. The weights are given as percentages of original weight. The boards were 6 in. x 1 in. Messmate, and were all cut from the same length of timber.

	Treatment.			
Date	In air	24 hrs. in steam	Air	48 hrs. in steam
	%	%	%	%
4/11/18	100	100	100	100
9/11/18	91.5	87.5	90.9	89.3
19/11/18	82.8	82.7	83.8	80.8
29/11/18	77.4	75.8	76.7	75.5
16/12/18	68.8	69.0	69.7	68.1
8/1/19	65.6	65.5	66.7	63.8
28/1/19	64.5	64.4	65.6	62.8
14/2/19	64.5	64.4	64.7	63.8

It will be seen that the specimen steamed for 48 hours has lost slightly more than the others. This is often the case, as tannin and kino are dissolved out of the wood.

While the drying rate is not affected, the amount of shrinkage is seriously affected. Two typical cases are given. The timber was 6 in. x 1 in. messmate. The first specimen was steamed for six hours, and then put out in the air to dry. The corresponding piece was left in the air.

			Steamed		Unsteamed
Shrinkage	Breadth	-	$\frac{18}{32}$in.	-	$\frac{11}{32}$in.
	Depth	-	$\frac{3}{32}$in.	-	$\frac{2}{32}$in.

The second specimen was steamed for 12 hours.

			Steamed		Unsteamed
Shrinkage	Breadth	-	$\frac{17}{32}$in.	-	$\frac{11}{32}$in.
	Depth	-	$\frac{4}{32}$in.	-	$\frac{3}{32}$in.

It will be seen that the steaming has greatly increased the amount of shrinkage. The cause of this extra shrinkage is not yet known, but it may be due either to the steam affecting the union of the cells or the constitution of the cell wall may be affected.

A very interesting result was obtained by cutting a length of 6 in. x 1 in. timber into 10 in. lengths, and subjecting each piece to a different mode of treatment before putting it out in the air to dry.

The result of one experiment is as follows :—

	Treatment			
Date	In air	2 hrs. in steam at 10 lbs. pres.	2 hrs. in steam at atmos. p.	In oven at 110°c
	%	%	%	
7/11/18	100	100	100	100
9/11/18	97.4	95.4	96.8	93.1
19/11/18	89.9	88.5	89.2	88.6
29/11/18	86	83	84.3	84.7
16/12/18	80.8	78.3	79.5	79.7
8/1/19	78.6	76	77.6	77.4
28/1/19	77.8	75.2	77.9	76.6
14/219	77.7	74.9	76.9	76.4

The weights are given as percentages of the original weights. It will be noticed that the piece treated at 10 lbs. pressure of steam is the lightest. This is due to various substances being dissolved out of the wood. The interesting feature of the experiment lies in the fact that all the pieces have dried approximately at the same rate. With the exception of the second weighing, the difference between any pair of weights never exceeds 3% at any weighing, and in this 3% difference must be included the loss of tannin and kino. The difference between the un-treated specimen and the oven-treated specimen is very small. Other experiments gave the same results. Hence we may conclude that sudden drying of the surface does not affect the ultimate rate of drying.

The amount of shrinkage in breadth of these specimens is also of interest:—

	Treatment			
	In Air	10 lbs. steam	Steam at atmos. p.	Oven at 110
Shrinkage	$\frac{17}{32}$	$\frac{18}{32}$	$\frac{17}{32}$	$\frac{16}{32}$

These results are similar to those of other experiments. It will be seen that the suddenly dried specimen gives the least shrinkage.

The amount of shrinkage that takes place when our timber is seasoning, is highly important. The measurements taken are not extensive, but they should prove a guide for future work.

Measurements were made on both Messmate and Mountain Ash. In length the shrinkage is very small, and averaged 1/32 in. for 6 ft. Lengths from 2 ft. to 6 ft. were used.

For shrinkage in radial and tangential direction, 6 in. x 1 in. boards were used mainly. The shrinkage in a tangential direction is generally supposed to be much greater than in a radial direction, but the difference was not as great as expected. The results for Mountain Ash (E. regnans) are as follows:—

In the radial direction the shrinkage averaged—

$\frac{10}{32}$in. for 6in. or about 5%.

In the tangential direction the shrinkage averaged—

$\frac{1}{2}$in. for 6in. or about 8%.

For Messmate the results were as follows:—

In the radial direction the shrinkage averaged—

$\frac{12}{32}$in for 6in. or about 6%.

In the tangential direction the average was—

$\frac{15}{32}$ for 6in. or about 8%.

It is still a debated question as to how long it takes our timber to season in the open air. Apparently no accurate observations have been made, and hence doubt exists. In my former paper I gave some observations on the drying of a stack of timber. Another stack was made in January of this year. The boards were 6 in. x 1 in., and were placed horizontally with 1 in. fillets between them. Laterally there was a 3 in. space between boards. There were 30 boards in the stack, each 6 ft. The stack was not in the most favourable position for drying, since it was shut in by walls on three sides, and was beneath an elm tree. The lowest humidity recorded was 13%, and this was on the day of the disastrous fires in the Otway Ranges. All the boards dried in about four weeks. The percentage of moisture remaining was about 12 %, this being the average of three boards.

The actual and percentage weights of the boards that lost most are as follow :—

Date		Weight		%		Weight		%
18/1/19	-	16.6	-	100	-	16	-	100
25/1/19	-	13.3	-	80.6	-	12.5	-	76.9
1/2/19	-	11.14	-	72.5	-	10.15	-	68.4
8/2/19	-	10.15	-	66.8	-	10.1	-	62.9
15/2/19	-	10.6	-	63.4	-	9.12	-	60.9
22/2/19	-	10.5	-	63.0	-	9.14	-	61.7
1/3/19	-	10.4	-	62.6	-	9.14	-	61.7

It will be noticed that the latter one began to weigh more. This is always the case with dry boards, for they vary with the humidity of the atmosphere. The result of this experiment indicates the need for more extensive observations on the natural drying of timber in our climate, especially during the summer. If inch boards can be seasoned by a month's air drying in summer time, to kiln-dry such boards would be quite unnecessary and would hardly save any time. I desire to thank the manager of the Victorian Hardwood and Milling Co., and also Messrs. R. Grundy and Co., for their care and promptness in supplying the timber for these experiments.

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