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

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Part I.

Part II.

[Proc. Roy. Soc. Victoria, 47 (N.S.), Pt. I., 1934.]

Art. I.—*Notes on the Histology of the Alimentary Canal in some Australian Termites.*

By JEAN L. SUTHERLAND, M.Sc.

(With Plates I. and II.)

[Read 8th March, 1934; issued separately, 22nd December, 1934.]

Introduction.

Observations on the alimentary canal of Metatermitidae of the genus *Eutermes* show several peculiar features which seem to have been overlooked in the most complete previous account, that of Holmgren (1909). It is the purpose of this paper to recapitulate Holmgren's description, to describe the structures which he did not mention, and to compare them with analogous structures, if present, in termites of other families.

The classification adopted is that of Holmgren.

The order Isoptera is divided into four families:—

Mastotermitidae (type *Mastotermes*), Protermitidae (*Archotermopsis, Calotermes, Porotermes, Stolotermes*). Mesotermitidae (*Coptotermes*), and Metatermitidae (*Eutermes*).

Method.

Longitudinal and transverse serial sections, usually 10μ thick, were cut of alimentary canals dissected out and fixed in Bouin or corrosive acetic. Delafield's haematoxylin and Heidenhain's iron haematoxylin, with or without an eosin counterstain, were the most generally satisfactory stains; occasionally picric acid was used to show chitinous structures. Unstained alimentary canals mounted whole were useful for observing the demarcation of the various regions.

General Features of Alimentary Canal.

The alimentary canal of a termite may be divided externally into the following regions:—

(1) *Fore-gut,* consisting of pharynx, oesophagus, crop and gizzard. Posteriorly the fore-gut may be invaginated into the mid-gut, the invaginated portion and the tube immediately anterior to it being termed by Holmgren the "collum" and by Imms (1919) the "oesophageal valve."

(2) *Mid-gut,* the posterior boundary of which is marked by the opening of the Malpighian tubes.

(3) *Hind-gut,* which can be divided into five parts:—

  (*a*) A narrow tube of varying length, extending from the end of the mid-gut to the posterior curvature. This division is particularly long in Metatermitidae, but short in the other three families.

(*b*) The region extending from the posterior curvature to the greatly dilated "large intestine" of Imms. The walls of this part of the gut are very muscular, deeply folded, and bear numerous chitinous spines. The great development of muscular coats suggests that the final subdivision of food occurs here; this region which is called by Imms the "pyloric valve" has been termed in this paper the *posterior gizzard*.

(*c*) The large intestine named by Holmgren the "Hinterdarmblase" is a large thin-walled sac projecting to one side of the intestine.

(*d*) A narrow tube leading from the large intestine to the slightly expanded rectal portion.

(*e*) Rectum.

As types of the family Metatermitidae *Eutermes dixoni,* and *E. exitiosus,* which very closely resembles it, have been used.

These species agree in most particulars with *Eutermes chaquimayensis* as described by Holmgren, but show some interesting and characteristic structures which are not mentioned in his account.

Macroscopic Structure of Genus Eutermes.

In the genus *Eutermes,* the pharynx is short. The oesophagus extends through the thorax to a dilated conical crop, behind which lies the gizzard. This is lined by large crushing plates, clearly visible in alimentary canals which have been dissected out and mounted whole.

The mid-gut is long, tubular, and U-shaped. From it, at the point of entry of the four Malpighian tubes, leads the hind-gut.

The slender anterior part (= section (*a*)) of the hind-gut is elongated in *Eutermes,* and forms a large loop passing behind the posterior end of the crop. The dilated large intestine, which immediately follows the tubular anterior portion, forms one limb of another loop. It bends back on itself, and is continued as the tubular hind part, which becomes expanded at the posterior end to form the rectum, and opens to the exterior by the anus.

Histology of Eutermes dixoni and E. exitiosus.

Fore-Gut.

The *fore-gut* is similar to that of *E. chaquimayensis.*

The *oesophagus* consists of cubical epithelium, beneath which lies an outer circular and an inner longitudinal muscle layer.

The *crop* has the same two layers as the oesophagus, but its lumen is much dilated.

The *gizzard* is characterized by continuous longitudinal ridges used for grinding food. These ridges are heavily chitinized, and are of two types:—

(1) Tall narrow folds, constricted at the base, which appear club-shaped in transverse section.
(2) Lower cushion-like folds over which the chitinous lining is thinner.

Each ridge contains a core of connective tissue covered by columnar epithelium which secretes the chitin. The edges of the tall ridges are finely serrated. There is a well-developed circular layer of striated muscle.

The *oesophageal* valve or collum, which projects from just below the gizzard into the mid-gut, is composed solely of thin columnar cells resting on a basement membrane.

MID-GUT.

The wall is slightly folded, and is composed of cells arranged in three ways:—

(1) An outer thin epithelium of flattened cells.
(2) Elongated columnar cells, which are broader at their outer edge, and have a striated border, a large nucleus and definite nucleolus. They have the appearance of glandular tissue.
(3) Crypts of cells, lying at right angles to the long axis of the mid-gut. These vary in number and in depth in different specimens. It is probable from their great variability that they are nests of young cells from which the epithelium is regenerated, as suggested by Imms, rather than glandular crypts as assumed by Holmgren. In some sections the crypts are so numerous and deep that the gut wall has a "scalloped" appearance, while in surface view the wall shows a mosaic effect.

The muscle-layers are very poorly developed. The cells seem to be bounded on the outside by a thin membrane only.

Malpighian Tubes, four in number, are lined by a single layer of flattened epithelium, the cells of which frequently contain refractive granules.

HIND-GUT.

(Pl. I., Fig. 1F; Pl. II., Figs. 2A, B, and 3A, B, C, and D.)

Eutermes dixoni and *E. exitiosus* are similar to *E. chaquimayensis* in many ways, but show some conspicuous features not included in Holmgren's description.

Division (*a*) of the hind-gut is very much elongated, and has down one side for half its length a strip of cell continuous with and similar to those forming the mid-gut wall, i.e., apparently glandular cells interspersed with regenerative crypts. This structure extends from the mid-gut to a point half-way between the opening of the Malpighian tubes and division (*b*)—the posterior gizzard.

Except for this strip the wall of this division of the hind-gut is composed of a thin layer of flattened epithelium.

Running longitudinally on each side of the strip is a fold or valve (Fig. 2A). The tissue composing this forms a nearly complete ring at the level of the Malpighian opening (Fig. 3A and B), and then is continued backwards as two projecting folds (Fig. 3C). Anteriorly the folds project inwards towards the middle line. Further back they meet and fuse (Fig. 3D), thus enclosing a space between them and the strip of glandular tissue. No food has ever been observed in this space, even when the main cavity of the gut is full of food.

Each fold consists of two layers (Fig. 2B) :—

(1) An inner flattened or cubical layer on the side towards the glandular strip.

(2) An outer layer of deep columnar cells with clear protoplasm and distinct nuclei.

The Malpighian tubes open above the origin of the valve, i.e.. into the posterior end of the mid-gut.

The region of the hind-gut leading from division (*a*) to the large intestine is very characteristic. It is here termed the *posterior gizzard* (division (*b*)) since in *Eutermes*, as in other genera, the folded muscular walls have a chitinous lining bearing numerous pointed toothlike projections (Fig. 1F). The lumen of this region is narrow and the walls are very muscular. It is probable that it serves to grind any larger particles of food which have been left by the anterior gizzard before they enter the large intestine. Imms working on *Archotermopsis,* names this region the " pyloric valve," and holds that the backwardly-pointing teeth serve to prevent the regurgitation of large particles into the mid-gut. He considers that the fluid contents of the hind-gut can be regurgitated, and are acted upon by the secretion of the mid-gut. Grassi and Sandias (1895) held a similar view, and termed the mid-gut the " chylific ventricle."

Holmgren does not mention the presence in *Eutermes chaquimayensis* of either double valve or mid-gut strip, neither does he record the presence of chitinous teeth in the posterior gizzard region, although he describes " lashes " in the large intestine itself. The writer has seen no constant structures corresponding to his " lashes," but occasionally chitinous threads can be observed stretching from the tip of some of the folds to the food. In other respects the histology of the " large intestine " of *Eutermes dixoni* and *E. exitiosus* is similar to that which Holmgren describes for *E. chaquimayensis.* The more slender part of the gut behind the large intestine and the dilated rectal portion are also similar to those of *E. chaquimayensis.*

Comparison between certain Structures of the Hind-Gut in Eutermes and in Termites of other Families.

1. MASTOTERMITIDAE.

Mastotermes darwiniensis (Figs. 1A, 4).—The wall of the first division of the hind-gut is thrown into longitudinal folds made up of columnar epithelium supported on a pad of connective tissue. For a short distance anterior to the gizzard, the wall bears fine spines pointing forwards. Although there is a fair development of muscles here, they are much less marked than in the posterior gizzard itself.

The posterior gizzard bears four deep longitudinal folds, which are supported by well-developed outer circular and inner oblique muscle layers. In some sections the oblique muscles seem so disposed that one fibre goes to each epithelial spine-bearing cell, suggesting independent movement of the individual teeth. The lining epithelium is composed of short columnar cells, bearing large backwardly-directed spines.

From the gizzard to the large intestine there extend four shallower folds, the chitinous lining of which bears spines like those of the gizzard. The actual spine-bearing surface is greater in *Mastotermes* than in any other termite which the author has examined.

2. PROTERMITIDAE.

In termites of this group, as well as those of the Mastotermitidae and Mesotermitidae, the first division of the hind-gut is not elongated, i.e., the Malpighian tubes arise comparatively near the large intestine.

Archotermopsis wroughtoni.—The histology of the alimentary canal of this termite was fully described by Imms (1919).

> "The first portion of the hind-gut is 0.9-1 mm. in length. . . . . Near the middle of its course is a group of three inwardly-projecting folds, covered by a chitinous lining, and invested with fine backwardly-directed spines. . . . These folds are well-supplied with muscle-fibres, and serve as a valve. . . . At the junction with the large intestine, four groups of columnar epithelial cells pass back from the valve region, and project for a short distance into the cavity of the large intestine."

Imms states that the folded walls of the gut, both anterior and posterior to the posterior gizzard or "valve" have a chitinous lining, but he does not mention the occurrence of spines in either position.

Calotermes insularis (Fig. 1B).—Posterior to the opening of the Malpighian tubes, the hind-gut wall is thrown into longitudinal folds. Anteriorly these consist of columnar epithelium, but this changes to cubical epithelium, i.e., the folds become lower, towards the posterior gizzard.

The portion of these folds next to this gizzard bears, for approximately one-third of the total length, small chitinous teeth which point in the opposite way to those in the gizzard itself. These latter are developed on continuous, rather shallow longitudinal folds, which lead directly into the large intestine. The muscle-layers are not so easily defined as those of *Mastotermes.*

Stolotermes victoriensis (Fig. 1c).—The hind-gut of *Stolotermes* shows a condition intermediate between that found in *Calotermes,* and that of the more highly-developed *Porotermes.* The walls are thrown into folds which are shallower and more uniform than those of *Porotermes,* and are lined by low columnar epithelium. The posterior gizzard is very muscular, the arrangement being similar to that previously described in *Mastotermes.* The chitinized epithelium of the posterior gizzard has large spines, but there are no spines on the folds anterior to it as were described in *Calotermes,* and no toothless folds posterior to it.

Porotermes grandis (Figs. 1D, 5).—Immediately posterior to the entry of the Malpighian tubes, the walls are thrown into irregular longitudinal folds. These may be divided into two series, separated transversely by more flattened cells. The folds of the anterior series are made up of tall columnar epithelium with a small central core of connective tissue; while those of the posterior series consist of slightly lower cells resting on a well-marked basement membrane, and supported by a thick connective tissue cushion. There are no chitinous spines in this region.

Behind these folds is the tooth-bearing posterior gizzard. This shows longitudinal ridges which are lower than those of the preceding series, and bear large chitinous spines. The muscle-layers are thick, and as in *Mastotermes,* consist of inner oblique fibres, sometimes showing a fan-like arrangement beneath the spine-bearing cells, and outer longitudinal fibres. The posterior gizzard is shorter than in *Calotermes,* i.e., the tooth-bearing region is more concentrated. Folds similar to those of the second series lead from the gizzard to the large intestine.

The hind-gut of *Porotermes* seems to be leading on to the *Coptotermes* type. It differs from that of *Eutermes* in those points which have already been described for *Calotermes.*

3. MESOTERMITIDAE.

Coptotermes flavus (Fig. 1E).—Between the entry of the Malpighian tubes and the posterior gizzard, the walls of the hind-gut are folded, and lined with columnar cells.

The posterior gizzard has well-marked teeth, and its walls have numerous irregular longitudinal folds. As in *Porotermes,* there is a definite demarcation between the toothless longitudinal folds and those of the posterior gizzard, and also, as in *Porotermes,* there is a series of toothless folds between gizzard and large intestine. These probably correspond to the "four groups of columnar cells" which Imms describes as extending from the "pyloric valve" of *Archotermopsis* to the large intestine.

These three groups of termites, therefore, although showing considerable variation, resemble each other in general plan, and differ markedly from the Metatermitidae.

Discussion.

The alimentary canals of termites of different families can be arranged in a definite series, corresponding to their systematic positions. This series shows a progressive reduction of the spine-bearing area, together with elaboration of the folds in front of the posterior gizzard, and development of a further series of toothless folds behind it.

The most primitive termite, *Mastotermes,* has, as described above, an extensive spine-bearing area both anterior and posterior to the posterior gizzard. The folds at the beginning of division (*a*) of the hind-gut are relatively simple.

The comparatively unspecialized Protermitidae, *Archotermopsis* and *Calotermes,* closely resemble *Mastotermes.* In *Archotermopsis* the spine-bearing area anterior and posterior to the true gizzard is represented merely by a thickening of the chitinous lining. In *Calotermes* the posterior folds leading into the large intestine are very poorly developed, and there is no thickening of their chitinous lining, but the region anterior to the posterior gizzard retains its teeth. In both *Calotermes* and *Mastotermes* these anterior teeth point in the opposite direction to those of the gizzard.

Stolotermes, although its anterior folds are simple, shallow, and uniform, has no teeth except in the posterior gizzard. *Porotermes* also has its teeth confined to a short thick-walled gizzard, but the anterior folds are very well-developed, and are divided by a circular constriction into two series. There are also definite toothless folds behind the posterior gizzard.

Of the Mesotermitidae, *Coptotermes* very closely resembles *Porotermes* except that the folds behind the posterior gizzard are better developed.

In Metatermitidae such as *Eutermes,* the typical structures of the anterior part of the hind-gut are very much altered, and new parts are introduced. Thus the characteristic double valve may be regarded as a modification of the most anterior folds of other forms, correlated with the elongation of division (*a*) of the hind-gut. The glandular strip, histologically resembling mid-gut tissue, is a new development, as is the thin-walled tube which forms the hinder part of division (*a*).

Termites of this family are regarded by Imms, Tillyard, Wheeler, and others as the most highly-evolved Isoptera. They have usually no intestinal protozoa, although Cleveland (1926) has found a few small amoebae and flagellates in two species of *Amitermes*. Numerous spirochaetes and fungi are usually present. The fungus-gardens described by many authors are made only by termites of this family. Many Metatermitidae are grass-eating; others, however, are wood-feeding.

Although it is, so far, not possible to establish any definite relationship between the mode of nutrition and the structure of the alimentary canal, it is worthy of note that the extreme modifications of structure occur in those termites in which the digestive function of the alimentary canal must differ greatly from that of other groups.

Summary.

(1) The general external features of the alimentary canal in termites are described. The hind-gut can be divided into five regions, termed (*a*), (*b*), (*c*), (*d*), and (*e*), of which (*a*) and (*b*) are treated in some detail.

Division (*a*) is greatly elongated in the Metatermitidae.

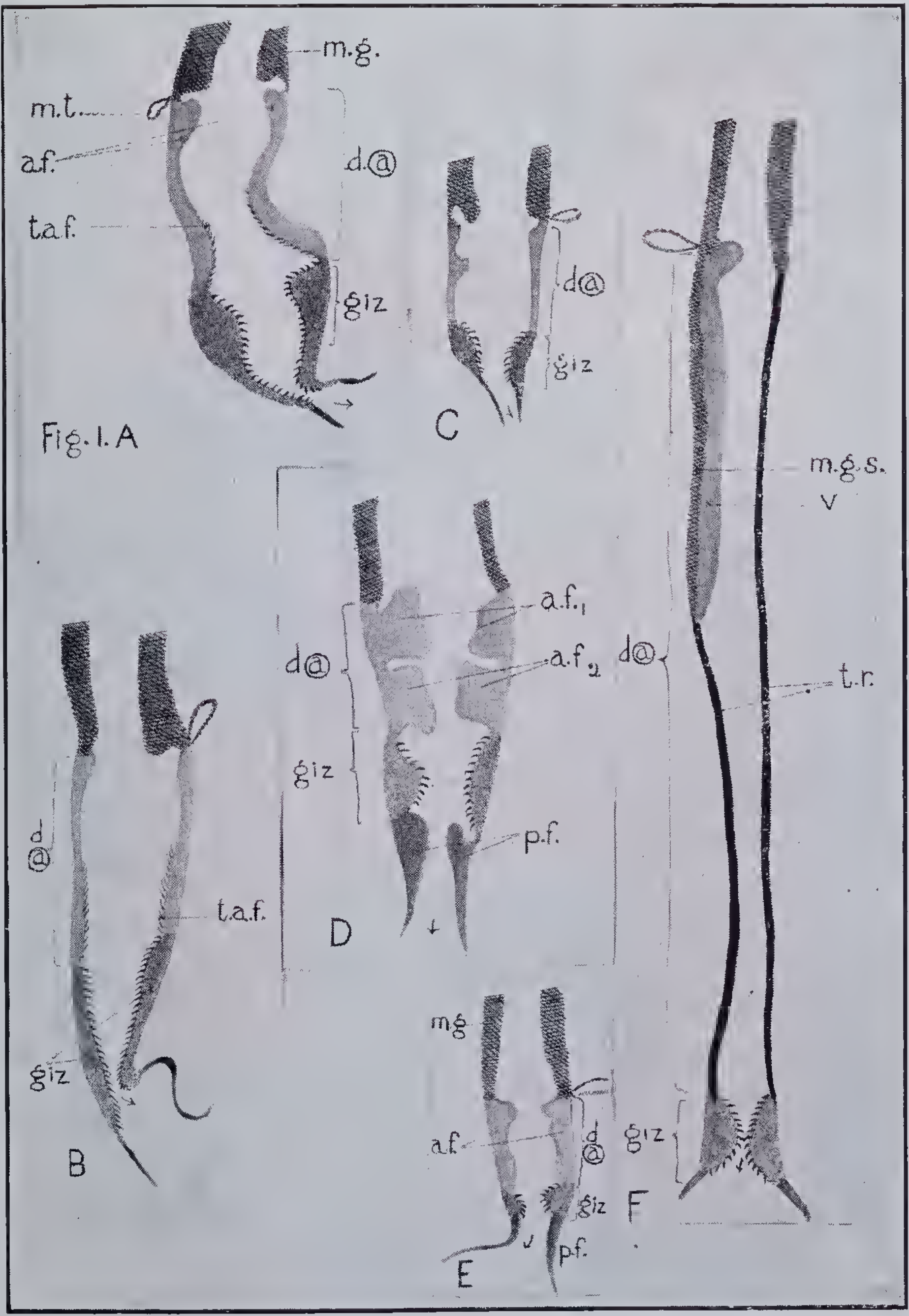
(2) Macroscopic features of the alimentary canals of *Eutermes dixoni* and *E. exitiosus* are described. These are very similar to *Eutermes chaquimayensis* as given by Holmgren (1909).

(3) The histology of the alimentary canal of *E. dixoni* and *E. exitiosus* is described, with particular reference to divisions (*a*) and (*b*) of the hind-gut.

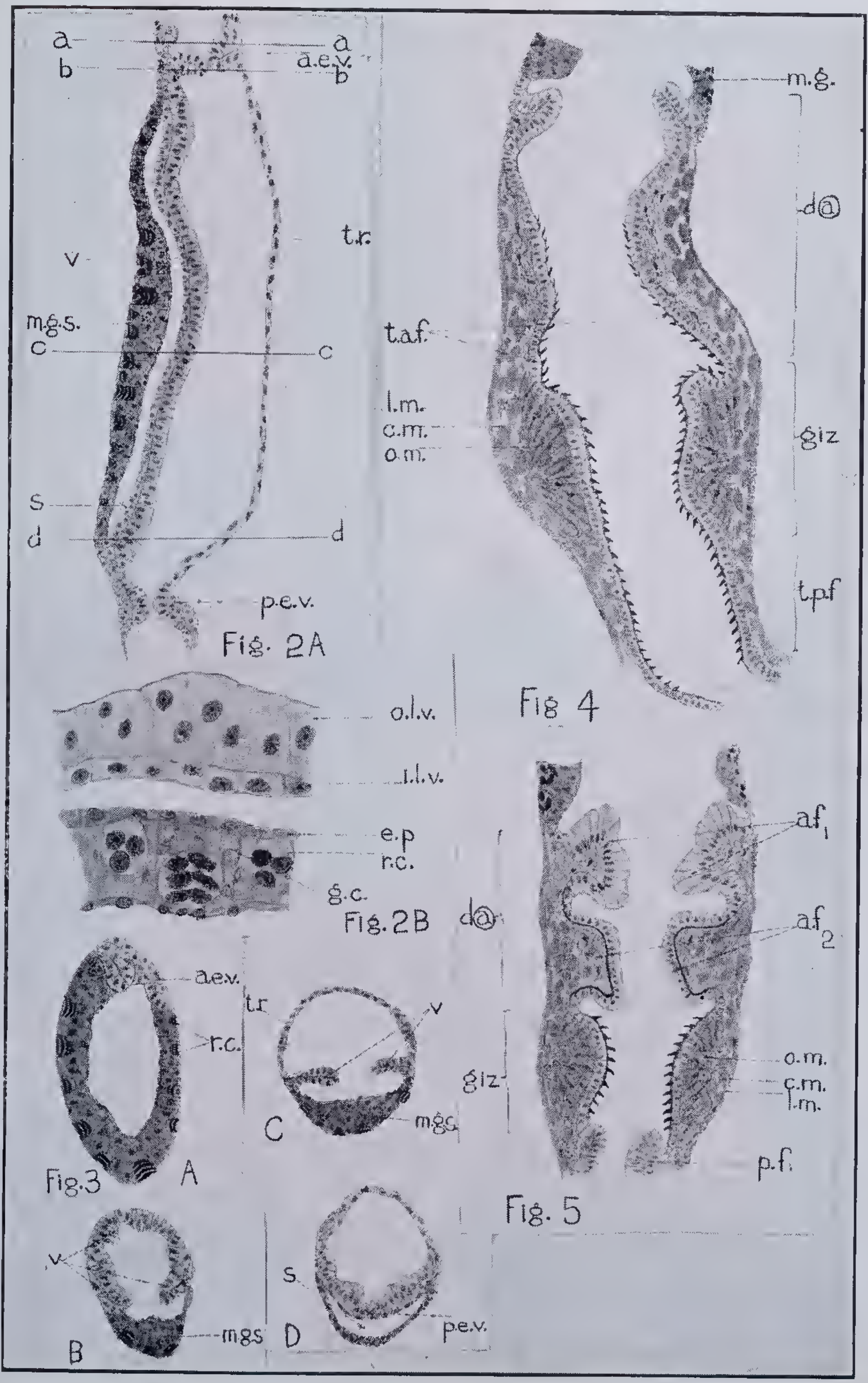
Certain structures are present which were not mentioned by Holmgren. A strip of glandular cells similar to those of the mid-gut extends down one side of division (*a*) of the hind-gut. This strip has on each side of it a fold of epithelium forming a double valve; the folds almost surround the gut at their extreme anterior end, and fuse in the mid-line at the posterior. The rest of division (*a*), which is extremely elongated, is lined by flattened epithelium not seen in termites of other families. Division (*b*) bears chitinous spines, and the wall is deeply folded and very muscular. It has here been termed the posterior gizzard, and leads directly into division (*c*)—the large intestine.

(4) Brief descriptions of the histology of divisions (*a*) and (*b*) of the hind-gut of Mastotermitidae (*Mastotermes*), Protermitidae (*Calotermes, Stolotermes, Porotermes*) and Mesotermitidae (*Coptotermes*) are given. In main features these resemble each other, and differ greatly from Metatermitidae.

(5) The alimentary canals of termites of various families are arranged in series, corresponding to their systematic position. This series shows a reduction of the spine-bearing area, and an elaboration of the folds anterior and posterior to it.



Alimentary Canals of Termites.



Alimentary Canals of Termites.

Eutermes shows the greatest modification of primitive structures, as shown in *Mastotermes*, and also the introduction of new ones. This is probably correlated with its lack of intestinal protozoa, which would imply a mode of nutrition different from that of other termite families.

In conclusion, I wish to thank Professor Agar for his supervision, and Dr. G. Buchanan for her help throughout the year. My thanks are also due to Mr. G. F. Hill, of the Council for Scientific and Industrial Research, who has supplied and identified most of my material.

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Explanation of Plates I. and II.

All outlines were drawn with the camera lucida.

Fig. 1.—Plan only; details of Figs. 2, 3, 4 and 5 were compiled from two or three adjacent sections.

PLATE I.

Fig. 1.—Longitudinal sections of alimentary canals of various termites to show the demarcation of the different regions. (× 40.)

A. *Mastotermes;* B. *Calotermes;* C. *Stolotermes;* D. *Porotermes;* E. *Coptotermes;* F. *Eutermes.*

PLATE II.

Fig. 2.—A., L. S. Alimentary canal of *Eutermes.* (× 66.)

a-a, b-b, c-c, d-d, levels of transverse sections in Fig. 3.

B., H. P. Portion of valve and mid-gut strip. (× 360.)

Fig. 3.—A, B, C, D. T. S. Alimentary canal of ***Entermes*** at levels shown in Fig. AA. (× 66.)

Fig. 4.—L. S. Alimentary canal of *Mastotermes.* (× 66.)

Fig. 5.—L. S. Alimentary canal of *Porotermes.* (× 66.)

LETTERING.

a.e.v. = anterior end of valve. a.f. = folds anterior to posterior gizzard. a.f.$_1$ and a.f.$_2$ = 1st and 2nd series of anterior folds. c.m. = circular muscle-fibres. d. a. = division a of hind-gut. e.p. = epithelium. g.c. = glandular cell. giz. = posterior gizzard. i.l.v. = inner layer of valve. l.m. = longitudinal muscle-fibres. m.g. = mid-gut. m.g.s. = strip of mid-gut like tissue. m.t. = malpighian tube. o.l.v. = outer layer of valve. o.m. = oblique muscle-fibres. p.e.v. = posterior end of valve. p.f. = folds behind posterior gizzard. r.c. = regenerative crypt. s. = space between valve and mid-gut strip. t.a.f. = tooth-bearing folds anterior to posterior gizzard. t.p.f. = tooth-bearing folds posterior to posterior gizzard. t.r. = thin-walled region opposite valve. v. = valve.

[Proc. Roy. Soc. Victoria, **47** (N.S.), Pt. I., 1934.]

Art. II.—*Zooecial Variation within Species of the Catenicellidae.*

By LEO. W. STACH.

[Read 8th March, 1934; issued separately, 22nd December, 1934.]

Introduction.

A close study of the morphology of the zooecia of both Recent and fossil species of the Catenicellidae has shown the necessity for an understanding of the directions in which the zooecia of species of this group tend to vary. It may be safely asserted that all major zooecial structures vary, within certain limits. This paper attempts to illustrate the extent of variation of the zooecia within species.

Waters (1883) realized that zooecia of the Catenicellidae showed considerable variation, and stated that " . . . until the amount of variation in Recent species has been carefully studied, it will be very difficult for palaeontologists to determine the *Catenicellae*." Macgillivray (1895) in his observations on *Catenicella hastata* has remarked that it is a very variable species, but his observations are apparently based on specimens of several species of the genus *Costaticella* Maplestone (1899), which are shown to be distinct by their different types of ovicells.

Variation, together with the imperfect state of preservation of fossil specimens, has led to duplication of fossil species by early workers, and it is believed that this contribution will justify the reduction of the number of species recorded from the Victorian Tertiary deposits.

The zooecia of each species figured were taken from the same zoarium, except the fossil zooecia of *Strophipora harveyi* (Wyv.-Th.).

Variations of Zooecia.

Outline.

The shape of the outline of the zooecia depends mainly on the development of the scapular compartments, which feature will be considered later.

The proportion of length to width, often a distinctive character, varies considerably, depending upon the position of the zooecium in the zoarium. Generally speaking, the older zooecia near the base of the main branch are abnormally elongated; higher up on the main branch the zooecia tend to become broader, while the zooecia near the base of the subsidiary lateral branches tend to elongate, those near the tips of the branches becoming broader.

At the extremities of the branches the developing, immature zooecia are generally broadly oval, and show no distinctive character in their outline, owing to the fact that the lateral compartments have not become fully developed.

Zooecia of individual species vary considerably in size, particularly in the genus *Scuticella* Levinsen (1909), although the majority of the zooecia of a zoarium conform to a fairly constant mean.

APERTURE.

The shape and dimensions of the aperture are practically constant. The proximal rim may be made more salient in older zooecia by elevation of the sternal area just proximal to the aperture as in *Cribricellina cribraria* (Busk). The distal rim in young zooecia is not thickened.

STERNAL AREA.

The variation in proportion of length to width of the zooecia and the development of the proximal and distal infrascapular compartments considerably modify the shape of the sternal area.

The fenestrae vary considerably in size and disposition. The variable number of fenestrae depends to a certain extent on the length of the sternal area, which is generally longer in older zooecia. In a specimen of *Scuticella urnula* (MacG.), five, six, seven, eight, and nine fenestrae were seen on different individuals in a continuous series of twelve zooecia.

LATERAL COMPARTMENTS.

In young zooecia terminating the branches, the scapular compartments are the last to develop. They may or may not lodge avicularia. The scapular compartments may be developed upward into long hollow projecting spines in some species. This is found in the younger zooecia of those species which have this characteristic. In old zooecia of such species the spine is rarely developed, and this feature gives an entirely different aspect to the zooecium.

The scapular compartments may develop into enormous avicularia, almost equal in size to that of the zooecium. In *Scuticella plagiostoma* (Busk), large avicularia and others much smaller are developed. The widest range in size of avicularia is seen in *Strophipora harveyi* (Wyv.-Th.). A series of fossil zooecia are figured to illustrate this. They vary from small avicularia surmounting short tubular protuberances to large avicularia greater than the size of the zooecium itself. In *Claviporella aurita* (Busk) also, the avicularia are almost as large as the zooecia.

The direction in which the avicularium faces is fairly constant in some species, but may vary greatly in others. In *Strophipora harveyi* (Wyv.-Th.), they may be directed forward, obliquely laterally, laterally, or backward. In *Scuticella plagiostoma* (Busk), they may face laterally or forward.

The suprascapular compartments in old zooecia of many species of *Scuticella* face forward, whereas in young zooecia of these species, they are directed upward. They also extend much further proximally in the older zooecia, as in *Scuticella ventricosa* (Busk).

Generally in old zooecia the proximal infrascapular compartment is greatly increased in extent, the distal one being correspondingly reduced. They vary slightly in the direction in which they face.

Conclusion.

Zooecial features, in species of the Catenicellidae, vary considerably, and the sum total of the characters of all structures must be considered in the identification of isolated zooecia of species of this group. The variation between old and young zooecia of individual species is particularly remarkable.

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Explanation of Text Figures.

(All figures drawn with camera lucida.)

Fig. 1.—*Pterocella alata* (Wyv.-Th.). (*a*), (*b*) Zooecia, illustrating variation in proportion of length to width; (*c*) Young zooecium, scapular and suprascapular compartments not fully developed.

Fig. 2.—*Cribricellina rufa* (MacG.). (*a*) Elongate zooecium from base of subsidiary lateral branch; (*b*) Broad convex zooecium from tip of branch.

Fig. 3.—*Scuticella lorica* (Busk). (*a*), (*b*) Zooecia showing variation in size.

Fig. 4.—*Costaticella solida* (Levinsen). (*a*) Mature zooecium; (*b*) Young zooecium, distal lateral compartments not developed.

Fig. 5.—*Scuticella urnula* (MacG.). (*a*) Single zooecium showing seven fenestrae; (*b*) Geminate pair showing nine fenestrae on mother zooecium and five on daughter zooecium.

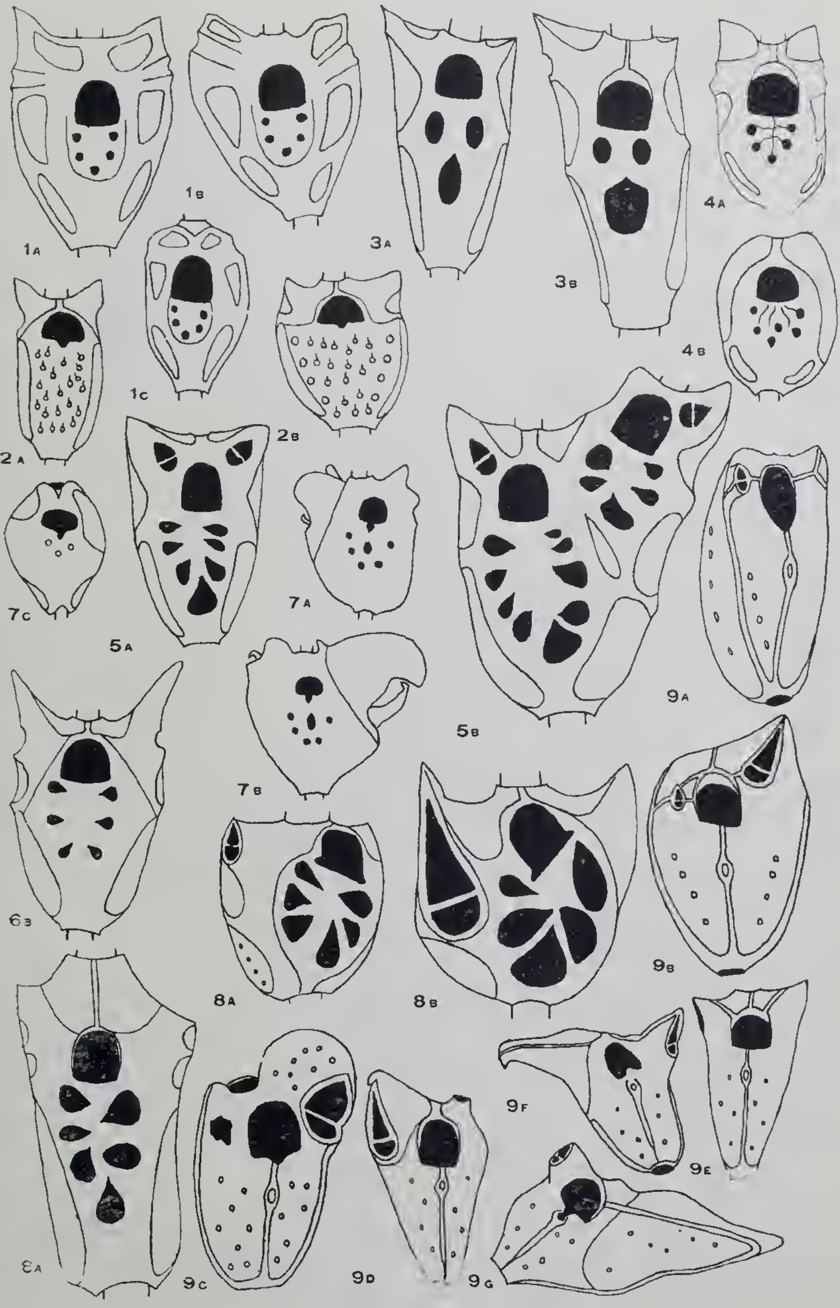
Fig. 6.—*Scuticella ventricosa* (Busk). (*a*) Old zooecium, showing great development of suprascapular and proximal infrascapular compartments, reduction of scapular compartments lacking the upward projection into a hollow spine; (*b*) Mature zooecium.

Fig. 7.—*Claviporella aurita* (Busk). (*a*) Zooecium with normally developed scapular compartment; (*b*) Zooecium showing abnormally large scapular compartment; (*c*) Young zooecium lacking distal lateral compartments.

Fig. 8.—*Scuticella plagiostoma* (Busk). (*a*) Zooecium showing small laterally-directed avicularium; (*b*) Zooecium showing large avicularium facing forward.

Fig. 9.—*Strophipora harveyi* (Wyv.-Th.). (*a*) Zooecium showing small forwardly-directed avicularium mounted on tubular protuberance; (*b*) Zooecium showing large forwardly-directed and small protruding avicularium; (*c*) Zooecium showing large bulbous forwardly-directed avicularium; (*d*) Zooecium showing large laterally-directed and small upwardly-protruding avicularium; (*e*) Zooecium showing two normal laterally-directed avicularia; (*f*) Zooecium showing abnormally large laterally-directed avicularium; (*g*) Zooecium showing enormous backwardly-directed avicularium.

(Magnification is in every case × 45.)



Zooecial Variation.

[Proc. Roy. Soc. Victoria, 47 (N.S.), Pt. I., 1934.]

Art. III.—*Victorian Tertiary Catenicellidae, Part II.*

By LEO. W. STACH.

(With Plate III.)

[Read 8th March, 1934: issued separately, 22nd December, 1934.]

Introduction.

This paper consists of a revision of the fossil species of the genera of the Catenicellidae having a terminal gonoecium, which are here grouped in the sub-family Scuticellinae, containing the greatest number of genera and species in the Catenicellidae.

There is usually very little evidence to aid the correlation of gonoecia of the Scuticellinae with their zooecia, since during the process of fossilization, the chitinous joints between the zooecia and gonoecia decay, resulting in their separation and scattering, while in those genera with adnate ovicells the characters of the pertaining zooecia serve as evidence for correlation. Certain characteristics of the zooecia are sometimes expressed in the gonoecia, but a correlation can only be tentative in those genera with a large number of species. In those genera with few species, such as *Strophipora* Macgillivray, the choice is correspondingly restricted, and a correlation of the gonoecia with their zooecia is then possible.

Terminal gonoecia are extremely rare in Tertiary deposits owing to the small number produced by each zoarium; they are consequently of little importance in stratigraphical palaeontology, and are therefore not dealt with in this contribution, except where correlation has been possible.

A study of variation in the zooecia of Recent species (Stach, 1934), has shown the necessity for a considerable reduction in the number recorded from the Victorian Tertiary deposits. Macgillivray's figures (1895) of some of the species of this group are misleading, and Maplestone, who in many cases did not have the opportunity of examining Macgillivray's types, has unfortunately duplicated several of Macgillivray's species. This has been revealed by an examination of both Macgillivray's and Maplestone's type specimens. Maplestone has also described young zooecia of previously described forms as separate species.

In those genera having several species, keys have been supplied for ready identification. As far as possible, the least variable characteristics have been employed, but it is necessary to refer to the descriptions in order to check the identification of abnormal zooecia.

Systematic Description.

Sub-family VITTATICELLINAE.

Genus **Vittaticella** Maplestone, 1901.

VITTATICELLA ELEGANS (Busk, 1852).

(Pl. III., figs. 1-4.)

Catenicella elegans Busk, 1852, p. 361, fig. 2; *idem*, 1852, 2, p. 10, pl. ix., figs. 1-4. P. H. Macgillivray, 1859, p. 161; *idem*, 1868, p. 143. Hutton, 1880, p. 181. Jelly, 1889, p. 36. Ortmann, 1890, p. 27, pl. ii., fig. 1. Kirkpatrick, 1890, p. 17; *idem*, 1890, 2, p. 611. Thornely, 1905, p. 109.

Vittaticella elegans (Busk), Maplestone, 1901, p. 203. Waters, 1913, p. 484, pl. lxv., figs. 1-7, 12. Okada, 1921, p. 27. Livingstone, 1927, p. 57; *idem*, 1929, p. 99. Canu and Bassler, 1929, pp. 439, 440, text figs. 173 A, E, F, 174 A-N.

Catenaria elegans (Busk), Levinsen, 1909, p. 255, pl. xiii., figs. 3A-B, pl. xxi., fig. 2A.

Description.—To Levinsen's description (1909), it needs to be added that the narrow vittae have a single row of six to ten pores.

Dimensions.—Fossil specimen: Zooecium, length 0.42 mm., width 0.23; aperture, diameter 0.08. Recent specimen: Zooecium, length 0.41, width 0.22; aperture, diameter 0.08 (from Two Sisters' Is.).

Distribution.—Recent: Pacific Ocean: Bass Strait 48 fathoms, Port Dalrymple on stones at low water (Busk, 1852); "Challenger" station 188 (Torres Strait) 28 fathoms; 163 a off Twofold Bay (N.S.W.) 150 fathoms, Port Cooper, Banks' Peninsula (Busk, 1884); off Two Sisters' Island (Bass Strait) (coll. J. Gabriel); Three Kings' Island 65 fathoms, Stewart Island 35 fathoms (New Zealand) (Livingstone, 1929); Sagamibai (Japan) (Ortmann, 1890); shallow sea at Hamajima and Kushimoto (Japan) (Okada, 1921); Tizard bank (China Sea) 6 fathoms (Kirkpatrick, 1890); the authorities of the Australian Museum, Sydney, have kindly supplied the following additional Australian localities: Broughton Island (N.S.W.), 12-22 miles N. ½ E. from Green Cape (N.S.W.) 39-46 fathoms, Port Darwin (Northern Territory), Noosa Head (South Queensland), Oyster Bay (Tasmania) 40 fathoms, Banks' Strait (Tas.), 50 miles S. of Cape Wiles (South Australia).

Indian Ocean: Gulf of Manaar, attached to floating oyster cages (Thornely, 1905); Arafura Sea, Zanzibar channel 10 fathoms (Waters, 1913); Algoa Bay (Busk, 1884).

Atlantic Ocean: Madeira, J. G. J. (*fide* Busk, 1884); "Challenger" station 135 Tristan da Cunha 60-1,100 fathoms, 122 South Atlantic 32-400 fathoms (Busk, 1884).

Lower Miocene: Forsyth's (below remanié nodule bed) on Grange Burn Creek (Hamilton).

Observations.—This well-known species, unlike the vast majority of the Catenicellidae, has a surprisingly wide distribution throughout tropical and temperate seas. This, however, constitutes its first record as a fossil. Maplestone (1904) has indicated that Waters had recorded this species from Muddy Creek and Curdie's Creek. It was, however, "*Catenicella elegans* var. *buskii*" which he recorded.

It appears to thrive in waters of moderate depth, but it is interesting to note Busk's record of its occurrence on stones at low water at Port Dalrymple.

As is usual with such a widespread species, it varies somewhat, particularly in its dimensions, length of vittae, and proportion of length to width. It is readily recognized, however, by its narrow vittae facing forward with a single row of pores, and the generally elongate form of the zooecia, which, however, does not approach the elongation of *V. praetenuis* (MacG., 1895), to which it is allied.

VITTATICELLA SPECIOSA (Macgillivray, 1895).

Catenicella elegans var. *buskii* Waters (non *C. buskii* Wyv.-Th.), 1881, p. 317, pl. xvi., figs. 42, 43; *idem*, 1883, p. 430. Jelly, 1889, p. 35.
Caloporella speciosa Macgillivray, 1895, p. 19, pl. ii., fig. 15.
Vittaticella speciosa (Macgillivray), Maplestone, 1901, p. 202; *idem*, 1904, p. 189. Stach, 1933, p. 90, pl. viii., figs. 1-3.
Vittaticella cruciformis Maplestone, 1911, p. 271, pl. xxxviii., fig. 13.

Observations.—The geminate pair figured by Waters (1881) has the vittae facing obliquely forward, whereas *Vittaticella buskii* (Wyv.-Th.) has the vittae facing laterally. His comparison of this form with *Cornuticella perforata* (Busk) is also disallowed by this observation. Maplestone (1904) has apparently referred this form to *Vittaticella elegans* (Busk), since the only localities given for it (under the name of *Catenicella elegans* Busk), are those given by Waters (1883), which Maplestone acknowledges. Waters did not record *V. elegans* Busk from the Victorian Tertiary. The form figured agrees in all respects with *Vittaticella speciosa* (MacG., 1895). The following additional locality should thus be added to those of *V. speciosa*; Curdie's Creek (Waters).

Marcus (1920) has included *C. elegans* var. *buskii* Waters (non *C. buskii* Wyv.-Th.) in his synonymy of *Catenicella buskii* Wyv.-Th.

Artificial Key to the Tertiary Species of Vittaticella Maplestone.

1.	Vittae facing forward	2
	Vittae facing laterally	3
	Vittae facing obliquely	4
2.	Vittae with one row of pores	5
	Vittae with two rows of pores ..	*V. grandis* (Mapl.)
	Vittae with four rows of pores ..	*V. enormis* (Mapl.)
3.	Zooecium ovate	6
	Zooecium hastate	*V. rostrata* (Mapl.)
4.	Vittae with one row of pores	7
	Vittae with two rows of pores	*V. speciosa* (MacG.)
5.	Length: width of zooecium as 2 : 1 ..	*V. elegans* (Busk)
	Length: width of zooecium as 3 : 1 ..	*V. praetenuis* (MacG.)
6.	Marginal flange in dorsal view	*V. teres* (MacG.)
	No marginal flange in dorsal view ..	*V. hannafordi* (MacG.)
7.	Length: width of zooecium as 3 : 1 ..	*V. sacculata* (Busk)
	Length: width of zooecium as 2 : 1 ..	*V. insignis* (MacG.)

Sub-family SCUTICELLINAE, sub.-fam. nov.

Description.—Internodes of one zooecium or a geminate pair, rarely three zooecia in each internode.

Avicularia well developed, usually facing laterally and situated about the level of the aperture; suprascapular and infrascapular compartments usually membranous, rarely calcified; one or two pairs of infrascapular compartments. Avicularia rarely present on adzooecial side of mother zooecium of geminate pair.

Sternal area may be ornamented by fenestrae, hollow spines separated by fissures, scattered pores, a submarginal row of pores around a central spinous area, or may be represented by a median ridge with a central pore.

Ovicell a terminal gonoecium.

Genus **Scuticella** Levinsen, 1909.

Scuticella Levinsen, 1909, p. 221 Canu and Bassler, 1927, p. 21; *idem*, 1929, pp. 444, 446, 447, text-fig. 179.

Genotype.—*Scuticella plagiostoma* (Busk, 1852).

Observations.—This genus, well-described and figured by Levinsen (1909) and Canu and Bassler (1929), is characterized by its fenestrate sternal area and non-calcified suprascapular compartments. Although Levinsen designated no genotype, the first species, *S. plagiostoma* (Busk), which he described very fully, should be chosen, although a more typical species of this group could have been selected.

SCUTICELLA AURICULATA (Macgillivray, 1895).

Catenicella auriculata Macgillivray, 1895, p. 15, pl. ii., fig. 5. Maplestone, 1904, p. 186.

Catenicella baccata Maplestone, 1899, p. 8, pl. ii., figs. 15, 15A; *idem*, 1904, p. 186.

Description.—Zooecium elliptical in outline; greatest width, at middle level of zooecium, slightly greater than one-third length of zooecium.

Slightly convex proximal rim, in middle third of zooecium, situated one-third of distance proximally from distal connecting-tube aperture. Height of aperture equals half distance from proximal rim to distal connecting-tube aperture.

Elongate, semielliptical sternal area, equalling in length slightly more than one-third length of zooecium, has nine to thirteen fenestrae.

Scapular compartments, situated at level of distal half of aperture, lodge small avicularia facing obliquely forward. Suprascapular compartments well-developed, broad, and facing obliquely forward. Distal infrascapular compartments extend to middle level of zooecium, the proximal infrascapular compartment extending to base; both face obliquely forward.

Dorsal surface moderately convex, depressed at projecting distal angles. Axis of daughter zooecium inclined at 60 deg. to that of mother zooecium.

Ovicell not observed.

Dimensions.—Zooecium from Glencoe No. 7 bore 790 feet; Zooecium, length 0.56 mm., width 0.24; aperture, diameter 0.10.

Distribution.—Lower Miocene: Clifton Bank (Muddy Creek, Hamilton), Campbell's Point (Mulder), north side of Armstrong's Creek 10 chains east of Torquay-road, Mitchell River at Bairnsdale, Knight's bore at Dartmoor, Glencoe No. 7 bore 790 feet, Mooroduc No. 6 bore 4 feet-6 feet, Balcombe Bay.

Upper Oligocene: Glencoe No. 7 bore 1,270 feet.

Observations.—This species is characterized by its elongated zooecium and sternal area with nine to thirteen fenestrae and the small obliquely-directed avicularia, which, however, tend to become laterally-directed in old zooecia of this species.

The geminate pair described as *Catenicella baccata* by Maplestone (1899) agrees in every detail with *S. auriculata* (MacG.). The fact of its having opaque spots on the dorsal surface (it is not papillose as stated by Maplestone, 1899) is considered to be of no systematic value.

Waters (1904) has compared his *Catenicella frigida* with this species. It differs from *S. auriculata* (MacG.) in having only five to eight fenestrae, while the observed range in *S. auriculata* is nine to thirteen. There seems no doubt that these two species are distinct.

SCUTICELLA URNULA (Macgillivray, 1887).

(Plate III., figs. 5, 6.)

Catenicella urnula Macgillivray, 1887, p. 34, pl. i., figs. 2, 2A; *idem,* 1879-1890, dec. xv., p. 174, pl. 146, figs. 2, 2A; *idem,* 1887, 2, p. 197. Jelly, 1889, p. 39.

Catenicella nobilis Macgillivray, 1895, p. 9, pl. i., fig. 3. Maplestone, 1904, p. 187.

Catenicella acutirostris Maplestone, 1899, p. 9, pl. ii., fig. 19; *idem,* 1904, p. 186.

Scuticella urnula (Macgillivray), Levinsen, 1909, p. 231, pl. xi., figs. 4A-B, pl. xx., figs. 1A-E. Stach, 1934, p. 15, text-figs. 5A-B.

Description.—Levinsen (1909) has given a satisfactory diagnosis of this species.

Dimensions.—Zooecium from Mitchell River, Bairnsdale; Zooecium, length 0.61 mm., width 0.37; aperture, diameter 0.12.

Distribution.—Recent: Port Phillip Heads (Macgillivray).

Middle Miocene: Glencoe No. 7 bore, 330 feet.

Lower Miocene: Clifton Bank (Muddy Creek, Hamilton), Forsyth's (below remanié nodule bed) on Grange Burn (Hamilton), Campbell's Point (Mulder), Mitchell River at Bairnsdale.

Observations.—A comparison of Macgillivray's type of *Catenicella nobilis* and Maplestone's type of *Catenicella acutirostris* with Recent zooecia of *S. urnula* (MacG.) has shown that they differ in no essential feature.

This species is characterized by its prominent avicularia constantly facing directly forward. The size of the avicularia varies slightly in both fossil and Recent zooecia.

SCUTICELLA LORICA (Busk, 1852).

(Text-figs. 1-4.)

Catenicella lorica Busk, 1852, p. 358; *idem*, 1852, 2, p. 6, pl. i., figs. 1-3. Maplestone, 1882, p. 49. Jelly, 1889, p. 37 (early synonymy). Harmer, 1902, p. 310.

Scuticella lorica (Busk), Levinsen, 1909, pp. 215, 219. Stach, 1934, p.   , text-figs. 3A, B.

Description.—Zooecium subrectangular in outline, tapering slightly to proximal connecting-tube aperture; greatest width, at summit of zooecium, equals two-thirds length of zooecium.

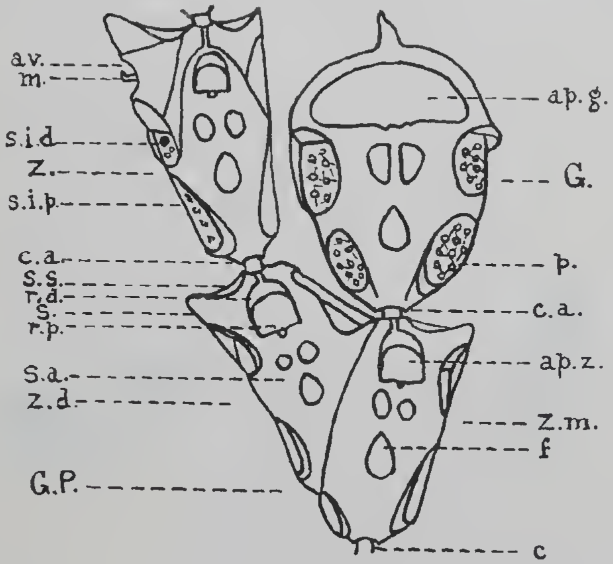


FIG. 1.

(Magnification ×45.)

FIG. 1.—*Scuticella lorica* (Busk), fragment of zoarium illustrating terminology; ap.g., aperture of gonoecium; ap.z., aperture of zooecium; av., avicularium; c. connecting tube; c.a., connecting-tube aperture; f., fenestra; G., gonoecium; G.P., geminate pair; m., mandible; p., septulae; r.d., distal rim of aperture; r.p., proximal rim of aperture; s., scapular compartment; s.a., sternal area; s.i.d., distal infrascapular compartment; s.i.p., proximal infrascapular compartment; s.s., suprascapular compartment; Z., single zooecium; Z.d., daughter zooecium; Z.m., mother zooecium.

Straight proximal rim in middle third of zooecium, with partly closed small sinus, situated one-quarter of length of zooecium proximally from distal connecting-tube aperture. Lateral and distal margins as in *S. marginata* (Waters).

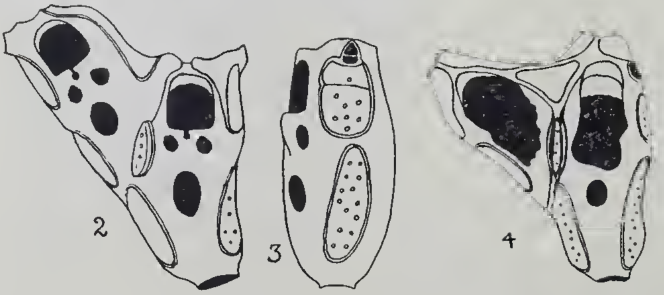
Broad, smooth sternal area, slightly elevated in region of proximal rim, has three large elliptical fenestrae, the proximal median fenestra, equalling about two-thirds area of aperture, being the largest.

Scapular compartments, variable in size, and usually lodging a small avicularium, situated at and above level of distal half of aperture, facing directly laterally. Upwardly-directed suprascapular compartments shallow and of small extent. Distal infrascapular compartments, pierced by about seven septulae, reach almost to middle level of zooecium. Proximal infrascapular compartments pierced by numerous septulae, and flanged at their proximal extremities. Both infrascapular compartments face almost directly laterally.

Dorsal surface shows moderately convex elongated hexagonal area flanged at proximal and distal ends by lateral compartments.

Axis of daughter zooecium inclined at 40 deg. to that of mother zooecium of a geminate pair.

Gonoecium ovate in outline, erect, surmounted by an upwardly-projecting avicularium. Sternal area, two-thirds length of gonoecium, has three large fenestrae. Aperture almost equal in width to that of gonoecium. Height of aperture one-third its width. Two pairs of lateral compartments, below level of proximal rim, and facing obliquely forward, are pierced by numerous septulae.



FIGS. 2-4.

(Magnification × 45).

FIG. 2.—*Scuticella lorica* (Busk). Recent incinerated geminate pair from Bass Strait cable. FIG. 3.—*S. lorica* (Busk). Recent incinerated single zooecium from Bass Strait cable showing avicularium and septulae of infrascapular compartments in side view. FIG. 4.—*S. lorica* (Busk). Fossil geminate pair from Mitchell River cliffs at Bairnsdale.

Dimensions.—Recent specimen, single zooecium: Zooecium, length 0.65 mm., width 0.41; aperture, diameter 0.1. Recent specimen, mother zooecium: Zooecium, length 0.60, width 0.27. Fossil specimen, mother zooecium: Zooecium, length 0.69, width 0.31.

Distribution.—Recent: Southern Australia: Bass Strait cable, off Two Sisters' Island (Bass Strait), Western Port (J. Gabriel); Bass Strait, 45 fathoms (Busk); off Devonport and Launceston (Tasmania), off Gabo Island 100-200 fathoms (Australian Museum coll.).

Lower Miocene: Mitchell River at Bairnsdale.

Observations.—This species is readily distinguished by its three large fenestrae and subrectangular outline.

A single geminate pair of this species was found fossil. It agrees closely with the dimensions of Recent zooecia, and shows the large elliptical proximal median fenestra, and a suggestion of the two distal fenestrae on the mother zooecium. The disposition of the lateral compartments is identical with that of *S. lorica*. Although the specimen is damaged, it undoubtedly belongs to this species.

The fossil and a Recent geminate pair are figured for comparison.

SCUTICELLA GIPPSLANDICA, sp. nov.

(Text fig. 7; Pl. III., figs. 7, 8.)

Catenicella marginata Macgillivray (*non* Waters), 1895, pl. i., fig. 26.

Description.—Zooecium somewhat elliptical in outline; greatest width, across centre of zooecium below avicularia, equals about two-thirds length of zooecium.

Straight proximal rim of aperture, in middle third of zooecium, situated slightly above level of greatest width, aperture extending less than half distance to summit from proximal rim, the much-thickened distal and lateral rims forming an arc greater than a semicircle. Two small denticles above level of proximal rim.

Scutiform sternal area extends two-thirds distance from proximal rim to distal connecting-tube aperture bordered by wide raised margins of infrascapular compartments. Fenestrae six or seven.

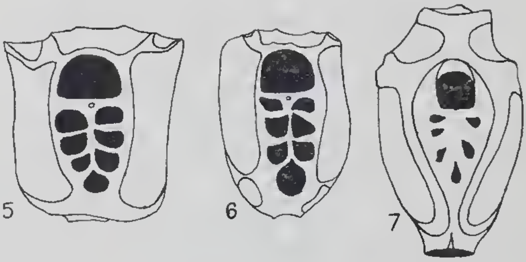
Scapular compartments, level with upper half of aperture, face directly laterally and equal in extent half height of aperture. A broad raised band descends from summit to distal rim and laterally to the scapular compartments, then to base, the latter branch bordering a single infrascapular compartment on each side of zooecium facing obliquely laterally.

Dorsal surface smooth, moderately convex in axial region, merging into a distinct flange around lateral margins of zooecium.

Geminate pair or ovicell not observed.

Dimensions.—Holotype, from Mitchell River: Zooecium, length 0.69 mm., width 0.50; aperture, diameter 0.10. Specimen from Largon Creek: Zooecium, length 0.79, width 0.54; aperture, diameter 0.11.

Distribution.—Lower Miocene : Mitchell River at Bairnsdale, Largon Creek off Toorloo Arm (8 miles E. of Lakes Entrance).



FIGS. 5-7.

(Magnification × 45).

FIG. 5.—*Scuticella wilsoni* (Macgillivray). Recent normal zooecium showing single long infrascapular compartment as found in *S. gippslandica* sp. nov. FIG. 6.—*S. wilsoni* (Macgillivray). Recent abnormal zooecium showing trace of development of a proximal infrascapular compartment. FIG. 7.—*S. gippslandica*, sp. nov. Zooecium showing the single long infrascapular compartment typical of this fossil species.

Observations.—Macgillivray has placed this distinctive form with *Scuticella marginata* (Waters) from which it differs in many respects. The elliptical outline, single infrascapular compartment and the lesser number of fenestrae distinguish this species.

It is closely allied to *Scuticella wilsoni* (MacG.) (1879-1890), both having a single long infrascapular compartment and seven fenestrae. *S. wilsoni,* however, differs in the distinctly quadrate outline and the greater proportionate width of its zooecia.

This somewhat rare species has shown but little variation except in the number of fenestrae and the dimensions mentioned above.

S. gippslandica is restricted to the Miocene deposits of Gippsland, to which feature it owes its specific designation.

SCUTICELLA AMPLA (Waters, 1881).

Catenicella ampla Waters, 1881, p. 317, pl. xvi., figs. 46, 50; *idem,* 1882, p. 259; *idem,* 1883, p. 429. Macgillivray, 1895, p. 9, pl. i., figs. 4-6. Maplestone, 1904, p. 186; *idem,* 1911, p. 266, pl. xxxvii., fig. 2.

Catenicella stricta Macgillivray, 1895, p. 15, pl. ii., fig. 6. Maplestone, 1904, p. 188.

Catenicella lunipora Macgillivray, 1895, p. 16, pl. ii., fig. 2. Maplestone, 1904, p. 187.

Catenicella ovoidea Macgillivray, 1895, p. 16, pl. ii., figs. 3, 4. Maplestone, 1904, p. 187.

Calpidium morningtoniensis Maplestone, 1898, p. 20, pl. ii., figs. 17, 18; *idem*, 1904, p. 190.

Catenicella dennanti Maplestone, 1899, p. 9, pl. ii., fig. 17; *idem*, 1904, p. 187.

Description.—Zooecium subovate in outline; greatest width, at middle level of zooecium, equals about one-half its length.

Slightly convex proximal rim, made salient by elevation of distal median portion of sternal area, situated in middle third of zooecium one-quarter of distance proximally from distal connecting-tube aperture.

Broad sternal area, with five to nine pyriform fenestrae, equals in length two-thirds that of zooecium.

Scapular compartments extend from level of proximal rim to slightly above level of distal connecting-tube aperture and face directly laterally, appearing as auricular processes in frontal view. Suprascapular compartments small in extent and upwardly-directed. Distal infrascapular compartments extend to a level one-half to two-thirds distance proximally from distal connecting-tube aperture, proximal infrascapular compartments extending to base of zooecium. Both infrascapular compartments face obliquely backward.

Dorsal surface with a median longitudinal groove flanked by the depressions of the lateral compartments. Axis of daughter zooecium inclined at 30° to that of mother zooecium.

Ovicell not observed.

Dimensions.—Zooecium from Moorooduc No. 6 bore 4 feet-6 feet: Zooecium, length 0.71 mm., width 0.45; aperture, diameter 0.13. Zooecium from Glencoe No. 7 bore 790 feet: Zooecium, length 0.67, width 0.39; aperture, diameter 0.13.

Distribution.—Lower Miocene: Clifton Bank (Muddy Creek, Hamilton), Flinders, Torquay, Campbell's Point (Mulder), Griffin's near Batesford, Hamilton bore 80 feet-85 feet, Glencoe No. 7 bore 580 feet, 650 feet, 660 feet, 705 feet, 725 feet, 790 feet, Moorooduc No. 6 bore 4 feet-6 feet, Grice's Creek (near Frankston), Balcombe Bay, Mitchell River at Bairnsdale, Curdie's Creek.

Upper Oligocene: Glencoe No. 7 bore 1270 feet.

Observations.—This species is characterized by its large auricular laterally-directed avicularia and its distinctive dorsal surface, the appearance of which is caused by the infrascapular compartments being directed obliquely backward. In some zooecia the infrascapular compartments tend to become laterally-directed.

An examination of the type specimen of *Catenicella stricta* MacG. revealed no fundamental difference from typical specimens of *S. ampla,* the zooecium being slightly more elongate than normal zooecia of this species.

Catenicella lunipora MacG. represents an old zooecium of *S. ampla.*. It has the typical avicularia of the latter species, but has fewer fenestrae (five) and the infrascapular compartments tend to become laterally-directed, both departures being due to normal zooecial variation within species of the Catenicellidae (Stach, 1934).

Macgillivray's figures of *Catenicella ovoidea* show a frontal view in all respects similar to his figures of *S. ampla* (1895, pl. i., figs. 5, 6), but his representation of the dorsal view does not show the infrascapular compartments directed obliquely backward as is seen in Macgillivray's plesiotypes. This species was also recognized as *S. ampla* by T. S. Hall, who examined the Macgillivray collection after the latter's death.

The fenestrae of the type specimen of *Catenicella dennanti* Mapl. are not strongly bordered as Maplestone has figured them. The specimen has the same disposition of lateral compartments and the typical avicularia of *S. ampla.*

The apparent great protrusion of the distal rim of the aperture of *Calpidium morningtoniensis* Mapl. is exaggerated in Maplestone's figures, the specimen showing the thickened distal and lateral rims of the aperture accentuated by fracture of the elevated distal portion of the sternal area. This zooecium agrees in all respects with typical zooecia of *S. ampla.*

SCUTICELLA MARGINATA (Waters, 1881).

Catenicella marginata Waters, 1881, p. 317, pl. xvi., figs. 44, 45. Macgillivray, 1895, p. 13, pl. i., figs. 25-27. Maplestone, 1904, p. 187.

Catenicella daedala Macgillivray, 1895, p. 14, pl. i., fig. 28. Maplestone, 1898, p. 16, pl. i., figs. 4, 5; *idem,* 1904, p. 187.

Catenicella bairnsdalei Maplestone, 1911, p. 266, pl. xxxvii., fig. 8.

Description.—Zooecium oval in outline, slightly constricted near base; greatest width, one-third of distance proximally from distal connecting-tube aperture, equals one-half length of zooecium.

Proximal rim of aperture, in middle third of zooecium, situated one-third distance proximally from distal connecting-tube aperture. Aperture extends one half to two-thirds distance from proximal rim to distal connecting-tube aperture, lateral and distal margins forming an arc greater than a semicircle; distal rim greatly thickened. Proximal rim straight with two short denticles a short distance up lateral margins.

Elongate scutiform sternal area extends two-thirds distance from proximal rim to proximal connecting-tube aperture, bordered by wide raised margins of infrascapular compartments. Fenestrae, eight to eleven.

Scapular compartments, facing directly laterally, situated at middle level of aperture and equal in extent half height of aperture; a broad band extends half way round summit descending to and following distal rim, then branching out to scapular compartments, forming border of suprascapular compartments. Below scapular compartment is the small elliptical depressed area of the distal infrascapular compartment facing obliquely forward, extending one-third distance from base of scapular to proximal connecting-tube aperture, bordered by a broad raised band continuing around proximal infrascapular compartment which extends as a depressed elliptical area to base.

Dorsal surface smooth, very convex in axial region; lateral chambers form narrow flange around zooecium.

Axis of daughter zooecium inclined at 50 deg. to that of mother zooecium.

Ovicell unknown.

Dimensions.—Old zooecium from Mitchell River: Zooecium, length 0.92 mm., width 0.52; aperture, diameter 0.12. Young zooecium from Balcombe Bay: Zooecium, length 0.60, width 0.42; aperture, diameter 0.12.

Distribution.—Middle Miocene: Glencoe No. 7 bore, 330 feet.

Lower Miocene: Clifton Bank (Muddy Creek, Hamilton), Forsyth's (below remanié nodule bed), Flinders, Griffin's (near Batesford), Campbell's Point (Lake Connewarre), Thompson's Creek (south of Moriac), mouth of Spring Creek, north side of Armstrong's Creek 10 chains east of Torquay-road, Batesford Tunnel marl, Prowse's marl pit (2 miles west of Mount Moriac), Mitchell River at Bairnsdale, Largon Creek off Toorloo Arm (8 miles east of Lakes Entrance), Dartmoor (at foot of railway bridge over Glenelg River), Knight's bore (Dartmoor), Curdie's Creek (Waters), Hamilton bore 80 feet-85 feet, Glencoe No. 7 bore 650 feet–1,110 feet, Mooroduc No. 6 bore 4 feet–6 feet, Balcombe Bay.

Upper Oligocene: Glencoe No. 7 bore, 1,270 feet.

Observations.—This very common and widespread species varies considerably as regards size, proportion of length to width and convexity of dorsal surface.

In zoaria of the Catenicellidae there is a tendency for the early-formed zooecia to be larger in size, elongated, and with a slightly curved dorsal surface. The young zooecia at the summits of the curling tips of the branches tend to be shorter and more convex dorsally.

The form described as *Catenicella daedala* by Macgillivray, represents a young zooecium of *Scuticella marginata,* no fundamental difference being apparent between the two forms. Macgillivray's figured specimens of *C. marginata* represent old zooecia of the species.

An examination of Maplestone's type of *Catenicella bairnsdalei* shows that it is a rotund young zooecium of *S. marginata* (Waters).

This form is readily distinguished by the thick margins of the lateral compartments and the great thickening of the distal rim of the aperture.

SCUTICELLA PAPILLATA (Maplestone, 1899).

Catenicella papillata Maplestone, 1899, p. 7, pl. ii., figs. 14, 14A-B; *idem,* 1904, p. 187.

Catenicella concinna Maplestone, 1911, p. 267, pl. xxxvii., fig. 5.

Description.—Zooecium elongate-oval in outline; greatest width, at upper level of scapular compartments, equals about half length of zooecium.

Slightly concave proximal rim, in middle third of zooecium, situated less than one-third distance proximally from distal connecting-tube aperture. Height of aperture slightly more than one-half distance from proximal rim to distal connecting-tube aperture. A pair of small denticles on lateral margins of aperture.

Small elongate sternal area, equal in length to one-third that of zooecium, with eight to ten fenestrae.

Scapular compartments, at level of distal rim of aperture, lodge small avicularia facing directly laterally. Suprascapular compartments face obliquely forward. Distal infrascapular compartments extend to middle level of zooecium, the proximal infrascapular compartments extending to proximal connecting-tube aperture; both face obliquely forward.

Dorsal surface moderately convex, slightly flattened at distal end of zooecium.

Axis of daughter zooecium inclined at about 80 deg. to that of mother zooecium.

Ovicell not observed.

Dimensions.—Syntype (single zooecium) from Clifton Bank; Zooecium, length 0.52 mm., width 0.29; aperture, diameter 0.09.

Distribution.—Lower Miocene: Campbell's Point (Lake Connewarre), Clifton Bank (Muddy Creek, Hamilton), Flinders, Batesford Tunnel marl, Knight's bore (Dartmoor), Hamilton bore 80 feet–85 feet, Balcombe Bay.

Observations.—An examination of the types of *Catenicella papillata* Maplestone and *C. concinna* Maplestone reveals no fundamental difference between the two specimens.

This species is characterized by its elongate oval outline and the position of the scapular compartments on a level with the distal rim of the aperture.

The "papillose dorsal surface" of Maplestone (1899) is seen to be quite smooth in the syntype (specimen showing dorsal view), but opaque white spots are visible in the otherwise transparent dorsal surface. This is believed to be due to external influences either in life or during preservation, and is therefore regarded as being of no specific value. Other specimens from the type locality (Clifton Bank) agree in every feature with the types, except in not having a spotted dorsal surface.

The name *Catenicella concinna* has previously been used by Macgillivray (1881) for a form which Maplestone (1899) and Jelly (1889) regard as synonomous with *Strongylopora pulchella* (Maplestone), and therefore Maplestone's name for his later *Catenicella concinna* (1911) could not be used in any case.

SCUTICELLA VENTRICOSA (Busk, 1852).

Catenicella ventricosa Busk, 1852, p. 357; *idem*, 1852, 2, p. 7, pl. ii., figs. 1, 2, pl. iii., figs. 1-5. Macgillivray, 1859, p. 160; *idem*, 1868, p. 143. Waters, 1883, p. 431. Kirchenpauer, 1885, p. 535. Jullien, 1888, p. 275, pl. xi., fig. 3. Jelly, 1889, p. 39 (early bibliography). Macgillivray, 1889, p. 25; *idem*, 1890, p. 6; *idem*, 1895, p. 9, pl. i., figs. 1, 2. Hamilton, 1898, p. 194. Maplestone, 1904, p. 188.

Scuticella ventricosa (Busk), Levinsen, 1909, p. 227, pl. xi., figs. 6A-B, pl. xx., figs. 5A-C. Livingstone, 1928, p. 116. Canu and Bassler, 1929, p. 439, text-fig. 173 D, p. 447, text-figs. 179 A-F. Livingstone, 1929, p. 97. Stach, 1934, text.-figs. 6A-B.

Description.—Levinsen (1909) has given an excellent diagnosis of this species.

Dimensions.—Recent zooecium from Bass Strait: Zooecium, length 0.58 mm., width 0.39; aperture, diameter 0.13. Fossil zooecium from Mitchell River: Zooecium, length 0.55, width 0.33; aperture, diameter 0.13.

Distribution.—Recent: Victoria: Bass Strait 45 fathoms (Busk); Queenscliff, Western Port, Sealers' Cove (Macgillivray); off Two Sisters' Island (Bass Strait) (J. Gabriel coll.); Lorne, Glennie Group (Wilsons Promontory) (Austr. Mus. coll.). New South Wales: 3–4 miles off Eden (J. Gabriel coll.); Port Jackson, Newcastle, Broughton Island, 12–22 miles north ½ east from Green Cape 39–46 fathoms, La Perouse (Botany Bay) (Austr. Mus. coll.). South Australia: Robe (Macgillivray); Sanders Bank (Kangaroo Island) (Austr. Mus. coll.). Tasmania: 7 miles north-east of Cape Pillar 50–60 fathoms, Oyster

Bay 40 fathoms, off Launceston and Devonport, Circular Head (Austr. Mus. coll.). New Zealand: Napier, Wellington, Dunedin, Foveaux Strait (Hamilton); Stewart Island 35 fathoms, 10 miles off Cape Maria van Diemen 50 fathoms, Colville Channel 35 fathoms (Livingstone).

Lower Miocene: Clifton Bank (Muddy Creek, Hamilton), Campbell's Point (Lake Connewarre), Spring Creek (Torquay), Mitchell River at Bairnsdale, Glencoe No. 7 bore 705 feet; Mooroodue No. 6 bore, 4 feet–6 feet.

Observations.—This common species has a wide distribution in south-east Australian and New Zealand waters of moderate depth.

The fossil specimens have been compared with incinerated zooecia of typical Recent specimens from Bass Strait, with which they are identical. In the fossil specimens examined, however, the upward protrusion of the scapular compartments is invariably broken off.

Scuticella lata, sp. nov.

(Plate III., figs. 9, 10.)

Description.—Zooecium semielliptical in outline; greatest width, at level of distal connecting-tube aperture, almost equals length of zooecium.

Straight proximal rim, in middle third of zooecium, situated less than one-third of the distance proximally from distal connecting-tube aperture. Aperture semielliptical, equalling in height three-quarters of distance from distal connecting-tube aperture to proximal rim, below which is a large subcircular ascopore.

Broad sternal area equal in length to half of that of zooecium. Fenestrae five to seven.

Scapular compartments, at and above level of distal half of aperture, lodge small avicularia facing directly laterally. Upwardly-directed shallow suprascapular compartments of small extent. Distal infrascapular compartments extend to middle level of zooecium, proximal infrascapular compartments extending below it almost to proximal connecting-tube aperture, both facing obliquely forward.

Dorsal surface moderately convex, depressed at distal angles.

Axis of daughter zooecium inclined at 35 deg. to that of mother zooecium.

Ovicell not observed.

Dimensions.—Recent zooecium from Western Port: Zooecium, length 0.60 mm., width 0.49; aperture, diameter 0.14. Fossil zooecium from Forsyth's: Zooecium, length 0.53, width 0.43; aperture, diameter 0.14.

Distribution.—Recent: Western Port (J. Gabriel coll.).

Lower Miocene: Clifton Bank (Muddy Creek, Hamilton), Bell's Beach (between Torquay and Point Addis), Prowse's marl pit (2 miles west of Mount Moriac), Flinders, Forsyth's (below remanié nodule bed), Mitchell River at Bairnsdale.

Observations.—This species is characterized by the broad outline of the zooecium, the large scapular compartment projecting upward and the subcircular ascopore. The fossil specimens, although the sternal area is damaged in all those examined, agree in all other details with the Recent specimens, as will be seen from a comparison of the figures.

S. lata is allied to *S. margaritacea* (Busk) (1852), from which it is distinguished by its broader outline and comparatively large ascopore.

SCUTICELLA INTERMEDIA (Macgillivray, 1868).

(Text-figs. 8, 9.)

Catenicella intermedia Macgillivray, 1868, p. 127. Jelly, 1889, p. 37 (early bibliography). Macgillivray, 1895, p. 16, pl. ii., fig. 1. Maplestone, 1904, p. 187.

Scuticella intermedia (Macgillivray), Levinsen, 1909, pp. 215, 219.

Catenicella longispinosa Maplestone, 1911, p. 268, pl. xxxvii., fig. 8.

Description.—Zooecium broadly semielliptical in outline; greatest width, at level of distal connecting-tube aperture, almost equals length of zooecium.

Slightly convex proximal rim, one-quarter width of zooecium in length, situated one-third distance proximally from distal connecting-tube aperture. Height of aperture equals three-quarters distance from proximal rim to distal connecting-tube aperture. A minute ascopore below proximal rim.

Ovate sternal area, equalling in length half that of zooecium, is ornamented with five to eight pyriform fenestrae varying considerably in size.

Scapular compartments, facing directly laterally, usually developed into large avicularia extending to level of distal connecting-tube aperture from level of proximal rim. Suprascapular compartments, of small extent, face forward and upward. Distal infrascapular compartments extend to a level almost one-half distance distally from proximal connecting-tube aperture, the proximal infrascapular compartments extending to base; both face obliquely laterally.

Dorsal surface slightly convex, flattened along lateral margins and distal angles of zooecium.

Axis of daughter zooecium inclined at 40 deg. to that of mother zooecium.

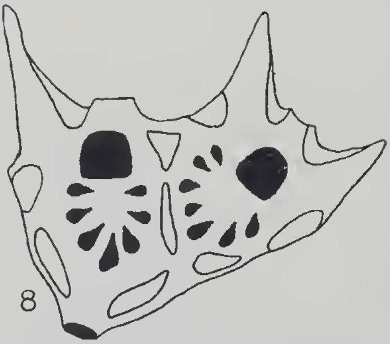
Ovicell not observed.

Dimensions.—Recent specimen: Zooecium, length 0.50 mm., width 0.46; aperture, diameter 0.13. Fossil zooecium from Campbell's Point: Zooecium, length 0.53, width 0.50; aperture, diameter 0.14.

Distribution.—Recent: Port Phillip Heads, off Launceston and Devonport (Tasmania) (Austr. Mus. coll.).

Lower Miocene: Clifton Bank (Muddy Creek, Hamilton), Flinders, Griffin's (near Batesford), Campbell's Point (Lake Connewarre), Mitchell River at Bairnsdale, Balcombe Bay.

Observations.—This species is closely allied to *Scuticella lata,* sp. nov., from which it is distinguished by its very minute ascopore and the relatively large size of the fenestrae. In some zooecia the minute ascopore is only represented by a narrow sinus.



Figs. 8, 9.

(Magnification × 45).

Fig. 8.—*Scuticella intermedia* (Macgillivray). Maplestone's type of *Catenicella longispinosa.* Fig. 9.—*S. intermedia* (Macgillivray). Recent zooecium showing large avicularium approaching the size of those in Fig. 8.

This species is characterized by its minute ascopore and the large avicularia extending upward to the level of the distal connecting-tube aperture. No essential difference could be observed between fossil and Recent zooecia of this species.

The specimen described as *Catenicella longispinosa* by Maplestone (1911) is a mature zooecium of this species, in which the avicularia are very well developed. In the small fragment of a Recent zoarium examined by the author, some zooecia had avicularia approaching the size of those seen in Maplestone's specimen, and there appear to be no grounds for regarding *Catenicella longispinosa* Maplestone as a separate species.

Artificial Key to the Victorian Tertiary Species of Scuticella Levinsen.

1.	Scapular compartments directed laterally ..	2
	Scapular compartments directed obliquely forward	*S. auriculata* (MacG.)
	Scapular compartments facing directly forward	*S. urnula* (MacG.)
2.	Sternal area with three oval fenestrae ..	*S. lorica* (Busk)
	Sternal area with more than three fenestrae	3
3.	One infrascapular compartment	*S. gippslandica* sp. nov.
	Two infrascapular compartments ..	4
4.	Non-spinous scapular compartment extending above level of distal connecting-tube aperture	*S. ampla* (Waters)
	Not as above	5
5.	Elongate sternal area bounded by thick margins of proximal lateral compartments	*S. marginata* (Waters)
	Not as above	6
6.	Scapular compartment developed upward into a hollow spine	*S. ventricosa* (Busk)
	Not as above	7
7.	Zooecium elongate	*S. papillata* (Mapl.)
	Zooecium broad	8
8.	Large sub-circular ascopore present ..	*S. lata* sp. nov.
	Not as above	*S. intermedia* (MacG.)

Genus **Costaticella** Maplestone, 1899.

Costaticella Maplestone, 1899, p. 9. Canu and Bassler, 1927, p. 21; *idem,* 1929, pp. 445, 448, text-fig. 180.

Costicella Levinsen, 1909, p. 233.

Genotype.—*Costaticella lineata* (Macgillivray, 1895).

Observations.—An examination of Recent specimens of species of Levinsen's genus *Costicella* and fossil specimens of Maplestone's genus *Costaticella* shows that no generic distinction can be drawn between the fossil and Recent groups. *C. lineata* (MacG., 1895), has a sternal area similar in structure to that of *C. hastata* (Busk, 1852), and the lateral compartments are all calcified in both species. The form described as *Costaticella escharoides* by Maplestone (1899) is regarded as a mature zooecium of *C. lineata* (MacG., 1895), Macgillivray's holotype obviously being a young zooecium. Contrary to Maplestone's statement (1899), the sternal area has fenestrae at the base of the hollow spines, but they are comparatively small in his figured specimen.

Levinsen (1909) has given a good account of this genus, and the distinctive characteristics are seen to be that the lateral compartments are all calcified and that the sternal area is ornamented with a series of hollow spines separated by fissures and with a corresponding number of fenestrae at their bases.

Macgillivray's *Catenicella latifrons* (1895) has the lateral compartments partly uncalcified, and it is proposed to erect a new sub-genus *Costaticellina* for its reception. This sub-genus has all the characteristics of typical species of *Costaticella,* but differs in not having the suprascapular compartments calcified.

COSTATICELLA LINEATA (Macgillivray, 1895).

Catenicella lineata Macgillivray, 1895, p. 14, pl. i., fig. 30. Maplestone, 1904, p. 187.

Costaticella lineata (Macgillivray), Maplestone, 1899, p. 10. Canu and Bassler, 1929, p. 445.

Costaticella escharoides Maplestone, 1899, p. 10, pl. i., fig. 13; *idem,* 1904, p. 190.

Description.—Zooecium subrectangular in outline; width equals approximately one-half length of zooecium.

Slightly concave proximal rim, in centre third of zooecium, situated one-third of distance proximally from distal connecting-tube aperture. Height of aperture slightly greater than one-half distance from proximal rim to distal connecting-tube aperture.

Elongate sternal area, about three times as long as wide, has about 27 small oval fenestrae, with as many hollow spines separated by fissures and equals almost one-half length of zooecium.

Scapular compartments, situated at level of proximal half of aperture, face directly laterally. Suprascapular compartments extend slightly above level of distal connecting-tube aperture. Distal infrascapular compartments, facing directly laterally, extend slightly below middle level of zooecium, proximal infrascapular compartments extending to proximal connecting-tube aperture.

Dorsal surface depressed along lateral margins.

Axis of daughter zooecium inclined at 50 deg. to that of mother zooecium.

Ovicell not observed.

Dimensions.—Mother zooecium of Maplestone's figured specimen: Zooecium, length 0.70 mm., width 0.37; aperture, diameter 0.13.

Distribution.—Lower Miocene: Campbell's Point (Lake Connewarre), Glencoe No. 7 bore 650 feet, Balcombe Bay.

Observations.—Canu and Bassler (1929) have erroneously named a figure of *Costaticella hastata* (Busk) taken from Harmer (1902) as *Costaticella lineata* (MacG.).

Macgillivray's type of *Catenicella lineata* is a young zooecium of Maplestone's *Costaticella escharoides,* as an examination of the type specimens readily shows. In the holotype of *C. lineata* the distal lateral compartments are not developed.

This species is characterized by its subrectangular outline and the elongated sternal area with the exceptionally large number of fenestrae and spines.

Contrary to Maplestone's statement (1899), small oval fenestrae are visible at the outer extremities of the spines of the sternal area of his figured specimen.

COSTATICELLA CRIBRIFORMIS (Waters, 1881).

Catenicella cribriformis Waters, 1881, p. 317, pl. xvi., fig. 39; *idem*, 1883, p. 428. Maplestone, 1904, p. 186.

Catenicella ampliata Maplestone, 1899, p. 8, figs. 16, 16A; *idem*, 1904, p. 186.

Description.—Zooecium broadly semielliptical in outline; greatest width, at summit of zooecium, equals slightly less than length of zooecium.

Straight proximal rim, equalling one-quarter width of zooecium in length, situated more than one-third distance proximally from distal connecting-tube aperture. Height of aperture equals nearly two-thirds distance from proximal rim to distal connecting-tube aperture.

Short broad sternal area, equalling in length slightly more than one-third length of zooecium, has ten to eleven fenestrae.

Small scapular compartments, situated at middle level of aperture, face laterally. Large suprascapular compartments extend above level of distal connecting-tube aperture. Distal infrascapular compartments extend to a level almost two-thirds distance proximally from distal connecting-tube aperture and face laterally. Proximal infrascapular compartments extend to base and face obliquely forward.

Dorsal surface not observed.

Axis of daughter zooecium inclined at 40 deg. to that of mother zooecium.

Ovicell not observed.

Dimensions.—Zooecium from Balcombe Bay: Zooecium, length 0.59 mm., width 0.55; aperture, diameter 0.14.

Distribution.—Lower Miocene: Griffin's (near Batesford), Campbell's Point (Lake Connewarre), Spring Creek (Torquay), Curdie's Creek (Waters), Balcombe Bay.

Observations.—Of this rare species only the two specimens on Maplestone's type slide have been seen. The one which Maplestone did not figure is the more perfect.

This species is characterized by the broadness of the zooecium and its ten to eleven fenestrae. The type specimen figured by Waters (1881) is not as broad as the zooecia designated *Catenicella ampliata* by Maplestone (1899), but otherwise there is no essential difference between the two forms.

COSTATICELLA BENECOSTATA (Levinsen, 1909).

(Pl. III., figs. 11, 12.)

Catenicella hastata Waters (non Busk, 1852), 1883, p. 431. Jelly, 1889, p. 37 (Waters, 1883 only). Macgillivray, 1895, p. 13, pl. i., figs. 21-23. Maplestone, 1904, p. 187.

Costicella benecostata Levinsen, 1909, p. 237, pl. xii., figs. 1A-B, pl. xx., fig. 9A.

Observations.—Levinsen (1909) has given a figure of the aperture and sternal area of this species, but gives no idea of the general outline of the zooecium either in the description or figure. He has, however, named his figures on the plate *Catenicella hastata*, and it may be assumed that the general appearance of the zooecium is that of *Costaticella hastata* (Busk, 1852).

The sternal area of Macgillivray's (1895) figured specimens and of all the specimens examined agree exactly with Levinsen's figures. The observed range in the number of fenestrae was nine to fourteen.

This species differs from *Costaticella hastata* (Busk) in the more elongate form of the zooecium and sternal area and the greater number of fenestrae.

Waters (1883) has recorded *Catenicella hastata* from Waurn Ponds and Torquay, but this is open to doubt since no specimen in the National Museum collections or in those of the author can be referred to *Costaticella hastata* (Busk).

Recent specimens of *C. benecostata* have not been available for examination and comparison.

Dimensions.—Zooecium from Clifton Bank (Muddy Creek): Zooecium, length 0.47 mm., width 0.28; aperture, diameter 0.10.

Distribution.—Recent: Western Port (Levinsen).

Lower Miocene: Waurn Ponds and Spring Creek (Torquay) (Waters), Clifton Bank (Muddy Creek, Hamilton), Griffin's (near Batesford), Campbell's Point (Lake Connewarre), Batesford Tunnel marl dump, Mitchell River at Bairnsdale, Glencoe No. 7 bore 580 feet-790 feet, Balcombe Bay.

COSTATICELLA HIULCA (Maplestone, 1899).

Catenicella hiulca Maplestone, 1899, p. 9, pl. ii., fig. 18; *idem*, 1904, p. 187.

Costicella cuspidata Levinsen, 1909, p. 235, pl. xx., figs. 6A-C.

Description.—Levinsen (1909) has given a satisfactory diagnosis of this species.

Dimensions.—Of holotype: Zooecium, length 0.53 mm., width 0.49; aperture, diameter 0.11. Recent zooecium from Western Port: Zooecium, length 0.47, width 0.42; aperture, diameter 0.11.

Distribution.—Recent: Port Phillip (Levinsen), Western Port (J. Gabriel, coll.).

Lower Miocene: Clifton Bank (Muddy Creek, Hamilton).

Observations.—A comparison of Recent specimens with Maplestone's type of *Catenicella hiulca* shows that these two forms are identical. Maplestone's obscure figure is rather misleading, but an examination of the specimen leaves no doubt as to the two forms being conspecific.

This species is characterized by its broad zooecium and its sternal area with seven to ten fenestrae and spines.

Sub-genus **Costaticellina,** sub-gen. nov.

Description.—This sub-genus has all the characters of the genus *Costaticella* Maplestone, except that the suprascapular compartments are not calcified.

Observations.—This sub-genus has been erected for the reception of *Catenicella latifrons* Macgillivray, which differs from all other species of *Costaticella* in having uncalcified suprascapular compartments.

COSTATICELLA (COSTATICELLINA) LATIFRONS (Macgillivray, 1895).

Catenicella latifrons Macgillivray, 1895, p. 15, pl. i., fig. 31. Maplestone, 1904, p. 187.

Plicopora daedala Macgillivray, 1895, p. 26, pl. iv., fig. 4.

Catenicella orbicularis Maplestone, 1898, p. 15, pl. i., fig. 1; *idem*, 1904, p. 187.

Description.—Zooecium broadly subovate in outline; greatest width, at level of scapular compartments, almost equals length of zooecium.

Slightly concave proximal rim, in middle third of zooecium, situated one-quarter of distance proximally from distal connecting-tube aperture. Height of aperture equals two-thirds distance from proximal rim to distal connecting-tube aperture.

Sub-circular sternal area, equalling in length nearly three-quarters that of zooecium, is ornamented by about fifteen hollow spines separated by fissures with a corresponding number of fenestrae.

Scapular compartments, at level of distal half of aperture, face laterally or obliquely upward. Restricted suprascapular compartments face upward and obliquely forward. Distal infrascapular compartments extend to middle level of zooecium and proximal infrascapular compartments extend to proximal connecting-tube aperture, both facing directly laterally.

Dorsal surface depressed in middle line and along the lateral and distal margins.

Axis of daughter zooecium inclined at 30 deg. to that of mother zooecium.

Ovicell not known.

Dimensions.—Mother zooecium of holotype: Zooecium, length 0.56 mm., width 0.42; aperture, diameter 0.14.

Distribution.—Lower Miocene: Clifton Bank (Muddy Creek, Hamilton), Griffin's (near Batesford), Campbell's Point (Lake Connewarre), Flinders, Glencoe No. 7 bore 580 feet, Moorooduc No. 6 bore 4 feet-6 feet, Balcombe Bay.

Observations.—This species is characterized by its broad outline and the very large sternal area. The latter is not always preserved, but the bases of the hollow spines may be seen as a submarginal row of crenulations.

Macgillivray's *Plicopora daedala,* which he has figured with the distal end downwards, is an old zooecium of this species which has the sternal area worn off.

Maplestone's *Catenicella orbicularis* is a well-preserved old zooecium of this species, and differs in no essential feature from *C. latifrons.*

Artificial Key to the Victorian Tertiary Species of Costaticella Maplestone.

1.	Suprascapular compartments not calcified	*C.* (*Costaticellina*) *latifrons* (MacG.)
	Suprascapular compartments calcified ..	2
2.	More than twenty-five fenestrae	*C. lineata* (MacG.)
	Less than twenty-five fenestrae	3
3.	Length: width of zooecium as 1 : 1	*C. cribriformis* (Waters)
	Length: width of zooecium as less than 1 : 1	4
4.	Zooecium elongate	*C. benecostata* (Levinsen)
	Zooecium broad	*C. hiulca* (Maplestone)

Genus **Digenopora** Maplestone, 1899.

Digenopora Maplestone, 1899, p. 6. Canu and Bassler, 1927, p. 21; *idem,* 1929, p. 449, text figs. 181 C, D.

Genotype.—*Digenopora retroversa* (Macgillivray, 1895).

Observations.—Maplestone (1899) described the single species *Digenopora compta* as belonging to this genus, but an examination of the type specimen of *Catenicella retroversa* (Macgillivray, 1895), shows it to be an old zooecium of Maplestone's *Digenopora compta,* between which a connecting series can readily be obtained.

The distinctive characteristics of this genus are that the suprascapular compartments are not calcified, and the frontal combines the sternal ornamentation of *Costaticella* Maplestone, 1899, and *Strongylopora* Maplestone, 1899.

This genus is placed provisionally in the sub-family Scuticellinae since no ovicell which can be correlated with the genotype has been discovered. Its general affinities are, however, with this group, as is shown by its uncalcified suprascapular compartments and its sternal area ornamented by hollow spines as in *Costaticella*, but with the additional submarginal row of oval pores, typical of *Strongylopora* Maplestone, 1899 which, however, is not a member of the Scuticellinae.

To Maplestone's description (1899) should be added. that the suprascapular compartments are not calcified.

DIGENOPORA RETROVERSA (Macgillivray, 1895).

Catenicella cribraria Macgillivray (non Busk, 1852), 1895, pl. i., fig. 20.

Catenicella retroversa Macgillivray, 1895, p. 13, pl. i., fig. 24, Maplestone, 1904, p. 188.

Digenopora compta Maplestone, 1899, p. 6, pl. i., figs. 10, 10a; *idem*, 1904, p. 190. Canu and Bassler, 1929, p. 449, text figs. 181 C, D.

Description.—Zooecium ovate in outline; greatest width, at level of scapular compartments, equals two-thirds length of zooecium.

Broad short sternal area, less than one-third length of zooecium, bears seven to nine hollow spines and fenestrae. A submarginal row of nine to thirteen oval fenestrae borders the sternal area.

Scapular compartments, at and above level of distal rim of aperture, lodge small avicularia facing directly laterally and slightly upward. Forwardly and upwardly-directed shallow suprascapular compartments have a proximal extension bordering distal rim of aperture. Distal infrascapular compartments, facing directly laterally, extend to middle level of zooecium, proximal infrascapular compartments extending to proximal connecting-tube aperture.

Slightly convex proximal rim, in middle third of zooecium, situated more than one-third distance proximally from distal connecting-tube aperture. Height of aperture equals one-half to two-thirds distance from proximal rim to distal connecting-tube aperture.

Dorsal surface depressed at lateral margins and distal angles of zooecium.

Axis of daughter zooecium inclined at 50 deg. to that of mother zooecium.

Ovicell not known.

Dimensions.—Mature zooecium from Balcombe Bay: Zooecium, length 0.63 mm., width 0.46; aperture, diameter 0.14. Old zooecium from Hamilton bore 80 feet–85 feet: Zooecium, length 0.55, width 0.48; aperture, diameter 0.14.

Distribution.—Lower Miocene: Clifton Bank (Muddy Creek, Hamilton), Campbell's Point (Lake Connewarre), Griffin's (near Batesford), Flinders, Hamilton bore 80 feet-85 feet, Mitchell River at Bairnsdale, Glencoe No. 7 bore 650 feet, 705 feet, 790 feet, Mooroodue No. 6 bore 4 feet-6 feet, Balcombe Bay.

Upper Oligocene: Glencoe No. 7 bore 1,270 feet.

Observations.—Macgillivray's figure of *Catenicella retroversa* represents an old zooecium of the same species as the mature zooecia figured by Maplestone (1899) under the name of *Digenopora compta.* In old zooecia of this species the lateral margins tend to become backwardly-directed, and the sternal area is more heavily calcified; the outline of the zooecium becomes sub-circular.

The specimen figured by Macgillivray (1895) under the name of *Catenicella cribraria* is seen on examination to be a zooecium of this species, as suggested by Maplestone (1899) who, however, also thought it might be a distinct species.

The position of the avicularia, the characters of the sternal area and the suprascapular compartments extending around the distal rim of the apertur are distinctive features of this species.

Genus **Cribricellina** Canu and Bassler, 1927.

Cribricella Levinsen, 1909, pp. 220, 238 (name preoccupied by Canu, 1902, *fide* Canu and Bassler, 1927).

Cribricellina Canu and Bassler, 1927, p. 21; *idem,* 1929, p. 449, text fig. 182.

Genotype.—*Cribricellina rufa* (Macgillivray, 1868).

Observations.—This very natural group is characterized by the sternal area being perforated by scattered pores and by the presence of uncalcified suprascapular compartments. Levinsen's name, as pointed out by Canu and Bassler (1927), is preoccupied (Canu, 1904).

CRIBRICELLINA CRIBRARIA (Busk, 1852).

Catenicella cribraria Busk, 1852, p. 359; *idem,* 1852, 2, p. 9, pl. v., figs. 3, 4. Macgillivray, 1859, p. 161; *idem,* 1868, p. 143. Jelly, 1889, p. 36 (early bibliography). Macgillivray, 1889, p. 25; *idem,* 1895, p. 12. Hamilton, 1898, p. 194. Maplestone, 1904, p. 186.

Cribricella cribraria (Busk), Levinsen, 1909, p. 240, pl. xii., figs. 8 a-c.

Cribricellina cribraria (Busk), Canu and Bassler, 1929, p. 450, text figs. 182 H-K. Livingstone, 1929, p. 97. Stach, 1934, p. 15.

Description.—Levinsen (1909) has given an adequate description of this species.

Dimensions.—Recent zooecium: Zooecium, length 0.47 mm., width 0.38; aperture, diameter 0.11. Zooecium from Glencoe No. 7 bore 330 ft.; Zooecium, length 0.53, width 0.35; aperture, diameter, 0.11.

Distribution.—Recent: Victoria: Queenscliff, Port Phillip, Sealers' Cove (Macgillivray); off Two Sisters' Is. (J. Gabriel coll.); Griffith's Point (Aust. Mus. coll.). New South Wales: 3-4 miles off Eden 25-30 fathoms, 12-22 miles N. ½ E. from Green Cape 39-46 fathoms (Aust. Mus. coll.). Queensland: Port Denison (Aust. Mus. coll.). Tasmania: off Launceston and Devonport (Aust. Mus. coll.). New Zealand: Akaroa (Levinsen); Napier, Wellington, Dunedin (Hamilton); Three Kings' Is. 65 fathoms, Colville Channel (Livingstone).

Middle Miocene: Glencoe No. 7 bore 330 feet.

Lower Miocene: Clifton Bank (Muddy Ck., Hamilton), Campbell's Point (Lake Connewarre), Mitchell River at Bairndale, Balcombe Bay.

Observations.—The zooecia of this species are very variable in character. Old zooecia show very large and well-marked sub-marginal pores, and are larger and much more elongated than younger zooecia. There is no doubt of the identity of the fossil specimens with Recent zooecia.

The specimen figured by Macgillivray (1895) as *Catenicella cribraria* is seen on examination to be a zooecium of *Digenopora retroversa* (MacG.), 1895, but many authentic specimens of *Cribricellina cribraria* (Busk, 1852), have been seen in the Macgillivray collection.

Genus **Strophipora** Macgillivray, 1895.

Strophipora Macgillivray, 1895, p. 17. Levinsen, 1909, p. 257. Canu and Bassler, 1929, p. 449, text fig. 184.

Genotype.—*Strophipora harveyi* (Wyville-Thompson, 1858).

Observations.—The terminal gonoecia described as *Strophipora triangularis* and *S. episcopalis* by Maplestone (1911, 1913) are regarded as ovicells of the genotype, and on this evidence (p. 45) this genus is placed in the sub-family Scuticellinae. Wyville-Thompson's diagnosis (1859) of the ovicell of the genotype is believed to be a description of an abnormal avicularium such as that figured by the author (1934, text fig. 9g).

Canu and Bassler (1929) have proposed that Macgillivray's genera *Stenostomaria, Microstomaria* and *Ditaxipora* should be made sub-genera of the genus *Strophipora*. The form described as *Strophipora bellis* by Maplestone (1898) shows an ovicell surmounting the mother zooecium of a triglobulus, the daughter zooecium of which has the distinctive characters of *Stenostomaria solida* (Waters). Maplestone (1899) later figures the distal portion of a similar specimen, naming it the ovicell of *S. solida* (Waters). The ovicell of *Stenostomaria* is thus shown to belong to the mother zooecium of a triglobulus, as is also the case in the genera *Pterocella* Levinsen, *Claviporella* Macgillivray, and

Strongylopora Maplestone. Since *Stenostomaria* has a different type of ovicell from that found in the genus *Strophipora*, it should retain generic rank.

The affinities of the genus *Microstomaria* Macgillivray with the Catenicellidae are very doubtful. The holotype of the genotype, *M. tubulifera* Macgillivray, does not show any distal connecting-tube apertures, and until a series of specimens have been examined, its validity must remain in doubt.

The zoarial habit of *Ditaxipora* appears to be sufficiently distinctive for the retention of its generic rank.

Levinsen (1909) has given a good diagnosis of *Strophipora*.

STROPHIPORA HARVEYI (Wyville-Thompson, 1858).

Catenicella harveyi Wyville-Thompson, 1858, p. 137 (*fide* Nickles and Bassler (1900) and Macgillivray (1895)); *idem*, 1859, p. 145. Jelly, 1889, p. 37 (early bibliography).

Strophipora harveyi (Wyville-Thompson), Macgillivray, 1895, p. 17, pl. ii., figs. 9-12. Maplestone, 1904, p. 188. Levinsen, 1909, p. 258, pl. xxi., figs. 6 a-f. Canu and Bassler, 1929, p. 449, text fig. 184. Stach, 1934, p. 15, text figs. 9 a-g.

Strophipora triangularis Maplestone, 1911, p. 268, pl. xxxviii., figs. 9, 9a.

Strophipora laevis Maplestone, 1911, p. 269, pl. xxxviii., fig. 10.

Strophipora episcopalis Maplestone, 1913, p. 355, pl. xxvii., fig. 2.

Description.—Levinsen (1909) has amply described and figured zooecia of this species and Maplestone (1911, 1913) has described and figured the ovicell.

Dimensions.—Zooecium from Forsyth's (below remanié nodule bed). Zooecium, length 0.54 mm., width 0.27; aperture, diameter 0.10.

Distribution.—Recent: Bass Strait (Wyville-Thompson), Western Australia (*fide* Maplestone, 1904).

Lower Miocene: Clifton Bank (Muddy Creek, Hamilton), Batesford Tunnel marl, Waurn Ponds, Spring Creek (Torquay), Fyansford, Griffin's (near Batesford), Campbell's Point (Lake Connewarre), Bell's Beach (between Torquay and Pt. Addis), Forsyth's below remanié nodule bed (Grange Burn, Hamilton), Mitchell River at Bairnsdale, Nhill (Maplestone), Hamilton bore 80 feet–85 feet, Glencoe No. 7 bore 580 feet, 650 feet, 705 feet, 725 feet, Balcombe Bay.

Observations.—This species is characterized by its elongate oval outline and proportion of length to width. Old zooecia tend to become broader and very rotund, the small avicularia generally facing forward. These characters serve to distinguish old zooecia of this species from zooecia of *Strophipora lata* Macgillivray.

This distinctive species varies considerably, particularly as regards the form of the avicularia as pointed out by the author (1934). Unfortunately, no Recent specimens were available for examination, and Wyville-Thompson's original paper (1858) was inaccessible to the author. However, a review of his paper has been given (1859) together with the original descriptions of the species, and this, together with Levinsen's description and figures (1909) of zooecia from the original zoarium taken by Harvey, form the basis of comparison.

The fossil forms agree with Levinsen's description and figures, but since he only dealt with a small fragment of the zoarium, it is possible that all the variations recorded by the author (1934) in fossil zooecia did not appear on this fragment. Levinsen (1909) did, however, record a certain amount of variation in size and position of the avicularia.

The ovicell of this species has been described by Wyville-Thompson (1859) as follows, "Ovicell calyptriform; sessile by a broad base in the position of one of the avicularian processes of the cell, which it replaces. Back of ovicell furnished with a very large sessile avicularium." It is believed that Wyville-Thompson has described a large avicularium, similar to that figured by the author (1934, text-fig. 9G), being deceived into regarding this as an ovicell by the large swelling seen in frontal view. This also strengthens the belief that the abnormal forms figured (Stach, 1934) come under the category of zooecial variation.

The ovicell is believed to be a terminal gonoecium, and the forms described as *Strophipora triangularis* (1911) and *S. episcopalis* (1913) by Maplestone are correlated with this species. The evidence for this correlation is that three specimens of this type of ovicell are known, and *S. harveyi* is by far the most prolific species of the genus *Strophipora*. The ovicell of *S. excavata* Maplestone, represented by a single specimen in the Macgillivray collection, has certain features in common with its zooecia, and by a process of elimination these ovicells must belong to *S. harveyi* since Maplestone has recorded them from localities at which *S. harveyi* is common, but from which *S. lata*, the remaining species, has not been recorded.

The form described as *Strophipora laevis* by Maplestone (1911) is obviously a young zooecium of *S. harveyi*, the "curved spinous processes arching over the distal part" being the beginning of the development of the distal boundaries of the lateral compartments.

Macgillivray's *S. harveyi* var. *porosa* (1895) is regarded as a zooecium in which excessive calcification of the septulae has made them salient. Calcification of pores is a common feature in old zooecia of species of the Catenicellidae. It may here be stressed that it is practically useless to give fossil forms varietal standing from a study of a series of isolated zooecia, since it is almost impossible to decide whether the distinctive character does or does not come under the category of zooecial variation.

STROPHIPORA EXCAVATA Maplestone, 1899.

Strophipora excavata Maplestone, 1899, p. 10, pl. ii., figs. 20, 20a; *idem,* 1904, p. 188.

Strophipora sulcata Maplestone, 1899, p. 10, pl. ii., figs. 21, 21a; *idem,* 1904, p. 188.

Description.—Zooecium sub-triangular in outline tapering to proximal connecting-tube aperture, lateral margins concave; greatest width, at summit of zooecium, equals half length of zooecium.

Slightly concave proximal rim, one-third width of zooecium in length, situated one-third distance proximally from distal connecting-tube aperture. Height of aperture equals two-thirds distance from proximal rim to distal connecting-tube aperture.

Large elliptical pore, situated in centre of zooecium one-third distance proximally from proximal rim to proximal connecting-tube aperture, surrounded by a raised band extending from proximal rim to proximal connecting-tube aperture.

Small scapular compartments, situated at level of distal rim of aperture, face directly laterally or surmount forwardly-directed short tubular prominences. Small suprascapular compartments face obliquely forward and upward. Long forwardly-directed infrascapular compartments extend from level of distal rim of aperture to proximal connecting-tube aperture, perforated by about five septulae.

Dorsal surface with a broad median longitudinal ridge raised at the margins.

Axis of daughter zooecium inclined at 50 deg. to that of mother zooecium.

Ovicell a terminal gonoecium transversely elliptical in outline. The aperture, facing obliquely downward, equals one-half length of zooecium; slightly concave proximal rim situated less than half distance proximally from proximal connecting-tube aperture to summit of ovicell. Oval pore below proximal rim in centre of raised band extending from proximal rim to proximal connecting-tube aperture. About five septulae pierce depressed areas on either side of raised band. A large pore pierces ovicell above distal rim of aperture.

Dorsal surface very convex with a median broad raised band giving off lateral branches at level of proximal rim.

Dimensions.—Zooecium from Clifton Bank: Zooecium, length 0.45 mm., width 0.30; aperture, diameter 0.11. Ovicell from Clifton Bank: Length 0.83, width 0.92; aperture, diameter 0.48.

Distribution.—Lower Miocene: Clifton Bank (Muddy Creek, Hamilton), Flinders, Campbell's Point (Lake Connewarre), Glencoe No. 7 bore, 580 feet.

Observations.—This species is characterized by its outline and the more proximal position of the central pore.

An ovicell from Clifton Bank, where this species is most prolific, was found in the Macgillivray collection. It is correlated with this species mainly on the characters of the central pore and of the depressions on either side of the raised median band.

Maplestone's *Strophipora sulcata* (1899) is a zooecium of this species with large avicularia which decrease the extent of the depressions on either side of the median ridge seen in dorsal view. A series of zooecia can readily be obtained to link these two forms, and they undoubtedly both belong to the same species.

STROPHIPORA LATA Macgillivray, 1895.

Strophipora harveyi, var. *lata* Macgillivray, 1895, p. 18, pl. ii., fig. 12.

Description.—Zooecium broadly semielliptical in outline; greatest width, at summit of zooecium, equals length of zooecium.

Concave proximal rim, in centre third of zooecium, situated almost one-half distance proximally from distal connecting-tube aperture. Height of aperture equals three-quarters of distance from proximal rim to distal connecting-tube aperture. A pair of stout downwardly-curved denticles situated one-third distance distally from proximal rim to distal rim of aperture which is salient.

Large circular pore, situated in centre of zooecium one-third distance distally from proximal connecting-tube aperture to summit of zooecium, surrounded by a transversely-elliptical raised border.

Moderate-sized scapular compartments, situated at level of distal half of aperture, face directly laterally. Suprascapular compartments small and directed upward. Extensive infrascapular compartments on each side of zooecium are longitudinally depressed in middle line and have about seven septulae.

Dorsal surface very strongly arched in plane of axis of zooecium and depressed along lateral margins. A raised band extends distally from proximal connecting-tube aperture and, proximal to distal connecting-tube aperture, divides into two branches extending to tips of avicularia.

Axis of daughter zooecium inclined at 30 deg. to that of mother zooecium.

Ovicell not known.

Dimensions.—Single zooecium from Hamilton bore 80 feet–85 feet: Zooecium, length 0.57 mm., width 0.56; aperture, diameter 0.14.

Distribution.—Lower Miocene: Clifton Bank (Muddy Creek, Hamilton), Flinders, Batesford Tunnel marl, Hamilton bore 80 feet–85 feet, Balcombe Bay.

Observations.—This species is characterized by its usually laterally-directed avicularia, broad outline, strong denticles, and the transversely-elliptical raised border surrounding the central pore.

Macgillivray's *Strophipora harveyi* var. *lata* is raised to specific rank, since the above characters are practically constant and afford sufficient character to separate this form as a distinct species.

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Explanation of Plate III.

All figures (except fig. 5) drawn with camera lucida.

Magnification is × 54, except where otherwise stated.

Fig. 1.—*Vittaticella elegans* (Busk). Geminate pair from Forsyth's (below remanié nodule bed) Grange Burn, Hamilton (Stach Coll.). Nat. Mus. Coll., Regd. No. 13898.

Fig. 2.—*V. elegans* (Busk). Single zooecium from same locality. Nat. Mus. Coll., Regd. No. 13898.

Fig. 3.—*V. elegans* (Busk). Single zooecium from near Two Sisters' Is. (Bass Strait) (Coll. J. Gabriel). Nat. Mus. Coll., Regd. No. 68050.

Fig 4.—*V. elegans* (Busk). Geminate pair from same locality (Coll. J. Gabriel). Nat. Mus. Coll., Regd. No. 68050.

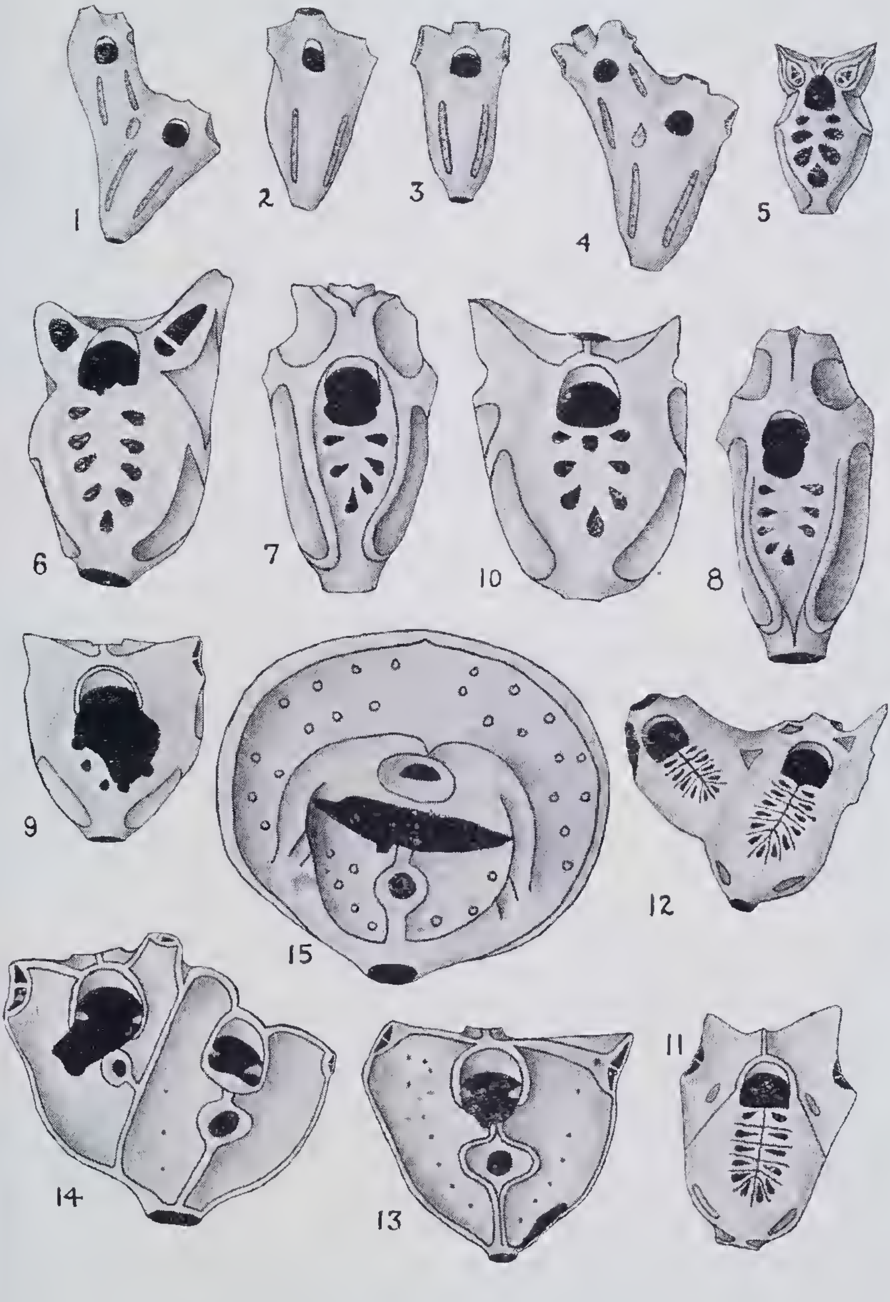
Fig. 5.—*Scuticella urnula* (Macgillivray). Single Recent zooecium (modified from Levinsen, 1909), × 33.

Fig. 6.—*S. urnula* (Macgillivray). Single zooecium from Forsyth's (below remanié nodule bed), Grange Burn, Hamilton (Stach Coll.). Nat. Mus. Coll., Regd. No. 13899.

Fig. 7.—*S. gippslandica*, sp. nov. Single zooecium (holotype) from Mitchell River at Bairnsdale (Stach Coll.). Nat. Mus. Coll., Regd. No. 13900.

Fig. 8.—*S. gippslandica*, sp. nov. Single zooecium (paratype) from Largon Ck., off Toorloo Arm, 8 mls. E. of Lakes Entrance (Stach Coll.). Nat. Mus. Coll., Regd. No. 13901.

Fig. 9.—*S. lata*, sp. nov. Single zooecium (paratype) from Forsyth's (below remanié nodule bed), Grange Burn, Hamilton (Stach Coll.). Nat. Mus. Coll., Regd. No. 13902.



Victorian Tertiary Catenicellidae.

Fig. 10.—*S. lata*, sp. nov. Single zooecium from holotype zoarium from Western Port (J. Gabriel Coll.). Nat. Mus. Coll., Regd. No. 68051.

Fig. 11.—*Costaticella benecostata* (Levinsen). Single zooecium from Batesford Tunnel marl (Stach Coll.). Nat. Mus. Coll., Regd. No. 13903.

Fig. 12.—*C. benecostata* (Levinsen). Geminate pair from Clifton Bank (Muddy Ck., Hamilton) (Stach Coll.). Nat. Mus. Coll., Regd. No. 13904.

Fig. 13.—*Strophipora lata* Macgillivray. Single zooecium from Hamilton bore 80 ft.-85 ft. (Geol. Surv. Vic. Coll.). Nat. Mus. Coll., Regd. No. 13905.

Fig. 14.—*S. lata* Macgillivray. Geminate pair from same locality. Nat. Mus. Coll., Regd. No. 13906.

Fig. 15.—*S. excavata* Maplestone. Ovicell from Clifton Bank (Muddy Ck., Hamilton) (Macgillivray Coll.). Nat. Mus. Coll., Regd. No. 13907.

[Proc. Roy. Soc. Victoria, **47** (N.S.), Pt. I., 1934.]

Art. IV.—*Observations on Saw-flies of the Genus Perga, with Notes on some reared Primary Parasites of the Families Trigonalidae, Ichneumonidae, and Tachinidae.*

By JANET W. RAFF, M.Sc., F.R.E.S.

(With Plates IV. and V.)

[Read 12th April, 1934; issued separately, 22nd December, 1934.]

In a previous paper (11) details are recorded of emergences from four broods of saw-fly larvae of the genus *Perga*. It was not realized then that delayed emergences occurred, and further saw-flies and parasites subsequently emerged from three of the broods (Broods 1, 2, and 4). The total emergences are now recorded, together with identifications of the species. The saw-fly reared from Brood 2 was a new species, *Perga nemoralis* Wilson (14), with marked sexual dimorphism. Results of emergences from other broods are also recorded, the conditions of isolation of these " captive " broods being similar in all cases.

The details of emergences from the different broods forms the second section of this paper. It is preceded by a general account of the history of saw-fly development from the time the fully-grown larva enters the soil, for cocoon-spinning, to the emergence of the adult. This is desirable as discrepancies have appeared in accounts of this portion of the life-history: Froggatt (5, 6) has apparently confused the stages of a parasite (probably an Ichneumonid) with those of the saw-fly. By removing the cocoons from the soil, examining them from time to time, and noting the contents of cocoons from which emergences have occurred, a correct idea of the order of development has been obtained. This sequence of events is important for the interpretation of the meaning of exuviae or " remains," found in cocoons under examination, especially with a parasitized brood.

The third section comprises notes on three types of primary parasites, bred from " captive " broods of saw-flies, viz., Trigonalidae, Ichneumonidae, and Tachinidae. The existence of a Trigonalid as a primary parasite is noteworthy, as the Trigonalidae have hitherto been recorded only as secondary parasites.

Section A.—Life-history of the Saw-flies from Time of Entering the Soil for Cocoon-spinning to Emergence of the Adult.

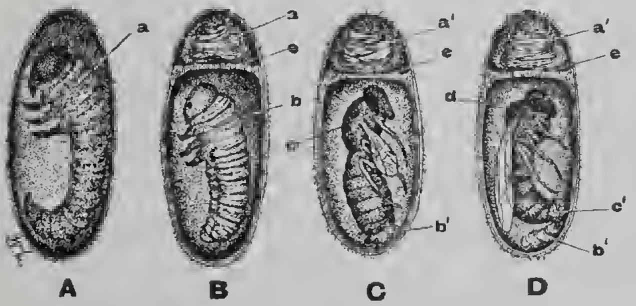
From an examination of cocoons removed from the soil, the following four stages have been identified, and are represented diagrammatically in Fig. 1:—

A. Cocoon containing the " above-ground " larva: cocoon weak or incomplete at top.

B. Cocoon containing the prepupa, the larval exuvia being shut off at top of cocoon.

C. Cocoon containing pupa, with prepupal exuvia adhering.

D. Cocoon containing adult, with exuviae of prepupa and pupa.



TEXT-FIG. 1.—Diagram showing metamorphosis of saw-fly. (*a*), Larva; (*a*¹), Exuvia of larva; (*b*), Prepupa; (*b*¹), Exuvia of prepupa; (*c*), Pupa; (*c*¹), Exuvia of pupa; (*d*), Adult; (*e*), Partition.

These four stages indicate the following sequence of events in the life-history after the cessation of feeding:—The fully-fed larva enters the soil and spins an oval cocoon, weak or incomplete at the top. The cocoon is firm, of a silky texture mixed with sand, and more or less "glazed" in appearance inside—Text-fig. I A. They are generally massed together from 1 to 3 inches beneath the surface of the soil. Almost immediately after cocoon-spinning, the larva moults or changes to the *prepupal* stage, the cast skin being left at the top of the cocoon. A firm flat partition is then formed near the top, shutting off the larval exuvia—Text-fig. 1 B. The partition is a closely woven meshwork appearing more or less lace-like from above. The inner walls of the cocoon are apparently "glazed" still further by the prepupa, the glazing being continued over the lower surface of the partition. The prepupa is larval in appearance, but compared with the above-ground larva, is shorter and more compact, with a softer and lighter-coloured body. The folds of the body wall are more pronounced, the legs are shorter, and owing to the lighter colour of the head, the single black ocellus is conspicuous on either side (Pl. IV., Fig. 1). There is no external indication of wings. The prepupa can apparently change its position while glazing the inner walls (Pl. IV., Fig. 2). The usual position of rest appears to be with the head at the top of the cocoon. Without entering into the minute differences in structure of the cocoon-spinning larva and the prepupa, it may suffice to mention the differences in the mandibles, as these are useful in determining the nature of the exuviae or "remains" found in cocoons. The mandibles of the larva are hard and heavily chitinized throughout, dark brown or black, and bluntly toothed, (Pl. V., Fig. 9). The mandibles of the prepupa are much less heavily chitinized, especially at their outer or lateral margins; they are yellowish, with the cutting edges dark brown, the latter furnished with sharply-pointed teeth (Pl. V., Fig. 10). The cutting edges of the right and left mandibles differ slightly from each other in both stages.

After a varying period, which may be very prolonged, ecdysis occurs, and the pupal stage is revealed, the prepupal exuvia adhering to the hinder abdominal region of the pupa—Text-fig. 1 C. The pupa is soft and whitish at first, darkening later, and has the head region placed against the flat partition of the cocoon (Pl. IV., Figs. 3 and 4). The pupal stage is probably very short. At the next ecdysis the fully-formed adult is revealed (Pl. IV., Fig. 5), the thin transparent exuvia being pushed to the bottom of the cocoon, where it is seen along with the old prepupal exuvia—Text-fig. 1 D. The pre-pupal and pupal exuviae often appear to be cemented together, no doubt by the moulting fluid, and by the movements of the adult. They can easily be separated and identified, after soaking for a short time in a weak potash solution.

To emerge from the cocoon, the adult cuts the partition in a more or less neat circle at the top. It is very active and capable of strong flight immediately.

The above facts show that in normal healthy broods of saw-flies, complete or unopened cocoons should contain either the saw-fly larva, or one of the three subsequent stages (prepupa, pupa, or adult), along with the exuviae of their previous instars. "Opened" cocoons, i.e., those from which emergences have occurred naturally, should contain the exuviae of all stages. These are to be found generally inside the cocoon mixed with loose sand which has fallen in when the adult was emerging.

In cases where cocoons are found to contain stages other than those mentioned above, parasites are present. A careful examination is necessary to determine the relationship of the parasite to the host.

Notes on the Prepupa and Pupa.

The prepupal stage refers to the stage interpolated between the fully-fed larva and the pupa. In the case of *Perga* sp., it is the larva-like, non-feeding form enclosed in the cocoon, and is the stage following the fully-fed cocoon-spinning larva. It is referred to as the "ultimate" larval stage by MacGuillivray(7). In some cases, this prepupal stage apparently spins the cocoon: thus Middleton(8) says "the prepupa, or seventh larval instar, is the non-feeding cocoon-spinning stage in which the larvae search out a suitable place to spend their quiescent period"; and Miles (9) notes, regarding saw-flies infesting Ribes, that the prepupal stage forms the cocoon.

In all cases, however, the prepupa is the stage which "lasts over" for varying periods before changing to the pupal stage.

In captivity the duration of the prepupal period varies considerably in the case of *Perga* sp., even in individuals of the same brood. Where larvae have entered the soil in the spring, emerging as adults towards the end of the following summer, as exemplified in Broods 1, 2, and 4, it is probable that nearly the whole of this period was spent as a prepupa, viz., between four and five months. In those broods where further emergences occurred at the end of the *second* summer (as in Broods 1 and 2), the prepupa would "last-over", the prepupal period being probably between sixteen and seventeen months. *Indirect* evidence of the existence of this long prepupal stage is obtained from examination of cocoons of "captive" broods from time to time, from the frequency with which the prepupal stage is found. The writer has obtained direct evidence of a prolonged prepupal period in three individual cases; the most noteworthy occurred in Brood 2, where the saw-fly remained in the prepupal stage for nearly four years. The other two cases are those of prepupae living for three years and four months, and for two years at least (Broods 1 and 10). Details of these cases are as follows:—

Case 1. *Prepupal Period*—3 years, 11 months: Brood 2.

> *Perga nemoralis* Wilson (see Section B). Larvae entered the soil on 16th October, 1928: emergences occurred, during March and April, 1929, and again in March, 1930. On February 24th, 1932, as no further emergences had occurred, the cocoons were removed from the soil and examined; one contained a living prepupa. This prepupa had then lived for 3 years and 4 months. The cocoon was placed in a gelatine capsule supported in damp sawdust, and kept isolated for further observation. The prepupa was alive on 14th September, 1932, i.e., after a period of 7 months, bringing its total existence in this stage to 3 years and 11 months. Owing to the growth of moulds later, it died. This appears to be a record of longevity.

Case 2. *Prepupal Period*—3 years, 4 months: Brood 1.

> *Perga dorsalis Leach* (see Section B). Larvae entered the soil 9th October, 1928: emergences occurred during March and April, 1929, and in April, 1930. Cocoons were examined on 24th February, 1932, i.e., 3 years and 4 months after being spun, a living prepupa was found in one. In June, 1932, this prepupa was found dead, being attacked by mites and moulds.

Case 3. *Prepupal Period*—2 years at least. Brood 10.

> *Perga polita* Leach. Three larvae entered the soil on 16th October, 1930. On February 24th, 1932, no emergences having occurred, the cocoons were removed for examination. One was opened, revealing a prepupa, the other two were kept intact. The opened cocoon was tied round with cotton and replaced, with the other two, in the soil. In July they were again examined; the prepupa was living, and had repaired the hole previously made in the cocoon wall. The cocoons were now placed in separate phials plugged with cotton-wool and supported in damp sawdust. On 26th October, 1932, an adult female emerged from one of the previously unopened cocoons; examination of the previously opened cocoon showed that the prepupa was living and apparently healthy, that is, after a period of at least two years. In March, 1933, the prepupa was found dead, owing to attack by mites and moulds. In July, 1933, when the third cocoon was opened a developed female was found infested with moulds. No doubt it should have emerged during the previous March or April.

There appears to be no previous record of this prolonged prepupal period for Australian saw-flies. Of British species, Cameron (1) mentions the possibility of a period of two years in the cocoon before changing into the pupa, though he does not seem to recognize a prepupal instar. He says: " When the larva has become full fed it proceeds to pupate. Some larvae spin no cocoon . . . . but most species spin oblong silken cocoons. After being in the cocoon the larva in a short time shortens and contracts its shape, the legs at the same time being withdrawn into the skin as it were. The period which elapses between the spinning of the cocoon and becoming a pupa varies according to the season. With the summer broods it may be seven to ten days, but the autumnal broods do not change until the following spring, so that the greater part of their larval existence is spent in this inert condition. In exceptional cases they may remain two years in the cocoon before changing."

Dealing with *Dielocerus formosus* Klug, da Costa(2) refers to the probable oestivation of the larva in the cocoon, for at least three years. Apparently, however, these cocoons had not been isolated or kept under quarantine conditions during that period.

The duration of the pupal stage is probably very short, and is easily overlooked. Pupae found in cocoons opened for examination, being soft and delicate, are easily damaged, and fail to metamorphose. As other broods become available for examination, it is hoped to determine the length of this pupal period. Cameron(1) remarks that the pupal state does not last over 12 or 14 days, as a rule, and may be shorter.

The well-developed pupae shown in Plate IV., Fig. 4, were found within three months of the larvae entering the soil. As the details available to date for this brood of larvae (Brood 46) are not shown in Section B, they are noted as follows:—Larvae, collected at Healesville by Mr. H. G. Andrewartha, entered the soil on 27th November, 1933: cocoons were opened and these pupae exposed on 16th February, 1934: on 21st February the pupal skins were cast, revealing adults of *Perga dorsalis* Leach.

Section B.—Results of Emergences from captive Broods of Saw-fly Larvæ.

The following details are results of emergences from different broods of larvae, collected from time to time, and kept isolated for observation. The main object in view at first was to determine the proportion of sexes emerging from the various broods, and this has been set out in each case. Owing, however, to frequent internal parasitism of the larvae when collected, this has been masked in most cases. Parasitism is frequent, particularly by Tachinid flies.

Another object in view was to associate the larvae with the adults for identification. When the various larvae were collected, a few were preserved in alcohol, with the brood number attached, while others were allowed to enter the soil.

The dates have been shown for each brood, these being important, especially in regard to the relative times of emergence of males and females. Though no generalization can be made from the data, the females appear to preponderate, and males are the earliest to emerge. The "lasting-over" of both saw-flies and parasites is also shown for some of the broods.

The conditions in captivity were as follows:—The different broods were placed on soil in flower-pots covered with hurricane lamp chimneys or fly-wire covers. In most cases, the pots have been buried in soil in larger glazed pots, and by keeping the soil in these moist, suitable conditions have been maintained in the inner pots. These have been kept in the Insectary at the School of Agriculture, University of Melbourne.

Brood 1. *Perga dorsalis* Leach.

Larvae collected by Mr. G. F. Hill, at Warrandyte, Victoria, October.

9th October, 1928.—34 larvae entered soil for cocoon-spinning.

Emergences occurred as follows:—

15th March, 1929.—1 saw-fly (male).
8th April, 1929.—5 saw-flies (females).
29th August, 1929.—5 Tachinid flies.

13th September, 1929.—1 Tachinid fly.
8th April, 1930.—1 saw-fly (male).
16th April, 1930.—1 saw-fly (female).
22nd April, 1930.—1 saw-fly (male).
16th September, 1930.—1 Tachinid fly.
22nd September, 1930.—1 Tachinid fly.

Total Emergences.—Three male and six female saw-flies and eight Tachinid flies.

24th February, 1932.—In cocoons opened for examination, ten developed female saw-flies, apparently unable to emerge from the cocoons, were found; also a living prepupa.

Brood 2. *Perga nemoralis* Wilson.

Larvae collected by the writer at Wonga Park (South Warrandyte), Victoria, October, 1928.

16th October, 1928.—Larvae entered soil.

Emergences occurred as follows:—

14th March, 1929.—2 saw-flies (1 male and 1 female).
20th March, 1929.—3 saw-flies (females) .
1st April, 1929.—2 saw-flies (females).
9th April, 1929.—1 Tachinid fly.
24th March, 1930.—1 saw-fly (male).
27th March, 1930.—2 saw-flies (1 male and 1 female).
28th March, 1930.—2 saw-flies (1 male and 1 female).
30th March, 1930.—3 saw-flies (females).
31st March, 1930.—1 saw-fly (female).
17th April, 1930.—1 Tachinid fly.
1st May, 1930.—1 Tachinid fly.

Total Emergences.—Four male and twelve female saw-flies, and three Tachinid flies.

24th February, 1932.—On examination of cocoons removed from soil, one was found to contain a living prepupa.

Brood 3. *Perga polita* Leach.

Larvae collected, by the writer, at Blackburn, Victoria, October, 1928; 19 larvae entered the soil almost immediately.

Details of emergences have already been given (11).

Total emergences were as follows:—During March and April, 1929, sixteen female saw-flies emerged.

Brood 4. *Perga dorsalis* Leach.

Larvae collected by the writer at Eltham, Victoria, September, 1929.

11th October, 1929.—16 larvae entered soil.

Emergences ocurred as follows:—

12th December, 1929.—5 Tachinid flies.
13th December, 1929.—1 Tachinid fly.
14th December, 1929.—1 Tachinid fly.
16th December, 1929.—1 Tachinid fly.
18th February, 1930.—1 Tachinid fly found dead (actual date of emergence not known).
28th March, 1930.—1 saw-fly (female).
30th March, 1930.—1 saw-fly (female).
2nd April, 1930.—2 saw-flies (females).
5th April, 1930.—1 saw-fly (male).
8th April, 1930.—1 saw-fly (female).
12th July, 1930.—1 Tachinid fly.

Total Emergences.—One male and five female saw-flies, and ten Tachinid flies.

BROOD 14. *Perga dorsalis* Leach.

Larvae collected Eltham, Victoria, October, 1931.

17th October, 1931.—35 larvae entered soil.

Emergences occurred as follows:—

19th February, 1932.—Two cocoons were removed from the soil and opened—found to contain prepupae.
18th March, 1932.—5 saw-flies femalcs).
19th March, 1932.—2 saw-flies (1 male and 1 female).
21st March, 1932.—3 saw-flies (females).
23rd March, 1932.—1 saw-fly (female).
Total Emergences.—One male and ten female saw-flies.

Examination of cocoons on 30th May, 1932, yielded the following results:—

11 cocoons contained saw-fly exuviae only, and represented those from which saw-fly emergences had already occurred.
2 cocoons contained dead prepupae.
5 cocoons were not opened.
13 cocoons contained 18 Tachinid parasites (larvae and puparia) with remains of saw-fly prepupae.

BROOD 16. *Perga dorsalis* Leach.

Larvae collected, by the writer, Healesville, Victoria, December, 1931.

23rd December, 1931.—22 larvae entered the soil.

Emergences occurred as follows:—

15th February, 1932.—1 Tachinid fly (female).
29th February, 1932.—1 saw-fly (male).
1st March, 1932.—1 saw-fly (male).

3rd March, 1932.—1 Tachinid fly (female).
4th March, 1932.—3 saw-flies (females).
8th March, 1932.—1 saw-fly (female).
10th March, 1932.—1 saw-fly (female).
29th March, 1932.—1 Tachinid fly.

Total Emergences.—Two male and five female saw-flies, and three Tachinid flies.

This is the shortest period noted for complete metamorphosis.

Examination of cocoons on 9th July, 1932, yielded the following results:—

7 cocoons contained saw-fly exuviae only, and represented those from which emergences had occurred.
3 cocoons each contained a prepupa (two dead, and one living; from the latter a female emerged between March and May, 1933).
1 cocoon contained a dead adult saw-fly, enveloped in its pupal membrane.
6 cocoons contained Tachinid parasites (two of these were subsequently bred out—emerging in September, 1933.)
2 cocoons each contained an Ichneumonid cocoon.

Brood 22. *Perga dorsalis* Leach.

Larvae collected by Miss J. Robertson, at Eltham, Victoria, October, 1932.

25th October, 1932.—About 16 larvae entered soil.

Emergences occurred as follows:—

7th March, 1933.—1 saw-fly (male).
16th March, 1933.—1 saw-fly (male).
17th March, 1933.—1 saw-fly (female).
23rd March, 1933.—2 saw-flies (females).
24th March, 1933.—1 saw-fly (male).
27th March, 1933.—1 saw-fly (female).
8th August, 1933.—1 Tachinid fly (male).
12th August, 1933.—1 Tachinid fly (female).
23rd August, 1933.—1 Tachinid fly (female).
28th August, 1933.—1 Tachinid fly (female).
30th August, 1933.—1 Tachinid fly (male).
5th September, 1933.—1 Tachinid fly (female).
18th September, 1933.—1 Tachinid fly (female).
19th September, 1933.—1 Tachinid fly (male).

Total Emergences.—Three male and four female saw-flies, and eight Tachinid flies.

BROOD 23. *Perga dorsalis* Leach.

Large mass of larvae, collected by Mr. K. M. Ward, at Mooroopna, Victoria, October, 1932.

26th October, 1932.—Larvae entering soil.

Emergences were as follows:—

28th March, 1933.—2 saw-flies (1 male and 1 female).
30th March, 1933.—3 saw-flies (females).
3rd April, 1933.—3 saw-flies (females).
4th April, 1933.—14 saw-flies (4 males, and 10 females).
5th April, 1933.—4 saw-flies (1 male and 3 females).
6th April, 1933.—3 saw-flies (1 male and 2 females).
10th April. 1933.—1 saw-fly (female).
3rd May, 1933.—6 Trigonalids (females).
8th May, 1933.—1 Trigonalid (female).
9th May, 1933.—2 Trigonalids (females).
(?) May, 1933.—1 Trigonalid (female).
(?) May, 1933.—Cocoons were examined — 1 dead Trigonalid female found.

Total Emergences.—Seven male and twenty-three female saw-flies, and eleven female Trigonalids.

(A large number of this brood died during moulting.)

BROOD 24. *Perga nemoralis* Wilson.

Larvae, collected by the writer, at Eltham, Victoria, October, 1932.

5th November, 1932.—Larvae entered soil.

Emergences occurred as follows:—

16th March, 1933.—1 saw-fly (male).
17th March, 1933.—2 saw-flies (males).
18-20th March, 1933.—6 saw-flies (2 males and 4 females).
22-29th March, 1933.—11 saw-flies (females).
3rd April, 1933.—1 saw-fly (male).
11th April, 1933.—1 Trigonalid (female).
26th April, 1933.—2 Trigonalids (males).
26th April, 1933.—Cocoons were removed from soil, and subsequent emergences were as follows:—
27th April, 1933.—2 Trigonalids (1 male and 1 female) emerged on cocoons being opened slightly.
29th April, 1933.—1 Trigonalid (male) emerged.
29th April, 1933.—2 Trigonalids (1 male and 1 female) emerged on cocoons being opened slightly.
30th April, 1933.—1 Trigonalid (male) emerged.
27th June. 1933.—2 Ichneumonids emerged.

Total Emergences.—Six male and fifteen female saw-flies, nine Trigonalids (6 male and 3 females), and two Ichneumonids.

Examination of 17 cocoons from which emergences had not occurred yielded the following results on 28th April, 1933:—

6 cocoons each contained a prepupa.

4 cocoons each contained a Trigonalid (3 pupae and one larva, apparently decaying).

7 cocoons each contained an Ichneumonid cocoon (5 containing an Ichneumonid larva, and 2 an Ichneumonid pupa).

Section C.—Notes on Primary Parasites of Perga spp., viz., Trigonalidæ, Ichneumonidæ, and Tachinidæ.

1. TRIGONALIDAE.

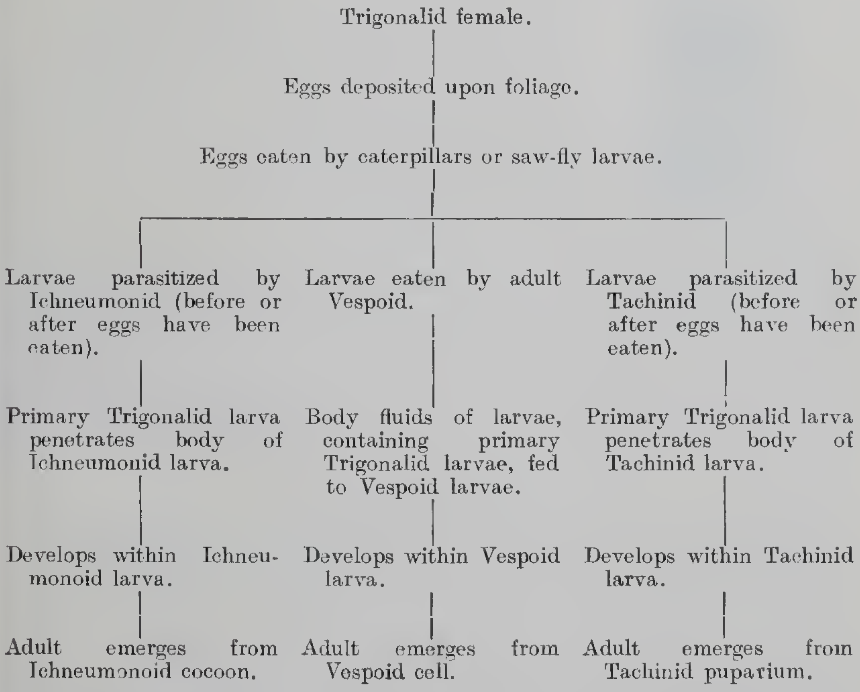
The occurrence of wasps of the family Trigonalidae emerging from "captive" broods of saw-fly larvae is of special interest; they have, until now, been shown to be secondary parasites only. It is now established that the species bred is a primary parasite on *Perga nemoralis* Wilson, and on *P. dorsalis* Leach. The specimens from both broods are identical with *Trigonalis maculatus* Sm., (= *Taeniogonalos maculatus* Sm.), in the collection of the National Museum.

The family Trigonalidae, though small and rare, is widely distributed, only two species being known in Australia, viz., *Trigonalis maculatus* Sm., and *Mimelogonalos bouvieri* Sch. Tillyard (13) places the family in the Super-family Vespoidea, mainly on the presence of a terminal ovipositor, and the extension of the sides of the pronotum back to the tegulae. He notes, however, that "This small family appears to be intermediate between the Ichneumonoidea and typical Vespoidea, as it has the divided trochanters and many-segmented antennae of the former, whereas the ovipositor issues from the end of the abdomen, and closely resembles those of the latter, though it does not appear to be known whether it is used as a sting or not."

Other external features of the adult Trigonalid are the following:—Body brownish-black with yellowish markings; antennae with 25 segments; tarsal claws pectinate; tip of abdomen of female turned ventrally, directed towards a median process on the hinder edge of the second visible sternite. In the male, the second visible sternite has a depressed circular area in the position of the process of the female. Details of the anatomy of the family, with figures, are given by Schultz (12).

The Trigonalidae are known chiefly as secondary parasites on Vespoids and on Tachinids. Recently, however, Clausen (3) has recorded the emergence of a Trigonalid (*Poecilogonalos thwaitesii* Westw.), from cocoons of an Ichneumonid (*Henicospilus rufus* Tosq.), the latter being regarded as a parasite of a "lepidopterous larva, probably of the Noctuidae." In this case, therefore, the Trigonalid is also a secondary parasite. In a later paper, Clausen (4) has reviewed the literature on Trigonalidae, giving the known habits of the species. From his summary all cases recorded to that time (1931) were secondary parasites only. In searching for caterpillar hosts of Ichneumonids, from which the Trigonalids emerged, Clausen secured a single saw-fly larva, which on dissection was found to contain in the body cavity three Trigonalid larvae in first stage. All his rearings of Trigonalids, however, were from cocoons of Ichneumonids, which previously parasitized some unknown phytophagous larva, that is, they were secondary parasites.

The life cycle of the Trigonalidae in the Ichneumonid, Vespoid, and Tachinid hosts, is set out by him (hypothetically in the case of Vespoids), in tabulated form, as follows:—



Trigonalid female.

Eggs deposited upon foliage.

Eggs eaten by caterpillars or saw-fly larvae.

Larvae parasitized by Ichneumonid (before or after eggs have been eaten).

Primary Trigonalid larva penetrates body of Ichneumonid larva.

Develops within Ichneumonoid larva.

Adult emerges from Ichneumonoid cocoon.

Larvae eaten by adult Vespoid.

Body fluids of larvae, containing primary Trigonalid larvae, fed to Vespoid larvae.

Develops within Vespoid larva.

Adult emerges from Vespoid cell.

Larvae parasitized by Tachinid (before or after eggs have been eaten).

Primary Trigonalid larva penetrates body of Tachinid larva.

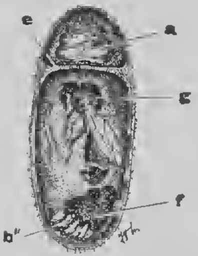
Develops within Tachinid larva.

Adult emerges from Tachinid puparium.

Evidence of Primary Parasitism of a Trigonalid on Perga spp.

The details of emergences show that in Brood 23 (*Perga dorsalis* Leach), the only parasites present were Trigonalids, whereas in Brood 24 (*Perga nemoralis* Wilson) parasites belonging to both Trigonalidae and Ichneumonidae appeared. An examination of the cocoons from which the Trigonalids had emerged, or which might still yield Trigonalids, was made to determine the relationship of the parasite to the saw-fly, as many of the broods of larvae under observation had yielded Tachinid parasites. In Brood 24, where Trigonalids were present, Ichneumonid cocoons were also found in some of the saw-fly cocoons, and Ichneumonids have recently been recorded as hosts for Trigonalids.

If the Trigonalid is a *primary* parasite on the saw-fly, one would expect to find inside the host cocoons, where the Trigonalids are present (or had been), not only the larval and pupal exuviae of the Trigonalid, but also "remains" of the saw-fly larva, or prepupa, left by the parasite. If, on the other hand, it is a *secondary* parasite, then there also should be present, in the cocoon, exuviae, or "remains" of some other form representing the primary parasite. Examination of every fragment of material which might represent exuviae or "remains" of possible hosts, was made with a binocular microscope.



TEXT-FIG. 2.—Diagram showing arrangement of parts in host cocoon, when Trigonalid is present. (a^1), Exuvia of larva of saw-fly; (b^{11}), Remains of prepupa of saw-fly; (*e*), Partition; (*f*), Meconium, and exuviae of Trigonalid larva and pupa; (*g*), Adult Trigonalid.

Examination of cocoons of Brood 24 yielded the following results:—Trigonalids were about to emerge from four of them when opened. The adult Trigonalid was free from the pupal covering. The antennae were vibrating actively, and it immediately escaped through the hole made. It was active and capable of flight. (There was no cocoon belonging to the Trigonalid—compare Clausen (4)). After the walls of the saw-fly cocoon were sufficiently cut away, the relative position of the contents was as represented in Text-figure 2. At the top of the cocoon was a flat partition, with a saw-fly larval exuvia above. At the bottom was a compact dark-greyish mass, "livery" in appearance, surrounded by a firm membrane, with the dried remains of the saw-fly prepupa adhering to it. Two exuviae were seen to be adhering to the "livery" mass, and these, after softening slightly in weak potash, could be separated easily, and were identified as Trigonalid larval and pupal exuviae respectively. The larval exuvia is dirty white, and bears two tridentate mandibles (Plate V., Fig. 11), resembling those of the full-grown larva of the Trigonalid figured by Clausen (3). The pupal exuvia was translucent white, and showed a pair of slight bulges or papillae, which later were seen to be the portions of the pupal covering, in the region of the adult mandibles. The "livery" mass is the meconium, or material voided from the alimentary canal of the Trigonalid larva. By teasing out this meconium, numerous sharp, sickle-like mandibles (Plate V., Fig.

12) were found scattered through the mass, also minute chitinous head-capsules, an occasional one of which bore one or both mandibles. These closely resemble the heads and sharp mandibles of the earlier instars of Trigonalid larvae, as figured by Clausen (3), and no doubt represent the remains of the younger and weaker Trigonalid larvae. The remains of these competitors would be in the alimentary canal of the surviving Trigonalid larva, and therefore in the meconium, expelled at ecdysis from larval to pupal stage. These mandibles and head capsules are extremely minute and difficult to separate from the more or less brittle mass of meconium when preserved in alcohol. In some cases the whole of the meconium has not been teased out; the greatest number of head-capsules and mandibles found in any one meconium has been five of the former and nine of the latter.

Of the three cocoons which contained each a Trigonalid pupa (Brood 24), the arrangement of the contents was similar to the above four cases (with, of course, the absence of the Trigonalid pupal exuviae). In these three cases, the meconium and the Trigonalid larval exuviae were attached to the pupa, near the anus. In one case the saw-fly had metamorphosed to the pupal stage, the skin of the latter, as well as the exuvia of the prepupal stage, being found. When the five cocoons from which Trigonalids had emerged whilst in the soil were opened for examination, it was found that the contents resembled those of cocoons where Trigonalids were observed emerging. The examination revealed no indication of the presence of any form, other than the Trigonalid and the saw-fly. It is concluded, therefore, that the Trigonalid is a primary parasite on the saw-fly.

2. ICHNEUMONIDAE.

Of the various broods of larvae kept under observation, Ichneumonids have occurred in Broods 16, 24, 25, and 36. The arrangement of the contents of saw-fly cocoons, when parasitized by Ichneumonids, is somewhat similar to that described for the Trigonalid parasite, excepting that the Ichneumonid is enclosed in a cocoon within the saw-fly cocoon. Examination of these cocoons shows that the Ichneumonids are primary parasites. The usual arrangement within the host cocoon is as follows:—The saw-fly larval exuvia is at the top chamber of the cocoon, the Ichneumonid cocoon almost fills the space within the host cocoon; in most cases it was found to contain a large larva (Plate IV., Fig. 6). Where the parasites had metamorphosed to the pupal stage, the cast larval skin and the meconium were also present, adhering to the tip of the pupa. Lying on the outer side of the Ichneumonid cocoon, and flattened against the wall of the host cocoon, the remains of the saw-fly prepupa are found. In some of the cocoons it was noticed that the sieve-like partition had not been formed, the prepupa being weakened by the parasite.

In these cases, both the saw-fly larval exuvia and the remains of the prepupa were found attached to the outside of the Ichneumonid cocoon.

Though Ichneumonids have most often been found to be the only parasite present in a particular brood, it has already been indicated (Brood 24) that there was also a Trigonalid. Both these parasites have been proved to be primary in different larvae of the brood. In two cases which have come under my notice, both Ichneumonids and Tachinid flies have been found as parasites in the same brood; these, however, being primary parasites, on separate individuals.

The following details regarding the Ichneumonid parasites have been recorded from the four broods of saw-fly larvae:—

Brood 16.—From the data set out in Section B, it is seen that when the host cocoons were examined in July, 1932, two were found to contain an Ichneumonid cocoon. On opening one of these, the parasite was still in the larval stage. The Ichneumonid had thus spent at least seven months as a larva within the host cocoon.

Brood 24.—Two Ichneumonids (species not indentified) emerged on June 27th, 1933, i.e., seven months after the cocoon-spinning of the host (see data, Section B). The cocoons of these Ichneumonids had been removed from the host cocoons during April, 1933; each was supported in a phial, plugged with cotton-wool, and placed in an incubator kept at 20 deg. C.

When the host cocoons were examined in April, 1933, five Ichneumonid larvae had lived for at least five months within the host cocoon, while two others had metmorphosed to the pupal stage at the end of that time.

Brood 25.—*Perga polita* Leach. (Date not given in Section B).

15th November, 1932.—Seven saw-fly larvae, collected at Eltham by the writer, entered the soil..
4th April, 1933.—One saw-fly (female) emerged.
21st July, 1933.—One Ichneumonid (*Paniscus productus* Brulle) emerged.

The Ichneumonid emerged eight months after the cocoon-spinning of the host.

Brood 36.—Identification of saw-fly not known, as no emergences occurred. (Data not given in Section B.)

Larvae collected at Kalorama, Victoria, by Miss H. V. Steele.

10th May, 1933.—Twenty larvae entered the soil.
19th July, 1933.—Cocoons removed from soil.

Cocoon No. 1 was opened slightly and found to contain a prepupa which evidently supported an internal Ichneumonid, for on July 31st on re-examination it contained an Ichneumonid cocoon. "Remains" of prepupal saw-fly were also present.

Two others (Nos. 9 and 10) containing Ichneumonid cocoons were kept in separate phials plugged with cotton-wool, for possible emergences. These were placed in a vessel containing saturated salt solution (about 75 per cent. relative humidity) and kept at ordinary room temperature. A mass of about eight cocoons was kept under similar conditions for possible emergences.

4th December, 1933.—Male Ichneumonid (*Labium associatum* T. and W.) emerged from mass of cocoons.

2nd February, 1934.—Ichneumonid (*Eriostethus* ?sp.) emerged from cocoon No. 9.

2nd February, 1934.—Ichneumonid (not identified) emerged from cocoon No. 10.

In this brood an Ichneumonid larva (cocoon 1) fed within its host for two months before spinning its cocoon. Two Ichneumonids (cocoons Nos. 9 and 10) emerged six to seven months, at least, after spinning their cocoons, and eight to nine months after the host larva had spun.

3. TACHINIDAE.

In the numerous broods of *Perga* larvae held in captivity, the commonest parasite proved to be the Tachinid fly. Of the broods collected, some have failed to spin, others spun weak cocoons and died. Of 20 normal or apparently healthy broods of larvae, Tachinids were present in fourteen. Some emerged normally, others were found in cocoons removed from the soil. In these broods there was no external indication of parasitism (with the exception of one case—Brood 16—where eggs were found adhering to the skin of the fully-grown larvae). Examination of host cocoons, noting exuviae, &c., shows the Tachinid fly to be a *primary* parasite.

The early larval stages of the parasite have not been studied, nor has the association of the parasite to the host regarding attachment for respiratory purposes. The stages found have been well advanced, corresponding to those represented in Figs. 7 and 8. A prepupa has been found to support, internally, five Tachinid larvae, though the usual number appears to be one or two. On opening cocoons, the host prepupa may appear perfect, but in time the body of the prepupa becomes irregular, and appears shrivelled except where one of more parasite larvae are present. Later they leave the host and pupate within the host cocoon (Plate IV., Fig. 8). It is noticeable that where complete puparia have been found, lying freely within the cocoon, with the shrivelled remains of the prepupa pushed to one side, the sieve-like partition at the top invariably shows an aperture or break. This partition, however, always appears complete when the parasite is within the body of the prepupa. Apparently the partition is cut by the Tachinid larva, previous to pupating, to facilitate emergence of the fly.

There is seldom any indication of the existence of these parasites when the larvae are collected, no doubt due to an ecdysis having taken place after the Tachinid eggs were laid on the body of the host. In some broods, however, where parasitism occurred it was noticed that the host cocoons were spun irregularly, i.e. more or less horizontally instead of vertically, and singly instead of in masses.

The length of time spent by the Tachinid within the host is shown in the emergence data in Section B.:—

Brood 1.—Tachinids emerged ten months after cocoon-spinning of the host, and again twelve months later.

Brood 2.—Tachinids emerged six months after cocoon-spinning, and again twelve months later.

Brood 22.—Tachinids emerged between nine and eleven months, after cocoon-spinning.

Brood 4.—Tachinids emerged two months after cocoon-spinning, and again nine months later.

Although all the larvae of these four broods spun during the same month (October), the time spent by the parasites within their host cocoons varies widely in the different broods. This might be accounted for by the fact that some broods were attacked in early larval life, while others remained free until more fully grown.

In *Broods* 1 and 2 it appears that the Tachinid may be capable of "lasting-over" for a year, as was seen to be the case in the host. From the emergences noted in *Brood* 4, one might surmise that the individual host larvae of that brood had been "struck" at varying intervals during their larval life. The individuals of this brood would, at the time of spinning, contain parasitic larvae of various ages, which would account for the irregularities noted in the times of emergences of the parasites. This might also be the case in *Brood* 16, which spun in December and emerged in February and March, and again in September. The latter emergences occurred from cocoons which had previously been removed from the soil. (Some of the larvae of this brood were noted to be carrying eggs of Tachinids.)

Brood 14.—Of the thirteen cocoons found to contain Tachinid parasites, nine contained one each, three contained two each, and one had three. Of the nine hosts with a single parasite each, four of the latter were full-grown larvae, feeding within the host prepupa; the remaining five parasites, which were beginning to darken into the puparial condition, were lying freely within their host cocoon, having apparently only recently worked their way out of the prepupa. In those four host cocoons which each carried either two or three Tachinids, the latter had already metamorphosed into the pupal stage, the darkened puparia lying freely within the cocoons. It was noticeable that where there was more than one Tachinid puparium in the cocoon, there was a big difference in their sizes.

Brood 35.—*Perga* sp. (Data not given in Section B.) Larvae collected at Kalorama, Victoria, by Miss H. V. Steele.

28th April, 1933.—Four larvae entered the soil.

19th July, 1933.—Cocoons dug up for examination.

Three cocoons were removed, and on being opened slightly were found to contain one Tachinid puparium each. The cocoons were supported in phials plugged with cotton-wool, and were stood in a vessel containing saturated salt solution (about 75 per cent. relative humidity); these were then kept in an ordinary glass-house, and the following emergences occurred:—

14th August, 1933.—One Tachinid.

25th August, 1933.—One Tachinid.

28th August, 1933.—One Tachinid.

The Tachinids emerged, in this brood, within four months from the time of cocoon-spinning of the host.

Brood 36.—*Perga* sp. (Data not given in Section B.)

10th May, 1933.—Larvae entered the soil.

19th July, 1933.—Cocoons removed for examination.

One cocoon was found which contained a large Tachinid larva within the prepupa.

31st July, 1933.—Tachinid larva exposed by cutting the saw-fly prepupa.

5th August, 1933.—Tachinid still in larval stage.

8th August, 1933.—Tachinid puparium formed.

11th September, 1933.—Still in puparium condition.

26th September, 1933.—Tachinid emerged.

The metamorphosis of the fully-grown Tachinid larva to adult stage, occupied no more than seven weeks.

Acknowledgments.

I wish to express grateful thanks to Professor Wadham for his kindly advice during the progress of this work, to Miss F. V. Murray, M.Sc., for drawing the text-figures, and to Mr. A. O'Brien for producing the accompanying photographs. My thanks are also due to Mr. J. Clark, Entomologist to the National Museum, for his ready assistance at all times, and for indentification of species; to Mr. F. E. Wilson, F.R.E.S., who described the new species to enable me to record emergences under a name; and to various collectors of larvae used in the breeding experiments.

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Explanation of Plates IV. and V.

Plate IV.

(All photographs on Plate IV. are approximately natural size.)

Fig. 1.—Cocoon-spinning larva (above), and prepupa (below), of *Perga dorsalis* Leach (Brood 14).

Fig. 2.—Mass of cocoons of *Perga* sp., four of which have been cut open to show the living prepupae: and cocoon-spinning larva (preserved in alcohol) of the same brood (Brood 33).

Fig. 3.—Living prepupa and pupa of *Perga* sp. (Brood 44).

Fig. 4.—Cocoons of *Perga dorsalis* Leach, opened to expose pupae (Brood 46).

Fig. 5.—Cocoon of *Perga dorsalis* Leach, cut open to show adult ready to emerge. Note partition and larval exuvia at top of cocoon. Other exuviae not visible.

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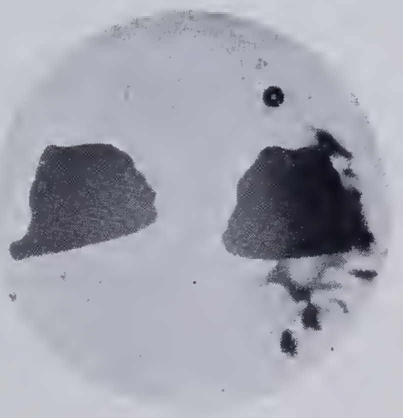
Saw-fly and Parasite.



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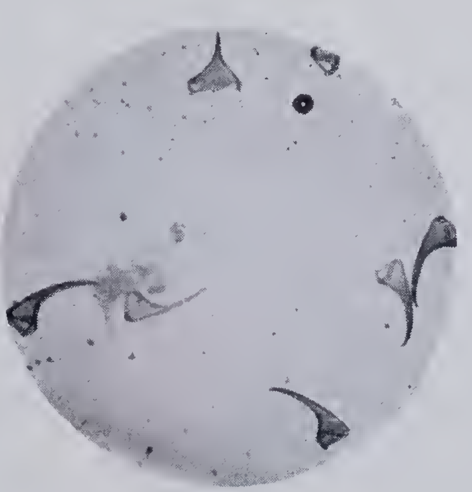

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Saw-fly and Parasite.

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Fig. 6.—Cocoons of *Perga* sp. (Brood 36) opened to show Ichneumonid primary parasite: right, Ichneumonid cocoon in position; left, Ichneumonid larva removed from its cocoon.

Fig. 7.—Mature larva of Tachinid fly exposed by cutting open shrivelled prepupa of *Perga* sp. (Brood 36).

Fig. 8.—Puparial shells of Tachinid fly, exposed by cutting open cocoon of *Perga* sp.

PLATE V.

Fig. 9.—Photomicrograph of mandibles of cocoon-spinning larva of *Perga nemoralis* Wilson (Brood 24). × 15.

Fig. 10.—Photomicrograph of mandibles of prepupa of *Perga nemoralis* Wilson (Brood 24). × 15.

Fig. 11.—Photomicrograph of portion of exuvia of mature larva of *Trigonalis maculatus* Sm., showing tri-dentate mandibles. × 29.

Fig. 12.—Photomicrograph of sickle-like mandibles of early instars of *Trigonalis macultaus* Sm. larvae, teased out from meconium of a mature larva of same. × 29.

[Proc. Roy. Soc. Victoria, **47** (N.S.), Pt. I., 1934.]

Art. V.—*An Investigation into the Influence of Sulphate of Ammonia on Stubble-sown Oat Crops in Victoria.*

By D. C. WARK, B.Agr.Sc.

(Communicated by G. W. Leeper, M.Sc.)

Introduction.

[Read 10th May, 1934; issued separately, 22nd December, 1934.]

A series of experiments at the Waite Institute, South Australia(5, 6), has shown that cereal crops when grown on land which has carried a crop the previous year respond to the application of nitrogenous fertilizers. It was with the object of determining whether a similar response occurs in the region of higher rainfall (20 inches or more per annum) in Victoria that this investigation was initiated. Oaten hay, being the cereal crop most sown on stubble in Victoria, was chosen for the experiment. Although Howell(3), thirty years ago, described experiments in which the application of 1 cwt. of sulphate of ammonia per acre increased the yields of hay crops by as much as 0.5 to 0.8 ton per acre, comparatively little attention has since been given to this matter.

Two series of field trials were conducted, one at Bannockburn, one at Buangor.

The Bannockburn plots were on the property of Mr. F. G. Mason, 4 miles from Bannockburn, which is 13 miles from Geelong on the railway line to Ballarat.

The plots were sown on a level area of uniform soil which has been derived from later Tertiary sediments and has undergone considerable leaching. The surface soil is a fine-textured sandy loam, light brown in colour and slightly acid. Below 8-9 inches there is a yellow clay subsoil which becomes lighter in colour with increase in depth.

The Buangor plots were on the property of Pickford Bros., about 1 mile from Buangor, which is 14 miles west of Beaufort. The plots were sown on a level piece of ground, but the soil is very variable, four different types of surface soil being present. These occur in patches of 1 square yard or less, and differ from each other in colour and in the amount of gravel they contain. This gravel, locally known as buckshot, consists mainly of iron oxide. All the types are slightly acid loams or clay loams, grey or brown in colour. The types of subsoil contain more clay and silt than the types of surface soil immediately above them. The buckshot gravel is irregularly distributed in depth. This variability of soil is typical of a large area in this part of the Western District of Victoria. This soil is derived from Ordovician marine sediments. Red box (*Eucalyptus polyanthemos*) and red stringybark (*Eucalyptus macrorrhyncha*) are the chief native trees.

The mechanical analyses of the various types of soil are shown in Table I.

At Bannockburn the total rainfall during the year was 19½ inches, of which 12 inches fell during the growing period of the crop (May–November). At Buangor the total rainfall was 23 inches, of which 14½ inches fell during the growing period of the crop. The monthly rainfall at both places and the number of days on which one or more points were recorded are shown in Table II.

TABLE I.—MECHANICAL ANALYSES OF THE SOILS AT BANNOCKBURN AND BUANGOR.

Site	Bannockburn.			Buangor.							
Soil type	..	..		Grey loam.		Grey rubbly loam.		Light brown clay loam.		Dark-brown clay loam.	
Depth, inches ..	0–8	8–11	28–32	0–5	18–24	0–8	21–24	0–11	11–20	0–8	8–12
Coarse sand ..	% 24·9	% 18·7	% 16·8	% 19·8	% 7·3	% 21·5	% 13·7	% 4·9	% 11·6	% 6·5	% 1·2
Fine sand	31·5	26·2	20·6	34·1	22·5	36·1	20·6	21·4	17·7	31·4	12·6
Silt	23·4	8·0	9·5	24·7	44·0	23·3	36·6	22·6	12·6	16·8	25·3
Clay	13·1	34·7	41·6	14·8	14·6	14·3	19·7	40·4	48·6	41·5	47·2
Loss on peroxide + acid treatment	5·0	7·0	7·7	5·6	1·8	3·5	2·3	4·7	0·1	2·0	3·1
Moisture	2·6	6·5	4·6	2·6	11·2	2·4	7·2	7·7	9·8	4·0	9·3
Gravel (in air-dry sample) per cent.	2·8	5·5	2·0	5·7	10·3	31·5	20·6	4·9	26·3	4·2	0·2
Total nitrogen, per cent.	0·07	..	..	0·11	..	0·13	..	0·11	..	0·09	..
Soil reaction pH ..	5·5	5·3	7·2	5·1	6·8	5·4	6·8	6·0	5·6	5·7	5·2

TABLE II.—THE MONTHLY RAINFALL AND THE NUMBER OF RAINY DAYS IN 1933 AT BANNOCKBURN AND AT BUANGOR.

—	Bannockburn.		Buangor.	
	Rainfall (Points).	Number of Rainy Days.	Rainfall (Points).	Number of Rainy Days.
January	34	3	57	5
February	30	3	..	..
March	53	3	137	4
April	129	5	105	5
May	262	9	224	10
June	124	8	114	8
July	170	8	205	10
August	171	12	240	16
September	128	4	281	12
October	70	4	129	6
November	288	3	267	4
December	491	7	540	10
Total	1,950	69	2,299	90

Experimental Procedure.

(*a*) *General.*—At each site the unit plot was 1/20th acre in area. Each plot received a basal dressing of 1½ cwt. of superphosphate per acre, and the oats were sown at the rate of 2 bushels per acre. The treatments included were:—

1. No nitrogen.
2. Sulphate of Ammonia, ¾ cwt. per acre.
3. Sulphate of Ammonia, 1½ cwt. per acre.

Commercial fertilizer mixtures were used to supply these dressings, and were drilled in with the seed. Each treatment was replicated four times, and the plots were arranged in the form of a "randomized block" (1) At harvest the hay obtained from each plot was weighed separately, and the yields of each treatment expressed as cwt. per acre. The grain yields were estimated from selected samples of the crop. (See section *c*). In addition, the features *b, c,* and *d* were studied by the methods described.

(*b*) *Changes in the Nitrate and the Ammonia Content of the Soil.*—The soil from each plot was sampled to a depth of 9 inches, at monthly intervals, throughout the growing period of the crop. A ¾-inch soil tube was used and nine cores were removed at distances of 9 yards apart along the midline of each plot. These were mixed to form the sample. A larger tube, 1¼ inches in diameter, was sometimes used, but the sampling method was otherwise the same. Moisture, ammonia, and nitrate were determined on each sample. The moisture contents were determined by drying the material in an oven at 105 deg. C. for 24 hours. The loss of weight is expressed as a percentage of the weight of the oven-dry soil. Nitrate was determined by Harper's phenoldisulphonic acid method(2), and ammonia by the method described in Appendix 1. It may be noted here that the amounts of nitrogen added to the top 9 inches of soil in the dressings of ¾ and 1½ cwt. sulphate of ammonia were 6½ and 13 parts per million of soil respectively.

(*c*) *Census Study of Growth and Yield of the Crop.*—A census study was included, so that the effect of the different quantities of sulphate of ammonia on the growth of the individual plants could be observed. The plants on fifteen one-foot lengths of drill-row on each plot were counted, and their development studied at intervals throughout the growing period.

Three weeks after germination the plants on each selected length of drill row were counted, and the average number of plants per foot was calculated, in the case of each plot, and each treatment. In October, the average number of plants per foot was again determined, together with the average number of tillers per plant. At harvest time the number of plants per foot, the number of ears per plant, and the number of spikelets and grains per ear were determined, together with the average weight of 1,000 grains and the bushel weight of the grain.

The grain from these samples and from fifteen other one-foot length of drill row on each plot was thrashed out and weighed, and the weights were used to estimate the yields of grain from each plot.

(*d*) *Nitrogen Content of the Crop.*—The nitrogen content of the crop on each plot was determined on the material collected in October for the tillering count. The plants on fifteen one-foot lengths of drill row on each plot were hand-pulled and the roots were later removed. The above-ground material was analyzed by the Kjeldahl method. The nitrogen content of the grain and of the straw at harvest were determined on the material from fifteen one-foot lengths of drill row from each plot. The amount of nitrogen removed from the soil was then calculated.

Details of Results.

BANNOCKBURN.

(*a*) *General.*—The plots were sown on 5th May, 1933, the unit plot being a 14-row drill strip 88 yards long and 1/20th acre in area. (The heaviest dressing contained only 152 lb. each of superphosphate and sulphate of ammonia, instead of the desired 168 lb. of each.)

The plots were harvested on 24th November. The final hay yields and the estimated grain yields are given in Table III. The grain yields were estimated from the material of 30 1-foot lengths of drill row on each plot.

TABLE III.—FINAL YIELDS AT BANNOCKBURN.

Treatment.	Hay Yields (Cwt. per Acre).	Increment Due to Nitrogen (Cwt. per Acre).	Estimated Grain Yield (Bushels per Acre).	Increment Due to Nitrogen (Bushels per Acre).
No nitrogen	17·9	..	21·4	..
Sulphate of ammonia, $\frac{3}{4}$ cwt. per acre	31·8	13·9	36·8	15·4
Sulphate of ammonia, $1\frac{1}{2}$ cwt. per acre	38·3	20·4	41·8	20·4

The differences in the hay yields are significant*, the standard error of the mean being 0.84 cwt. per acre. The grain yield on the $\frac{3}{4}$ cwt. per acre treatment is significantly higher than that on the no-nitrogen treatment, the standard error of the mean being 2.14 bushels per acre.

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* A "significant" difference is one that might be obtained by chance not more than once in twenty times. The term is used throughout this Paper with this meaning.

(*b*) *Nitrate and Ammonia Content of the Soil.*—Samples of the soil were analyzed at monthly intervals until 9th October. The results of the analysis are shown in Table IV., and are illustrated in the form of a graph in Figure 1.

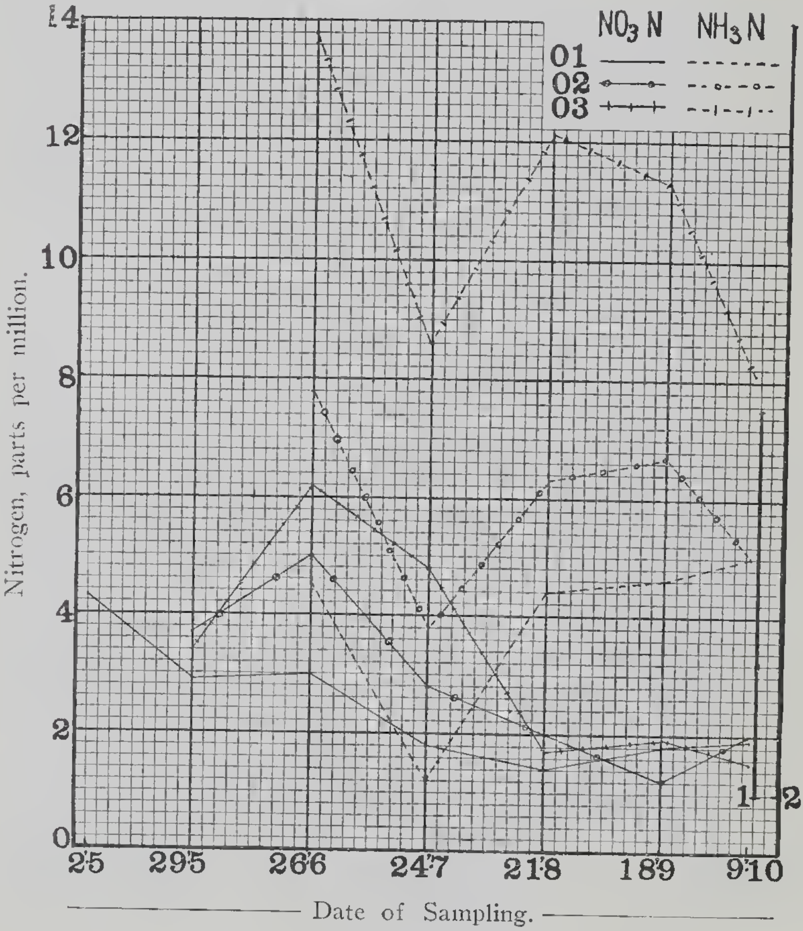

FIGURE 1.

Graph showing changes in nitrate and ammonia nitrogen content of the soil at Bannockburn during the growing period of the crop 1933.

1. Amount of nitrogen applied in ¾ cwt. sulphate of ammonia per acre.
2. Amount of nitrogen applied in 1½ cwt. sulphate of ammonia per acre.

Treatments.

01. No nitrogen.
02. Sulphate of ammonia—¾ cwt. per acre.
03. Sulphate of ammonia—1½ cwt. per acre.

TABLE IV.—CHANGES IN THE MOISTURE, NITRATE, AND AMMONIA CONTENT OF THE SOIL AT BANNOCKBURN.

Date.	Treatment.	Moisture Content Per Cent.	Nitrate Nitrogen Content—Parts per Million.	Ammonia Nitrogen Content—Parts per Million.
2.5.33	Before seeding	10·2	4·3	..
29.5.33	No nitrogen	13·2	2·9	..
	Sulphate of ammonia, ¾ cwt. per acre	11·3	_3·7_	..
	Sulphate of ammonia, 1½ cwt. per acre	10·0	3·4	..
26.6.33	No nitrogen	15·2	3·0	4·5
	Sulphate of ammonia, ¾ cwt. per acre	15·7	_5·0_	_7·8_
	Sulphate of ammonia, 1½ cwt. per acre	15·5	_6·2_	_13·8*_
24.7.33	No nitrogen	12·6	1·8	1·2
	Sulphate of ammonia, ¾ cwt. per acre	13·2	2·8	_3·8_
	Sulphate of ammonia, 1½ cwt. per acre	13·5	_4·8_	_8·6*_
21.8.33	No nitrogen	13·4	1·4	4·4
	Sulphate of ammonia, ¾ cwt. per acre	14·1	2·0	6·3
	Sulphate of ammonia, 1½ cwt. per acre	14·4	1·7	_12·1*_
18.9.33	No nitrogen	11·7	1·8	4·6
	Sulphate of ammonia, ¾ cwt. per acre	10·8	1·2	6·7
	Sulphate of ammonia, 1½ cwt. per acre	9·6	1·9	_11·3*_
9.10.33	No nitrogen	10·5	1·9	5·0
	Sulphate of ammonia, ¾ cwt. per acre	8·7	2·0	5·0
	Sulphate of ammonia, 1½ cwt. per acre	_7·0_	1·5	8·1

All figures in *italics* are significantly different from the corresponding figures for the no-nitrogen plots.

* These figures are also significantly different from those in the preceding row.

The chief points of interest are—

(1) The disappearance of the ammonia, whether by absorption by the plants, by leaching, or by change to nitrate or to other nitrogen compounds in the soil, was slow. Five months after the fertilizer was applied there was still appreciably more ammonia nitrogen in the soil of the 1½ cwt. per acre plots than in that of the no-nitrogen plots. This can be explained by assuming either that the addition of ammonium sulphate had a stimulating effect on the organisms which form ammonia in the soil, or that the nitrification (i.e., change to nitrate) was unusually slow in this soil. However, all the added ammonia on the ¾ cwt. per acre plots had disappeared during the first five months after application.

(2) In June and July there was a significantly higher content of nitrate nitrogen in the soil of the sulphate of ammonia plots. The nitrate content was then appreciably higher on the 1½ cwt. per acre plots than on the ¾ cwt. per acre plots. This was in accordance with general experience, as was the low value for the nitrate content of the soil in September and October.

It must be noted that the soil was sampled between the drill rows, so that the samples did not exactly represent the soil on which the plants were growing.

(*c*) *Census Study of Growth and Yield of Crop.*—The results of the census study are summarized in Table V.

TABLE V.—RESULTS OF THE CENSUS STUDY AT BANNOCKBURN.

——	No Nitrogen.	Sulphate of Ammonia, ¾ Cwt. per Acre.	Sulphate of Ammonia, 1½ Cwt. per Acre.
(1) *Population.*			
Mean number grains sown per foot, 5th May, 1933	16·2	16·2	16·2
Germination—Mean number plants per foot, 19th June, 1933	12·7	11·3	_10·3_
Mean number plants per foot, 9th October, 1933	13·2	12·3	_10·9_
Mean number plants per foot at harvest, 24th November, 1933	11·7	11·1	8·6
Percentage survival of plants to harvest ..	89·0	90·0	79·0
(2) *Tillering.*			
Average number of tillers per plant, 9th October, 1933	3·5	_5·2_	_6·2_*
†Estimated green weight of the crop (cwt. per acre), 9th October, 1933	37·4	_67·6_	_82·7_*
Average number of tillers per foot, 9th October, 1933	45·3	63·4	_67·6_
(3) *Ears and Grains.*			
Average number of ears per plant ..	1·2	1·6	_2·0_
Average number of ears per foot	14·2	17·3	17·1
Percentage of tillers formed which produce ears	31·4	27·4	25·3
Average number of spikelets per ear ..	7·1	_9·8_	_10·6_*
Average number of grains per spikelet ..	1·82	1·89	_1·90_
Average number of grains per ear ..	12·8	_18·6_	_20·0_*
Average number of sterile grains per ear ..	0·46	0·67	0·58
Average weight of 1,000 grains (grams) ..	28·3	29·5	29·2
Bushel weight of the grain, lb. per bushel ..	36·7	37·7	38·2
Estimated grain yield, bushels per acre ..	21·4	36·8	41·8

All figures in *italics* are significantly different from the corresponding figures for the no-nitrogen plots.

* These figures are also significantly different from those in the preceding column.

† This figure indicates the amount of silage that could have been obtained from the crop. The estimated air-dry weights at this stage are given in Table VII.

The chief points of interest are as follows:—

(1) There was a depression of germination on the sulphate of ammonia plots, the effect being more marked on the 1½ cwt. per acre plots. Germination was later on the sulphate of ammonia plots than on the no-nitrogen plots.

(2) There was an increased formation of tillers on the sulphate of ammonia plots, and this more than compensated for the depression of germination. However, there was a lower percentage survival of tillers to harvest on the sulphate of ammonia plots. This was a direct result of the large number of tillers formed, and the competition between them.

(3) There was an increase, both in the number of ears produced per plant and in the size of the ears, on the sulphate of ammonia plots. Nevertheless, there were no more ears produced per foot of drill row on the 1½ cwt. per acre plots than on the ¾ cwt. per acre plots.

(4) The main reason for the higher yield of grain on the sulphate of ammonia plots than on the no-nitrogen plots was the larger number of grains per ear. There were also more ears per plant and per foot of drill row (see 3).

(5) There was no appreciable difference in the average size of the individual grains from the various treatments, but the bushel weight was slightly greater in the case of the grain from the sulphate of ammonia plots.

(6) The crop on the no-nitrogen plots showed marked yellowing in July and August, but the sulphate of ammonia plots were a healthy bright green in colour. Although the no-nitrogen plots showed superior growth in May and June, the sulphate of ammonia plots showed superior growth in the next four months. The plots that had received ¾ cwt. and 1½ cwt. per acre were respectively 3 inches and 6 inches taller than the no-nitrogen plots in October. The crop was also much denser on the sulphate of ammonia plots than on the no-nitrogen plots. At harvest, however, there was little difference in height between the crops on the various plots.

(*d*) *Nitrogen Content of the Crop.*—The nitrogen content of the crop in October, and that of the grain and straw at harvest, are shown in Table VI.

TABLE VI.—NITROGEN CONTENT AS PERCENTAGE OF AIR-DRY MATERIAL, IN OCTOBER AND AT HARVEST.

Treatment.	Percentage of Nitrogen in Crop on 9th October, 1933.	Percentage of Nitrogen at Harvest.	
		In Grain.	In Straw.
No nitrogen	1·07	1·46	0·37
Sulphate of ammonia, ¾ cwt. per acre	1·06	1·46	0·37
Sulphate of ammonia, 1½ cwt. per acre	1·07	1·47	0·39

The added nitrogen had no effect on the percentage of nitrogen in the crop. Richardson and Fricke(6) have also shown that dressings of sulphate of ammonia applied at the rates of less than

1 cwt. per acre did not appreciably increase the nitrogen percentage of the grain or of the straw of barley. Larger dressings caused a marked increase in the nitrogen percentage of both the grain and the straw.

The total amounts of nitrogen removed by the crop per acre under each treatment was then calculated. The results, as well as the quantity of nitrogen applied to the soil per acre under each treatment, are shown in Table VII.

TABLE VII.—TOTAL NITROGEN REMOVED BY THE VARIOUS CROPS.

Treatment.	Nitrogen Applied in Fertilizer (lb. p.a.).	October Material.		Harvest Material.				Total Nitrogen Removed by crop (lb. p.a.).
				Grain.		Straw.		
		Dry Weight (lb. p.a.).	Nitrogen Removed (lb. p.a.).	Weight (lb. p.a.).	Nitrogen Removed (lb. p.a.).	Weight (lb. p.a.).	Nitrogen Removed (lb. p.a.).	
No nitrogen ..	..	2,036	21·8	856	12·50	1,144	4·23	16·7
Sulphate of ammonia, $\frac{3}{4}$ cwt. per acre ..	17·8	3,831	36·1	1,472	21·49	2,088	7·73	29·2
Sulphate of ammonia, $1\frac{1}{2}$ cwt. per acre ..	35·6	4,452	41·6	1,672	24·58	2,608	10·17	34·7

It will be noticed that the total nitrogen content in the above-ground portions of the crop was greater in October than at harvest. Knowles and Watkins(4) have shown that there is a migration of the various plant nutrients from the above-ground portions of the wheat plant during the later stages of the life history.

BUANGOR.

(*a*) *General.*—The plots were sown on 9th May, 1933. The unit plot was a 15-row drill strip 83 yards long, the area being 1/20th acre. The outside row on each side was removed immediately before the plots were harvested. The area at harvest was 1/25th acre.

The final hay yields and the estimated grain yields are shown in Table VIII. The grain yields were estimated from thirty 1-foot lengths of drill row from each plot.

TABLE VIII.—FINAL YIELDS AT BUANGOR.

Treatment.	Hay Yields (Cwt. per Acre).	Increment Due to Nitrogen (Cwt. per Acre).	Estimated Grain Yield (Bushels per Acre).	Increment Due to Nitrogen (Bushels per Acre).
No nitrogen	27·8	..	35·9	..
Sulphate of ammonia, $\frac{3}{4}$ cwt per acre	43·9	16·1	46·2	10·3
Sulphate of ammonia, $1\frac{1}{2}$ cwt per acre	57·4	29·6	59·5	23·6

All the above differences are significant, the standard error of the mean being 1.6 cwt. per acre in the case of the hay yields, and 2.7 bushels per acre in the case of the grain yields.

(*b*) *Nitrate and Ammonia Content of the Soil.*—Samples of the soil were analyzed at monthly intervals until 3rd October. The results are shown in Table IX., and are illustrated in the form of a graph in Fig. 2.

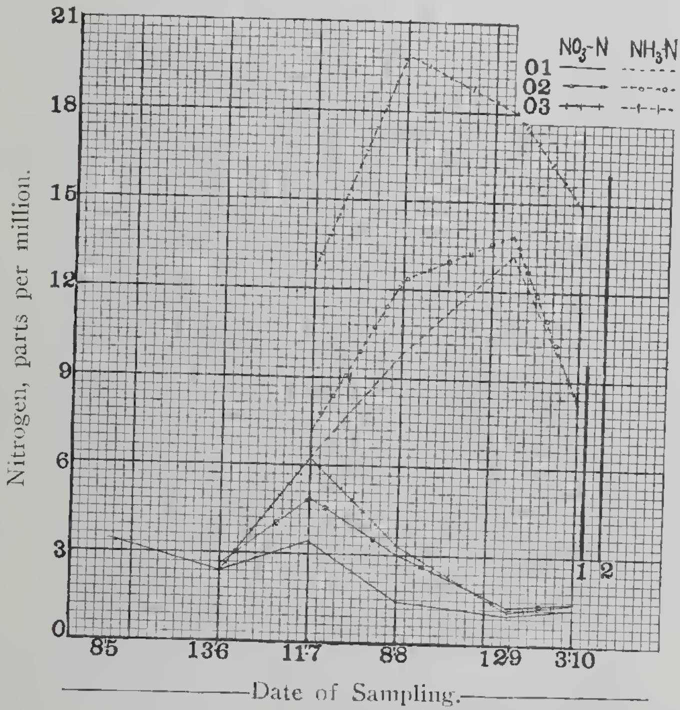

FIGURE 2.

Graph showing changes in nitrate and ammonia nitrogen content of the soil at Buangor during the growing period of the crop 1933.

1. Amount of nitrogen applied in ¾ cwt. sulphate of ammonia per acre.
2. Amount of nitrogen applied in 1½ cwt. sulphate of ammonia per acre.

Treatments.

01. No nitrogen.
02. Sulphate of ammonia—¾ cwt. per acre.
03. Sulphate of ammonia—1½ cwt. per acre.

TABLE IX.—CHANGES IN THE MOISTURE, NITRATE, AND AMMONIA CONTENT OF THE SOIL AT BUANGOR.

Date.	Treatment.	Moisture Content Per Cent.	Nitrate Nitrogen Content—Parts per Million.	Ammonia Nitrogen Content—Parts per Million.
9.5.33	Before seeding	10·7	3·4	..
13.6.33	No nitrogen	22·5	2·4	..
	Sulphate of ammonia, ¾ cwt. per acre	22·5	2·6	..
	Sulphate of ammonia, 1½ cwt. per acre	22·5	2·4	..
11.7.33	No nitrogen	21·3	3·4	6·2
	Sulphate of ammonia, ¾ cwt. per acre	21·8	*4·9*	7·2
	Sulphate of ammonia, 1½ cwt. per acre	22·6	*6·2**	*12·6**
8.8.33	No nitrogen	22·4	1·4	9·8
	Sulphate of ammonia, ¾ cwt. per acre	20·6	3·0	12·3
	Sulphate of ammonia, 1½ cwt. per acre	20·0	*3·3*	*19·9**
12·9·33	No nitrogen	22·0	1·0	13·2
	Sulphate of ammonia, ¾ cwt. per acre	22·0	1·3	13·9
	Sulphate of ammonia, 1½ cwt. per acre	22·0	1·1	*18·0*
3.10.33	No nitrogen	19·8	1·2	8·4
	Sulphate of ammonia, ¾ cwt. per acre	21·7	1·4	8·2
	Sulphate of ammonia, 1½ cwt. per acre	21·1	1·4	14·9

All figures in *italics* are significantly different from the corresponding figures for the no-nitrogen plot.

* This figure is also significantly different from that in the preceding row.

The chief points of interest are:—

(1) As was the case at Bannockburn, the plots that had received 1½ cwt. of sulphate of ammonia per acre still showed an appreciably higher ammonia content than the no-nitrogen plots five months after the application. It was expected that all would have been absorbed by the plants, changed to other nitrogen compounds, or been leached from the surface soil by this time. The excess ammonia in the plots that had received ¾ cwt. of sulphate of ammonia per acre had, however, all disappeared during the first five months.

(2) The sulphate of ammonia plots had, in July and August, more nitrate nitrogen than the no-nitrogen plots. The nitrate content of the soil was then highest on the 1½ cwt. per acre plots.

The results of these soil analyses are not as reliable as those of the Bannockburn soil. The errors of sampling are large because the soil is variable.

The samples were taken from between the drill rows, and so do not accurately represent the soil on which the plants were growing.

(*c*) *Census Study of Growth and Yield of Crop.*—The results of the census study of the crop are summarized in Table X.

TABLE X.—RESULTS OF THE CENSUS STUDY AT BUANGOR.

——	No Nitrogen.	Sulphate of Ammonia, ¾ Cwt. per Acre.	Sulphate of Ammonia, 1½ Cwt. per Acre.
(1) *Population.*			
Mean number grains sown per foot, 9th May, 1933	16·1	16·1	16·1
Germination—Mean number plants per foot, 30th June, 1933	11·2	11·7	11·6
Mean number plants per foot, 3rd October, 1933	11·6	12·5	11·6
Mean number plants per foot at harvest, 9th December, 1933	10·6	11·3	11·2
Percentage survival of plants to harvest ..	92·5	90·5	97·0
(2) *Tillering.*			
Mean number tillers per plant, 3rd October, 1933	3·8	*5·2*	_6·0_*
†Estimated green weight of crop (cwt. per acre), 3rd October, 1933	44·3	*81·5*	*101·4*
Mean number tillers per foot, 3rd October, 1933	41·4	63·5	69·3
(3) *Ears and Grains.*			
Mean number ears per plant	1·3	1·7	*1·8*
Mean number ears per foot	14·0	18·9	*20·0*
Percentage of tillers formed which produce ears	34·8	29·8	27·8
Mean number spikelets per ear	9·9	10·4	11·2
Mean number grains per spikelet	1·91	1·90	1·88
Mean number grains per ear	18·9	19·4	21·2
Mean number sterile grains per ear ..	0·66	0·61	0·66
Mean weight of 1,000 grains (grams) ..	32·2	31·7	33·4
Bushel weight (lb. per bushel)	37·0	39·0	40·2
Estimated grain yield (bushels per acre) ..	35·9	46·2	59·5

All figures in italics are significantly different from the corresponding figures for the no-nitrogen plots.

* This figure is also significantly different from that in the preceding column.

† This figure indicates the amount of silage or green feed that could have been obtained. The estimated air-dry weights of the crop at this stage are shown in Table xii.

The chief points of interest are as follows:—

(1) There was no depression of germination on the sulphate of ammonia plots.

(2) There was an increased formation of tillers on the sulphate of ammonia plots.

(3) There was an increase in the number of ears produced per plant, as well as in the size of the ears on the sulphate of ammonia plots.

(4) The higher yield on the sulphate of ammonia plots than on the no-nitrogen plots was mainly due to an increase in the number of ears per foot of drill row. There was also an increase in the size of the ear.

(5) There was no appreciable difference in the size of the individual grains from the various treatments. The bushel weight was slightly higher in the case of the grain on the sulphate of ammonia plots.

(6) In July and August yellowing was widespread—particularly on the no-nitrogen plots. It was particularly noticeable on the light-brown patches of soil. In August and September the crop on the sulphate of ammonia plots was definitely taller than that on the no-nitrogen plots. This difference in height increased until at harvest the plants on the 1½ cwt. plots were at least 9 inches taller than those on the no-nitrogen plots. Those on ¾ cwt. plots were intermediate in height.

(*d*) *Nitrogen Content of the Crop.*—The nitrogen content of the crop in October, and of the grain and straw at harvest, is shown in Table XI.

TABLE XI.—NITROGEN CONTENT AS PERCENTAGE OF AIR-DRY MATERIAL, IN OCTOBER AND AT HARVEST.

Treatment.	Percentage of Nitrogen in Crop on 9th October, 1933.	Percentage of Nitrogen at Harvest.	
		In Grain.	In Straw.
No nitrogen	1·05	1·44	0·35
Sulphate of ammonia, ¾ cwt. per acre	1·06	1·44	0·36
Sulphate of ammonia, 1½ cwt. per acre	1·10	1·46	0·36

In October there was no appreciable difference in the nitrogen percentage of the crops grown with the various treatments. At harvest there was no appreciable difference in the nitrogen percentage of the grain or the straw.

The actual amounts of nitrogen removed by the crop, together with that applied in the fertilizer dressing, appear in Table XII.

Table XII.—Total Nitrogen Removed by the Various Crops.

Treatment.	Nitrogen Applied in Fertilizer (lb. p.a.).	October Material.		Harvest Material.				Total Nitrogen Removed (lb. p.a.).
				Grain.		Straw.		
		Dry Weight (lb. p.a.).	Nitrogen Removed (lb. p.a.).	Weight (lb. p.a.).	Nitrogen Removed (lb. p.a.).	Weight (lb. p.a.).	Nitrogen Removed (lb. p.a.).	
No nitrogen ..	..	1,965	20·6	1,436	20·68	1,796	6·29	27·0
Sulphate of ammonia, ¾ cwt. per acre ..	17·8	3,677	38·9	1,848	26·61	3,138	11·30	37·9
Sulphate of ammonia, 1½ cwt. per acre ..	35·6	4,034	44·4	2,380	34·75	4,161	14·98	49·7

It will be noticed that the total nitrogen in the crop was greater at harvest than when the October material was collected. This material was collected at an earlier stage of maturity than that at Bannockburn, and probably had not developed the maximum nitrogen content.

Comparison of Results from Bannockburn and Buangor.

The final yields at Bannockburn and at Buangor given in Tables III. and VIII. respectively may be compared as follows:—

A. Final Yields.

Hay Yields.—At each place the increment in yield obtained with the first ¾ cwt. of sulphate of ammonia per acre was greater than that obtained with the second ¾ cwt. per acre. The yield on the no-nitrogen plots was greater at Buangor than at Bannockburn, and the actual increments in yield due to sulphate of ammonia were greater at Buangor. At both places the yield was more than doubled by applying 1½ cwt. per acre.

Grain Yields.—At Buangor the first ¾ cwt. of sulphate of ammonia increased the yield by 10 bushels per acre (=25 per cent. of the no-nitrogen yield). The second ¾ cwt. increased the yield by an equal amount. At Bannockburn the first ¾ cwt. increased the yield by 15 bushels (=70 per cent. of the no-nitrogen yield), the second ¾ cwt. increased it only by 5 bushels. The grain yields were higher at Buangor than at Bannockburn.

If sulphate of ammonia is valued at 9s. 9d. per ¾ cwt. applied (market price = £12 7s. 6d. per ton f.o.r.) oaten hay at 30s. per ton, and oats at 1s. 6d. per bushel, the profit or loss of applying each successive ¾ cwt. per acre is shown in Table XIII.

Table XIII.—The Profit (+) or Loss (—) per acre of Applying Increasing Dressings of Sulphate of Ammonia.

Due to—	Bannockburn.		Buangor.	
	For Hay.	For Grain.	For Hay.	For Grain.
	s. *d.*	*s.* *d.*	*s.* *d.*	*s.* *d.*
First ¾ cwt. per acre	+ 11 6	+ 13 0	+ 14 6	+ 5 0
Second ¾ cwt. per acre ..	+ 1 0	— 2 0	+ 11 6	+ 8 0
Total 1½ cwt per acre ..	+ 12 6	+ 11 0	+ 35 6	+ 13 0

With these assumed prices, 1½ cwt. per acre with a suitable dressing of superphosphate, is profitable at both places when oats are grown for hay.

If oaten hay were valued at 20s. per ton the profits of applying successive ¾ cwt. dressings at Bannockburn would have been + 4s. 6d. and — 3s., and at Buangor they would have been + 6s. 6d. and + 4s., so that ¾ cwt. per acre would be the more profitable quantity to apply at Bannockburn.

At Bannockburn, ¾ cwt. per acre is the more profitable amount to apply if the oats are grown for grain. At Buangor 1½ cwt. per acre is the more profitable amount.

B. Nitrate and Ammonia Content of the Soil.

At both places there was, from the time of application onwards, a steady decline in the amount of ammonia that the sulphate of ammonia plots contained in excess of the no-nitrogen plots. There was a definite seasonal change in the ammonia content of the soil, and the graph representing this was of the same form at each place, although the ammonia content of the soil was somewhat higher at Buangor than at Bannockburn. It is usual for the nitrate content of the soil carrying a cereal crop to be very low in September and October.

At both places there was a steady drop in the nitrate content of the soil in the no-nitrogen plots from seeding to October. The nitrate content of the soil was lower at Buangor than at Bannockburn. On the sulphate of ammonia plots there was an increase in the nitrate content of the soil from the end of June to the beginning of August. This was largest on the 1½ cwt. plots. The increases in nitrate content on the sulphate of ammonia plots was almost equal at each place.

C. CENSUS STUDIES OF GROWTH AND YIELD OF CROP.

(1) *Population.*—At both places the number of grains sown per foot of drill row was slightly over 16.

The germination on the no-nitrogen plots was higher at Bannockburn than at Buangor. At Bannockburn, the sulphate of ammonia delayed germination, and caused a definite depression of germination. This was probably due to the osmotic power of the concentrated solution formed in the soil, which had an injurious action on the seeds. It did not occur at Buangor, where the soil is heavier.

In October, there were in many cases actually more plants per foot of drill row than in June. This was because grains which had failed to germinate in the dry soil did so after the heavy rains in June (108 points fell at Bannockburn between 22nd June and 28th June; at Buangor light rains towards the end of June were followed by 45 points on 10th July).

At both places there was a slightly lower percentage survival of plants till harvest on the no-nitrogen plots than on the sulphate of ammonia plots. At Bannockburn, however, the no-nitrogen plots still contained the most plants per foot of drill row.

(2) *Tillering.*—At each place most tillers were formed per plant and per foot of drill row on the sulphate of ammonia plots that had received 1½ cwt. per acre, and least were formed on the no-nitrogen plots.

(3) *Ears and Grains.*—At Buangor the applied nitrogen caused an increase in the number of ears produced per plant, and in the number of spikelets and grains per ear. The number of ears per foot of drill row was also increased. There was little difference in the size of the individual grains, but the bushel weight was slightly higher on the sulphate of ammonia plots.

Similar results were obtained at Bannockburn, except that there was no difference between the number of ears formed per foot of drill row on the ¾ cwt. per acre and on the 1½ cwt. per acre plots.

The higher yields at Buangor than at Bannockburn were due more to larger ears and larger grains than to an increase in the number of ears.

D. NITROGEN CONTENT OF THE CROP.

October Material.—The results obtained at the two places are not comparable as the material from Bannockburn was at a later stage of maturity than that from Buangor. At neither place was there any appreciable difference in the nitrogen percentage of the crops due to the various treatments.

Harvest Material.—Neither the grain nor the straw showed any appreciable difference in nitrogen percentage due to the various treatments. At neither place was the nitrogen applied in the fertilizer completely recovered in the crop. However, about two-thirds was recovered in the crop; the amount of the heavier dressing recovered being higher at Buangor than at Bannockburn.

Summary.

The effect of ammonium sulphate on the growth and yield of stubble-sown oaten hay crops has been studied on field plots at Bannockburn and Buangor, where the rainfall for 1933 was 19.5 and 23 inches respectively. At each site the field plots were arranged in the form of a randomized block.

The final yields of hay and of grain were markedly increased by an application of sulphate of ammonia at seeding. At both sites a dressing of $\frac{3}{4}$ cwt. per acre gave an increase in the hay yield and in the grain yield, which would be economic at current prices. The increase given by a second $\frac{3}{4}$ cwt. per acre was likewise economic for hay at both places, and for grain at Buangor.

Although the ammonia content of the soil is not generally thought to have any relationship with the crop yield, it was found that marked variations occurred in the ammonia content of the soil throughout the growing period of the crop. The amount of ammonia that the sulphate of ammonia plots contained in excess of the no-nitrogen plots became gradually less in amount as the season advanced. The change was slow, requiring more than five months for completion on the $1\frac{1}{2}$ cwt. per acre plots. The nitrate content of the soil increased from June to August on the sulphate of ammonia plots.

Census studies showed an increase in the tillering of the plants, an increase in the number of ears produced and in the size of the ears, on the sulphate of ammonia plots. There was also a slight increase in the bushel weight of the grain. At Bannockburn, but not at Buangor, there was a depression of germination on the sulphate of ammonia plots.

The nitrogen percentage of the crops in October showed no differences between the different treatments, nor was there any difference in the nitrogen content of the grain or straw at harvest.

The total nitrogen removed by the crop on the sulphate of ammonia plots was in all cases more than that removed by the crop on the corresponding no-nitrogen plots, but the difference in nitrogen removed by the crop was less than two-thirds the difference in the amounts of nitrogen applied in the corresponding fertilizer dressings.

Acknowledgments.

The writer wishes to thank Nitrogen Fertilizers Pty. Ltd., which company financed the investigation, and provided transport to and from the plots. He wishes, in particular, to thank Mr. O. H. Gepp, who greatly assisted him with the field work.

He wishes to thank Mr. Mason and Messrs. Pickford Bros., on whose land the field trials were conducted, and who kept the records of the rainfall. He also wishes to thank Mr. G. W. Leeper, under whose guidance the work was done, and Prof. S. M. Wadham, for kindly interest in the work.

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Appendix.

Method Used to Determine the Ammonia Content of the Soil.

Twenty-five grams of soil are leached with 250 c.c. of N/10 hydrochloric acid. The soil is shaken with 100 c.c. of the acid, and is washed on to a filter paper in a Buchner funnel. The acid is slowly drawn through the soil on the filter paper. When just sufficient acid to wet the soil remains in the funnel, a further 25 c.c. are added. This is repeated until the whole 250 c.c. of acid have been drawn through the soil.

The washings are distilled with magnesium oxide into a measured amount of N/50 HCl, and the titration is completed with N/50 NaOH.

[Proc. Roy. Soc. Victoria, **47** (N.S.), Pt. I., 1934.]

Art. VI.—*A Disease of Cauliflowers in Victoria, Australia. (Gloeosporium concentricum (Grev.) Berk. and Br.).*

By FRANCES J. HALSEY, M.Sc.

(*Government Research Scholar.*)

(With Plate VI.)

[Read 10th May, 1934; issued separately, 22nd December, 1934.]

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Introduction.

A disease of cauliflowers is very prevalent in Victoria, not only affecting the leaves, but also damaging the inflorescences, especially if heavy rains occur during the season. Affected plants greatly deteriorate in market value. The disease was brought under the writer's notice by Mr. D. Adam, Government Pathologist, Department of Agriculture, Victoria, in February, 1933. From communication with Mr. Adam the writer learns that a fungus resembling the Victorian pathogen has been isolated from *Brassica* leaves in England, and is considered to be a *Gloeosporium*. There exists no published account of this isolation.

The following account has been undertaken with the view of establishing the identity of the fungus isolated in Victoria, and of placing on record a detailed survey of the behaviour of the pathogen as it occurs on the host and in pure culture.

Symptoms.

The fungus occurs on the thick fleshy midribs, laminae, and petioles of cauliflower leaves, on both upper and lower surfaces (Plate VI., Fig. 1). The most characteristic feature is the presence of minute, roughly circular, greyish-white patches on both surfaces of the leaf. These are arranged in a more or less concentric pattern; each individual patch is the result of the fungus sporing beneath the cuticle of the host.

The formation of spores creates an internal pressure, which eventually ruptures the overlying cuticle. The spores then escape, and collect on the surface of the leaf in clusters; the latter are very white and fluffy, suggesting extremely minute fragments of cotton wool (Plate VI., Fig. 2). On the midribs and petioles these snow-white clusters of spores are not so easily seen, owing to the lack of contrasting green colour. However, brown to almost black scarred areas develop abundantly, usually after the spores have ruptured the cuticle. The scars are narrow, elongated in the direction of the course of the midrib, varying in length from less than 1 cm. to more than 2 cm., more or less raised at the margin, and slightly sunken towards the centre.

Small patches of brown discolorations may extend on to the laminae of the leaves, and are then found in the neighbourhood of the sporing areas. On the midribs and petioles the scars later become wrinkled or furrowed in appearance, owing to the formation of cork (Plate VI., Fig. 1).

Historical.

The genus *Cylindrosporium* was set up by Greville (9) in 1823, on the basis of *Cylindrosporium concentricum* Grev., found on both surfaces of cabbage leaves (*Brassica oleracea* Linn.). Greville stated, " The peculiarity of its cylindrical sporidia, and its situation on the surface of living leaves, fully entitle it to generic distinction."

In 1850, Berkeley and Broome (2) examined Greville's original material, and found that the spores were produced beneath the cuticle, and formed " little heaps by oozing out as in other species of *Gloeosporium*," and hence placed the fungus in this genus.

It is clear, therefore, that *C. concentricum* Grev. = *G. concentricum* Berk. and Br. Von Höhnel (16) in 1916 abandoned the old genus *Gloeosporium* as a mixture, and replaced it by four new genera, *Gloeosporina*, *Monostichella*, *Gloeosporidium*, and *Cylindrosporella*, of which the first two and the last had subcuticular acervuli, and in the third the acervuli lay deeper. *Gloeosporina* possessed micro-conidia. Nannfeldt (24) in 1931 showed that spore size was a very unreliable character, as acervuli may contain both macro- and microconidia, while others may possess microconidia only; he suggested that *Gloeosporina* was founded in this way. He also regarded the attempt to divide the genera by their position in the host as futile.

In 1927, Karakulin (21) discussed von Höhnel's attempt to break up the genus *Gloeosporium,* but he did not accept this suggestion in its entirety, owing to the lack of constancy in the morphological characters of the new genera. Karakulin regarded it as too early to abandon the old genus *Gloeosporium,* as it had widespread recognition, and no entirely satisfactory subdivision had, as yet, been proposed.

Since Greville's time, many species were placed, by Saccardo, under the genus *Cylindrosporium,* and a great deal of confusion resulted. Von Höhnel (17), however, in 1924, clarified this point. He discussed thirty-three species of *Cylindrosporium,* and referred these to eleven genera, five of the latter being new. Von Höhnel regarded *Cylindrosporium concentricum* as the only true species of the genus.

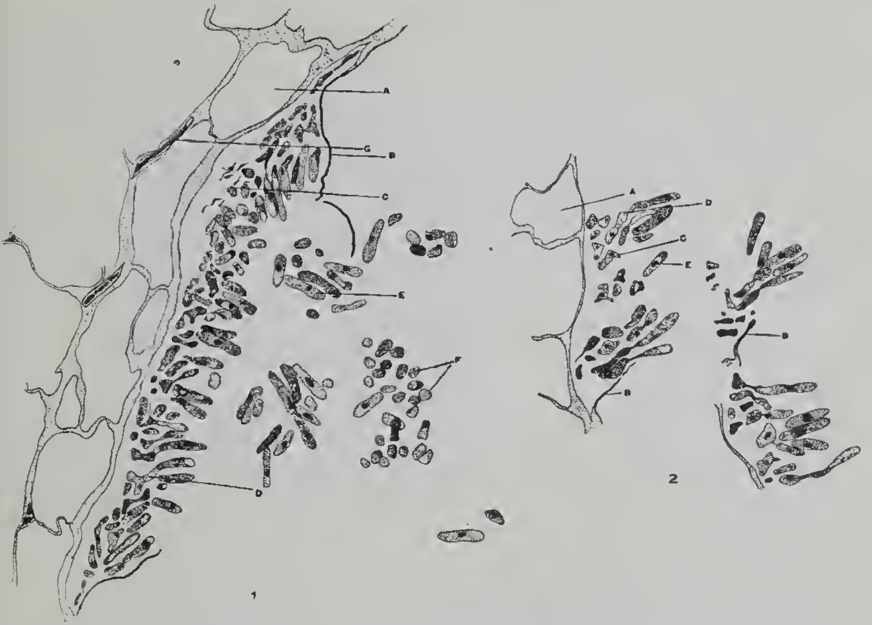
If Berkeley and Broome are correct, and the fungus is named *Gloeosporium concentricum* (Grev.) Berk. and Br., then there is nothing left in the genus *Cylindrosporium.*

Description of the Pathogen on the Host.

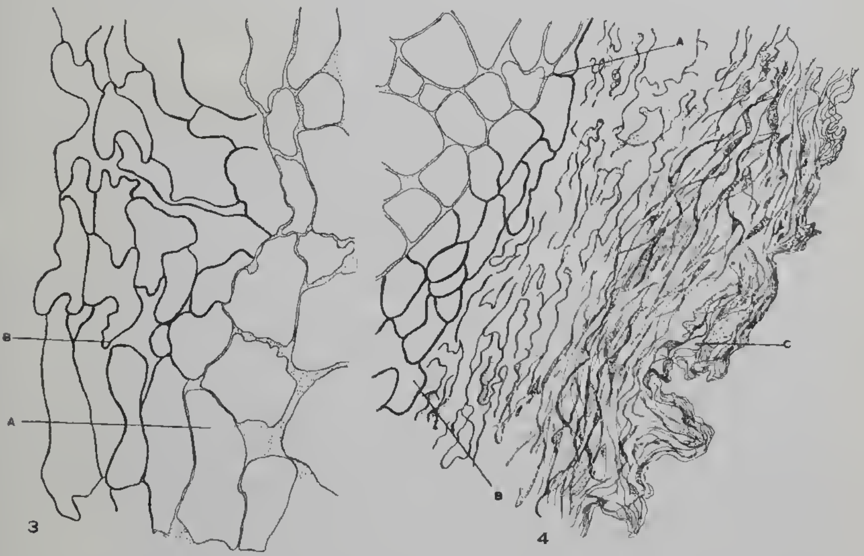
Spores of the fungus were easily obtained from the small snow-white fructifications on the leaves of the host, and were examined microscopically. They were extremely numerous, and each possessed a mucilaginous envelope. The spores measured on the average $11.9 \times 3\mu$, and were cylindrical, rounded at each extremity, hyaline, straight, or slightly curved, one-celled, generally bi-guttulate, sometimes, however, more than one oil drop occurring at each end.

Portions of leaves of a diseased cauliflower were fixed, and embedded, and sections about 5μ thick were cut, and stained by Haidenhain's iron-alum haematoxylin method. In this way sections were obtained which showed the fructifications at a fairly young stage before the rupture of the cuticle, and a still later stage depicting mature fruiting areas when the cuticle of the host had been ruptured (Fig. 1).

The acervuli were subcuticular; intercellular fungal hyphae were observed within the leaf tissue, extending several layers below the cuticle (Fig. 1G). From a slight, but nevertheless well-defined stroma, the conidiophores arose perpendicularly. These were unbranched, fairly closely packed, short, usually one-celled, from which the conidia, each with a single well defined nucleus, were constricted off one at a time from the apex. One conidium was completely formed and set free before another started to develop (Fig. 2). The acervuli finally became erumpent, and the spores oozed out on the leaf surface.



FIGS. 1, 2.—1. Transverse section of an acervulus on the under surface of a cauliflower leaf. × 364. 2. Portions of transverse sections of ascervuli, showing conidia borne on conidiophores. × 364. A. Epidermis of leaf; B. ruptured cuticle; C. stroma of acervulus; D. conidiophore constricting off a spore; E. spores set free; F. spores cut transversely; G. intercellular hyphae.



FIGS. 3, 4.—3. Transverse section through a midrib of a cauliflower leaf, at an early stage in cork formation. × 282. 4. A later stage showing the deep-seated cork cambium, and layers of diseased tissue. × 168. A. Cork cambium; B. cork cells; C. diseased leaf tissue.

Sections of midribs and petioles showing brownish-black scars were also cut and stained. They showed acervuli similar to those found on the laminae of the leaves. Sections of the scars after they became wrinkled in appearance showed a very extensive development of corky tissue, on the surface of which fungal hyphae were distinguishable, also a few spores. Early and later stages in cork formation are depicted in Figs. 3 and 4. Staining with chlor-zinc-iodine served to define the full extent of the corky tissue.

Description of the Pathogen in Culture.

(*a*) *Isolation from Host, and Growth on Various Media.*

The pathogen was first isolated from the leaves of *Brassica oleracea* in 1932, and since then frequent isolations have been made, and the fungus obtained in pure culture without any great difficulty.

The following media were used:—Malt agar, oatmeal agar, Brown's synthetic potato dextrose agar, cabbage agar*, sterilized cabbage midribs, sterilized potato slopes, turnip juice.

Malt agar (Plate VI., Fig. 3).—Growth is fairly slow and restricted. Young colonies have a puckered appearance with a moist cream-coloured mycelium, due to the formation of spores in great numbers. Later the culture turns dark green to black in colour, except at the growing edges, and small black spherical to sub-spherical bodies appear. These vary from 200μ–670μ in diameter, and may be simple or confluent. These structures appear macroscopically very like pycnidia. Ashby (1) in investigating *Gloeosporium musarum* states that, "Both Lasnier (22) and Toro (30) refer to these structures as pycnidia. Krüger calls them pseudopycnidia." The term was originated by Potebnia (25) when describing certain species of *Septoria*. Following Potebnia's example, the term pseudopycnidium will be used throughout this account.

A mature pseudopycnidium possesses a rounded or sometimes stellate ostiole, which opens wide to expose the hymenial layer of branched conidiophores bearing conidia.

Oatmeal agar.—Compared with the rate of growth on malt agar measured in terms of diameter of the colony, growth on oatmeal agar is quick. As the culture ages, the hyphae turn dark-green to black. On the dark mycelium, discrete sporing areas of a dirty cream colour, together with black spherical pseudopycnidia, are clearly visible. Aerial mycelium is absent in these cultures.

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* 500 gms. of fresh cabbage leaves were boiled in 500 ccs. of water. The extract so obtained was made up to 500 ccs., added to 500 ccs. of 2 % agar plus 1·5 % dextrose, and autoclaved in Erlenmeyer flasks.

Brown's synthetic potato dextrose agar.—This medium is unfavourable to growth. The mycelium is slightly raised and very restricted, white to cream, and not moist, on account of limited spore formation.

Cabbage agar.—Growth on this medium is similar to that on malt agar. The pseudopycnidia, however, are not as numerous, and growth, on the whole, is more restricted.

Sterilized cabbage midribs.—On cabbage tissue the fungus exhibits a different mode of growth. The mycelium is more aerial in type. As the culture ages, there is a darkening of the tissue, and also of the fungal mycelium. Pseudopycnidia are developed.

Sterilized potato slopes.—This medium also exhibits a distinct type of growth. Young cultures appear quite dry, pure white, dense and decidedly wrinkled; later becoming black, accompanied by blackening of the potato tissue. Spore formation is very restricted and no pseudopycnidia are formed.

Turnip juice.—Growth in a liquid medium such as turnip juice is very slow, a mycelium is gradually formed on the surface. The spores may sink to the bottom of the tube, where they germinate.

It is evident, therefore, that starchy media, such as Brown's agar, and potato slopes, are unfavourable for the growth of this fungus; this was also noted by Lasnier (22) in his account of the growth of *Glomerella* (*Gloeosporium*) *Cattleyae* on starchy media.

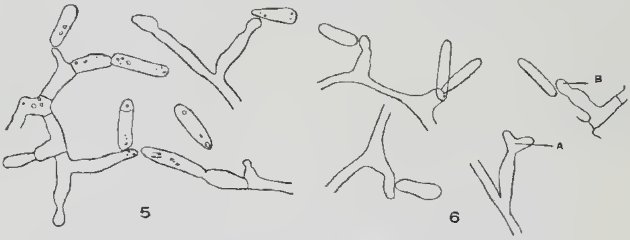
The optimum temperature for growth on any medium is from 19 deg. C.–20 deg. C., and all the cultures described above, were grown at approximately 19 deg. C.

b. Spore Production in Culture.

In culture the average spore measurements are as follows: 10.4–13.1μ × 2.5–2.8μ, and conidial formation takes place in three distinct ways:—

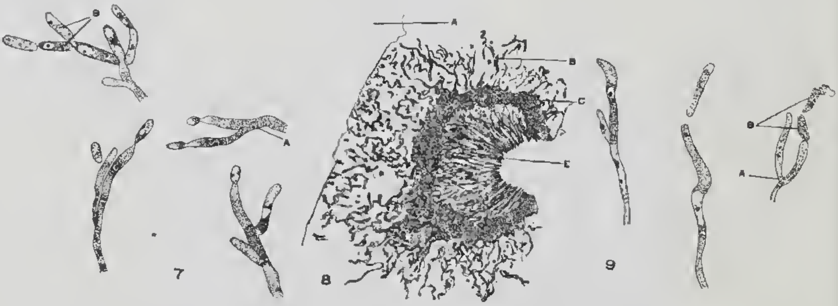
1. Conidia may be formed at any point throughout the culture; the conidiophores are short, branched, and arise from the ordinary growing hyphae. The conidia are constricted from the tip of a conidiophore, one by one; when one conidium is completely formed, it is set free, and then the conidiophore sends out a second spherical protuberance, which elongates until it reaches the normal dimensions of a spore, and is then set free. In this way numerous spores are formed from the one conidiophore, which is soon completely masked by them. This type of spore

formation is best studied in single spore colonies, which are sown in malt agar in petri dishes. Conidia commence to develop after about four days at 19 deg. C. (Figs. 5 and 6).



Figs. 5, 6.—5. Colony grown on malt agar, from a single spore, showing conidia being formed at any point from short branched conidiophores, after five days. × 261. 6. The same after six days. × 261. A. Conidiophore commencing to divide into two; B. the second spore being formed, in succession.

2. The discrete sporing areas, which are easily seen on oatmeal cultures, are seen, when sectioned, to consist of a definitely raised plectenchymatous stroma, and from this arise numerous branched conidiophores, multicellular, elongated, and producing spores in the same way as described above. (Fig. 7.) On account of the well-developed stromata, these fructifications may be termed "sporodochia."

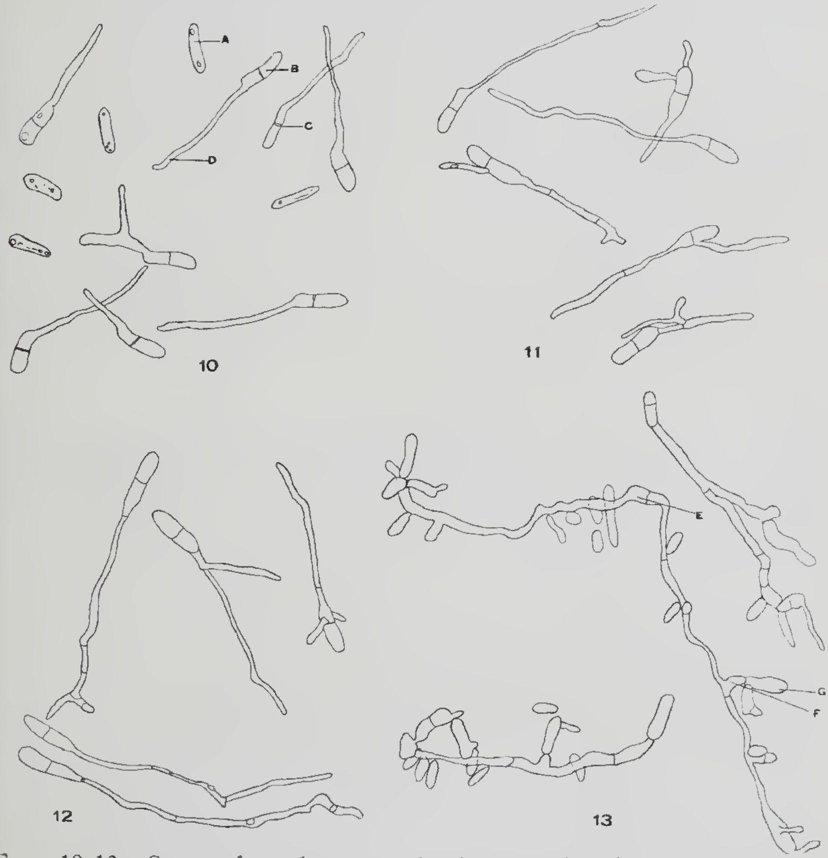


Figs. 7–9.—7. Conidiophores and conidia from discrete sporing areas on oatmeal agar, from transverse sections. × 400. A. Elongated, branched conidiophore; B. conidia formed in succession. 8. Transverse section of a mature pseudopycnidium, growing on malt agar. × 43. A. Surface of culture medium; B. outer region of loose hyphae; C. dark inner region; E. elongated branched conidiophores. 9. Conidiophores and conidia from a pseudopycnidium. × 418. A. Branched conidiophore; B. conidia forming in succession.

3. Finally conidia are produced in pseudopycnidia. When sectioned a typical pseudopycnidium shows an outer region of loosely arranged hyphae, and a dark inner region, about 40μ in thickness, which consists of closely compressed hyphae. This inner region is lined by elongated, branched, conidiophores (Fig. 8), which produce conidia from their tips in the usual manner (Fig. 9).

c. Spore Germination.

This was studied in hanging drops of sterile water. Spores were germinated at 19 deg. C. and also at the fluctuating temperature of the laboratory. Germination commenced slightly earlier, and was more rapid at 19 deg. C. than at room temperature. The experiments were carried out with spores obtained directly from the host, and also with spores produced in culture.



FIGS. 10–13.—Spores from host, germinating in a hanging drop of water. × 291. 10. After 24 hours. 11. After 48 hours. 12. After 72 hours. 13. After six days. A. Conidium before germination; B. germinating conidium; C. medium septum in germinating conidium; D. germ tube; E. original conidium; F. conidiophore; G. secondary conidium.

After twenty-four hours spores about to germinate appeared slightly swollen, and others still further advanced showed a median septum. The first germ tube generally proceeded from one end of the spore, and later the other section of the spore produced germ tubes (Fig. 10). After forty-eight hours the germinating filaments exhibited septa, and some showed the commencement of branching (Fig. 11). Finally secondary conidia were produced from short conidiophores, as shown in Fig. 13, at or after six days.

Appressoria such as were observed in hanging drops of *Gloeosporium musarum* spores, were *not* formed by the fungus from *Brassica* leaves. The hanging drops were inverted, so that a great number of the spores when they germinated came into contact with the glass coverslip, thus receiving the contact stimulus necessary for the production of appressoria, but in no case were appressoria observed.

d. Chlamydospore production.

Chlamydospores were not noticed on actively growing cultures, but were frequently observed in very old cultures and were abundantly developed on Brown's agar. The chlamydospores measure from $10–15\mu \times 5–9\mu$, and may be developed either in an intercalary position or terminally. (Fig. 14.) They are roughly oval to round in shape, and pale yellow in colour.

Inoculations to prove Pathogenicity.

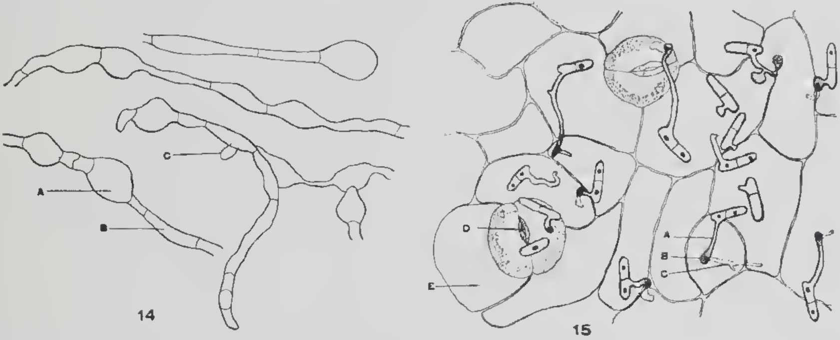
Healthy cauliflower seeds were planted in seed boxes, and when the plants had grown about three inches high, they were transplanted into small flower pots, one plant in each pot, and allowed to establish themselves.

Then four plants were sprayed with a suspension of spores in distilled water and controls with distilled water alone. The seedlings were placed in a glasshouse and kept in a moist atmosphere for four days. Then they were placed under ordinary glasshouse conditions, and the plants closely examined each day for the first sign of infection.

After ten days minute blackish scars were noticed on the stems of the infected plants. At this stage the pots were transferred to a sheltered position out of doors.

Later the small scarred areas extended up the midribs of the leaves and along the veins. Spores were easily demonstrated from stems or leaves, occurring in the characteristic snow-white areas, associated with the darkened regions. (Plate VI., Fig. 4.) Symptoms were developed by each of the four infected plants. The control plants showed no sign of infection, remaining healthy throughout the experiment. The above experiment was repeated with the same results. The pathogen was isolated quite readily from the sporing areas on the leaves or stems of the seedlings, and its appearance on culture media agreed in every particular with the growth of the fungus isolated from diseased plants in the field.

In order to determine the way the pathogen entered the host, seedling leaves of cauliflowers were sprayed with a spore suspension and the plants treated as before. After four days, the leaves were removed from the plants, and fixed in Gilson's fixative, then stained with cotton blue in lacto-phenol for about an hour. When examined microscopically the spores with their germ tubes were stained a deep blue, the single cross wall in each germinating spore was clearly defined. The germ tubes seemed to penetrate the leaves more readily on the lower surface, and in many instances just at the point of penetration the filament seemed to swell slightly, but in no case was a definite appressorium developed. The germinating filaments, after piercing the cuticle, could easily be traced for some distance, appearing a paler blue colour, owing to the overlying cuticle. Germ tubes entered the leaf through the walls of the epidermal cells and the guard cells, but were not found passing through the stomatal pore in any case. (Fig. 15.)



Figs. 14, 15.—14. Chlamydospores developed on Brown's agar. × 282. A. Chlamydospore; B. hypha; C. conidium. 15. Spores germinating on the under surface of a cauliflower leaf, after a period of 4 days. × 282. A Germ tube on surface of leaf; B. point of penetration; C. germ tube after penetrating cuticle; D. stomatal pore; E. epidermal cell of leaf.

The Effect of pH on Spore Germination.

The effect of various pH values on spore germination was tried. Hanging drops over a wide range of pH values were set up in sterile water, with spores obtained directly from the host. The hanging drops were placed in a moist atmosphere, and left at room temperature for 24 hours. The maximum temperature during this period was 14.4 deg. C., and the minimum 10 deg. C. Spores in sterile water (pH 6.0) were used as controls.

The percentage germination at each particular pH value was determined after taking counts from five microscope fields. The results are tabulated below:—

Spores Germinating in Lactic Acid.		Spores Germinating in Na_2CO_3.	
pH.	Average Germination.	pH.	Average Germination.
	%		%
4·9	62	8·4	75
3·9	73	9·4	73
3·7	39	9·6	67
3·5	35	9·9	74
3·4	32	10·1	61

The controls gave an average percentage germination of 95.5 per cent. On each side of pH 6 a general fall in percentage germination of spores took place, from 95 to some 73 per cent., within a range of pH 9.9 and 3.9. Beyond this range the percentage germination fell sharply, especially on the acid side.

Discussion.

In 1823, Greville described a fungus from *Brassica* leaves in Scotland, which he named *Cylindrosporium concentricum*. Later Berkeley and Broome examined Greville's original material, and changed the name to *Gloeosporium concentricum* (Grev.) Berk. and Br. Buddin, whose work is unpublished, isolated a fungus in England which (Miss) Wakefield considered to be undoubtedly *Gloeosporium concentricum* (Grev.) Berk. and Br.

The average spore measurements of the fungus found on *Brassica* leaves in Victoria are 11.9 × 3μ. Buddin's spore measurements for his fungus are 10 × 2μ. The latter show a good practical correspondence with the measurements obtained for the Victorian pathogen. The spores are not very narrow in relation to their length, and come well within the range of spore measurements for a typical *Gloeosporium* species. The way the conidia are borne on the ends of short conidiophores, in this case usually unbranched in the acervuli, is also typical of *Gloeosporium*. The type of spore formation when compared with that of *Gloeosporium musarum* is found to agree in every particular. A typical *Gloeosporium*, however, generally develops appressoria, when the germinating filaments are stimulated by mechanical contact. The greater number of diseases described as anthracnoses fall under the genera *Gloeosporium* and *Colletotrichum*, and in the majority of these appressoria are developed. However, both on the host and in hanging-drop cultures of water, appressoria fail to develop in the fungus under discussion. It is usually considered that a genuine *Gloeosporium* develops subepidermally, whereas this fungus originates subcuticularly. It has been mentioned above that Nannfeldt regards the attempt to classify genera by their position within the host (subcuticular, subepidermal, &c.) as futile. The perfect stage of the fungus has not been found, as yet, on the host or in culture. Many methods of culture have been tried, in order to try and induce the perfect stage, but up to date without success.

From the data collected, it is evident that the lack of appressoria is the only real divergence from *Gloeosporium*. Correspondence with Butler reveals the fact that it is uncertain whether Greville's fungus and that isolated by Buddin are the same species. Butler suggests that until Greville's fungus is redescribed the name *Gloeosporium concentricum* (Grev.) Berk. and Br. may stand.

The form isolated in Victoria seems to resemble Buddin's isolation. Therefore, until the redescription of Greville's fungus and the discovery of a perfect form, Butler's suggestion is followed—the Victorian pathogen is retained in the Melanconiaceous genus *Gloeosporium*, the full nomenclature being *Gloeosporium concentricum* (Grev.) Berk. and Br.

Summary.

1. A study of a disease of cauliflowers in Australia has been made, as a result of which the pathogen is named *Gloeosporium concentricum* (Grev.) Berk. and Br.

2. A disease was recorded on *Brassica* leaves in Scotland by Greville in 1823, when he considered the pathogen peculiar enough to entitle it to generic distinction—hence he named it *Cylindrosporium concentricum* Grev. Berkeley and Broome, in 1850, examined Greville's material, and changed the name to *Gloeosporium concentricum* (Grev.) Berk. and Br.

Buddin isolated a fungus in England which Wakefield considered to be *Gloeosporium concentricum* (Grev.) Berk. and Br. However, Butler is uncertain whether Greville's fungus and that isolated by Buddin are the same species, and suggests that until Greville's fungus is redescribed, the name *Gloeosporium concentricum* (Grev.) Berk. and Br. may stand.

3. The disease is characterized by minute snow-white clusters of spores, which burst through the cuticle of the leaves and stalks, the sporing areas or acervuli being arranged more or less concentrically.

4. The pathogen was isolated from the host, and obtained in pure culture. Growth on different media was studied.

5. Spore germination was followed in hanging drops of sterile water, and the effect on germination of varying pH values was studied.

Acknowledgments.

The author wishes to record her appreciation of the helpful interest of Professor Ewart, and to thank Dr. McLennan, under whose guidance the work was done. Gratitude is also expressed to Dr. Butler of the Imperial Mycological Institute, for his valuable suggestions.

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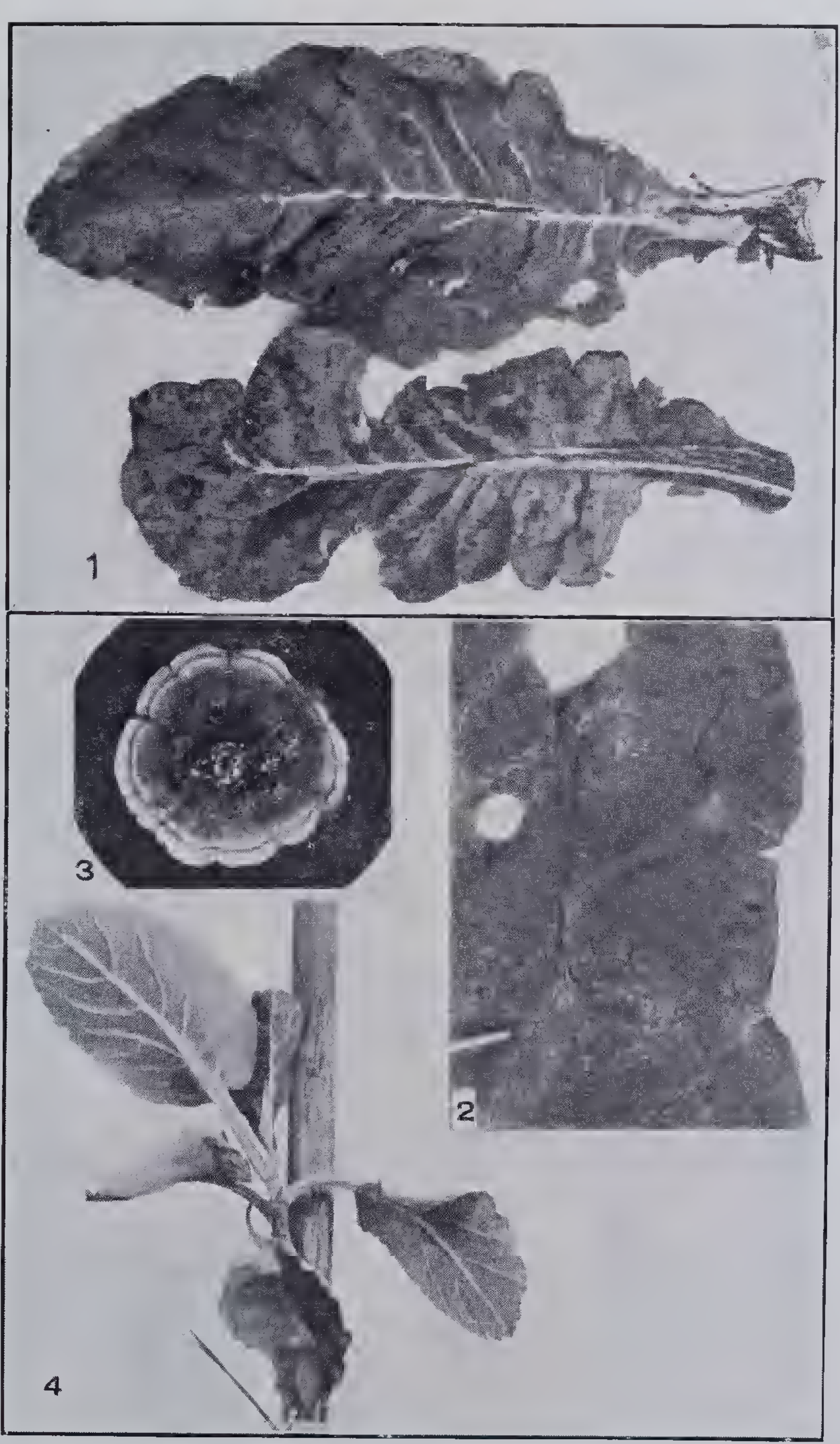

Gloeosporium concentricum on Cauliflower.

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Explanation of Plate VI.

Fig. 1.—Cauliflower leaves infected with *Gloeosporium concentricum.* Note the white sporing areas associated with the blackened regions on the laminae, and the corky scars on the midribs.

Fig. 2.—Portion of a cauliflower leaf infected with *Gloeosporium concentricum*, showing the white fructifications somewhat concentrically arranged.

Fig. 3.—*G. concentricum*, growing on malt agar. Note small black pseudopycnidia, blackened stroma, and white growing zone.

Fig. 4.—Cauliflower seedling, which developed symptoms of the disease after being sprayed with a spore suspension of *G. concentricum.*

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Art. VII.—*Tertiary Dykes and Volcanic Necks of South Gippsland, Victoria.*

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(With Plate VII.)

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Introduction.

The Geological Survey of Victoria, over a period of years from 1890 to 1920, published a number of reports, by Stirling (1892), Kitson (1903, 1917), and Ferguson (1909), in which were included detailed accounts of the geology of the areas covered by a series of Quarter Sheets—Nos. 67.S.E., 67.N.E. 75.SW., 76.SW, and 76.NW. (unpublished). In the course of this field work, an extensive collection was made from the dykes and volcanic necks herein described, to which later workers have added. The specimens were sectioned, and five analyses were prepared in the Survey Laboratory.

At the time of the author's departure for England to take up an 1851 exhibition, this collection was put at his disposal through the generosity of the present Director of the Geological Survey of Victoria, Mr. W. Baragwanath, together with a number of unsliced specimens. These latter have been sectioned in the Geology Department of Imperial College, and six further analyses have been completed.

The general geological map of South Gippsland, published in the Report of the Secretary for Mines, Victoria, for the year 1917, has been used as the basis of the appended sketch map. Locations of dykes and plugs were added from quarter-sheets, parish plans, and other records. The positions of the fault lines are based upon information supplied by the Geological Survey of Victoria.

The probable extent and strength of the dyke swarm can only be conjectured, owing to the limitation of exposures by the deep surface soils and vegetable accumulations of the gullies, by the dense undergrowth and forest that covers most of the hills, and by the burying of the dykes in the down-faulted blocks by later Tertiary sands. Bore records show that the dykes occur, to unknown extent, in these down-thrown areas.

General Features of the Dykes and Volcanic Necks.

The Dykes.

These are composed of a suite of analcite-olivine-dolerites (crinanites), olivine-basalts, and monchiquites. They show a strong north-westerly trend, with indications of a minor group striking north-easterly to easterly, both groups being contemporaneous.

They are best exposed in the strip of Jurassic country parallel with the coast line from Kilcunda to Cape Paterson, either along the shore-line, or on the deforested hills. Describing this area, Ferguson (1909, p. 8), states:—

> "All the dykes observed were in the Jurassic rocks and were basaltic, though their texture varies . . . so that they appear to range from fine-grained basalts to gabbros. They vary in width from a few inches to two chains. . . . and range up to 20 chains in length."

Stirling (1890, 1892), examined dykes in the Parishes of Jeetho, Jeetho West, Poowong, and Korumburra. These dykes also intruded and indurated the Jurassic country rocks, and all but one showed the north-westerly strike. The exception was a large doleritic dyke which crosses the railway cutting in the Korumburra township reserve, and trends north-easterly. A small basaltic dyke just west of Outtrim township has an east-west strike; and a large dolerite dyke met with in the workings at Turton's Creek strikes north-east; but all other dykes whose strikes have been recorded have the north-west strike. They have been affected by both major and minor faults, and the Bena and Korumburra dykes rise through anticlinal structures in the Jurassic sediments.

The dykes described by Stirling are generally larger than those in the Kilcunda area, the largest being the Cruikston Dyke (allotments 21, 23, Parish of Poowong), which is about 16 chains across, and has a coarse gabbroic texture. It thins out to the south-east. The Cheviot Neck (Parish of Jumbunna East) is similar.

Felsitic Dykes.

Felsitic dykes have been recorded in various parts of the area (Murray, 1876; Stirling, 1892). These intrude the Jurassic sediments, and were locally faulted during the intrusion of the dolerite dykes. They are commonly much decomposed, but fresh samples show them to be trachyandesites. It seems probable that they represent an acid differentiate of the "crinanitic" suite.

The Volcanic Necks.

The volcanic necks of South Gippsland are divisible into two main groups:—A group of eight, all of a basic, and generally clastic, character, outcropping along the coast from Cape Paterson to Anderson's Inlet: and another group of about ten, which are more basaltic, and generally free from clastics, occurring north-west of the Kongwak Fault, in the Parish of Jumbunna East. Isolated plugs occur farther to the north, e.g., the olivine-nephelinite plug near Drouin West.

The largest of the four necks at Cape Paterson has a three-quarter acre pear-shaped outcrop, and intrudes Jurassic sediments, which are indurated for several feet from the contact. The greater part of the plug is occupied by a dense blue-black tuff, composed of fragments of basic igneous rocks. It is traversed by small irregular dykes, and in places roughly columnar monchiquite is found. This contains scattered crystals of felspar, and large masses of olivine, much of which is decomposed, up to 2 feet across. Inclusions of Jurassic material are numerous.

The four volcanic necks at Anderson's Inlet (Kitson, 1903), differ from those in the other parts of the area by being composed almost entirely of clastic material. Blocks of two types of basalt are found in the agglomerates—a dark dense rock (monchiquite) with patches of olivine, and a very vesicular grey basalt. The neck near the mouth of Screw Creek is rimmed with a narrow shell of finely vesicular scoriaceous mud-basalt, which shows laminations parallel with the wall. It contains some hard blocks of basalt, but is mainly composed of an agglomerate of blocks of decomposed basalt, Jurassic sediments, tuff and lapilli, and a material that resembles volcanic mud. The largest neck of the group has a visible extent of outcrop of 12 chains by 8 chains before it passes under the sea, or into the mangrove swamps.

The group of volcanic necks north-west of the Kongwak Fault have been described by Kitson (1917) :—" In size the necks vary from a few square feet to 53 acres. They are ranged roughly along certain lines, and occur either singly, or in small groups. The rocks forming the necks are either coarse-grained or very fine-grained. The coarse-grained type (dolerites) occurs at the Cheviot Neck, and at Pollock's Hill (allotment 54, Parish of Jumbunna East). There are several similar occurrences to the north and north-east.

The fine-grained type (monchiquite) . . . may contain scattered crystals of felspar, hornblende, black mica, olivine, and pieces of glass. The porphyritic type occurs in the four largest necks (Moyarra, Wilson's Knob, the adjoining neck, and the Wolonga Neck). The cryptocrystalline rock occurs at Thompson's Hill, Krowera, and in one of the group of necks of allotment 54, Parish of Jumbunna."

Tufaceous basaltic outcrops, possibly necks, occur in allotment 30A, 37, 41A, and 23C of Kongwak, and in allotment 31 of Kirrak. Ferguson also regards as possible necks the three outcrops in allotments 26A and 94C of Woolamai, and 9 of Kirrak.

Petrography.

OLIVINE-NEPHELINITE.

A single plug of this rock has been found in South Gippsland; and the only other occurrence known in Victoria is a plug associated with monchiquite dykes, found near Greendale. It is not known for certain that the nephelinite belongs to the association to be described in the following pages, but it is of the same age, and many features suggest that it should be included. The Greendale nephelinite has more distinct monchiquitic features.

The olivine-nephelinite, which has been described by Mahony (1931), is worked in a quarry in allotment 91, Parish of Drouin West, and from the map appears to penetrate, and so post-date the Older Basalts. Actually it is surrounded by basaltic soils, and no definite relations are to be observed, but it has been proved to be a plug by boring.

Microscopically it is a holocrystalline, panidiomorphic rock, consisting of nepheline, augite, olivine, and iron-ore; felspar is absent. Nepheline, in limpid and colourless crystals, some of which are 0.25 mm. wide, and almost microporphyritic, forms about one-third of the rock. Pyroxene is the next most abundant mineral, forming colourless to greenish, and non-pleochroic prisms, about 0.08 mm. long, in felted aggregates between the nepheline crystals. Olivine is microporphyritic in fairly abundant idiomorphic crystals from 0.5 to 1.5 mm. across; it is partially altered to serpentine, and is then marked along the rim by a strong irregular border of iron-ore crystals, thrown down during the serpentinization. Abundant cubes of titaniferous iron-ore and rods of apatite are scattered uniformly throughout the rock. Elongated zeolites are present, probably of natrolite.

The Greendale nephelinite approaches closer to a monchiquite, having less nepheline, and rather more augite, both in the ground mass and as microphenocrysts—a brown augite, with a narrow rim of titanaugite. The augite crystals are idiomorphic and zoned, with their cores rich in iron-ore inclusions ("spongy"), or the core may be greenish, due to the presence of the aegirine molecule. The analyses (Table 1, Nos. 1 and 2), show the difference in amount of nepheline and pyroxene in the higher Na_2O and lower CaO of the Drouin rock; and it is to be noted that while the TiO_2 content of the two rocks is similar, only one of them reflects its presence in possessing titanaugite.

MONCHIQUITES.

True monchiquites have been collected from some twelve localities within the area, including both dykes and volcanic necks; and though the latter might be designated limburgites appropriately, it has been thought simpler to describe all the very similar specimens by the same name. The close similarity between these rocks and the monchiquite dykes of the Bendigo gold-field makes the term monchiquite the more suitable. No analysis of the typical monchiquite has been made on this account, but a Bendigo analysis is quoted (Table I., No. 3), to give the approximate composition.

In hand specimens the rocks are generally dense and bluish-black in colour, with occasional microphenocrysts of greenish olivine, and more numerous small white vesicles.

Under the microscope the microphenocrysts of olivine are seen to be thoroughly serpentinized. They average about 0.3 mm. across, and retain their idiomorphic outline. Xenocrysts of fresh olivine, showing strong reaction rims or corrosion, are occasionally observed. These are as large as 3 mm. in diameter, and irregularly concentrated.

These phenocrysts are set in a uniformly fine ground-mass, which consists of idiomorphic prisms of augite, a little altered olivine, iron-ore, some biotite, hornblende, and a quantity of glassy material. Patchiness, due to local concentration of glass, is a feature of the groundmass, just as in the Bendigo dykes (Stillwell, 1912). Rare grains of picotite are present.

The augite shows zoning—a diopsidic core with a titanaugite rim—and is markedly idiomorphic. The titanaugite is pleochroic, generally faintly, with X = yellowish, Y = reddish-violet, Z = yellowish. The iron-ore is equally idiomorphic, in octahedra, smaller in size than the augite prisms with which it is associated. Intersertal between these is the glassy material, which is generally clear and colourless, but turns yellow and deposits trichytes of iron-ore during devitrification. It is always an important constituent.

Occasional scales of biotite and hornblende occur in association with lighter-coloured patches of the groundmass, and with certain of the vesicles. These scales may be shreds with no structure, or laths up to 0.1 mm. long, showing strong pleochroism from brown to straw-yellow, and provide a close parallel with the biotite and hornblende flakes of the Bendigo dykes. Reaction between the iron-ore and the apparently felspathic glassy residuum seems to contribute to their formation.

No felspar is observed in the typical sections, but in one or two with basaltic tendencies a few fine laths or microliths of labradorite are dispersed through the groundmass.

Amygdales may be very abundant, and may contain (*a*) fibrous natrolite, (*b*) chlorite and aragonite, or (*c*) an isotropic material similar to the glassy base. The last (*c*) is often surrounded by dark zones, due to the abundant development of skeletal iron-ore, together with biotite and hornblende laths. Crystals of the latter minerals are largest at the outer edge, and there show tendencies towards radial orientation of their long axes about the amygdale. Nearer the amygdale the skeletal iron-ore is concentrated, and the biotite and hornblende diminish to mere scraps. Some of these amygdales contain ragged cores of calcite within the glass, and in the calcite are small isotropic cubes of analcite (?). In some cases these amygdales extend as short veins into the rock.

Cape Paterson Variety.

The rock from the largest neck at Cape Paterson contains microphenocrysts of both olivine and augite, set in a glassy base which is rich in iron-ore. The olivine is generally fresh, and is margined by well-marked reaction rims of brown to purple-brown augite. Like the olivine, the augite microphenocrysts are idiomorphic. They consist of a colourless core of diopsidic material, with an outer zone of purplish-brown, pleochroic titanaugite. Some of the crystals exhibit twinning parallel to (100), with thin lamellae separating the principal parts of the twin.

Picotite is present in small grains, included within olivines, and small zeolites are frequent. The analysis (Table I., No. 4) shows the rock to be richer in magnesia, and poorer in titania than the normal type, and agrees well with a microscopically similar rock (Analysis No. 5) from Moorabool East, which is also associated with normal monchiquite dykes.

Anderson's Inlet Variety.

The specimen from Townsend Bluff (Neck No. 1, of Kitson) is richer in augite than that at Cape Paterson, and contains microliths of plagioclase. The augites show three zones; the innermost zone is occasionally green, and pleochroic to yellow, indicating the earlier development of the aegirine molecule, but more commonly both the inner zones are colourless, the second being very narrow. The rim is of brownish-purple titanaugite, which is pleochroic with X = yellow, Y = brownish-purple, Z = faint yellow. The central zone may contain inclusions of more or less altered olivine. The groundmass, apart from the plagioclase, is similar to that of the Cape Paterson rock.

Xenoliths of Dunite.

Masses of olivine, up to 2 feet in diameter, have been observed in the monchiquitic volcanic necks. These must represent either segregations of the olivine from the magma of the monchiquite, or a dunitic phase within the magma chamber, through which, or from which, the monchiquitic material was forced.

Such a xenolith, found in the large Cape Paterson neck, consists almost entirely of olivine and picotite. The edges of the olivine crystals are sometimes deeply iron-stained, and almost opaque. The olivine itself is colourless, and contains less than 12 per cent. of FeO. Individual grains reach 1.5 mm. across, but the average is 0.5 mm. They are allotriomorphic, and the picotite is either included within, or caught up between the crystals. The approximate composition is:—Picotite 5 per cent., olivine 70 per cent., and opaque iron-stains about 25 per cent.

MONCHIQUITE-BASALTS.

The rocks of this group are about as equally developed as the true monchiquites, and include most of the smaller plugs of the Jumbunna East group. They grade by increase of plagioclase into olivine-basalts, and by decrease of plagioclase into true monchiquites.

In the hand specimen they are not to be differentiated from the monchiquites. They weather to a greyish rock with a fine hackly fracture. Analyses have been made from the Moyarra Neck, in the south-west of allotment 55, Parish of Jumbunna East, and from Glanfield's cultivation paddock, near Kilcunda (Table 1, Analyses Nos. 6 and 5 respectively).

These rocks differ from the monchiquites in that the olivine crystals are usually rounded by resorption. The groundmass is equally uniform, but coarser, and contains a characteristic, though variable, amount of plagioclase, which may be in the form of minute microliths, or as numerous laths of the composition $Ab_{50}An_{50}$. The glassy base appears to be related to the felspar, and is rich in trichytes of iron-ore. Analcite may be present, and is accompanied by shreds of biotite. Fine needles of apatite are abundant, and rare grains of picotite are included in the olivine crystals. The zeolites parallel those of the monchiquites.

This gradation of monchiquite into olivine-basalt is similar to that described by Stillwell (1912) for the Bendigo monchiquites.

Anorthoclase Crystals.

The large crystals of felspar found in these rocks (Kitson, 1917) are of a composition approaching $Or_{23}Ab_{68}An_{9}$, from a poor analysis (Mahony, 1928).

OLIVINE-ANALCITE-BASALTS.

These may be described under two groups.

Group A.—Basaltic Dykes with Titaniferous Augite.

Several of the necks, and a number of the dykes, fall in this group. The typical analysis from Callanan's Hill (Table 1, No. 8) shows very little difference in composition from those of the monchiquite-basalts; but there is a marked contrast in their microscopical appearance, owing to the much coarser and less uniform groundmass of the olivine-basalt. These average about the texture of a medium-grained intergranular basalt, and grade towards the analcite-olivine-dolerites with increase of grain size. The difference is accentuated by the increased amount of plagioclase present in the sections.

The idiomorphic or corroded microphenocrysts of olivine average about 0.4 mm in diameter, and are serpentinized to varying degrees. They are set in an intergranular, sometimes partially ophitic groundmass, in which the felspar laths tend towards parallel orientation. The augite of the groundmass equals the plagioclase in quantity, and is idiomorphic, or in small plates of reddish-violet colour, with weak pleochroism to a faint yellow, the violet colour often being limited to the rim zone about a diopsidic core. The iron-ore is coarser than in the monchiquite-basalts, and less evenly distributed. Analcite occurs abundantly intersertal to the other minerals, or in zeolitic patches, and is both turbid and clear. A little colourless felspar, possibly orthoclase, shreds of biotite and needles of apatite accompany it.

Group B.—Basaltic Dykes Poor in Analcite and with no Titanaugite.

Analysis No. 9 (Table 1) shows this variety to be richer in Al_2O_3 and poorer in MgO than the group preceding. This is reflected in an increase in plagioclase at the expense of olivine. The augite is generally colourless, but may show a faint violet colouration under high magnification. There is also a trace of the aegirine molecule where analcite appears, but the amount of the latter discernible is very small. The titania has gone to the iron-ore crystals, which are rod-like and skeletal. Interstitial orthoclase is present, and in some cases the plagioclase laths are larger than usual, developing microphenocrystic habit.

ANALCITE-OLIVINE-DOLERITE.

Analcite-olivine-dolerites (crinanitic dolerites) are the most widespread type among the dykes, and they also form the larger volcanic necks, e.g., Cheviot's Hill and Pollock's Hill. With a decrease of olivine and an increase of analcite the latter outcrops would become teschenites.

The hand-specimens have a coarsely crystalline grey to greenish appearance, suggestive of a fine-grained gabbro, with individual felspars and augites as large as 5 mm. in length.

The typical rock consists of olivine, augite, labradorite, and analcite, with some alkali felspar, iron-ore, biotite, in some cases a little aegirine, and rare scraps of barkevikite. Natrolite and analcite form zeolitic patches, and the rock is pierced with abundant coarse rods of apatite. Ophitic texture is prominent, but may be subdued by the idiomorphic tendencies of the augite.

The olivine forms unaltered, but corroded, crystals up to 3 mm. across. Being the first mineral to crystallize, apart from the apatite, it is often enclosed by small unorientated augite individuals, or by poecilitic augite plates.

The augite is more abundant than the olivine, and is strongly zoned, the inner zone being colourless or faintly yellow, and the outer a pleochroic pinkish-violet, with X = faint yellow, Y = pinkish-violet, Z = faint yellow. It shows twinning parallel to (100), with thin lamellae separating the principal parts. In some dykes the crystals are strongly idiomorphic, but more generally the augite forms plates from 2 to 3 mm. across, which may be fractured by differential movements. The colour varies locally, and in some examples the augite is colourless or only very faintly violet.

Analcite appears in varying quantities, reaching a maximum of about 15 per cent. by volume in the Doomburrim and Cruikston dykes. It occurs interstitially, as clear or turbid patches, between the felspar laths, and when in contact with the violet augite, it reacts with the latter to form a green pleochroic pyroxene, of a composition varying between aegirine-augite and aegirine, depending on the degree to which the Na_2O has been incorporated in the pyroxene. Small idiomorphic crystals of aegirine, pleochroic from green to yellow, are found within patches of analcite. Aegirine develops only where augite is in contact with analcite; the rims cease where the augite has been sheltered by a plagioclase lath or an olivine crystal. Rare scraps of barkevikite are found within the analcite areas. The analcite has "patterned" the plagioclase, but the latter is too fresh to have been the source of the soda in the analcite; it must be regarded, therefore, as pyrogenetic or deuteric in origin.

Two types of felspar are present:—(*a*) laths of labradorite, and (*b*) interstitial alkali felspar, which appears to be orthoclase (this would agree with the high percentages of K_2O shown by the analyses, Table 1, Nos. 10–13). The plagioclase laths in the coarser rocks are 3 mm. by 0.5 mm., but for the more average-grained types are between 1 and 2 mm. long. They are generally of labradorite composition—$Ab_{45}An_{55}$; but in some cases are more acid. Some show strong zoning, with a marginal zone of oligoclase, while in the Korumburra dyke the marginal zone is nearly as wide as the labradorite core, and is of albite-oligoclase. The felspars, like the augites, are fractured by differential movement.

The iron-ore occurs as irregular plates, up to 1 mm. in diameter, generally ophitic about plagioclase laths. A few inclusions of it are seen within the augites, but never within the olivine crystals. Associated with the iron-ore and the analcite is a small amount of biotite, which forms strongly pleochroic laths and scales, making partial or complete rims about the iron-ore crystals. The abundant apatite rods may be up to 2 mm. long.

The order of crystallization has been:—Apatite; olivine; iron-ore, augite , plagioclase; alkali felspar, analcite, biotite, aegirine, barkevikite, and natrolite.

Felsitic Dykes.

Only one specimen of the felsitic or "wackenitic" dykes of Stirling (1892) was sufficiently preserved for sectioning.

This rock, which intrudes the Jurassic sediments in the Outtrim cemetery, consists of microphenocrysts of acid andesine, $Ab_{65}An_{35}$, and long flakes of hornblende, set in a holocrystalline groundmass of slightly more acid plagioclase, orthoclase, a trace of quartz, shreds of hornblende and biotite, and a very little iron-ore. The felspar phenocrysts are idiomorphic, and show combined Carlsbad and albite twinning with strong zoning, and have a microscopic outer rim of orthoclase. The hornblende is a light green variety, idiomorphic in small crystals, but more commonly poorly structured, and apparently about to change over to biotite. Both sets of phenocrysts show sub-parallel orientation from flow movements.

The groundmass is granular to sub-trachytic, and formed of idiomorphic basic oligoclase $Ab_{70}An_{30}$, with intersertal orthoclase and quartz, shreds of biotite, and hornblende, and grains of iron-ore.

Reactions Observed.

The reactions observed to be taking place throughout the suite may be summarized as follows:—

1. Olivine → diopsidic augite → titanaugite → aegirine-augite → aegirine → barkevikite.
2. Ilmenite + analcite (or plagioclase) = biotite.
3. Ilmenite + analcite (or plagioclase) = hornblende.
4. Lime-soda plagioclase → soda lime plagioclase.
5. Olivine = serpentine + magnetite.

The serpentinization has occurred before consolidation. Idiomorphic olivine microphenocrysts in the monchiquites are strongly, if not completely, serpentinized, but in some slides there are found, in addition, fresh corroded xenocrysts of this mineral; and in others, some fresh cores of olivine have been retained by the formation around them of a protecting rim of augite. In the doleritic rocks serpentinization of the olivine is a minor feature, and commonly absent. The water vapour has preferred combination with the analcite molecule.

Geochemistry and Differentiation.

The Analyses.

The table of analyses is most informative when considered in conjunction with the table of norms. While the CaO content does not vary greatly throughout the series, the normative anorthite content rises more or less progressively from the basic to the less basic rocks. This represents an increase in plagioclase and a corresponding decrease in pyroxene. Normative olivine decreases as the anorthite increases. Albite and nepheline, as individuals, fluctuate; but taken in combination, they show an increase parallel to that of the anorthite. The Na_2O content in the analyses reflects this; but among the dolerites the concentration of Na_2O shows marked local variation, according as to whether the individual dykes are rich or poor in analcite. The K_2O, by contrast, remains much steadier throughout, and is higher than is usual for crinanitic rocks, while the TiO_2 is low for them (a fact reflected in the pale colour of the titanaugite), and falls progressively from the nephelinite towards the dolerites.

ANALYSES.

——	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	——
SiO_2	41·13	42·39	40·92	41·95	43·12	44·71	45·73	47·15	45·12	47·70	49·30	47·56	46·76	SiO_2
Al_2O_3	15·74	16·17	11·34	12·50	12·65	15·40	15·17	20·48	15·60	17·76	16·36	16·79	22·85	Al_2O_3
Fe_2O_3	4·02	4·29	0·54	4·02	2·66	4·14	3·90	1·61	9·01	2·23	2·74	3·05	3·80	Fe_2O_3
FeO	7·71	5·79	12·96	9·38	8·49	7·64	7·66	9·33	7·21	8·25	8·58	8·71	5·83	FeO
MgO	7·98	7·66	7·78	12·76	14·86	10·83	9·03	4·61	9·01	6·50	6·43	6·30	4·32	MgO
CaO	10·48	11·57	9·28	8·48	10·49	9·00	8·97	8·13	8·04	9·37	8·55	8·57	8·05	CaO
Na_2O	5·56	4·26	3·27	2·82	2·43	2·75	3·21	3·64	3·52	3·34	3·41	4·96	5·30	Na_2O
K_2O	1·12	1·46	1·94	1·34	0·73	1·64	2·27	1·66	0·88	1·59	1·64	1·78	1·54	K_2O
H_2O+110	2·11	1·85	1·77	2·31	1·25	0·65	1·02	1·30	1·61	0·85	0·59	2·23	1·55	H_2O+110
H_2O-110	0·58	0·56	0·64	1·15	0·53	1·00	0·51	0·32	..	0·27	0·88	..	..	H_2O-110
CO_2	Nil	Nil	2·82	0·87	0·28	0·60	tr.	Nil	..	tr.	Nil	..	..	CO_2
TiO_2	2·34	2·13	6·57	1·32	1·55	0·89	1·96	1·46	..	1·02	1·00	..	..	TiO_2
P_2O_5	0·54	1·16	0·51	0·48	0·61	0·60	0·60	0·38	..	0·51	0·40	..	Tr.	P_2O_5
MnO	0·14	0·23	0·13	0·33	0·20	0·27	0·18	0·25	tr.	0·24	0·25	tr.	..	MnO
Li_2O	tr.	..	..	..	..	..	..	..	..	..	..	..	..	Li_2O
Cl	Nil	0·11	..	0·08	0·01	tr.	0·03	0·02	Nil	0·03	Nil	..	..	Cl
S	Nil	0·13	..	Nil	Nil	Nil	tr.	tr.	Nil	0·02	Nil	tr.	..	S
BaO	Nil	0·01	..	Nil	0·06	Nil	0·01	tr.	..	0·03	Nil	..	..	BaO
Total	99·45	99·70†*	100·47	99·75*	99·92	100·11	100·33*	100·38*	100·00	99·69*	100·13	99·95	100·00	Total

† NiO nil, Cr_2O_3 0·03, V_2O_3 0·01, SrO tr.

* Corrected for Cl, S.

NORMS.

Q	..	..	..	..	..	..	..	..	..	..	..	..	..	Q
Or	6·64	8·62	11·46	7·90	4·34	9·68	13·37	5·19	9·79	9·68	9·45	10·55	9·15	Or
Ab	2·26	11·85	20·24	15·34	10·07	17·88	15·20	24·56	24·50	28·84	22·86	16·33	19·41	Ab
An	14·61	21·12	10·51	17·51	21·45	24·84	20·19	24·12	34·42	24·55	28·76	18·21	33·94	An
Ne	24·32	12·67	4·01	4·58	5·68	2·92	6·50	2·88	3·41	..	2·84	13·94	13·84	Ne
C	..	..	..	..	..	..	..	..	..	..	..	..	..	C
di	27·29	20·57	11·71	12·82	19·89	9·73	16·32	12·64	2·87	12·63	11·77	20·10	4·99	di
hy	..	..	..	..	..	..	..	..	..	0·19	..	..	..	hy
ol	10·23	8·68	19·25	26·97	27·77	21·70	17·25	15·93	17·58	16·03	16·43	14·16	11·62	ol
mg	5·83	6·22	0·79	5·84	3·85	6·00	5·65	13·06	2·34	3·97	3·24	4·42	5·51	mg
il	4·42	5·06	12·47	3·14	2·93	1·69	3·72	..	2·78	1·90	1·94	..	..	il
hm	..	..	..	..	..	..	..	..	..	..	..	..	..	hm.
ap	1·18	2·76	1·21	1·14	1·45	1·61	1·42	..	0·94	0·94	1·21	..	..	ap
cal	..	..	6·41	1·98	0·64	1·36	..	..	..	..	..	..	..	cal
pyr	..	0·24	..	..	..	..	..	..	..	..	..	..	..	pyr

Analyses:—

1. Olivine-nephelinite, plug in allot. 91, Parish of Drouin West. (F. F. Field.) Proc. Roy. Soc. Vict., 1931.
2. Olivine-nephelinite, plug, 8 chains S. of Greendale Hotel, Parish of Blackwood. (A. B. Edwards.)
3. Monchiquite dyke, Central Red, White, and Blue Mine, Bendigo. (F. Stillwell.) Proc. Roy. Soc. Vict., 1912.
4. Monchiquite pipe, Old Landing Place, Cape Paterson, Gippsland. (A B. Edwards.)
5. Monchiquite dyke. allotment 2, section VIII., Parish of Moorabool East, in Korweinguboora Creek. (A. B. Edwards.)
6. Monchiquite-basalt, Glanfield's Cultivation Paddock, Kilcunda, Parish of Woolamai. (A. B. Edwards.)
7. Monchiquite-basalt, Moyarra Neck, Parish of Jumbunna East. (A. B. Edwards.)
8. Olivine-analcite-basalt, Callanan's Hill, north end, Parish of Jumbunna. (Bayly, 1902—poor analysis.)
9. Olivine-basalt dyke, Logan's Paddock, Kilcunda, Parish of Woolamai. (A. B. Edwards.)
10. Olivine-analcite-dolerite, alkali-felspar type, Creek west of Gibson's allotment, Kilcunda, Parish of Woolamai. (A. B. Edwards.)
11. Olivine-analcite-dolerite, dyke opposite Cadd's smithy, Kilcunda, Parish of Woolamai. (A. B. Edwards.)
12. Analcite-olivine-dolerite, Cruikston dyke, allotment 21, Parish of Jeetho. (J. Dennant.) Prog. Rept. X., 1899.
13. Analcite-olivine-dolerite, Kilcunda-road State School, Parish of Jumbunna East. (Bayly, 1903.)

The Variation Diagram.

The variation diagrams (Fig. 1), plotted from analyses calculated to 100 per cent., free of water and calcium carbonate, place the rocks as follows, in the decreasing order of their silica percentage:—Analcite - olivine - dolerites; olivine - analcite - basalts; monchiquite-basalts; monchiquites; olivine-nephelinites. This arrangement is parallel with the decreasing order of grain size of the crystals (Fig. 2).

Three of the constituents give approximately straight-line graphs—K_2O, TiO_2, and P_2O_5, except for the TiO_2 of No. 3, the typical monchiquite. A different form of curve is necessary to fit the points for the other constituents. As the basic end of the series is approached, the stem of the curve splits along two divergent paths towards the monchiquite group and the nephelinite group respectively.

The divergence is most complete for Al_2O_3 and Na_2O; in the other three graphs one or other of the monchiquite points falls on the nephelinite curve.

In the acid region (the dolerites), three analyses (Nos. 9, 11, 13) fall above or below the curve. If arranged in the reverse order of their acidity—13, 9, 11—it is seen that a deficiency of iron and magnesia corresponds with an equally great excess of alumina, suggesting that excess sinking of olivine is the explanation of this divergence.

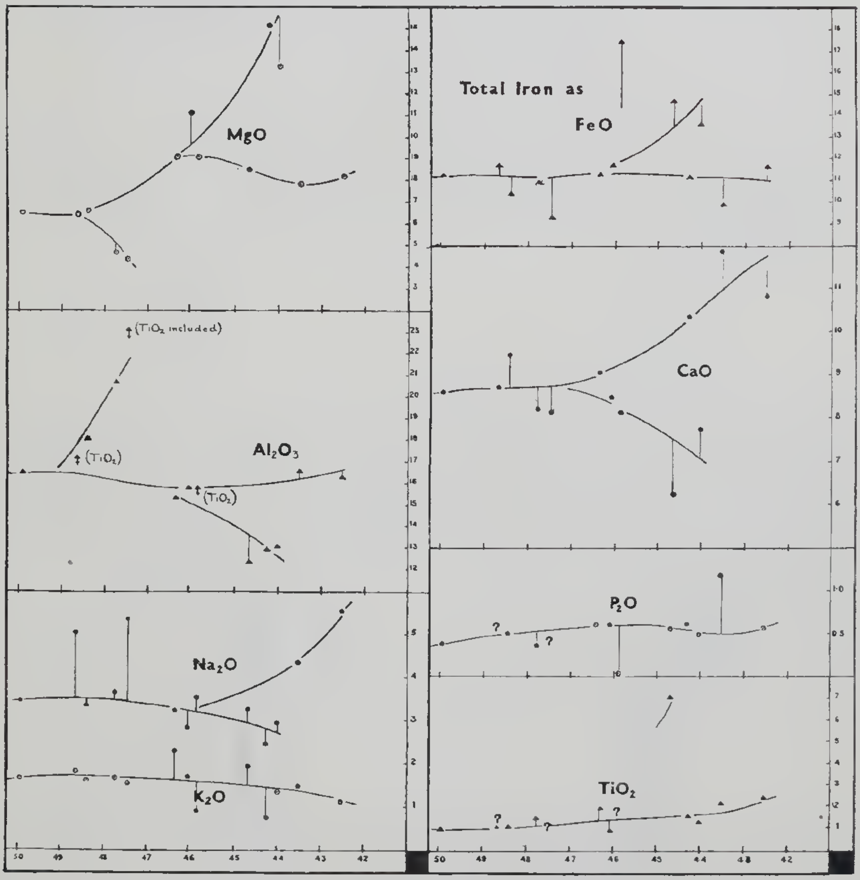

Fig. 1.—Variation Diagram.

The source of the high Na$_2$O in analyses 13 and 12 cannot be explained in this manner; but it is reflected in the rocks, which are especially rich in analcite. It suggests that the concentration of soda is independent of the concentration of the lime, and takes place locally. This suggests that the origin of the analcite might be deuteric (compare Daly, 1933, p. 398, in connexion with the late concentration of soda in the crinanite of the Shiant Isles).

The graphs throw little light upon the origin of the nephelinites, beyond demonstrating a number of points which they have in common with the monchiquites.

Differentiation.

No instance of one dyke rock intruding another type is known. The only direct evidence for age sequence is a xenolith of colourless augite ophitically intergrown with plagioclase (acid labradorite) found in one of the monchiquite necks at Anderson's Inlet. All the varieties occurs as dykes in close parallel associations, the dolerites being dominant, intruded contemporaneously, so that the differentiation, or much of it, must have occurred within a pre-extrusion magma chamber.

Assuming this, the rocks have been arranged in a column of increasing order of acidity, which should represent in some degree the state of differentiation and the temperature gradient of the magma immediately prior to the intrusion of the dykes. The table of specific gravities, where known, for this arrangement is :—

Dolerites	2.28–2.95
Basalts	2.68
Monchiquite-basalts	2.78
Monchiquites	2.80–2.99
Nephelinites	3.05

This, in itself, carries little weight as evidence.

Figure 2, drawn in conjunction with this assumption, illustrates the relative grain size of the constituent minerals. It is seen that olivine was phenocrystic throughout, but that cooling to a greater degree in the upper regions permitted the individual crystals in the dolerite types to crystallize more completely, and to attain larger dimensions than those in the lower, and hotter, regions of the column. Moreover, in the upper regions the olivine has been

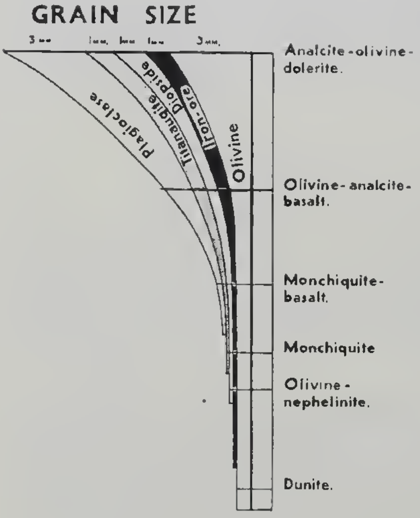

Fig. 2.

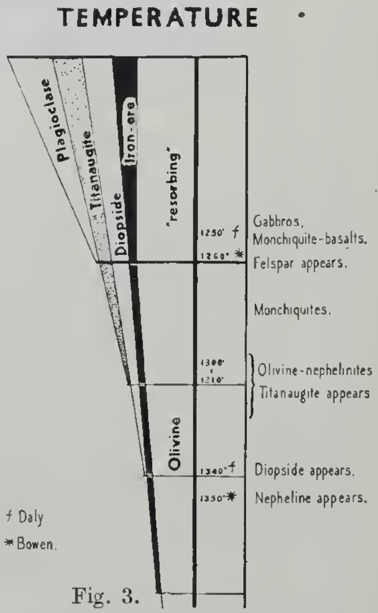

Fig. 3.

actively resorbed, while at the higher temperatures of the "monchiquitic layers" idiomorphic outlines are retained, showing that resorption had not set in. Resorption might be expected to commence with the appearance of diopsidic augite (Bowen, The System: Forsterite-Anorthite-Silica). Actually there seems to be a delay, and the corrosion of olivine is not appreciable until after the plagioclase has commenced to crystallize.

The augite was initiated as a diopsidic material, and had grown to a moderate size in the upper regions before the temperature of the lower part of the column had fallen sufficiently for it to appear there. By the time it was forming in the lower regions, titanaugite was crystallizing in the upper parts, wherever the titania was free to enter the pyroxene molecule. Plagioclase commenced to crystallize soon after the appearance of titanaugite, and the stronger crystallizing force of the former prevented idiomorphic growth of the latter as soon as a crystal mesh was established.

Intrusion apparently occurred just before the augite of the monchiquite layer reached the titanaugite stage, but not before augites had begun to sink towards these layers. Rapid cooling set up numerous diopsidic cores in the fluid magma, and a final rim of titanaugite developed before the consolidation or freezing. Movement into position probably squeezed out much of the residual liquor, concentrating the crystals, but a large portion of the fluid, of felspathic character, congealed as glass. In the slightly cooler "monchiquite-basalt layer," the pre-intrusion cooling had advanced sufficiently for felspar to commence to crystallize in increasing proportion. A factor supporting the view of intrusion in this almost fluid state is the uniform fineness and idiomorphic character of the groundmass crystals in the monchiquitic rocks, as opposed to the variable coarseness of the less basic types.

In the higher parts of the column, where crystallization had proceeded further, gravitational differentiation had been increasingly active, probably about a mean composition of magma represented by the olivine-analcite basalt, resulting in a downward movement of the olivine, and to a lesser extent, of augite. In a few rocks even the plagioclase shows evidence of sinking. The soda content appears to have concentrated locally in the upper region, quite independently of gravitational differentiation, enriching individual dykes, and may have been carried into place by the volatile fluxes, such as the water vapour now associated with it in the analcite. It arrived immediately prior to complete consolidation, enabling a slight reaction with the pyroxene to take place, and producing an intersertal distribution of the incoming material, i.e., the analcification was deuteric.

There might in this manner be some comparison between the differentiation of the rocks forming these dykes and necks, and such bodies as the Garbh Eilean sill of the Shiant Isles (Walker, 1930); but while in the latter case there was a floor on which the sinking olivine might concentrate, the lack of floor in the magma chamber here postulated, or its abyssal situation would lead merely to the remelting of the olivine as it sank to depth, and the consequent enrichment of the magma in magnesia and iron. Such clots of olivine as have been found in the monchiquites (p. 11) are to be regarded as remnants of this "potential layer," rather than as evidence of such a layer itself.

The nephelinite, on account of its restricted and isolated occurrence, presents difficulties. The early crystallization of nepheline with diopside indicates that the conditions peculiar to agpaitic differentiation (Backlund, 1932) obtained during the early period of differentiation. In such a system nepheline and orthoclase are among the first minerals to separate, and are forced by their specific gravities to rise in the magma, and concentrate at the top of the magma column. Kranck (1928), in discussing the origin of the abyssal melilite rock, turjaite, showed that the crystallization of nepheline precedes that of orthoclase, the nepheline accompanying diopside, while the appearance of orthoclase was delayed until the aegirine molecule commenced to crystallize strongly. This should lead then to the nepheline concentrating in the uppermost layers, as an urtitic magma, while nepheline and orthoclase in decreasing amount would form the layers beneath.

From the petrographic evidence of the Gippsland suite, olivine commenced to crystallize earlier than did nepheline, and was still crystallizing when the nepheline appeared (see Fig. 2); but the olivine of the nephelinite is wholly phenocrystal, and does not appear in the groundmass, so that olivine had ceased to crystallize within the nephelite magma before extrusion caused consolidation. This would suggest that the olivine of this uppermost layer of the magma column was sinking while the nepheline was rising: and that the extrusion of the nephelinite "fixed" the magma in this intermediate stage of differentiation, and left behind a magma enriched in magnesia and somewhat impoverished in soda. Backlund writes (p. 11):—" . . . . The early and sudden crystallization of felspars and felspathoids, and their strong tendency to rise in the thin but heavy residual fluid, leads to the formation of a film at the top of the advancing channel of the magma chamber in such a manner as to preclude an escape of gas. In consequence of this, pressure (and temperature) in the top film rises . . . . As a result, pronounced rhythms of periodical culminations tend to develop, viz., intrusions at regular intervals. . . . Meanwhile the volatiles accumulate."

The ultimate tendency is to separate the mother liquid into two sheet-like suites—the upper of felsic, and the lower of femic composition, probably grading into one another. It is suggested that the nephelinite represents the upper "sheet" in mid-process of differentiation, and that the felsitic dykes of the area represent the process at the stage when orthoclase is concentrating in the upper region, partial removal of the nepheline leaving the residual magma enriched in silica, which has led to the formation of oligoclase rather than nepheline in the felspar "sheet." The main suite of dykes, spasmodically enriched in analcite by fluxing of the alkalis by the partially retained gases, represent the femic "sheet." It is probable that the analcite-rich dolerites belong, as in the hypothetical column of Fig. 2, to the upper part of this zone, where the gas attack would be concentrated.

Temperatures.

In Fig. 3, an attempt has been made to suggest the temperatures of formation of the various dyke types, and the minerals constituting them. Like Fig. 2, it is based on the assumption of differentiation within a magma chamber.

The temperatures suggested are, at best, wide approximations, since they are based on data for the melting points of single crystals (Daly, 1933) or from suggestively similar points within restricted systems (Bowen, 1923). The effects of fluxing or eutectic crystallization are ignored.

The olivine crystallized out before the iron-ore, but later than the picotite. Daly gives 1,580 deg. C. as the melting point of magnetite, and that of olivine as 1,360 deg.–1,410 deg. C., while forsterite is formed about 1,890 deg. C. It would seem that Daly's figure is low, and that the olivine appeared about 1.580 deg. C.+.

The mineral to crystallize after magnetite appears to have been nepheline (commences to crystallize at 1,350 deg. C., Bowen; melts at 1,370 deg. C., Daly). Following closely, or simultaneous with it, the diopsidic augite appeared. From Bowen's experimental data, this might be expected to coincide with the beginning of the resorption of olivine, at a temperature of about 1,370 deg. C., but actually the resorption is delayed until the appearance of plagioclase, about 1,260 deg. C. (Daly, gabbros commence to crystallize about 1,250 deg. C.; Bowen, 1,260 deg. C.). Daly gives the figures 1,391 deg. C., 1,310 deg. C.–1,370 deg. C., and 1,185 deg. C,–1,200 deg. C. for the melting point of artificial diopside, bronzites, and augites respectively. Here the diopsidic augite crystallizes at or about 1,350 deg. C., and titanaugite between this temperature and 1,250 deg. C., when plagioclase appears, i.e., approximately at 1,300 deg. C.–1,310 deg. C.

Then the olivine-nephelinite should have been extruded at about 1,310 deg. C.–1,350 deg. C., monchiquites at about 1,260 deg. C.–1,310 deg. C., and monchiquite-basalts around 1,250 deg. C. The analcite-olivine-dolerite, despite its ability to form aegirine, has done so to only a very slight degree, the probable prohibitive factor being consolidation. Daly gives the melting point of acmite as 975 deg. C. (natural), and 990 deg. C. (artificial). If aegirine is assumed to melt about this range, the dolerites should have completed solidification between 950 deg. C.–1,000 deg. C., and were probably intruded at a temperature not greatly above 1,100 deg. C. The analcite-basalts, which show little or no sign of aegirine, must have solidified about 1,000 deg. C., and have been intruded at a correspondingly higher temperature, between 1,100 deg. C.–1,200 deg. C. This agrees approximately with the statement of Daly, that the Clee Hill dolerite (England) flows readily when heated to 1,070 deg. C. This rock is of a grain size intermediate between the basalts and the dolerites here described.

The felsitic, or trachyandesitic dykes, contain a little green hornblende, which could not have formed above 750 deg. C. (green hornblende changes to brown at 750 deg. C. or above, Kozu, Yoshiki, and Kani, 1927). Grout suggests a temperature of 550 deg. C. for the formation of such an amphibole, but this seems too low, since the remainder of the rock is entirely felspathic and fine-grained.

Age Relations and Correlations.

The age of these dykes and necks cannot be fixed precisely, but they pre-date the major faulting of South Gippsland, and appear to have been intruded before the previous subsidence period, when the Brown Coals were deposited, which would place them at least as old as Older Basalt (i.e., Lower Oligocene). Their relation to the Older Basalts of this area is not yet known, but isolated slides of the latter have many characters in common with the dykes, which may represent feed channels from which the basalts are now eroded. At Berwick and Aberfeldy large anorthoclase crystals, similar to those of the Moyarra Neck, are found in the basalts. The age of these Older Basalts was regarded formerly as Miocene, but with accumulating evidence as to the age of the younger Brown Coals, they are becoming to be regarded to be at least as old as Lower Oligocene.

The other possibility is that the Older Basalt period closed with a widespread intrusion of dykes about various centres—one in South Gippsland, one about Bendigo, and another south of the Harcourt granitic massif. The dykes of the latter centre intrude the Older Basalts there.

The constancy of the north-west strike throughout all these dyke areas is probably due to the equally constant north-westerly strike of the Palaeozoic basement through which they have all penetrated.

The remarkable similarity to the smallest detail between the monchiquites of Gippsland, and those of Bendigo, Ballarat, Gorong, Greendale, Maldon, and Daylesford, in Central Victoria, is such as to convince the author that they must have had a closely similar origin, despite the absence of crinanites from the latter areas. They show early segregation of olivine, with widespread serpentinization of that mineral, and an inclusion in one Bendigo dyke points to the existence of a gabbro body at depth. The associated dykes are camptonites, olivine-basalts, and some olivine-dolerites, while at Greendale there is the olivine-nephelinite referred to in this paper (p. 115). It seems apparent that in these areas the gravity differentiation has acted alone, and that late-stage analcitization did not develop.

The north-west dykes of Colonsay (Mem. G. S. Scott, 1908, 1911), consisting of crinanites, olivine-dolerites, a minor number of monchiquites, and occasional nepheline-bearing monchiquites, present a close parallel to the Gippsland association, both in the types developed, and their relative quantities. In composition, however, the Gippsland "crinanites" are nearer to the Palaeozoic crinanites of Scotland (Tyrrell, 1923, 1928), in that they have a high potash content. They differ from both of these groups in their low titania content. The picrite-crinanite sill of the Shiant Isles (Walker, 1930) provides a further parallel association, if the individual types of dyke are regarded as representing, in step form, the gradation there produced by gravity differentiation. There again, the analcitization has been independent of the differentiation, and developed at a late stage (Daly, 1933, p. 398).

Conclusions.

A suite of dykes, with a prevalent north-westerly strike, was intruded into the Jurassic sediments of South Gippsland in Lower Oligocene time. The suite comprises trachyandesites, analcite-olivine-dolerites, olivine-analcite-basalts, monchiquite-basalts, monchiquites, and possibly olivine-nephelinites. When arranged in this order of increasing basicity, they exhibit chemical and petrological gradation into the adjacent types, and are considered to have been derived from a common magma, of a composition about that of the olivine-analcite basalt, mainly by gravity differentiation, initiating under agpaitic conditions. The analcitization, however, developed independently, and locally, at a late pre-consolidation stage, by volatile fluxing, the fluxing agent being probably water vapour. The fluxing action on the alkalis was selective in favour of the soda, possibly because potash does not so readily enter into solution or combination with water vapour.

The rocks may post-date, but are probably genetically related to the Older Basalt Series. The very similar monchiquite dykes of Central Victoria are considered to be contemporaneous with the Gippsland dykes, and to have had a similar origin, but in that area the analcitization has not been developed.

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GEOLOGICAL SKETCH MAP OF SOUTH GIPPSLAND

Compiled from the maps of the Geological Survey of Victoria. (Ann. Rept. Sec. Mines, 1917).

[Proc. Roy. Soc. Victoria, **47** (N.S.), Pt. I., 1934.]

Art. VIII.—*Ecological Studies in Victoria. Part III.—Coastal Sand Dunes.*

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(With Plates VIII. and IX.)

[Read 12th July, 1934; issued separately, 22nd December, 1934.]

Coastal Dunes are a universal phenomenon, and, as remarked by Lundegardh (4), they are very similar ecologically, no matter where found, but the species which constitute the vegetative cover, while being morphologically similar, may be entirely different taxonomically.

In all latitudes, the dune plants are subjected to the same environment, but the particular species present is mainly a matter of the floral province in which the dune finds itself. This is well illustrated by the dunes along the Victorian coast, and the majority of plants found are closely related to typical Australian genera and families.

Although we are considering the dune as an association (and indeed Dune Vegetation is of a special type), it must be borne in mind that from the outermost or seawards dune to the innermost, there occurs a succession, both of growth forms and of species, so much so that there is a greater difference between the vegetation of the first and last dune than is usual between many associations, or indeed higher units (Pl. VIII. B, IX. C.) Nevertheless, by common consent, we take the dune vegetation as a unit, since the two main factors of the environment, sand and wind, are the determining factors in fixing the limits of the association. Once the sand is fixed permanently, other associations take the place of the coastal vegetation. Thus we find that both *Eucalyptus viminalis* and its common associate, *Pteridium aquilinum*, are present in the area immediately succeeding where the dunes have been fixed, but they do not occur in the area of moving sand. The dunes then cannot be said to have a uniform physiognomy, nor a constant composition, except spacially. The composition is constant from front to rear, but not in any unit area. If we were to take quadrats, even of very large size, they would give very differing results. Nevertheless, across the width of the dunes the same factors of environment are operating, but their incidence steadily diminishes from front to rear, and at last ceases to have effect. It is a peculiar feature of this association that the environmental factors change comparatively rapidly. As a rule, the environmental factors are uniform throughout an association, but here, as indicated, the uniformity is only in space, and not in minimum area. The definition of Flahault and Schroter (Braun Blanquet (1)) that an association has definite composition, must be read in a very broad sense.

Uniformity there is, however. The recognition of the Dune Vegetation as a unit of Vegetation, and not several units, bears witness to the fact that it is the environment which finally determines the particular association and growth forms found in any particular locality. No one would attempt surely to separate Dune Vegetation into its two extreme constituent parts, Grassland and Forest (Pl. VIII. B, IX. C), which are distinctive enough. There is here from first to last a struggle for existence. The sand dune is in a hostile area (Pl. IX. A), and on the outermost dune the hostile forces of the environment, advancing from the sea, meet the outposts of vegetation advancing from the land. (Pl. IX. B.). The moving sand, derived from the disintegration of rocks by the constant action of the sea, is finally arrested, and the vegetation makes a complete canopy (Pl. VIII. B).

Although we pass from grass to trees in the succession, the change is due to the modification of the unfavorable elements, moving sand and wind, by the vegetation itself. This feature compels one to keep dissimilar elements, grass and trees, together in the one association. In other areas, where trees or shrubs abruptly succeeded grassland (Pl. VIII. C), one would naturally expect a material change in the environment.

Environment is the primary cause of plant associations whose distinctive features are due to the growth forms occurring in them. Hence classification of associations to be truly scientific must ultimately rest on the cause or effect, i.e., on either the environment or growth forms. Linnean species, as such, retreat into the background as a basis of classification. Indeed, it can be shown that Linnean species themselves are partly the outcome of the environment. The members of diverse associations may be related taxonomically, but wholly unrelated ecologically. Thus the dunes along the Victorian coast bear the genera *Helichrysum*, *Olearia*, *Senecio*, *Leptospermum*, *Acacia*, and *Banksia*, as may the adjacent heath lands, but the two associations are not related ecologically. It merely illustrates the fact that the composition of any particular association is due to the general floral composition of the land in which it finds itself. Thus we shall see that the sand dune flora, which essentially is characteristic, yet is taxonomically connected with other widely differing associations. Change or variation is an inherent quality of life and, through this, forms are evolved which gradually colonize new land areas capable of sustaining plant growth.

The dune, since it is new land, is populated by a pioneer vegetation. This is the same in all climates, and it is of interest to note the families and genera that contribute to these pioneers. It may be concluded, since those families and genera, constituting the settled and stable communities in the hinterland, give rise to the population of the adverse area, that evolution and environment are closely associated. Not all evolution is a response to environment, but the latter is a contributing factor.

In a pioneer vegetation, but few forms are to be found. The limit of variation has to be stretched wide, hence few occur. The more favorable a locality, generally the greater is the number of species. The Fern Gully may be regarded as an exception, but it is an association far removed from its chief source of development. The front rank of the dune association is essentially composed of pioneers, which stand, not in close proximity (Pl. IX. C), but far removed from one another. Conditions of life are hard, and the struggle against the destructive forces of inanimate nature is severe. Struggle for existence goes on in two directions; firstly, against similar individuals, in which thousands perish for each survivor which is more or less perfect; secondly, against the destructive forces of nature. They survive only because they rise superior to their surroundings.

Dunes exist extensively along our coast, but although the same forces are operating, they differ appreciably both as to their degree and extent of development. They may be only a few yards wide or, as at Tarwin Meadows, may be hundreds of yards wide. All stages of development are met; there may be only fragmentary parts of the typical dune vegetation, or there may be complete development, from free sand to complete cover, as at Lakes Entrance. While attention has been given to the dunes at various points along the coast, the occurrences at Lakes Entrance have been most closely studied.

The Habitat.

A. SAND.

Were it not for the constant action of the wind the sand would be very readily settled by vegetation. In the dune the moving sand has to be arrested effectively before satisfactory colonization can finally take place. The sand is composed chiefly of silicon dioxide, but in the vicinity of rocky headlands, as along Phillip Island, where both seaweeds and shell fish are abundant, both the organic and calcareous content may be high and conspicuous to the naked eye. Neither of these constituents, however, affects the vegetation of the dunes. They are broken down into fragments as small as sand, and physically behave as such. In other areas, as along the Ninety Mile beach, both the organic and calcareous content are low. Any chemical or other effect that such constituents might have in other associations is lost here, since the physical environment is of greater consequence. Evenness of size of particle is an outstanding character. Darbishire (2) gives the size of grains in the dunes investigated by him as between 0.2 and 0.4 mm., while Warming (10) states that the grains generally average $\frac{1}{3}$ mm. In Table I. is given a series of analyses of material taken from dunes along the Victorian coast, and for comparison analyses of drift sand from the Victorian Mallee and of dune sand collected by the author in the Northern Sahara, in the vicinity of Biskra, Algeria, are included. The sizes of the fractions are given in inches.

TABLE I.—MECHANICAL ANALYSES OF SAND DUNE MATERIAL.

Locality.	Percentage of Fractions—Inch.					
	1/10 to 1/20.	1/20 to 1/40.	1/40 to 1/60.	1/60 to 1/80.	1/80 to 1/100.	Less than 1/100.
Phillip Island ..	..	1·14	**48·50**	46·00	4·20	·04
Tarwin Meadows ..	..	·07	13·25	**60·75**	23·50	2·17
Brighton Beach ..	·05	·11	27·33	**62·66**	8·50	·95
Lakes Entrance ..	..	11·20	**81·01**	7·45	·29	..
Mallee Drift ..	·01	22·20	**50·31**	12·22	5·80	9·41
Sahara	..	·95	21·00	**50·00**	20·00	8·05

It will be noted that a high percentage of the grains lies between 1-40 (0.6 mm. app.) and 1-80 in. (0.3 mm. app.). The lower limit is in agreement with those of Darbishire and Warming. The grains are not strictly spherical, but are more or less ellipsoid or ovoid as indicated by Darbishire (2). The similarity in the size of sand grains constituting dunes in various parts of the world suggests that the forces forming them are similar. It has been found by Vageler (9) that there is a relationship between strength of wind and size of sand particles moved, expressed in the equation

$$y = .0268x,^{1.568}$$

where y = diameter of particle in mm., and x = wind velocity in metres per sec. For a particle 0.5 mm. in diameter, which closely corresponds to 1-50 in., this formula would give a value of 6.46 mm. per sec.. or slightly more than 14 miles per hour. Experiments with the fraction 1-40–1-60 in. showed that the grains just moved in a wind speed of 12 miles per hour, but moved freely at 15 miles per hour, which agrees with the value obtained from the formula. It has been shown by Stevenson and by Hellman, quoted by Lundegardh (4), that wind velocity is greatly retarded by the earth's surface, and that the wind velocity steadily increases upwards. Thus, to quote Lundegardh, the force at 0.05 m. and 0.5 m. is as 1 : 1.9, that is nearly twice as great at half a metre above the surface; a strength, then, which will just move sand, must be blowing in the shrub phase at about 30 miles per hour. A wind with sufficient velocity to move the sand grains only occasionally blows, and therefore sand movement is irregular. It will be found on examination of sections of dunes that they are built up intermittently, and not continuously.

B. MOISTURE.

It would appear from some writers on sand dunes that drought is a feature of the habitat, and that the xeromorphic character of dune vegetation is the outcome of the xerophytic conditions there existing (Schimper (6)). Darbishire (2), on the other hand, quotes Swellengrebel as stating that the lower layers of the dunes are tolerably moist. The moisture content of these layers he believes to be under the influence of the ground water. This may be true for very shallow dunes, but in high dunes, such as occur at Tarwin Meadows, this cannot be so. The roots of *Spinifex hirsutus* have been traced down 6 feet, but ground water is not found at that depth. The dampness of the deeper layers is due entirely to the percolation of rain water. In contrast to other associations, no rain water is lost in run-off, and very little in evaporation, for practically all the rain that falls passes into the soil. Experiments with percolation of water through dune material show that an inch of water penetrates on the average 3.3 inches into the sand, so that a rainfall of 30 inches would sink 8 ft. 3 in. However, the depth to which this amount of water actually penetrates is much greater than this. The depth to which water will percolate is governed not only by the character of the soil particles, but also by the depth of the moist sand itself. When the water has sunk to a certain depth, it exerts a downward pull on the upper portion of the water column, and therefore less water is held in the upper layers of soil than when only a few inches are present. The high percentage in the upper layers of the soil can no longer be held by the sand grains against the force of gravity, and therefore the water-holding capacity of the upper layers varies with the depth to which the moisture has penetrated. The experiment of adding small and large quantities of water to long columns of dune sand, arranged so as to permit of drainage from the bottom, showed that after equal intervals of time the amount of moisture of the upper 2 inches in the short moistened section was always much greater than that of the upper 2 inches of the long moistened column. After standing for 24 hours, it has been found that the ratio of moisture in the short moistened section to that of a similar length from the completely moistened column averaged 5.9:1. Furthermore, if a long column be completely saturated, and then left to drain, evaporation from the upper surface being guarded against, there is, as long as the experiment be conducted, a very great difference in the moisture content between the upper and lower portions of the column. This has been extensively studied by King (3).

Size of soil particle and depth to which the moisture penetrates are not the only factors, for time is also a factor in determining the amount of water in the upper layers. Hence the usual determination of water-holding capacity of soils has no real ecological significance. In Table II. are given the moisture contents of the upper 2 inches of sand columns 73 cm. long and 2.3 cm. in diameter, the columns being first saturated, and then left to drain for varying lengths of time, the first measurement being taken after dripping at the bottom had actively ceased.

Table II.—Moisture Content of Upper 2 inches of a Saturated Sand Column Left to Drain for Times Given.

Time.	Percentage of Moisture.
	%
3 hours	5·6
24 hours	3·3
48 hours	3·0
15 days	2·3

The depth of the moisture available for plants in the dunes is thus very variable, depending not only upon the above factors, but also upon the amount of sand that has been added to or removed from the area by the wind. Along the Victorian coast it rarely happens that the plants are in need of water, but in the year 1923 the water content had reached an amount too low for the needs of these plants, and wilting occurred extensively. The rainfall for the six months, November to April, for 1922-23, as well as the average for these months, is given in Table III.

Table III.—Comparison of Average Monthly Rainfall of Melbourne with that of 1922-23.

Month.	Actual Rainfall.	Average 66 Years.
	Points.	Points.
1922—		
November	105	224
December	202	232
1923—		
January	99	188
February	61	170
March	33	223
April	0	223

It has been repeatedly found that the dunes are constantly moist a short distance beneath the surface, and during the early part of 1934 a series of investigations was made to ascertain the moisture content, the results of which are given in Table IV. At Melbourne and Cowes (a few miles from Cape Woolamai), the rainfall for February and March was below normal, and conditions were favorable for a low moisture content of the soil. At Lakes Entrance the rainfall was well above normal. The samples were all taken from the highest point of the dunes; those at Woolamai being taken at an elevation of 100 feet.

TABLE IV.—MOISTURE CONTENT AT VARIOUS DEPTHS OF SAND DUNES.

Locality.	Date.	Moisture Content.					
		Surface.	6 In.	12 In.	18 In.	24 In.	30 In.
Lakes Entrance ..	5.2.34	..	2·06	..	2·85	..	3·12
Brighton Beach ..	14.3.34	Trace	1·06	1·26	..	..	..
Cape Woolamai ..	17.3.34	0·33	1·44	2·23	2·4	..	..
Lakes Entrance ..	2.4.34	..	2·7	..	2·3	..	2·9

The percentage of moisture in the dunes appears to be very low, but germination experiments with wheat and mustard showed that these seeds can germinate in dune sand with as low a moisture content as 1 per cent., and from this it may be assumed that the amounts of moisture given in Table IV. are generally sufficient for the growth of plants.

The rapid entry of rain water and its continuous movement downwards are both important factors in the conservation of moisture, but equally important are the new layers of dry sand blown over the moistened area. Usually wind is a desiccating agent, but on the dune it acts as a conserver of moisture by adding the sand mulch. How effective is the retardation by a dry sand layer of water loss from damp dune sand can be seen from Fig. 1, where the losses from bare surface are contrasted with similar surfaces covered by 1, 2, and 3 cm. of dry sand respectively.

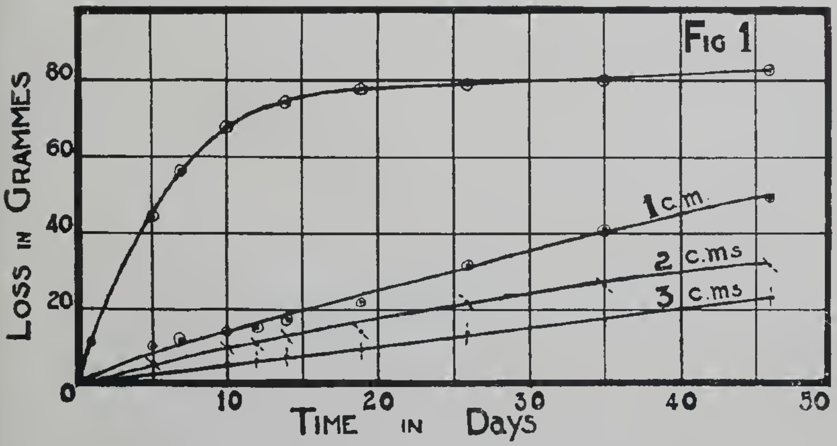


FIG. 1.—Effect of sand mulch on the loss of moisture from moist dune sand.

It is probable that with all the factors operating for the conservation of moisture, the evaporation loss is surprisingly small. This, together with the uniform distribution of rain (Table V.) throughout the year, indicates that there is normally no scarcity of moisture at the roots, and therefore the habitat, in so far as the soil is concerned, is in no way xerophytic.

Table V.—Distribution of Rain Throughout the Year for Stations along the Victorian Coast.

(Rain recorded in points; 100 points = 1 inch.)

Station.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Average Annual.
Portland ..	136	138	163	264	371	412	**422**	417	347	281	194	180	3325
Cowes ..	182	154	251	261	238	**320**	275	287	280	258	220	213	2989
Lakes Entrance	258	174	262	223	217	231	234	181	243	**293**	209	243	2768

Although the dunes are in close proximity to the sea, the salt content of the dune is very low and negligible from an osmotic point of view. The contrary view was held by Schimper (6), but Warming (10) and Darbishire (2) have found the same condition, so that it may be taken as a feature of environment that the water in the sand dune has no osmotically ecological significance. Even if salt were present, its solubility and the ready percolation of water would cause the salt to be carried far down out of the region of the roots.

C. Dune Building.

It is only on the outer dune that sand is free to move. The distance, however, from the high-tide level to the arrest of the sand differs enormously. At Sydenham Inlet, the dunes are densely clothed but a few yards from high tide, while at Tarwin Meadows there are some hundreds of yards between these two points. The reasons for these differences are probably that the amount of material produced is more at some points than at others, and also that the conditions favouring accumulation vary. In this latter connection, land of low elevation extending for a considerable distance inland is more favorable for extensive sand accumulation than where rising ground exists. The narrowness of dunes, on the other hand, may be due to the destructive force of wind, or to the encroachment of the sea upon the land. Dunes are not built continuously and gradually, but rather by layers, since wind action is not constant. In breached dunes the successive layers may be seen. There are two sand-fixing agents, water and plants. Water has a binding action, and holds the dunes against the destructive force of the wind. It is the only binding force on the plantless dunes. A moisture content of 1 per cent. holds the sand grains together only feebly, but at 2 per cent. the cohesive force is very manifest. Examples of this are best seen near Cape Woolamai, where the dunes are 100 feet high, and quite devoid of vegetation. Excavations along the sides of these show how moist they are.

Plants act in a twofold manner. The aerial portions are a direct obstacle in the path of the moving sand, and the particles are arrested. This action is important in the building of the dune. The roots do not assist in the building, but are resistant to the destructive action of the wind. On the lee side of the dune the sand comes to rest at an angle of 32 deg. to the horizontal. This value has been taken from measurements at Wilson's Promontory, Lakes Entrance, and Sydenham Inlet. This angle of rest is usually found only at the inner face of the first dune, which is sparsely covered with vegetation, since the rapid deposition of sand makes it difficult for plants to establish themselves.

On the outer face of the first dune the angle of inclination is very variable, being frequently higher than the angle of rest, due to the holding action of roots of *Spinifex hirsutus.* These roots are long and slender, and bear very short laterals. The combined action of these is to resist the destructive action of wind. Measurements of Spinifex-fixed dunes at Lakes Entrance gave an average value of 49 deg. for the outer face, while at Wilson's Promontory the outer face in many cases was almost vertical.

Composition.

It has already been remarked that a pioneer vegetation must be drawn from those families and genera inhabiting the nearby vegetated areas. In habitats so widely different, it is obvious that but few species could occur in both. It is true that some do, but they occupy but a minor place in the vegetation. The author prefers to call such forms "versatile wides" since their distribution is not controlled by any particular set of ecological conditions. On the sand dunes are found such accommodating forms as *Pelargonium australe* and *Acaena Sanguisorba*, but they are not conspicuous. The dune vegetation is very distinctive, and is formed of characteristically littoral species. There is a close relationship, although naturally a pioneer settlement is sparse as regards number of species present, with the adjacent heathland floor, which has been called Cheltenham flora (5). In fact, some of the heathland consists of old dunes (5). The reason why the dune flora, with the exception of *Leptospermum laevigatum*, remains close to the sea, and does not move inland, is probably due to the change in the soil conditions. The leaves of the dune vegetation are large (see Table VII.) compared with the heath vegetation.

The composition in so far as the larger Dicotyledons are concerned, is essentially Australian, the characteristic genera being found in other typical Australian associations.

In Table VI. are given the commonly occurring species found on the dunes. A feature of this association is that there are no dominants, for in each phase the members are of almost equal height.

Table VI.—Species Occurring on Sand Dunes in Victoria.

I.—Monocotyledonae.

Gramineae—Spinifex hirsutus (V.C.).
Festuca littoralis (C.).
Cyperaceae—Lepidosperma gladiatus (F.).
Scirpus nodosus (F.).

II.—Dicotyledonae.

Archichlamydeae.

Proteaceae—Banksia integrifolia (V.C.).
Polygonaceae—Muehlenbeckia adpressa (F.).
Chenopodiaceae—Rhagodia baccata (C.).
Aizoaceae—Mesembrianthemum aequilaterale (C.).
Ranunculaceae—Clematis microphylla (C.).
Rosaceae—Acaena Sanguisorba (F.).
Leguminosae—Acacia Sophorae (V.C.).
Geraniaceae—Pelargonium australe (F.).
Myrtaceae—Leptospermum laevigatum (V.C.).

Metachlamydeae.

Epacridaceae—Leucopogon parviflorus (C.).
Apocynaceae—Alyxia buxifolia (C.).
Myoporaceae—Myoporum insulare (V.C.).
Goodeniaceae—Scaevola calendulacea (R.R.).
Compositae—Olearia axillaris (V.C.).
Helichrysum cinereum (V.C.).
Calocephalus Brownii (C.).
Senecio spathulatus (C.).

V.C. = very common; C. = common; F. = frequent; R.R. = rather rare.

It will be seen that the families and genera so conspicuous on the adjacent heath lands, Proteaceae (*Banksia*), Leguminosae (*Acacia*), Myrtaceae (*Leptospermum*), Epacridaceae (*Leucopogon*), Compositae (*Olearia*), are found here. However, no commonly occurring characteristic species, with the exception of *Leptospermum laevigatum,* is common to both associations. It has already been pointed out that species as *Acaena Sanguisorba,* which are very subordinate members, are found also in other widely differing associations. They are capable of existing under very diverse environments. Such species are capable of being Wides in the sense of Willis (11). There is a connexion, too, with the Fern Gully Association in the families Compositae (*Olearia*), Leguminosae (*Acacia*), Ranunculaceae (*Clematis*), and Apocynaceae. The last family is mostly tropical, but is represented here by two genera, each with one species.

The pioneers of this new land are therefore derived from the adjacent vegetation. However, since no species except one is common, it may be taken that a long time has elapsed since they first arose. Their lack of spread is an argument against Willis's (11) Theory of Age and Area, in so far as time only is concerned. The theory is true in a general way, but the confining of a species to a particular area is not necessarily because it is new born, nor because of any physical barrier to its spread, but possibly because of the dissimilarity of ecological conditions. The characteristic dune species are ecologically spot-bound.

One family of interest is Myoporaceae, which has a great development in the Mallee. Very frequently *Casuarina stricta* is found on the innermost dunes, and this tree is also a versatile wide.

Succession.

It has already been noted that the vegetation on this narrow strip along the coast, from outermost to innermost dune, is very diverse, and in other areas would be divided into separate associations, but here the same set of factors, wind and sand, operate, modified by the interference of the pioneers. The steady arrest of the moving sand is associated with a number of other changes, and the sequence of these changes is known as Succession.

The outermost dune is usually sparingly covered with *Spinifex,* with which a few other plants are sparsely associated. In Pl. IX., C, is shown an outermost dune at Lakes Entrance, where *Spinifex hirsutus* is the chief species, but both *Senecio spathulatus* and *Calocephalus Brownii* are also sparingly present. Occasionally *Festuca littoralis* is met with. The binding action of the roots and rhizomes, and the accumulative action of the leaves steadily bring about more stable conditions. At Lakes Entrance, *Spinifex* is abundant on the outer part of the second dune, but here low, extensive, prostrate masses of the so-called *Acacia Sophorae* effectively protect the soil (Pl. VIII. C.). This Acacia is in all probability but a biotype of *Acacia longifolia* which occurs in the rearmost dunes. It may, however, be merely a habitat form of the latter. At Lakes Entrance probably the most extreme forms of it occur. The phyllodes are exceedingly thick (Fig. 3) and broad. This *Acacia* sends out widely spreading horizontal roots, which are close to the surface, and may be exposed by the wind. On the underside of these, secondary roots occur, which grow downwards. On these, nodules of *Bacillus radicicola* are abundantly produced. In this spreading mass of the *Acacia,* plants of other species, particularly *Olearia axillaris,* are found. The *Acacia* marks the end of the *Spinifex* phase (Pl. VIII. C.) and the commencement of the scrub phase, which is composed, in addition to the two species just mentioned, of *Helichrysum cinereum* and *Scaevola calendulacea,* which may also form extensive prostrate masses. With these may be associated smaller plants as *Acaena Sanguisorba, Pelargonium australe,* and *Mesembrianthemum æquilaterale.* These latter are infrequent, and never affect the physiognomy. There is a marked difference here between these two successive stages. The vegetation is higher, and covers considerably more than half the surface of the soil. In the scale suggested by Braun Blanquet (1) the plant cover (Deckungsgrad), on the outermost dune being less than 5 per cent. has a numerical value of 1, while in the shrub or second phase (Pl. VIII., D) the area of soil covered is between 50 per cent. and 75 per cent., and to this the value 4 is given. The change is very abrupt, as can be seen in Pl. VIII., C. On the innermost dune (Pl. VIII., B) the degree of soil covering is complete, and this has the numerical value of 5. In this last phase, shrubs are replaced by small trees, and associated with these are both lianes and parasites. The tree species are *Banksia integrifolia, Myoporum insulare, Leptospermum laevigatum*, and with these are associated the tall shrubs *Alyxia buxifolia* and *Leucopogon parviflorus*. The degree of soil cover is so great—denser than any other local association, except possibly the Fern Gully—that there is an accumulation of raw humus. This is unusual in warm temperate climates. The dampness is shown by

Phase I.	Phase II.	Phase III.
Senecio spathulatus.	*Acacia Sophorae.*	*Leptospermum laevigatum*
Calocephalus Brownii.	*Olearia axillaris.*	*Myoporum insulare*
Spinifex hirsutus.	*Helichrysum cinereum.*	*Banksia integrifolia*
Festuca littoralis.	*Scaevola calendulacea.*	*Alyxia buxifolia*
	Myoporum insulare.	*Leucopogon parviflorus*
	Banksia integrifolia.	*Clematis microphylla*
	Clematis microphylla.	
	Acaena Sanguisorba.	
	Pelargonium australe.	
	Spinifex hirsutus.	

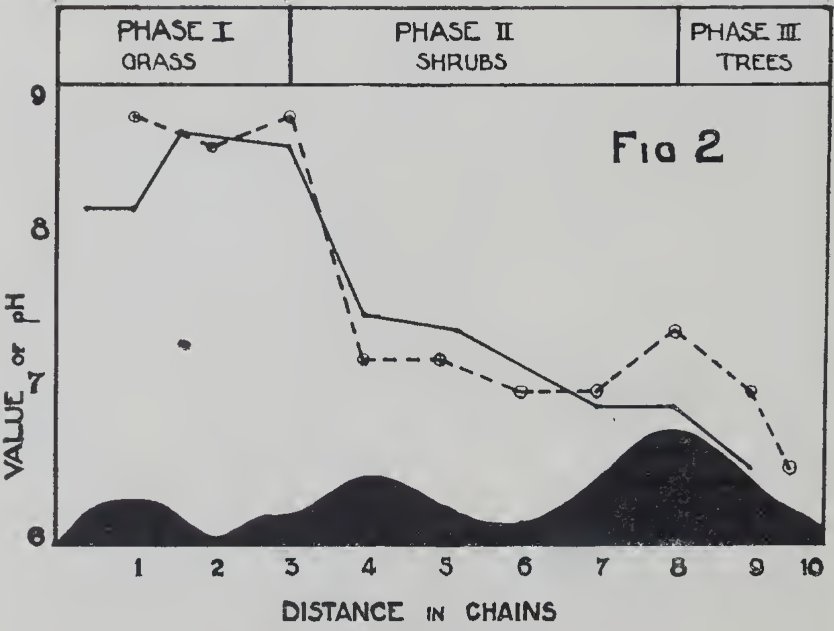


Fig. 2.—Variation in the soil acidity from front to rear of the sand dunes.

the presence of species of Bryophyta. The soil may be discoloured for several inches, due to the accumulation of plant debris. The slowness of decomposition of the leaves may be due to the thickness of the cuticle (Fig. 3). No such accumulation, however, occurs on the adjoining heathlands, for here the material is quickly decomposed.

The presence of the tree phase gives opportunity for other life forms to occur, such as lianes, but only one, *Clematis microphylla*, is commonly met with. Occasionally another liane, *Muehlenbeckia adpressa*, also occurs. In this phase phanerogamous parasites make their appearance, being represented by a species of Loranthaceae.

The succession above ground, life forms, species, height of phases, degree of soil cover, fixation of sand, accumulation of litter, is also associated with a succession as regards soil acidity. This is to be expected, since in the foremost dunes shell fragments occur, and in the innermost dunes plant remains are accumulating. In Fig. 2 are given two graphs of the pH values, ascertained by the Hellige Comparator, from front to rear of the dunes, one series of soil samples being taken at regular intervals of a chain, and the other being taken from front, top, and rear of each dune respectively.

Morphology.

The leaves of the dune plants are essentially xeromorphic (xeromorphy being defined as by Thoday (8)), but it cannot be contended on that account that the plants are xerophytic, since there is usually no deficiency of water for deeply penetrating roots. Although there is sufficient soil water, the strong winds provide a powerful desiccating force. Hence the xeromorphy must be ascribed to this cause. The xeromorphy extends right through the succession, those leaves occurring in the more favorable situation behind the third dune are just as xeromorphic. There are some truly mesomorphic leaves, as those of *Acaena Sanguisorba, Pelargonium australe,* and *Clematis microphylla,* but these plants occur in sheltered places, and are not exposed to the wind.

The xeromorphy of the leaves does not express itself in any particular direction, for we find that there is no uniformity as regards the leaf in (1) size, (2) structure, (3) cuticle, (4) disposition or number of stomata, (5) moisture content.

Size of Leaf.

Size is very variable, ranging from the leptophyll of *Calocephalus Brownii* to the microphyll of *Banksia integrifolia.* In Table VII. is given the percentage of leaf sizes according to Raunkaier (7) for the dunes at Lakes Entrance. The monocotyledons are excluded, as Raunkaier's system is not applicable to these.

TABLE VII.—LEAF SIZE CLASSES OF DUNE VEGETATION AT LAKES ENTRANCE.

	Per cent.
Leptophyll	20
Nanophyll	33
Microphyll	47

It is surprising to find so high a percentage of microphyllous leaves, for in adjacent heath flora only one microphyll is found. On the other hand, in the heath flora, leptophyllous leaves are abundant (5), while in the dune vegetation they form only 20 per cent., and these are all species of Compositae, confined to the first and second dunes.

STRUCTURE.

The leaf types, so far as the arrangement and development of tissues are concerned, may readily fall into three classes—normal, isobilateral, and succulent.

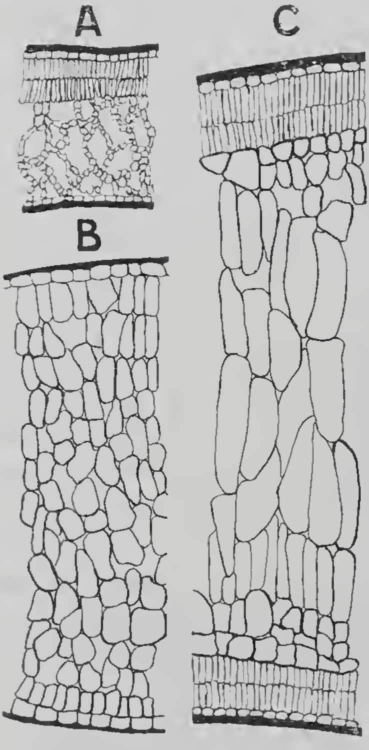


Fig 3.

FIG. 3.—Section of leaves of Dune Vegetation. (A) *Alyxia buxifolia*; (B) *Senecio spathulatus*; (C) *Acacia Sophorae* (section of leaf from exposed position).

(*a*) *Normal.*—The normal type (Fig. 3A) has palisade cells on the upper side, a well developed spongy mesophyll below, and stomata confined to the lower surface. These leaves are placed horizontally, and function as ordinary mesophyllous leaves. The spongy mesophyll is particularly well developed, and the air spaces are abundant. This type is represented by *Banksia integrifolia, Alyxia buxifolia*, and *Olearia axillaris.*

(*b*) *Isobilateral.*—The phyllode of *Acacia Sophorae* has almost identical structure with the true leaves of *Myoporum insulare* and *Leptospermum laevigatum* (Fig. 3, C). In these organs the palisade occurs on both surfaces, and stomata occur on both also. The association of stomata with palisade is an inversion of the normal structure. There is no spongy mesophyll, and the tissue between the outside layers of palisade is thin-walled and devoid of chlorophyll. This tissue is pith-like in character. The leaves of this type are not horizontal, but are more or less vertical. In *Acacia* the leaves are held strictly upright.

(*c*) *Succulent.*—There is a greater variety here than in the other two types, but the modifications are all in the direction of dispensing with normal cell arrangement and of ,conversion of all tissues to water storage. The family Aizoaceae is represented by *Mesembrianthemum aequilaterale* and *Tetragona implexicoma;* in the latter even the epidermal cells are converted into water vesicles. Also the family Chenopodiaceae, which contains many succulents, is represented here by *Rhagodia baccata.* Of more interest, however, is *Senecio spathulatus* (Fig. 3, B), which occurs on the outermost dune, and *Scaevola calendulacea.* In these two latter, palisade tissue is non-existent, and there is no normal spongy mesophyll. The cells are thin-walled, and air spaces are fairly plentiful. Stomata occur on both surfaces. Chlorophyll may occur right through the leaf, but it is not concentrated in particular layers as in the first two types.

CUTICLE.

The xeromorphy expresses itself particularly in regard to the development of the cuticle. This reaches its greatest development in *Acacia Sophorae*, where it occurs on the exposed parts of the second dune. These measurements of the cuticles, given in Table VIII., are taken from leaves collected at Lakes Entrance. It is of interest to note that all of the species occurring in the shelter of the third dune have well-developed cuticles.

TABLE VIII.—THICKNESS OF CUTICLE OF LEAVES OF SAND DUNE PLANTS.

	Microns (μ)
Acacia Sophorae	18.6
Alyxia buxifolia	15.2
Olearia axillaris	15.0
Banksia integrifolia	13.6
Myoporum insulare	13.0
Leptospermum laevigatum	12.2
Senecio spathulatus	9.6
Spinifex hirsutus	8.0

STOMATA.

Mostly the stomata are sunk beneath the level of the cuticle, and this fact, together with the thickness of the cuticle, may be regarded as protection against excessive transpiration. The number of stomata per sq. mm. is, on the whole, only moderate. A feature of the association is the number of plants that have stomata on both surfaces. Since the stomata are sunken, and since they do not abut on spongy mesophyll where diffusion readily takes place, and also since the leaves are thick, or very thick, stomata are probably necessary on both surfaces in order to fulfil the ordinary functions of a plant. To have stomata on both surfaces gives double the efficiency. However, it must be emphasized that as regards number of stomata per unit area, comparisons between an ordinary mesophytic dorsiventral leaf and a xeromorphic leaf, such as occur here, are of very little value, since other structures of the leaves are so widely different. The number of stomata per sq. mm. is given for the dune plants in Table IX.

TABLE IX.—NUMBER OF STOMATA PER SQ. MM. ON LEAVES OF SAND DUNE PLANTS.

Leaf Type.	Species.	Average Number on Each Surface.
Normal	*Alyxia buxifolia*	152 — 0
	Acacia Sophorae	138 — 138
Isobilateral	*Leptospermum laevigatum* ..	122 — 58
	Myoporum insulare ..	69 — 69
Succulent	*Senecio spathulatus* ..	69 — 69
	Scaevola calendulacea ..	82 — 48

Further it may be remarked that the number of stomata per unit area cannot be ascertained from such plants as *Spinifex hirsutus,* where the stomata are set in grooves, nor from *Banksia integrifolia,* because the stomata are not uniformly distributed over the leaf, but are localized between broad sclerenchymatous strands. Where the veins are excessive, there cannot be any effective measure of the number of stomata per sq. mm., but some larger unit is needed. In other words the sq. mm. is too small a unit for leaves that have a great number of veins. It is of interest to note that *Acacia melanoxylon,* found in the Fern Gully, averages 307 stomata per sq. mm. on each surface of the phyllode.

MOISTURE CONTENT.

It is natural to expect that sclerenchymatous leaves would necessarily contain a low amount of water. It has already been shown (5) that the moisture content of the heath plants, which are true xerophytes, is low. These leaves are generally xeromorphic and sclerenchymatous. If we consider similar leaves here, we find also a low average content of the leaves, namely, 163 per cent., calculated to the dry weight.

Leaves such as those of *Myoporum insulare,* which are xeromorphic and coriaceous, have a high moisture content, and such leaves might almost be classed as semi-succulent.

The true succulents—*Senecio spathulatus, Scaevola calendulacea,* and *Tetragona implexicoma,* have a very high moisture content.

In Table X. are given the moisture contents, calculated to dry weight, of typical dune plants.

TABLE X.—MOISTURE CONTENT OF THE LEAVES OF DUNE PLANTS GIVEN AS A PERCENTAGE OF DRY WEIGHT.

Helichrysum cinereum	118
Leptospermum laevigatum	121
Banksia integrifolia	129
Alyxia buxifolia	165
Spinifex hirsutus	184
Acacia Sophorae	275
Myoporum insulare	408
Scaevola calendulacea	635
Senecio spathulatus	683
Rhagodia baccata	756
Tetragonia implexicoma	1,040
Mesembrianthemum aequilaterale	1,338

Adaptation to Environment.

Warming (10) has given certain adaptations of plants growing on sand, and these in part are the case here. *Spinifex hirsutus* has long runners (Pl. IX. B.), in cases up to 20 feet, but normally the moving sand does not permit unrestricted development. These runners are facultative rhizomes, for when buried the runner functions as a rhizome, and sends up shoots. *Acacia Sophorae,* which is the immediate successor to *Spinifex hirsutus,* has also prostrate shoots which root at intervals. This is an unusual character for the genus *Acacia.* This habit enables the *Acacia* to form large masses (Pl. VIII. C.).

Another adaptation given by Warming is that of tufted habit, which is exemplified by *Senecio spathulatus.*

Hairiness is not an outstanding character, for it occurs on but a few plants. Glabrousness is more common. *Senecio spathulatus* is quite glabrous, and this occurs (Pl. IX. C.) side by side with the very hirsute *Spinifex hirsutus.* The leaves of the shrubby Composites are hairy underneath, as are also those of *Banksia integrifolia.* The cushion plant, *Calocephalus Brownii,* exhibits the extreme case of hairiness.

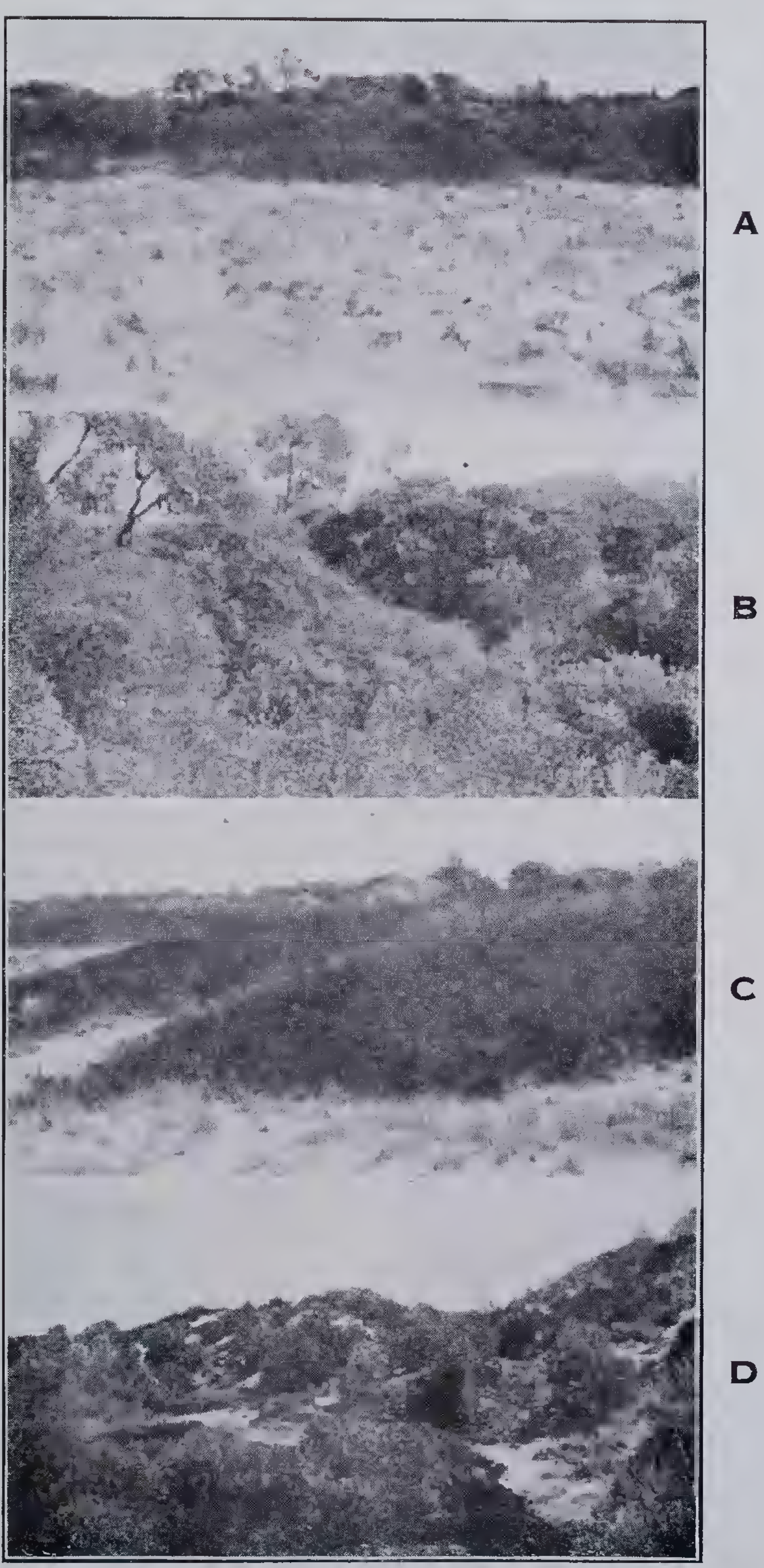
Succulence occurs only to a minor extent. The extremely succulent members of Aizoaceae are not very frequent. Instead of succulence, sclerophylly is more often the case both in the foremost and last dunes. Succulence and sclerophylly are found side by side in *Senecio spathulatus* and *Spinifex hirsutus.*

As a possibly important factor in the vegetation, light might be considered. There is a powerful reflection from the glistening white sand, particularly on the first dune and the outerside of the second dune. It cannot be said, however, that there is any particular adaptation against it. As soon as vegetation covers the sand, this factor ceases to be of importance, yet the morphological characters of the vegetation persist.

The outstanding example of adaptation to environment is to be found in *Spinifex hirsutus.* Its whole organization is a marked series of adaptations. This plant grows on the exposed outer dune, and its life is spent in one long continuous struggle with adverse conditions. It is the ultimate victor in the suppression of the destructive forces, but at times it suffers defeat and destruction.

In its habit of rooting, each node sending down a few long sparsely branched roots, it not only obtains a constant supply of moisture, but (Pl. IX. A.) binds the sand together against erosion by wind. These roots, even when dead, still have binding power. The runners when buried send up shoots to the new surface, and shoots and rhizome combined assist the roots in sand binding. Another adaptation is to be found in the fact that the stomata occur in grooves on the upper surface of the leaf which is mostly inrolled. In addition to the hairiness, there is a cuticle When the leaf is inrolled the stomata are no longer exposed to the air, and thus transpiration is restricted. In addition, cuticle and hairy covering prevent cuticular transpiration. The plants are dioecious, and therefore must be wind-pollinated. The distribution of the seed (Pl. IX. D.) is again wind-controlled. The inflorescence breaks off, and is rolled by the wind, dropping the seed until it finally is arrested by the shrub succession. These spherical inflorescences are extremely light and easily moved. In germination there is a final adaptation. In seeds which have a coleoptile, the depth of soil through which the seedling can emerge is limited by the length of the coleoptile. In general the coleoptile is a very short organ, and limits the depth to which grass seed may be sown. Once the coleoptile ceases growth in length, the first leaf emerges, and leaves are very poor instruments for getting through the soil. The percentage of germination very rapidly falls when the seed is sown deeper than the length of the coleoptile. In *Spinifex hirsutus,* however, where there is the constant danger of the seed being buried deeper than the length of the coleoptile, there occurs a hypocotyl which can carry the coleoptile high up towards the surface of the sand. From seed to tip of coleoptile, 5 inches have been measured.

Generally speaking, there cannot be said to be any one constant adaptation in this association except prevention of water loss due to the constant wind. The modification of leaf structure, whether sclerophyll or succulent, is most probably connected with wind action. Where there is water supply at the root, xeromorphy is not a matter of course, no matter how powerful the condition for transpiration and evaporation may be.



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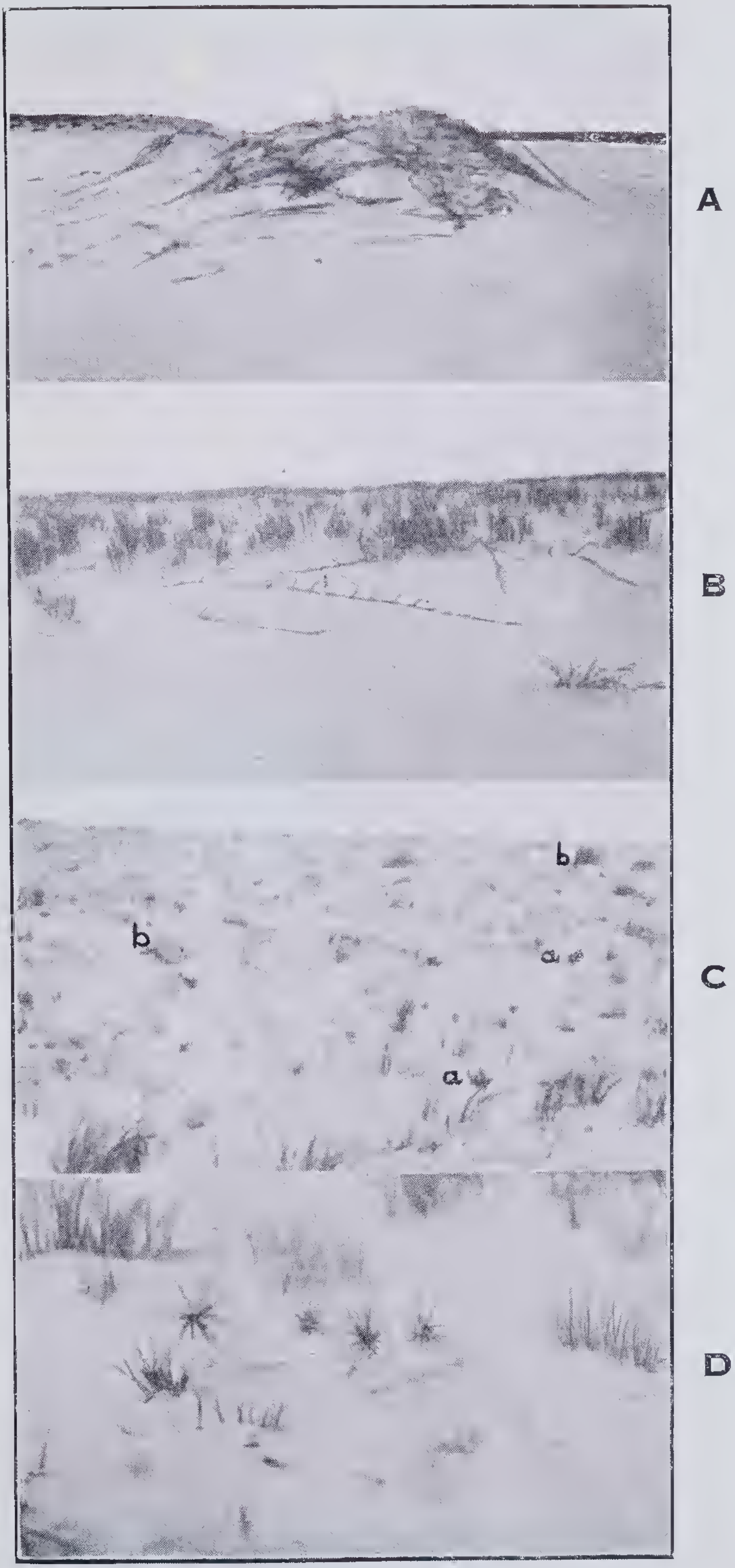
Vegetation of Sand Dunes.



Vegetation of Sand Dunes.

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Explanation of Plates VIII. and IX.

PLATE VIII.

A.—Second Dune showing the junction of Phase I. (Grass) and Phase II. (Shrubs). Photograph taken from top of First Dune looking towards the Third Dune. *Banksia integrifolia* on upper left.

B.—Third Phase (Trees) of Dune Vegetation. Photo taken from top of Third Dune seen in A.

C.—Prostrate masses of Acacia Sophorae at junction of Phases I. and II.

D.—Shrub phase. Photo taken from rear of Second Dune looking towards the Third Dune.

PLATE IX.

A.—*Spinifex hirsutus* protecting an isolated Dune against denudation.

B.—Runners of *Spinifex hirsutus* on top of First Dune advancing seawards.

C.—Top of First Dune. Vegetation mainly *Spinifex hirsutus,* but at (*a*) are seen plants of *Senecio spathulatus* and at (*b*) specimens of the Cushion Plant, *Calocephalus Brownii.*

D.—Inflorescences of *Spinifex hirsutus.*

[Proc. Roy. Soc. Victoria, 47 (N.S.), Pt. I., 1934.]

Art. IX.—*Some Fundamental Concepts in Victorian Physiography.*

By EDWIN SHERBON HILLS, M.Sc., Ph.D.

[Read 12th July, 1934; issued separately, 22nd December, 1934.]

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Introduction.

It may readily be gathered from the somewhat scant literature, that there is no general agreement among Victorian physiographers as to the nature of the chief factors that have combined to influence the topographic evolution of the State, more particularly the south-central portions, since the beginning of the Kainozoic Era. The extent to which the views of the workers concerned diverge may be gathered from the following table, which presents in summarized form the main results achieved since 1903, when Gregory published his "Geography of Victoria."

TABLE I.

REFERENCE.	EROSION SURFACES.	AGE.
Gregory, 1903 ..	One peneplain, with the divide lying well to the north, in the Strathbogies and Mt. Buller	?
Skeats, 1910 ..	1. Ancient peneplain, represented in the summits of Mt. Macedon and the Dandenongs 2. Second peneplain, represented in the level of the country around Mt. Macedon	1. Pre-M. Kainozoic 2. ?
Jutson, 1911 ..	Nillumbik peneplain, including the Yarra Plateau and the Croydon Senkungsfeld	Post-Older Basalt, pre-Kalimnan
Keble, 1918 ..	Various erosion cycles are described, but apart from the old river valleys, erosion surfaces are not recognized	
Fenner, 1918 ..	" Great Peneplain." Level of the summit of the Blackwood and Brisbane Ranges ; an extremely well-developed peneplain	Pre-Older Basalt, and called M. Tertiary
Summers, 1923 ..	Planation complete at the beginning of tho Tertiary period. This again refers to the " Great Peneplain "	Early Tertiary
Fenner, 1925 ..	" Great Peneplain," destroyed in the Middle Tertiary	M. Tertiary
Baragwanath, 1925	1. Older peneplain, now at 4,500 feet–5,000 feet 2. Second peneplain, which is the pre-Older Basaltic erosion surface. Now at 3,000 feet–3,500 feet	1. Older than No. 2 2. Pre-Older Basaltic

Lack of a well-attested theory of historical physiography is particularly felt in teaching, and the present contribution aims at supplying, in so far as is at present possible, a basis for discussion and further advance. I have been over most of the country dealt with, in order to test the suggestions here put forward, and have been greatly helped by discussions with members of the staff of the Geology School at the University, Mr. F. A. Singleton, whose advice was especially welcome in connexion with Tertiary stratigraphy, and Mr. H. B. Hauser, in particular. The accurate relief model of the country around Port Phillip and Western Port Bays, constructed from the Military Survey Maps by Mr. H. B. Hauser and Mr. J. S. Mann, has proved of inestimable value.

PART I.

RECOGNITION OF EROSION SURFACES.

1. The Cretaceous Terrain.

It may be seen around the Dandenong Ranges that the land surface at the time of extrusion of the Older Basalts was of diversified relief, the resistant Devonian lavas rising above the general level of the surrounding country. With a topography such as this, the possibility exists that at the summits of the monadnocks of resistant rocks, we might find relics of the former land surface, which upon elevation and dissection gave rise to the later surface upon which the Older Basalts were poured out. Although such relics do not occur either at Mount Macedon or in the Dandenong Ranges, where the outcrops of resistant lavas are so small that the escarpments on the eastern and western sides of the lava outcrops have intersected to produce a ridge (see Fig. 1), the conditions are different further to the east. Here, the much larger outlier of Devonian lavas stretching from Warburton to Healesville, Marysville, the Cumberland Valley, and north to the Rubicon River, is so extensive that the summit still preserves, though no doubt in a somewhat modified form, a remnant of the old uplifted land surface. This mountain mass is to-day a dissected plateau, the summit of which ranges from about 5,000 feet at Mount Torbreck, down to 3,500 feet at Mount Strickland, near Marysville (see Hills, 1932, pp. 147-48). Therefore, the Devonian lavas must, at some period long antedating the extrusion of the Older Basalts, have been so reduced by erosion as to have formed part of a well-developed erosional plain, more complete than any which has since been developed in south-central Victoria.

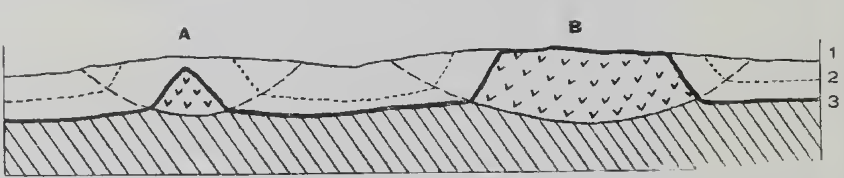

Fig. 1.—Diagrammatic section to show the evolution of a residual ridge (A) and of a plateau remnant (B). The old land surface is represented by the thin line 1, and there are two outliers of resistant lavas, a smaller at A and a larger at B. Upon uplift of the land, erosion of the soft bedrock begins, and escarpments develop at the junctions of the lavas and bedrock. An intermediate stage with two plateau remnants is shown by the broken line 2, and the existing topography, where A represents ridges such as the Macedon and Dandenong Ranges, and B dissected plateaus such as that around Donna Buang and northwards, is shown by the thick line 3.

Our estimate of the probable age of this erosional plain (whether it is to be termed "peneplain" or "panplain" will be, as yet, a matter of opinion), depends on the age assigned to the

Older Basalts. By the time these lavas were extruded, the old erosional plain had been uplifted and dissected to a late mature, or perhaps even old stage (see section on the pre-Older Basaltic Terrain), so it is clear that the uplift must have antedated the basalts by a very considerable period. Unfortunately, the evidence of age of basalts that do not come into relationships with marine Tertiary deposits is usually inconclusive, but it is now generally believed that the earliest flows were at least as old as Oligocene. If the basalts of the older deep leads are of this age, or even slightly younger, it is clear that the old erosional plain whose age is in question must have been uplifted either well down in the Eocene, or perhaps earlier still. The epi-Cretaceous movements which produced folding in Queensland may, in Victoria, have resulted in broad upwarping of the Upper Cretaceous land surface, and I would suggest that the ancient land surface preserved around Donna Buang, Marysville, and in the Cerbereans, is this uplifted Upper Cretaceous surface. Other probable remnants of this land surface, such as the Baw Baw Plateau, which was recognized by Baragwanath (1925) as representing a "peneplain" uplifted and dissected before Older Basaltic times, will be indicated below.

As we pass eastwards from the Melbourne district, the Older Basalt residuals become, in the Eastern Highlands, progressively more elevated. At the same time, the interfluves of the pre-Older Basaltic streams become continuously more eroded and reduced, so that we pass from a region where the Older Basalt may still occupy lower ground than the old interfluves (more especially than the old divides) to a region where the residuals now occupy the highest land, and where extensive relics of the monadnocks and interfluves of Older Basaltic times no longer exist. This explains why relics of the Cretaceous Terrain (see Glossary for terms used with a special significance) are more easily recognizable nearer Melbourne than in the Alps. The pre-Older Basaltic land surface has been differentially elevated, being tilted up to the east about an axis in the Melbourne district chiefly as a result of post-Kalimnan movements (q.v.).

2. The Pre-Older Basaltic Terrain.

It has for long been realized that, in the sub-Older Basaltic deep leads, we have preserved traces of an ancient river system, which has been discussed in detail by Keble (1918) and Baragwanath (1925). The land surface over which these rivers flowed is the "Great Peneplain" described by Fenner (1918, 1925), and by Summers (1923), the 3,000 feet–3,500 feet peneplain of Baragwanath (1925), and is probably the low level peneplain referred to by Skeats (1910) at Mount Macedon.

The evidence of the sub-Older Basaltic leads shows that over an extensive inland region, in the valley tracts of the rivers, the surface was maturely dissected, and towards the south, in the plain tracts of the streams, there was much flat land. In the south, the basalts which further inland were confined within the stream courses, often spread out as sheets. Above these extensive regions at a mature or old stage of dissection, residuals of resistant Devonian lavas and "granite" rose.

3. The Pre-Older Basaltic Divide.

A. Discussion of Gregory's Hypothesis.

Gregory (1903) has suggested that the main divide at this period was in the Strathbogies, and that from there streams ran south, over the present divide. Similarly, it is suggested (Keble, 1918) that a stream ran south from Mount Buller to join the well authenticated parent of the twin streams Thomson-Aberfeldy. The following considerations bear on this question:—

(i) *The Gorge of the Goulburn at Trawool.*—On Gregory's hypothesis the Goulburn has developed by headward erosion from an initial source west of the King Parrot Creek. At Trawool, the Goulburn has been superimposed upon a granite massif, through which, clearly over a protracted period of time, it has cut a gorge. It is difficult to find any reason why a stream so retarded should have been able to effect any significant extension of its headwater regions by headward erosion, a process which depends so completely upon the ability of a stream to rapidly degrade its course. Furthermore, it is difficult to see why, if the Goulburn in this district were not very early established as a master stream, it should not have been itself captured by a stream working round the south end of the Trawool granite.

(ii) *The Reversal of Former South-flowing Streams.*—Gregory's hypothesis also necessitates the postulate that the streams flowing south from the Strathbogies and Mount Buller, i.e., the streams now represented by the Upper Goulburn, Acheron, Yea, and King Parrot Creek, have been reversed, apparently by continually having their headwaters encroached upon by vigorously headwardly eroding streams of the developing Goulburn system. It must be pointed out that the Goulburn, as well as being handicapped by traversing the Trawool granite, would on Gregory's hypothesis be able to capture only a meagre amount of water from the supposed south-flowing streams, for it would have been necessary for it to have effected its development at the headwaters of those streams, near a presumably well-marked and mountainous divide. That it should have succeeded in reducing a mountain mass to a great valley, indeed to a river system, during post-Older Basaltic times is inconceivable, especially in view of the comparatively insignificant extent of post-Older Basaltic erosion on the Yarra Plateau, where in addition, the streams have been aided by post-Kalimnan uplift.

(iii) *The Yarra Plateau.*

(*a*) *Kangaroo Ground Residual.*—The Kangaroo Ground and adjacent residuals on the Yarra Plateau are some 900 feet lower than the divide at Kinglake. If the Kangaroo Ground pre-Older Basaltic stream had to pass over the divide on its way from the Strathbogies, this difference in elevation between two parts of its course so far from the headwaters is, assuming a normal thalweg, impossible. The conditions are better satisfied by assuming a pre-Older Basaltic divide not far from the present divide and only slightly higher.

(*b*) *Watson's Creek Residual.*—Watson's Creek and the creek to the south of it are twin streams, and the basalt residuals on the ridge between them are still at a lower level than the adjacent interfluves, which clearly represent the reduced pre-Older Basaltic interfluves. The Christmas Hills ridge, determined by a hard quartzite band (Jutson, 1911), is also higher than the residuals, and as shown by Keble and recognized by Jutson, must have been a divide between pre-Older Basaltic streams flowing west and east of this area. Followed to the north, the Christmas Hills merge into the Kinglake Plateau at the divide. It follows that the present divide itself, like the Christmas Hills, formed part of the pre-Older Basaltic Terrain.

(iv) *Conclusions.*—The above will have shown that it is impossible to place the pre-Older Basaltic divide as far north as the Strathbogies and Mt. Buller; that already in the pre-Older Basaltic times the Goulburn system was well developed, whether in its present form or not is immaterial; that therefore the pre-Older Basaltic divide approximated to the present divide.

(B) ALTERNATIVE HYPOTHESIS.

We may now consider the proposition that the pre-Older Basaltic divide was situated not far from the present divide, as an alternative hypothesis.

It has already been pointed out by Jutson (1911) and Keble (1918) that the Watts River, within the outcrop of the Devonian lavas, occupies an ancient course. This is the course initiated or rejuvenated on the break-up of the Cretaceous Terrain. The headwaters of the Acheron, by analogy, may be regarded as holding a similar inherited course. Donna Buang being the highest peak on the Warburton-Healesville Plateau, we may take it as marking the continuation of the old divide in this region. The Yarra at Warburton has clearly come to occupy a transverse course because of the ease of erosion in an east-west direction as compared with that in a north-south direction, and during the course of erosion from the beginning of Tertiary time to the present, has become a master stream because of this fact. At the present time the thalwegs of the Yea River and King Parrot Creek are at a much lower gradient than the streams flowing to the Yarra from the Kinglake Escarpment (see Fig. 2). This is due to the fact that the Goulburn, between its confluence with the King Parrot Creek and the Yea River, averages some 500 feet above sea level, while the Yarra is only 100 feet above the sea at its confluence with Diamond Creek. These gradients are the reverse of what would be expected on Gregory's hypothesis of stream development.

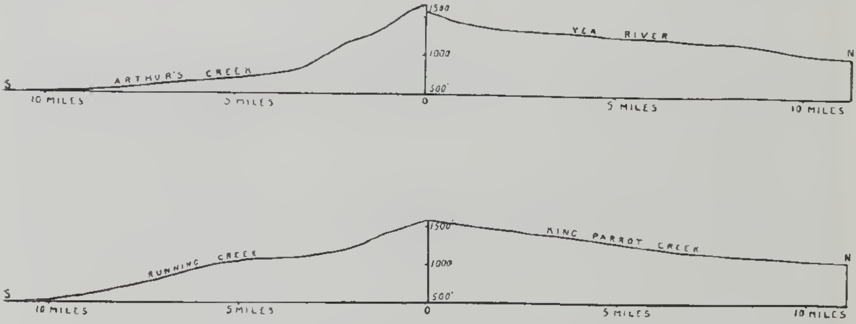

Fig. 2.—Stream profiles north and south of the divide. Data from Military Survey maps. Note the low gradient of the north-flowing streams. These erode relatively to the level of their confluence with the Goulburn, which is still some 500 feet above sea level. The irregular gradients of the south-flowing streams are probably due to the presence of hard bands in the Silurian rocks which they traverse, the effects of these hard bands being accentuated because of the steep gradient.

The Kinglake Plateau is a reduced pre-Older Basaltic land surface. Being at a divide, where rivers are stable in their courses for very long periods, this surface has been preserved, and merely reduced in level by gradual removal of soluble material from the soil, which is deep and rich, in contrast with the soils on the Silurian rocks of the Yarra Plateau, a younger land surface until recently undergoing active denudation. The actual divide is slowing migrating northwards, due to the steep gradient of the southern streams, the higher land at Mount Sugarloaf marking the probable position of the pre-Older Basaltic divide. The Older Basalt near Flowerdale on the King Parrot Creek is at a lower elevation than the divide at the head of the creek, and this clearly shows that the divide is an ancient feature. It is probable therefore that the Hume Plateau, which rises high above the present divide and above the basalt residuals, is a relic of the Cretaceous Terrain, and was a plateau remnant in pre-Older Basaltic times, as it is to-day.

(C) THE WERRIBEE GORGE AREA.

Fenner, in his papers (1918, 1925) on the Werribee River and Bacchus Marsh Basin, insists on the existence of only one peneplain, the Great Peneplain, which is the pre-Older Basaltic Terrain. This peneplain, now dissected, is the level surface exhibited by the upthrown blocks of the Blackwood Ranges and the Brisbane Ranges, and is the second peneplain of Skeats, above which Mount Macedon rises. I believe this view to be in great measure correct, but as will be pointed out later, if this is so our ideas of the nature of the Greendale and Spring Creek faults must be considerably revised.

4. The Nillumbik Peneplain.

This is defined by Jutson as including the Yarra Plateau of Gregory, together with the Croydon "Senkungsfeld." The peneplain was produced after the extrusion of the Older Basalts and before the deposition of the Barwonian and Kalimnan fluviatile and shallow marine sands and gravels of the Melbourne district, which rest upon it.

In the Port Phillip region, immediately after or during the main Older Basaltic outbursts, depression of the land, leading to the marine incursions of the Barwonian, was initiated. This depression persisted until Kalimnan times, and during these periods it is clear that river erosion in the neighbouring districts must have been retarded. We may picture the streams distributing sand and gravel as flood-plain deposits in the lower parts of their courses, and, by lateral planation, producing local level erosion surfaces. It is clear, however, from the fact that Older Basalt residuals were left on the erosion surface, that no widespread erosional plain was produced. The Nillumbik Peneplain is best regarded as a modified pre-Older Basaltic Terrain, which, within the area prescribed, was of low relief. I propose, for reasons given below (see Peneplain, in the Glossary), to refer to it as the Nillumbik Terrain. It may be seen to-day as a stripped fossil plain, along the Mitcham-Tunstall axis, where the overlying Tertiary sands have been removed by erosion.

5. Post-Kalimnan Earth Movements.

We have no evidence that any major period of uplift, such, for instance, as might have raised the Eastern Highlands to their present elevation, took place between the extrusion of the Older Basalts and the end of Kalimnan times in Victoria. It is the post-Kalimnan movements which have determined the major topographic features of the State.

Evidence for a general Pliocene uplift antedating by some time the Newer Basalts is afforded by the uplifted marine Kalimnan sands of the Melbourne district. The fluviatile deposits which cap the hills in many parts of the Central Highlands were also uplifted before the Newer Basalts were erupted, and their physiographic relations are analogous to those of the Kalimnan sands around Melbourne, which themselves grade inland into fluviatile deposits. It is considered that the thick gravel deposits around Bairnsdale are Pliocene also, and these gravels, or a similar series, cap the hills as far inland as Buchan. It will be seen that there is good reason to place a general period of uplift somewhere between the Kalimnan (Lower Pliocene) and the earliest Newer Basalts. Before the basalts were erupted mature valleys were excavated in the uplifted land.

To turn to South Gippsland, the youngest deposits affected by the late Tertiary faulting are again the " Older Pliocene " fluviatile series. Here there is no doubt that the hills owe their elevation to post-Kalimnan movements, repercussions of which are still to be felt. In attempting to define a period of maximum late Tertiary uplift, it must be borne in mind that we are concerned with movements that can be shown to have been of wide geographical extent and of restricted time range. Locally, uplift or depression with minor oscillations has gone on throughout practically the whole of Tertiary time, as in the ancient Murray Gulf and at Sorrento. In addition, we once more come up against the difficulty that it is hard to fix the age of a series of subaerial lavas, the Newer Basalts. In the Western District, vulcanicity clearly continued into Pleistocene or Recent times, but the lava fields around Melbourne have been more deeply dissected, and appear to be slightly older. They were already extruded when swamp deposits containing *Diprotodon* were laid down, and a soil cover derived from the weathering of the basalts themselves is universal. If all the Newer Basalts are to be regarded as Pleistocene, those of the Melbourne district must belong to the earliest part of that period.

The period of maximum Pliocene uplift, then, as shown by all the evidence to date, was post-Lower Pliocene and pre-Pleistocene. Movements along the Rowsley and neighbouring faults of post-Newer Basaltic age seem to have been concerned chiefly with the depression of Port Phillip, and not with the uplift of the Highlands. There is no evidence anywhere in Victoria for a maximum uplift in the Pleistocene (Kosciusko Uplift), the elevation of the Highlands having taken place throughout Middle and Upper Pliocene times, culminating in the Upper Pliocene. In the Eastern Highlands it may prove to be the case that upwarp began earlier still near the divide, with concomitant downwarp in the Gippsland region.

PART II.

FAULT MOVEMENTS IN RELATION TO PHYSIOGRAPHIC EVOLUTION.

1. The Croydon Senkungsfeld.

In his paper on the Yarra, Jutson (1911) postulated a depressed area, bounded by faults—many of which are admittedly hypothetical—and named this area the Croydon Senkungsfeld. Keble (1918), however, presented an entirely different explanation of the topographic evolution of the district, unfortunately without any attempt to discuss Jutson's earlier work. The supposed fault scarps of the Brushy Creek and Yarra Faults are, it would appear, regarded by Keble as erosion escarpments, marking the position of an ancient watershed, the Wurunjerri Range, of which the Christmas Hills form part.

(i) BRUSHY CREEK AND YARRA FAULTS.

It is a remarkable coincidence that, as was clearly pointed out by Jutson himself (1911, *a*), the line of the supposed Brushy Creek and Yarra Faults should be faithfully followed, on the high level side, by a band of the most highly siliceous Silurian quartzite found by Jutson on the Yarra Plateau. As the strike of this hard band varies, so do the supposed faults change their course, striking east of north in the south, then west of north, and later east of north again. Jutson explains this by postulating a line of weakness along the hard beds, but there is no *a priori* reason to suppose that such actually existed. Jutson finds himself in difficulty when he traces these hard beds further north where they determine the Christmas Hills Spur. The same conditions hold—there is the hard band, the high land on the west, and the lower land on the east. But it is impossible to place a fault at the foot of the Christmas Hills, which are clearly (as was recognized by Gregory, Jutson, and Keble) a spur developed by differential erosion, jutting out from the Kinglake Plateau. Jutson therefore arbitrarily places a northern limit to the Yarra Fault movement, and marks a purely hypothetical fault running east-west across the spurs on the north side of the Yarra. As there is every reason to believe that the Christmas Hills owe their relative elevation to differential erosion, then stronger evidence than has yet been adduced is necessary to prove that the eastern boundary of the Yarra Plateau is not an erosion escarpment also, determined by the hard quartzite described by Jutson.

(ii) DANDENONGS FAULT.

On the eastern side of the Acheron valley, between Marysville and Taggerty, there are Upper Devonian lavas resting unconformably upon Silurian sediments, and the dissection of these, as in the case of the rhyolites at Mount Wellington, has produced a well-defined escarpment parallel to the strike of the lavas. There is no reason to doubt that the escarpment at the edge of the Devonian lavas extending from Healesville round to Warburton is due to the same cause, for the boundary of the lavas and the Silurian, as mapped by Junner (1915) and Edwards (1932), is a natural one. The fault mapped by Jutson is non-existent. At the Dandenongs, remapping of the boundary of the Devonian lavas by Edwards, as shown in a MS. map kindly placed at my disposal, shows that the boundary faults marked by Morris Morris (1912) do not exist, the junction with the Silurian rocks being again a natural one. An escarpment at the edge of the hardest of the lavas is therefore to be expected as at Marysville and Healesville.

(iii) STEELE'S AND BRIATY'S HILLS.

These peaks on a north-south trending ridge of Silurian rocks (the Waranmate Hills) are marked by Jutson as being on the upthrown side of one of the boundary faults of the "Senkungsfeld." They are composed of silicified sandstones much more resistant than the average Silurian sediments of the district, and differential erosion is again sufficient, in my opinion, to explain their present elevation above the surrounding country.

I therefore maintain that there are no adequate grounds for regarding the basin of the middle Yarra and the Croydon Lowlands as a Senkungsfeld.

2. Alternative Hypothesis.

An alternative hypothesis must give an adequate explanation of (i) the course of the Yarra across the Yarra Plateau; (ii) the Yarra Flats; (iii) the general high level of the plateau as compared with the Croydon Lowlands; and (iv) the Yering Gorge.

(i) *The Course of the Yarra across the Yarra Plateau.*—Keble explains the present transverse course of the Yarra as being due to the capture of a stream formerly flowing south through Lilydale by the streams flowing west from the old divide of the Wurunjerri Range. Such a contingency is most improbable, firstly because of the extreme slowness of the migration of divides, and secondly because the conditions of the bedrock are such that, on Keble's hypothesis, the streams working in soft rocks are captured by those working in hard rocks (see section on the Yarra Plateau), and, moreover, are captured across a well-defined resistant ridge, the Wurunjerri Range.

I would suggest as a possible alternative that the diversion of the Yarra across the Wurunjerri Range was brought about by the blocking of the valley of the former north-south river flowing through Lilydale in pre-Older Basaltic times by ejectamenta from the Older Basalt vent recognized at Lilydale (Morris Morris, 1912). In pre-Older Basaltic times the edge of the Dandenongs escarpment would have been a little further west, the denudation of the toscanites would not have progressed to the extent seen to-day, and thus at Lilydale the valley of the pre-Older Basaltic stream must have been somewhat constricted. If blocked by lavas and tuffs, a lake would have been formed which would have found an outlet across a low part of the Wurunjerri Range, probably at the head of one of the tributaries of the stream flowing in the position of the Kangaroo Ground residual.

(ii) *The Yarra Flats.*—The level of the outlet so formed would act as a local base level of erosion, since composed of hard rock, and upstream from it the Yarra would meander and deposit extensive flats—the Yarra Flats. The level of these flats should be continually in a process of reduction if this hypothesis is true. We should find alluvium extending from the flats up among the higher hills around Lilydale, particularly in the valleys, into which long-continued rain action would wash most of the material. This is actually the case.

If the Flats are due to the exceedingly slow uplift of the Yarra Plateau, then they should never have been more extensive than they now are, and, further, since movement along the hypothetical Yarra Fault has presumably ceased, the Yarra should now be cutting away the Flats. This is not the case; the factor causing their development is still operative, and is to be sought in the presence of the hard rocks of the old Wurunjerri Range.

(iii) *The Yarra Plateau.*—The general high level of this region is due mainly to the resistant nature of the rocks of which it is composed. Quartzites, sandstones, and conglomerates occur there, and, in addition, the rocks have been indurated by the penetration of siliceous solutions, quartz veins being common in the mining districts. It was from various places on the Plateau and its southern extension in the Melbourne district that building stones were obtained in the early days of Melbourne's growth. East of the Plateau, especially to the south of the Yarra, the usual type of rock is a soft shale, often highly fossiliferous, any harder rocks being found as high land.

(iv) *The Yering Gorge.*—On the hypothesis here presented, this is to be explained as a part of the edge of the Yarra Plateau, isolated by having superimposed on it, from the older high level alluvium, a meander of the Yarra.

3. The Ballan Sunkland.

The data given by Fenner (1918) allow a reconstruction of the condition of the Ballan Sunkland immediately after the operation of the Greendale and Spring Creek Faults (see Figure 3). It is clear from this section that, if we are to regard the level of the Blackwood and Brisbane Ranges as representing the uplifted surface of the pre-Older Basaltic Terrain (Great Peneplain), then our interpretation of the geological history must be somewhat more complex than has usually been considered necessary.

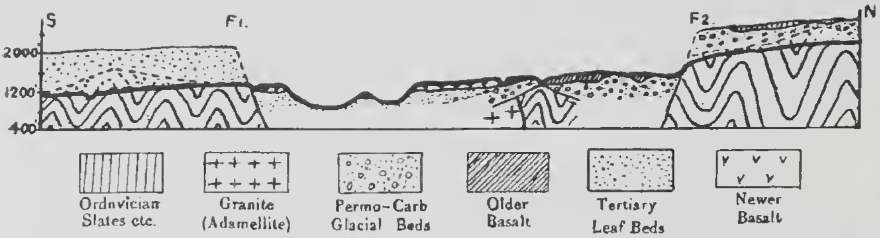

Fig. 3.—Section across the Ballan Sunkland. This section shows the sunkland as it was immediately after the operation of the Spring Creek Fault (F1) and the Greendale Fault (F2), according to data given by Fenner (1918). The existing topography is represented by the heavy line at about 1,200 feet in the south and over 2,000 feet in the north. The lower part of the section is from Fenner's Figure 13.

It will be clear that either the present level of the Blackwood Ranges (north of F2) is not that of the Great Peneplain (the pre-Older Basaltic surface), or that most of the movement along this fault had already occurred before the completion of the peneplain. If the Brisbane Ranges are regarded as part of the peneplain, then either they are a stripped and slightly dissected fossil plain, from which the Tertiary sands have been removed, or else the sands occupy a basin initiated by movements along the Spring Creek line.

The possibilities are as follows:—

(*a*) If the Spring Creek Fault is correctly drawn, then the Brisbane Ranges are a "stripped fossil plain," from which the overlying Tertiary sands have been washed, not so much by normal stream erosion, but as "mud may be washed from a board" (an expression recently used, as a quotation, by Fenner in another connexion). The great ease of erosion of these beds makes this quite a feasible idea.

(*b*) The Spring Creek fault may be regarded as a line of post-Older Basaltic sag, initiating a basin which was filled by the lignitiferous sands of the Parwan Basin and Lal Lal district. The sands on this hypothesis never covered the Brisbane Ranges.

(*c*) The preservation of so much Permocarboniferous tillite on the downthrown side of the Greendale Fault is a very strong indication that most of the movement along this line went on during the formation of the Great Peneplain, or earlier still, for the upthrown side has suffered about 1,000 feet of reduction since the major movement went on. If the Blackwood Ranges represent the Great Peneplain surface, the erosion must have been pre-Older Basaltic. Later movement of small amount has probably gone on.

4. The Mansfield District.

In his paper on this area, Fenner (1914) discusses the evolution of the rivers, and concludes that the drainage has been directly affected by what he clearly regards as Tertiary block faulting, although the age of the faults is not unequivocally stated, and no stratigraphical evidence for their existence was obtained. As a result of a visit to the Mansfield and neighbouring districts in 1928, I was able to supply the missing stratigraphical evidence of block faulting, which is of fundamental importance for an understanding of the geology of the region, but could find no evidence that the movements are of Tertiary age. The scarps are all fault line scarps, and the presence of quartz veins along certain of the fault lines, as on the western side of Mount Timbertop, is a good indication that the faults are much older than Tertiary, more probably Upper Palaeozoic. One of the faults postulated by Fenner is, he thinks, connected with the uplift of the Cerbereans, but, as has already been shown,

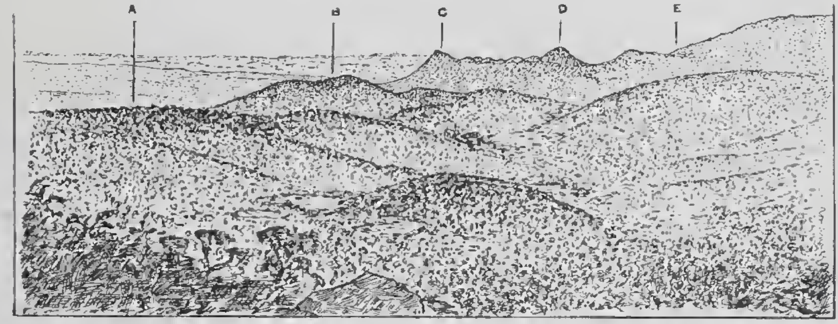

Fig 4.—View from Keppel's Lookout, Marysville, looking north. This view over the timbered valleys of the Taggerty and Steavenson Rivers illustrates the importance of subsequent stream dissection. The Lookout is situated on the top of the escarpment bounding the Devonian lavas, and the continuation of the escarpment to the north is seen at (E). The lavas at (E) probably once covered the hard Silurian sandstones of the Cathedral Range (C-D), which pass beneath the Devonian at the saddle between the Sugarloaf (D) and the escarpment (E). The curve of the talus slope from the Cathedral (C), a massive sandstone dipping to the east, is well shown. At Buxton, an intrusion of garnetiferous grandodiorite porphyrite forms the hill (B) to the east of the village. Between Buxton and Marysville the rocks are Silurian sediments, and the topography is determined by differences in hardness among these beds. The ridge (A) leading up to Mount Gordon is composed of hard sandstones.

these mountains are a relic of the Cretaceous Terrain, and their steep edge is the escarpment at the edge of the Upper Devonian lavas of which they are in part composed (Hills, 1932). In the absence of more definite evidence to the contrary, therefore, I would suggest that the development of the complex middle course of the Goulburn has been controlled, not by Tertiary faulting, but by subsequent (differential) dissection of a region of complex geology.

5. Conclusion.

The above remarks are not intended to minimize the importance of Tertiary faulting as a physiographic control in Victoria. In Gippsland, particularly, the evidence for extensive late Tertiary faulting is conclusive and illuminating, but in the Eastern Highlands such is not the case, and no undoubted Tertiary fault has yet been identified. My own reference (1932) to the "tilted blocks of a broken peneplain," occurring west of the Black Hills, Taggerty, is incorrect. The supposed tilted blocks are a series of strike ridges. Indeed, a preconceived idea of the dominance of block faulting in this region for long prevented the author from realizing what is actually the chief topographic control over extensive areas, and that is, geological structure, etched out by the long continued attack of erosive agents.

6. Glossary and Summary.

A. Systematic Terms.

1. *Terrain.*—The land surface at any specified time within the region under consideration. It is sometimes preferable to use this term instead of "erosion surface," since it includes erosion surfaces of all ages represented in the topography.

2. *Inherited.*—A term used to describe physiographic entities such as stream courses or summit levels, the former condition of which has left a very marked impress upon the existing feature.

3. *Peneplain.*—The errors that may be introduced by a loose application of this term to all moderately flat (often, too, only locally flat) erosion surfaces are very great. Wherever preliminary investigations only are made without detailed study, it is preferable to use a term such as "Terrain," without the genetic significance attached to the word "peneplain."

4. *Plateau Remnant.*—A small plateau or table mountain, representing a relic of a former land surface of low relief, uplifted and dissected in a new cycle of erosion.

B. REGIONAL TERMS.

1. *Cretaceous Terrain.*—The land surface, of uniformly low relief, before the major late-Cretaceous uplift. Remnants now to be seen are (*a*) the Cerbereans—Donna Buang Plateau; (*b*) the Hume Plateau; (*c*) the Trawool Plateau; (*d*) Baw Baw Plateau.

2. *Pre-Older Basaltic Terrain.*—This is the "Great Peneplain" of Fenner. It is the land surface produced by erosion between the late-Cretaceous uplift and the earliest Older Basalts. The plateau remnants of the Cretaceous Terrain described above were monadnocks on the pre-Older Basaltic surface, but large areas, especially in the Palaeozoic sediments, were of low relief. Remnants now to be seen are (*a*) the Kinglake Plateau—representing the modified pre-Older Basaltic divide; (*b*) the Christmas Hills; (*c*) the Brisbane Ranges (in part); (*d*) the Blackwood Ranges (in part); (*e*) the sub-Older Basaltic leads.

3. *Nillumbik "Peneplain."*—This is the land surface produced during post-Older Basaltic and pre-Kalimnan times in the Yarra Plateau and Croydon Lowlands. It is a modified pre-Older Basaltic surface, and may now be seen as a stripped fossil plain, along the Mitcham Axis.

4. *Hume Plateau.*—The Hume "Ranges" are really a plateau, whose summit ranges from 2,200 feet to 2,500 feet.

5. *Trawool Plateau.*—The granitic country south of Trawool is a plateau, more deeply dissected than the Hume Plateau because nearer the Goulburn, but with a summit at much the same elevation.

6. *Kinglake Escarpment.*—See Kinglake Plateau.

7. *Kinglake Plateau.*—The present divide from Kinglake West to above Kinglake is a narrow plateau trending roughly east-west, at an elevation of 1,600-1,800 feet. This is bounded on the south by a steep erosion escarpment, for which I propose the term Kinglake Escarpment. The plateau bears deep and rich soils, which extend down in places on to the tops of the main spurs that run off from it to north and south, and which are, like the Plateau, ancient topographic features.

8. *Yarra Plateau.*—This comprises the country from the Christmas Hills to the Plenty River, and from Kinglake Escarpment to the divide on the Mitcham Axis. It is composed mainly of relatively hard and resistant Silurian sediments. (Gregory, 1903; Jutson, 1911).

9. *Croydon Lowlands.*—Since I believe that the term "Senkungsfeld," as applied to the Croydon district, implies an erroneous conception of the history of the area, I propose the name Croydon Lowlands for the country between the Yarra Plateau and the Dandenongs, south of Lilydale.

10. *Brushy Creek and Christmas Hills Escarpments.*—The scarps of the supposed Brushy Creek and Yarra Faults are, I believe, erosion escarpments. The scarp of the so-called Yarra Fault, continued to the north, is seen to form part of the Christmas Hills Escarpment.

11. *Wurunjerri Range.*—A pre-Older Basaltic divide, represented to-day by the Christmas Hills, and the eastern edge of the Yarra Plateau (Keble, 1918).

12. *Mitcham Axis.*—A line, possibly a post-Kalimnan warp axis, from Burt's Hill through " Pinemont " and Blackburn to Camberwell (Jutson, 1911).

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ART. X.—*A Revision of the Nomenclature of the Permian Foraminifera of New South Wales.*

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Introduction.

So long a period has elapsed since the publication of the "Monograph of the Foraminifera of the Permocarboniferous Limestone of New South Wales" by two of the present authors (Chapman and Howchin, 1905), and such great advances in our knowledge of Upper Palaeozoic foraminifera have been made in recent years, that, as a preliminary to further work on the Permian of Australia, it has been necessary to revise the determinations given in 1905. In this revision, which we now submit, we have not attempted to add to the list of forms recorded previously, although further material from Pokolbin has been examined with the object of settling several doubtful points. Correlative notes on published occurrences elsewhere in Australia are given, and the species referred to their accepted genera.

Although in the former publication the two foraminiferal horizons dealt with were referred to as in the Permocarboniferous system, in the latest note on the subject by Professor Sir T. W. Edgworth David and Mr. Süssmilch, they are now regarded as of Permian age; the beds at Pokolbin being placed in the Lower Permian, and those at Wollong in the Middle Permian. The Pokolbin foraminiferal horizon is very closely comparable with that of Fossil Cliff, Irwin River, in Western Australia, which is also included in the Lower Permian by the authors named.

In recent publications on the Upper Palaeozoic foraminifera, many new genera have been described, and a better understanding of the structure and relationships of a number of forms has also been gained. Much work, however, yet remains to be done, particularly in regard to the character of the shell-wall of several genera, before their positions can be satisfactorily settled. As three of them, viz., *Monogenerina, Geinitzina,* and *Spandelina* (including its sub-genus *Spandelinoides*) appear to have been recorded under these or other generic names, from the Permian rocks of New South Wales, it is deemed advisable to make some comments on these genera before proceeding with the revision and the systematic notes on the species.

Notes on the Genera Monogenerina, Spandelina (including Spandelinoides) and Geinitzina.

Genus **Monogenerina** Spandel, 1901.

This genus was described by Spandel (1901, p. 181) from the Permocarboniferous of Hooser, Kansas, U.S.A., with two species, *M. atava,* the genotype, and *M. nodosariaeformis,* both based on sections of specimens in silicified limestone. While Spandel was uncertain as to whether the shell-wall was sandy or calcareous, he placed the genus between *Bigenerina* and *Textularia,* and stated that the chambers and the aperture had the form characteristic of those in *Bigenerina.* He mentions he was unable to see any pores in the shell of *M. atava.*

Cushman (1933, p. 110), in the second edition of his "Foraminifera," describes the wall as finely arenaceous, with much cement and a thin outer covering, and groups the genus with the Textulariidae. Galloway (1933, p. 168), on the contrary, states that the walls are finely fibrous or finely granular, or with fibrous inner layer and granular outer layer, not arenaceous. He includes *Spandelinoides* Cushman and Waters, in the synonomy of *Monogenerina,* which he places in the family Nodosinellidae.

Without an opportunity of examining the type species of *Monogenerina* and *Spandelinoides,* we can only base our opinion as to their relationships on published descriptions and figures, and on our knowledge of Palaeozoic faunas. It appears to us that *Monogenerina* is one of the group of *Cribrostomum* Möller, *Climacammina* Brady, *Deckerella* Cushman and Waters, and *Cribrogenerina* Schubert. The large aperture and the general form strongly suggest to us, as they did to Spandel and Cushman, a relationship with the Textulariidae. They are quite different from those of *Spandelinoides,* which we discuss later under *Spandelina.* Since we regard *Monogenerina* as having an agglutinated test, the species described by two of us as *M. pyramidis,* from Pokolbin, New South Wales, is now transferred to *Nodosaria,* as the wall is hyaline and perforate.

Genera **Geinitzina** and **Spandelina** (including sub-genus **Spandelinoides**).

In view of the generally accepted family relationship of *Geinitzina, Spandelina,* and *Spandelinoides,* it seems to be advantageous to discuss them together. We will first give the history of each, its genotype, salient characters, geological and geographical distribution, and then consider the position of the three.

Genus **Geinitzina** Spandel, 1901.

This genus was originally described by Spandel (1898, p. 7), as *Geinitzella* from the Zechstein of Germany. This name was found to be preoccupied, and the genus was renamed by Spandel (1901, p. 189), in his paper on the foraminifera of the Permocarboniferous of Hooser, Kansas, United States of America. Spandel referred two species to *Geinitzella, Textularia cuneiformis* T. R. Jones and *G. acuta*, sp. nov., both of which he figured.

Subsequently, *Textularia cuneiformis* Jones was designated the genotype of *Geinitzina* by Cushman. As Galloway, following Jones and H. B. Brady, considers *T. cuneiformis* to be biserial, he restricts *Geinitzina* to this and similar biserial species, and places other described species of *Geinitzina* in *Spandelina*. In doing so, he makes (*loc. cit.*) the following observations:—" It is very unfortunate that Cushman designated *Textularia cuneiformis* Jones as the genotype of *Geinitzina*, thereby changing the definition of that genus from a uniserial form, as intended by Spandel, to a biserial form."

This does not necessarily follow, as the genus must rest on Spandel's type material.. As Spandel described and figured both species of *Geinitzella* as uniserial, therefore *Geinitzina*, if used at all, must be restricted to uniserial forms, unless, as is exceedingly unlikely, the species he had were actually biserial.

After studying Jones's figure and description of *Textularia cuneiformis* (Jones, 1850, p. 18, pl. vi., fig. 6), which is at best an unsatisfactory species, we consider that the form figured by Spandel under this name was wrongly identified. In our opinion, Spandel's two figures represent the one species, *G. acuta;* either the differences between the two specimens are due to dimorphism, or, what appears more probable in the light of our experience of the Australian species, *G. triangularis* Chapman and Howchin, the two specimens are both megalospheric examples of the same species, with proloculа of different sizes.

The general characters of *Geinitzina* may be described as follows:—Test free, triangular in outline, much compressed, especially along the median line; chambers uniserial, in a rectilinear series, usually arched in the early stages, becoming more or less transverse in the mature shell; aperture generally elliptical, but in *G. ciscoensis* Cushman and Waters, it may be linear, and more or less zig-zag in shape.

The nature of the shell-wall in *Geinitzina* is of major importance in determining the position of the genus. Spandel by placing *Geinitzina* in the " Nodosaridae," interpreted it to be hyaline. Cushman (1933, p. 111), in his latest classification, states that it is finely arenaceous, with much cement and a thin outer layer when well preserved, and includes the genus in the

Textulariidae. Galloway (1933, pp. 164, 169, under *Spandelina*), describes the wall as calcareous, finely granular or fibrous, with the fibres at right angles to the surface of the test, possibly finely perforated. *Spandelina* is placed by him in the Nodosinellidae.

According to published records, *Geinitzina* occurs only in the Carboniferous and the Permian, and is often abundant in the latter. It has a wide geographical distribution, being known from Germany, United States of America, Australia, Japan, and Timor.

Genus **Spandelina** Cushman and Waters, 1928.

Spandelina and its sub-genus *Spandelinoides* were both originally described from the Upper Pennsylvanian-Lower Permian of Sutton County, Texas, United States of America (Cushman and Waters, 1928, pp. 363 *et seq.*). The genoholotype of *Spandelina* is *S. excavata* Cushman and Waters, and the subgenoholotype of *Spandelinoides*, *S.* (*S.*) *nodosariformis*, of the same authors.

Cushman (1933, p. 110), describes the genus as follows:—"Test uniserial, the chambers in a generally rectilinear series, the earlier ones at least compressed, especially in the microspheric form; wall calcareous, finely arenaceous, with a thin coating; aperture simple, terminal, elliptical or rounded. Without the thin outer covering, the wall of *Spandelina* appears perforate, especially when calcitized, as is common." He places it in the Textulariidae. In the original description of *Spandelina* and *Spandelinoides,* the wall was stated to be calcareous and perforate.

It will be noted that the above description embraces rounded as well as flattened forms, the former being placed in the subgenus *Spandelinoides,* which is apparently an isomorph of *Nodosaria.*

Galloway (1933, p. 169) considers the wall of *Spandelina* to be calcareous, finely granular or fibrous, and finely perforate. As we have said under *Monogenerina*, he gives a similar description the shell-wall of *Spandelinoides,* except that no mention of its being perforate is then made. All three are included by him in the Nodosinellidae.

We may observe that Cushman and Waters described costate, as well as smooth, species of *Spandelina* and *Spandelinoides.* Costation is of very unusual occurrence in the other genera placed by Cushman in the *Textulariidae,* and in those included by Galloway in the Nodosinellidae. It is generally characteristic of the hyaline forms of foraminifera.

According to Cushman (1933, p. 110), *Spandelina* occurs in the Permian, and doubtfully in the Pennsylvanian, the only published records appear to be from North America.

Discussion on the Relationships of Geinitzina and Spandelina.

Comparison of the generic characters of *Geinitzina* and *Spandelina* (*sensu stricto*) will show that *Spandelina* has a proportionately more elongated test than *Geinitzina*, and the majority of the chambers are slightly arched. As in *Geinitzina*, each face may have a strong median groove, or may be flat, or even slightly concave. Galloway, as we have already remarked, considers the differences between the two are so slight as to justify the use of one genus only.

In general, the forms placed in *Geinitzina, Spandelina*, and *Spandelinoides* remind one strongly of the Nodosariidae; *Geinitzina* and *Spandelina* of *Frondicularia*, and *Spandelinoides* of *Nodosaria*. No trace of coiling has, however, been recorded in the genera under discussion. No figures of the early stages of the microspheric form of any of the species have been given. Cushman (1933, p. 11), however, states that the microspheric form of *Geinitzina* shows a trace of the biserial ancestry. Of *Spandelina*, he says (*op. cit.*, p. 110), that the microspheric form is compressed in the early chambers, but no mention of biseriality is made.

We have no personal knowledge of the type species of *Geinitzina and Spandelina* (including *Spandelinoides*), and are, therefore, placed at a disadvantage in considering the position of these genera. *Geinitzina* has, however, been recorded from the Permian of New South Wales by two of us (F. C. and W. H.), and there can be little doubt that the species included in the same work under the names of *Frondicularia woodwardi* Howchin, and *Nodosaria labiata* (Spandel) are of similar types of shell structure to the forms placed by Cushman and Waters in *Spandelina*.

Frondicularia woodwardi was described by Howchin (1895, p. 197, pl. x., figs. 4-6) from the "Permo-Carboniferous" of the Irwin River, in Western Australia, together with another new species, *Nodosaria irwinensis*, which closely resembles the costate forms placed in *Spandelinoides*. By the kindness of Professor E. de C. Clarke, of the University of Western Australia, we have a quantity of material from the same locality. This contains many exceptionally well preserved foraminifera, including, in addition to the species already mentioned, *Geinitzina triangularis*. As all three occur in considerable numbers, we have studied them carefully to see if they throw any light on the relationships of *Geinitzina* and *Spandelina*. Examples of each have been examined as opaque objects and in section, and the shell-wall has been studied under the petrological microscope.

In thin sections of the best preserved specimens, the wall is typically hyaline, but generally there has been an alteration in its character which, in such cases, is finely granular. This structure has been interpreted by some authors as evidence that the wall is *not* hyaline, but we find exactly the same structure in some Upper Cretaceous examples of species of *Flabellina* and *Frondicularia,* from the Chalk of Gingin, Western Australia. Under crossed nicols, the delicate pinks and greens of calcite plates are visible.

The wall is closely and finely perforate, the tubules in *Geinitzina triangularis* measuring 0.0015 mm. in diameter.

Externally, the shell-wall in all three species is indistinguishable from that of fossil Nodosariidae; in *Frondicularia woodwardi* and *Geinitzina triangularis* the surface is polished.

The aperture in *Nodosaria irwinensis* is circular and terminal and situated at the base of a slight depression. It is not radiate, and is similar to that found in *Spandelinoides.* In *Frondicularia woodwardi* and *Geinitzina triangularis,* we have what does not appear to have been recorded in any other Palaeozoic foraminifer, a stellate aperture. This is weakly developed in some specimens; but, as a rule, is quite typical when the margin is regularly toothed and slightly exsert. In *G. triangularis* the aperture is elongate, and in *F. woodwardi* it is rounded. The apertural chamberlet described by Cushman (1928, pp. 22, *et seq.*) is absent from both species.

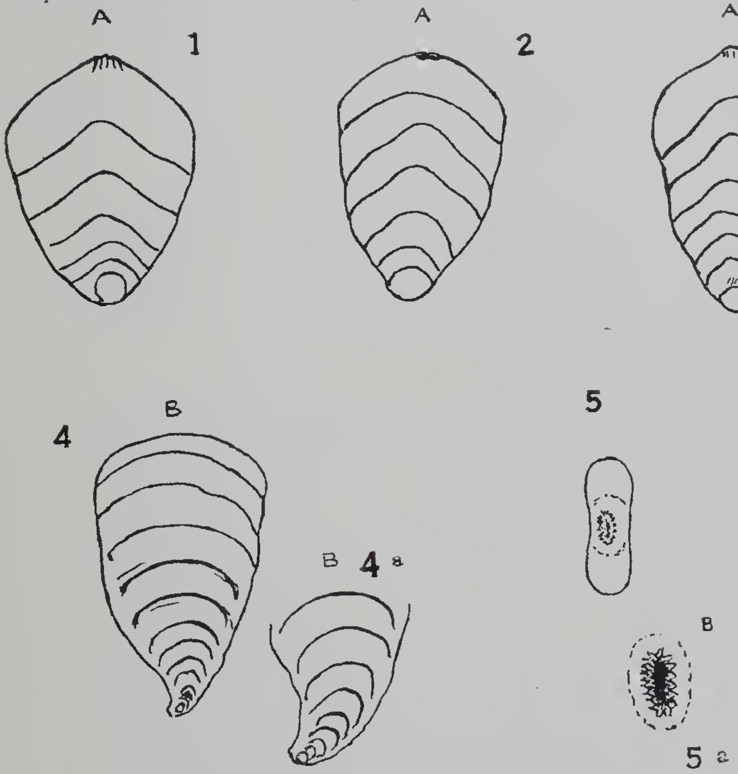
Amongst the specimens of *Geinitzina triangularis,* we were so fortunate as to find several examples of the microspheric form. These begin with a minute proloculum, measuring in the specimen figured 0.01 mm. in diameter, which is succeeded by a gently curved series of three or four chambers, gradually increasing in size. These in turn are followed by chambers similar to those seen in the megalospheric form. In no case are the chambers biserially arranged. We figure examples showing the arrangement of the chambers in Forms A and B.

In view of the above evidence, it appears to us that all three species were correctly placed in the genera under which they were dscribed. *Frondicularia woodwardi* is typical of the genus. Except for the radiate aperture, *Geinitzina triangularis,* in its megalospheric form, is similar in generic characters to the species placed by Spandel in *Geinitzina.* The stellate aperture is, in our opinion, merely a development from the simple oval orifice of *G. acuta* (Spandel), an intermediate stage in its evolution being represented by the zig-zag slit seen in *G. ciscoensis* Cushman and Waters. Similarly, we believe that *Nodosaria irwinensis* is, despite the absence of a radiate aperture, a true nodosarian.

It will be observed that, except for the rare microspheric examples of *Geinitzina triangularis,* our three species are rectilinear forms. Cushman and Waters had a similar association of such forms in their material from Sutton County. There can, therefore, be little doubt, as we have already suggested, that our species belong to the same genera as theirs. What, then, is the position of *Geinitzina* and *Spandelina*? Are they true Nodosariidae, and if not, what are their relationships?

The hyaline test, radiate aperture, and evidence of coiling in the microspheric form, of *Geinitzina triangularis,* point to an affinity with the Nodosariidae, in which family Spandel placed the genus.

Spandelina was grouped by Cushman and Waters with the Textulariidae because of the compression of the early stages in the microspheric form, and of the absence of evidence of any of the species having a coiled young stage. To understand the position of *Spandelina,* it is necessary to remember that, in the two latest classifications of the foraminifera, those by Cushman (1933), and Galloway (1933), the primitive Nodosariidae are stated to be coiled forms. Galloway (1933, p. 232) says, " *Lenticulina* is the most primitive member of the family, from which, directly or indirectly, all the other genera of the family were derived." Cushman (1933, p. 175) is not so definite, but, after referring to *Robulus, Darbyella,* and *Planularia,* he goes on to remark, " From



Geinitzina triangularis Chapm. and Howch.

1-3. Outlines of Form A, showing simple test and megasphere. × 33.

4. Outline of Form B (microspheric), showing ancestral openly coiled commencement. × 33.

4*a*. Early stage of same, more highly magnified. × 66.

5. Aperture of *G. triangularis.* × 33.

5*a*. Ditto, more highly magnified. × 44.

these coiled forms there are several different genera developed." Of these later genera, we need mention only *Flabellina, Frondicularia, Dentalina, Nodosaria,* and *Lingulina.*

When the early geological history of the Nodosariidae is studied, we find in the Trias and Jurassic, an abundance of straight, curved, and partially uncoiled forms, many of which are ornamented with costae, while the closely coiled ones are fewer and of simple types of structure. This is particularly apparent in Terquem's memoirs on the foraminifera of the Lias (Terquem, 1858-1866). In the Permian, most of the species are rectilinear, with a few dentaline ones, but closely coiled forms have not been recorded from rocks of this epoch. The straight forms have been described under the generic names of *Frondicularia, Nodosaria, Spandelina, Spandelinoides, Geinitzina, Lingulina,* and *Orthocerina.* The predominance of such forms and the absence of closely coiled ones from known Permian faunas have undoubtedly contributed to the present understanding that these genera are not true Nodosariidae.

Brady (1876) and Spandel (1898) have figured dentaline forms from the Permian of Europe, and one of the present authors (W. J. P.) has recently met with both smooth and costate *Dentalinae,* of primitive types, in the Permian of Western Australia. We may also refer to the record of a curved nodosarian under the name of *Nodosaria* (*Dentalina*) *farcimen,* from the Carboniferous Limestone of England (Howchin, 1888, p. 11, pl. ix., fig. 21*a, b*). Except in the last-mentioned case, the dentaline forms occur together with the straight forms. As we now find the microspheric stage of *Geinitzina triangularis* to begin with a gently curved series of chambers, it seems that the straight forms were derived from curved forms. It is also suggested that all are species of the Nodosariidae, and that this family evolved, not from a closely coiled ancestor, but from a curved or openly coiled one. The closely coiled genera such as *Lenticulina* and *Robulus* are probably not primitive types, as has been thought, but a specialized development from an openly coiled one.

Since writing the above, we have received from Dr. J. Hofker a copy of his work on the foraminifera collected by Dr. Th. Mortensen during the Danish Expedition to the Kei Islands in 1922 (Hofker, 1933). On page 117 of this, we were much interested to read, in his notes on *Cristellaria costata* (Fichtel and Moll), the following: "The first chambers of the microspheric shells show the peculiarity of being arranged in a very slowly coiling spiral, not only in this species, but also in other ones of the genus *Cristellaria.* This characteristic points to the possibility that this genus might descend from a form closely related to *Nodosaria* or something like that (*Marginulina* ?). This would be in agreement with the fact that such genera are geologically older than *Cristellaria.*"

It appears to us, therefore, that *Spandelina* is one of the genera of the Nodosariidae, and that the flattened forms placed in it by authors are true *Frondiculariae.* Similarly we consider that the sub-genus *Spandelinoides* is inseparable from *Nodosaria.* We retain *Geinitzina* for the short forms of Frondicularian type with a slit-like aperture, for purposes of taxonomy, but it is clear from our Western Australian material that, in regard to any points of distinction between the original conception of *Geinitzina* and *Frondicularia,* the characters of transverse septation and median surface depression are not constant even in the one species, for different parts of the same test will show *Geinitzina, Geinitzina-Frondicularia* and *Frondicularia* phases. This variability is, as is well known, a special feature of the Nodosariidae, and has been responsible for much of the difficulty experienced by authors in satisfactorily separating the genera of the family.

Revised Names of Foraminifera recorded in "A Monograph of the Permocarboniferous Limestones of New South Wales." (Chapman & Howchin, 1905.)

FORMER NAME.	REVISED NAME.
Nubecularia stephensi Howchin, p. 5, pl. i., figs. 1, 2; pl. iii., figs. 13, 14; pl. iv., figs. 1, 4.	*Calcitornella stephensi* (Howchin).
Pelosina hemisphaerica Chapman & Howchin, p. 6, pl. ii., figs. 2*a, b.*	*Pelosina hemisphaerica* Chapman & Howchin.
Hyperammina vagans Brady, p. 6. pl. ii., fig. 1.	*Tolypammina vagans* (Brady).
Haplophragmium agglutinans (d'Orb.) p. 7, pl. i., fig. 5.	*Ammobaculites* sp.
Haplophragmium emaciatum Brady, p. 7, pl. i., figs. 10*a, b.*	*Haplophragmoides neocomianus* (Chapman).
Haplophragmium pokolbiense Chapman & Howchin, p. 7, pl. i., fig. 6.	*Ammodiscus millettianus* Chapman.
Haplophragmium cf. *tenuimargo* Brady, p. 8, pl. i., fig. 11.	*Ammobaculites* ? *pseudospiralis* (Williamson) ?
Placopsilina tenuitesia Chapman & Howchin, p. 8, pl. iii., fig. 9.	*Placopsilina tenuitesta* Chapman & Howchin.
Lituola cristellarioides Chapman & Howchin, p. 9, pl. i., figs. 3, 4.	Not a foraminifer.
Lituola cf. *rhaetica* (Chapman), p. 9, pl. i., fig. 7; pl. iii., fig. 7.	*Ruditaxis* sp. cf. *rhaetica* (Chapman).
Thurammina papillata Brady, p. 9, pl. ii., fig. 13.	*Thurammina papillata* Brady.
Ammodiscus incertus (d'Orb.), p. 10, pl. ii., fig. 3.	Specimens not available for revision.
Ammodiscus millettianus Chapman, p. 10, pl. ii., fig. 3.	*Ammodiscus millettianus* Chapman.
Ammodiscus anceps (Brady), p. 11, pl. iii., fig. 1.	*Trochamminoides anceps* (Brady).
Ammodiscus ? sp., p. 11, pl. i., figs. 12*a-e.*	*Ammodiscus ovalis* Chapman.
Stacheia simulans Chapman & Howchin, p. 11, pl. ii., fig. 4.	Not a foraminifer.
Endothyra bowmani Phillips, p. 12, pl. i., figs. 13*a-e.*	*Endothyra* cf. *bowmani* Phillips.

Endothyra macella Brady, p. 12.	*Endothyra macella* Brady.
Monogenerina pyramidis Chapman & Howchin, p. 13, pl. iii., fig. 5.	*Nodosaria pyramidis* (Chapman & Howchin).
Valvulina bulloides Brady, p. 13, pl. i., figs. 9*a-c*.	*Globivalvulina bulloides* (Brady).
Bulimina affinis d'Orb, p. 14, pl. ii., fig. 7.	*Lingulina davidi*, sp. nov.
Pleurostomella ? antiqua Chapman & Howchin, p. 14, pl. ii., fig. 5.	*Nodosaria ? antiqua* (Chapman & Howchin).
Lagena acuta (Reuss), p. 14, pl. iii., fig. 10.	Not a foraminifer (Zooecium of polyzoan).
Nodosaria permiana (Spandel), p. 15, pl. ii., fig. 6.	*Nodosaria permiana* (Spandel).
Nodosaria (*Dentalina*) cf. *farcimen* (Reuss), p. 15, pl. ii., fig. 11.	Foraminifer, gen. et sp. indet.
Nodosaria (*Dentalina*) ? *bradyi* (Spandel), p. 15, pl. ii., fig. 12.	*Dentalina bradyi* Spandel.
Nodosaria (*Dentalina*) *labiata* (Spandel), p. 16, pl. iii., fig. 4.	*Nodosaria irwinensis* Howchin.
Frondicularia woodwardi Howchin, p. 16, pl. iii., fig. 2.	*Frondicularia woodwardi* Howchin.
Geinitzina triangularis Chapman & Howchin, p. 16, pl. ii., figs. 9 *a*, *b*, 10.	*Geinitzina triangularis* Chapman & Howchin.
Geinitzina postcarbonica Spandel, p. 17, pl. iv., fig. 3.	*G. triangularis* Chapman & Howchin.
Lunucammina cf. *permiana* Spandel, p. 17, pl. iii., figs, 6, 12.	Fig. 6, *Dentalina* sp. Fig. 12, Gen. et. sp. indet.
Marginulina cf. *breoni* (Terquem), p. 17, pl. iii., fig. 11.	*Dentalina* ? sp. indet.
Vaginulina cf. *legumen* (Linné), p. 18, pl. iii., fig. 8.	*Frondicularia* ? sp. indet.
Anomalina supracarbonica Chapman & Howchin, p. 18, pl. i., figs. 8*a-c*.	Specimen lost before revision undertaken.
Truncatulina haidingeri (d'Orb.), p. 18, pl. iii., figs. 3*a-c*.	*Ammodiscus planoconvexa*, sp. nov.

Systematic Notes on the Species.

Family NODOSARIIDAE.

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

DENTALINA BRADYI Spandel.

Dentalina bradyi Spandel, 1901, p. 16, text-fig. 9.

Nodosaria (*Dentalina*) *bradyi* (Spandel)?; Chapman & Howchin, 1905, p. 15, pl. ii., fig. 12.

No further examples of this species have been met with.

Genus **Nodosaria** Lamarck, 1812.

NODOSARIA IRWINENSIS Howchin.

Nodosaria irwinensis Howchin, 1895, p. 196, pl. x., figs. 7, 8.

Nodosaria (*Dentalina*) *labiata* Chapman & Howchin,, (non *Dentalina labiata* Spandel), 1905, p. 16, pl. iii., fig. 4.

The only example available for the present revision is that figured from Pokolbin. This is now found to be very finely costate, and is identical with the species described by one of us

(W.H.) under the name of *Nodosaria irwinensis,* from the Permian of the Irwin River, in Western Australia. The same form is very common in beds of similar age in the Wooramel River district, also in that State. While generally perfectly straight, in a large series of specimens dentaline examples are usually met with. The aperture of *N. irwinensis* is circular, and situated at the base of a slight depression. Spandel's *Nodosaria striato-clavata,* from the Zechstein of Germany, is related to the present form.

NODOSARIA PYRAMIDIS (Chapman and Howchin).

Monogenerina pyramidis Chapman & Howchin, 1905, p. 13, pl. iii., fig. 5.

For reasons which are given earlier in our notes on *Monogenerina,* we now transfer this species to the genus *Nodosaria.* It is known only from thin sections, no free examples having been met with.

NODOSARIA (?) ANTIQUA (Chapman and Howchin)

Pleurostomella ? antiqua Chapman & Howchin, 1905, p. 14, pl. ii., fig. 5.

The present species was originally referred, with some slight reservation, to the genus *Pleurostomella,* to which it is now clear it certainly does not belong. The generic position of this form, which is represented by a unique example is, however, still doubtful. The first three or four chambers of the type specimen are laterally compressed; the next is circular in section, while the remaining chambers are flattened in a plane at right angles to that of the early portion of the test. The shell appears to have been crushed, and the apertural end has been broken away. The affinities of the species appear to lie with *Nodosaria,* to which genus, in the absence of better material, we doubtfully refer it.

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

LINGULINA DAVIDI, sp. nov.

Bulimina affinis Chapman & Howchin (non d'Orbigny), 1905, p. 14, pl. ii., fig. 7.

Description.—Test rectilinear, sub-pyriform, slightly compressed, initial end acute, apertural end bluntly pointed; beginning with a small globular proloculum, followed by four or five chambers which increase rapidly in size as added, sutures distinct, slightly depressed in the later part of the shell; wall calcareous, perforate, aperture radiate.

Length of holotype (in collection of Department of Mines, Sydney) 0.62 mm.; longest diameter, 0.34 mm.; shortest diameter, 0.26 mm., from Permian of Wollong, New South Wales.

Remarks.—This species is apparently the same as that previously recorded under the name of *Bulimina affinis* d'Orbigny. The specimen then figured has unfortunately been lost during the revision, and before it was thoroughly examined. The present specimen is a finer example which we have since picked out of the same sample, and we have no doubt it is the same species. The genus *Lingulina* has previously been recorded by Spandel from the Permian (Zechstein) of Germany.

We desire to associate the name of the late Professor Sir T. W. Edgeworth David, F.R.S., with this new form.*

Genus **Ammodiscus** Reuss, 1861.

Ammodiscus ovalis Chapman.

Ammodiscus ? sp. Chapman & Howchin, 1905, p. 11, pl. i., figs. 12 *a-c*.

Ammodiscus ovalis Chapman, 1913, p. 170, pl. xvi., figs. 5 *a, b*.

This species was originally doubtfully referred to the genus *Ammodiscus,* but we have obtained some additional examples which confirm its identification by one of us (F.C.) with *A. ovalis,* described later by him from the Kalimnan (Lower Pliocene) of the Mallee Bores.

Ammodiscus planoconvexa, sp. nov.

Truncatulina haidingeri Chapman & Howchin, (non *Rotalina haidingeri* d'Orb.), 1905, p. 18, pl. iii., figs. 3 *a-c*.

Description.—Test planoconvex, periphery sub-acute; proloculum large, tubular chamber increasing rather quickly in diameter, forming two to two and a half coils, obliquely flattened in section and on the convex side of the test overlapping the earlier coils; suture on flat side depressed; wall comparatively thick, composed of small sand grains, firmly cemented, surface not smoothly finished; aperture oblique, formed by the end of the tubular chamber.

Diameter, 0.77 mm.; thickness, 0.25 mm.

Holotype (Collection of Department of Mines, Sydney), from Pokolbin, New South Wales.

Remarks.—This is a very interesting well-defined species which connects *Ammodiscus* with *Trochammina,* having the form of the latter, but with the undivided tube of *Ammodiscus.* The figured specimen is the only one that has been found.

Genus **Tolypammina** Rhumbler 1895.

Tolypammina vagans (Brady).

Hyperammina vagans Brady, 1879, p. 33, pl. v., fig. 3. Chapman & Howchin, 1905, p. 6, pl. ii., fig. 1.

This species has not so far been met with elsewhere as a fossil in Australia. It has a long geological history, beginning at least as far back as the Carboniferous. The specimen figured from

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* It is with deep regret that we record the decease of Sir Edgeworth, while this paper, in which he took a keen interest, was passing through the press.

Wollong resembles *T. confusa,* described by Galloway and Harlton (1928, p. 344, pl. xlv., fig. 5), as *Ammovertella ? confusa* from the Middle Pennsylvanian of Oklahoma, United States of America.

Genus **Calcitornella** Cushman and Waters, 1928.

CALCITORNELLA STEPHENSI (Howchin)

Cornuspira, sp. nov. Jones, 1882, p. 6.
Nubecularia lucifuga Defrance var. *stephensi* Howchin, 1894, p. 345, pl. x*a*, xi*a*.
N. stephensi Howchin: Chapman & Howchin, 1905, p. 5, pl. i., figs. 1, 2; pl. iii., figs, 13, 14; pl. iv., figs. 1, 4. Etheridge, jnr., 1907, p. 13, pl. xii., fig. 11.

This species belongs to the genus *Calcitornella,* described in 1928 by Cushman and Waters from the Pennsylvanian and Permian of the United States of America. The only occurrences of the genus outside America with which we are acquainted are those given above, and it is of much interest to note that this generic type was met with by Professor Rupert Jones as long ago as 1882, when he recorded it from the Piper River beds in Tasmania as "a contorted porcellanous foraminifer (new species of *Cornuspira*)." *C. stephensi* is now known to occur in the Permian of New South Wales, Tasmania, Western Australia, and Northern Territory.

Genus **Trochamminoides** Cushman, 1910.

TROCHAMMINOIDES ANCEPS (Brady).

Trochammina anceps Brady, 1876, p. 76, pl. iii., figs. 8 *a, b.*
Ammodiscus anceps (Brady): Chapman & Howchin, 1905, p. 11, pl. iii., fig. 1.

Brady's description of this species indicates that it is referable to the genus *Trochamminoides,* the tubular chamber being merely constricted, and not truly septate. The example figured from Pokolbin is the only one available; it is very typical.

Genus **Haplophragmoides** Cushman, 1910.

HAPLOPHRAGMOIDES NEOCOMIANUS (Chapman).

Haplophragmium neocomianum Chapman, 1894, p. 695, pl. xxxiv., figs. 2 *a, b.*
Haplophragmium emaciatum Chapman & Howchin, (non H. B. Brady), 1905, p. 7, pl. i., figs. 10 *a, b.*

The specimens formerly recorded under the name of *Haplophragmium emaciatum* Brady, from Wollong, are thin and almost complanate, and are now referred to the present species, which they closely resemble. This was described from the Bargate Beds of Surrey, England.

Genus **Ammobaculites** Cushman, 1910.

AMMOBACULITES sp.

Haplophragmium agglutinans Chapman & Howchin (non *Spirolina agglutinans* d'Orbigny), 1905, p. 7, pl. i., fig. 5.

This species is represented by a single example, which, while referable to the genus *Ammobaculites,* differs from *A. agglutinans* in having a broader, less regular test, of quite different form. In the absence of better defined material, we hesitate to attach a name to it.

AMMOBACULITES ? PSEUDOSPIRALIS (Williamson) ?.

Haplophragmium cf. *tenuimargo* Chapman & Howchin (non Brady), 1905, p. 8, pl. i., fig. 11.

Only one example of this form is available, and a section is necessary to determine its generic position, hence we doubtfully refer it to the above genus and species, which it resembles more than *A. tenuimargo.*

Genus **Ruditaxis** Schubert, 1920.

RUDITAXIS sp. cf. RHAETICA (Chapman).

Lituola cf. *rhaetica* Chapman: Chapman & Howchin, 1905, p. 9, pl. i., fig. 7; pl. iii., fig. 7.

The present specimens are referable to Schubert's genus *Ruditaxis.* The range of this is given by Cushman in his latest classification as from Carboniferous to Permian, but it apparently extends into the Triassic, as *Lituola rhaetica* Chapman, from the Rhaetic of England, belongs to this genus.

Genus **Globivalvulina** Schubert, 1920.

GLOBIVALVULINA BULLOIDES (Brady).

Valvulina bulloides Brady, 1876, p. 89, pl. iv., figs. 12-15. Chapman & Howchin, 1905, p. 13, pl. i., figs. 9 *a-c.*

The only example is from Wollong, but is typical. The known range of this genus is Carboniferous to Permian.

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[Proc. Roy. Soc. Victoria, 47 (N.S.), Pt. I., 1934.]

Art. XI.—*New Species of a Crinoid (Lecanocrinus) and a Cephalopod (Ophidioceras), from the Silurian of Yass.*

By F. CHAPMAN, A.L.S., F.G.S.

(Commonwealth Palaeontologist).

(With Plate X.)

[Read 12th July, 1934; issued separately, 22nd December, 1934.]

Introduction.

The crinoid here described as *Lecanocrinus breviarticulatus* was presented many years ago to the National Museum by Mr. A J. Shearsby of Yass, who from time to time added many interesting and unique specimens to the Collections.

It was held over in the hope of discovering further specimens, but up to the present it remains unique. It is the first occurrence of the genus in Australia.

The Cephalopod *Ophidioceras giblini* has also the distinction of being the first occurrence of that genus in Australia. Although partially preserved as a cast, some of the fine ornament of the shell is still visible, enabling a more precise diagnosis to be given than from a mere cast and mould. Professor Giblin has presented this and another unique Silurian specimen to the Commonwealth Collection.

Class CRINOIDEA.

ORDER FLEXIBILIA.

Fam. LECANOCRINIDAE.

Genus **Lecanocrinus** J. Hall.

Lecanocrinus breviarticulatus, sp. nov.

(Pl. X., Figs. 1-6.)

Description of Holotype.—Crown broadly ficiform in outline, but somewhat compressed, due to inclusion in shaly limestone, Height, 34 mm.; greatest width, 31.5 mm. Dorsal cup showing vestiges of two infrabasals, a basal (cf. postbasal), a radial (1st left R), an upper plate, and the centrodorsal or summit stem-joint, which is much thicker and wider than the adjacent columnals.

The infrabasals are moderately small and unequal; the post-basal(?) fairly large, apparently pentagonal, but not clearly defined on all margins; radials large, pentagonal, and more or less shield-shaped, faceted above and steeply sloping inwards, bearing broad low axillaries which are medially grooved on the ventral size, and visible where worn down. Radianal hexagonal, apparently resting on the right upper truncated side of the post-basal, and between the left and right radials. Special anal slightly larger than the radianal and subrectangular, resting on the postbasal, and supported between the right (?) basal and the right postradial.

Arms dichotomous, twice branched; pinnules simple. Brachials low and numerous, sutures crenulate, the lower having on the inferior surface toothed projections which fit into corresponding sockets in the adjacent ossicles. Primibrachs 2, wide and low; secundibrachs about 6, gradually decreasing in height, distally, and one-half the width of the primibrachs. Arms spirally inrolled at the distal ends, around the summit of the crown. Summit of tegmen visible, showing a pentagonal (?) madreporite with a distinctly perforated area, and connected with what is apparently a portion of the ventral tube.

Columns (preserved as hollow mould) roundly cylindrical, rather wide; average diameter about 5 mm.; strongly curved, especially near the junction with the cup; 35 mm. in length, so far as preserved, the distal extremity missing. Stem-joints, as shown by a wax impression, very low, alternating, discoidal and flanged, with a minutely tuberculate surface. The proximal joints are thinner, and consequently more numerous. This character, by the way, appears to be more typical in the taxocrinids.

Observations.—This specimen, although not so perfectly preserved as could be desired, shows a definite relationship with the genus *Lecanocrinus,* and may be compared in general features with *L. billingsi* Angelin, which occurs in the Silurian of Gotland (Angelin, 1878, p. 12, pl. xxii., figs, 25, 25*a*). It has a considerably larger crown than Angelin's species, more numerous lower arm-ossicles, and more distinctly granulated columnar joints.

Another genus which at first sight bears resemblance to the present specimen is *Ichthyocrinus pyriformis* (Phillips) from the Wenlock Series of Dudley and Kendal (*Cyathocrinites pyriformis* Phillips, 1839, p. 672, pl. xvii., fig. 6, and Angelin, 1878, p. 13, pl. xvii., fig. 6).

The presence of a radianal and special anal plate in our fossil shows, however, that it cannot be referred to that genus. The tegmenal portion of the crown seems to have been previously unobserved in *Lecanocrinus,* and the same may be said for *Ichthyocrinus* (Wachsmith and Springer, 1869, p. 256). Another feature in favour of placing our crinoid with *Lecanocrinus* is the regular size of the columnars throughout. From *Euspirocrinus,* which also has simple, dichotomous and inrolled arms, the present example differs in the heavily plated calyx, the narrower primibrachs, and the distinctly regular columnar joints.

Horizon and Locality.—Silurian. Hatton's Corner, Yass, New South Wales. Collected by Mr. A. S. Shearsby, F.R.M.S., and presented to the National Museum. Reg. No. 13897.

Class CEPHALOPODA.

Order NAUTILOIDEA.

Fam. OPHIDIOCERATIDAE.

Genus **Ophidioceras** Barrande.

OPHIDIOCERAS GIBLINI, sp. nov.

(Pl. X., Fig. 7.)

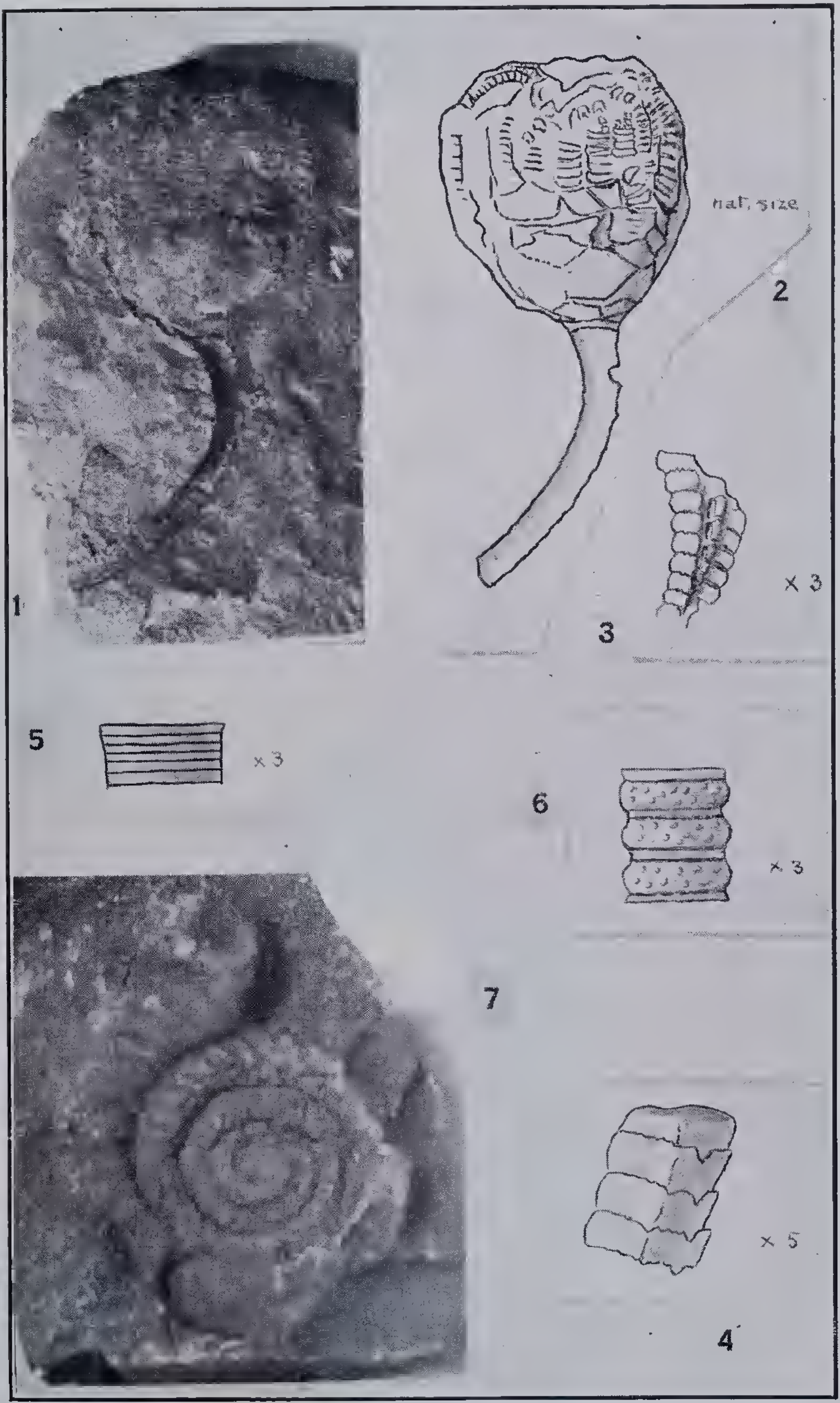
Description.—Shell discoidal, in all but the last stage closely coiled, centrally depressed; consisting of 5 whorls of which the last fifth of the outer whorl is free and reverted. Whorls slightly compressed at sides. Dorsum in region of body chamber compressed and widely concave, the surface transversely conspicuously grooved and crossed by threadlike longitudinal striae. Aperture broadly Y-shaped, the ventral lobe being longer than the others. The lateral lobes are prominent and thickly bordered. Whorls costae, the ribs sub-acute to sharp, closely arranged in the early stages, more widely spaced and prominent in the last two whorls, the outer whorl bearing 28 costae. The shell surface is transversely striated, the striae (10 in intercostal area) reverted obliquely across the costae on the ventral and dorsal.

Dimensions.—Greatest diameter of shell, from the ventral tip to opposite side of the 5th whorl, 56 mm. Diameter of shell across 4th whorl, 38 mm. Approximate thickness of shell on the 4th whorl, 7 mm.; ditto at aperture, 12 mm.

Observations.—This is the first recorded occurrence of the genus *Ophidioceras* in Australia. Although the fossil is preserved in a hard, reddish-brown mudstone, it is not merely a cast, for it shows the delicate ornament of the shell-wall as well as the original costation. The fossil therefore represents a partial replacement of the test.

At first sight *Ophidioceras giblini* might be confused with the shell figured by Etheridge, jun., from the same locality, named *Cyclolituites bowningensis* (Etheridge, jun., 1904, p. 75, pl. viii.), but that the latter, besides having other characters which makes it generically distinct, shows about 36 costae on the strongly depressed whorls. In *C. bowningensis,* moreover, the whorls are closely wound, and strongly impressed against one another, whilst the hyponomic lobe is V-shaped rather than U-shaped as in *Ophidioceras giblini.* The close coiling of the shell in *Cyclolituites* as distinct from the free and reverted termination of *Ophidioceras,* is a generic difference.

There are apparently no very close affinities between *O. giblini* and the species of *Ophidioceras* previously described from England or Bohemia, to which countries the genus has hitherto been restricted.



Lecanocrinus and Ophidioceras: Silurian, Yass, N.S.W.

[*Page 193.*]

Ophidioceras articulatum (Sow.) occurs in the Wenlock shales of Dudley and Ludlow (*Lituites articulatus* J. de C. Sowerby, 1839, p. 622, pl. xi., fig. 5, non fig. 7). It is a small form never more than 1½ inches in diameter, having, however, the same number of annulations to the whorl, from 26 to 28 as compared with 28 in *O. giblini*. *O. articulatum* differs from the present species in having comparatively straight costae on the lateral surface, whereas in *O. giblini* they are strongly recurved, especially in the earlier whorls. The distinct tesselation of the surface in *O. giblini*, which is especially well seen on the earlier whorls, is apparently absent in *O. articulatum*.

The species *Ophidioceras tessellatum* Barrande, occurring in the Silurian (Salopian) of Bohemia (Barrande, 1867, p. 186, pl. xcvii., figs. 13, 14, 16, 17, *pars.*, and 19) resembles the present form in its fine surface ornament, but it is smooth, and has fewer whorls, with only slightly curved costae.

Ophidioceras rudens Barrande has narrower whorls, and is more closely ribbed (Ibid., pl. xlv., figs. 13, 14, 16, 17, *pars*, and 21).

This unique fossil (holotype) is named in honour of Professor L. F. Giblin, D.Sc., M.C., M.A., who presented it to the Commonwealth Palaeontological Collection (Reg. No. 63). It was discovered by Master Ian Filshie.

Horizon and Locality.—Silurian (Bowning Series). Hatton's Corner, near Yass, New South Wales.

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Explanation of Plate X.

Fig. 1. *Lecanocrinus breviarticulatus*, sp. nov. Nearly complete crown with arms and mould of stem. Holotype. Silurian. Hatton's Corner, Yass, N.S. Wales. Nat. size.

Fig. 2. Ditto, with plan of preserved plates. Nat. size.

Fig. 3. Ditto. Portion of arm in ventral aspect with interlocked brachials. × 3.

Fig. 4. Ditto. Four brachials, more highly magnified. × 5.

Fig. 5. Ditto. Proximal columnars showing low platy character. ×3.

Fig. 6. Ditto. Columnars of distal part of stem, with tuberculate surface. × 5.

Fig. 7. *Ophidioceras giblini*, sp. nov. Holotype. Silurian. Hatton's Corner, Yass, N.S. Wales. Nat. size.

[Proc. Roy. Soc. Victoria, **47** (N.S.), Pt. I., 1934.]

Art. XII.—*The Palaeozoic Brittle-Stars of Victoria.*

By ROBERT B. WITHERS, B.Sc., Dip. Ed.,
and R. A. KEBLE, F.G.S.
(Palaeontologist, National Museum, Melbourne.)

(With Plate XI.)

[Read 12th July, 1934; issued separately, 22nd December, 1934.]

This paper completes the work of the authors on the Palaeozoic Stelleroidea, the results of their studies of the Asteroidea having been published in an earlier volume of these Proceedings (Withers and Keble, 1934).

The known Victorian Palaeozoic brittle stars before this work was undertaken numbered only four, namely:—

Species.		Reference.
Protaster brisingoides Gregory	..	Gregory, 1889
Gregoriura spryi Chapman ..	..	Chapman, 1907 (i)
Sturtzura leptosomoides Chapman	..	Ibid.
Palaeocoma sp.	..	Chapman, 1913

The faunal list now comprises thirteen species. Seven of these are entirely new, and two are species which have not hitherto been recognized in Victoria. The remaining four are those previously described or recorded by Gregory and Chapman; but the nomenclature of these forms has been subject to revision. The complete faunal list is now as follows:—

Form.	Horizon.	Locality.	Page.
cf. *Aganaster gregarius* (Meek and Worthen)	Carboniferous ..	Mansfield ..	207
Crepidosoma kinglakensis, sp. nov.	Silurian	Kinglake West	200
Eospondylus tenuis, sp. nov.	Silurian (Yarravian)	Moonee Ponds	206
Furcaster bakeri, sp. nov. ..	Silurian (Yarravian)	Studley Park	204
F.kilmorensis, sp. nov. ..	Silurian	Kilmore ..	205
F.leptosomoides (Chapman) ..	Silurian (Yarravian)	Moonee Ponds	206
Gregoriura spryi, Chapman ..	Silurian (Yarravian)	South Yarra	197
Hallaster parvus, sp. nov. ..	Silurian	Blue Hills, Taggerty	203
Lapworthura miltoni (Salter)	Silurian (including Yarravian)	Moonee Ponds, and Kinglake West	201
L.pulcherrima, sp. nov. ..	Silurian (Yarravian)	West Brunswick	201
Sturtzaster aff. *mitchelli*, Etheridge	Silurian (Yarravian)	Moonee Ponds, and Melbourne (excavations)	202
Sturtzura brisingoides (Gregory)	Silurian (Yarravian and Yeringian)	Moonee Ponds, and Parish of Yering	198
Taeniactis yeringae, sp. nov. ..	Silurian (Yeringian)	Parish of Yering	199

All the above species are classed in Schondorf's group the Auluroidea, true Ophiuroidea of Palaeozoic age being rare here as elsewhere. As with the Asteroidea, Victoria is practically the only Australian locality for Palaeozoic Brittle Stars. *Sturtzaster* (?) *mitchelli* Eth. fil. (Etheridge, 1899) from the Silurian beds of Bowning, New South Wales, is the only exception.

The best preservation of these forms is found in sandstone, though the cast has a negative character. Several are preserved in mudstone, and one in limestone. In some cases the ossicles are represented by films of limonite on the rock. This is the case with the type of *Gregoriura spryi* Chapman, and makes the interpretation of structure a difficult matter. The material was again obtained chiefly from the National Museum, Melbourne, and the Museum of the Geology School, Melbourne University.

We are indebted to Dr. E. S. Hills for the loan of specimens of *Hallaster parvus,* sp. nov., from the Silurian of Blue Hills, Taggerty; and to Miss Irene Crespin and Mr. F. Chapman for generously placing at our disposal the only Carboniferous species recorded, cf. *Aganaster gregarius* (Meek and Worthen), from Mansfield. This is the only species which is not of Silurian age.

A note should perhaps be added on the locality of certain of the specimens from the neighbourhood of Melbourne. The terms "Flemington" and "Moonee Ponds" were both used by the early Geological Survey for the one locality (B8). The term "Union St. Cliff" is also identical.

The classification adopted, as with the Asteroidea, is that of Schuchert (1915), with additional genera later erected by Spencer (1914 *et seq.*). To both these works we again record our very deep indebtedness.

Sub-Class AULUROIDEA Schondorf.

Order LYSOPHIURAE Gregory.

Family PROTASTERIDAE Miller.

Genus **Gregoriura** Chapman.

GREGORIURA SPRYI Chapman.

1889. *Protaster brisingoides* Gregory. *Geol. Mag.* (3), vi., pp. 22-24, text-fig. 3 (not text-figs. 1 and 2).

1907. *Gregoriura spryi* Chapman. *Proc. Roy. Soc. Vic.* (n.s.), xix., p. 5, pl. vi., fig. 1; pl. viii., figs. 1-3.

1915. *Gregoriura spryi* Chapman. Schuchert, *Bull.* 88, *U.S. Nat. Mus., p.* 233.

This species is the genoholotype and only species of the genus. For notes on the identity of certain specimens of *Protaster brisingoides* Gregory with the above form, see under *Sturtzura brisingoides.*

Associates.—*Caractacaster yarraensis,* sp. nov.; *Petraster angustior,* sp. nov. Brachiopods, pelecypods, trilobites, &c.

Horizon.—Silurian (Yarravian Series).

Locality.—South Yarra, Victoria. Type specimen No. 9105 in National Museum, Melbourne. Collected and presented by F. P. Spry.

Family PALAEOPHIURIDAE Gregory.

Genus **Sturtzura** Gregory.

STURTZURA BRISINGOIDES (Gregory).

1889. *Protaster brisingoides* Gregory. *Geol. Mag.* (3), vi., pp. 22-24, text-figs. 1, 2 (not text-fig. 3).

1897. *Sturtzura brisingoides* (Gregory). *Proc. Zool. Soc. London* for 1896, p. 1034.

1907. *Protaster brisingoides* Gregory. Chapman, *Proc. Roy. Soc. Vic.* (n.s.), xix., p. 22, pl. vi., fig. 2; pl. viii., fig. 2.

1914. *Sturtzura brisingoides* (Gregory). Schuchert, *Fossilium catalogus.* Animalia, pt. 3, pp. 35, 41, 42.

1915. *Sturtzura brisingoides* (Gregory). Schuchert, *Bull.* 88, *U.S. Nat. Mus.*, p. 236.

1927. *S. brisingoides* (Gregory). Spencer, Monograph of British Pal. Asterozoa, *Mem. Pal. Soc.* for 1925, p. 366. Text-figs. 232*b*, 233*b*.

A good deal of confusion has arisen over the nomenclature of this genus (*vide* Spencer, *loc. cit. supra,* p. 365). The original material from Moonee Ponds was described by Gregory in 1889 as a species of *Protaster.* In 1897, he made it the type of the new genus *Sturtzura.* The next investigator was Chapman, who, working in Australia on a large collection of similar material in 1907, showed that the genus *Sturtzura* had been founded on misinterpretation of the specimens. Chapman showed that the specimens were negatives of the original form, and that the true structure was that of *Protaster,* the genus in which Gregory first placed it. Spencer, investigating the type material in the British Museum in 1927, re-instituted the name *Sturtzura,* apparently regarding the ossicles as sufficiently distinct from *Protaster* to warrant this. His figures make it clear that he appreciates the negative character of the specimens. We have therefore followed him in reverting to *Sturtzura.* We think however that he has misinterpreted parts of Chapman's work. It is not correct to say that "Chapman decided that Gregory's specimens represented more than one species." (p. 365). Chapman merely renamed Gregory's specimens from the Silurian of Moonee Ponds as *P. brisingoides,* which is the first species he refers to in his 1907 paper. The second species (described as *Gregoriura spryi*) was not known to Gregory, the specimens being discovered at a later date and from a different locality, though from the same horizon Neither did he know the third species, *Sturtzura leptosomoides,* though from the same locality and horizon as *P. brisingoides.* Mr. Chapman, in a personal communication, states he would not be prepared to identify Gregory's figure 3 (which is of mouth part only), with *Gregoriura spryi,* for he has found considerable variation in the mouth part of *S. brisingoides.* As, however, Dr. Spencer refers to a difference in the vertebra of the type specimens on which figure 3 is based compared with those for figures 1 and 2, we must leave that point to him.

S. brisingoides has no real relationship with *Furcaster leptosoma* (Salter), which was named by Gregory *Sturtzura leptosoma;* nor with the corresponding Australian species, *Sturtzura leptosomoides* Chapman. The differences between *Furcaster leptosomoides* and *Sturtzura brisingoides* were clearly brought out by Chapman in 1907 (*loc. cit.*, pl. 8).

Associates.—*Petraster smythi* McCoy; *Promopalaeaster meridionalis* (Eth. fil.); *Camarotoechia decemplicata* (Sow.), &c.

Horizon.—Silurian (Yarravian Series).

Locality.—Near Flemington, Victoria.

Family TAENIACTINIDAE Spencer.

Sub-Family TAENIACTINAE Spencer.

Genus **Taeniactis** Spencer.

TAENIACTIS YERINGAE, sp. nov.

(Text-fig. 1.)

1913. *Urasterella* sp. Chapman, F., *Aust. Assoc. Adv. Sci.*, xiv., p. 223.

Description.—Five long slender and slowly tapering arms radiating from a circular disc. The plates of the disc vary in both size and shape, and are irregularly arranged. The boundary of the disc is convex, but this may be due to post-mortem distortion. For the same reason, the original size of the disc is uncertain. Ambulacral plates opposite and quadrate with a prominent ridge bordering the thread-like ambulacral channel and a less prominent transverse ridge situated medially. The two ridges thus form a T. Adambulacrals elongate, subrectangular and tumid, outer edge slightly concave; inner edge bearing a prolongation opposite the transverse ridge on each ambulacral. The point of attachment of a spine can be seen on the outer edge of some of the adambulacrals. Mouth angle plates elongate and curved. Apical side unknown.

Dimensions.—Greatest length of arm preserved 17 mm.; apparent radius of disc 6 mm.

Remarks.—This interesting form is the first stelleroid described in the Yeringian series of the Victorian Silurian. The two specimens on which it is based were discovered by the Geological Survey of Victoria in 1862. They were referred to by Chapman (1907 (i), p. 23), and recorded by him in 1913 (p. 223), as *Urasterella* sp. The arrangement of the ossicles, however, and the existence of the central disc free from the arms class the form as a brittle star. The elongate adambulacrals, and the subquadrate ambulacrals, with the T-shaped ridge, show close relationship with the Wenlock species *Taeniactis wenlocki* Spencer, from Pentland Hills, Scotland. (Spencer, 1927, p.

380, pl. xvii., figs. 4, 5; text-figs. 245-247). *T. yeringae* is a larger form with slightly stouter adambulacrals. There are also differences in the disc structure. The boundary in *T. wenlocki* is concave; but in *T. yeringae* it is convex. Little dependence can be placed on this, however, for it has been largely determined by post-mortem distortion.

Horizon.—Silurian (Yeringian Series).

Locality.—Section 12, Parish of Yering; Geol. Surv. Locality B15. Specimens in National Museum, Melbourne, Nos. 13827 (holotype) and 13828 (topotype).

Family ENCRINASTERIDAE Schuchert.

Sub-Family EUZONOSOMATIDAE Spencer.

Genus **Crepidosoma** Spencer.

Crepidosoma kinglakensis, sp. nov.

(Pl. XI., fig. 3. Text-figs. 2, 3.)

1933. *Palaeaster* sp. nov. (nomen nudum), Withers, *Proc. Roy. Soc. Vic.* (n.s.), xlv. (1), p. 21.

Description.—Five short straight arms, broadest at disc margin, thence tapering to a finely drawn-out extremity. Disc circular, relatively large, extending about one-third of the distance along the arms, margined by a ring of rectangular plates with convex surfaces, at least six plates in each interradius. Orally, the ambulacrals are elongate rectangular; apically they are quadrate. Adambulacrals convex, large, almost elliptical in shape, except that extremities are angular; with major axis inclined to axis of arm. Mouth frame composed of long slender bars in apical view, but orally they appear stouter.

Dimensions.—Holotype, R = 10 mm.; r = 2.5 mm.

Remarks.—The specimens comprise a negative of the oral side, very well preserved (holotype), and one of the apical side, in which the arms are incomplete but the mouth frame shows clearly (paratype). All the essential features of *Crepidosoma* are present; but our species is only half the size of the corresponding Wenlock species of Scotland, *Crepidosoma wenlocki* Spencer. (Spencer, 1930, p. 430, pl. 27, figs. 1, 2, 7; text-figs. 276, 277). *C. wenlocki* has only three marginal plates in each interradius. Otherwise the British form shows very close correspondence to the Australian.

Associates. — *Lapworthura miltoni* (Salter); *Schuchertia junori* Withers and Keble; *Rutroclypeus junori* Withers.

Horizon.—Silurian.

Locality.—Collin's Quarry, Kinglake West, Victoria. Specimens presented to National Museum by their finder, Mr. P. Junor. Nos. 13831 (holotype) and 13832 (paratype).

Order STREPTOPHIURAE Bell.

Family LAPWORTHURIDAE Gregory.

Genus **Lapworthura** Gregory.

LAPWORTHURA MILTONI (Salter).

(Pl. XI., fig. 4.)

1925. *Lapworthura miltoni* (Salter). Spencer, *Mem. Pal. Soc.,* pp. 302-309, pl. i., figs. 9, 10; pl. xix., figs. 3-6; pl. xx., figs. 2, 3; pl. xxi., figs. 7, 8; Text-figs. 175, 188-191, 203-205.

The full synonymy is given in the above paper. Two specimens are known from Victoria. One (from Kinglake) is a mould of the oral side preserved in a hard greenish sandstone. Only one arm is fully preserved, and this is about 2.5 cm. in length. In England, the form ranges from the Upper Ordovician to the Ludlow, the Ordovician specimens generally being smaller than the Silurian. The Kinglake specimen is nearly as small as the minimum size known from the Ordovician. The second specimen (from Moonee Ponds) is a single incomplete arm 3 cm. in length.

Associates.—*Schuchertia junori* Withers and Keble; *Rutroclypeus junori* Withers (Kinglake); *Promopalaeaster meridionalis* (Eth. fil.); *Petraster smythi* McCoy; &c., (Moonee Ponds).

Horizon.—Silurian; also Silurian (Yarravian Series).

Locality.—Collin's Quarry, Kinglake West, Victoria. The specimen (No. 13833) was found by Mr. P. Junor and donated by him to the National Museum; also known from Moonee Ponds Creek. (Specimen No. 1035, Geology School, University of Melbourne).

LAPWORTHURA PULCHERRIMA, sp. nov.

(Pl. XI., figs. 1, 2. Text-figs. 4, 5.)

Description.—Five short flexible petaloid arms. Apically the arms have a prominent double row of alternate ambulacrals forming a central ridge. Each ossicle closely resembles a knuckle-bone; it is quadrate with concave boundaries, the outer lateral concavity being the deepest; and has a broad, well-marked transverse groove. Orally, the ambulacrals are boot-shaped, the lateral distal corner being deeply excavated for the ventral longitudinal muscle. Adambulacrals viewed from apical side elongate sub-rectangular, and set obliquely to axis of the arm. The proximal edge of the rectangle is modified so as to rise to a low point in the middle. The outer end of the adambulacral is tapered. Orally the ambulacrals are more slender than apically, and are approximately L-shaped. The L consists of a sharp ridge set obliquely to the ambulacrals, joined laterally to a stouter piece making an obtuse angle with the first. Attached to the latter are slender, oblique spines of length about equal to adambulacrals. Frame composed of narrow and high mouth angle plates.

Dimensions.—Syntypes:—Length of arm, 10 mm.; maximum width of arm (in middle), 3 mm.; diameter of oral pentagon, 2.5 mm.

Remarks.—In size, and in the petaloid form of the arms this species is like *Furcaster leptosomoides* (Chapman), which is found in neighbouring beds. The subquadrate shape of the ambulacrals (in apical view) clearly indicates however that it is *Lapworthura.* Further the arms are relatively flat, the mouth structure not sufficiently acute for *Furcaster* and the spines not parallel with the arms. From *Lapworthura miltoni,* the only other species of this genus, the form is distinguished by the more transverse side shields, and the petaloid arms. *L. miltoni* ranges from the Upper Ordovician to the Ludlow in Great Britain.

Associates.—*Cyphaspis spryi* Gregory; *Encrinurus* (*Cromus*) *spryi* Chapman. Less than a quarter of a mile away the types of *Furcaster leptosomoides* (Chapman); *Sturtzura brisingoides* (Gregory); *Petraster smythi* McCoy were obtained.

Horizon.—Silurian (Yarravian Series).

Locality.—Dawson-street, West Brunswick, about ¼ mile north of the Geological Survey of Victoria Locality "Flemington" (B8). Specimen found by D. McCance, Esq., and now in Museum of Geology Department, University of Melbourne. Syntypes:—No. 1157, apical specimen; and No. 1500, oral specimen (counterpart).

Genus **Sturtzaster** Etheridge.

STURTZASTER aff. MITCHELLI Etheridge.

1913. *Palaeocoma* sp. Chapman, *Aust. Assoc. Adv. Sci.,* xiv., p. 214.

The name *Sturtzaster* was proposed by Etheridge (1899, p. 129) for the genus *Palaeocoma* Salter (1857, pp. 324-327). The latter name, he pointed out, had already been used by d'Orbigny (1850, p. 240) as a new generic name for *Ophiura mulleri* Phillips, a distinct type of brittle-star from the Lias. *Palaeocoma marstoni* Salter has become the genotype of *Sturtzaster.* The genus has a large disc which has caused some authors to place it among the Asteroids, but the long slender spines and the ambulacral characters show it is an Auluroid. The two Victorian specimens are not well preserved, but they both have a large disc, subquadrate ambulacrals, large quadrate adambulacrals, and long spines on the margins of the disc and arms. These features are sufficient to show a relationship with *Sturtzaster* (?) *mitchelli* Etheridge, though we have not been able to examine the type specimen of the latter. *S.* (?) *mitchelli* occurs in the Silurian (Wenlock) beds at Bowning, N.S.W.

Horizon.—Silurian (Yarravian Series).

Locality.—Swanston-street, Melbourne (excavations), No. 13835, presented by Mr. F. P. Spry. Also Moonee Ponds, No. 13836. Both specimens in the National Museum, Melbourne.

Genus **Hallaster** Sturtz.

HALLASTER PARVUS, sp. nov.

(Pl. XI., figs. 5, 6. Text-figs. 8, 9.)

1929. *Taeniaster* (?) aff. *spinosus* Billings. E. S. Hills, *Proc. Roy. Soc. Vic.* (n.s.), xli., p. 179.

Description.—A small species with five short, petaloid arms. Only faint traces of the central disc preserved. Orally the arms are high, and have two central columns of sub-quadrate plates with the outer distal side scooped so as to resemble a stout boot. The side plates are first narrow then broader, slightly curved and set obliquely to the axis of the arm. No spines were observed. Apically the ambulacral plates unite in a low central ridge. They are sub-quadrate. Side plates similar to apical view. Oral armature made of stout sub-triangular plates; but not well preserved.

Dimensions.—Syntypes:—R = about 5 mm.: r, indeterminate.

Remarks.—The species bears quite a strong resemblance to *Taeniaster spinosus* Billings (Billings, 1858, p. 81, pl. 10, figs. 3 *a-d*; Schuchert, 1915, p. 219, pl. 36, fig. 1; text-fig. 17); but is distinctly smaller. The ambulacrals in apical view, and the side plates are also stouter. In these respects *T. parvus* resembles *Hallaster cylindricus* (Billings) (Spencer, 1925, p. 291, pl. 19, figs. 1, 2; pl. 21, figs. 1-5; text-figs. 178, 179, 198-201), originally described by Billings as *Taeniaster cylindricus*. *H. cylindricus* exhibits the asteroid-like oral armature which is a rather striking feature of our species. This structure is not well preserved, so that the exact details cannot be made out. It is also possible that the stout appearance is due to a foreshortening of the plates. (Spencer, *loc. cit.*, p. 294). *T. spinosus* occurs in the Middle Ordovician (Trenton Limestone); *H. cylindricus* is found in Canada, U.S.A., and Scotland, and ranges from the Middle Ordovician to the Lower Devonian.

Associates.—*Orthis* (*Dalmanella*) *testudinaria* Dalman; *Coleolus* cf. *aciculum* J. Hall, &c.

Horizon.—Silurian.

Locality.—Blue Hills, Taggerty. Specimens (counterparts) collected by Dr. E. S. Hills in 1929; now in collection of Geological Department, University of Melbourne. Syntypes: Nos. 792 (oral), No. 793 (apical).

Genus **Furcaster** Sturtz.

FURCASTER BAKERI, sp. nov.

(Pl. XI., figs. 9, 10. Text-figs. 10, 11.)

Description.—Five small flexible arms emanating from a small central disc and tapering only slowly. The oral aspect of arms shows a central row of alternating hatchet-shaped ambulacrals, the broadest part of each ambulacral adjoining the median line of the arm. Adambulacrals sub-rectangular but tapering laterally, arranged obliquely with outer tips pointing distally. Apically the ambulacrals are much excavated; for the most part they are thin slabs laid end to end. The only prominent part is a ridge which broadens near the axis of the arm. Adambulacrals in apical view appear as elongate tapering plates bordering the arm, each with a lateral process opposite the ridge on the corresponding ambulacral. Mouth frame not preserved. Spines on side plates not observed.

Dimensions.—Syntypes:—Greatest length of arm, 7 mm.; greatest width of arm, 1.5 mm. Diameter of oral pentagon about 3 mm.

Remarks.—The specimens comprise the mould of the oral side in sandstone, and its counterpart which is a mould of the apical side. Apically the ambulacrals resemble closely those of *Furcaster leptosoma* (Salter), from the Lower Ludlow of England (Spencer, 1925, p. 320, text-figs, 211), the characteristic median ridge being clearly discernible. Orally they differ from all other species of *Furcaster*. In place of the typical boot-shape, they are hatchet-shaped; that is, the excavation for the dorsal longitudinal muscle eats into the proximal edge of one ossicle and the distal edge of the adjoining ossicle, instead of into the distal edge of each ossicle. The ossicles of *F. bakeri* are thus a link between those of *Hallaster* or *Lapworthura* and those of the typical *Furcaster*. *F. bakeri* is smaller than *F. leptosomoides* (Chapman), and smaller again than *F. kilmorensis;* and its arms are not petaloid as in these two species. It is distinguished from *Lapworthura pulcherrima,* sp. nov. by the absence of the long oblique spines (of generic importance), the more excavated ambulacrals, and its smaller size. The arms have been preserved in an attitude indicative of its wriggling mode of progression. An unpaired arm is thrust out to the rear; and this has to either side, first a slightly curved arm, and then one of the forward arms strongly retroflexed (see Pl. XI., figs. 5, 6).

Associates.—Fossils from the same locality, though not the same bed are *Camarotoechia decemplicata* (Sow.); *Monograptus chimaera; M. roemeri; M. colonus; M. varians* (all Ludlovian.)

Horizon.—Silurian (Yarravian).

Locality.—East side of new Yarra Boulevard, vicinity of Dight's Falls, Studley Park. The specimen was not *in situ*. Collected by G. Baker, Esq. Museum of Geology School, University of Melbourne, Nos. 1498 (oral), 1499 (apical).

FURCASTER KILMORENSIS, sp. nov.

(Pl. XI., fig. 8. Text-figs. 6, 7.)

Description.—Five moderately long arms; orally, when the groove is open, they are petaloid, but apically they are straight and slender. The oral surface is composed of two rows of boot-shaped ambulacrals, arranged slightly alternately. The back of the boot faces proximally; the toe distally. Adambulacrals rectangular, with a prominent ┌-shaped ridge. The horizontal portion of the ridge is first thin, becoming stouter as the lateral portion is approached. The latter, which is directed distally, is both thick and prominent. No spines were observed. Apically the ambulacrals form a high ridge; they appear subquadrate with the median and lateral boundaries concave; the adambulacrals are also quadrate, and bear a prominent ridge similar to that seen orally. Mouth frame petaloid and acute, made of five pairs of first ambulacrals surmounted by five pairs of slender mouth angle plates.

Dimensions.—Holotype:—Length of complete arm, 20 mm.; greatest width of arm, 2.5 mm. (groove open). Paratype: Width of arm, 2 mm.; diameter of oral pentagon, 4.5 mm.; arms incomplete. Other specimens are only slightly smaller or slightly larger.

Remarks.—The holotype is a preservation of the oral side with the groove wide open; the paratype shows the apical side, including an excellent view of the mouth parts. *Furcaster kilmorensis* is a larger species than *F. leptosomoides*. It most closely resembles *F. leptosoma* (Salter), which is found in Great Britain and Europe in rocks of Upper Ordovician to Carboniferous age. Our specimens, however, are most like those from the Lower Ludlow beds of England, which they resemble in size and disposition of arms. They differ in having petaloid arms, in lacking the thin transverse ridge on the ambulacrals, in the alternate arrangement of the latter and in consequence the absence of the well-marked hollow between apical halves of the vertebral ossicles.

Associates.—The specimens come from the same district as *Salteraster selwyni* (McCoy), and *Salteraster biradialis* Withers and Keble, but not the precise locality, for the matrix is a yellow sandstone, while in the latter cases it was red.

Horizon.—Silurian.

Locality.—Kilmore, Victoria. Collected and presented by G. Sweet, Esq., to National Museum, Melbourne. Holotype No. 13829, paratype No. 13830.

FURCASTER LEPTOSOMOIDES (Chapman).

1907. *Sturtzura leptosomoides* Chapman. *Proc. Roy. Soc. Vic.* (n.s.), xix., p. 26, pl. vii., figs. 1, 2; pl. viii., fig. 4.

The genus *Furcaster* was erected by Sturtz in 1886 to receive a species (*F. palaeozoicus*) from the Lower Devonian of Germany. Since then, members of the genus have been recorded from horizons ranging from the Lower Silurian to the Lower Carboniferous in England, Europe, and America. The form is extraordinarily variable in size, and as a result has been described under a number of generic and specific names. In 1925, however, Spencer (pp. 312-326) made an exhaustive study of the genus, and among other things, placed *Sturtzura leptosoma* (Salter), in the genus *Furcaster*. Hence the change in name in the Victorian form, which is certainly congeneric with Salter's species from the Lower Ludlow.

Associates.—*Petraster smythi* McCoy; *Promopalaeaster meridionalis* (Eth. fil.), &c.

Horizon.—Silurian (Yarravian Series).

Locality.—Moonee Ponds Creek, Flemington. (Geol. Surv., Locality B8).

Family EOLUIDIIDAE Gregory.

Genus **Eospondylus** Gregory.

EOSPONDYLUS TENUIS, sp. nov.

(Pl. XI., fig. 7. Text-fig. 12.)

Description.—Arms five, flexuous, exceedingly slender. Each half of a vertebra has the appearance of a long boot, the back of the boot facing towards the tip of the arm. Side plates very small, and round, close to vertebrae, and bearing long slender spines set almost at right angles to axis of the arm. Disc probably large, consisting of squamose granulate plates. Mouth frame large.

Dimensions.—Length of arms uncertain, the parts preserved projecting little beyond the disc. Radius of disc (approximately), 7.5 mm.; width of arm, 1 mm.

Remarks.—The specimen comprises part of a disc and portions of each arm (oral side). The only species of the genus *Eospondylus* known from elsewhere is *E. primigenius* (Sturtz), from the Lower Devonian of Bundenbach, Germany (Spencer, 1925, p, 309, pl. 21, fig. 9; text-figs. 206 *a-e*). *E. primigenius* is a larger species than *E. tenuis,* the ventral ossicles are stouter, and the side plates more prominent.

Horizon.—Silurian (Yarravian Series).

Locality.—Moonee Ponds. Specimen found by Dr. E. S. Hills in 1926; now in the collection of the Geological Department, University of Melbourne, No. 1497. Holotype.

Family AGANASTERIDAE Sturtz.

Genus **Aganaster** Miller and Gurley.

cf. AGANASTER GREGARIUS (Meek and Worthen).

1915. *Aganaster gregarius* (Meek and Worthen). Schuchert, *Bull,* 88, *U.S. Nat. Mus.,* p. 264.

1925. *Aganaster gregarius* (Meek and Worthen). Spencer, Mon. Pal. Asterozoa, pt. 6. *Mem. Pal. Soc.* for 1922, p. 285, pl. 18, fig. 3; pl. 20, figs. 4, 5, 6; text-figs. 194, 195.

The Victorian specimens of this form are poorly preserved in a hard chocolate sandstone. Five very slender arms radiate from a small central disc. The arm structure consists of a double row of rectangular to sub-quadrate plates, as in *A. gregarius.* Another character which assists in identification is the gregarious nature of the form. In many British and American specimens the rock is crowded with a large number of small forms. In our specimen there are three tiny forms not more than an inch away from each other.

The American examples are from the Keokuk formation (Lower Carboniferous) of Indiana, U.S.A. The disc in these specimens varies from 3-7 mm., and the longest arm is 15 mm. The British specimens, from the Lower Carboniferous of Ardross, Fife, are smaller (R : r :: 6 mm.; 1 mm. maximum, with many specimens only half as large).

This is the first stelleroid identified from the Victorian Carboniferous.

Dimensions.—Maximum length of arm preserved, 3.5 mm.; diameter of disc about 1 mm.

Horizon.—Carboniferous.

Locality.—At back of homestead, Maindample Park, Mansfield, Victoria. The specimen was discovered by Miss Irene Crespin, B.A., and presented by her to the National Museum. No. 13834.

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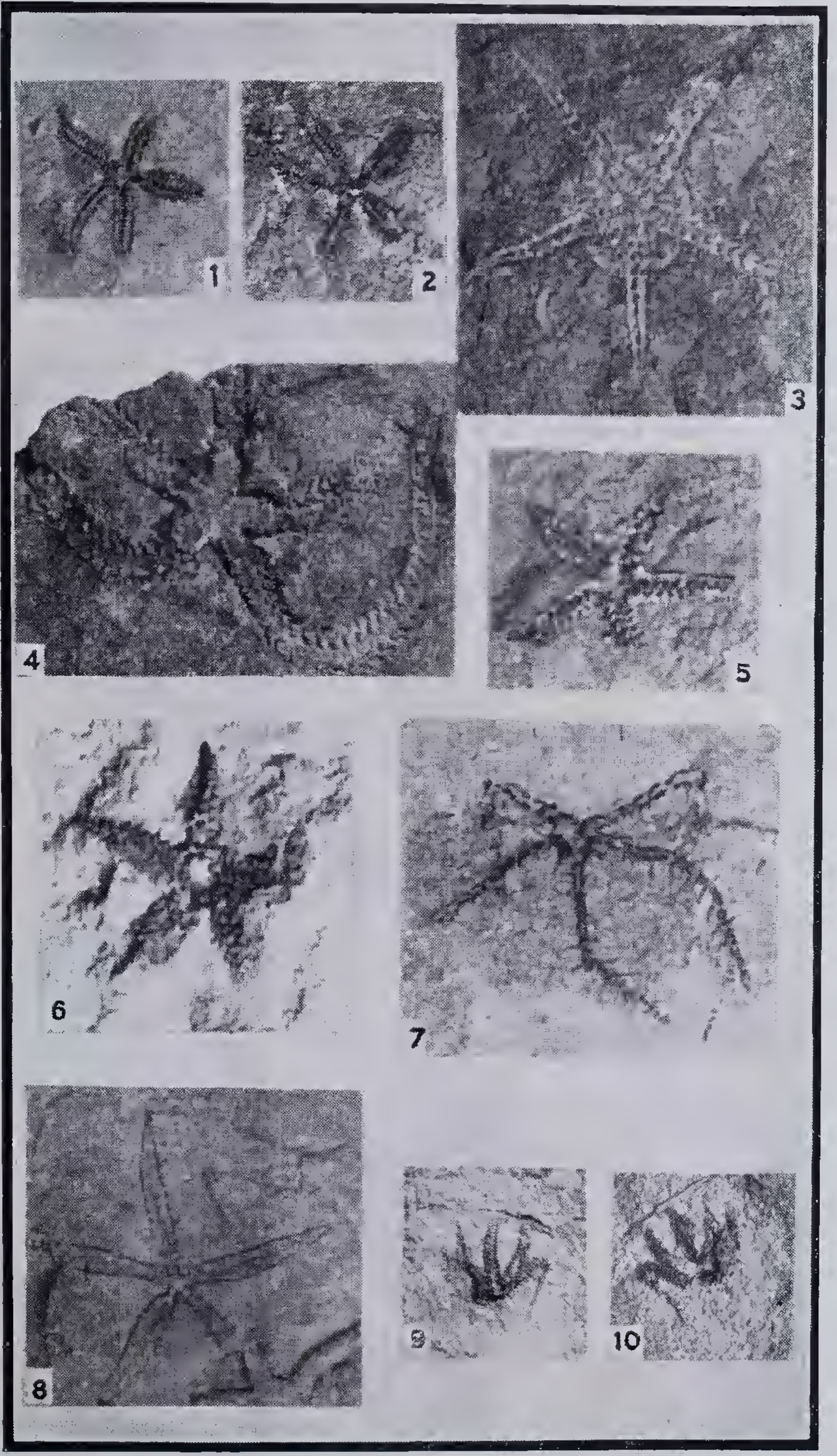
Explanation of Plate XI.

(Note.—All specimens of Silurian age, except *Aganaster* (Carboniferous)).

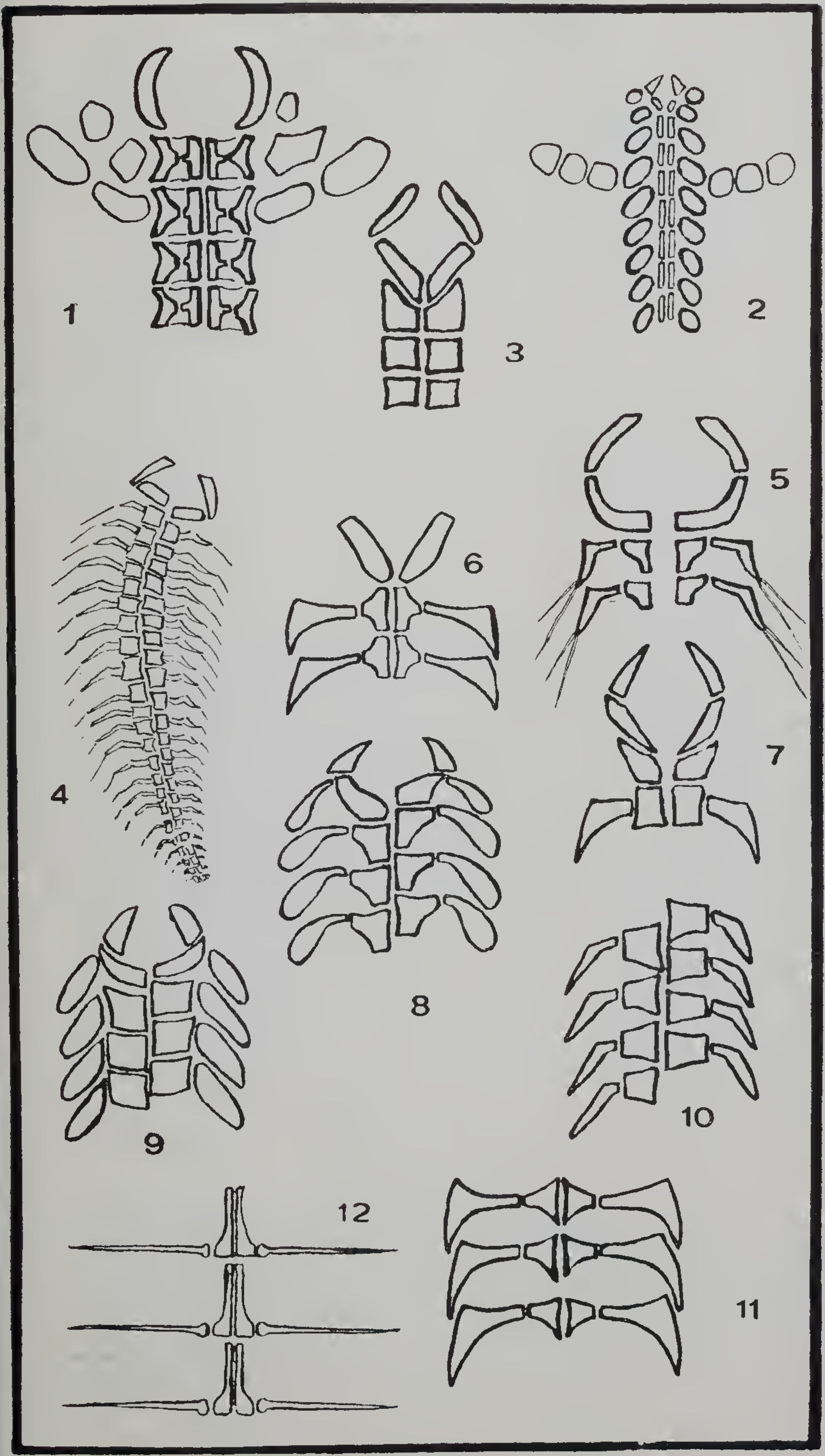
Fig. 1.—*Lapworthura pulcherrima,* sp. nov. Apical side of syntype. × 1.5. West Brunswick. Coll. by D. McCance, Esq. Mus. of Geol. School, Univ. of Melb., No. 1157.

Fig. 2.—*L. pulcherrima,* sp. nov. Oral view of syntype. × 1.5. West Brunswick. Coll. by D. McCance, Esq. Mus. of Geol. School, Univ. of Melb., No. 1500.

Fig. 3.—*Crepidosoma kinglakensis,* sp. nov. Oral view of holotype. × 2.5. Kinglake West. Coll. by P. Junor, Esq. Nat. Mus. Coll., No. 13831.



Palaeozoic Brittle-Stars.



TEXT FIGS. 1-12.

Fig. 4.—*Lapworthura miltoni* (Salter). Oral view. × 2. Kinglake West. Coll. by P. Junor, Esq. Nat. Mus. Coll., No. 13833.

Fig. 5.—*Hallaster parvus,* sp. nov. Oral view of syntype. × 4.5. Blue Hills, Taggerty. Coll. by Dr. E. S. Hills. Mus. of Geol. School, Univ. of Melb., No. 792.

Fig. 6.—*H. parvus,* sp. nov. Apical view of syntype. × 4.5. Blue Hills, Taggerty. Coll. by Dr. E. S. Hills. Mus. of Geol. School, Univ. of Melb., No. 793.

Fig. 7.—*Eospondylus tenuis,* sp. nov. Oral view of holotype. × 4. Moonee Ponds. Coll. by Dr. E. S. Hills. Mus. of Geol. School, Univ. of Melb., No. 1497.

Fig. 8.—*Furcaster kilmorensis,* sp. nov. Oral view of holotype. × 1.5. Kilmore. Coll. by G. Sweet, Esq. Nat. Mus. Coll., No. 13829.

Fig. 9.—*Furcaster bakeri,* sp. nov. Oral view of syntype. × 1. Studley Park. Coll. by G. Baker, Esq. Mus. of Geol. School, Univ. of Melb., No. 1498.

Fig. 10.—*F. bakeri,* sp. nov. Apical view of syntype. × 1. Studley Park. Coll. by G. Baker, Esq. Mus. of Geol. School, Univ. of Melb., No. 1499.

TEXT FIGURES 1-12.

(1) *Taeniactis yeringae,* sp. nov. Oral view of mouth structure, disc, and part of arm. × 3½. (2, 3) *Crepidosoma kinglakensis,* sp. nov.: (2) Oral view of mouth structure, disc and part of arm. × 3½. (3) Apical view of same. × 3½. The oral groove is closed so that side plates have moved almost entirely to that side. (4, 5) *Lapworthura pulcherrima,* sp. nov.: (4) Apical view of arm. × 5. (5) Oral view of mouth parts and portion of arm, with spines. × 9. (6, 7) *Furcaster kilmorensis,* sp. nov.: (6) Oral view of part of arm and mouth structure (latter imperfect). × 7. (7) Apical view of mouth structure and part of arm. × 7. Figured from paratype—No. 13830. Nat. Mus. Melb., of which no photograph is given. (8, 9) *Hallaster parvus,* sp. nov.: (8) Oral view of mouth structure and part of arm. × 17. (9) Apical view of same. × 17. (10, 11) *Furcaster bakeri,* sp. nov.: (10) Oral view of mouth structure and part of arm. × 14. (11) Apical view of same. × 17. (12) *Eospondylus tenuis,* sp. nov. Oral view of mouth structure and part of arm. × 14.

H. J. Green,
Govt. Printer, Melbourne.

[Proc. Roy. Soc. Victoria 47 (N.S.), Pt. II., 1935.]

Art. XIII.—*The Muckleford Fault in the Guildford-Strangways Area (near Castlemaine, Victoria.)*

By D. E. THOMAS, B.Sc.

[Read 9th August, 1934; issued separately, 8th May, 1935.]

I. Introduction and Acknowledgments.

The Muckleford Fault was postulated by Harris and Thomas (9) as a north and south fault which in the area between Castlemaine and Newstead separates Lancefieldian beds on the west from Darriwilian on the east. Owing to the nature of the country the line of fault can be traced only approximately in the field, though the palaeontological evidence in support of it is strong. North-west of Guildford, however, excavations by the Guildford Plateau Mining Company exposed a fault which was noticed by the Director of Geological Survey (Mr. W. Baragwanath) who drew my attention to it. My thanks are due to Mr. Baragwanath for the opportunity of studying the occurrence. I am also indebted to Mr. G. G. Dunstan for much general information; to Mr. Ray, the manager of the mine, for many acts of kindness during the progress of my work; and lastly to Dr. W. J. Harris, who placed his knowledge of the graptolites of the area at my disposal.

II. Physiography.

The area north of Guildford consists of a basalt plateau (Fig. 1) about 900 feet above sea level, with steep and—in places—precipitous slopes to the two lateral streams, the Loddon River on the south and the Muckleford Creek on the west. These separate the plateau from the rolling hills of Ordovician rocks on the south and west, while the basalt thins out on the slopes of similar hills to the north. The streams flow about 200 feet below the surface level of the plateau. The Muckleford Creek, after a general southerly course, turns to the west before joining the Loddon, flowing through a narrow valley. The Loddon, flowing towards the west, has a flat-bottomed valley. The plateau and the alluvial flats along the Loddon are the fertile areas of the district. The Ordovician hills are generally tree-covered. Apart from the line of gentle eastward slope north of the Guildford Plateau shaft, to be discussed later, the plateau slopes generally towards the west.

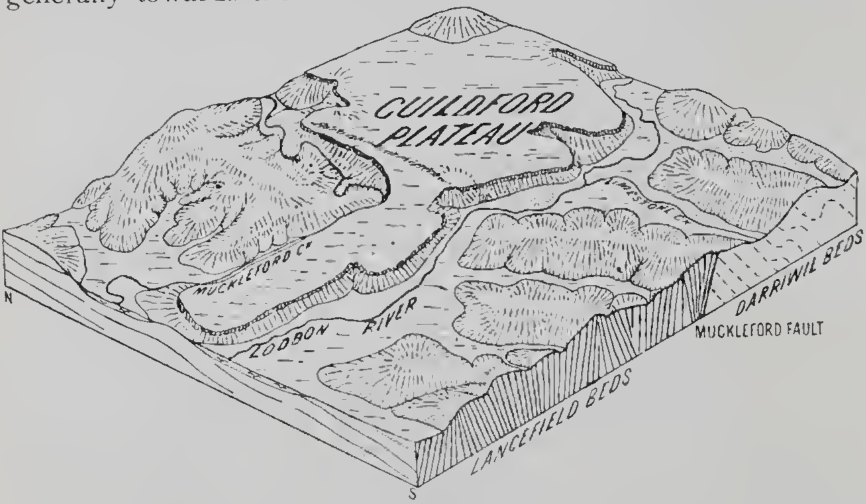


FIG. 1.

III. Previous Work.

Q.S. 15 N.E. of the Geological Survey of Victoria (by Ulrich and Aplin) is the only detailed geological map of the area. The physiography and distribution of the various groups of rocks are very accurately shown, even though this sheet was published in 1864. Later work has increased our knowledge of the graptolite succession in the area. Apart from this Quarter-sheet the only other detailed references to the geology of the area are to be found in mining reports.

IV. Geology.

The rocks of the area are Lower Ordovician sandstones and shales, covered in part with a relatively thin mantle of basalt and river gravels or "wash" of pre-basaltic age. (Figs. 2 and 3).

The age of the Ordovician rocks is known from their contained graptolites, while from analogy with similar occurrences in other parts of Victoria the gravels are referred to Tertiary times (Miocene to Pliocene).

(i) Lower Ordovician Rocks.

The Lower Ordovician rocks consist, as is usually the case in Victoria, of sandstones ranging from coarse- to fine-grained, with intercalated shales and mudstones. Their strike is slightly to the west of north; they are inclined at a high angle (in places they are almost vertical), and they are closely folded, as may be seen from the sections exposed along the Muckleford Creek and in railway and road cuttings. The high angles of dip make it impossible to trace individual folds for any distance.

Many of the graptolite localities were first found by Harris(8) who showed that the beds along the railway line between Guildford and Limestone Creek were of Darriwilian age. Later Harris and Thomas(9) recorded additional localities and showed that the Muckleford Fault formed a dividing line between Lancefieldian and Darriwilian. The most westerly outcrop at which graptolites were found along the Castlemaine-Newstead railway line (87 m. 52 ch.) yielded the following forms indicating a low Darriwilian zone (D4):—

Isograptus caduceus var. divergens Harris, and other variants.
Cardiograptus morsus Harris and Keble.
Oncograptus upsilon var. biangulatus (H. and K.).
Didymograptus v-deflexus H. and K.
Trigonograptus sp. (probably T. ensiformis Hall).
Phyllograptus sp.

Oncograptus beds also occur on the north and south road south of the railway crossing at 87 m. 33 ch., and *Cardiograptus morsus* beds at 86 m. 57 ch. on the railway and further east. Poorly preserved graptolites may also be obtained from the soft shales along the Loddon below the outlier of Tertiary gravels, the commonest forms being Darriwilian varieties of *I. caduceus.*

The spoil heap of the Guildford Plateau mine contains many fragmentary graptolites. The mudstone here, however, is doubly cleaved, making the extraction of specimens difficult. The following were identified:—

Isograptus caduceus var. maximo-divergens Harris.
I. caduceus var. divergens Harris.
I. forcipiformis (Rued.).
Didymograptus v-deflexus H. and K.
Didymograptus spp.
Tetragraptus serra Brong.
Tetragraptus sp. (cf. headi Hall).

Although *Oncograptus* was not found, the assemblage points to a low Darriwilian horizon (probably D5).

Two other outcrops yielded assemblages indicating passage-beds between the D3 and D2 zones, or perhaps what might better be called the basal beds of the D2 zone (zone of *D.* (*Glyptograptus*) *austrodentatus*). Previously this assemblage had been recorded only from the Brisbane Ranges. One of these localities, originally discovered by Mr. Baragwanath, is the spoil-heap of the old Plateau shaft, which was sunk through basalt in Allot. 26, Guildford. The following forms are present:—

Isograptus caduceus var. maximo-divergens Harris.
I. caduceus var. divergens Harris.
I. hastatus Harris.
Skiagraptus gnomonicus (Harris and Keble).
Cardiograptus morsus H. and K.
Tetragraptus serra Brong.
Tetragraptus spp.
Goniograptus speciosus T. S. Hall.
Trigonograptus ensiformis J. Hall.
Phyllograptus cf. nobilis H. and K.
Didymograptus v-deflexus H.
Diplograptus (Glyptograptus) austrodentatus H. and K.

The Grand Trunk tunnel dump yielded:—

Cardiograptus morsus H. and K. (long narrow variety).
Didymograptus spp.
Tetragraptus sp.
Trigonograptus cf. ensiformis J. Hall.
Phyllograptus cf. nobilis H. and K.
Loganograptus sp.
Variants of I. caduceus.

All these localities are east of the Muckleford Fault and show the strata ascending eastward towards the centre of the Muckleford synclinorium which Harris and Thomas place as near the 85½ mile-post on the railway.

To the west of the fault in the Lancefieldian belt the search for graptolites was less successful. Lancefieldian forms (L1) (*Tetragraptus decipiens* T. S. Hall, *T. approximatus* Nicholson, and *Clonograptus* sp.) occur at the locality marked as Note 25 on Q.S. 15 N.E. The strike of this band would pass to the west of the Guildford Plateau mine. Lithologically the rocks east and west of the Muckleford Fault resemble each other, although waxy brown shales common to the Lancefieldian are missing from the Darriwilian. Generally speaking, hard sandstones predominate in the west and thick shales with softer sandstones in the east, with the result that surface relief is greater in the west. The differences, too slight to enable individual outcrops to be separated, give a regional distinction. This, together with the strike of the Lancefieldian band recognized, and the occurrence of Darriwilian graptolites near the Guildford Plateau mine, makes it reasonably certain that the fault exposed in the excavation at the mine is on the line of the Muckleford Fault. This Fault, which is responsible for the absence at this locality of the whole of the Bendigonian and Castlemainian series, must be, as far as one can estimate, of the order of 4,000 feet.

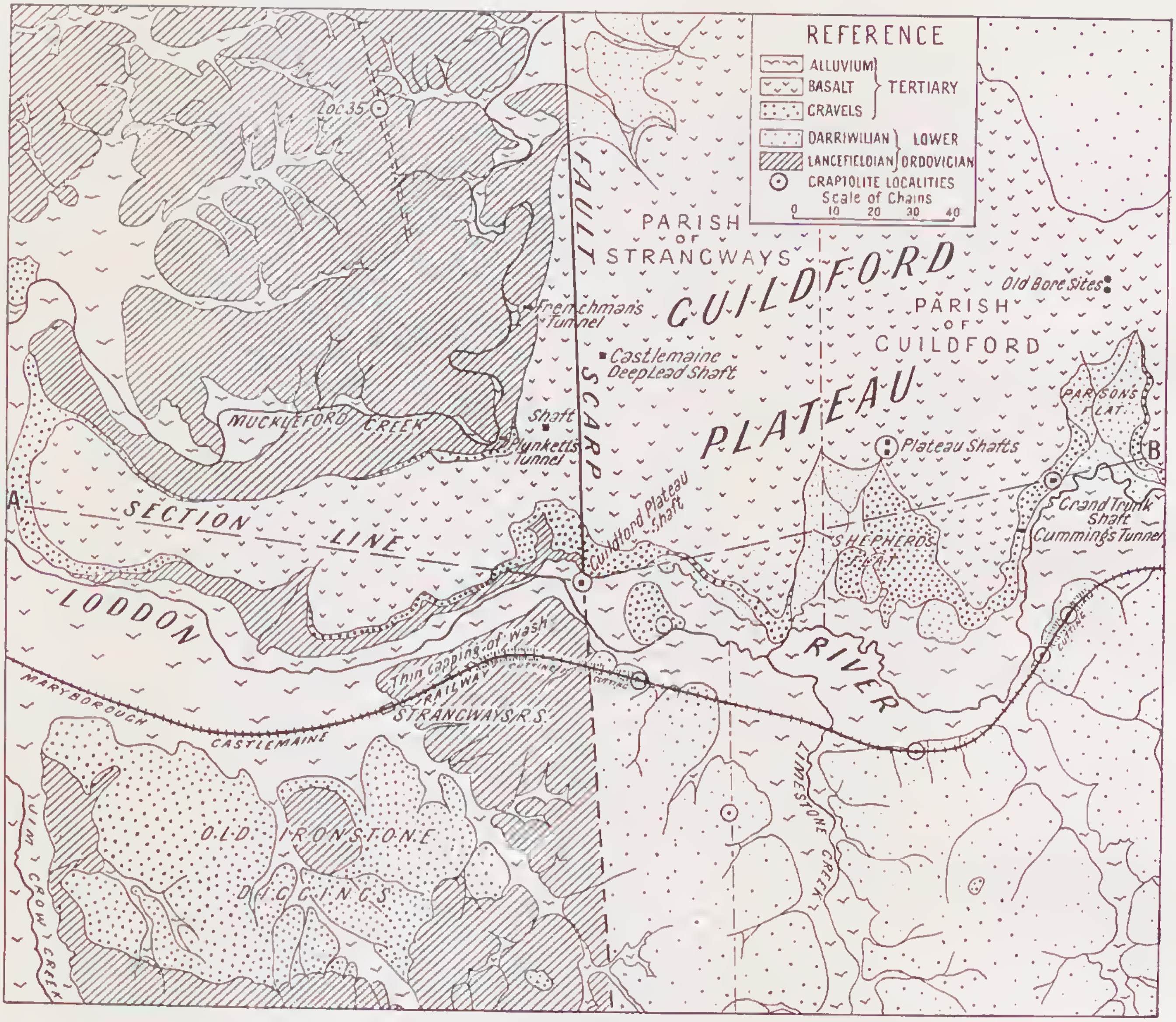
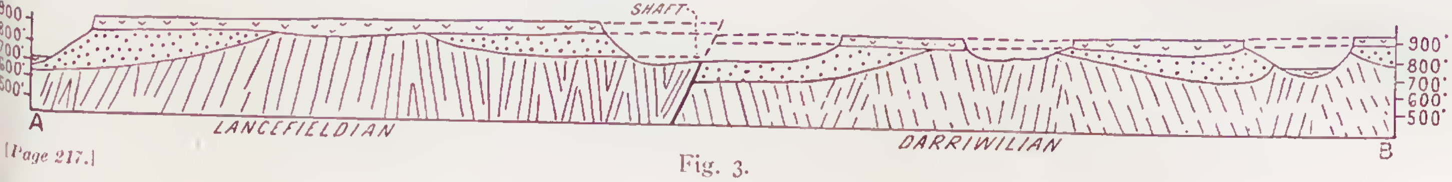


Fig. 2.



[Page 217.]

Fig. 3.

(ii) TERTIARY ROCKS.

The Tertiary rocks are represented by the pre-basaltic auriferous wash and the basalt flows. Since the distribution of the wash and the basalt is connected with the Tertiary physiography, it becomes important to reconstruct as far as possible the early Tertiary topography.

(*a*) *Pre-basaltic Tertiary Gravels.*

These gravels range from a coarse conglomerate to fine sandy beds cemented by ferruginous material or quite unconsolidated. The thickness varies considerly, as might be expected from a fluviatile deposit laid down in a wide valley. The size of the boulders, their worn nature and their composition (vein quartz and quartzite predominate), afford information as to the velocity of the streams and the time needed for the deposition of the gravels. They must belong to a period when the climate was wetter and the relief more pronounced than at present. The gradient was steeper than at present, as east of Guildford the bed of the ancient stream is higher than the present Loddon, while further west it lies below the Loddon alluvium, as is shown in the workings of the Guildford Plateau mine.

West of the fault and south of Strangways railway station is an extensive area of exposed gravels, known as the Old Ironstone Diggings. This lies to the south of the Loddon, but probably represents a meander of the ancient Loddon as, immediately to the north, the basalt rests directly on bed-rock without any intervening gravel. The wash here was extensively worked, the sinking being comparatively deep—as far as one can gather from the old shafts and from information available, just over 100 feet. The surface level is about 800 feet so that the floor of the old valley would be under 700 feet. Immediately west of the Guildford Plateau mine the bottom of the wash is at a level of approximately 790 feet.

East of the fault the "bottom" lies below river level, and the mine workings show it to be about 675 feet above sea level. Further upstream the deepest part of the gravels is under the basalt, and its course can be traced roughly from the two shafts on the plateau, called the Old Plateau and New Plateau shafts, and by Cumings' and the Grand Trunk Tunnels.

Upstream from the Grand Trunk Tunnel the lead passed partly under the Loddon and here dredging yielded good results, and still further upstream it passed once more under the basalt, as is shown by the hillside workings. Here conflicting data make it difficult to reconstruct the course of the lead. The Forest Creek and Upper Loddon lead systems junctioned near the Guildford railway station (the "Guildford Gap") and flowed beneath the basalt. Two bores(14) near the north-east corner of Allot.

25, Guildford, proved the presence of auriferous wash at a depth of 200 feet—about the same level as on the worked lead to the south. A feasible explanation is that this is gravel deposited by a lateral stream developed on the northern side of the first basalt flow, but in the absence of full boring records this cannot be definitely asserted.

The Muckleford Lead lies along the Muckleford Creek and its upper part around Muckleford township has not been covered by basalt. Several tunnels have been driven from the valley of the Muckleford Creek to intercept the portion of this lead that lies beneath the basalt, the largest being Frenchman's Tunnel. (3, p. 131.) This tunnel proved that the course of the lead was very tortuous. The exact position of this lead is now being fixed by boring. While, as far as can be gathered, only the wash at the base of the gravel has been worked in the western part of this area, there is evidence of another run of consolidated auriferous wash or false bottom at a higher level in the east. (2, p. 26).

(*b*) *Basalt Flows.*

The main or upper basalt flow of the plateau is a dark greenish-grey, more or less vesicular rock, which in some places along the escarpment has a rough columnar structure, while a platy structure is developed elsewhere. Crystals of olivine and augite can be seen with the naked eye, the largest being about 2.5 mm. long. An older flow exposed near the Guildford Gap immediately underlies the younger flow, but it must extend a considerable distance downstream as both the old shafts on the plateau went through this flow.

The upper flow is composed essentially of olivine, pale brown augite, labradorite and iron ores. There is a marked tendency towards a glomero-porphyritic structure of the ferro-magnesian minerals and occasional felspar phenocrysts occur. The augite encloses small crystals of magnetite. The groundmass consists of granules of augite and olivine and rods and plates of magnetite, between the felspar laths which average 0.2 to 0.3 mm. in length. A fair amount of carbonate and occasional needles of apatite are present, and some olivine is altered to iddingsite.

The underlying basalt is on the whole finer-grained and less vesicular. Crystals of olivine up to 2.5 mm. in length alter to serpentine, not to iddingsite. Augite occurs as crystals up to 2 mm. long. The felspar is less acid than in the upper flow, some of the larger crystals giving symmetrical extinctions of 25°. Much interstitial felspar is untwinned or shows undulose extinction as in the oligoclase basalts, so that the affinities of this flow are with the basic mugearites. Some iron ore, apatite and carbonate are also present. The basalt flows which are in direct contact have a maximum thickness of over 75 feet.

(iii) FAULTING.

The fault, which may be seen in the excavation at the mine, displaces the gravel nearly 100 feet. It is a reversed fault hading in the west at 70° on the surface, where it is 21 feet from the east side of the shaft, while at the 97-foot level it is 7 ft. 6 in. from the same side. The Ordovician rocks are bleached for about 10 feet from the fault while the blue mudstones are shattered. A very sharp syncline lies just to the west, and on this another fault can be seen which, however, does not affect the Tertiary rocks. Along the fault affecting the Tertiaries about 6 inches of coarse gravel may be seen representing auriferous wash caught up during the faulting movement as colours of gold may be obtained by panning. To the east the "gravel" is represented by clay bands, sandy beds, and some conglomerate, with an easterly dip of 30°. The flexure certainly seems to be due to the fault which has its upthrow side to the west. The floor on which the wash rests has been displaced vertically 100 feet (± 5 feet), as can be seen from the surface exposures and the level of the mine workings. Although the wash has been displaced 100 feet vertically, the basalt has been displaced rather less than 50 feet, indicating two movements along the fault line, each of about 50 feet. No other direct evidence of pre-basaltic faulting was seen, but the post-gravel physiography seems to show that movement caused by the fault interfered with the drainage system before the outpouring of the upper basalt flow. As a general rule the basalt flowed down the valley in which the gravel had been deposited. Lateral streams developed one on each side of the basalt, and have exposed pre-basaltic wash. The area of auriferous gravels in the neighbourhood of Shepherd's Flat was probably deposited at the junction of two broad valleys excavated by the pre-basaltic Loddon and Muckleford Creek in the soft Darriwilian bed-rock. To the west, however, the deposits at the Old Ironstone Diggings represent a large meander south of Strangways railway station, and show that the valley here was narrow and steep-sided. The basalt did not follow this meander, but flowed west and rejoined the old valley further down stream. It thus seems likely that changes of level due to movement along the fault caused the stream to cut through a low neck of bed-rock and abandon the meander, and it is through this gap that the basalt flowed. An alternative explanation is that a basalt covering of the Old Ironstone gravels has been completely denuded, but it is improbable that this is so since such a great amount of erosion locally would be hard to explain when compared with the smaller amount both up- and down-stream.

North of the Guildford Plateau mine the Quarter-sheet indicates by its hachuring a sudden change of level along a line corresponding with the hidden extension of the fault. On both sides of this line the basalt is similar, while the general slope of the plateau surface on both sides is to the west in the general direction of the flow of the basalt, but in the opposite direction to the local slope shown by the hachures. Though the observed fault cannot be definitely identified with the Muckleford Fault, which as already stated is of much greater magnitude, it seems clear that it represents movement along the line of this greater fault. The Muckleford Fault displaces the Lower Ordovician beds vertically at least 4,000 feet, the auriferous wash is displaced 100 feet while the basalt has been displaced only 50 feet, thus showing at least three movements along the same line of weakness, the last movement being very recent.

V. Some late Tertiary Faults affecting Alluvial Workings in Victoria.

Late Tertiary faults play an important part in the geological history of eastern Australia. The existence of many faults has been inferred, and the following have been actually verified chiefly by underground mining operations. Nicholas (12), discussing the workings of the New Australian Company, Creswick, refers to a "well-formed vertical wash" 20 feet in height worked over a length of 200 feet, and states that no doubt it was the result of an upheaval. While this is a case where auriferous wash has been worked along the fault line, his statement that as a rule "there is a general absence of wash between the upper and lower part parallel to the cleavage" evidently means that faulting of wash is not uncommon; it is rarely that wash is found along the fault plane itself.

In 1917, E. J. Dunn(5) described a post-Tertiary fault at Beechworth, in a section which he had first noted in 1871(4) without realizing its significance. This fault is a thrust fault with a hade of 45° and a vertical displacement of about 20 feet. Dunn considers it to be of the same age as faults in the Berry Lead at Spring Hill and elsewhere near Allendale. W. Baragwanath(1) has recorded post-Newer Basalt faulting in the Ballarat area.

A late Tertiary fault affecting alluvial mining appears to be present in the Sebastian area(15), as H. S. Whitelaw reports, "Extremely good gold, it is said, was traced from near the Frederick the Great Company's main shaft westward to Myer's Creek, a distance of about a quarter of a mile where a sudden drop of 70 feet from 30 feet to 100 feet was encountered."

Harris states (personal communication) that the Whitelaw Fault at Bendigo—a fault in every way comparable with the Muckleford Fault—also shows evidence of post-Tertiary movement, auriferous gravels being carried 50 to 100 feet downwards on the Darriwilian side of the fault line.

These late Tertiary faults observed during mining operations are insignificant compared with those postulated in south-eastern Australia by physiographers and palaeo-geographers. Fenner (6), for example, finds evidence of two periods of Tertiary fault movements in the Bacchus Marsh area—the post-Older Basalt block faults and the post-Newer Basalt movement along the Rowsley Fault. Others have also explained the development of the physiography of this part of Australia by invoking faulting. (10, 13).

VI. Summary.

1. Reversed faulting has occurred along the line of the Muckleford Fault, with a hade to the west of approximately 70°.

2. Evidence based on graptolites from the east and west sides of the fault line, together with the estimated thickness of the Ordovician graptolite zones in this locality, indicates that the vertical displacement is of the order of 4,000 feet.

3. The greater part of this movement took place before the deposition of the pre-basaltic auriferous river gravels.

4. The movement continued in Tertiary times two late movements being observable, (i) of about 50 feet after the deposition of the gravels, but before the extrusion of the upper basalt flow, though probably after the lower flow, and (ii) of another 50 feet in post-basaltic times.

5. Similar Tertiary faults, including many of considerably greater magnitude, have been postulated to explain the physiography of south-eastern Australia or have been observed in mine workings elsewhere in Victoria.

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Art. XIV.—*Manganese Deficiency of Cereals: Plot Experiments and a New Hypothesis.*

By G. W. LEEPER, M.Sc.

[Read 11th October, 1934; issued separately, 8th May, 1935.]

Introduction.

It is now generally recognized that manganese is an essential element in the growth and reproduction of plants. Oats are especially sensitive to a deficiency of manganese. Barley and wheat are not quite so sensitive, while rye and most of the common grasses are far less sensitive, though not even rye is immune. The actual symptoms of the deficiency are shown in most characteristic fashion by oats, in which the disease has been called "grey-speck." These symptoms have been fully described and illustrated by Samuel and Piper (1928), and by Davies and Jones (1931).

In the last few years, cases of manganese deficiency have been reported from many parts of Europe, North America, and Australia, as occurring on many important crops besides wheat, barley, and oats. This deficiency occurs sometimes on soils that have naturally a neutral or alkaline reaction, as in the cases recorded in Western Australia by Carne (1927), and in South Australia by Samuel and Piper (1928), and sometimes on soils naturally acid in reaction, after so much lime has been added as to make them neutral or alkaline, as in Wales (Davies and Jones, 1931), Rhode Island (Gilbert *et al.*, 1926), Sweden (Arrhenius, 1926), etc. The present case belongs to the second class, and is the first of its kind to be reported in Australia; and though the soil in question does not belong to any type met with in practice, the results obtained show some features of general interest.

Description of Soil.

The area referred to in this work is a plot of land 21 yards by 9 yards, in the grounds of the Agriculture School of the University of Melbourne. The soil is a grey sandy loam to a depth of 18 inches; below this it rapidly becomes heavier, with occasional lumps of yellow clay, until at 30 inches it passes into an impermeable yellow clay which is derived from the Silurian mudstones of the district.

The surface soil, which is homogeneous in texture and appearance to a depth of 18 inches, has the same origin as the adjacent garden beds of the University grounds; this is a sandy loam which contains about 3 per cent. of gravel (above 2 mm. diameter), in the form of ironstone and quartz grains. The fine earth consists of 32 per cent. of coarse sand (2 to 0.2 mm.) 38 of fine sand (0.2 to 0.02 mm.) 15 of silt (0.02 to 0.002 mm.), 12 of clay (below .002 mm.), and about 3 of organic matter. The coarse sand consists of quartz together with some grains of ironstone. The fine sand contains, besides much quartz, 18 per cent. of plagioclase, 6 per cent. of augite, and other basaltic minerals. This augite is mostly angular, and shows no sign of weathering. It appears that the soil consists of material derived from the nearby basalt country, but not normally weathered. (It has been suggested that it may have been made up from road sweepings derived from the use of basalt as road-metal.) Its natural pH value is 5.0. (This figure, like all other pH values recorded in this paper, refers to a 1:1 soil-water suspension measured with the quinhydrone electrode at 20° C.; where the value of a surface soil is quoted, this refers to the 8 inches of surface soil).

The area under discussion has been cropped fairly continuously with numerous varieties of crops, mainly cereals, since 1914, and is protected from birds by wire netting. It has been heavily limed, and contains about 0.2 per cent. $CaCO_3$ in the 9 inches of surface soil; the last liming was a dressing of about 2 tons to the acre in 1923. The effect of this liming has been to bring the pH of the upper 18 inches well into the alkaline range. The reaction of the surface soil varies from 7.2 to 7.7 over the area; this falls to about 7.0 at 18 inches, then 6.5 from 18 to 30 inches, and then rises again to 8.0 at 40 inches, where the heavy clay occurs. It may be remarked that the disease discussed here does not seem to occur on soil derived directly from the Silurian mudstones, even after liming.

Results of Plot Trials.

Experiments in 1928*.

A portion of the area was used in 1928 for various experimental treatments in work carried out by Glynne. For some years previously it had been noted that oats, wheat, and barley had been making poor growth, and it was thought that the sickness of the crops might be due to parasitic organisms in the soil. Sulphur and various sulphur compounds were used, and the treatments comprised varying applications of ammonium sulphate (ranging from 27 to 81 cwt. per acre), sulphur (from

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* In all these experiments the seed was put in during the last ten days of May, and plants were harvested by pulling up in the last fifteen days of December.

6 to 20 cwt. per acre), sulphuric acid (from 1 ton to 3 tons), sodium thiosulphate crystals (from 17 to 75 cwt.), calcium carbonate (from 1 to 3 tons), and various combinations of these last three substances. These tests were replicated over 44 plots each one yard square, on ground that had grown partly wheat and partly oats in the previous season. The plots were sown with Federation wheat, 4 rows per plot. Superphosphate, which had been applied at 2 cwt. per acre for some years past, was omitted this year.

The season of 1928 was a dry one, and the crop was an almost complete failure on all but nine of the plots. These successful plots included the heavier treatments with sulphur (13 cwt. or more) and sulphuric acid (2 tons or more) and the lightest treatment with ammonium sulphate (27 cwt.) The heavier treatments with ammonium sulphate, and all the thiosulphate treatments, were evidently toxic.

The pH values of the 8 inches of surface soil of various plots were determined in December, 1928. It is shown in Table I. that all plots of pH more alkaline than 6.7 were failures irrespective of treatment; but while all the control plots, of pH from 7.4 to 7.7, failed to produce any grain worth mentioning, the nine plots that produced grain had pH values ranging from 5.5 to 6.6, with yields of from 5.3 to 30.3 bushels per acre.

TABLE I.—FEDERATION WHEAT, 1928.

Treatment.	Number of Plots.	Yield, bushels per acre.	
		Average.	Maximum Yield.
All thiosulphates and heavier amm. sulph.	12	Nil (Toxic)	0·0
All treatments and controls, pH 6·7–7·7	11	0·4	1·7
Various treatments, pH 6·0–6·6 ..	6	14·2	26·2
Various treatments, pH < 6·0 ..	3	22·5	29·9

Rainfall, May to November inclusive, 9·65 inches.

No evidence of parasitical attack was found on the control plots, and in her account of the work Glynne (1929) suggested that there was an actual deficiency of sulphur in the soil; but this suggestion cannot be right, as the sulphate sulphur in the surface soil of the control plots is 0.01 per cent., enough for many successive crops.

EXPERIMENTS IN 1929.

In 1929 the same plots were resown with Federation wheat on the same lines, with 2 cwt. per acre superphosphate, but no further treatment. Yields were far better this year, but in spite of high variability among the control plots, the correlation of good yield with low pH was again very noticeable. Control plots ranged from 8.5 to 33.4 bushels, while acidic plots and those previously treated with thiosulphate gave yields ranging from 14.1 to 56.2 bushels. The results are summarized in Table II., where thiosulphate treatments are collected in one group, irrespective of pH. It is remarkable that the best yields on the acidic plots were on those of pH more acid than 6.3. The heavy applications of ammonium sulphate have brought down the pH to 6.7 or less.

TABLE II.—FEDERATION WHEAT AFTER WHEAT, 1929.

Treatment.	Plots.	pH.	Yield, bushels per acre.	
			Average.	Maximum.
All thiosulphates ..	10	6·6–7·6	28·1	56·0
Excluding thiosulphates—				
All below pH 7·0 ..	7	5·6–7·0	34·0	52·3
Intermediate ..	4	7·0–7·2	25·2	32·5
All above pH 7·2 ..	23	7·2–7·8	16·9	33·2

Rainfall, May to November inclusive, 13·99 inches.

EXPERIMENTS IN 1930.

It was thought that the effect of sulphur might have been connected with the intake of nitrogen or phosphorus. A fresh experiment was therefore carried out in 1930, in which the treatments included, beside a 1-ton per acre dressing of sulphur, a 2-cwt. dressing of sodium nitrate and a 4-cwt. dressing of superphosphate. These three treatments were replicated four times each, and with four control plots this gave a total of sixteen plots each of 2 square yards. Free Gallipoli wheat was sown on adjacent soil that had been fallowed the previous year and had accumulated large reserves of nitrate. Most of the nitrate was washed away by heavy rain in early May (before sowing), but there was an ample supply left in all plots; the nitrate nitrogen in the surface soil (0-9 in.) averaged 36 lb. per acre at sowing (May 25), 15 lb. at the end of July, and then fell to a steady value of about 5 lb. through September and October. The nitrate concentration of the various plots during June and July was correlated with the tiller count made on September 19; but when the harvest was taken in December, there was no correlation between autumn or winter nitrate and yield. Nitrate concentration was also unconnected with the use of sulphur or superphosphate. The application of superphosphate had no effect on tillering nor on the final yield; this is not surprising in view of the heavy doses given in former years. But the correlation of final yield with pH was as marked as in previous years. The sulphur oxidized quickly in the autumn and lowered the pH (determined on a composite of six cores), from 7.3-7.6 to 6.3-6.6 within six weeks after application. It would seem that the bacteria responsible for this oxidation are somewhat sensitive to the acidity which they produce, as even in December a considerable amount of sulphur remained unchanged, especially around the roots of the plants. A similar effect has been noted by Rountree (1933) at Renmark. One of the unsulphured plots in this experiment had a consistent acidic reaction, about 6.6. It is not known how this occurred, but this plot is included with the four sulphured plots in Table III., leaving eleven alkaline plots with which to compare the acidic plots. (This seems reasonable since in their whole behaviour the plants on this exceptional plot followed those on the sulphured plots). The high production of tillers per plant is due to the fact that the rows were spaced at an interval of 2 feet.

TABLE III.—FREE GALLIPOLI WHEAT AFTER FALLOW, 1930.

—	No. of Plots.	pH.	Tillers.		Ears.		Grain.		
			Per Plant	Per square yard.	Per square yard.	Per cent. surviving.	Gram per ear.	Bushels per acre.	
								Average.	Range.
Alkaline plots	11	7·2–7·6	5·3	208	126	61	0·69	15·5	10·8–18·8
Acidic plots	5	6·4–6·7	4·8	186	**147**	**79**	**0·86**	**22·6**	20·2–25·3

Standard error of difference of mean, 1·3 bushels per acre.
Rainfall, May to November, 15·30 inches.
Yields significantly different from controls are in black type.

Experiments in 1931.

It had by now seemed likely that the trouble was manganese deficiency, and further tests were then carried out with this in mind. It is known that the good effects of sulphur on certain soils are connected with the flocculating effect of the calcium sulphate that is formed, so a 1-ton gypsum treatment—enough to give a marked flocculation—was included in 1931. Other treatments were 40 lb. each of "chemically pure" crystalline hydrates of $CuSO_4$, $FeSO_4$, $MnSO_4$, and $Ca(MnO_4)_2$; and sulphur at 30 cwt. per acre. Eact treatment was replicated over four plots of 1 square yard each. Free Gallipoli wheat was sown in rows at intervals of 1 foot, with 2 cwt. superphosphate and 2 cwt. calcium nitrate on all plots. Tillers were counted as before in late September, and these showed a mean value of 2.6 per plant, no treatment showing any significant difference from any other. Neither gypsum nor any other salt applied showed any significant difference from the control plots at harvest. Treatments other than sulphur are therefore not entered separately in Table IV., which compares the four sulphured plots with (*a*) the four control plots, and (*b*) sixteen alkaline plots of various treatments, chosen from those neighbouring the sulphured plots.

TABLE IV.—FREE GALLIPOLI WHEAT AFTER OATS AND BARLEY, 1931.

—	No. of Plots.	pH.	Tillers.		Ears.		Grain.		
			Per Plant.	Per square yard.	Per square yard.	Per cent. surviving.	Gram per ear.	Bushels per acre.	
								Mean.	Range.
Alkaline plots (control) ..	4	7·3–7·6	2·69	210	133	63	0·61	14·7	8·9–19·7
Alkaline plots (various) ..	16	7·2–7·7	2·58	214	120	56	0·67	14·3	3·0–34·8
Acidic plots	4	6·3–6·5	2·50	206	141	68	**0·92**	**23·5**	18·7–29·3

Standard error of mean of 4 plots, 2·76 bushels per acre.
Rainfall, May to November, 17.26 inches.
Yields significantly different from controls are in black.

The result was similar to that of 1930. Yields on control and other alkaline plots were very erratic, although the alkalinity was nowhere greater than pH 7.7 nor less than pH 7.2.

On one patch of soil in this test the disease hardly showed itself, so that a sulphured plot in this section could not gain much advantage over the control, while on another patch the sulphured plot gave a yield of 128 gm. to the square yard, where surrounding alkaline plots averaged only 29 gm. This characteristically high variability of the soil with respect to manganese deficiency was partially eliminated from the calculation of the standard error, by Fisher and Wishart's (1930) method of analysis of total variance. The figures, however, underestimate the true effect of the sulphur.

The manganese used in this test was applied at the rate of 10 lb. Mn per acre, in four plots each as $Ca(MnO_4)_2$ and $MnSO_4$ at germination and in four more plots as $MnSO_4$ in early September. It is remarkable that this addition to the soil of about 100 times as much manganese as the crop needed had no perceptible effect on the development of the plant. Chemical analyses at harvest time showed that these plants had taken up no more manganese than the controls. Other tests done on this soil, together with results reported elsewhere by Samuel and

Piper (1928), indicate that at least 30 lb. per acre of soluble manganese applied at sowing to the soil may be needed if such severe deficiency is to be overcome by a surface application. Many disappointing results of the surface application of manganese salts have been due to the use of too small quantities. For example, Turner and Findlay (1932) in Yorkshire attempted to control the disease with 45 lb. per acre of $MnSO_4$ crystals, sprayed over the crop. This was successful to a limited extent, but only if done after the disease had appeared—i.e., the manganese was then absorbed through the leaf, and not through the soil and root.

EXPERIMENTS IN 1932.

Since the deficiency is confined to soils of pH above about 6.7, there are two possible ways of overcoming the unfavourable state of the soil in the field. The soil may be left alkaline and enough manganese be added, preferably as sulphate, to carry the plant through the season, or the reaction of the soil may be permanently changed by the addition of sulphur or any other acidifying agent—a line of action that is feasible only when the $CaCO_3$ in the soil is fairly low, as here. The literature to date contains no comparisons of the effects of these two treatments on the development of the plant. With this comparison in view, therefore, a fresh experiment was carried out in 1932.

In this year Free Gallipoli wheat was sown with 2 cwt. each superphosphate and calcium nitrate; treatments comprised sulphur (1 ton per acre), $MnSO_4$ crystals at germination (1 cwt. and 3 cwt.) and in early September (1 cwt.). Each treatment was replicated four times in square-yard plots, and four control plots were included. The original pH of about 7.5 was brought down by the sulphur only to 6.8-7.0, a figure not low enough to ensure a uniform cure of the deficiency; however, some definite conclusions may be drawn from the results which are summarized in Table V.

TABLE V.—FREE GALLIPOLI WHEAT AFTER WHEAT, 1932.

—	No. of Plots.	Tillers.		Ears.		Grain.		
		Per Plant.	Per square yard.	Per square yard.	Per cent. surviving.	Gram per ear.	Bushels per acre.	
							Mean.	Range.
Control ..	4	2·93	253	130	51	0·98	22·5	11·2–38·9
Sulphur ..	4	3·37	259	**188**	**72**	**1·33**	**44·2**	30·2–59·0
$MnSO_4$—								
1 cwt. (autumn)	4	**3·62**	**303**	**211**	**70**	**1·41**	**53·0**	35·5–78·6
1 cwt. (spring)	4	3·06	259	**167**	**64**	1·06	31·3	18·5–39·1
3 cwt. (autumn)	4	**3·54**	**280**	**176**	**63**	1·17	36·5	20·6–48·0

Standard error of mean of four plots, 7·1 bushels per acre.
Rainfall, May to November, 13·44 inches.
Yields significantly different from controls are in black.

These figures are not as significant as one would desire. For instance, the figure of 53 bushels quoted for 1 cwt. $MnSO_4$ includes an individual plot of 78.6 bushels. The sulphur was not applied heavily enough to control the disease uniformly, and the application of $MnSO_4$ to the surface soil after germination also failed to give complete or uniform control. It has been shown by Scott (1932) at Corny Point, South Australia, that manganese applied with the seed, like superphosphate, gives the plant a better chance of overcoming the deficiency than when applied to the surface after germination; 28 lb. of the hydrated crystals used in this way were more effective than 112 lb. applied to the surface soil.

EXPERIMENTS IN 1933.

The experiment was therefore continued in 1933 on the same plots. Superphosphate, 2 cwt. per acre, was applied with the seed, but no nitrogenous fertilizer was added. Sulphur was again applied, and an extra 10 cwt. per acre now brought the pH to the desired range (6.2-6.5). The plots given $MnSO_4$ late in 1932 were now given $MnSO_4$ sown with the seed, those given 3 cwt. in 1932 were given 1 cwt. applied to the soil after germination, while those given 1 cwt. early in 1932 were left without further manganese in order to determine if there were any residual effect. Results are summarized in Table VI.

TABLE VI.—FREE GALLIPOLI WHEAT AFTER WHEAT, 1933.

—	No. of Plots.	Tillers.		Ears.		Grain.		
		Per Plant.	Per square yard.	Per square yard.	Per cent. surviving.	Gram per ear.	Bushels per acre.	
							Mean.	Range.
Control ..	4	2·23	196	54	27	0·66	6·3	1·1–9·8
Sulphur ..	4	2·47	194	**128**	**66***	**1·30***	**29·4***	22·6–39·6
$MnSO_4$—								
With seed ..	4	**2·75**	**251**	**119**	**47**	**0·82**	**17·4**	9·1–26·8
After germination ..	4	2·47	216	**100**	**46**	**0·93**	**16·5**	9·8–24·7
Residual ..	4	2·46	218	84	**39**	**0·85**	12·8	3·1–21·2

Standard error of mean of four plots, 2·39 bushels per acre.
Rainfall, May to November, 13·53 inches.

Yields significantly different from control are in black. Yields significantly the highest in their respective columns are asterisked.

This season was definitely less favourable than the preceding, and in addition the soil was poor in available nitrogen; the nitrate nitrogen in the top 9 inches of soil at sowing averaged eight parts per million on the alkaline plots and four on the sulphured, acidic plots. When the results of the various years were compared, it was seen that there is a very marked dependence on the weather, as is shown by the complete failure of alkaline plots in the dry season 1928 as compared with 15-bushel yields in the better years 1930 and 1931, and 22.5 bushels in the excellent season 1932, in which the distribution of rainfall was very favourable. It has, in fact, often been noted that manganese deficiency is more marked in a dry year than in a wet one.

Review of Results from Experimental Plots.

While the results reported here are largely confirmatory of previous work, they have peculiar features which in spite of the artificial nature of the soil may have a bearing on the problem in other countries. Some of these are as follows:—

1. *Tillering.*—In each of four years 1930 to 1933, the number of tillers per square yard, counted in late September, was unaffected by sulphur, although the leaves of plants on acidic soil were a darker green. On the other hand, germination was rather adversely affected by sulphur in 1933; and both in 1930 and still more in 1933, the plants on the acidic plots were definitely yellower and poorer in appearance than those on the control, or other alkaline plots, up till the end of August. In 1933 this was correlated with a lower accumulation of nitrate on the acidic soil during the preceding summer and autumn, though it is doubtful if this alone explains the effects noted.

Manganese sulphate, on the other hand, increases the tillering somewhat if it is applied early enough and copiously enough to the soil. If it is applied in the most efficient way—with the seed—it is shown in Table VI. to have a very favourable effect on tillering.

2. *Survival of Tillers to Ears.*—The survival of tillers to ears is much improved by either sulphur or manganese, but in the less favourable year 1933 sulphur was far more effective in this respect. In every year there is a very striking relative improvement of the sulphured plots during October and November, and they show their superiority in every way at harvest.

3. *Size of Ears.*—While the total number of ears is much increased by either treatment, the ears on the sulphured plots gave far more grain than those sown with $MnSO_4$ in 1933. Analysis shows that this superiority exists in both mean number of spikelets per ear, mean number of grains per spikelet, and weight per grain.

Sterility is more marked on the alkaline plots; representative samples from these in 1931 showed that on the average 41 per cent. of the spikelets were sterile, compared with 32 per cent. on the acidic plots. Both grains per spikelet and weight per grain are also higher on the acidic plots—all of which illustrates the importance of manganese for the development of flower and fruit.

The course of the disease seems to vary a good deal according to climate and soil; while in Melbourne the plants on " deficient " soil appear fairly healthy through winter and sicken only when the soil begins to dry in spring, in Western Australia (Carne, 1927) the plants appear to recover in spring after looking poor in August; this recovery by plants that have shown " grey speck " in September has also been observed on inadequately sulphured plots in Melbourne, and is probably connected with mild cases of deficiency only. Odland and Crandall (1932) in Rhode Island found deficiency showing in some years on the spring crops and not on the autumn, and vice versa in other years.

4. *Residual Effect of $MnSO_4$.*—The effect of heavy application of $MnSO_4$ a year earlier is still seen in a somewhat healthier growth, but is strikingly small.

5. *Effect of Heavy Applications of $MnSO_4$.*—The comparative failure in 1932 of the crop on soil given 3 cwt. per acre of $MnSO_4$ crystals is striking; however, the yield is not significantly lower than that of the 1 cwt. plots, and the difference only shows how variable the soil is with regard to the deficiency-effect. (See manganese content of grain, below.)

6. *Effect of Nitrates.*—Nitrates are said to make the disease worse. In this work, the deficiency has been more marked on plots of higher nitrate status, both in 1930 and in 1933.

7. *Effect of Ammonium Salts.*—Ammonium sulphate has been recommended on grounds of economy for grey-speck in countries of northern Europe, notably by Arrhenius (1926) in dealing with lime-induced grey-speck on podzolic sands in south-western Sweden. Its good effect is clearly related to its acidifying action, though it is hard to see how it could be as efficient in the small amounts used (2 cwt.) as is sulphur in large doses. In the work reported here, the amounts of ammonium sulphate used in 1928 (Table I.) were so huge as to lower the pH to a point where manganese is available; the effect seems to have nothing to do with the amount of soluble nitrogen in the soil, which in 1930 was no higher on the ammonium sulphate plots of 1928 than on the controls, although the treated plots were very much healthier.

8. *Effect of Thiosulphates.*—Thiosulphates are oxidized in the soil according to the ultimate scheme,

$$HO_2 + Na_2S_2O_3 + 2O_2 \rightarrow 2NaHSO_4,$$

but in many plots the fall in alkalinity due to the $NaHSO_4$ produced was not very marked; in fact, the best plot in 1929, yielding at the rate of 56 bushels per acre, after a 75-cwt. dose of $Na_2S_2O_3.5H_2O$ in early 1928, had a pH in bulk sample (surface 8 inches) of 7.3. It is possible that there was a local production of high enough acidity to overcome the deficiency. Otherwise, the highly reducing nature of the thiosulphate ion may have been responsible for the effect noted. (This will be discussed later.)

9. *pH Value of Profile.*—The pH of the soil falls to 6.5 at 18 inches. At such a value one would expect a fair availability of manganese, and the failure of a wheat plant to collect its necessary fraction of a milligram from this level may be partly due to the fact that it is essential for the manganese to be at hand from the earliest stages of growth. (However, spraying $MnSO_4$ solution on very sick oat plants growing on this soil, in early September, led in about a week to a recovery from an apparently hopeless position, and finally these plants yielded reasonable amounts of grain.) But a plant already suffering from deficiency would not be likely to explore the 18-inch level at all thoroughly.

10. *Varietal Differences.*—It has often been noted that different varieties show very different degrees of tolerance (e.g., Davies and Jones, 1931). This effect was very marked in this work also, from observations on varieties of wheat, barley, and oats which were grown in connexion with other work. Common wheat was found to be less sensitive than emmer and macaroni, while single varieties of spelt and "mummy" were about as tolerant of deficiency as most varieties of common wheat. Barley is generally more tolerant than oats, but the most tolerant oat vareties (viz., Lachlan, and still more Palestine) are better than some barley varieties (such as Gatami and Hänchen). But there are many oat varieties which are so sensitive that they may die in September, an extreme case being Dawn (a local variety), though others such as Fulghum and Algerian are also very sensitive. Of the barleys, Pryor and Moira are the least sensitive.

11.—*Manganese in Dry Matter and Requirements of Various Plants.*—The total manganese in the dry matter of a plant is closely connected with its availability in the soil. The manganese content of healthy plants of wheat, oats, and barley ranges from 15 to over 200 parts per million (p.p.m.) of dry matter; a figure of less than 15 p.p.m. indicates a probable deficiency. The difference in sensitiveness of various plants to this deficiency has already been remarked on; it is very striking to see how invariably rye yields a splendid crop while the neighbouring row of oats or wheat is languishing. Wimmera rye-grass (*Lolium subulatum*) and wild vetches (*Vicia sativa*) also grow vigorously to maturity on this soil, which is evidently highly fertile for all but sensitive plants. In fact, weeds of all kinds have been observed to flourish; and during the autumn of 1934 it was observed that alkaline plots of the previous year's experiments were supporting a vigorous growth of weeds, largely *Sonchus oleraceus, Malva rotundifolia,* and *Portulaca oleracea,* while the acidic plots were almost bare. This avoidance of acidic plots may have been due to the direct effect of the sulphur, in lowering the pH, causing a very high concentration of $CaSO_4$, or producing other unfavourable oxidation products. It was incidentally noted in 1930 that the activity of *Azotobacter* was adversely affected by sulphuring. These facts may be compared with the poor growth shown also by wheat on the acidic soil up till late in August. Rye, rye-grass, and the tolerant barley variety Pryor, were sampled in the spring of 1931 and the whole plants were analyzed for manganese. It was found in each case that the total manganese was only 10 to 11 p.p.m. of dry matter. It would appear, therefore, in accordance with Samuel and Piper's work on culture solutions, that tolerance implies a lower need for manganese, rather than a greater power to obtain it, though no doubt plants differ in this power also; of course, the *total* Mn in the crop of the tolerant plant may be considerable. The question is bound up with that of the function of manganese, about which very little is known as yet.

TABLE VII.—MANGANESE IN GRAIN OF WHEAT.

Treatment.	Sample.	Year.	Yield of oven-dry grain at selected point, grams per square yard.	Mn parts per million dry matter.	Mn in grain.	
					Milligrams per square yard.	Grams per acre.
Control (alkaline) ..	1	1930	77	12	0·92	4·5
	2	1930	59	8	0·47	2·3
	3	1931	73	9	0·66	3·2
	4	1932	65	12	0·78	3·8
	5	1932	39	10	0·39	1·9
	6	1933	50	5·5	0·28	1·3
$MnSO_4$ in autumn ..	7	1931	69	10	0·69	3·3
	8	1932	440	12	5·28	25·6
	9	1932	189	30	5·67	27·5
	10	1933	45	12	0·54	2·6
	11	1933	135	32	4·33	2·1
Sulphur (acidic) ..	12	1930	103	21	2·16	10·5
	13	1932	119	7	0·83	4·5
	14	1932	324	27	8·75	42·5
	15	1933	136	32	4·35	21·1

The figures collected in Table VII. refer only to the grain of Free Gallipoli wheat. The table shows, firstly, that the manganese content of grain from alkaline, deficient soil (samples 1 to 6) ranges from 5.5 to 12 p.p.m., the yields being mainly poor. Of samples 7 to 11, from soil to which $MnSO_4$ had been applied, Nos. 8, 9, and 11 showed a marked response to the applied manganese. The low proportion of manganese in the grain of the enormous crop of No. 8 is striking; however, the total Mn removed by the crop is quite high. Information is not available about the Mn in the straw. Samples 7 and 10 showed symptoms of Mn deficiency, and both the yield and the Mn content are of the same order as in the control plots—in each case the added $MnSO_4$ was presumably precipitated out of reach of the main mass of roots. Sample 10 was collected from soil that had been treated with 3 cwt. per acre of $MnSO_4$ crystals; it gives clear evidence that the comparative failure of these 3-cwt. plot was connected with very low local availability of added manganese. Samples 12, 14, and 15 show the typical increase in concentration in Mn that follows acidification. Sample 13 was taken from an inadequately sulphured patch of pH 7.0, where the yield was disappointing and symptoms of deficiency were seen. The figure 7 p.p.m. again recalls the alkaline plots.

General Discussion of Availability of Manganese in Soil.

These experiments make it of interest to review the question of the availability of manganese in the soil. The nature of this availability has been discussed by several workers, a useful summary being given by Piper (1931). Work in South Australia has made it clear that figures for the total manganese in the soil (above a certain minimum), or for strong or dilute acid extracts, have little or no bearing on the problem; a healthy soil may well yield less soluble manganese to an extracting acid than will a deficient soil (Samuel and Piper, 1928). Soils more acid than pH 6.7 do not show the disease. On such soils manganese compounds do no good, and on more definitely acidic soils they may be harmful. On the alkaline side of this boundary line (especially beyond pH 7.0) the manganous ion may be represented by the bicarbonate, by exchangeable manganese, or by basic compounds (phosphate, carbonate, silicate) which as Britton (1930) showed, begin to appear as bulky precipitates below pH 7. The existence of such basic compounds makes it irrelevant in this regard to quote the laboratory precipitation of manganous hydroxide from chloride solutions at pH 8 to 9. It is probably safe to say, however, that exchangeable manganese is the only important store of the bivalent ion available in alkaline soils of any considerable degree of maturity.

At pH values above 7, bivalent manganese is easily oxidized in the air to a higher valence. The composition of this manganic material is not constant, but it may be conventionally written as the dioxide, MnO_2. Piper showed that water-soluble manganese (as $MnSO_4$) was largely converted* into the " dioxide " within

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* His method, however, as is shown later in this paper, is bound to underestimate the extent of this conversion (Piper, 1931, p. 766).

three weeks when it was added to a soil of high pH, whether deficient or not, at a water content well below saturation. As the dioxide is practically insoluble it follows that soluble manganese compounds, when added to a soil of high pH, will be precipitated at the surface even more effectively than other elements (such as potassium) which are held by the soil only in the form of exchangeable bases. The failure of light applications of $MnSO_4$ to overcome manganese deficiency may be explained by the complete precipitation of manganese in the surface inch of soil, which can be reached by only a small proportion of the root system, i.e., the failure is positional, not physiological. This aspect of availability is discussed in general by Spencer and Stewart (1934). This concentration of manganese in the surface soil under certain conditions was well shown by Bishop (1928), who found that the surface soil at a depth of 3 inches under a Eucalyptus tree contained 3 to 7 per cent. Mn, derived from the leaves, twigs, and bark, while the subsoil, and the surface soil away from the tree, contained 0.25 to 0.6 per cent. Mn.

Previous Hypotheses.

The scheme put forward by Piper may be summarized as follows:—Manganese is absorbed only as the bivalent ion, and MnO_2 is unavailable. While at low pH values Mn exists in solution in fair concentration, it exists at high pH only as the bivalent exchangeable base or as insoluble dioxide. There is an equilibrium between these forms, swinging towards the exchangeable form as conditions favour reduction, and towards the dioxide as conditions favour oxidation. The occurrence of deficiency on neutral and alkaline soils must therefore depend on the oxidation-reduction potential (E_h) of the soil.

Under fully aerobic conditions, the effect of the very low solubility of the manganic compounds would be to reduce the maximum possible concentration of manganous ions in equilibrium with the atmosphere to a very low figure, especially if bacteria were also oxidizing manganous to manganic compounds.

Steenbjerg (1933) accepts the same explanation as Piper. He discusses the prevalence of the disease on light, sandy soils, and concludes (p. 428), " The content of available manganese in the soil is controlled by (1) the reaction, and (2) the oxidation-reduction conditions."

This hypothesis is supported by the fact that some manganese present in soils as MnO_2 may be brought back into solution by reducing conditions; this may be connected with the good effects of thiosulphate referred to earlier in this paper, but is best shown by waterlogging, especially in the presence of a source of bacterial energy such as glucose. Piper used for many of his tests the deficient soil that occurs locally around Mount Gambier (S. Aust.). This soil type has been described by Prescott and Piper (1931); it is a highly immature volcanic ash, containing variable quantities of $CaCO_3$. The University soil appears to be, in fact, a synthetic imitation of the Mount Gambier soil, being light, permeable, calcareous, well-drained, and highly immature, with an abundance of primary minerals such as augite in the fine sand, and of good fertility except for the manganese deficiency. The similarity extends also to the very low availability of added $MnSO_4$. For the effect of waterlogging, Piper compared a sample from Mount Gambier, of pH 7.4, with a sample from the experimental fields at the Waite Institute, Glen Osmond—a a red-brown earth, also of pH 7.4, on which no sign of manganese deficiency had been observed. These soils were waterlogged under various conditions for three weeks; in every case the water-soluble manganese was increased by this treatment, though the healthy soil yielded always more than the deficient soil. In all cases pot tests showed that deficient soils, after a long enough waterlogging, became free from deficiency during the following few months at least, and possibly for much longer.

It is thus implied that healthy soils of high pH either have a lower oxidation-reduction potential, or are capable of developing one more easily, than deficient soils. It is, of course, conceivable that even a well-drained soil on account of natural heterogeneity might contain numerous tiny waterlogged patches in which the dioxide might be reduced. However, the following facts show that this explanation cannot be right.

EXPERIMENTS ON WATERLOGGING.

The alkaline "deficient" University soil, sampled to 8 inches, was compared with the sulphured, healthy soil from neighbouring plots, and with the surface soil from Dooen, in the Wimmera district of Victoria. This soil is typical of the so-called "Wimmera Black" soil. It is a grey self-mulching clay, slightly calcareous and of pH 7.3; it produces good crops of wheat in a normal season, and the dry matter of the crop contains 90 p.p.m. of manganese.

Samples of the deficient (alkaline) and of the healthy (sulphured) University soil, and of the Dooen soil, were waterlogged at laboratory temperatures (about 10° C.) both with and without the addition of 0.25 per cent. of their weight of glucose, and at the end of three weeks were shaken for an hour with enough water to bring the soil : water ration to 1 : 5, and filtered through candle filters. This was the method used by Piper, whose figures for the Mount Gambier and Glen Osmond soils are also included in Table VIII. for comparison, though doubtless the temperature of waterlogging was considerably higher in his experiments.

TABLE VIII.—AMOUNTS OF MANGANESE MADE WATER-SOLUBLE BY THREE WEEKS' WATERLOGGING.

(Parts per million.)

——	University Soil.		Dooen.	Mount Gambier.	Glen Osmond.
	Alkaline.	Sulphured.			
Waterlogged without glucose ..	0·08	2·8	0·02	1·2	6·3
Waterlogged with 0·25 per cent. glucose	2·5	11·8	2·6	5·4	13·0

It will be seen that the waterlogging has brought manganese into solution in greatest amounts in the Glen Osmond and healthy (sulphured) University soils; but the equally healthy Dooen soil has yielded less soluble manganese than the two deficient soils studied. In another experiment on the Dooen soil not a trace was found. The waterlogging with glucose shows a similar order of results.

Even under intensely reducing conditions the Dooen soil cannot produce manganous ions for the soil solution. But, in fact, the Dooen soil is more actively *oxidizing* than the deficient University soil. This was shown by shaking each soil with solutions of benzidine and of guaiacum, which are turned blue by actively oxidizing soils. The Dooen soil gave a good colour with each reagent, while the University soil gave no colour. This test will be seen to support the suggestion put forward later in this paper.

EXPERIMENTS WITH LEACHING REAGENTS.

Piper also found that the Mount Gambier soil yielded only 4.2 p.p.m. of soluble manganese to rapid leaching with cold 0.05N sulphuric acid, while the healthy Glen Osmond soil yielded 65.7 p.p.m. Further leaching with the same acid containing 0.2 per cent. quinol in each case dissolved relatively huge amounts of manganese, presumably from the state of MnO_2 (again using this formula in a conventional way). This supports his idea that a deficient soil contains only small quantities of exchangeable manganese, while it may be rich in the dioxide.

The same extracting method was therefore tried on both deficient (alkaline) and healthy (sulphured) soil from the University plots, and also on alkaline soil to which manganese sulphate had been added. In each case 30 gm. samples of air-dry soil were leached first with 500 c.c. of 0.05N H_2SO_4, then with 500 c.c. of 0.05N H_2SO_4 containing 1 gm. quinol in solution.

TABLE IX.—AMOUNTS OF MANGANESE DISSOLVED FROM SOILS BY LEACHING WITH VARIOUS REAGENTS.

(Parts per million.)

(*a*) Without quinol. (*b*) With 0.2 per cent. quinol.

Soil.	pH.	Dissolved by ·05N H_2SO_4.		Dissolved by ammonium acetate pH 4·6.		Dissolved by ammonium acetate pH 7·0.		Total soluble in conc. HCl.
		(*a*)	(*b*)	(*a*)	(*b*)	(*a*)	(*b*)	
Glen Osmond	7·4*	66*	315*	..	..	..	..	260*
Mount Gambier ..	7·4*	4*	124*	7·5	18	0·2	3·7	324*
University alkaline ..	7·3	34	11	12	..	1	11	160
„ + 30 parts per million Mn	7·3	50	23	..	..	3	39	..
University sulphured ..	6·1	44	11	..	..	5	13	..
Dooen	7·3	97	166	10	170	Tr.	137	370
Tatchera sand	8·6	40	..	40	..	3·6	154	..
Penola	6·9*	0	<1	..	..	Tr.	0·4	50*
Corny Point	8·0*	3	8	..	..	2·6	8·0	187*

* These figures are taken from Piper (1931), and Samuel and Piper (1928).

Piper's figures for Glen Osmond and Mount Gambier are also included for comparison in Table IX.

It will be seen that in spite of the mineralogical and physical similarities of the soils from the University and from Mount Gambier, the results here reported seem incompatible with the theory discussed at the beginning of this section. There is little significant difference in acid-soluble manganese between deficient and healthy samples of University soil and the healthy Glen Osmond soil; but the most striking fact about the sulphuric acid extracts is the very low figure for the "dioxide" values (quinol-soluble manganese) of the former.

Further tests were therefore made by leaching 30 gm. of soil with 500 c.c. of a normal solution of ammonium acetate at pH 7.0, followed by further leaching of the residual soil with the same solution containing 0.2 per cent. quinol. In a few cases additional tests were made in which the solution at pH 7.0 was replaced by a solution of ammonium acetate and acetic acid, of pH 4.6, normal with respect to total acetate. In each case the soil was first warmed to 50° with 100 c.c. of the leaching solution, then cooled and filtered under gentle suction, using successive portions of 50 c.c. of the leaching solution at room temperature. The whole 500 c.c. took about seven hours to filter.

Ammonium acetate was chosen partly for its buffer capacity as emphasized by Schollenberger and Dreibelbis, who proposed its use (1928), and partly because it can be completely destroyed in the leachate, so making it possible to use small amounts of liquid for estimating the very small quantities of manganese sometimes present. In spite of these advantages, Steenbjerg

(1933) has shown that ammonium is much less efficient than calcium or magnesium in replacing manganese from alkaline soil. However, the differences between various soils found in this work would almost certainly reappear with other leaching agents so long as the pH of leaching were standardized.

Table IX. summarizes the results, together with Piper's figures already referred to. The soils tested included the above-mentioned soils, and also the following:—

(1) A sample of Tatchera sand, a Mallee soil, from Tresco (Vic.). This soil has been described by Taylor *et al.* (1933). It has a pH of 8.6, and is perhaps representative of the lighter soils of the Victorian Mallee. Manganese deficiency has never yet been found on such a soil.

(2) A heavy clay from Penola (S. Aust.). This is a reclaimed swamp, of pH 6.9, is highly deficient, and has been experimented on by Piper (1931).

(3) A grey highly calcareous soil from Corny Point (S. Aust.), of pH 8.0. This represents about 10,000 acres of deficient country, and work has been reported on it by Piper and by Scott (1932).

Comparison of results for manganese replaced at various pH values shows how quickly this is repressed by growing alkalinity, until at pH 7 the figures are all small, especially for the Dooen soil, for which not a trace of manganese could be detected. The figures for the "dioxide" manganese, however, show a huge contrast between the deficient and healthy soils; the former have very little at pH 7, the latter have a copious supply at all pH values. Since the pH value of the soil solution in the alkaline and calcareous soils here compared would seldom fall much below 7.0, it would appear that the secret of the success of the Wimmera soil is connected with the presence, not of exchangeable manganese, but of *active* manganese dioxide, which can be easily reduced at a high pH value. The Dooen soil contains more than twelve times as much of this component as does the "deficient" soil from the University. This may explain the results obtained with benzidine and with guaiacum, referred to above.

While healthy alkaline soils *may* be higher in manganese set free by waterlogging (e.g., Glen Osmond) or exchangeable at pH 7.0 (e.g., Tatchera sand), than are deficient soils, these tests fail for the Dooen soil. There is only one respect in which all healthy and deficient soils of high pH are distinguished—viz., in their content of active "dioxide" which is brought into solution by 0.2 per cent. quinol in normal ammonium acetate at pH 7.0. It appears, therefore, that quinol is a chemical metaphor for the plant roots in much the same style as has been suggested for dilute citric acid in the problem of phosphate availability. This can happen only in one or both of two ways; reducing conditions may be set up at the surface of the root providing a direct source of manganous ions from the more active dioxide, or else colloidal manganic oxide, such as readily oxidizes quinol, can be directly absorbed by the plant. In favour of the former possibility, one may quote the observation of Schreiner, Sullivan, and Reid (1910), that selenites may be reduced to selenium on the surface of a root—a reaction that calls for a higher reducing power at pH 7 than the reduction of manganese dioxide. The possibility of colloidal absorption is not generally favoured, though Comber (1922) has argued in its favour, and work on the water-soluble phosphate of soils points to it (Parker and Pierre, 1928), while the very considerable intake of silica into grasses and cereals growing on soils of pH 5 or less may well be colloidal. Such colloidal material, however, would seem to be a "second choice," being less available than ordinary ions, and therefore needing to be present in fairly copious amount to avoid a deficiency. In either case, one must dispense with the belief in an intermediate condition of manganous ions in the soil solution, especially in view of the failure of the Dooen soil to produce more than a trace of soluble manganese under a waterlogging far more drastic than would occur in the field even in a wet winter (since the drainage of this soil is good.)

The success of $KMnO_4$ in curing manganese deficiency in some cases (Gilbert *et al.* 1926; Samuel and Piper, 1928) may also be explained if it is the most active form of "manganese dioxide" which prevents deficiency at high pH values. $KMnO_4$ can only *increase* the oxidation-reduction potential, so could only do harm if that were the important factor. However, this salt must change very quickly to a bulky mass of colloidal MnO_2, which is probably very easily available. Reports on the success of applications of MnO_2 as such are conflicting, probably because the physical state of the MnO_2 is so important.

It is interesting to note that apparently only two cases have been reported of manganese deficiency occurring on soils of basaltic or similar origin—namely, the two highly immature soils from Mt. Gambier and the University. Evidently the slow supply of manganese coming from the rich reserve of primary minerals is not enough for the purpose.

Oxidizing Power of Manganic Compounds.

It is well known that rising alkalinity increases the power of solutions of given strength of either Fe^{++} or Mn^{++} to reduce many oxidizing agents such as oxygen. The interaction with oxygen is clearly seen in the rapid deepening in colour of ferrous and manganous hydroxides as soon as they are precipitated. The prior formation of an actual basic precipitate of the bivalent form is not necessary to this oxidation, since ammoniacal solutions of $MnSO_4$, if exposed to the air, show a rapid separation of a manganic deposit, while all but strongly acidic solutions of $FeSO_4$ are similarly attacked. In each case this effect is due to the very low solubility of the hydroxide of the more highly oxidized ion. The oxidation-reduction potential (E_1) at 30°C. of an inert electrode dipping into a solution containing ferric and ferrous ions in molar concentrations per liter, $[Fe^{+++}]$ and $[Fe^{++}]$ respectively, is given by (1), where the low concentrations considered may be taken as equal to activities:—

$$E_1 = 0{\cdot}74 + 0{\cdot}06 \log \frac{[Fe^{+++}]}{[Fe^{++}]} \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

If the solution is in equilibrium with solid $Fe(OH)_3$ (which might well be the case at pH greater than 3) one can combine this formula with the solubility product of $Fe(OH)_3$, namely:—

$$[Fe^{+++}] \cdot [OH^-]^3 = 10^{-36},$$

or multiplying by $[H^+]^3$, and using the relation $[H^+]^3 \cdot [OH^-]^3 = 10^{-42}$,

$$[Fe^{+++}] = 10^6 [H^+]^3$$

(1) now becomes—

$$E_1 = 0{\cdot}74 + {\cdot}06 \log \frac{10^6[H^+]^3}{[Fe^{++}]}$$

$$= 0{\cdot}74 + 0{\cdot}36 - {\cdot}18\,\mathrm{pH} - {\cdot}06 \log [Fe^{++}]$$

One may arbitrarily fix $[Fe^{++}]$ at 10^{-5} (about 0·5 parts per million of soil solution), since it is unlikely to exceed such a figure. If $[Fe^{++}]$ is thus considered constant, this gives:—

$$E_1 = 1{\cdot}40 - {\cdot}18\,\mathrm{pH} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (2)$$

This great fall in oxidation potential with rising pH is due to the removal of ferric ion in an insoluble form; a similar fall may be obtained without a change in pH by the addition of ions such as F^- or $C_2O_4^{--}$, which form stable complexes with Fe^{+++} and so again remove it from the system. In such a case, ferrous salts can reduce cupric salts, as described by Müller (1908).

In the case of manganese, the potential for a solution in contact with solid MnO_2 is given different values by different workers; as the accurate value is of minor importance in this argument, we may use the value given by Latimer and Hildebrand (1929):—

$$E_2 = 1{\cdot}33 + {\cdot}03 \log \frac{[H^+]^4}{[Mn^{++}]} \quad \ldots \quad \ldots \quad \ldots \quad (3)$$

Keeping $[Mn^{++}]$ constant at 10^{-5}, this gives

$$E_2 = 1{\cdot}48 - {\cdot}12\,\mathrm{pH} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (4)$$

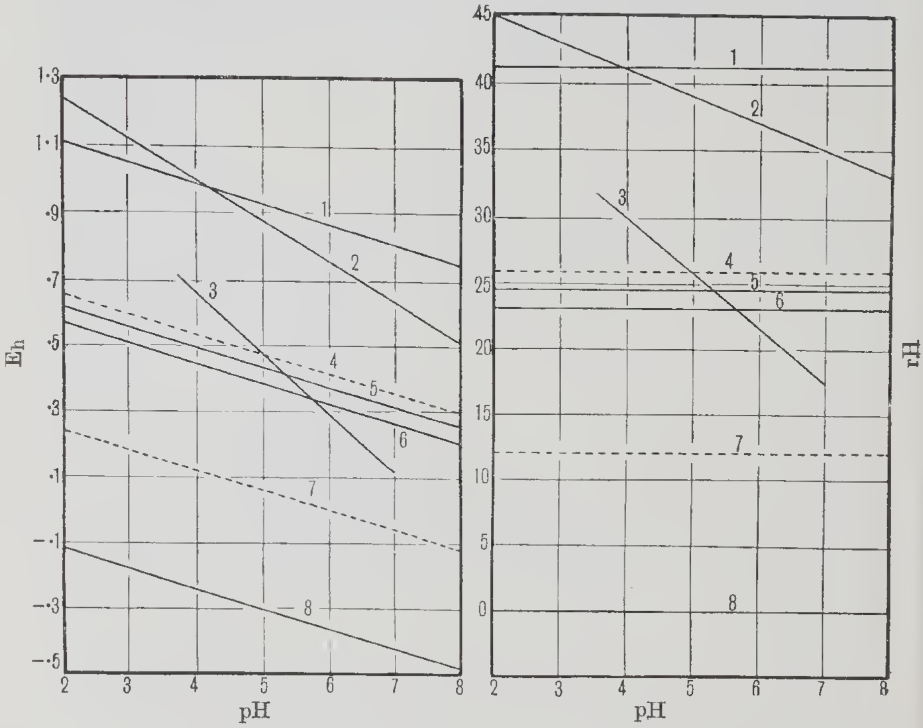
The rate of fall of potential with rising pH is three times (for iron) and twice (for manganese) the rate of 0.06 volts per pH shown by the oxygen, quinhydrone, and hydrogen electrodes. It follows therefore that the compounds $Fe(OH)_3$ and MnO_2 are much stronger oxidizing agents and so more easily reduced, in an acid than in a neutral environment. The importance of this fact (illustrated in Fig. 1) has not been realized enough by soil scientists, although the use of excess acid to prevent or destroy any MnO_2 precipitate has long been a commonplace of titrations involving $KMnO_4$ and oxalates. Very strong acidification raises MnO_2 into the region of oxygen overvoltage—solutions in fairly strong H_2SO_4, for instance, slowly evolve oxygen on standing.

The use of the term rH is convenient here. This may be taken (for 30° C.) as the thirtieth part of the difference in millivolts between the system considered and the normal hydrogen electrode at the same pH; the rH value of the system $MnO_2 — Mn^{++}$ at pH 0 from (4) would be 49.3; and at pH 7 it would be 35.3. The iron system would have rH = 34.3 at pH 3, and 18.3 at pH 7—i.e., a fall of two and four rH units, respectively, for every rise of one pH unit.

As yet, little is known of the factors controlling the E_h (oxidation-reduction potential) and the rH of soils. Heintze, however, has shown (1934) that the soils which she studied lie in a range of rH just above the quinhydrone system, and this rH seems to be independent of pH. However, it must be emphasized that in so far as the potential is set by the system (Mn^{++}, sat. MnO_2), it should give a lower rH on liming and a higher rH on acidification.

This point was excellently brought out by Sen-Gupta (1925), who measured the amount of phenol which was destroyed by rapid oxidation when it was added to various soils which had been brought to a low pH value by previous treatment with an acid, followed by a leaching out of the free acid. It was shown conclusively that this oxidizing power of soils depended on their content of MnO_2; $Fe_2(SO_4)_3$ was only very feebly active. This power could be destroyed by mineral acids stronger than 4.5 N, especially by concentrated HCl—i.e., the conditions where MnO_2 has its highest rH, so is most easily destroyed. So long as this limit was not exceeded, the stronger the acid treatment the better the destruction of the phenol. It was also found that the power of the soil to destroy phenol was removed by treatment with citric or tartaric acid. These acids, being strongly reducing, can dissolve MnO_2, being themselves oxidized in the process; working on the manganiferous soils of Hawaii, Dean and Dean (1929) noticed that citric acid was largely destroyed by the active MnO_2 that was present, so that citric acid extractions for phosphate were often useless.

But if the pH of the soil was raised to the alkaline range (by washing with alkali), phenol was no longer destroyed; re-acidifying largely restored the power to oxidize phenol rapidly. There must obviously have been a big difference in pH values between the alkali-treated and the acid-treated samples—probably enough to change the gap of oxidation-reduction potential between soil and phenol by 300 to 400 millivolts or 10 to 13 rH units; the actual pH figures, however, were apparently not measured.



1 (*a*) FIG. 1. 1 (*b*)

FIG. 1.—1 (*a*) E_h values, and 1 (*b*), rH values, of various systems, numbered as follows:—

1. $O_2 + 4H^+ + 4e = 2H_2O$
2. $MnO_2 + 4H^+ + 2e = Mn^{++} (10^{-5}M) + 2H_2O$
3. $Fe(OH)_3 + 3H^+ + e = Fe^{++} (10^{-5}M) + 3H_2O$
4. Normal Soil
5. $H_2SeO_3 + 4H^+ + 4e = Se + 3H_2O$
6. $C_6H_4O_2 + 2H^+ + 2e = C_6H_6O_2$
7. Waterlogged Soil
8. $2H^+ + 2e = H_2$.

Most of Sen-Gupta's tests were made on soil that was treated with acid for 20 minutes, then washed free of acid and tested with the phenol. If the acid was allowed to stand on the soil for some days, the phenol-destroying power of the soil gradually decreased. It seems very likely that during this period the organic matter of the soil gradually reduced the MnO_2—an effect that would be impossible at the pH found in the field, on account of the very different gap of oxidation-reduction potential between MnO_2 and organic matter at the two pH values of about 1–2 and 6–7 respectively. Soils rich in organic matter were less active than others; this may have been due to the absence of much MnO_2 in the original soil, or to its partial destruction by organic matter on acidifying.

Figs. 1 (*a*) and 1 (*b*) represent graphically the main issues in this argument. 1 (*a*) shows the actual difference in potential (E_h) between the various systems and the normal hydrogen electrode, while 1 (*b*) shows the same systems reduced to the rH scale, on which the value for the hydrogen electrode at all pH values is taken as zero. The systems (Mn^{++}, MnO_2) and (Fe^{++}, $Fe(OH)_3$) are plotted in each case for an arbitrary concentration of 10^{-5} gm.–ions per liter of the bivalent ion (such as would not be likely to be greatly exceeded) in equilibrium with the solid oxide or hydroxide of higher valence. The absolute level of the E_h and rH lines must depend on this arbitrary concentration, and incidentally there is no agreement about the normal potential of the former system. However, the object of the graph is to illustrate the smallness of the rH gap between MnO_2 and normal soils at high pH, as contrasted with the bigger gap between MnO_2 and normal soils at low pH, and that between MnO_2 and waterlogged soils at high pH values. The rH of normal soils is a rough average taken from Heintze (1934), while that of waterlogged soils is a similar average taken from Gillespie (1920), who found a fall due to waterlogging of about 13 rH units for the soils under test. It is of course not implied that these potentials of soils necessarily follow a straight-line formula; the lines as drawn are meant to represent the most typical results obtained to date.

Quinhydrone Drift.

It is known that the pH values of certain soils are hard to measure accurately with the quinhydrone electrode. The potential shows a rapid drift in the direction of increasing alkalinity, amounting to several tenths of a pH unit within a few seconds after adding the quinhydrone. This effect has been studied by several workers, and the information was well summarized by Best (1931), who showed that it is due to "active" MnO_2, which rapidly oxidizes the quinol of the quinhydrone. The $Mn(OH)_2$ thus produced is an active base, as pointed out by Schollenberger (1928), so that the pH of the suspension steadily rises. Best estimated this "active MnO_2" by determining the manganese liberated from the soil by 0.05N $H_2SO_4 + 0.2$ per cent. quinol.

It would seem from the soil analyses quoted in Table IX., and from the above account of Sen-Gupta's work, that such a method is liable to lead to too high a figure. It is the MnO_2 active at the pH of the soil (usually 6 to 7) which is responsible for "quinhydrone drift", and it appears more satisfactory to estimate such MnO_2 by leaching with a dilute solution of quinol at approximately the actual pH of the soil, as is done, for example, in the neutral ammonium acetate method described above. Sen-Gupta's test of the destruction of phenol is a qualitative test similar to Best's, showing only acid-active MnO_2. Other qualitative tests for active MnO_2 are carried out at the soil's own pH, viz., the blue colour developed with alcoholic guaiacum or with benzidine, and the green colour developed on long standing with KCNS, as was discussed by Brewer and Carr (1926).

The concentrations of MnO_2 found in healthy alkaline soils in this work are of the order of 0.01 per cent. Mn. This is below the level at which Best found that the quinhydrone electrode was liable to "drift". Hence, one need not expect that all healthy alkaline soils would show a "quinhydrone drift", but it must follow from the hypothesis suggested in this paper that a soil showing such a drift cannot be associated with manganese deficiency. It is interesting to note that of the soils listed by Best, the deficient Mount Gambier soil does not drift, while the healthy Glen Osmond soil does so. Schollenberger (1930) describes how a "drifting" soil lost its power to drift after leaks of natural gas had made it anaerobic, so reducing MnO_2 to $Mn(OH)_2$.

Nature of Manganic Compounds ("MnO_2") in Soil.

The state of this active manganic material in the soil is not at all clear. It appears that the manganic oxides may form a continuous series, from the most active to the most inert; for convenience, one may separate these oxides into four classes—(*a*) extremely active, capable of oxidizing quinol at pH 7 and of oxidizing the organic matter of the soil rapidly in sulphuric acid suspension (pH 1.5 to 2); (*b*) also very active, capable of oxidizing quinol at pH 7, but only slowly attacking organic matter at pH 1.5-2; (*c*) moderately active, capable of oxidizing quinol at about pH 2 or $Na_2S_2O_4$ at pH 7 (see Table X. below); and (*d*) inert (including all the remaining manganic compound). The *total* Mn of the soil also includes (*e*) bivalent Mn present in the minerals of sand, silt, and clay.

Best, for instance, (1931), found that a soil from Bundaberg (Queensland), which gave a bad drift with quinhydrone, yielded 0.32 per cent. of manganese to dilute sulphuric acid, and a further 0.27 per cent. on adding quinol or ferrous ammonium sulphate to the sulphuric acid. These two figures would correspond respectively to (*a*) and to (*b*) + (*c*). Sen-Gupta's test for "active

MnO_2" would also give (*b*) + (*c*). Only (*a*) and (*b*), however, are concerned in insuring against manganese deficiency, causing "quinhydrone drift", or reacting with guaiacum.

It is suggested that this difference in activity is to be put in the same category as the "ageing" of colloids. The active fraction (*a*) is then analogous to the fresh precipitate obtained in the reaction between a permanganate and a manganous salt. Such a precipitate, after thorough washing with 0.05N H_2SO_4, when mixed with Mt. Gambier soil (also well leached with the same acid), will give large quantities of Mn to the solution on further leaching with 0.05N H_2SO_4. (Probably most normal soils will do the same as Mt. Gambier.) Schollenberger (1928) ascribed the presence of Mn. in a filtrate of a mixture of soil and 0.1N HCl, to the same reduction. The fraction (*d*) on the other hand is analogous to the most resistant residues of pyrolusite, which dissolve in oxalic and sulphuric acid only after prolonged boiling. In this case, all the fractions are thermodynamically capable of performing the reactions described, but they differ enormously in the speed of reaction.

Robinson (1929) and Sen-Gupta (1925) agree that active MnO_2 is present mainly in the coarser fractions. While this statement is no doubt true of the more definitely manganiferous soils, no attempt has been made to test it in the present work with regard to the soils under study; in any case, colloidal activity might well be shown on the surface of the coarser particles.

However, all this discussion assumes that the formula of manganic oxides in the soil is uniformly MnO_2, whereas in fact there would probably be compounds of every combining proportion from MnO to MnO_2, which might differ chemically in their oxidizing capacities. In the absence of any information on this matter it is not considered further here.

This separation of MnO_2 into four categories does not rule out the possibility of change from one state to another. Such changes are inevitable in a dynamic system such as soil. The dynamic equilibrium,

$$\text{Exchangeable Mn} \rightleftharpoons \text{Unavailable } MnO_2,$$

of former workers, however, may now be replaced by some such series as—

$$\text{Exchangeable Mn} \rightleftharpoons MnO_2\ (a) \rightleftharpoons MnO_2\ (b) \rightleftharpoons MnO_2\ (c) \rightleftharpoons MnO_2\ (d),$$

where it must again be emphasized that the four classes are separated by arbitrary tests. Waterlogging will displace the equilibrium from right to left, as has in fact been shown by Piper (1931). The Dooen soil, for instance, after six weeks' waterlogging, showed a rise of exchangeable Mn from 0 to 8 p.p.m., and of types (*a*) and (*b*) together from 137 to 200. The speed of any change in the direction (*b*) to (*c*) is quite unknown. It may well be that the change from (*c*) to (*b*) on waterlogging takes place by way of the bivalent ion, but it seems unlikely that this bivalent Mn should escape almost complete oxidation on restoring good drainage.

TABLE X.—AMOUNTS OF MANGANESE DISSOLVED FROM DEFICIENT SOILS BY VARIOUS SUCCESSIVE TREATMENTS.

(Parts per Million.)

Soil.	Normal ammonium acetate pH 7·0.				Sulphuric acid + 0·2 per cent. quinol.	
	(i)	(ii)	(iii)	(iv)	$\frac{N}{20}$ acid	$\frac{N}{2}$ acid.
Mount Gambier	0·25	3·7	2·0	58	..	..
Penola	Tr.	0·4	0·0	0·4	0·1	3·5
Corny Point	2·6	8	n.d.	17	..	..

(i) No reducing agent; (ii) With 0·2 per cent. quinol; (iii) With 0·4 per cent. Na_2SO_3; (iv) With 0·4 per cent. $Na_2S_2O_4$.

Three of the deficient soils studied here were tested successively with more drastic reagents than the solution of 0.2 per cent. quinol at pH 7.0—viz., solutions of 0.4 per cent. Na_2SO_3 and 0.4 per cent. $Na_2S_2O_4$, in N ammonium acetate, and then with 0.2 per cent. solutions of quinol, first in 0.05N, then in 0.5N H_2SO_4. The results, given in Table X. show the success of $Na_2S_2O_4$ at pH 7.0 in the case of both Gambier and Corny Point soils. The acid treatment was not tried on the latter as it contains such large amounts of $CaCO_3$; but in the case of Penola, treatment with 0.5N acid + quinol was needed to dissolve even as much as 1 of the 50 parts of Mn which every million parts of this soil contain. From these figures one might have predicted the results actually obtained by Piper (1931, p. 771) in pot tests—viz., that Penola soil (which has hardly any MnO_2 of class (*c*)) would respond more to added Mn than to waterlogging, that the Mt. Gambier soil, with plenty of class (*c*), would show the best response to waterlogging of the three, while the Corny Point soil would be intermediate.

Figures are included in Table IX. which show that the University soil, to which 30 p.p.m. of Mn had been added in past years as $MnSO_4$, gave almost complete recovery of this extra Mn at pH 7.0. Too much importance must not be given to the exact agreement of these results, on account of the large sampling error; but they do indicate that much of the added $MnSO_4$ is held in the soil in a form at least as available as the class (*b*) above. Yet symptoms of manganese deficiency were observed in the wheat on these plots, and the last two months of growth were disappointing. This fact is provisionally put down to the completeness of precipitation of the Mn in the surface layer of the soil: the plots in these experiments were not dug (in order to avoid the risk of mixing the soil of neighbouring plots). It is intended to test at a future date how far the response to added $MnSO_4$ depends on the thoroughness of mixing of the soil. The chemical analyses quoted above would certainly indicate that a fairly active MnO_2, if well mixed with the soil to a depth of several inches, should be quite as effective as any soluble salt of manganese, and 30 p.p.m. of this Mn should ensure against a deficiency. It is clear that manganese brought into the available state by waterlogging must be already intimately mixed with the soil.

While the fairly drastic treatment of waterlogging may be very good for soils which, like that of Mt. Gambier, have large stores of MnO_2 just below the critical level of availability, it is difficult to see how such a mild reducing agent as well-rotted farm-yard manure could make available to plants any MnO_2 except such kinds as the plants can in any case secure for themselves. It seems more likely that the good effects sometimes claimed for farm-yard manure are due to its own content of manganese and to its lowering of pH values.

As the pH value of the soil is lowered, more manganese may be leached out, partly, no doubt, by direct reduction of the dioxide and partly because it is easier for exchangeable Mn set free by weathering to accumulate at these more acid levels. The sulphured University soil, for instance (Table IX.), evidently owes its health to the greater concentration of manganese exchangeable at pH 7 and to the greater availability of this manganese at its pH of 6. However, it is not possible from the information available, to determine what importance to ascribe to "exchangeable Mn" which may easily be leached out at low pH levels but cannot be leached at pH 7. The 34 parts of manganese leached by 0.05N acid from the University soil must have come from some other source than the "*(a)* + *(b)*" MnO_2, which alone could provide only 11 parts. This source might well be a manganous silicate, since the soil is so immature; such a compound might be dissolved at low pH but be quite unavailable at pH 7. It is also interesting to recall the often-noted fact that during the electro-dialysis of soils, manganese is released only in the later stages—i.e., as the pH of the soil drops. This appearance of manganese may be at least partly due to the reduction of MnO_2.

It appears that useful information may be obtained about the state of Mn in the various horizons of the soil by the method followed in Table IX.—leaching with buffered solutions at various pH values, containing reducing agents chosen to bring the solution to given rH values.

It is possible that some reagent may be found to replace quinol, which is troublesome to destroy before analyzing extracts for Mn. Meanwhile, it may be noticed that deficient soils contain less than

15 p.p.m. of Mn replaceable by normal ammonium acetate at pH 7.0, including the help of quinol, so that one might guess that a content of, say, 25 to 30 p.p.m. of this manganese was needed to avoid deficiency. No more definite statement can be made with the present figures. In fact, the limit for deficiency probably depends on the climate as well as on the crop.

As the pH of the soil decreases, the life of more active manganic oxides becomes shorter. McGeorge (1923), in discussing the Hawaiian soils that are rich in MnO_2, says that none has been found with a pH below 5.9. At lower values one would expect the organic matter to reduce the MnO_2 more easily, so that bivalent manganese would be formed and would be washed out.

Since reserves of "active MnO_2" fall off rapidly with a fall in pH, one might forecast that, other things being equal, it is more dangerous to lime a highly acid than a moderately acid soil. It may be remarked that many of the soils that have become "deficient" after liming have naturally a very acid reaction.

Effect of Liming.

Steenbjerg (1933) working on field plots, has shown how successive additions of lime to an acid soil quickly lower the amount of manganese replaceable by semi-molar magnesium nitrate. He also estimated the manganese leached in successive portions of 25, 50, or 100 c.c., and showed that while acid soils released most of their total manganese in the first 100 c.c., with alkaline soils this release was much more gradual and prolonged. The difference between these two types is shown in Fig. 2, where the percentage of the total replaceable manganese in the filtrate is plotted against the volume of the filtrate, using Steenbjerg's figures. From the shape of these curves he worked out a function called qS, which is low for acid soils (curve 1), and high for alkaline soils (curve 2). Steenbjerg concluded that exchangeable manganese was bound in a different and a far firmer way in the alkaline soils; but though this may be true, the differences obtained in the values of qS must be partly due to the fact that the leaching solutions were unbuffered, so that the first 50 c.c. would be leaching the soil at a much lower pH for acid than for alkaline soils, and so the leaching solution would be more efficient, as shown in Table IX.. Steenbjerg also came to the conclusion (p. 423) that "Other things being equal, of two soils each with the same low figure for total exchangeable Mn, deficiency will be more likely on the soil that has the higher qS value." One would expect a soil to have a higher qS value—a slower rate of liberation of Mn—if it had more $CaCO_3$; but it is not clear whether $CaCO_3$ content is included among the "other things" that are equal.

Whatever may be the importance of this greater firmness of holding of replaceable manganese, it is clear that a great deal of the Mn is oxidized by liming, as is shown by the appearance of black MnO_2 on the particles of $CaCO_3$ (Robinson, 1929), as well as by Piper's experiments quoted on p. 237. The normal decrease in the quantity of Mn available to plants following liming is also shown by Steenbjerg's plant analyses on experimental limed plots, by Mann's work (1930) in laboratory tests, and by Piper's work on the increase of Mn absorbed by plants on acidifying the soil from both Glen Osmond and Mt. Gambier.

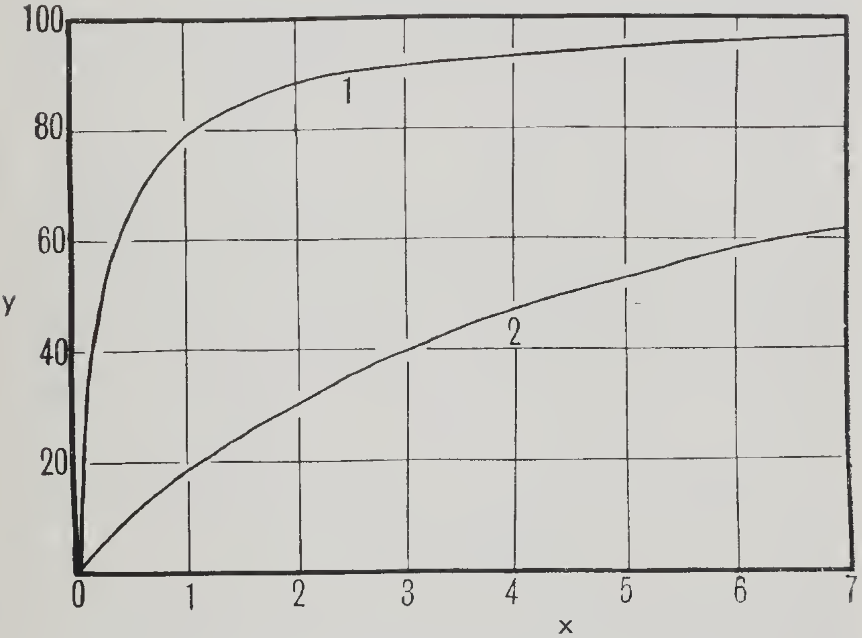


Fig. 2.

Fig. 2.—Curves to illustrate rate of liberation of exchangeable manganese from two types of soil, after Steenbjerg (1933). Curve 1, Soil No. 685, pH = 5.3. qS = 0.256; Curve 2, Soil No. 1011, pH = 7.6, qS = 4.39. Each curve corresponds to the equation $y\ (x + qS) = 100x$.

The soil, after liming, contains small amounts of Mn exchangeable at pH 7, together with very variable amounts of MnO_2 soluble in quinol at pH 7. The very small amounts of exchangeable Mn may perhaps delay the onset of deficiency disease for a few years; Clausen (1931), for instance, states that in Holstein the maximum effects are shown six years after overliming, and a similar position apparently holds for the University soil, since when the original, acidic soil was treated with lime, pot tests with oats showed manganese deficiency only in the second year after heavy overliming. This delayed effect may also be connected with the slow process of oxidation, by atmospheric oxygen or by bacteria, by which basic manganous compounds are turned to MnO_2.

The MnO_2 formed from Mn^{++}, after liming to over pH 7, is probably of the most actively oxidizing kind, but it is possible that in some circumstances it gradually " ages " and becomes less available. Though the active MnO_2 is held to be available, it is definitely inferior to the bivalent form as a source of plant food; so that while a soil may before liming be perfectly healthy with 10 p.p.m. of Mn exchangeable at pH 7, and no reserve of active MnO_2, it will no longer be healthy after liming when much of the exchangeable Mn is converted into MnO_2. The healthy alkaline soils tested here both contain well over 100 p.p.m. of active " dioxide " Mn.

Lack of available manganese exists naturally on both light (e.g., Mt. Gambier) and heavy soils (e.g., Penola), while after liming it seems to occur almost entirely on sandy podzols, which may sometimes be rich in organic matter. The University soil is related to the limed podzols on the one hand and to the Mt. Gambier soil on the other. The deficiency of the University and the Mt. Gambier soils appears to be connected with their extreme immaturity. Possibly a waterlogging, unaccompanied by leaching, occurring even once in many years, would cure both of these soils.

Where the deficiency occurs naturally on heavy soils liable to waterlogging, as at Penola and in North Carolina (Willis, 1932), it is probable that the active MnO_2 as soon as it is formed, is continually reduced and washed out; at Penola the *total* Mn is also very low. The acid podzols, on the other hand, lose their active MnO_2 by reduction at low pH, followed by leaching; there is less need at low pH values to have the assistance of waterlogging to effect this change. The rapidity with which soluble Mn accumulates in some acid soils under optimum conditions, described by McCool (1934), illustrates this point.

It is suggested that about 25 p.p.m. of manganese soluble in ammonium acetate + 0.2 per cent. quinol at pH 7.0 is a safety limit for heavy liming. It is of course essential to test many more soils before such a figure can be accepted. The number of cases of deficiency following overliming in Australia is as yet one (here described) or perhaps two (see Bellarine, below), so that such tests would need to be made on soils in the podzol belt of the United States of America or of north-western Europe. Up to the present, however, liming has not been carried on to any great extent in the podzol belt of Victoria; and the figures of the Mn replaced by ammonium acetate at pH 7.0, with and without quinol, given in Table XI., refer to some typical southern soils.

TABLE XI.—AMOUNTS OF MANGANESE DISSOLVED AT pH 7.0 FROM PODZOLIC SOILS OF SOUTHERN VICTORIA.

——	University.	Timboon.	Bellarine.	Coleraine.	Dixie.	Larpent.	Yarragon.
Ammonium acetate	15	0·2	5	7	21	98	100
,, + 0·2 per cent. quinol	0	0·7	3	10	33	127	285
pH of soil ..	5·0	5·6	5·4	6·1	5·5	5·8	5·5

Of the four soils low in available manganese, the University soil showed a deficiency some years after overliming, while the Bellarine soil has shown, in a heavily-limed patch, symptoms believed to be those of manganese deficiency. Pot tests are in progress to determine whether the other two soils of these four are liable to develop deficiency on heavy liming. If the surface soil is shallow, it is of course possible that the subsoil might avert deficiency in the field.

It might incidentally be pointed out that manganese deficiency cannot possibly be due to excess calcium ion concentration (cf. Lundegårdh, 1931, p. 219). The well sulphured University plots, on which not a sign of manganese deficiency was seen, had a higher concentration of calcium in solution (as calcium sulphate) than the alkaline plots, where the most soluble compound would be the bicarbonate. This higher concentration of the highly flocculating calcium ion on the acidic plots was shown by the very rapid flocculation of the soil after shaking with water.

Note on the Availability of Iron.

Plants growing on certain calcareous soils are liable to a chlorosis which may be overcome by treatment with iron salts. As manganese and iron are both essential to plants, and are chemically alike in many ways, it might be expected that the availability of iron in the soil would be similar to that of manganese. Each metal forms well-marked bivalent " ous " compounds, from which a hydroxide or basic salt may be precipitated about pH 7, and in each case this precipitate is easily changed at atmospheric oxygen to the " ic " state, corresponding to an extremely weak base. Again, deficiency is noted almost exclusively on soils on the alkaline side of neutrality, and may be overcome by treating the plant or the soil with a soluble " ous " salt, usually the sulphate. The bivalent state in the soil may also be reached in each case by reducing conditions such as waterlogging.

Ferrous hydroxide is both a weaker base than manganous hydroxide, and more easily oxidized. Halvorson (1931) estimated the concentration of ferrous ion in solutions of $FeSO_4$ of varying pH values exposed to the atmosphere for four months, and expressed his results by the formula—

$$[Fe^{++}]\ [OH^{-}]^2 = 4.8 \times 10^{-25},$$

where any attempt to increase the ferrous ion concentration at a given pH would lead to the deposition of ferric hydroxide. He also used the solubility product of $Fe(OH)_3$, the potential values of the ferric-ferrous electrode and the oxygen-hydroxide electrode to calculate the *theoretical* value of the above expression, namely—

$$[Fe^{++}]\ [OH^{-}]^2 = 3.7 \times 10^{-31}.$$

The difference between these two values is due to the slowness of the reaction. But each equation shows that the concentration of ferrous ion in solution in a well-aerated soil must be very low. While information is lacking as to the quantities of exchangeable Fe^{++} to be expected in soils, it has been pointed out by Afanassiev (1930), and by Morison and Doyne (1914), that the ferrous ion found in solutions extracted from soil by acids is due to the reduction of ferric compounds by organic matter at low pH values at which ferric compounds are more soluble, and hence strong oxidizing agents. Manganous ions are liberated at low pH values by an analogous reaction from manganic compounds.

Both ferric and manganic ions may be ruled right out of consideration as a source of food for plants above pH 6. The only other possibilities remaining are the absorption of these elements as complex ions, and the use of colloidal ferric or manganic compounds, as suggested above, directly, or by reduction at the root-soil interface. It is the former possibility that marks off iron from manganese. Manganic complexes certainly exist, but they are neither stable nor well-defined, while tervalent iron forms complexes, which are soluble at high pH values, with several hydroxy-acids, such as citric and tartaric acids. (It need hardly be pointed out that the ferric ion concentration at pH 7 is *lower* in the presence of citrate than in its absence.) It seems very likely that such "ferri-organic" complexes are the source of the high intake of iron by plants growing on peaty soils after heavy liming. Olsen (1930) has remarked that comparing soils of the same pH value, chlorosis is more likely to occur on soils poor in organic matter—a fact which he attributes to ferri-organic complexes, a far more likely explanation than the common one that the organic matter reduces the iron to the ferrous state, which is hard to accomplish in the presence of oxygen at such high levels of pH.

On account of these ferri-organic complexes, the actual content of iron in even highly chlorotic plants growing on calcareous soil may be of the same order as in healthy plants. (It may even be higher, which may be connected with the high stability of ferri-organic complexes at pH 7.) As these chlorotic plants readily respond to sprays or injections of ferrous sulphate or ferric citrate, it is clear that this chlorosis is due to immobility of the iron, i.e., a physiological disturbance; and Rogers and Shive (1932) have suggested that it is due to the failure of the affected plants, which all have a sap of high pH, to produce, or conserve, the hydroxy-acids needed to keep the iron in the sap soluble and mobile; and such a failure is associated especially with certain calcareous soils, and also with manganiferous, non-calcareous soils in the pineapple-growing regions of Oahu.

If, as has at times been suggested, the actual *intake* of iron from manganiferous soils is too low for healthy growth, it is conceivable that the following reason may hold: If iron can also be absorbed by the reduction of ferric colloids at the root-soil interface, a low rH must be reached (at the higher pH values) to achieve this; and this lowering of rH cannot be achieved so long as active manganic compounds are present. This, in fact, is implied by Willis (1932), who, however, was more concerned wih the *oxidation* of iron and manganese. Since all the iron and nearly all the manganese will in any case be in the more oxidized form in a well-aerated, neutral soil, it seems more helpful to focus attention rather on the possibility of *reduction* by the root. However, it is possible that the suggestion dealt with in this paragraph is superfluous.

Large amounts of iron were liberated by some of the treatments described in this paper, but no analyses were carried out.

It might be pointed out here—perhaps a fact of practical significance—that apparently no soil has yet been reported on which *both* iron and manganese deficiency exist.

Summary.

Wheat plants growing on a heavily limed soil have been found to suffer from lack of available manganese. This state of things was improved either (1) by acidification of the soil, most conveniently by sulphur, to a pH at least as acid as 6.5, or (2) by heavy applications of manganous sulphate to the soil.

The first treatment had no effect on early growth, nor on the number of tillers produced in late September, but it led to a far higher survival of tillers to grain-bearing ears, and an increase in the number of grains per ear, and in the weight per grain.

Powdered manganese sulphate had no effect when applied to the soil at the rate of 40 lb. of the crystals per acre, whether at germination or in the spring. The best response was obtained by applying 1 cwt. per acre, sown with the seed, or applied to the soil at germination, and a residual effect was noted a year later. The application of 1 cwt. increased the tillering, especially when applied with the seed, and also improved the survival rate of the tillers and the weight of grain per ear compared with the

control plots, but the $MnSO_4$ plots were very inferior to the sulphured plots in these last two values, so that the final yield of grain averaged the best on the sulphured soil.

It is possible that the poorer survival on the $MnSO_4$ plots was due partly to the too great tillering of the plants, leading to a loss in the warm, dry weather of late spring. In any case, the experiments definitely show that, if the production of grain is the aim, the more effective way of dealing with overliming, in the Melbourne climate at least, is to bring the pH down again by the use of heavy applications of sulphur, possibly in more than one annual instalment. It is, however, possible that results might have been different if the $MnSO_4$ had been thoroughly worked into the soil.

Laboratory tests on various soils have shown that the crucial test among soils of pH greater than 7 is to leach the soil with a solution of quinol at pH 7 (normal ammonium acetate was the reagent used). Deficient soils yielded less than 15 parts of Mn per million of soil to this solution, while two typical healthy soils tested gave over 130 parts per million.

The theory of this test is discussed in connexion with the oxidation-reduction potential of the system ($MnO_2 — H^+ — Mn^{++}$). It is suggested that the plant uses MnO_2 as its source of manganese, whether directly in the colloidal state or by reduction at the root-soil interface, and it is only the manganese dioxide dissolved by quinol at pH 7 which can be used by plants, and not the more copious supply that may sometimes be dissolved with or without quinol at low pH value (1 to 2). The magnitude of this figure (Mn dissolved by quinol at pH 7) may be taken as a test whether a given soil is liable to develop manganese deficiency after liming, though this suggestion can hardly be tested in this country, where no important areas have suffered from overliming.

If sulphuring is impracticable (as it will be on a very calcareous soil) an " active " MnO_2 should on theoretical grounds be as good as $MnSO_4$, especially if finely divided and worked well into the soil.

It is suggested that information may be gathered as to the state and translocation of manganese in the soil by leaching with a series of solutions buffered to a constant pH and poised to steady ranges of rH by a series of materials such as quinol.

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Appendix.

Method of Analyzing for Manganese.

Manganese was analyzed colorimetrically as the permanganate in all the above work, using a Dubosq colorimeter. The colour was developed by sodium periodate, usually in sulphuric acid solution, but sometimes in phosphoric acid solution if it was necessary to avoid the formation of large amounts of calcium sulphate. The plant ash material was treated with hydrofluoric acid to avoid loss of manganese as insoluble silicate, the hydrofluoric acid being then destroyed with sulphuric acid. The ammonium acetate solutions were treated by first evaporating them to small bulk. then destroying organic matter and ammonium ions with aqua regia, finally destroying chlorides by treating with sulphuric or phosphoric acid.

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SUPPLEMENTARY NOTE.

Pot tests carried out in the open since this paper was read have confirmed the above evidence that plants can use "active" MnO_2. One pot (A) contained 25 kg. of a typical "deficient" soil from Mount Gambier, which before being placed in the pot was thoroughly and uniformly mixed with a freshly prepared sample of MnO_2 containing 2 gm. manganese (or 80 parts of Mn per million of soil). This MnO_2 was made by mixing strong solutions of $NaMnO_4$ and $MnSO_4$, filtering the brown precipitate and washing it several times with dilute H_2SO_4, then with dilute NaOH, finally with water. The control pot (B) contained 25 kg. of the same deficient soil. Two grams each of superphosphate and sodium nitrate were applied to the surface of each pot, and 0.25 gm. $MnSO_4$ crystals was added at the same time uniformly to the surface of pot B. Six seedlings of a variety of Tasmanian White Oats (known to be sensitive to deficiency) were transplanted to each pot on 10th October, 1934, when all were in the one-leaf stage. Temperatures were normal during the next two months, and 13 inches of rain fell. Differences in growth appeared early in the experiment, and by 6th December the oats on pot A had tillered vigorously and were free from any sign of deficiency, while marked symptoms of "grey speck" were shown by the plants on pot B, which had made only poor growth. This clearly supports the suggestion that the failure of surface applications of manganese salts is due to "positional" unavailability, which may be overcome by thorough mixing. It also makes it more reasonable to expect that large applications of $MnSO_4$ will bring about a permanent cure on any soil, if thorough mixing is possible.

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Art. XV.—*Some Algae of Victorian Soils.*

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(Government Research Scholar.)

[Read 11th October, 1934; issued separately, 8th May, 1935.]

Although for a long time it has been recognized that many algae, especially Myxophyceae, grow on the surface of the soil, it is only during comparatively recent years that it has been realized to what a large extent they inhabit the deeper layers of the soil, and what a significant part they play in its economy. Their exact role has not yet been determined, but Schramm(34) and later Wann(42) considered that they had the power of fixing free nitrogen. Moore and Webster(23) also claimed that they had obtained definite nitrogen fixation by algae, but as their cultures were not free from bacteria, this may have affected their results. This theory was not upheld by Bristol-Roach and Page(9). Waksman(40), however, suggests that algae may aid bacteria in the fixation of nitrogen by providing the carbohydrates required by the bacteria. Whatever their part, their abundance in the soil suggests that they cannot be without some effect on its fertility.

Algae are more abundant in the upper layers of the soil, but they may exist at depths of 100 cm. beneath the surface. They are more numerous in manured than in unmanured ground. No very satisfactory count of their numbers has been made, but according to Bristol-Roach(4), they vary from 700 to many thousands per gram according to the conditions of the soil.

These soil Algae belong to four groups; (i) Myxophyceae or Blue-green Algae, (ii) Chlorophyceae or Green Algae, (iii) Heterokontae, (iv) Bacillariaceae including Diatoms. The Chlorophyceae and Heterokontae are universally distributed, while the Myxophyceae appear as a general rule in greater numbers in cultivated rather than in uncultivated soils(4), and Diatoms appear mostly in soil from old gardens(40).

In England, America, Germany, and Africa, soil microbiologists have succeeded in identifying soil forms representing over a hundred genera. However, no work of this kind has previously been attempted in Victoria or even, for that matter, in Australia. There have been, however, some investigations in connexion with fresh-water forms in Australia and New Zealand. As far as Victoria is concerned the most outstanding work is that of West(43) on the algae of the Yan Yean Reservoir. In this work, Professor West has identified over 300 species from material forwarded to him by Mr. Hardy of the Lands Department, Melbourne.

The purpose of this investigation is to identify as many Victorian soil species as possible. At first it was intended to make a count of the number of cells of each species per gram of soil using the method suggested by Bristol-Roach(6), but this was found to be impossible until the forms could be identified with greater ease. It is first necessary to obtain cultures of the organisms, and since many algae exhibit polymorphism in a marked degree, it is preferable to isolate each species and obtain cultures which are as far as possible pure—at least free from other algae even if contaminated by bacteria or fungi. This has not been possible in all cases, but some were readily obtainable in pure culture.

The following method was used: By means of a sterilized soil auger, 10 grams of soil were obtained, passed through a sterilized 3 mm. sieve, and then placed in a bottle containing 100 c.c. of a sterilized mineral salts solution, thus giving a 1 in 10 suspension. The solution was that recommended by Bristol-Roach(6) and was of the following composition:—

KH_2PO_4	1·0 gm.
$NaNO_3$	1·0 gm.
$MgSO_4 \cdot 7H_2O$	·3 gm.
$CaCl_2$	·1 gm.
$FeCl_3$	·01 gm.
Glass-distilled water	2,000 c.c.

Glass-distilled water is essential as water distilled in an ordinary copper still is unsuitable for this work, since even minute traces of copper are toxic to many algae.

The 1 in 10 suspension was carefully shaken for half an hour in order to thoroughly separate the organisms. This prolonged shaking was necessary because of the difficulty in separating the cells of many species on account of the layer of mucilage investing them. It is because of this difficulty that it has so far been impossible to obtain a really satisfactory count of the total number of algae present in the soil, especially of the Myxophyceae. After shaking, 50 c.c. of the 1 in 10 suspension were pipetted into an erlenmeyer flask containing 50 c.c. of the sterile mineral salts solution, thus giving a 1 in 20 suspension. From this second suspension, 50 c.c. were transferred into another flask containing 50 c.c. of sterile mineral salts solution giving a 1 in 40 suspension. This process of half and half dilution was repeated until a series of suspensions was obtained ranging in dilution from 1 in 20 to 1 in 1,310,720 in the seventeenth flask. These flasks were then exposed to light in a window with a northern aspect, the light stimulating the growth of the algae but retarding to a certain extent the development of contaminating bacteria. In four to five weeks' time, the surface of the solutions became quite green and the algae present were examined. The soil for the first and second series of cultures was taken from a garden at the Melbourne University, the soil being derived from Silurian mudstone and sandstone. The first sample was taken in July, 1930, and in the following March, a second series of flasks was set up in the above manner. Three months later, at the end of May, a third series was set up. This third sample was taken from virgin bush soil at Heathmont which is also in the Silurian belt. From these mixed cultures, pure cultures were then obtained as far as possible. There are two factors which render this task difficult; (i) the mucilage investing many forms making them not readily separable, and (ii) their slow growth in comparison with either fungi or bacteria. To obtain pure cultures the ordinary plating-out method was first used. The medium was mineral salts agar, 1.75 gm. of agar being added to a litre of the mineral salts solution previously used. This medium is suitable for the growth of algae, but is entirely unsuitable for the growth of most fungi and bacteria.

A loopful of the solution in No. 1 flask was put in 5 c.c. of sterilized mineral salts solution and carefully shaken for half an hour. From this, 1 c.c. was pipetted into a sterilized petri dish and then approximately 10 c.c. of the liquid agar medium at about 37° C. was run into the petri dish and left to solidify. This process was repeated with each flask, until a series of plates was obtained. In these plates the algae grow in colonies and can be cut out aseptically and transferred to fresh media. In this way pure cultures of *Chlorococcum humicola* (Naeg.) Rabenh. *Stichococcus bacillaris* Naeg., *Ulothrix variabilis* Kütz, *Bumilleria exilis* Klebs, *Phormidium tenue* (Menegh.) Gomont., *Phormidium autumnale* (Ag.) Gomont., *Trochiscia hirta* Hansgirg, *Protococcus viridis* Agardh, *Chlorella vulgaris* Beyerinck, have been obtained. Many organisms identified in the solutions in the flasks have not so far been obtained in pure culture. These include *Nostoc paludosun* Kütz, *Nostoc muscorum* Kütz, *Botrydiopsis arhiza* Borzi, and many others. Other organisms have not yet been identified or subcultured. The Chlorophyceae are by far the most numerous in the cultures, while very few Diatoms can be found. Only three genera of the Myxophyceae have been observed, and these did not develop for many weeks after the Chlorophyceae first appeared.

The following are the species which have been successfully identified as present in Victorian soil:—

——	*Garden Soil A.*	*Garden Soil B.*	*Bush Soil.*
I. MYXOPHYCEAE—			
Nostoc paludosum Kütz	×	×	
Nostoc muscorum Kütz	×		
Anabaena minutissima Lemm. ..	×		
Anabaena variabilis Kütz. ..			×
Phormidium foveolarum Gom. ..	×		
Phormidium tenue Gom.	×	×	
Phormidium autumnale Gom. ..	×		
Phormidium australe, n. sp. ..	×		
Phormidium subterraneum, n. sp. ..			×
II. CHLOROPHYCEAE—			
Chlamydomonas communis Snow ..			×
Chlamydomonas communis Snow., var. grandis, n. var.			×
Chlamydomonas gracilis Snow ..		×	
Chlorococcum humicola Rabenh. ..	×	×	×
Chlorella vulgaris Beyerinck. ..	×	×	×
Ourococcus bicaudatus Grobéty ..			×
Ankistrodesmus falcatus Ralfs. ..			×
Oocystis solitaria var. terrestris, n. var.	×		
Trochiscia hirta Hansgirg	×	×	
Protococcus viridis Agardh. ..	×	×	×
Muriella australis, n. sp.		×	
Ulothrix variabilis Kütz	×	×	
Ulothrix subtilissima Rabenh. ..			×
Ulothrix aequalis Kütz			×
Hormidium flaccidum A.Br. ..	×	×	×
Stichococcus bacillaris Näg. ..			×
Gongrosira australis, n. sp. ..			×
Vaucheria hamata (Vauch.) Lyngb. ..			
III. HETEROKONTAE—			
Botrydiopsis arhiza Borzi		×	
Chlorocloster minor, n. sp.			×
Ophiocytium terrestre Heyward ..			×
Heterococcus viridis Chodat ..	×		×
Bumilleria exilis Klebs	×	×	×
IV. BACILLARIACEAE—			
Hantzschia amphioxys (Ehr.) Grun. ..	×	×	
Navicula mutica Kütz	×		

Myxophyceae.

The Myxophyceae do not appear in the culture flasks until some months after the Chlorophyceae, and as a rule they appear in the flasks at the beginning of the series which are less dilute. Only three genera, *Nostoc, Phormidium,* and *Anabaena* were found, though each was represented by more than one species.

The Myxophyceae are difficult to obtain in pure culture, and so far only two have been successfully grown—*Phormidium autumnale* and *P. tenue.* However, it was quite possible to identify the other species from the mixed flasks without any measure of doubt. The following are the species found, with a brief description of each:—

Nostoc paludosum Kütz.

(Figure 1.)

This species was found in flasks Nos. 1 and 2 of the culture of garden soil A. Tiny hemispherical colonies were formed on the sides of the flask slightly above the level of the liquid medium. Where the edges of two colonies met, the sides became flattened (Fig. 1. A). Upon examination, each colony was seen to be without a firm outer sheath (Fig. 1. B), but each individual trichome possessed a distinct wide gelatinous sheath (sh), which varied in width from 1.5-5μ. The vegetative cells (v.c.) of the filament measured from 4-5.5μ in diameter and from 6-9μ in length, in some cases the length and breadth being approximately equal. The heterocysts (h) were slightly larger, measuring 5-6μ in diameter and 8-10μ in length. The spores were oval, being 5-6.5μ in diameter and 8-9μ in length. Although these measurements are slightly larger than those given by Pascher for this species, the type of colony without any firm outer sheath, the presence of a wide sheath around each individual trichome, and the type of spores formed seem to place it without doubt as *N. paludosum.* This species seems to be mainly a fresh-water form usually found in ditches and pools. This species has been recorded by Bailey(2) for Australia.

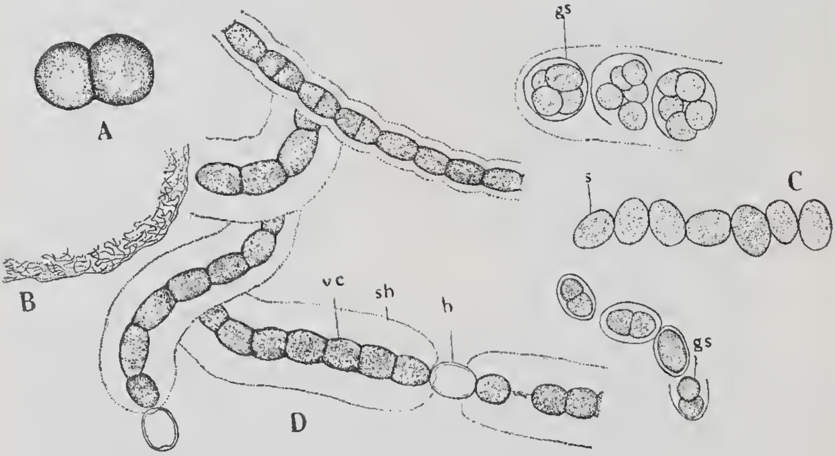
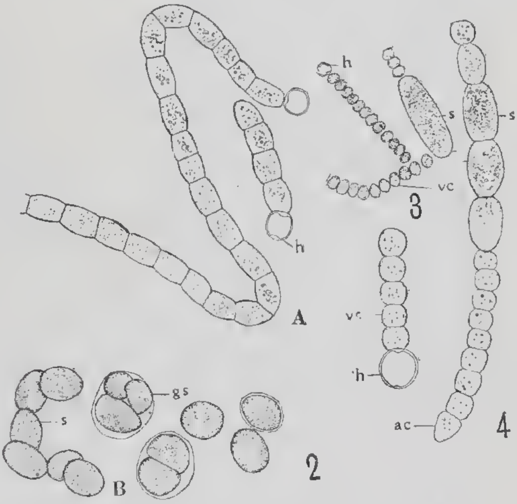


Fig. 1. Nostoc paludosum Kütz. A. Macroscopic view of two colonies side by side. B. Edge of the colony showing no firm outer sheath. C. Chain of spores. s. spore, gs. germinating spore, × 700. D. Vegetative trichome. h. heterocyst, vc. vegetative cell, sh. sheath.

NOSTOC MUSCORUM Kütz.

(Figure 2.)

The occurrence of this alga in one flask only of the culture of garden soil A, and, contrary to the general rule, in a later and more dilute flask of the series—No. 16—showed that it was not widely distributed. The colonies formed flat, irregular masses which floated on the surface of the liquid medium among other algae in the flask. The filaments were flexuous and densely entangled. The vegetative cells measured 4-4.5μ in breadth and were nearly twice as long as broad (Fig. 2 A). Hetrocysts (h) were almost spherical, being approximately 5μ in diameter. The spores (Fig. 2 B) were longer than broad, approximately 6μ in diameter and 8μ in length, and were found in chains. The sheaths of the trichomes were for the most part invisible, being apparent occasionally towards the edges of the colonies.



Figs. 2-4.—2. Nostoc muscorum Kütz. A. Vegetative trichome. B. Spores. 3. Anabaena minutissima Lemm. 4. Anabaena variabilis Kütz. h. heterocyst, s. spore, gs. germinating spore, vc. vegetative cell, ac. apical cell. × 700.

This species has frequently been recorded for the soil in other countries, but no previous record has been made for Australia.

ANABAENA MINUTISSIMA Lemm.

(Figure 3.)

Filaments which were found to correspond closely to the description of this alga were found growing among the algae in the cultures of garden soil A. The more or less straight filaments were isolated and did not form a definite colony. The vegetative cells measured 2-2.5μ in breadth and were slightly shorter than broad, being 1.5-2μ in length. Spherical heterocysts, approximately 2μ in diameter, were present. A few elongated spores developed later and measured 18-20μ in length and 4-5μ in diameter.

ANABAENA VARIABILIS Kuetz.

(Figure 4.)

A second *Anabaena* species was found in the bush soil. The vegetative cells were approximately as long as broad, measuring 4.5-5μ in breadth and 4-5.5μ in length, the end cell being obtuse-conical. The heterocysts were intercalary, spherical or sometimes slightly longer than broad. Spores were later developed in chains and measured 7-8μ in diameter, and 9-13μ in length. They were never found next to the heterocysts.

Bristol-Roach(4) has recorded this species as present in English soils.

PHORMIDIUM FOVEOLARUM (Montague) Gom.

(Figure 5.)

This alga was found in garden soil A, always in association with *P. tenue* and *P. autumnale,* and was therefore very hard to separate and obtain in pure culture. The cells of the trichome were more or less quadrangular, sometimes shorter than broad, but never longer. The breadth measured approximately 1.5μ, while the length was from 0.8μ-1.5μ. The trichome was pale blue-green in colour and was distinctly constricted at the transverse walls. The end cell (a.c.) of the trichome was rounded and did not taper The sheath (sh) was narrow and colourless.

P. foveolarum is a terrestrial species, but has not previously been recorded for Australia.

PHORMIDIUM TENUE (Menegh) Gom.

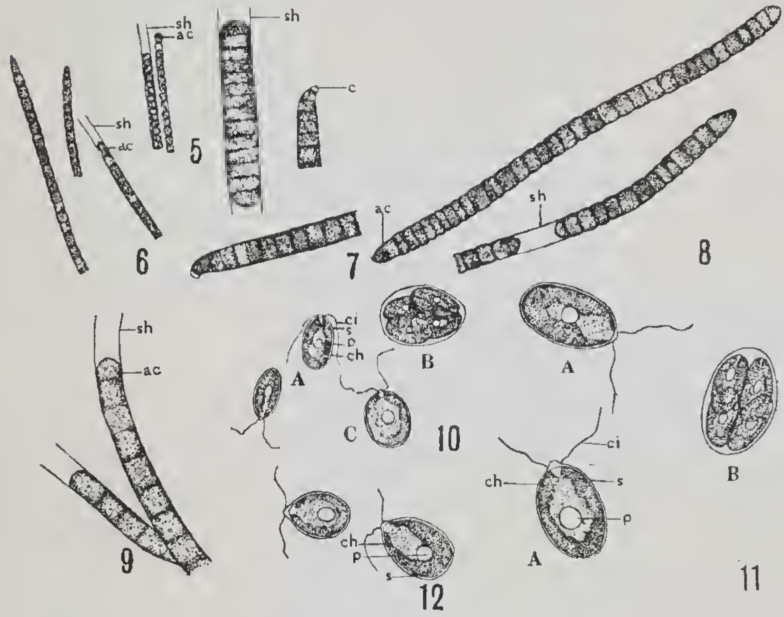
(Figure 6.)

In flasks Nos. 1 and 2 of garden soils both A and B, this species occurred frequently in association with *P. autumnale* and *P. foveolarum,* the three together forming a flat bluish-green matted mass adhering to the sides of the flasks or sometimes floating on the surface of the liquid.

Phormidium tenue is one of the two Myxophyceae which have been grown in pure culture on agar. The trichomes were a pale blue-green in colour, the cells measuring from 1.5-2μ in diameter and varying in length from 2-3μ, the end cell (a.c.) tapering. The trichome was slightly constricted at the transverse walls, which were more or less indistinct. The sheath (sh) was very narrow and could only be distinctly seen where the filament was broken and the sheath protruded past the trichome.

The species has a world-wide distribution in the soil, being recorded in England by Bristol Roach(4), in the United States of America by Moore and Carter(22), and in India by West.

It has also been recorded for Australia by Bailey(2).



Figs. 5-12.—5. Phormidium foveolarum Gom. 6. Phormidium tenue Gom. 7. Phormidium autumnale Gom. 8. Phormidium australe, n. sp. 9. Phormidium subterraneum n. sp. 10. Chlamydomonas communis Snow. A. Motile cell. B. Zoosporangium. C. Chlamydomonas communis var. ovata Playfair. 11. Chlamydomonas communis Snow var. grandis, n. var. A. Motile cell. B. Zoosporangium. 12. Chlamydomonas gracilis Snow. sh. sheath, ac. apical cell, c. calyptra, ci. cilia, s. stigma, p. pyrenoid, ch. chloroplast. × 700.

PHORMIDIUM AUTUMNALE (Ag.) Gom.

(Figure 7.)

This was another species which occurred in garden soil A in the first three flasks of the culture. The filaments were greyish-green in colour with very narrow sheaths (sh). The cells were shorter than broad, being 4.5-6μ in diameter and 3μ or less in length, and were not constricted at the transverse walls, which were often granulated. The filament tapered at the apex, which, as a rule, was slightly curved with a distinct calyptra (c) on the tip of the end cell. This species was often found in the flasks in association with *P. tenue* and *P. foveolarum,* but has not been obtained in pure culture.

This has been recorded for the soil in England by Bristol Roach(4).

PHORMIDIUM AUSTRALE, n.sp.

(Figure 8.)

A species of *Phormidium* occurred in flask No. 2 of the culture of garden soil A among the other species of this genus, but could not be identified with any form previously described. It was very slow in developing and did not appear in the flask in any appreciable quantity until after the other *Phormidium* species were more or less abundant. The trichome was a very light blue-green, the cells being approximately 4μ in breadth and slightly shorter than broad, with quite definite constrictions at transverse walls. The sheath was very narrow and was not apparent unless it protruded past the trichome. The end cell (a.c.) of the filament was elongated and tapering. *P. Jadinianum* Gom., which also measures approximately 4μ in the diameter of the cells, differs from this form in its colour, being an olive-green.

Cellulis palis caeruleis viridibus, latis 4μ, latioribus paulo quam longioribus, constrictis ab muris transversis. Extrema cella villi extenta et attenuata.

PHORMIDIUM SUBTERRANEUM, n.sp.

(Figure 9.)

In the cultures of bush soil another *Phormidium* was found which did not agree with any species previously described. The filaments were greyish in colour, with very indistinct transverse walls. The cells of the trichome were approximately 4.5μ in diameter and slightly longer than broad. The end cell (a.c.) was rounded, not tapering in any way and without a calyptra. The sheath (s) of the filament was narrow and showed only where it protruded past the trichome. It seemed closest to *P. ambiguum* Gom., which, however, is slightly constricted at the transverse walls.

Cellulis glaucis, latis 4-5μ, longioribus paulo quam latioribus, non constrictis ab muris transversis quae confusa sunt. Extrema cella villi globosa, non extenta nec attenuata.

Chlorophyceae.

These are plentiful in all cultures and the majority develop within a few weeks of inoculation. *Chlorococcum humicola* Rabenh. is the most frequent species, while *Stichococcus bacillaris* Näg. and a small species of *Chlorella* also appear constantly. Quite a number of these green forms have been obtained in pure culture on mineral salts agar. In the bush soil cultures, moss protonemas frequently occurred. The species identified are briefly described in the following pages.

CHLAMYDOMONAS COMMUNIS Snow.

(Figure 10.)

This species, although generally regarded as a plankton species, has been described from the soil by Bristol Roach(4) in England. In Victoria it was found in cultures from the bush soil and occurred in many of the flasks. The cells were oblong-ovate and measured on an average 10-11μ in length and 5-6μ in diameter. At the anterior end of the cell there was a distinct papilla, from either side of which two long cilia arose. The chloroplast was cup-shaped with a distinct central pyrenoid. A lateral stigma occurred near the anterior end. Reproduction by division of the cell contents into daughter cells has been observed, the mother cell previously shedding its cilia and settling into a non-motile state (Fig. 10B).

Playfair(30) has recorded this species in New South Wales, and mentions also an ovate or broader form of this organism which he calls *C. communis* Snow var. *ovata*. This description seems to agree with a broader form of *C. communis* found in the soil cultures (Fig. 10C).

CHLAMYDOMONAS COMMUNIS Snow var. GRANDIS, n. var.

(Figure 11.)

This species also occurred in the cultures of the bush soil. It differed from the preceding species only in size, being very much larger, hence it was thought to be a new variety, *C. communis* var. *grandis*. The cells were oval with a distinct papilla at anterior end, from either side of which the two cilia arose. There was a cup-shaped chloroplast with a distinct central pyrenoid and a small lateral stigma near the anterior end of the cell.

Non-motile cells dividing to form daughter cells have been observed (Fig. 11B).

CHLAMYDOMONAS GRACILIS Snow.

(Figure 12.)

A third *Chlamydomonas* was found in the cultures from garden soil B. This species was broader in comparison with its length than the preceding species; also it tapered more towards the anterior end, being almost pear-shaped. The cell measured from 11-15μ in length and from 7-8μ in breadth. A papilla was present at the anterior end between the two cilia. The chloroplast was cup-shaped, with a large pyrenoid towards the posterior end of the cell. A lateral stigma was noted near the posterior end. Reproduction typical of the genus has been observed.

The measurements are slightly larger than those given by Pascher for this species, but otherwise it seems to agree closely with the description given.

CHLOROCOCCUM HUMICOLA (Naeg.) Rabenh.

(Figure 13.)

This is perhaps the most commonly occurring species, being found in most flasks of both garden and bush soil. It grows well on mineral salts agar and is obtainable in pure culture without much difficulty.

The vegetative cells (Fig. 13A) are round, bright green, and very granulated in appearance. The diameter of the cells varies, being on an average from 15-17μ, while the maximum is 22μ. There is a single parietal bell-shaped chloroplast (Fig. 13 ch), with one large pyrenoid (Fig. 13 p) which seems to lie opposite the opening of the chloroplast. The pyrenoid seems occasionally to divide into several parts. The cell wall (Fig. 13 w) is thin, about 0.5μ in thickness. Reproduction by zoospores (Fig. 13 z) is quite common. When the cell reaches a certain size the contents divide to form from 16-32 zoospores (Fig. 13B). When these are ready to be freed, the mother cell wall (w) becomes mucilaginous and finally bursts. The zoospores are approximately 9μ long and 5μ broad, with a single parietal chloroplast containing one pyrenoid. There is an unpigmented space (s) at each end of the zoospore. Two cilia (Fig. 13 c) of equal length (10-12μ) are attached to the basal end. The zoospores swim actively around and finally settle down, shed their cilia, and gradually become adult rounded vegetative cells.

Figs. 13-16.—13. Chlorococcum humicola Rabenh. A. Vegetative cells. B. Zoosporangia. C. Zoospores. 14. Chlorella vulgaris Beyerinck. A. Vegetative cells. B. Cells forming autospores. C. Autospores freed from mother cell. 15. Ourococcus bicaudatus Grobety. A. Vegetative cells. B. Cells dividing. 16. Ankistrodesmus falcatus Ralfs. A. Vegetative cells. B. Cells forming autospores, w. wall, ch. chloroplast, p. pyrenoid, m. mucilaginous wall, z. zoospores, ci. cilia, ch. chloroplast, a. autospore, mw. mother cell wall, ap. appendage. × 700.

This form agrees with the description given by Pascher, but seems slightly larger than the normal species. In this respect it agrees with the Malay form described by Bristol Roach(5).

This species has been recorded from the soil in England by Bristol Roach(4), and in America by Moore and Carter (22).

CHLORELLA VULGARIS Beyerinck.

(Figure 14.)

This species also occurred frequently in the cultures of both bush and garden soil, and has been quite readily obtained in pure culture. The cells were round, varying in diameter from 5μ-9μ with a thin cell wall. There was a solitary parietal bell-shaped chloroplast (ch) with one pyrenoid (p) which was not always distinct.

The reproduction was by means of autospores, 4-8 of these being formed within the mother cell wall by the division of the cell contents, and being ultimately set free by the gelatinization of the old cell wall.

Several species of *Chlorella,* including *C. vulgaris,* have been recorded from the soil.

OUROCOCCUS BICAUDATUS Grobéty.

(Figure 15.)

There seems to exist some doubt regarding the nomenclature of this species, synonyms being *Keratococcus caudatus* Pascher and *Dactylococcus bicaudatus* A. Br., but because of its ability to divide vegetatively it has been taken out of Oocystaceae; therefore, it cannot be a *Dactylococcus*, and the name *Ourococcus* seems to have priority over *Keratococcus*. This species was found in the cultures of bush soil only, in one or two of the less dilute flasks. It has been grown on plates of mineral salts agar, but as yet no very successful pure culture has been obtained.

The cells were fusiform in shape, straight or slightly bent with an appendage at both ends, both of which were pointed or one was pointed while the other was more or less rounded. The length of the cells measured from 25-34μ, including the appendages, which were approximately 5μ long. The diameter of the cells varied from 3.5-6μ. The chloroplast was peripheral, with one pyrenoid, which was often indistinct.

Reproduction by longitudinal division was observed (Fig. 15B). Although autospore formation may occur in this species, it has not been observed.

This species has been recorded for the soil by Bristol Roach(4) in England.

ANKISTRODESMUS FALCATUS Ralfs.

(Figure 16.)

This species agrees with the form described from the soil in England by Bristol Roach(4) which, because of its habitat and special resistant powers, she regarded as a special form of the species *A. falcatus* forma *terrestris*. It has been found in the cultures of bush soil only. The cells were crescent-shaped with pointed ends, and measured approximately 17-20μ in length and

2.5-3.5μ in breadth. A single parietal chloroplast covering the entire cell wall was present, but no pyrenoid has been observed. Reproduction was by longitudinal division into 4 to 8 autospores which are set free by the gelatinization of the mother cell wall.

Playfair(30) recorded the presence of two varieties of *A. falcatus* in plankton in New South Wales, while West(43) found it among the algae of the Yan Yean Reservoir, Victoria.

OOCYSTIS SOLITARIA var. TERRESTRIS, n. var.

(Figure 17.)

A species of *Oocystis* was grown in several cultures of garden soil A, being one of the first forms to develop, but dying out of the cultures completely within a few months.

The cells were always solitary, being elongated in shape and measuring approximately 7-9μ in diameter and 19-27μ in length. Each cell contained several chloroplasts without pyrenoids, and at both ends the wall was thickened slightly. Reproduction was by the formation of autospores, which measured on an average 6μ in diameter by 8-9μ in length. No mother cell with an unbroken wall was observed, but in many cases autospores were seen lying within portions of the old mother wall (see Fig. 17B).

The identification of this species was rather difficult. At first sight it closely resembled *O. rupestris* Kirchner, but upon closer observation was seen, unlike this species, to have polar thickenings of the cell wall. Pascher mentions several varieties of *O. solitaria* Wittrock. This form was very close to *O. solitaria* var. *elongata* Printz., from which, however, it differed in the type of polar thickening. It was therefore regarded as a new variety—*O. solitaria* var. *terrestris.*

Species of *Oocystis* are found as a rule in lakes and ponds, and as far as can be ascertained this is the first record of one from soil. West(43) has recorded *O. solitaria* Wittrock from the Yan Yean Reservoir, Victoria, and Playfair(29) has described many species and varieties of *Oocystis* in New South Wales, among them being *O. solitaria* Wittrock, all, however, from ponds or swamps.

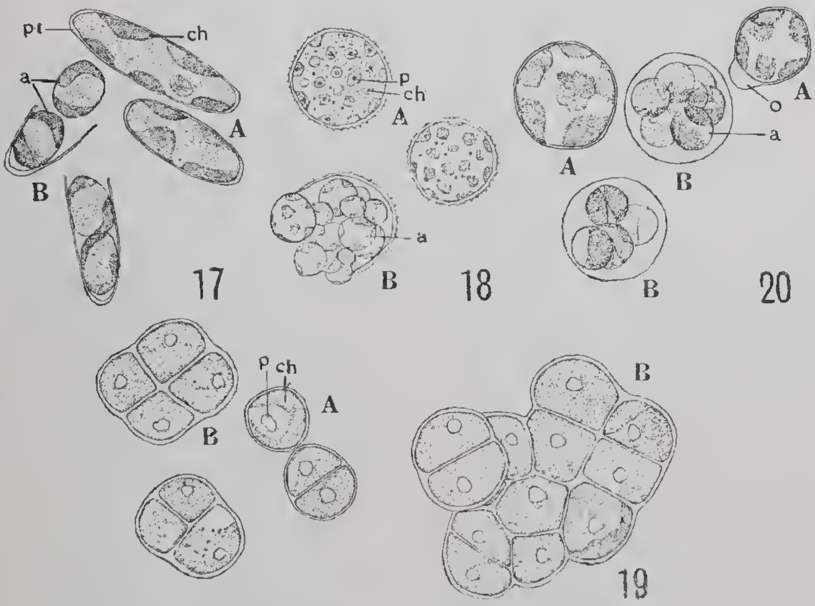
TROCHISCIA HIRTA (Reinsch) Hansgirg.

(Figure 18.)

This alga was found in several cultures of garden soils A and B, and has been obtained in pure culture. In this condition, unfortunately, the organism did not grow normally, and in many cases even developed an almost spineless wall. Some *Chorellas* have been described with appendages on their walls, but as this form contained several definite chloroplasts it seemed to be undoubtedly a *Trochiscia.* Following Pascher's key it was identified as *Trochiscia hirta.* With this identification, however, Professor Fritsch, to whom a culture of the organism was sent, did not agree. However, it has been concluded that the culture, on reaching him, was not in a normal condition, probably even the spines on the walls were undeveloped or reduced.

The cells were spherical, varying in diameter from 9.5μ-21μ, with minute needle-like spines covering the outer wall (Fig. 18A). There were several chloroplasts (ch), slightly yellowish-green in colour, some with a pyrenoid (p). Reproduction by autospores was common (Fig. 18B), the spores developing the characteristic spines on their outer walls only after liberation from the mother cell.

Several species of *Trochiscia* have been recorded from the soil, including *T. hirta* in England by Bristol Roach(4).



Figs. 17-20.—17. Oocystis solitaria var. terrestris, n. var. A. Vegetative cells. B. Autospores freed from mother cell. 18. Trochiscia hirta Hansgirg. A. Vegetative cells. B. Autospores being freed from mother cell. 19. Protococcus viridis Agardh. A. Single cell. B. Colony. 20. Muriella australis, n. sp. A. Vegetative cell. B. Autosporangium. ch. chloroplast, pt. polar thickening, a. autospore, p. pyrenoid, o. outgrowth. × 700.

PROTOCOCCUS VIRIDIS Agardh.

(Figure 19.)

Owing to one or two doubtful features, the identification of this species was left in abeyance for some time and the organism carefully observed in pure culture for over a period of two years. At the end of that time the organism was taken to be a *Protococcus* and more or less identical with *P. viridis*. This latter, however, usually has no pyrenoid, while in this form from the Victorian soil the pyrenoid was always very large and distinct (Fig. 19A (p)). West and Fritsch(44) draw attention to the fact that there seem to be two species of *P. viridis,* one with a pyrenoid and one without. Whether that is so or not, it is certain that this species was never without one.

The cells were spherical, containing a single peripheral bright-green chloroplast (ch) with a large central pyrenoid (p). Adult cells measured on an average 9-10μ in diameter. Reproduction was always by vegetative division into two, then four, &c., often all the daughter cells remaining together to form a large colony (Fig. 19B, c). This is one of the commonest of the green algae, being world-wide in distribution. It is found as a green scum not only on damp soil, but on fences, tree-trunks, &c.

MURIELLA AUSTRALIS, n.sp.

(Figure 20.)

In many of the flasks of the cultures of garden soil B an organism was observed which could not be identified with any known species. It has been grown in pure culture, and carefully watched for over two years. The cells were solitary and spherical, and contained several green chloroplasts without pyrenoids. The chloroplasts were slightly yellowish-green in colour, but the cell walls gave a very definite cellulose reaction with chlor-zinc-iodine and no blue colour change when boiled with HCl, hence it could not be placed among the Heterokontae.

Many of the cells in an old culture developed peculiar outgrowths on the cell wall (Fig. 20A, o), which were not unlike those found in *Excentrosphaera.* However, these thickenings were by no means general.

Reproduction was by autospore formation, four or more being formed within the mother cell (Fig. 20B). Although this species has been grown in pure culture in mineral salts agar as well as in liquid mineral salts, no sign of zoospore formation has been observed.

The organism agreed with the generic characters given by J. Boye Petersen in his description of *Muriella,* but differed from his species in being much larger, measuring 10-18μ in diameter, also in having a thicker cell wall, and therefore the name *Muriella australis* is proposed for it.

Cellulis globosis, latis 10-18μ *cum muris modice crassis, et aliquot irridibus chromatophoris sine pyrenoidibus. Reproductione per autospores.*

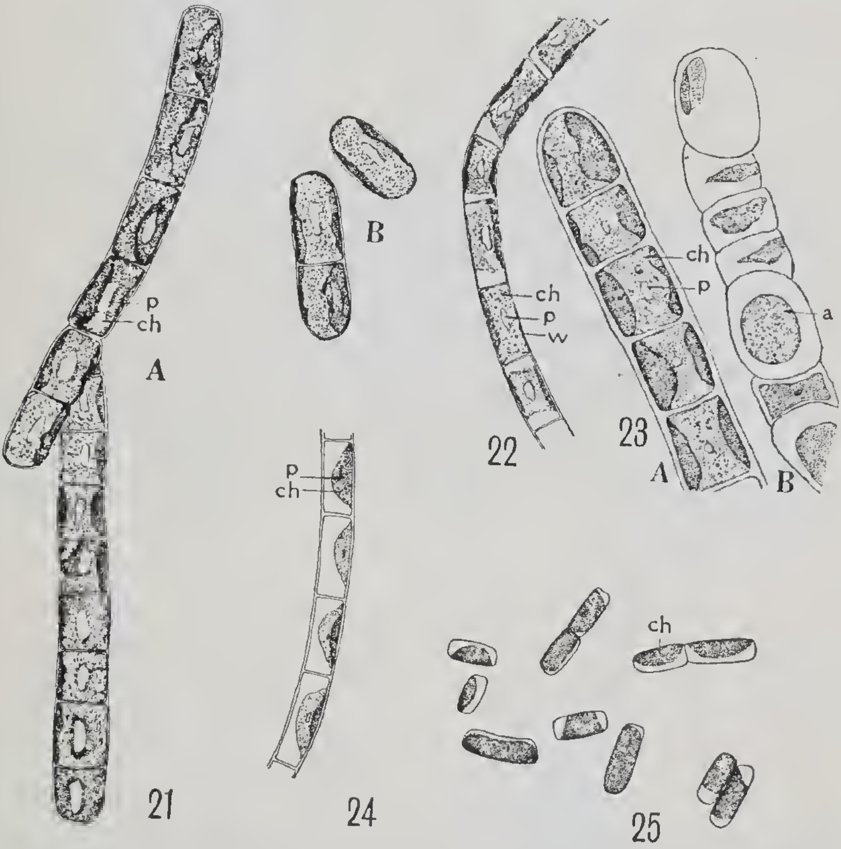
ULOTHRIX VARIABILIS Kützing.

(Figure 21.)

U. variabilis Kütz. was fairly common in the cultures from garden soils A and B, but was never found in the cultures of bush soil. It has been obtained in pure culture without any difficulty.

The organism consisted of long unbranched filaments, the individual cells of which measured 12-13μ in length and 7-8μ in diameter, with a single green chloroplast (ch) encircling two-thirds of the protoplast, and containing one large central pyrenoid (p). The end cell of the filament was rounded at the apex. In a fairly old culture the filaments break up into 2 or 3-celled fragments (Fig. 21B). This vegetative type of reproduction was the only kind observed, the typical method by zoospore formation not taking place in the cultures.

This species has been described by Bristol Roach (4) for the soil in Great Britain.



Figs. 21-25.—21. Ulothrix variabilis Kütz. A. Vegetative filaments. B. Filaments breaking up. 22. Ulothrix subtilissima Rabenh. 23. Ulothrix aequalis Kütz. A. Vegetative filament. B. Filament forming akinetes. 24. Hormidium flaccidum A. Br. 25. Stichococcus bacillaris Nag. p. pyrenoid, ch. chloroplast, w. thin cell wall, a. akinete. × 700.

ULOTHRIX SUBTILISSIMA Rabenhorst.

(Figure 22.)

Unlike the preceding one, this species was found in the bush soil only, and did not appear in any of the flasks containing garden soil. It has not yet been obtained in pure culture. The filaments were narrower than those of *U. variabilis,* measuring from 4.5-5.5μ in diameter, while the individual cells varied in length from 11-13μ, and contained a single chloroplast (Fig. 22 ch), encircling two-thirds of the protoplast with one central pyrenoid (p). The cell wall (w) was comparatively thin.

In this species of *Ulothrix* again no zoospore formation could be observed. This species does not appear to have been previously recorded for the soil.

ULOTHRIX AEQUALIS Kützing.

(Figure 23.)

This form was observed in cultures of the bush soil, and although small colonies have been found growing on agar plates, no pure culture has yet been obtained.

The thick cell wall distinguished it from the foregoing species of *Ulothrix*. The cells of the filaments measured approximately 12μ in diameter, and were as long as broad, sometimes slightly longer. Each cell contained a single chloroplast (ch), which covered the entire longitudinal wall and encircled two-thirds of the protoplast. According to Pascher there may be two pyrenoids present in each cell, but in all these cultures each cell contained one pyrenoid only (p).

No zoospore formation has been observed, but in many filaments, particularly those in older cultures, the contents of the cell have rounded off to form akinetes, the longitudinal walls of the filament in these cases being constricted (Fig. 23B).

This species does not appear to have been previously recorded from the soil.

HORMIDIUM FLACCIDUM A. Br.

(Figure 24.)

A few filaments which have been identified as *Hormidium flaccidum* A. Br. were found growing in one or two of the earlier or less dilute flasks of bush soil. The size of the chloroplast, which covered a small portion only of the cell wall, distinguished this genus from *Ulothrix*. The filaments were long and unbranched and did not break up as readily as many species of *Hormidium*. The individual cells of the filaments measured from 5-6μ in diameter and from 11-15μ in length. The chloroplast (ch) did not cover more than half of the cell wall, and contained a distinct pyrenoid (p). The vegetative filaments only have been observed, no reproduction having taken place.

Bristol Roach(4) records the presence of *H. nitens* Menegh, but this species does not appear have been previously recorded.

STICHOCOCCUS BACILLARIS Naegelli.

(Figure 25.)

This species occurred frequently in the cultures from both bush and garden soil. It grew particularly well on the mineral salts agar, and formed quite a large colony in a few weeks and was comparatively easy to obtain in pure culture. Although it belongs to the Ulotrichales, the filamentous form was rarely seen in culture, single cells predominating or two or three cells united in short chains.

The cells agreed in all particulars with the typical form as described by Pascher, being from 3-3.5μ in breadth and varying in length from 6-11μ, the ends being rounded. There was a single plate-like chloroplast (Fig. 25 c), which filled about two-thirds of the cell, but no pyrenoid was present.

This species is a common terrestrial form and has been recorded for the soil by Bristol Roach(4) in England and by Moore and Carter in Missouri, United States of America(22).

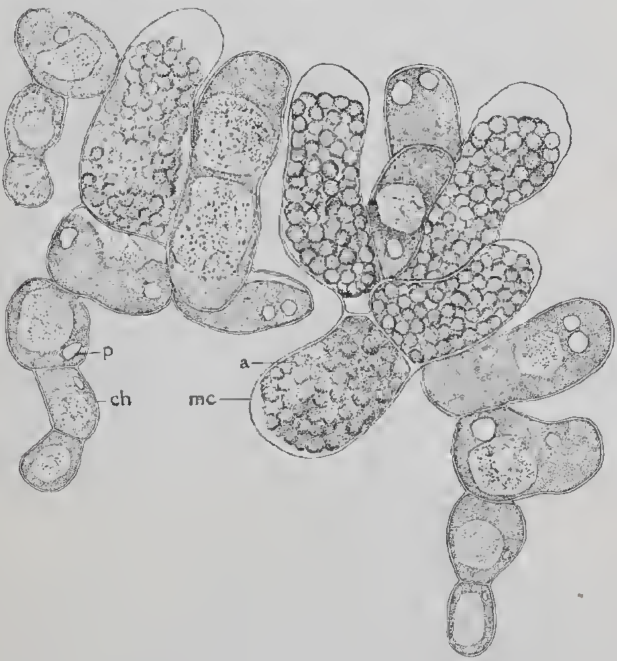


Fig. 26. Gongrosira australis, n. sp. ch. chloroplast, p. pyrenoid, mc. mother cell, a. spore.

GONGROSIRA AUSTRALIS, n. sp.

(Figure 26.)

This organism occurred frequently in the cultures of bush soil, either as small irregular colonies or short filaments two or three cells in length. It has been grown on mineral salts agar, where it formed spherical colonies. By its vegetative characters it was identified as a *Gongrosira,* but further investigation showed that no zoospores were ever formed. The organism was carefully watched for over a year, and during that period many of the larger cells of the filaments became gonidangia, their contents dividing up to form numerous small round gonidia or autospores which were never motile.

However, it was concluded that this was due to cultural conditions, as neither *Botrydiopsis arhiza* Borzi nor *Heterococcus viridis* Chodat, both of which normally form zoospores, did so under conditions identical with those under which this alga was grown. It was, therefore, decided that this species belonged to *Gongrosira,* and it is suggested that the generic description be modified to include the formation of non-motile spores under cultural conditions. The species, however, did not agree with any previously described, being closest to *G. terricola* Bristol but larger in size with both intercalary and terminal gonidangiums.

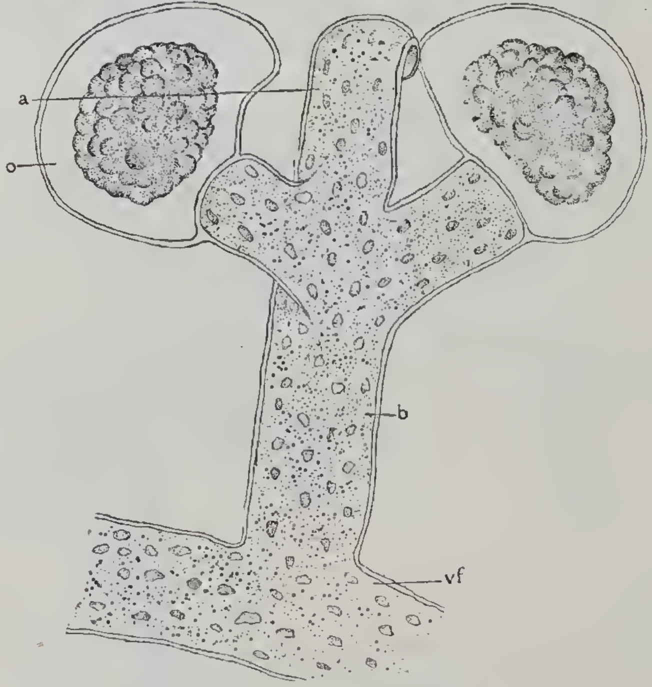


Fig. 27. Vaucheria hamata (Vauch.) Lyngb. × 400. vf. vegetative filament, b. sexual branch, o. oogonium, a. antheridium.

The thallus consisted of cells of varying sizes branching irregularly to form colonies, only slightly differentiated into basal cushion-forming cells and upper filamentous ones, the end cells of the filament gradually decreasing in size. There was a single irregular chloroplast (ch) in each cell, usually with one pyrenoid (p) but occasionally with two or even three. The vegetative cells were generally longer than broad, measuring from 8-15μ in diameter and from 12-45μ in length. Any of the larger cells in the filament was apparently capable of becoming a gonidangium (Fig. 26 mc), the contents dividing up to form numerous small round gonidia or autospores (a). The wall at the apex of the mother cell became swollen and mucilaginous, finally breaking down to free the gonidia.

Filamentis inferioribus cum cellulis subglobosis et superioribus erectis cellulis 8-15μ *latis, et longis* 12-45μ *cum singularis inaequalibus chromatophoris et* 1-3 *pyrenoidibus. Reproductione per gonidangias extremas vel intercalarias cum gonidiis multis rotundis.*

VAUCHERIA HAMATA (Vauch.) Lyngb.

(Figure 27.)

This alga did not grow in any of the culture flasks but grew in abundance on the surface of a sample of the garden soil A which had been placed in a sterile petri dish. The filaments (vf) measured approximately 35-40μ in diameter. Oogonia (o) were found on lateral branches, either one or two being present on each branch from which an antheridium (a) also grew. An oogonium measured about 70μ x 56μ, being subspherical, while an antheridium was 26μ in diameter, and very much curved. This species is frequently found growing on damp soil.

Heterokontae.

Only five species of Heterokontae have been identified from Victorian soils, and of these *Bumilleria exilis* Klebs is the most frequent form, occurring in garden soil A and B as well as in the bush soil. *Heterococcus viridis* Chodat occurs in one series of the garden soil and in the bush soil. *Botrydiopsis arhiza* Borzi also is a very common terrestrial form, being world-wide in its distribution, but here it was found only in one series of the garden soil cultures.

Brief descriptions of the five species are given.

OPHIOCYTIUM TERRESTRE Heyward.

In a previous paper(18) the author has described this species, which was found in the cultures of bush soil. The organism grew readily in the flasks but could not be obtained in pure culture. It was a non-colonial form not attached in any way to some substratum. The size of the adult cell (A) varied from 9-12μ in breadth and up to 135μ in length. The cell was slightly curved and had a distinct apical cap (a.c.), while at the basal end was a wavy stalk. Reproduction by both aplanospores and zoospores was observed.

This was the first occasion on which the genus was recorded from soil.

BOTRYDIOPSIS ARHIZA Borzi.

(Figure 28.)

This species was identified from cultures of garden soil B, but has not been obtained in pure culture. The cells were solitary and large, with very thin walls, and contained numerous yellowish-green disk-like chloroplasts. The cells varied in diameter from 15-30μ, the smaller ones containing fewer chloroplasts.

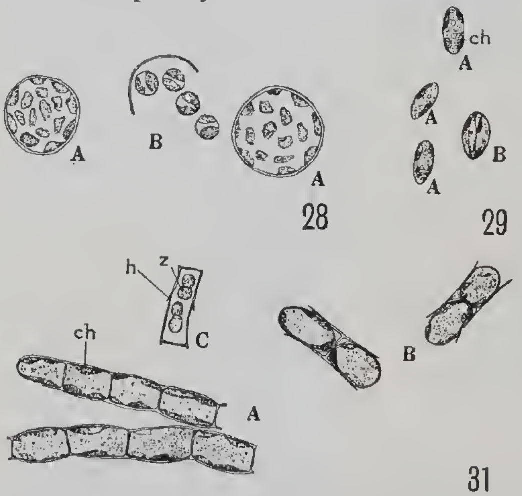
No zoospores were observed, but autospore formation was frequent, this being probably due to cultural conditions. The contents of the mother cell divided to form numerous rounded spores which were freed by the bursting of the mother cell wall (Fig. 28B).

This species is a very common terrestrial alga and has frequently been recorded for the soil.

CHLOROCLOSTER MINOR, n. sp.

(Figure 29.)

A small brownish-green unicellular alga was frequently observed in the earlier stages of development of the cultures of bush soil. Unfortunately, it could not be obtained in pure culture and later died out completely.



Figs. 28, 29, 31.—28. Botrydiopsis arhiza Borzi. A. Vegetative cell. B. Autospores being freed from mother cell. 29. Chlorocloster minor n. sp. A. Vegetative cell. B. Autosporangium. 31. Bumilleria exilis Klebs. A. Vegetative filaments. B. Filaments breaking down to form akinetes. C. Cell forming zoospores. ch. chloroplast, s. autospores forming, z. zoospores, h. h-shaped pieces showing. × 700.

The cells were solitary, elongated in shape, and contained two or more brownish-green chloroplasts. No starch reaction was given with iodine, while with chlor-zinc-iodine the cell walls gave no cellulose reaction. The alga was therefore placed in the Heterokontae and was found to be very similar to *Chlorocloster terrestris* Pascher, from which it differed in size, being much smaller. The length measured from 7-8μ while the diameter was 2.5-4μ. The cell wall was very thin, and each cell contained two or more chloroplasts (ch).

Reproduction took place by longitudinal division into autospores (Fig. 29B).

Cellulis solitariis extentis latis 2.5-4μ, longis 7-8μ cum duo aut multis chromatophoris fuscis irridibus. Reproductione per autospores.

HETEROCOCCUS VIRIDIS Chodat.

(Figure 30.)

This alga grew in the cultures of bush soil and garden soil A. It developed in a few weeks after inoculation and in the earlier examinations was one of the most prominent forms. Later it apparently died out of the culture. This disappearance, however, may have been due to the fact that the more mature filaments tended to break down into unicellular spherical organisms. This was proved by growing a colony on mineral salts agar and watching its development (see Fig. 30A, B, C).

Fig. 30. Heterococcus viridis Chodat. A. Young colony. B. Portion of filament. C. Filament breaking up into unicells. ch. chloroplast, s. autospores forming. × 700.

In its filamentous form, the organism was built up of cells of irregular shape and size, longer than broad, and containing numerous disk-like yellowish-green chloroplasts (ch). No pyrenoids were present and the cell walls gave a negative chlorophyll test with chlor-zinc-iodine. The diameter of the cells averaged from 7-10μ, while the length varied from 10-60μ. In the unicellular form the diameter measured from 10-15μ, and in many of these cells the contents divided up to form numerous small spores (Fig. 30c (s)). These may have been autospores or zoospores which had not then become motile, both types of reproduction taking place. This form has been recorded for the soil by Moore and Carter (22) in America.

BUMILLERIA EXILIS Klebs.

(Figure 31.)

This was perhaps the most frequently occuring member of the Heterokontae, being present in numerous flasks of both bush and garden soil. Identification of this species was difficult because the so-called characteristic H-shaped pieces in the cell wall were not very evident in the vegetative condition. This is apparently always the case in this species of the genus, and on this account Pascher suggests taking it out of *Bumilleria* and renaming it *Heterothrix exilis*.

The organism consisted of comparatively short unbranched filaments, the individual cells measuring 4-5μ in diameter and 10-15μ in length. In each cell there were usually two chloroplasts (ch), but occasionally more. The species has been obtained in pure culture on mineral salts agar and under these conditions reproduction took place by the liberation of akinetes. The contents of an individual cell rounded off to form a spherical spore which is set free by the breaking of the cell wall (Fig. 31c). In these circumstances H-shaped pieces are more apparent. In one instance only was more than one spore in a cell observed. Here the contents rounded off to form four small spores. It was impossible to tell whether these were zoospores or autospores as no motile organs were observed (Fig. 31B).

This species has been previously recorded for the soil by Bristol Roach (4) in England.

Bacillariaceae.

Very few diatoms or desmids have been identified in the culture flasks. They do not appear until long after the other algae are well established, and only two have been identified with certainty.

HANTZSCHIA AMPHIOXYS (Ehr.) Grun.

(Figure 32.)

This was the only diatom which was found in any appreciable quantity. It measured on an average 7μ x 33μ. This form has been described by Bristol Roach (4) from the soil in England and by Moore and Carter (22) in U.S.A.

NAVICULA MUTICA Kütz.

(Figure 33.)

This diatom was identified in many flasks of the cultures from garden soils A and B. The breadth of the valve averaged 6μ while the length varied from 14-17μ. This species was found by Bristol Roach (4) to be one of the commonest soil diatoms.

From this investigation, it will be realized how very cosmopolitan are the terrestrial algae in their distribution, many forms identified from soils in England, America, and Europe, reappearing here in Victorian soils. It is very significant to find three algae—*Chlorococcum humicola, Bumilleria exilis* and *Hantzschia amphioxys,* which Bristol Roach (4) points out as being three of the most frequently occurring species in English soils—again occupying that position in regard to Victorian soils. Quite a number of other species which have been identified in other parts of the world are also present here, including *Nostoc muscorum, Anabaena variabilis, Phormidium tenue, Phormidium autumnale, Chlamydomonas communis, Chlorella vulgaris, Ourococcus bicaudatus, Ankistrodesmus falcatus, Trochiscia hirta, Stichococcus bacillaris, Vaucheria hamata, Botrydiopsis arhiza,* and *Heterococcus viridis.* Some few, such as *Oocystis solitaria, Ulothrix subtilissima, Ophiocytium terrestre,* have not previously been recorded from the soil, while others again were found to be new species belonging, for the most part, to terrestrial genera e.g., *Phormidium australe, Phormidium subterraneum, Muriella australis, Gongrosira australis, Chlorocloster minor.*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Figs. 32. Hantzschia amphioxys (Ehr.) Grun. 33. Navicula mutica Kütz. × 700.

In conclusion I should like to thank all those who have helped me during this investigation—Professor Ewart for his unfailing interest, Dr. McLennan for her ever willing assistance and helpful suggestions, and Professor Fritsch of the London University, to whom many specimens were forwarded for verification.

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[Proc. Roy. Soc. Victoria, **47** (N.S.), Pt. II., 1935.]

Art. XVI.—*Victorian Graptolites* (*New Series*). *Part III.*

By WM. J. HARRIS, D.Sc.
and D. E. THOMAS, B.Sc.

[Read 11th October, 1934; issued separately, 8th May, 1935.]

The graptolites described in the present paper are for the most part high Darriwilian forms from the area east of Bendigo, and include those on which the subdivision of the Darriwilian beds is based. Others are interesting for purposes of comparison or from an evolutionary point of view.

Biserial forms predominate in the D2 and higher zones which have been included by one of us(11) in a *Diplograptus* series. *Glyptograpti* are abundant, including mutations between *D.* (*Glyptog.*) *dentatus* (Brong.) and *D.* (*G.*) *teretiusculus* (His.). *D.* (*G.*) *intersitus,* sp. nov., is one of these, and is so restricted in range that it serves as a zonal fossil. *D.* (*G.*) *euglyphus* (Lapworth) is common in the higher beds. Dichograptid species are still common, but become progressively rarer in the higher beds. Many of the *Didymograpti* show thecal elaboration. The presence of these complex forms adds interest but also difficulty to the task of description, since the material available is for the most part soft, soapy shale in which details of graptolite structure are not clearly seen.

A notable feature is the general resemblance of the upper Darriwilian forms here described to those described and figured by Bulman(1, 2) from South America. Though it seems unsafe to insist on specific identity in many cases, it seems clear that further work will emphasize the equivalence of horizon of our beds to the South American beds referred to the Llanvirnian, in spite of the notable absence of the dependent *Didymograpti* from these Victorian beds.

At the end of the paper a list is given showing the position of graptolite localities referred to by numbers in the body of the paper. The stratigraphy of the area from which most of the Upper Darriwilian forms were obtained, with graptolite associations and remarks on zoning, is given in an accompanying paper by Harris(11).

The forms described and figured are:—

Family DICHOGRAPTIDAE Lapworth.

Genus Pterograptus Holm.
    Pterograptus incertus, sp. nov.
Genus Trichograptus Nicholson.
    Trichograptus immotus, sp. nov.
Genus Tetragraptus Salter.
    Tetragraptus defensus, sp. nov.

Genus Didymograptus McCoy.
Didymograptus cognatus, sp. nov.
" distinctus, sp. nov.
" cuspidatus Ruedemann
" compressus, sp. nov.
" nodosus Harris
(?) Didymograptus dubitatus, sp. nov.

Family DIPLOGRAPTIDAE Lapworth.

Genus Diplograptus McCoy.
Sub-genus Glyptograptus Lapworth.
Glyptograptus austrodentatus Harris and Keble.
" intersitus, sp. nov.
" euglyphus (Lapworth).
Sub-genus Mesograptus Elles and Wood.
(= Diplograptus McCoy, sensu stricto.)
(?) Mesograptus decoratus, sp. nov.
Sub-genus Amplexograptus Elles and Wood.
Amplexograptus modicellus, sp. nov.
" confertus (Lapworth).
" differtus, sp. nov.
Genus Cryptograptus Lapworth.
Cryptograptus schaferi (Lapworth).

Family GLOSSOGRAPTIDAE Lapworth, emend. Elles and Wood.
Genus Glossograptus Emmons.
Glossograptus acanthus Elles and Wood.
(?) Glossograptus crudus, sp. nov.
Genus Lasiograptus Lapworth.
Sub-genus Hallograptus Carruthers.
Hallograptus proteus, sp. nov.
Sub-genus Thysanograptus Elles and Wood (= Lasiograptus Lapw).
Thysanograptus etheridgei Harris.

Family ISOGRAPTIDAE Harris.
Genus Cardiograptus Harris and Keble.
Cardiograptus crawfordi Harris.

Family DICHOGRAPTIDAE Lapworth.

Genus **Pterograptus** Holm.

Pterograptus incertus, sp. nov.

(Fig. 1, Nos. 1 and 1a; Fig. 2, Nos. 1–6.)

Description.—From a long and slender sicula two dependent stipes diverge at an angle usually of more than 90°, but sometimes less. These in turn, apparently by dichotomy, give rise to a number of stipes ranging from three or four to eight, forming a *Bryograptus*-like rhabdosome. Thecae of simple dichograptid type, 10–11 in 10 mm., 2–3 times as long as wide, with small overlap, concave ventral margins and straight or slightly concave apertures, the apertural margins approximately normal to the axis of the stipe. The sicula is rather less than 1 mm. long, and the first theca originates sub-orally. The first dichotomy takes place sub-orally from th 1^1 and th 1^2, and further dichotomy from succeeding thecae. The distal stipes are in every observed case less than 1 mm. wide and often considerably less.

Remarks.—This form provides an example of the difficulty of classifying graptolites by method of branching. By that criterion the four-branched forms might be regarded as dependent *Tetragrapti* like *T. pendens,* and the forms with more numerous branches resemble externally *Bryograpti* of a much lower horizon, yet the affinities of the species are rather with *Pterograptus* than with these earlier genera. Dichotomy may possibly be due to the equal spacing of the thecae as regards food supply.

Affinities.—The present species can be easily distinguished from *P. scanicus* Moberg and *P. lyricus* Keble and Harris by the general form of the rhabdosome. It is a much more robust form than *P. elegans* Holm, from which it differs also in thecal characters. In general habit it differs from the unnamed form figured by Bulman from Bolivia(1), although a form resembling this occurs in the same beds but has not yet been found in a sufficiently well-preserved state for description.

Localities and Horizon.—Widely distributed and locally abundant at Upper Darriwilian localities in the Strathfieldsaye district, where it is most characteristic of a sub-zone between the zones of *Diplograptus* (*Glyptograptus*) *austrodentatus* and *D.* (*G.*) *intersitus.* For example, on the road near Allot. 3 of Sect. IX., Strathfieldsaye (Caldwell's loc. A. 169), it is associated with *D.* (*G.*) *austrodentatus* and *D.* (*G.*) *intersitus,* while further south (locs. 283–285) it is associated with *D.* (*G.*) *intersitus.* At other outcrops of *D.* (*G.*) *intersitus,* apparently higher, such as loc. 196, it occurs very rarely.

Genus **Trichograptus** Nicholson.

TRICHOGRAPTUS IMMOTUS, sp. nov.

(Fig. 1, Nos. 2a-c; Fig. 2, Nos. 7, 8.)

Description.—Rhabdosome slender, bilaterally symmetrical, consisting of two main branches which diverge at about 150° but soon turn back to form almost a straight line or even take up a reclined position. Each of these gives off, from successive thecae near their apertures, secondary branches on the same side of the main stipes. These secondary stipes do not divide further. Sicula long and narrow, the primary thecae also long, narrow tubes, about 8 in 10 mm. Thecae on secondary stipes about 10–11 in 10 mm. inclined at an angle usually less than 25°, slightly overlapping, with apertural margins almost straight and generally at right angles to the axis of stipe.

Remarks.—By its size and general aspect this form may be distinguished from *Trichograptus fergusoni* T. S. Hall and *T. fragilis* (Nicholson). It is probably more closely related to *T. crinitus* Moberg, but differs from this Swedish form in having more rigid primary and secondary stipes and in having the thecae on the primary stipes more loosely spaced—8 in 10 mm. as compared with 10—thus spacing the secondary stipes more widely. The general characters of the thecae on the secondary stipes agree fairly well, but the overlap in our species is, if anything, somewhat less than in Moberg's species.

Horizon and Locality.—Rather rare in the upper Darriwilian beds (zone of *Didymograptus nodosus*) of Allot. 8, Section XXIX., Huntly (Bendigo).

Genus **Tetragraptus** Salter.

TETRAGRAPTUS DEFENSUS, sp. nov.

(Fig. 2, No. 9.)

Description.—Rhabdosome consisting of four reflexed stipes widening gradually from less than 1 mm. to nearly 2 mm. Thecae 16–10 in 10 mm. The characteristic feature is the presence on distal portions of the stipes of stout dorsal spines 1 mm. long, at right angles to the axis of the stipe and numbering 7 in 10 mm.

Remarks.—This description is based on one poorly-preserved specimen, but this is so distinct from any form yet found in Australia that special attention is called to it. In the nature and disposition of its dorsal spines this species resembles *T. echinatus* Clark (3, p. 65), but it seems to differ from Clark's species in every other respect—form, thecal measurements, etc. The state of preservation unfortunately does not permit of greater descriptive detail, and should better material be found later, the specific description may require amendment. From the description and figure future workers should be able to recognize any fragments that may come to light.

Horizon and Locality.—The single specimen was obtained from a band of pink and bluish-purple shale outcropping on the east and west road between Sects. 25 and 26, Strathfieldsaye, on the continuation of the band marked on Caldwell's plan of Strathfieldsaye as A.169. The horizon—high D2 (zone of *Diplograptus* (*Glyptograptus*) *austrodentatus*)—closely approximates to that recorded by Clark for *T. echinatus* (3, p. 56).

Genus **Didymograptus** McCoy.

DIDYMOGRAPTUS COGNATUS, sp. nov.

(Fig. 1, Nos. 4a–c; Fig. 2, Nos. 13, 14.)

Description.—Stipes occasionally up to 3 cm. long (longer if the reference of fragmentary stipes to this species is correct), but usually much shorter, very narrow throughout, not exceeding in our specimens a width of about 0.4 mm., diverging from a comparatively long and narrow sicula at an angle of 140°. Thecae 8 in 10 mm., triangular or slightly concavo-convex tubes with so little overlap as to appear to be placed almost end to end. Inclination very low, apertural margins straight or slightly concave, almost normal to axis of stipe.

Remarks.—The description of this slender *Didymograptus* approaches very closely that of *Didymograptus affinis* Nicholson. In spite of this, the cumulative effect of small differences is to give an impression quite distinct from that given by Elles and Wood's figures (4, pl. ii., figs. 1a, b). On close examination it will be seen that the overlap is even less than in the British species, the apertural margins are less concave, the ventral margins straighter, and there is no denticle. The species seems to have had a thin periderm, and consequently will be hard to find at outcrops where graptolites are not especially well preserved.

Horizon and Localities.—Common, but, on account of its delicacy, rarely well preserved in the upper Darriwilian beds of Bendigo East in the zone of *Didymograptus nodosus,* especially on the water-race in the south-east corner of Allot. 19, Sect. III., Strathfieldsaye (A.164).

DIDYMOGRAPTUS DISTINCTUS, sp. nov.

(Fig. 1, No. 3; Fig. 2, No. 10.)

Description.—Sicula relatively long and slender, 1.5 mm. in length, but tenuous and often unobservable, its position being indicated only by the divergence of the horizontal stipes and the unequal length of th 1^1 and th 1^2. Rhabdosome small, stipes as observed not more than 2 cm. long, originating nearer the apex than the aperture of the sicula and diverging at an angle of 180°. Thecae triangular tubes with negligible overlap, 9-10 in 10 mm., inclined at an angle of 40° or more, ventral margins slightly concave, apertural margins almost straight and making an angle of 100° with the distal portion of the stipe.

Remarks.—The type specimen shows clearly the divergence of th 1^1, the budding of th 1^2 and its horizontal growth. We are unable to cite any very close relations of this form. *Didymograptus acutidens* Lapw. MS. and *D. cuspidatus* Rued. approach it in some respects. From the former it is readily distinguished by its shorter, broader thecae, their greater angle of inclination and smaller overlap. From *D. cuspidatus* it differs in the initially greater angle of divergence (absence of a central v), uniform width of stipes, uniform angle of inclination, and widely-spaced thecae.

Horizon and Localities.—The type is from the Specimen Hill and Fryerstown water-race south of the Elphinstone-Chewton railway (C1—upper Castlemainian). It also occurs on the same horizon south of Bagshot railway station (Bendigo). Near the old agricultural show-grounds at Gisborne and in the Lancefield district $\left(\frac{\text{LL}}{20}\right)$ it is found in Darriwilian beds.

DIDYMOGRAPTUS CUSPIDATUS Ruedemann.

(Fig. 1, No. 9; Fig. 2, Nos. 11, 12.)

1904. *Didymograptus cuspidatus* Ruedemann, Graps. N.Y., Part I. *N.Y. State Museum Mem.* 7, p. 684, figs. 79, 80, pl. 13, fig. 16.

Description.—Stipes originating sub-orally at slightly different levels from a comparatively small sicula at an angle of 150–160°, but later becoming sub-horizontal. Stipes 2 cm. or more long, narrow at first but rapidly widening to rather less than 1 mm. Thecae 12–13 in 10 mm., mature thecae with an overlap of one-third. Inclination of earlier thecae low, increasing to 40° or more in the distal portion of the stipes. Apertural margins slightly convex in most cases and approximately normal to the axis of the stipes.

Remarks.—The above description, drawn up from specimens from the upper Darriwilian of Strathfieldsaye, agrees well with Ruedemann's description and figures, which are based on a single specimen.

Horizon and Localities.—Rare in the high Darriwilian beds of Allot. 19, Sect. III., Strathfieldsaye (A.164), and at other Bendigo East localities in the zone of *Didymograptus nodosus.*

DIDYMOGRAPTUS COMPRESSUS, sp. nov.

(Fig. 1, Nos. 6a–c; Fig. 2, Nos. 20, 21.)

Description.—Stipes up to 8 cm. in length, and from the evidence of detached stipes, probably longer; uniformly slender, diverging from a comparatively long and slender sicula at an angle of about 120° (though sometimes at a greater or less angle), very narrow proximally but widening gradually till a width of 0.6 mm. is reached, this width being then maintained. The stipes swing back to a sub-horizontal position. Thecae 8–10 in 10 mm. long, sub-rectangular tubes, 4–5 times as long as wide, in contact for one-third to one-half their length, and inclined at an angle as low even as 10°. Ventral margins slightly sigmoid, apertural margins inclined at an angle of a little less than 90°.

Remarks.—The thecae of this species are characteristic, and it is comparatively easy to recognize from a fragmentary stipe. The thecal tubes seem to be sub-rectangular and wider than deep. Where in a species such as *D. extensus* a profile view would be expected, in this species one seems to look down on the ventral side of the thecae in perspective, and this side is often lighter in shade than the rest of the rhabdosome. Proximal thecae often have an indented apertural margin as if the periderm were thin and had been frayed from between the marginal lists.

Occasionally specimens are found in the *Didymograptus nodosus* zone with spines like those of some specimens of *D. nodosus.*

Horizon and Localities.—Common at many upper Darriwilian outcrops in the Bendigo East area and characteristic of the *D.* (*Glyptog.*) *intersitus* zone between the D2 zone (zone of *D.* (*G.*) *austrodentatus*) and the zone of *D. nodosus.* It is also found, though more rarely, with *D.* (*G.*) *austrodentatus,* as at loc. 169, and with *D. nodosus.* It is commonest, perhaps, at loc. 196 in the State Forest, Sect. XIX., Strathfieldsaye, along the McIvor Road near the 97m. 36 ch. railway crossing, and in Sect. XXIX., Huntly. It is worth noting that Bulman's figures (2, pl. xxxiii., fig. 6) of *Didymograptus* aff. *euodus* show considerable resemblance to *Didymograptus compressus,* especially the two fragmentary stipes in fig. 6b. The horizon of these forms is very close to that from which *Didymograptus compressus* is recorded in Victoria.

(?) DIDYMOGRAPTUS DUBITATUS, sp. nov.

(Fig. 1, Nos. 5a–d; Fig. 2, Nos. 22–25.)

Description.—This deflexed form has stipes up to 25 mm. in length, and probably longer, diverging from a comparatively long conical sicula (1 mm. long) at an angle of about 135° and then gradually flattening out. The stipes are very slender, not exceeding 0.5 mm. in width. Thecae 10 in 10 mm., five times as long as broad, overlapping less than one-half, inclined at a very low angle as they arise and then lying almost parallel to the axis of the stipe. The proximal thecae have not been clearly seen, partly owing to the way they are impressed on the stipe, but appear to be rather more typically didymograptid than the distal ones. In the distal thecae, as stated above, the apertural half seems to lie parallel to the axis of the stipe, due to the sigmoidal curve of the early portion of each theca. In the obverse aspect the thecae appear to open into a small but distinct excavation; in the reverse aspect the thecal apertures are somewhat extroverted, with a slight but characteristic constriction. These differing aspects point to torsion of the thecal axis.

Remarks.—The thecae of this species are peculiar, approaching those of *Atopograptus woodwardi.* The stipes are so narrow that it is difficult to note the characters of proximal thecae, and small forms with indistinguishable thecal characters are included in the species. The stipes widen gradually for about 1 cm. and then are practically parallel-sided. Comparison with other species is difficult. There is some resemblance to *Didymograptus compressus,* sp. nov., but this latter form is more robust and its thecae very different. *Atopograptus woodwardi* Harris is the only form for which fragments of *D. dubitatus* may be mistaken, the thecal characters in one form of preservation having a great resemblance. *D. dubitatus,* however, is much narrower than the type specimen of *Atopograptus woodwardi* and its sicula is distinctly of the didymograptid type. This form is, therefore, left for the present as an aberrant *Didymograptus* showing thecal elaboration, as the development of *Atopograptus* is not well known, the only specimen of that genus showing proximal characters at all clearly being the type specimen, although fragments are common.

Horizon and Localities.—This species has been clearly seen only at one upper Darriwilian locality (loc. 164), at Strathfieldsaye (Bendigo East). It probably occurs in a similar association at other outcrops on the same horizon—zone of *Didymograptus nodosus*—but is difficult to recognize except from well-preserved material. The smaller forms provisionally included in the species are rather common in the Strathfieldsaye high Darriwilian beds.

DIDYMOGRAPTUS NODOSUS Harris.

(Fig. 2, No. 27.)

1926. *Didymograptus nodosus*.. W. J. Harris, *Proc. Roy. Soc. Vic.* (n.s.), xxxviii., p. 56, pl. i., figs. 1-4.

Two specimens of this species are figured showing a pronounced development of flexuous spines absent from the type material. This increases the resemblance of the species to *Didymograptus spinosus* Rued. (17, p. 689). If Ruedemann's specimens were less well-preserved it might be suggested that the two forms were identical, but the detail of *D. spinosus* as shown by Ruedemann in figs. 84, 85, shows a form quite distinct from *D. nodosus*. The spines are single and arise from the apertures of the thecae and also from the "heel," which is so pronounced a feature of the thecae of this species. As might be expected, the spines are best shown on distal thecae.

Horizon and Localities.—*Didymograptus nodosus* is a zonal graptolite of the highest Darriwilian beds, being associated with *Amplexograptus confertus* (Lapw.), (?) *Mesograptus decoratus*, etc. The spinose form has been collected at Strathfieldsaye (A.164) and at Huntly (Sect. XXIX).

Genus **Diplograptus** McCoy.

Sub-genus **Glyptograptus** Lapworth.

DIPLOGRAPTUS (GLYPTOGRAPTUS) AUSTRODENTATUS Harris and Keble.

(Fig. 3, Nos. 1–5.)

1932. W. J. Harris and R. A. Keble, *Proc. Roy. Soc. Vic.* (n.s.), xliv. (1), text figs. 1-4; pl. v., figs. 4-5.

This species is re-figured for comparison with *Diplograptus* (*Glyptograptus*) *intersitus*, sp. nov., which is a typical graptolite of the next higher zone of the Darriwilian. The rhabdosome is squat and short (up to 15 mm. long) and about 2 mm. wide, with parallel sides. Proximally there is a stout virgella, which is not always visible, but may be 2 mm. long. The first thecae are short, and the upward growth of th 1^1 and th 1^2 is not well marked. The proximal thecae have apertural spines. The thecae have well-marked ventral curvature and the apertures are slightly introverted. The virgula is produced for only a short distance beyond the distal end of the rhabdosome.

Horizon and Localities.—This graptolite is the zone fossil and commonest form in the D2 zone of the Darriwilian which has been placed as the basal bed of a *Diplograptus* series(11). Characteristic squat forms are figured, including some which are found as moulds in Allot. 2, Sect. XI., Sedgwick (A.310). The form is extremely common at many localities in the southern portion of the Bendigo East area, as well as in the Brisbane Ranges and at the other localities given by Harris and Keble (12, p. 41).

DIPLOGRAPTUS (GLYPTOGRAPTUS) INTERSITUS, sp. nov.

(Fig. 1, nos. 11a-e; Fig. 3, nos. 7-10.)

Description.—Rhabdosome comparatively small, averaging about 15 mm., but occasionally reaching 25 mm. in length, with a breadth not exceeding 2 mm. attained within the first 6 mm., usually with a short but conspicuous virgula distally and a short virgella proximally. Thecae 13–10 in 10 mm. The proximal end is quadrate, just over 1 mm. wide, and the first thecae have thin apertural spines which are not often preserved. The virgella is about 1 mm. long.

The sicula is just over 1 mm. long (about 1.2 mm.), and approximately three times as long as broad. Theca 1^1 arises about one-third of the distance from the apical end and grows downward before growing outward. Its aperture is distinctly everted. Theca 1^2 also grows distinctly downward, and its upward growth is stronger than that of th 1^1. Thereafter budding is normal. Septum is complete.

Thecae 1^1 and 1^2 have fine apertural spines, but these are not always preserved. Ventral margins show slight sigmoidal curvature, and apertural margins are either horizontal or slightly introverted. The low angle of inclination is very characteristic—generally about 20°. Thecal overlap is about one-half, and the thecae are 4–5 times as long as broad. Distally the virgula is usually prolonged for a short distance, but in some cases it may be over 5 mm. long

Remarks.—*D.* (*Glyptograptus*) *intersitus* is distinguished from *D.* (*G.*) *austrodentatus* by:—

(i) its less sigmoidally curved thecae, with less introverted apertures;
(ii) the narrowness and low angle of inclination of the thecae;
(iii) its more tapering and less squat rhabdosome;
(iv) its more pronounced virgula.

Its smaller size and narrower and more inclined thecae distinguish it easily from *D.* (*G.*) *teretiusculus,* to which it is closely allied, and it may be regarded as a forerunner of that species. Bulman(1) has described mutations between *D. dentatus* and *G. teretiusculus,* and the present form is similar in character. Its common occurrence, restricted range, and constant characters are factors which were considered in describing it as a distinct species.

Horizon and Localities.—*Diplograptus* (*Glyptograptus*) *intersitus* does not seem to occur with *D.* (*G.*) *austrodentatus,* the typical *Diplograptus* of the D2 zone, until the higher beds of that zone are reached as at loc. A.169, Strathfieldsaye. It then becomes exceedingly abundant as the typical graptolite of the next higher zone as at locs. 196, 210, 298, etc. It then becomes less common, but is occasionally found in the higher beds with *Diplograptus* (? *Mesograptus*) *decoratus* and *Didymograptus nodosus.* Its commonest associates in its particular zone are *Didymograptus compressus,* sp. nov., *Lasiograptus etheridgei* Harris, *Trigonograptus* cf. *ensiformis* Hall, *Glossograptus acanthus* E. and W., *Cardiograptus crawfordi* Harris, *Tetragraptus* spp., and *Phyllograptus* cf. *anna* Hall.

DIPLOGRAPTUS (GLYPTOGRAPTUS) cf. EUGLYPHUS (Lapworth).

(Fig. 3, nos. 39-41.)

1880. *Diplograptus* (*Glyptograptus*) *euglyphus* Lapworth, *Ann. Mag. Nat. Hist.* (5), v., p. 166, pl. 4, figs. 14A-E.

1907. *Diplograptus* (*Glyptograptus*) *teretiusculus,* var. *euglyphus* Lapw. Elles and Wood, *Mon. Brit. Graps.,* Part VI., p. 252, text-fig. 172, pl. xxxi, figs. 2A-D.

198. *Diplograptus* (*Glyptograptus*) *euglyphus* Lapw. Ruedemann, Graps. New York, Part 2, *N.Y. State Mus. Mem.* 11, pp. 369-370, pl. 25, figs. 21-23, text-figs. 315, 316

Description.—Rhabdosome typically long and narrow, up to 4.5 cm. in length, with a maximum breadth of 2.5 mm., widening gradually from a narrow sicular end (0.75 mm.) until the maximum width is reached in about 2 cm. There is a blunt virgella 1 mm. long. Lateral spines have not been observed. Thecae of the *Glyptograptus* type, proximally 13 in 10 mm., but distally only 9 or 10 in the same length, with overlap of about one-third to one-half.

Remarks.—In its general form and tapering rhabdosome our species approaches *D. teretiusculus* var. *euglyphus,* as figured by Elles and Wood (*vide supra*). The thecal measurements, however, are closer to those of *D.* (*Glyptograptus*) *teretiusculus* than to the variety or to *D. euglyphus* as described by Ruedemann(18). The proximal development is the same. It appears to be one of the many mutations between *D.* (*G.*) *dentatus* and *D.* (*G.*) *teretiusculus,* but is perhaps best recorded as *D.* cf. *euglyphus.*

Horizon and Localities.—Rare in the Upper Darriwilian as at Turner's Quarry (Bittern) and on the Howqua River. More common with D. (*Glyptograptus*) *teretiusculus* in the lowest beds of the Upper Ordovician, as at Ba67 (junction of Jackson's and Riddell Creek, Gisborne). The Upper Ordovician form seems to have rather more closely packed proximal thecae. These Victorian horizons can be correlated with the zones of *Didymograptus murchisoni* and of *Diplograptus teretiusculus* in the English succession, indicating that here *D. euglyphus* enters on a somewhat lower horizon than in England.

Sub-genus **Mesograptus** Elles and Wood.

(=**Diplograptus** McCoy, s.s.)

(?) MESOGRAPTUS DECORATUS, sp. nov.

(Fig. 3, nos. 31-38.)

1874. *Diplograptus pristis* His. R. Etheridge, *Ann. Mag. Nat. Hist.*, pl. 3, fig. 18.

1875. *Diplograptus palmeus* (Barr.). McCoy, *Prod. Pal. Vict.*, Dec. 2, p. 32, pl. xx., fig. 6.

Description.—Rhabdosome large, 3–6 cm. long, widening from a blunt proximal end (about 1.0 to 1.5 mm. wide) and reaching a maximum width of up to 4 mm., after which this width may be maintained or the rhabdosome may narrow slightly and gradually. The distal narrowing is very common. Virgella conspicuous and partly enclosed in a membrane. The virgula is usually well shown, and is often produced beyond the distal end of the rhabdosome to carry a heart-shaped vesicle. Thecae 12-7 in 10 mm., overlapping about one-half.

Remarks.—The type specimen is preserved as a pseudomorph in limonite, and shows features not observable in the more usual compressed specimens. The difference in appearance between the thecae on either side of the rhabdosome is due to the peculiar cross-section of the form which is shown in Fig. 3, No. 35B. This makes it impossible, strictly speaking, to refer the species to any of the described sub-genera of *Diplograpti*, but till further material in relief is available the erection of a new sub-genus would, in our opinion, be premature, since the sub-generic characters are not observable in ordinary specimens. Even in these, however, the difference between the appearance presented by the thecae on opposite sides of the rhabdosome is so constant that it cannot be regarded as due to deformation, but must be due to the shape of the cross-section.

On account of the limitation of the climacograptid appearance of the thecae to the proximal portion only, the form is tentatively referred to *Mesograptus*.

The apertural edges of the thecae are undulate (highest in the centre) and flanged, and the free ventral surface is also undulate with a medial longitudinal depression. The cross-section of the rhabdosome is such that no undistorted specimens show what is normally the bi-profile view of *Diplograptus* (cf. figs. of *D. euglyphus*). This difference will be noticed in Fig. 3, Nos. 35, 36, 38. On one side the thecae appear as almost horizontal indentations, while on the other they are hardly observable, but the low angle of inclination of the thecal walls is very pronounced. The aperture on this side is not observable, being directed obliquely behind the surface shown.

In America and Great Britain trouble has been experienced in separating *Amplexograptus coelatus* from *Climacograptus antiquus* (4, 17), and the difficulty we are faced with is not decreased by the resemblance the present form bears to both these species and by its possession of a vesicle identical with that recorded by Ruedemann (17, p. 449) as possessed by *C. antiquus*. Each of Ruedemann's figures—with the vesicle at the end of a long virgula, or resting on the distal end of the rhabdosome—may be paralleled by Victorian specimens. On the other hand, the cross-section of the Victorian form is in itself sufficient to prevent its inclusion in the genus *Climacograptus*.

In measurements and general appearance compressed specimens ot *D. decoratus* closely approach *D.* (*Amplexog.*) *coelatus* (Lapw.) which occurs on an equivalent horizon, and most Victorian records of *Diplograptus coelatus* are probably based on specimens of *D. decoratus*. It may be separated from *D. coelatus* by its *Amplexograptus* aspect in the proximal portion only, thus indicating a different cross-section in the mature portion. From British specimens of *D. coelatus* it is also distinguished by its distal vesicle. American forms with such a vesicle have, as stated, been referred to *C. antiquus*. The emphasis placed on the climacograptid character of *D. coelatus* is sufficient reason in itself for our description of *D. decoratus* as a distinct species having marked resemblances to *D. coelatus*. Lapworth (20) later emphasized the close relationship of *D. coelatus* and *D.* (*Glyptograptus*) *teretiusculus*. *D. decoratus* is a form which varies greatly, as may be seen from the figures, but every gradation between these forms may be found. Etheridge's and McCoy's descriptions of the present form were written when knowledge of the *Diplograpti* was limited, and it is unnecessary now to comment on their figures and descriptions (5, 15).

Horizon and Localities.—Common in the upper Darriwilian of Bendigo East, Cobaw (Geol. Surv. loc. B29, Q.S. 5 S.W.); Surprise Gully (Romsey); and north-west of Turner's main quarry, Allot. 27B, Bittern (Mornington Peninsula). It is characteristic of the zone above that of *Diplograptus* (*Glyptograptus*) *intersitus*, and is commonly associated with *Didymograptus nodosus*. However, it first appears with *D. intersitus* (it has not been recorded in association with *D.*

austrodentatus), and is also found in beds in which *Didymograptus nodosus,* if present, is rare. It has therefore a greater range than that form, and the *D. nodosus* association probably indicates the higher beds of its horizon.

AMPLEXOGRAPTUS MODICELLUS, sp. nov.

(Fig. 1, nos. 10a-f; Fig. 3, nos. 17-20.)

Description.—Rhabdosome small and parallel-sided—only a little over 5 mm. in length and 1 mm. wide. Sicular end unsymmetrically blunt, provided with a thin but conspicuous virgella, which may be more than 1 mm. long. Sicula narrow, 1 mm. long, the first theca budding some distance from its aperture and growing downwards along the sicula before turning outwards. Thecae closely spaced, 14–18 in 10 mm. (7–8 in 5 mm.), alternate, the free ventral edges slightly convex; excavations long, narrow and oblique, about one-fourth to one-third of the free ventral edge and one-third the width of the rhabdosome.

Remarks.—This small form (*modicellus,* very little) is similar in appearance to *Climacograptus pungens* Rued., but may be separated by the absence of the two proximal spines and the much more closely spaced thecae. It reminds one of *C.* cf. *modestus* as figured by Bulman (1, p. 51, fig. 22), but differs in the character of the proximal end and, what is more important, in the presence of a straight instead of a zig-zag septum. From *Amplexograptus arctus* E. and W., it may be separated by its small size and by the absence of lateral spines. Its nearest ally appears to be *Amplexograptus confertus* (Lapworth), but here again its smaller size makes it quite distinct.

Horizon and Localities.—Very abundant in certain bands of the Upper Darriwilian (zone of *Didymograptus nodosus*), associated with the characteristic assemblage of that zone. Some slabs, especially as loc. A164, Strathfieldsaye, are crowded with individuals showing all stages of growth.

AMPLEXOGRAPTUS CONFERTUS (Lapworth).

(Fig. 1, nos. 14a, b; Fig. 3, nos. 21-26.)

1875. *Climacograptus confertus.* Lapworth, *Quart. Journ. Geol. Soc.,* xxxi., p. 655, pl. xxxiv, figs. 4A-F.

1880. *Climacograptus confertus.* Lapworth, *Ann. Mag. Nat. Hist.* (5), v., p. 169, pl. iv., figs. 15A-C.

1907. *Diplograptus* (*Amplexograptus*) *confertus.* Elles and Wood, *Mon. Brit. Graps.* (*Pal. Soc.*), lxi, p. 269, text-figs. 185A-C, pl. xxxi., figs. 18A-C.

Description.—Length usually 1.5 to 2 cm., though a length of 3 cm. may occasionally be reached. Width under 2 mm. (usually about 1.8 mm.). Rhabdosome almost parallel-sided, about 1 mm. wide or rather more near the proximal end.

Virgella about 1 mm. long, and a virgula prolonged for about the same length distally. Proximal end sub-quadrate, spines on thecae 1^1 and 1^2 sometimes preserved. Thecae 14–10 in 10 mm., in reverse aspect with well-marked oblique excavations occupying one-third to one-fourth of the ventral margin and one-third the width of the rhabdosome, in obverse aspect; ventral margin rounded, apertural margin thickened, concave, and oblique.

Remarks.—This description is so like that given by Elles and Wood (the only points of difference being the somewhat looser spacing of the thecae and the gradual widening) that we hesitate to make it a distinct variety. It appears to be nearer the typical *D.* (*Amplexog.*) *confertus* than the *A.* cf. *confertus* figured by Bulman (1, p. 60; pl. v., figs. 7-9). In thecal measurements it approaches *Amplexograptus differtus*, sp. nov., but the rhabdosome is narrower and has not the decided widening of that form. From *A. arctus* it may be distinguished by its greater width and its more typical amplexograptid thecae.

Horizon and Localities.—Common in the *Didymograptus nodosus* zone of the upper Darriwilian at localities in Sect. XXIX, Huntly (Bendigo); less common at other outcrops of the same horizon at Bendigo East.

AMPLEXOGRAPTUS DIFFERTUS, sp. nov.

(Fig. 1, no. 15; Fig. 3, nos. 27-31.)

Description.—Rhobdosome up to 2.5 mm. long, widening gradually from a blunt proximal end and reaching its maximum width of 2.0 to 2.5 mm. in about 1 cm., this width then being maintained. Thecae 13–10 in 10 mm.; apertures slightly inclined with notably thickened margins, the apertures occupying one-third of the width of the rhabdosome and one-fourth to one-third of the free edge. Virgula occasionally prolonged beyond the distal end of the rhabdosome.

Remarks.—In shape and general appearance this species is reminiscent of *Amplexograptus perexcavatus* Lapworth, but the thecal measurements differ and the excavations are narrower and not so deep, and are distinctly oblique. Its proximal widening and greater width separate it from *A. confertus,* and the thecal spacing is more lax though the characters of the thecae are very similar. Its greater width and somewhat narrower excavations separate it from the South American *A.* cf. *confertus* figured by Bulman (1, p. 60, pl. v., figs. 7–9; text-fig. 28).

Horizon and Localities.—Rather common but rarely well-preserved in the upper Darriwilian beds (zone of *Didymograptus nodosus*) of Bendigo East, as, for example, in Sect. XXIX, Huntly.

Family GLOSSOGRAPTIDAE Lapworth, emend. Elles and Wood.

Genus **Glossograptus** Emmons.

The interpretation by Hadding (7, p. 310, fig. 1) of the structure of *Glossograptus* leads to the possibility of two genera being confounded under *Glossograptus.* The question is reviewed by Bulman (1, pp. 68, 69). Our material, unfortunately, is not sufficiently well-preserved to enable us at present to add to the discussion, but as septal spines have not been identified with certainty in *Glossograptus acanthus* E. and W., and are certainly absent in a new form which we have described as (?) *Glossograptus crudus,* the question of the generic characters of *Glossograptus* is left open.

GLOSSOGRAPTUS ACANTHUS Elles and Wood.

(Fig. 3, nos. 13-16.)

1908. *Glossograptus acanthus* E. and W. *Mon. Brit. Graps.,* Part 7, p. 314, pl. 33, figs. 4A-C.

Description.—Rhabdosome sub-fusiform, having a length of 20 mm. or more, widening gradually from the sicular end to a width of 3 mm. or more, and then narrowing distally. Thecae 10 in 10 mm., apertural margins distinctly everted, with robust, rigid, slightly-curved apertural spines, apparently only one per thecae, nearly equal in length to the width of the rhabdosome. No septal spines have been observed. In the proximal region the spines are directed downwards, but they gradually become horizontal and finally have a somewhat upward direction.

Remarks.—The above description differs only slightly from that given by Elles and Wood (*cit. sup.*). A long but thin virgula not noticed in the English description is prominent in many Victorian specimens.

After examination of a great number of forms sufficiently well-preserved to show external characters at least, we have been unable to detect septal or paired apertural spines. This corroborates Elles and Wood's conclusions, and in our opinion it is therefore difficult to retain the present form under *Glossograptus* as at present defined. The heavy spines of the species may be accounted for as being processes formed by the strong development of the apertural mucros, as is seen also in (?) *Glossograptus crudus,* sp. nov.

No evidence of the early stages of the species is available. The absence of a record of scalariform mode of preservation may be accounted for by the width of the rhabdosome being great compared with its thickness, so that it always came to rest in the profile position.

Horizon and Localities.—Common at many upper Darriwilian outcrops in Bendigo East, in the zone of *Diplog.* (*Glyptog.*) *intersitus.* Locally it is very abundant as at loc. 196, Strathfieldsaye. Forms referable to the species are also found on a somewhat higher horizon near the old Agricultural Show-grounds at Gisborne, and elsewhere, and on a slightly lower horizon (associated with *D.* (*Glyptograptus*) *austrodentatus*) at Guildford, the Brisbane Ranges, and Lancefield. These lower forms may later be separated as varieties.

(?) GLOSSOGRAPTUS CRUDUS, sp. nov.

(Fig. 1, no. 13; Fig. 2, nos. 15-17.)

Description.—Rhabdosome small, rarely more than 10 mm. long, commencing with a width of 2–3 mm., or even sometimes 5 mm., the initial width being usually maintained though some specimens narrow distally. Virgula conspicuous and often projecting beyond the distal end of the rhabdosome, which in juvenile forms is emarginate. Thecae 10–12 in 10 mm., inclined in the distal part at an angle of about 45°, though this angle may be either considerably greater or smaller, about twice as long as wide and with considerable overlap. Apertural margins of these thecae straight or slightly concave and directed upwards, or upwards and outwards. Thecae ending in a stout mucro or denticle directed outwards or slightly downwards.

Remarks.—This previously undescribed graptolite has been known for many years from middle Darriwilian (D4–D3) beds, and is responsible for the reference to *Glossograptus* in these beds. Strictly speaking, it is not possible to include it in that genus as there is no evidence of septal spines even in forms so preserved that, if present, they could hardly escape observation, and the thecae seem to be furnished with a strong mucro instead of the two apertural spines of *Glossograptus*—the apertural walls of the thecae appearing to coalesce ventrally and to be produced into this spinose projection. The species in its juvenile state has a considerable resemblance to *Isograptus* (*vide* fig. 1, No. 9), and it may form a connecting link between that genus and *Glossograptus.* The species is of importance as being the earliest typically biserial form to develop in the Darriwilian, occurring in the same beds as *Skiagraptus gnomonicus,* but before *Diplograptus* has become established. It shows at times a tendency to split along the median plane, and forms are found with more thecae on one side than the other, indicating either a complete median septum, or possibly that the form has originated by the concrescence of two didymograptid stipes growing back and at an angle of 360°. This would not be surprising if the form is related to *Isograptus.*

Horizon and Localities.—Widely distributed but rarely common in the middle Darriwilian beds along the Barker's Creek-Maldon pipe line (Castlemaine) and elsewhere in the same district; also in beds on the same horizon at Lancefield.

(?) GLOSSOGRAPTUS CRUDUS, var. GISBORNENSIS, var. nov.

(Fig. 2, nos. 13, 14.)

A form of (?) *Glossograptus crudus* is found rather commonly at some outcrops, e.g., along the Gisborne Creek, which is much narrower than the typical form. This may be separated as var *gisbornensis*. Its horizon is the same as that of the *forma typica*. The figured specimens are from the Gisborne Creek between the Bullengarook slate quarry and the Gisborne gold mine

Genus **Cryptograptus** Lapworth.

CRYPTOGRAPTUS SCHAFERI (Lapworth).

(Fig. 3, nos. 11, 12.)

1880. *Cryptograptus tricornis* var. *schaferi* Lapworth. *Ann. Mag. Nat. Hist.* (5) v., pl. v., figs. 28A-B.

1908. *Cryptograptus tricornis* var. *schaferi* Lapw. Elles and Wood. *Mon. Brit. Graps.*, part vii.. p. 299, pl. xxxii., figs. 13A-C.

1931. *Cryptograptus tricornis* var. *schaferi* Lapw. Bulman, *Arkiv f. Zoologi.* xxii A (3), p. 65, pl. 6, figs. 1-5, pl. 7, fig. 3. text-fig. 31.

1933. *Cryptograptus schaferi* (Lapworth). Bulman, *Quart. Journ. Geol. Soc.*, lxxxix, p. 352.

Description.—Rhabdosome about 10 mm. long, parallel-sided as a rule, and with a breadth, inclusive of denticles, of about 2 mm., usually with a long virgula sometimes inflated. Thecae 12–10 in 10 mm., with well-marked denticles. The proximal end bears a stout sicular spine, and the proximal thecae have short but well-marked coarse spines. The characteristic long spines of *C. tricornis* are absent. As far as can be made out, the proximal thecae grow downwards.

Remarks.—Lapworth's variety *schaferi* of *C. tricornis* has recently been raised to specific rank by Bulman (2, p. 352), and is so regarded here. Most, if not all, of the upper Darriwilian forms referred to *Cryptograptus tricornis* seem to fall under this heading, including some recorded by Harris (10). Now that the distinction is made future work may show the zonal importance, if any, of the two species.

Horizon and Localities.—Not uncommon in the upper Darriwilian of Bendigo East, most abundant, but sporadic, in the zone of *Didymograptus nodosus*, as at loc. 164, but widely distributed and perhaps ranging as low as the upper part of the D2 (*D. austrodentatus*) zone.

Genus **Lasiograptus** Lapworth.

Sub-genus **Hallograptus** Carruthers MS.

LASIOGRAPTUS (HALLOGRAPTUS) PROTEUS, sp. nov

(Fig. 1, nos. 12a-b; Fig. 2, nos. 30-33.)

Description.—Rhabdosome up to 3 cm. in length and 2 mm. wide, exclusive of spines and external meshwork; with the meshwork about 3 mm. Rapidly widening to almost its maximum width in the first two or three mm. and then widening much more gradually to about its centre, after which in mature specimens there is a slight and very gradual narrowing distally. Thecae about 11 in 10 mm., resembling those of *Glossograptus hincksii* (Hopkinson) at first, but later becoming quite distinctive. The spines of proximal thecae are recurved, but those of later thecae become normal to the axis of the rhabdosome, and at last directed distinctly upwards, these distal spines being much more massive than the earlier ones. Network delicate and sometimes only shown on the proximal portion of the rhabdosome, consisting, as usually seen, of an extra-marginal thread independent of the spines and looped to the rhabdosome by supports which alternate with the apertural spines. This apparent independence of apertural spines and meshwork does not seem to be absolute, and is less well shown on the distal portions of rhabdosomes where the meshwork seems sometimes to be supported by outgrowths from the upper side of the spines themselves.

Remarks.—This species is easily distinguished from a characteristic *Lasiograptus etheridgei* Harris by—

(*a*) its more parallel-sided and narrower rhabdosome.

(*b*) the greater development of spines, giving it a more *Glossograptus* aspect;

(*c*) the more regularly developed external meshwork.

A long spine often projects from the proximal end, but its origin and nature cannot well be made out.

Horizons and Localities.—Common at many Upper Darriwilian localities at Bendigo East (zone of *Didymograptus nodosus*). It is probable that MS. records of graptolites from this district include *L. proteus* under *L. etheridgei*. This latter species seems quite distinct and seemingly occurs on a slightly lower horizon. The two species may occur together, but as a rule they do not, there being no record of *L. proteus* from Allot. 95, Woodend; loc. B29, Sect. 20, Newham; nor from loc. A196, Strathfieldsaye, at all of which localities *Lasiograptus etheridgei* occurs, while *Lasiograptus etheridgei* does not seem to be known from such outcrops as loc. 164, Strathfieldsaye. The best specimens of *L. proteus* yet discovered came from this last-named locality and from spoil-heaps between the Eaglehawk and Bendigo Creeks in Sect. XXIX., Huntly.

LASIOGRAPTUS (THYSANOGRAPTUS) ETHERIDGEI Harris.

(Fig. 2, nos. 28, 29.)

1874. *Diplograptus mucronatus* Etheridge. *Ann. Mag. Nat. Hist.* (4), iv., p. 5, pl. iii., figs. 16, 17.

1924. *Lasiograptus* (*Thysanograptus*) *etheridgei* Harris. *Proc. Roy. Soc. Vic.* (n.s.), xxxvi. (2), pp. 98, 99, pl. vii., figs. 3-7.

Remarks.—Two figures of *Lasiograptus* (*Thysanograptus*) *etheridgei* Harris are given for comparison with *Lasiograptus* (*Hallograptus*) *proteus*, sp. nov. The most obvious differences between the two species are that *L. etheridgei* widens more gradually than *L. proteus* and has a much more fully developed meshwork. The glossograptid thecae of *L. proteus* are also much more clearly seen than the thecae of *L. etheridgei,* and the alternation of meshwork and apertural spines is also more marked in *L. proteus.* Forms, however, occur which can be separated only with difficulty, and it may be that *L. etheridgei,* by modification of thecae and simplification, passes into *L. proteus* and possibly into *Glossograptus hincksii* (Hopkinson).

Horizon and Localities.—One of the commonest graptolites at many outcrops in the upper Darriwilian beds of Bendigo East, as for example at locs. 163, 168, 169, 170, 172, 176, 298, etc., and in Sect. XII., Epsom. It appears on the horizon of *D.* (*Glyptograptus*) *austrodentatus* (zone D2), apparently in the higher part of this zone, is very common in some occurrences of the next higher zone (that of *D.* (*G.*) *intersitus*), and is commonest in what are probably the lower beds of the zone still higher (that of *Didymograptus nodosus*), then giving place in still higher beds to *Lasiograptus proteus,* with which, however, it may occur sparingly as at loc. 298. Outside the Bendigo district it occurs near Allot. 95, Woodend, and at Cobaw, as well as other less well-known outcrops.

Family ISOGRAPTIDAE Harris.

Genus **Cardiograptus** Harris and Keble.

CARDIOGRAPTUS CRAWFORDI Harris.

(Fig. 2, no. 26.)

1926. W. J. Harris. *Proc. Roy. Soc. Vic.* (n.s.), xxxviii, p. 57, pl. i., figs. 5-7.

In the original description of *C. crawfordi* (Harris, 1926, p. 57) it was stated that *C. crawfordi* could be distinguished from *C. morsus* H. and K. by smaller size and less pronounced emargination. Since then forms have been discovered which are undoubtedly *C. crawfordi,* but which also show distinct distal emargination. One of these is figured. The locality is north-west of Strathfieldsaye township (loc. 196) and the horizon is the lower part of the D1 (zone of *D.* (*Glyptograptus*) *intersitus*). Similar emarginate forms are also found on the higher horizon (zone of *Didymograptus nodosus*) of Sect. XXIX., Huntly.

List of Localities.

Localities mentioned by numbers or letters in this article are as follows:—

A 164. Emu Creek Water Race, No. 2, at the S.E. corner of allot. 19, sect. III., Parish of Strathfieldsaye.

A 169*a*. On E. and W. road near S.E. corner of allot. 25, sect. III., Parish of Strathfieldsaye.

A 170. On E. and W. road near S.E. corner of allot. 27, sect. III., Parish of Strathfieldsaye. (Outcrop hardly exposed.)

A 173. On Emu Creek No. 2 Water Race, near N.E. corner of allot. 1A of sect. V., Parish of Strathfieldsaye.

A 176. On Strathfieldsaye-Sedgwick road, about 11 chains N.W. of S.W. corner of allot. 1B, sect. V., Parish of Strathfieldsaye. (In small gutter on S.W. side of road.)

A 196. Near the most northerly corner of allot. 3, sect. XIX., Parish of Strathfieldsaye. (An extensive surfaced area.)

A 198. On S. side of E. and W. road, N. of allot. 8, sect. VI., Parish of Strathfieldsaye. (On slope above the right bank of Axe Creek.)

A 210. In bed of small watercourse on S. side of Bendigo-Heathcote road, about 170 yards W. of 97-miles 36-chain crossing on Bendigo-Heathcote railway, Parish of Strathfieldsaye.

A 298. In bed of watercourse in allot. 2, sect. V., Parish of Sedgwick.

A 310. In bed of eastern tributary of watercourse in allot. 2, sect. XI., Parish of Sedgwick.

CH 6. Chinamen's Creek, near Muckleford railway station. (Note 6, Q.S. 15 N.W.)

S.F. Sewerage Farm, allot. 8, sect. XXIX., Parish of Huntly.

G.C. Near N.E. corner of allot. 58, Parish of Bullengarook (cliff on south bank of Gisborne Creek).

Ba67. Near junction of Riddell and Gisborne Creeks (Q.S. 6 S.E.).

NOTE.—" A " numbers are from the plans of J. J. Caldwell, Geol. Survey of Vict. Other numbers refer to specimens in the Geological Survey Museum.

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18. ————. Graptolites of New York, Part 2. *N.Y. State Museum, Mem.* 11, 1908.

19. Tornquist, S. L. Lunds Univ. Arrskr. Afd. 1, No. 2, 1904, p. 4.

Figure 1.

All Figures are ×3½ except where otherwise stated.

No. 1. *Pterograptus incertus*, sp. nov. (*a*) proximal portion (30795), (*b*) proximal portion of stipe (30795). Loc.

No. 2. *Trichograptus immotus*, sp. nov. (*a*) proximal portion (37434), (*b*) proximal portion (37442), (*c*) distal portion (37434). Loc. S.F.

No. 3. *Didymograptus distinctus*, sp. nov. (37431). Fryerstown water-race, south of Elphinstone railway tunnel.

No. 4. *Didymograptus cognatus*, sp. nov. (*a*) proximal portion (37401 *b*), (*b*) distal thecae (37401 *a*), (*c*) proximal portion (37418) × 10. Loc. A 164.

No. 5. *Didymograptus dubitatus*, sp. nov. (*a*) proximal portion (37404), (*b*) distal thecae (37404), (*c*) proximal portion (37404) × 10, (*d*) distal thecae (37404) × 10. Loc. A 164.

No. 6. *Didymograptus compressus*, sp. nov. (*a*) proximal portion (37405), Loc. A 196, (*b*) distal fragment, (37405) Loc. A196, (*c*) distal thecae, (37417, *b*) × 10. Loc. A. 173.

No. 7. *Didymograptus nodosus* Harris. (37448.) Loc. A 164.

No. 8. *Didymograptus compressus* mut. (*a*) proximal portion, (37440), (*b*) distal thecae (37440). Loc. A 173.

No. 9. *Didymograptus cuspidatus* Ruedemann, (37402). Loc. A 164.

No. 10. *Diplograptus* (*Amplexograptus*) *modicellus*, sp. nov. *a, b, c, d,* to show various growth stages. (37394, 10*c* is 37444) (*e*) to show long virgula (37393), (*f*) Type (37392). Loc. A 164.

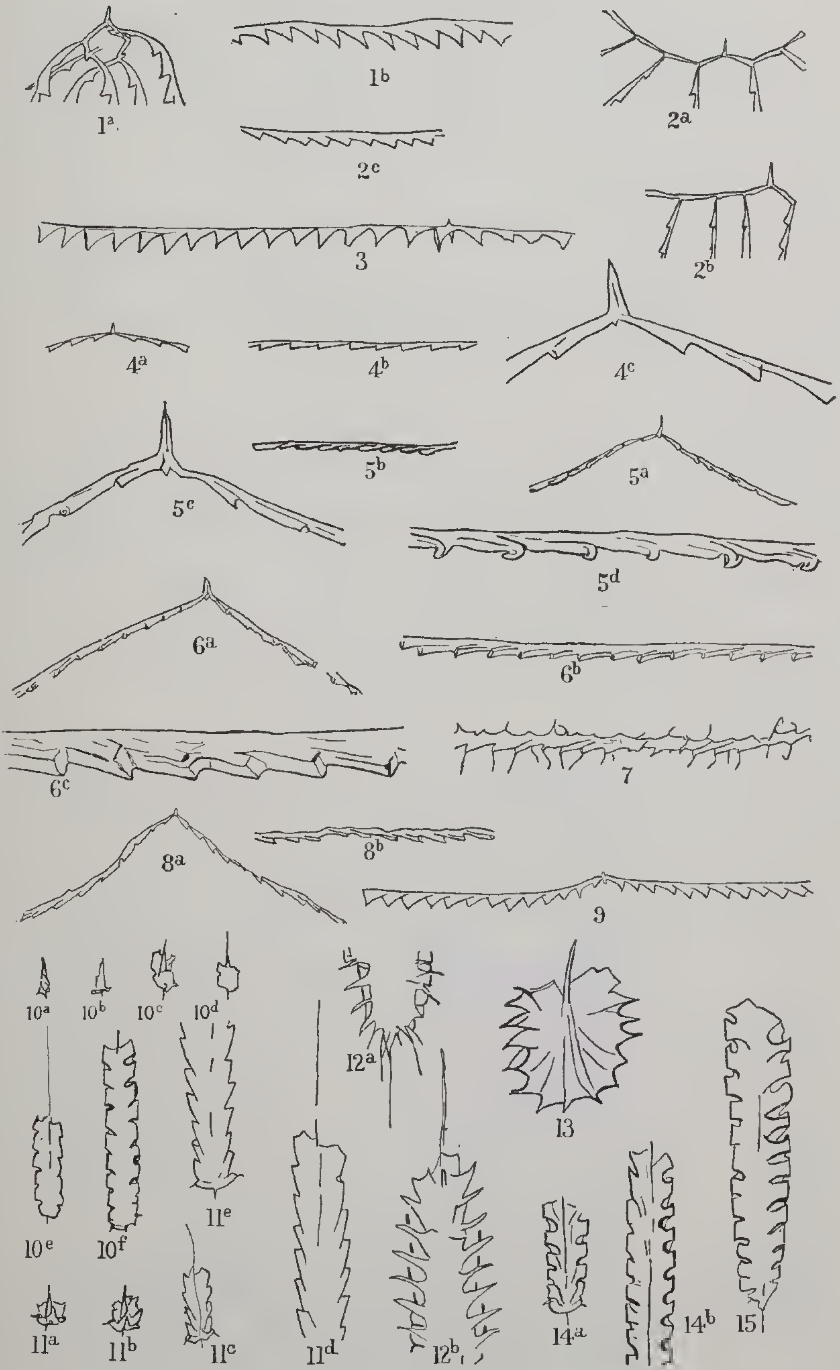
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Fig. 1.

No. 11. *Diplograptus* (*Glyptograptus*) *intersitus,* sp. nov. (*a, b, c*) young forms × 4 (37377). Loc. A 298. (*d*) distal × 4 (37428*a*), Loc. A 196, (*e*) proximal portion, (37428 *b*,—counterpart of 37428 *a*). Loc. A 196.

No. 12. *Lasiograptus proteus,* sp. nov. (*a*) proximal portion (37422), (*b*) distal portion (37421). Loc. A 164.

No. 13. (?) *Glossograptus crudus,* sp. nov. Young form × 4 (37409). Loc. A 164.

No. 14. *Diplograptus* (*Amplexograptus*) *confertus* Lapw. (*a*) proximal portion × 4 (37414), (*b*) distal portion × 4 (37414). Loc. S.F.

No. 15. *Diplograptus* (*Amplexograptus*) *differtus,* sp. nov., × 4 37385 *a*—counterpart of Type 37385). Loc. S.F.

FIGURE 2.

Figures are natural size unless otherwise stated.

Nos. 1-6. *Pterograptus incertus,* sp. nov. 1, 2. (30795). Loc. A 170. 3. Type. (37433). Loc. A. 170. 4. (37438). Loc. A. 210. 5. (opposite side of 4, on same slab) (37438). Loc. A 210. 6. (reverse of 30793). Loc. A. 170.

Nos. 7-9. *Trichograptus immotus,* sp. nov. 7. (37442). Loc. S.F. 8. Type (37434). Loc. S.F. 9. Type (37400). Loc. A 160.

No. 10. *Didymograptus distinctus,* sp. nov. (37431) (*vide* Fig. 1, No. 3).

Nos. 11, 12. *Didymograptus cuspidatus,* Rued., (37402, 37403). Loc. A 164.

Nos. 13, 14. *Didymograptus cognatus,* sp. nov., type, (37401, 37425). Loc. A 164.

Nos. 15-17. (?) *Glossograptus crudus,* sp. nov. (37406, 37408, 37415). Loc. CH 6.

Nos. 18, 19. (?) *Glossograptus crudus,* var. *gisbornensis,* var. nov. (37407, 37407 *a*). Loc. Gisborne Creek. (G.C.)

Nos. 20, 21. *Didymograptus compressus,* sp. nov. 20. Type, (37405). Loc. A 196. 21. Corrugated dorsal margin indicating approximation to nodose form *D. nodosus* (37417). Loc. A 173.

Nos. 22-25. *Didymograptus dubitatus,* sp. nov., Loc. A 164. 22. Type, (37404). 23. (37416). 24. Proximal portion of young form on same slab as 23 (× 2½). 25. Type, distal portion of stipe of type specimen (37404).

No. 26. *Cardiograptus crawfordi* Harris, shows emarginate rhabdosome not a specific character of this form (37410). Loc. A 196.

No. 27. *Didymograptus nodosus* Harris, shows spines at apertures and dorsal nodes of thecae (37445). Loc. S.F.

Nos. 28, 29. *Lasiograptus etheridgei* Harris (37435, 37436). Loc. A 176.

Nos. 30-33. *Lasiograptus proteus,* sp. nov. 30. Type (37432). Loc. S.F. 31. With long proximal spines and virgula (37421). Loc. A 164. 32. Young form showing well preserved meshwork (37423). Loc. A 164. 33. Typical young rhabdosome (37424). Loc. A 164.

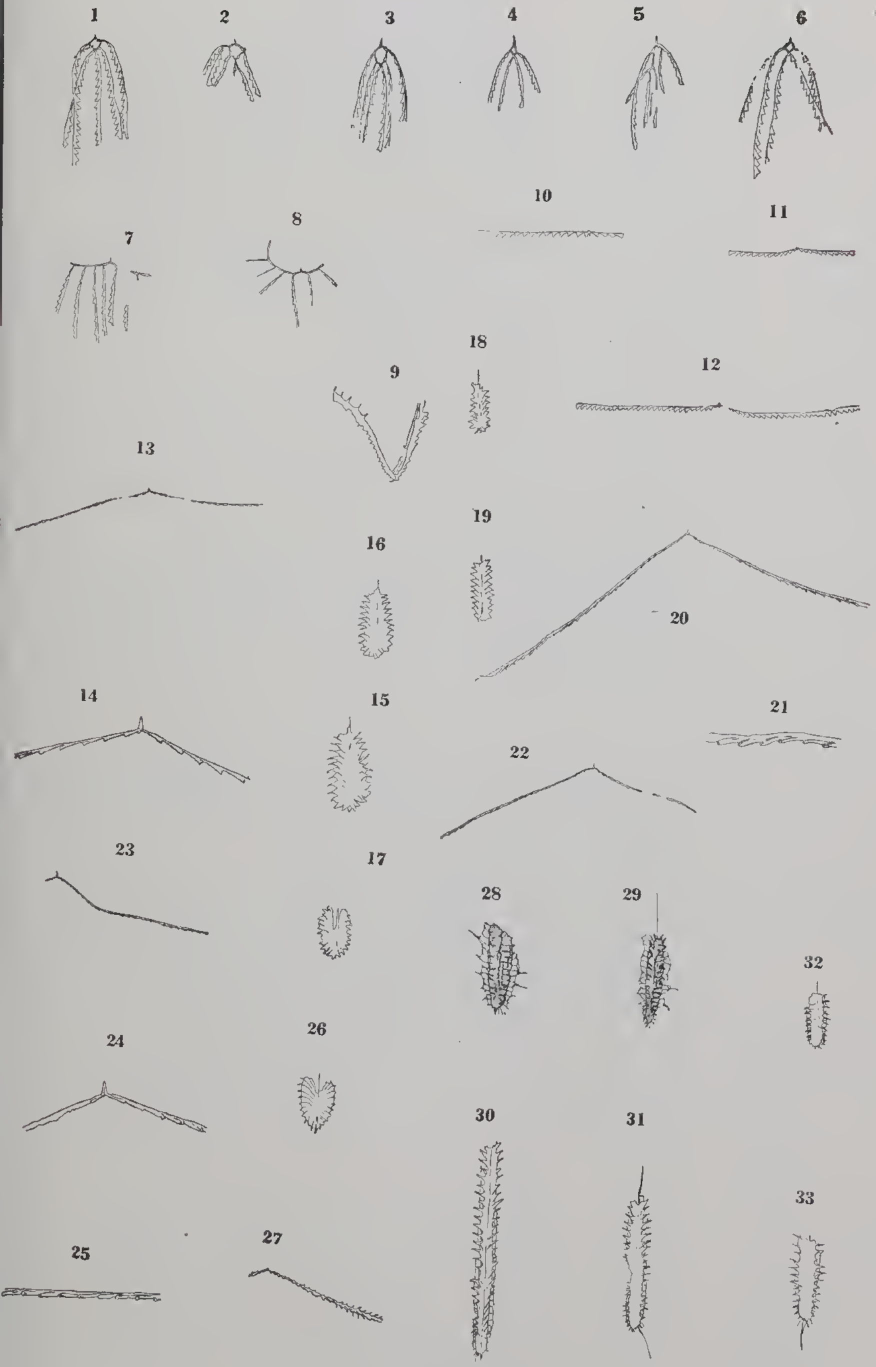
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FIG. 2.

Figure 3.

Figures are natural size unless otherwise stated.

Nos. 1-5. *Diplograptus* (*Glyptograptus*) *austrodentatus* (Harris and Keble). 1. Small form from D2 horizon (low.), (37372). Loc. A 198. 2. Typical rhabdosome (37373). Loc. A 310. 3. Typical rhabdosome (37374). Loc. A 310. 4. Typical rhabdosome (37375.) Loc. A 310. 5. Typical rhabdosome (37376). Loc. A 310.

Nos. 6-10. *Diplograptus* (*Glyptograptus*) *intersitus*, sp. nov., 6. Type *b*, (37428). Loc. A 196. 7. Distal counterpart of type (37428). Loc. A 196. 8. Marked 8 on slab, (37427). Loc. A 196. 9. Marked 9 on slab, (37427). Loc. A 196. 10. Smaller rhabdosome, (37377). Loc. A 298.

Nos. 11, 12. *Cryptograptus schaferi* Lapworth. 11. A typical group (37384). Loc. S.F. 12. (37439). Loc. A 164.

Nos. 13-16. *Glossograptus acanthus* E. and W. (37412, 37430, 37413, 37411). Loc. A 196.

Nos. 17-20. *Diplograptus* (*Amplexograptus*) *modicellus*, sp. nov., 17. Type (37392). 18. (37393). 19. Shows virgula and virgella (on same slab as 18). 20. (37395). Loc. A. 164.

Nos. 21-26. *Diplograptus* (*Amplexograptus*) *confertus* Lapworth. 21. Reverse aspect of long rhabdosome, (37388). Loc. S.F. 22. Obverse aspect of shorter rhabdosome (37384). Loc. S.F. 23. Reverse aspect (37443). Loc. S.F. 24. Obverse aspect and shorter rhabdosome (37391). Loc. S.F. 25. Obverse aspect and shorter rhabdosome (37390). Loc. S.F. 26. (37429). Loc. S.F.

Nos. 27-31. *Diplograptus* (*Amplexograptus*) *differtus*, sp. nov. 27. Obverse aspect, (37384). Loc. S.F. 28. Type, obverse aspect, (37385). Loc. S.F. 29. Obverse aspect, (37386). Loc. S.F. 30. Distal portion showing characteristic Amplexograptid thecae, (37387). Loc. S.F. 31. Intermediate aspect, (37384). Loc. S.F.

Nos. 32-38. *Diplograptus* (*? Mesograptus*) *decoratus*, sp. nov. 32. (37446). Loc. T.Q.M. 33. (37381). Loc. B.29. 34. (37379). Loc. A 176. 35. Type (37378), Limonite pseudomorph in relief. Loc. B/HR. 35A. Medial portion of Type × 2½. 35B. Cross section of distal portion of Type × 2½. 35C. Lateral view of distal thecae of Type × 2½. 36. (37380). Loc. S.F. 37. (37382). Loc. S.F. 38. (37384). Loc. S.F.

Nos. 39-41. *Diplograptus* (*Glyptograptus*) *euglyphus* Lapworth. 39. (37396). Loc. T.Q.M. 40. (37397). Loc. Ba67. 41. (37398). Loc. T.Q.M.

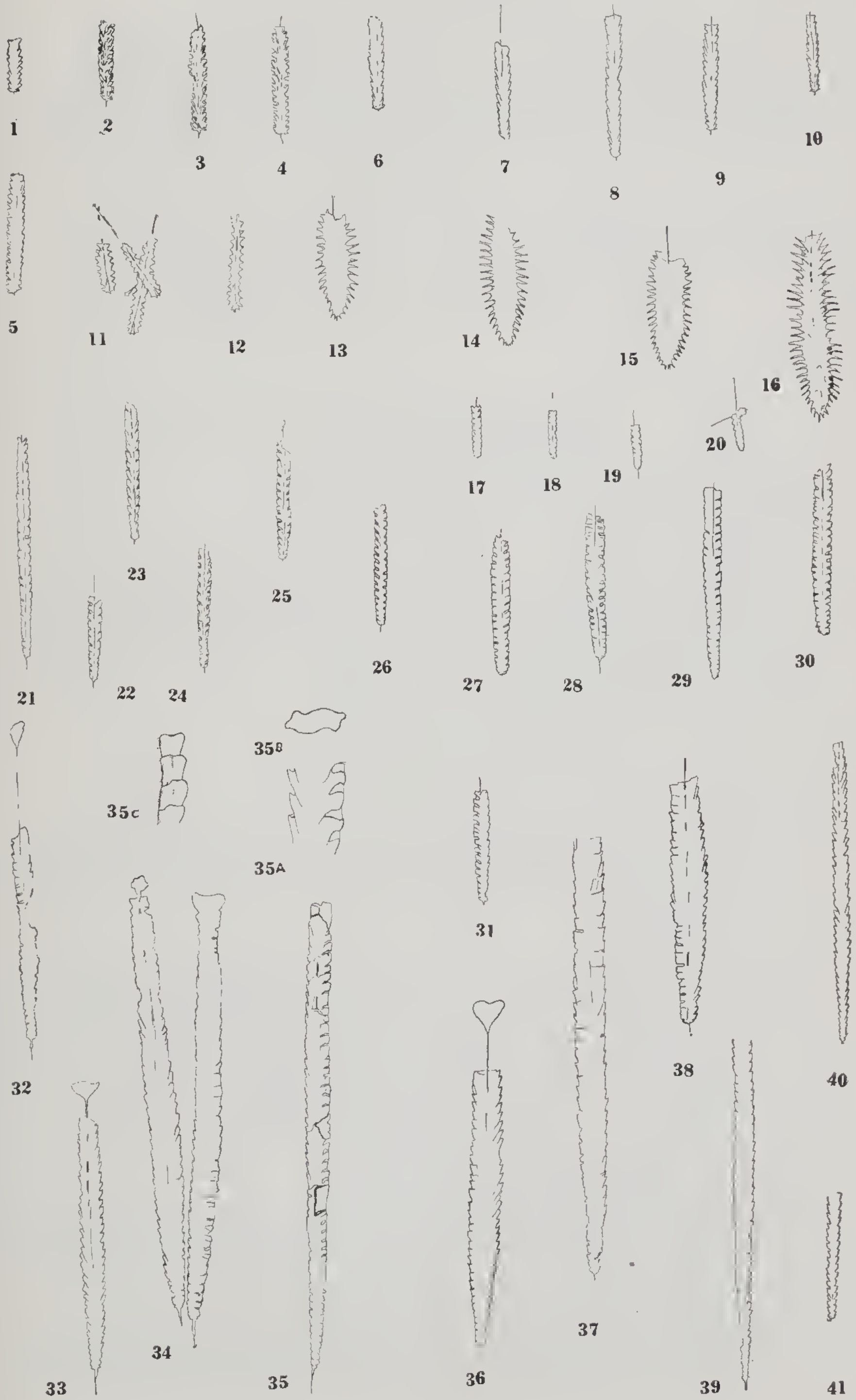
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Fig. 3.

[Proc. Roy. Soc. Victoria 47 (N.S.), Pt. II., 1935.]

Art. XVII.—*The Graptolite Succession of Bendigo East, with suggested Zoning.*

By WM. J. HARRIS, D.Sc.

[Read 11th October, 1934; issued separately, 8th May, 1935.]

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I. Introduction.

II. Acknowledgments.

III. Scope of the Survey.

The area discussed includes the parishes of Wellsford, Strathfieldsaye, and Sedgwick, with adjacent portions of other parishes. Attention is concentrated on the Darriwilian.

IV. Physiography.

The physiography of the area—a region of mature topography—is outlined.

V. General Geology.

The bed-rock of the district consists of Lower Ordovician sandstones and shales, striking west of north and closely folded. The Whitelaw Fault divides the area into two parts, older beds being on the west.

VI. Distribution of the Graptolite Series.

The general distribution of Lancefieldian, Bendigonian, Castlemainian, and Darriwilian series is described.

VII. Zoning of the Darriwilian Series.

An outline is given of the zoning of the Darriwilian as high as the D2 zone.

VIII. Incoming of the Diplograptidae.

It is contended that the incoming of the Diplograptidae in force in the D2 zone marks a very important stage in the graptolite succession, and the relationship of D2 beds to the lower zones is discussed.

IX. Typical Sections.

Five sections across the district from west to east are described. It is shown that after the Whitelaw Fault is crossed there is a normally descending series of beds, and that above the D 2 horizon two zones may be distinguished with possible passage beds, (*a*) a zone characterized by *Diplograptus* (*Glyptograptus*) *intersitus* H. and T., and *Didymograptus compressus* H. and T., and (*b*) a higher zone characterized by *Diplograptus* (? *Mesograptus*) *decoratus* H. and T., and *Didymograptus nodosus* Harris, and that these zones can be recognized right through the area.

X. The Upper Darriwilian Succession.

It is maintained that field and biological evidence fixes the position of the zones already mentioned, and that elsewhere in Victoria a higher zone of the Lower Ordovician can be recognized, while the basal graptolite bed of the Upper Ordovician (as at Ba. 67) should also be included in a *Diplograptus* series.

XI. Zoning of the Darriwilian and Castlemainian in Victoria.

The grouping of zones from D 2 to basal Upper Ordovician inclusive, as a *Diplograptus* series, leads to an attempt to treat lower beds in the same way. It is shown that the present breaks between the topical series are largely artificial and it is suggested that the zones below the *Diplograptus* series, i.e., from D3 downwards to C4 (inclusive) may be regarded as an *Isograptus* series. Below this series are passage beds marked out only by the occurrence of *Didymograptus proto-bifidus* Elles, while below these again the Bendigonian zones form a *Tetragraptus fruticosus* series. The proposed classification is then summarized.

XII. CORRELATION.

The *Diplograptus* series of Victoria is correlated with the Llanvirnian. The correlation of beds immediately below these will probably be facilitated by a study of the Victorian extensiform *Didymograpti.*

XIII. NOTES ON THE MAP.

XIV. INDEX TO GRAPTOLITE LOCALITIES.

XV. REFERENCES.

I. Introduction.

Attention was directed to the Bendigo East area by the discovery some years ago of high Darriwilian graptolite beds hitherto unknown from that part of Victoria. The existence of a definite and sharp boundary between these high beds and the lower beds of the Bendigo Gold-field has been demonstrated(1), and field work has been continued to ascertain whether any light could be thrown on the succession of Darriwilian graptolites above the zone of *Diplograptus* (*Glyptograptus*) *austrodentatus* (zone D2). The present paper is an account of this work.

II. Acknowledgments.

The field work in the northern half of the area, as far south as Strathfieldsaye, was carried out by the writer. In Strathfieldsaye his work and that of J. J. Caldwell of the Geological Survey of Victoria overlapped. In Sedgwick and the parishes east and west of it the present work is based on Caldwell's survey. Through the kindness of the Director of the Geological Survey (Mr. W. Baragwanath) the writer was able to study most of Caldwell's graptolite collections, and though these were rarely complete enough for detailed work they indicated the critical localities which were then visited and studied in detail. Except for the beds west of the Whitelaw fault in Sedgwick, for which R. A. Keble's identifications have been accepted, practically all important parts of the district have been visited often with Mr. D. E. Thomas of the Geological Survey or with Mr. P. Tilson (Echuca). Great assistance has been given by the officers of the Mines Department, both in Melbourne and at the Bendigo Mines Office—the latter at first under the late H. S. Whitelaw and then under Mr. W. Kingston—while the details given above will show the writer's indebtedness to Mr. J. J. Caldwell. For the re-drawing of the map thanks are due to Mr. W. Bennett of the Draughting Branch of the Mines Department.

III. Scope of the Survey.

The area discussed is roughly a rectangle measuring about 22 miles from north to south and 8 miles from east to west. It includes the parishes of Wellsford, Strathfieldsaye, and Sedgwick, portions of the two northern parishes, Huntly and Bagshot, and the edges only of the western and eastern parishes, Sandhurst, Mandurang, Axedale, and Eppalock. All parts of the 180 square miles have not been treated in equal detail, attention being concentrated on the Darriwilian beds.

IV. Physiography.

The whole of the area shows mature topography. There are no permanent streams except the Axe and Bendigo Creeks. The northern part is within the basin of Bendigo Creek, but in the centre and south the drainage of Sedgwick, Strathfieldsaye, and the southern part of Wellsford finds its way to the Campaspe River through Axe Creek and its tributaries. The general slope is to the north-east, the divide between the two drainage systems mentioned being almost unrecognizable in the field. Heights above sea level decrease from about 1,200 feet on the northern slopes of the Mount Alexander granodiorite massif to less than 500 feet in the north. The gentle slopes and creek flats provide rather poor grazing and agricultural land, and much of the poorer land, especially on the low ridges, is included in forest reserves, settlement being restricted mainly to narrow strips along the watercourses. In Wellsford there are few exposures of bed-rock, though numerous fragments of ironstone (limonite) litter the surface. There are no roads other than innumerable dray-tracks, and practically no mining excavations. In such an area search for graptolites is disheartening work, but fortunately the few fossiliferous outcrops discovered were so spaced as to give some idea of the general structure though details are not ascertainable.

In Strathfieldsaye and Sedgwick occasional shallow road cuttings, small watercourses, the Emu Creek No. 2 water-race, and the Bendigo-Heathcote railway provide most of the fossiliferous outcrops.

V. General Geology.

The bed-rock of the district consists of Lower Ordovician sandstones and shales and may be divided into two unequal parts (Fig. 3)—Lancefieldian, Bendigonian, and Castlemainian west of the Whitelaw Fault, and younger rocks, mostly Darriwilian, east of the Fault, though these descend in normal succession to the east and, partly outside the mapped area, Lancefieldian is also reached in the east. An important feature of the beds east of the Fault is the extensive development of beds above the middle Darriwilian (D2 and higher). This feature gives the district its special interest. The general strike of the Ordovician rocks is in most places 20° or more west of north, but local strikes of north-west or even almost east and west may be noted. The limited nature of fossiliferous rock exposures, together with close folding and pronounced cleavage, makes the working out of detailed structure impracticable at present.

VI. Distribution of the Graptolite Series.

(A) LANCEFIELDIAN.

Caldwell's survey demonstrated that the belt of Lancefieldian-Bendigonian which abuts on the Whitelaw Fault east and north of Bendigo can be traced right to the granite in the south of Sedgwick. It is uncertain whether the beds along the Fault in the southern part of the district are Lancefieldian or Bendigonian. No fossils were found sufficiently near the fault-line to settle the question. Caldwell shows the Lancefieldian as a narrow strip right along the fault-line. My own opinion is that the Lancefieldian beds narrow to the south and do not extend much further south than the southern boundary of Strathfieldsaye. In Sedgwick, if this is so, the Fault separates Darriwilian and Bendigonian. This opinion is partly based on the discovery of a slab showing *Tetragraptus fruticosus* along the Emu Creek water-race east of the south-west corner of Strathfieldsaye. Apart from this question of its relationship to the Whitelaw Fault, the western Lancefieldian belt does not appear to possess any features of special interest.

Caldwell also proved the existence of a wide belt of Lancefieldian to the east of the mapped area. This extends far east of Axedale. Only its north-western extension in the north of the parish of Axedale falls within the map. The relationship of this north-eastern area to the younger beds cannot be regarded as satisfactorily settled. Lancefieldian graptolites have been found at four rather widely separated outcrops. In the north-east of Wellsford, the Yankee Creek Gold-field occupies a narrow belt with the abnormal strike of N. 55-60° W. No fossils were obtained near the old workings, but the spoil-heaps show that thin coal-black bands occur among lighter-coloured sandstones and shales. These carbonaceous partings are badly cleaved and are now so badly weathered that at a touch they fall to powder. Their occurrence is suggestive of Lancefieldian, but the evidence is inconclusive since similar thin bands yield Bendigonian graptolites at Brett's Freehold, west of Bagshot railway station. These beds strike towards more meridional lower Castlemainian (C5) beds further west. Whether they ultimately are shown to be Bendigonian or Lancefieldian, faulting has probably been responsible for their abnormal features. Whitelaw(2) noted a fault which shifted the strata near the shafts 200 feet to the east, and much more extensive faulting is probable but unproved.

(B) BENDIGONIAN.

In the west of the mapped area the Lancefieldian beds are succeeded by the Bendigonian series in normal ascending order. This may be accounted for by presuming a southerly pitch in this part of the area, in accordance with the general observations of pitch in the southern portion of the Bendigo Gold-field. In the north-east the Lancefieldian is also bordered by a narrow belt of Bendigonian. Its narrowness may be the result of faulting as has been suggested above.

Bendigonian beds are more widespread in the north, definite Bendigonian graptolites having been found at Brett's Freehold, and also some distance east of Bagshot railway station. Whether these two outcrops are part of a continuous area is uncertain.

In Axedale and Eppalock the Castlemainian beds which succeed the Darriwilian on the east are in turn succeeded by Bendigonian.

(C) CASTLEMAINIAN.

In the south of Mandurang and the south-west of Sedgwick the Bendigonian beds give place to lower Castlemainian. This is the normal succession, which is also found in the west of Axedale and Eppalock.

In the north of the district a rather extensive area of upper Castlemainian occurs in the east of Huntly and the south of Bagshot, graptolites of this horizon being rather common in material from the spoil-heaps of shafts along the course of the Huntly Deep Lead. Most of the localities yield upper Castlemainian graptolites, but at least two show middle Castlemainian forms. These beds come in their normal place between Bendigonian and Darriwilian. One interesting feature was a bed at Huntly, which in both lithology and graptolite content was practically indistinguishable from the type C2 locality at Victoria Gully, Castlemaine.

A continuation of the Castlemainian belt runs through the east of Wellsford. *Didymograptus proto-bifidus* was obtained from small fragments of shale at two places along Yankee Creek, and *Isograptus caduceus* var. *victoriae* still further south. West of this last outcrop the presence of *Isograptus caduceus* var. *maximodivergens,* almost in the centre of the parish of Wellsford, indicated either a high Castlemainian or a low Darriwilian horizon. This is the Castlemainian belt which has already been mentioned as striking across the continuation of the Axedale-Yankee Creek Lancefieldian.

(D) DARRIWILIAN.

The Darriwilian beds, both from their extent and from their special features, are the most interesting in the district. The whole of the central portion of the map from north to south is included in this belt. The Whitelaw Fault crosses the southern boundary of the parish of Huntly and runs east of south to the Mount Alexander massif in the south of Sedgwick. Darriwilian beds border it on the east for the whole distance. They are succeeded on the east by a continuous belt of Castlemainian. These Dariwilian beds will be discussed in a later section of this paper.

VII. Zoning of the Darriwilian Series.

Since the Darriwilian zones were outlined in 1916(3) the succession of beds as high as the D2 zone (*Diplograptus austrodentatus*) has been tested in many parts of Victoria. With minor differences, probably due to passage-beds and locally abnormal ranges, the series has been described from Ingliston by Ripper(4) and from Lancefield by D. E. Thomas (personal communication).

The base of the Darriwilian is marked by the incoming in force of *Oncograptus upsilon* T. S. Hall, and the first appearance of *Trigonograptus* and *Didymograptus v-deflexus* H. and K. In beds which are stratigraphically closely connected with the upper Castlemainian the typical form of *Oncograptus upsilon* is common. *Oncograptus upsilon* var. *biangulata* seems to come in later, but passage-beds between D5 and D4 may be expected in any locality where the succession is shown in great detail. Later *Cardiograptus morsus* H. and K. appears. A typical assemblage from a D5 outcrop might include:—

Isograptus caduceus, var. maximo-divergens, Harris var.
,, ,, var. divergens, Harris var.
,, manubriatus (T.S.H.).
,, hastatus Harris.
,, forcipiformis (Rued.).
,, dumosus Harris.
Skiagraptus gnonomicus (H. and K.).
Oncograptus upsilon T.S.H.
,, ,, var. biangulata, H. and K. var.
Didymograptus v-deflexus H. and K.
,, uniformis E. and W.
Macandrograptus tau Harris.
? Cryptograptus sp.
Trigonograptus ensiformis J. Hall.
Phyllograptus sp.
Dichograptus octobrachiatus J. Hall.
Goniograptus speciosus T.S.H.
Tetragraptus quadribrachiatus J. Hall.
,, serra Brong. (normal and also abnormally large variety).
,, headi J. Hall.

This list is incomplete as there are many undescribed species. The common basis of the lower Darriwilian zones (D5, D4, D3) is shown by a comparison of this list with an assemblage from either of the two higher zones(4). Advance is shown by the incoming of *Cardiograptus morsus* in D4 and its usual survival beyond *Oncograptus* into D3, but the three beds form a stage in which the only important distinction is the degree of development of the Isograptidae as represented by *Oncograptus* and *Cardiograptus*. Even this distinction cannot always be made, though sometimes the dividing line is surprisingly sharp. Noting this we are forced to the conclusion, corroborated by the evidence of the Isograptidae themselves, that these zones represent a shorter time- or developmental-interval than is the average for other zones. The Isograptidae, as it were, shot ahead of their contemporary species. The Australian graptolite succession is more elaborate than other Lower Ordovician successions and its details are emphasized, especially when compared with a highly condensed succession such as that of the classic Point Levis section. Another point to be emphasized here is that the general character of an assemblage must be taken into account, and not the mere occurrence of a single " zonal " graptolite. *Oncograptus* and *Cardiograptus* are found rarely but definitely in assemblages which undoubtedly represent higher zones than D4 or D3. In the same way occasional specimens of *Diplograptus* may turn up—and may be expected to occur—on horizons lower than those characterized by this genus.

VIII. Incoming of the Diplograptidae.

With the zone above D3 a distinct stage is reached leading to the Upper Ordovician—the incoming in force of the Diplograptidae. Three of the important trends of evolution followed by the graptolites are (i) stipe reduction, (ii) growth-direction change, and (iii) thecal elaboration. Diplograptus marks an important stage in each of these, and the suddenness of its development in Victoria is specially noteworthy, though probably more detailed work will tend to show that its entry is not as dramatic as it now appears to be. It is doubtful if many of the records of *Diplograptus* below the D2 zone are reliable. The forms on which the records are based are probably referable to other genera, or at any rate are not typical *Diplograpti,* though they may be forerunners. Such forms appear in C2, but are rare, and are even rarer in C1. Since *Diplograptus* is so common in D2, representatives may be expected in zones D5-D3, and though they have not yet been recognized, the Bendigo East survey leads one to believe that they occur. In the D2 zone we have a sudden outburst of the genus. Not only is *Diplograptus austrodentatus* the commonest graptolite of the zone, but it often outnumbers all other species so as to give a distinct character to the horizon. Many D4 and D3 species persist and some higher forms enter, but all are subordinate to *Diplograptus austrodentatus*, which is as typical of the zone as *I. caduceus* var. *victoriae* is of zone C2.

The following actual assemblage is given as typical of the horizon:—

Diplograptus (Glyptograptus) austrodentatus H. and K. (v.c.).
Isograptus caduceus var. divergens, Harris var. (v.c.).
„ forcipiformis (Rued.).
„ hastatus Harris.
„ dumosus Harris.
Cardiograptus morsus (r) H. and K.
Skiagraptus gnomonicus (r) (H. and K.).
Didymograptus v-deflexus H. and K.
Tetragraptus serra Brong. (c).
Phyllograptus sp. (probably P. anna J. Hall) (v.c.).
Trigonograptus ensiformis J. Hall.
Dichograptus sp.

Though the Darriwilian succession as high as D2 is well established, few localities show a continuous section from D3 to D2. Ripper(4) reports that at Ingliston the succession is normal, but cannot be continuously traced. The zone is well represented in the Brisbane Ranges south of the area studied by Ripper, and observations made there by Thomas and the writer make it certain that *Diplograptus austrodentatus* enters with *Cardiograptus* and even with *Oncograptus* and ranges beyond these forms. The original locality for the zone of D2 was the Guildford-Strangways road west of Guildford(2), and here the succession from D3 to D2 is clear, *Diplograptus austrodentatus* and *Cardiograptus morsus* occurring at first together and being succeeded by beds from which *Cardiograptus morsus* is absent. (The *D.* cf. *angustifolius* mentioned was later described as *D. austrodentatus*). Thomas has since confirmed this observation as the result of his examination of the area north of the Loddon River in the same district. The normal succession also is found along the Gisborne Creek near the Gisborne gold-mine at Bullengarook, where D2 beds occur west of D3 beds in a succession which, traced from the east, is ascending normally to this horizon. Details of folding have not yet been worked out here. D2 beds are also extensively developed in the Brisbane Ranges and at Steiglitz, but no detailed work has been done in either area apart from an unpublished survey of Steiglitz by W. H. Ferguson, late of the Geological Survey. T. S. Hall identified many of Ferguson's graptolites(6), but in the light of later work the determinations both published and unpublished stand in need of revision. The writer has also recognized *Diplograptus austrodentatus* in a small collection from Sebastian (between Bendigo and Raywood) shown him by W. Kingston of the Bendigo Mines Office.

IX. Typical Sections.

(1) HUNTLY-BAGSHOT.

This section is taken across the north of the mapped area. As stated above, the Whitelaw Fault crosses the west of the parish, running diagonally through Section XXIX. In the south of this section the parish plan shows a " Stone and Gravel Reserve." This derives its local name, Ironstone Hill, from the capping of cemented gravel now partly removed by mining operations or for use as road-making material, and is on the western side of the fault-line. Immediately to the north-east the continuation of these gravels lies below the surface and they have been mined by shallow shafts, the spoil-heaps of which yield abundant upper Darriwilian graptolites. The difference of level is interesting as it is probably the result of post-Pliocene movement along the line of the Whitelaw Fault. Examples of later movement along fault-lines which are very old are found elsewhere in this district and in other parts of Victoria(7). Further to the south-east the similar gravel outcrops of the White Hills end rather abruptly at the fault-line and are succeeded on the north by buried gravels. A search of old mining records shows that the difference of level was observed nearly forty years ago. In 1898 James Stirling reported (8), " Mr. Mining Surveyor O'Dwyer has stated that on the Huntly Lead south of the White Hills the sinking is shallow—from 10-25 feet deep—but north it suddenly drops to 50 feet and at lower levels 70 feet." A similar abrupt change of level is recorded west of Sebastian where, although the only recorded graptolites are Darriwilian (D5 and D2), there is quite possibly a fault comparable with the Whitelaw Fault. Repeated movement along the lines of major faults is a widely recognized phenomenon. An interesting observation is that the floor of the Huntly Deep Lead beyond Brett's Freehold rises 27 feet in five miles instead of having the usual fall(9).

Practically every spoil-heap in the northern part of Section XXIX. Huntly (now used as a sewerage farm for the city of Bendigo) yields upper Darriwilian graptolites. A good collection, though in very soft, weathered shale, can be gathered in Allot. 8. Owing to the troublesome cleavage at many localities and our total ignorance of the folding of the bed-rock, detailed zoning is difficult and has not been attempted. The underlying rocks are probably closely folded, and beds as low as D2 may be present, though they have not been noticed.

East of the Bendigo Creek the spoil-heaps give a fairly complete section. Just outside the city area, between the Echuca-road and railway, upper Darriwilian graptolites are common, and this belt may be traced as far as the north-east of Epsom. The beds are characterized by the common occurrence of *Amplexograptus* and *Didymograptus nodosus* Harris, which are associated with other characteristic forms such as *Lasiograptus proteus* Harris and Thomas and *Cardiograptus crawfordi* Harris. These beds occur west of the Bendigo Pottery at Epsom (within the belt defined above), but a few chains north of the Pottery a somewhat different facies is observed (Sect. XII., Ascot.) Here several spoil-heaps show different *Diplograpti,* chiefly *Diplograptus intersitus* H. and T., and a different *Didymograptus, D. compressus* H. and T. The commonest *Lasiograptus* is also distinct —*Lasiograptus etheridgei* Harris. This belt may be traced north-westerly through Sections IV. and V., Huntly. Still proceeding east from Epsom *Diplograptus austrodentatus* makes its appearance in Section VIII., Huntly, and on the Sandy Creek-road near Allot. 7 of Section I. This has not been traced further north, though it is very likely that an exhaustive search would show it. In Section XX. D3 beds occur, though only a few graptolites were found, and then in Section XVIII., further north-east there are several occurrences of D4 and D5 beds. The last of these are just east of the Echuca-road north-east of Huntly township, but similar beds cross the railway at Huntly R.S. East of the Echuca-road the spoil-heaps in Section XIX., Huntly, and Section XII., Bagshot, give upper Castlemainian graptolites (C1 and C2), though there is an isolated record of D5 in Allot. 4, Section XII. C1 beds outcrop south of the railway on the Sandy Creek-road, and slightly lower beds are found not far from them. Along Yankee Creek, on the southerly continuation of the strike of these beds, the writer found *Didymograptus protobifidus* Elles, and then near Bagshot railway station, *Tetragraptus fruticosus* J. Hall, and other Bendigonian forms. The immediate purpose of this paper does not need the extension of this section further east, though this is the locality where the next beds to the east are Lancefieldian, apparently striking right into the Castlemainian.

For the present it is sufficient to sum up that—

(*a*) as low as the Castlemainian the succession is apparently normally sinking to the east.

(*b*) above the D2 beds is a bed characterized by *Diplograptus intersitus* and *Didymograptus compressus.*

(*c*) above (i.e., further west than this) is a bed characterized by *Diplograptus* (*?Mesograptus*) *decoratus* H. and T. (allied to *D. coelatus* Lapworth), *Amplexograptus,* and *Didymograptus nodosus* Harris.

This succession is seemingly in normal order, and attention is directed to it, since it seems to hold elsewhere in the district and will be used as a suggested zoning of these high Darriwilian beds. This section, although described first, was the last to be worked out in the field, when it was found that the boundaries provisionally fixed on the evidence of sections further south did not need adjustment.

(II.) MCIVOR-ROAD.

South of the Huntly-Bagshot section just described is the unsatisfactory area of Wellsford. The next line of section is along the Bendigo-Heathcote railway and the almost parallel road (McIvor-road). This gave a succession descending from upper Darriwilian to Castlemainian and even lower and seemed so promising that attention was devoted to it first. As in most sections, exposures are not continuous, but the gradually descending order generally as one went east from the Whitelaw Fault was soon evident. Local interruption and repetition of beds was to be expected, but the section proved to be unexpectedly complete. The two zones mentioned in the account of the more northern section as being above D2 were recognizable—in fact, it was along this section that they were first recognized—as well as probable passage-beds. Caldwell's survey enabled similar beds to be located further south, and from some of these, as well as from others already known to the writer, fairly extensive collections were made.

From the Whitelaw Fault to the crossing of road and railway at 97 miles 36 chains, a distance of about 1½ miles, there are numerous graptolite beds, all above the zone D2. As stated, two distinct zones could be noted, though there are minor differences between beds even of the same general zone. Some of these differences may later prove to be of stratigraphical value, or they may be due to the tendency of forms on this horizon to be abundant in some narrow bands and almost absent from bands quite close by.

The first locality from which a good collection was made is opposite the junction with the McIvor-road of a road from the north-east, about 30 chains east of the Whitelaw Fault. Similar beds occur near the north-west corner of the parish of Strathfieldsaye (loc. 209)*. A good collection can, with some trouble, be made at either outcrop, but the horizon—the zone of *Didymograptus nodosus*—is represented by better material south of Strathfieldsaye township (loc. 164) and elsewhere, and only its horizon need be noted. The second assemblage—the zone of *Diplograptus intersitus*—occurs nearer the crossing (locs. 210, 211) and in a fragmentary state at the crossing itself. All these beds extend through to the railway line a little distance to the north The loc. 210 assemblage is also better represented further south (locs. 196, 201, 298). Along this section then, as elsewhere, two assemblages above the D2 zone may be noted.

Proceeding east from the crossing the next fossiliferous band was found near the 97 mile post—the zone of *Diplograptus austrodentatus* (D2)—and this is repeated further east. Near the 96 m. 8 ch. crossing, a *Diplograptus intersitus* band crosses

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* For convenience Caldwell's field numbers are used hereafter for all localities which are marked on his plans.

the railway. If the normal descending order had been maintained, this bed should have been below the D2 zone, but there is little doubt that it is rather on the same horizon as loc. 210.

East of the 96 m. 8 ch. crossing a typical D4 outcrop is found, but this need not be considered in detail. Intervening beds may be hidden, but it is probable that the zones of D3 and D2 are missing from this part of the area. More than a mile of unfavourable beds or shallow cuttings separates this occurrence from the next to the east—beds of almost the same horizon in cuttings between Allots. 1 and 2, Section XVII., Strathfieldsaye. Caldwell's survey shows that still further east Castlemainian beds occur, and then, nearer Axedale, Bendigonian and Lancefieldian.

(III.) .STRATHFIELDSAYE.

The main Country Roads Board road through Strathfieldsaye to Eppalock has few cuttings, but a section can be obtained roughly along it. The Whitelaw Fault crosses the road almost on the western boundary of the parish of Strathfieldsaye, with Lancefieldian beds (loc. 230) west of it. The beds nearest to it, but east of it, are not well shown, but *Didymograptus nodosus* has been recorded from them. The next outcrop (loc. 196) yields abundant material which shows graptolites clearly when "green," but less distinctly when dry. *Diplograptus intersitus* and *Didymograptus compressus*, the zonal fossils, are very common. A few chains to the east, *Didymograptus nodosus* occurs, but the material is fragmentary. The variety of *Didymograptus nodosus* is less robust than the typical zonal form and the bed is probably transitional.

North of the township of Strathfieldsaye a very shallow water-race yields a limited amount of shale with indistinct graptolites. *Diplograptus intersitus* occurs here also. Badly cleaved graptolite shale (loc. 244) is also found in Allot. 41 about a mile east of the last outcrop mentioned. *Isograptus caduceus* occurs in association with poorly-preserved *Diplograpti*, probably *D. austrodentatus*, marking the southern extension of the D2 zone noted on the railway to the north. Still farther east a group of outcrops on the Axe Creek (locs. 159, 160) yield *Oncograptus upsilon biangulata*, *Cardiograptus morsus*, and *Didymograptus v-deflexus*, and can be correlated also with the similar beds on the railway. Before the parish boundary is reached the horizon is Castlemainian (locs. 226, 229), conclusive evidence being supplied by outcrops north and south of the road.

(IV.) EMU CREEK (Fig. 1).

This section is taken across the south of the parish of Strathfieldsaye. Bendigonian beds are shown in the south-west corner of the parish (locs. 179, 180, 181) on the west side of the Whitelaw Fault. Nearer the fault along the Emu Creek No. 2

water-race the writer found a single specimen of *Tetragraptus fruticosus,* and it is doubtful whether the Lancefieldian belt which lies along the west of the fault-line farther north extends as far south as this. It may pitch underfoot bringing Bendigonian beds up against the Darriwilian. Caldwell, however, shows a narrow strip of Lancefieldian right along the line. Once the fault-line is crossed there is an almost continuous section of upper Darriwilian along the water-race, which here cuts obliquely across the strike of the bed-rock. Probably the best outcrop of the *Didymograptus nodosus* zone in the district is on the water-race, but north of this section (loc. 164). Along the race most of the fossiliferous bands seem to belong to passage beds between the typical zones of *Didymograptus nodosus* and *Diplograptus intersitus,* but for the present are grouped with either one or the other. A locality such as 176 on the Sedgwick-road provides a good example. Here, *Diplograptus decoratus* is very common, associated with the less robust variety of *Didymograptus nodosus* and *Lasiograptus etheridgei,* the last-named species being usually associated with the *Diplograptus intersitus* zone in other parts of the district. This outcrop is included in the *D. nodosus* zone. Farther east, as at loc. 173, *Diplograptus intersitus* is found, but the variety of *Didymograptus compressus* associated with it shows some affinities with *Didymograptus nodosus.* It is remarkable that though the two mentioned species of *Didymograptus* are easily distinguished when typically developed, specimens are often found which seem to lie between them.

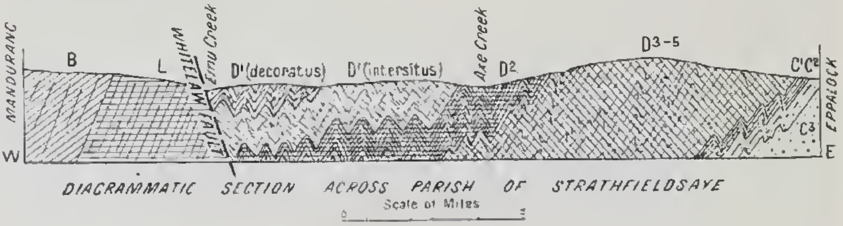


Fig. 1.

After the race is left near the Emu Creek State School, an outcrop of the *Diplograptus decoratus-Didymograptus nodosus* zone is found (loc. 167) and then, after beds on the *Diplograptus intersitus* horizon (loc. 203), *Diplograptus austrodentatus* appears in the north-east corner of Allot. 26, Section III., Strathfieldsaye, indicating that the D2 zone has been reached, though the presence of an occasional *Diplograptus intersitus* (loc. 169) is an indication that these beds are well up in the D2 zone. Similar, or slightly lower, beds are found on the other side of Axe Creek (loc. 198), though *Diplograptus intersitus* is well represented in beds a little to the west of this last locality (locs. 170, 202, 203). A mile east of loc. 198 the record of *Oncograptus* (loc. 205) shows that lower Darriwilian has been reached, and near the eastern boundary of the parish, upper and middle Castlemainian beds occur, C1 beds outcropping on the road between Sections VII. and VIII. about 150 yards west of the boundary and being separated by less than 50 feet from C2 beds. In the parish of Eppalock the succession is continued through middle and lower Castlemainian to Bendigonian and Lancefieldian.

(V.) SEDGWICK.

Sedgwick is the parish south of Strathfieldsaye. Little attention was given to beds west of the Whitelaw Fault since Keble's identifications from Caldwell's collections showed that Bendigonian beds near the fault were succeeded regularly on the west by lower Castlemainian (C5). No Lancefieldian graptolites have been recorded from the parish, though Caldwell shows a narrow strip of Lancefieldian right along the Whitelaw Fault.

In the eastern half of the parish the chief feature is the extensive development of the zone of *Diplograptus austrodentatus* (D2) and the zone of *Diplograptus intersitus.* No direct section was obtained across the area east of the fault-line, but a composite section can be made which gives a good idea of the structure. The first locality (loc. 300), is near the Sedgwick-road in the north of the parish. Here the *Diplograptus decoratus-Didymograptus nodosus* zone is well represented. Farther south loc. 303 on Axe Creek yielded *Diplograpti* probably of the same zone, and certainly higher than the zone of *Diplograptus intersitus.* These outcrops show that a narrow belt of the *Didymograptus nodosus* zone extends along the fault line.

The next group of localities lies south-east of loc. 300. Here a number of outcrops (locs. 298, 283, 284, 285) yield *Diplograptus intersitus* in profusion, the associated *Didymograptus, D. compressus,* being less common but occasionally forming tangled masses. The most northerly band (loc. 299) contains more rarely *Didymograptus nodosus,* and more commonly the larger *Diplograpti,* and is probably just above the *Diplograptus intersitus* horizon. East of Axe Creek *Diplograptus austrodentatus* is well represented (locs. 309, 313, 314) though *Diplograptus intersitus* is also present. Loc. 314 is particularly interesting, as not only do both these *Diplograpti* occur, but *Oncograptus upsilon* is sparingly represented, an example of survival which has already been commented on. At loc. 310 farther south is a typical outcrop of the *Diplograptus austrodentatus* zone, and here and at loc. 314 forms are occasionally found preserved as pseudomorphs in limonite or as moulds when the crumbling filling has fallen out. At both localities also a small species of *Phyllograptus* (? *P. anna*) is not uncommon, though this genus is more common on higher and lower horizons elsewhere. *Diplograptus intersitus* occurs as far south as Section XVI. (loc. 325) and east of the D2 belt, near the eastern boundary of the parish lower Darriwilian beds come in, typically represented by loc. 316. The survey has not been extended eastward into Lyell, but indistinct graptolites obtained about a mile within this parish appeared to be of lower Castlemainian age and lower Castlemainian and Bendigonian graptolites are found in the south of the parish.

X. The Upper Darriwilian Succession.

It will be seen that this district provides details of the D2-D1 succession not yet found elsewhere. The succession indicated by the development of the graptolites is corroborated by the field evidence. Commencing with *Diplograptus austrodentatus* we find this form the predominant graptolite at outcrops such as locs. 310, 313, and many outcrops in the south of the area, as also near the 97-mile post and elsewhere in the centre. Then at outcrops such as 169, 198, 309, and 314, although this form is one of the commonest graptolites, it is associated with *Diplograptus intersitus. Diplograptus intersitus* then characterizes a series of beds (locs. 196, 201, 210, 284, 298). It is then found associated with the larger *Diplograpti* such as *Diplograptus decoratus* (loc. 299) and finally these forms, mainly *Amplexograpti,* predominate, *D. intersitus* occurring only rarely (locs. 164, 176, and Section XXIX., Huntly).

Apart from the *Diplograpti* other forms also show progression. *Lasiograptus etheridgei* enters with *Diplograptus austrodentatus,* is common at some, but not all, beds with *Diplograptus intersitus* (it is rare at loc. 196), becomes one of the commonest graptolites in beds where *Diplograptus decoratus* is associated with the less rigid variety of *Didymograptus nodosus* (loc. 176), and finally is replaced by *Lasiograptus proteus* H. and T. (loc. 164, Section XXIX., Huntly). This latter species has a much less complete meshwork than *L. etheridgei* and in adult stages mimics *Glossograptus hincksii* with which it has probably been confused in some lists. *Glossograptus acanthus* E. and W. enters with *Diplograptus austrodentatus,* and is common with *Diplograptus intersitus,* but does not commonly range higher. *Diplograptus intersitus* is associated with a distinctive *Didymograptus* of restricted range (*Didymograptus compressus* H. and T.) This has at first a straight dorsal margin, but later forms are found in which this margin has become "corrugated" (loc. 173) and the appearance of the species approaches *Didymograptus nodosus. Didymograptus nodosus* itself appears to be preceded by a variety with initially narrow stipes resembling those of *D. compressus* (loc. 176, 197). Another graptolite typically restricted to the *D. intersitus* zone is *Pterograptus incertus* H. and T. *Cardiograptus crawfordi* is not characteristic of any bed below the zone of *D. intersitus,* but is found on this and higher horizons.

No zone higher than that of *Diplograptus decoratus-Didymograptus nodosus* has been found in this district, nor is the presence of any such zone indicated by the stratigraphy, but such a bed is known elsewhere in Victoria. Near the 8-mile stockyard on the Howqua River, eight miles upstream from the deserted township of Howqua (now commonly called "Fry's"), *Diplograptus* beds are found. More than one species of *Diplograptus* is present, but specimens showing thecal characters clearly are rare. One of the commonest forms is *Diplograptus* (*Glyptograptus*) *euglyphus* Lapw. With it are associated *Glossograptus hincksii, Pterograptus lyricus* K. and H., and *Isograptus ovatus* (T. S. Hall). The same assemblage is found at the more accessible locality of Turner's Quarry, Mornington Peninsula (Allot. 27B, Bittern). This assemblage bears a very close resemblance to that of Ba 67 at the junction of Jackson's and Riddell's Creeks (Q.S. 6 S.E.) usually taken as the basal graptolite zone of the Upper Ordovician, and the identifications of New Zealand forms by Keble and Benson(10) show from the Cobb River in Nelson a closely related assemblage, probably between our Howqua and Ba 67 beds. The New Zealand forms are preserved in hard blue-black shale, but have a "frayed" appearance which makes comparison with our more clear-cut forms difficult especially in the case of *Diplograpti;* but the painstaking work of the authors quoted leaves no doubt as to the general resemblance (*ibid.*, p. 845, loc. 1231). There is hardly a form which does not occur at Turner's Quarry or Ba 67, or is not closely related to forms occurring there, but the general aspect of the *Diplograpti* seems to point to a rather closer resemblance to the Turner's Quarry beds than to those of the higher horizon. This is a case where an opinion is based on the general nature of the assemblages and on evidence which a faunal list cannot weigh. At present the writer's personal opinion is that the Cobb River beds may best be regarded as passage beds which, in a broad classification, would be included in the same zone as those from Turner's Quarry.

To complete the *Diplograptus* series the Ba 67 beds should be included as the uppermost zone. Immediately and conformably above them are beds containing *Dicellograptus sextans* J. Hall and *Dicranograptus brevicaulis* E. and W. with an assemblage otherwise the same as the lower horizon. These beds mark the incoming of the Dicranograptidae, the first really important stage after the incoming of the Diplograptidae. (Throughout this paper the earlier appearance of one of the Diplograptidae, *Trigonograptus,* has not been emphasized owing to the general rareness of specimens of this genus). Thomas and Keble(11) leave Ba 67 as the base of the Upper Ordovician, with which stratigraphically its relationship is very close, but we have no certain knowledge that elsewhere in Victoria, as for example between Newham and Rochford, similar beds may not be found closely associated with typical D1 beds. Moreover, Keble has recorded from Mornington, north-east of Turner's Quarry, a bed which seems to be either equivalent to Ba 67 or a passage-bed leading to it. Unfortunately the outcrop is so limited that this information cannot be amplified.

XI. Zoning of the Darriwilian and Castlemainian in Victoria.

The erection of zones of *Diplograptus intersitus, Diplograptus decoratus,* and *Diplograptus euglyphus* from beds hitherto grouped as upper Darriwilian or D1 lessens the exactness of the index number. Since such numbers, though convenient for field use, do not of themselves convey any definite meaning, an attempt is now made to convert the present classification into one which will indicate the biological development of the graptolites selected as zonal fossils, it being kept in mind that a zonal fossil, like a zone number, is little more than a reference aid, the whole assemblage and relative abundance of forms being important factors.

The division of the Victorian graptolite succession into Lancefieldian, Bendigonian, Castlemainian, and Darriwilian series is due to T. S. Hall(12). The same pioneer worker used the term "zone" to include indifferently the "zone of *Tetragraptus caduceus*" (i.e., C.2), and the "zone of *Tetragraptus fruticosus*" (i.e., the whole Bendigonian series (13)), but it has long been evident that the division between any two series is not in any case more important than the division between some zones within the same series, while the local names are no longer descriptive since every series is represented in each of the serial districts except possibly at Darriwil. When Lancefieldian meant only the Mount William quarry assemblage, Bendigonian the typical beds of the Bendigo gold-field, and Darriwilian the isolated *Diplograptus* bed at Darriwil, the series could be regarded as distinct. Fig. 2 shows this diagrammatically, no attempt being made to represent the thickness of any zone or series.

Fig. 2.—Scope of Hall's scheme, 1899, shown by shaded portion. Present scope shown by full length of column.

With the extension of knowledge even in Hall's time the spaces in the succession were filled in, until when Hall's work was complete the only gaps were above the Castlemainian. It is not proposed to deal with the Bendigonian or Lancefieldian as they lie outside the scope of the present paper, but since the tuning-fork *Didymograpti* in England are associated with what are Darriwilian forms in Victoria, a beginning will be made with them.

The incoming of *Didymograptus proto-bifidus* is locally sufficient to warrant the erection of a transition series between the *Tetragraptus fruticosus* series and the succeeding series of *Isograptus.* The *Didymograptus proto-bifidus* beds may be divided into a lower and an upper part, and if the predominance of one species is not considered sufficient for the constitution of a separate series the lower bed would be the uppermost zone of the *Tetragraptus fruticosus* series, while the upper (C5) would be the base of the *Isograptus* series. The present numbers B1 and C5 express this. Later work on the horizontal *Didymograpti* may make possible a more useful zoning as apart from *D. proto-bifidus* in C5, the C5 and C4 beds have no easily recognized zonal forms, *Isograptus caduceus* not becoming important usually till the C3 horizon is reached.

Isograptus caduceus then, entering with *D. proto-bifidus* in C5, becomes important in C3 and the Isograptidae then predominate as high as the middle Darriwilian (D3). The dividing line between C1 and D5 does not mark an important break, the chief difference being the stage of development of the Isograptidae as indicated by the incoming of *Oncograptus*, though new forms such as *Didymograptus v-deflexus* and *Trigonograptus* also appear first in D5. The *Oncograptus-Cardiograptus* (D4) and *Cardiograptus* (D3) zones are usually recognizable, carrying on the development of the Isograptidae, but the occasional survival of both *Oncograptus* and *Cardiograptus* to a higher horizon, though upsetting to any hard and fast zoning, is what might be expected and in the field is not usually disconcerting. The developmental period occupied by zones D5-D3 was probably relatively brief. The zones commencing with D2 (zone of *Diplograptus austrodentatus*) mark an important advance and may be grouped as a *Diplograptus* series. Biologically this series should include all beds below that which marks the next important stage—the incoming of the Dicranograptidae. This would include in this series the Ba 67 bed. It is not necessary for the older serial names to be discarded for purposes of reference (in the field they are very useful). but the suggested scheme makes the basis of the succession clearer. An obvious classification would be to call the *Diplograptus* series Middle Ordovician, intermediate as these beds are in texture and life-content between the typical Lower and Upper Ordovician. This suggestion, first tentatively made in conversation by Thomas, has the disadvantage that in Britain the Middle Ordovician is characterized by *Nemagraptus, Dicellograptus* and *Climacograptus* (14), an assemblage corresponding with the lower zones of our Upper Ordovician.

The proposed *Diplograptus* series in outline is therefore as under:—

Diplograptus Series.

Zone of Diplograptus (Glyptograptus) teretiusculus (highest).

Typical locality—Ba 67 at junction of Riddell's and Jackson's Creeks (Q.S. 6 S.E.).

Characteristic assemblage:

Diplograptus teretiusculus (v.c.) His.
,, euglyphus (c) Lapw.
Climacograptus riddellensis (c) Harris.
Cryptograptus tricornis (c) Carr.
Glossograptus hincksii (c) Hopk.
Retiograptus speciosus (c) Harris.
Isograptus caduceus, var. tenuis (v.r.) Harris var.
Didymograptus (horizontal spp.) (c).
Pterograptus lyricus K. and H.

Zone of Diplograptus (Glyptograptus) euglyphus.

Typical localities—Turner's Quarry; 8-mile, Howqua River.

Characteristic assemblage:—

As above, except that *D. teretiusculus* has not been been recognized with certainty, *Tetragraptus* is more common, and *Retiograptus speciosus* not yet recorded. *Isograptus ovatus* occurs at both the typical localities, though elsewhere it seems to be an Upper Ordovician form.

Zone of Diplograptus (? Mesograptus) decoratus (D. aff. coelatus).

Typical localities—Loc. 164 Strathfieldsaye; loc. 300 Sedgwick; Allot. 8, Sect. XXIX, Huntly.

Diplograptus (? Mesograptus) decoratus (v.c.) H. and T.
,, (Amplexograptus) confertus (c) Lapw.
,, ,, differtus H. and T. (c).
,, ,, modicellus H. and T. (c locally).
Cryptograptus schaferi Lapw.
Lasiograptus proteus H. and T.
Isograptus forcipiformis (Rued.).
Cardiograptus crawfordi Harris.
Brachiograptus etaformis H. and K.
Trigonograptus ensiformis J. Hall.
Didymograptus nodosus (v.c.) Harris.
,, dubitatus H. and T.
,, cognatus H. and T. (c).
,, cuspidatus Rued.
,, acriculus K and H.
Atopograptus woodwardi Harris.
Phyllograptus nobilis (v.c.) H. and K.
Tetragraptus spp.

In what are probably the lower beds of this zone, *D. decoratus*, *Didymograptus nodosus*, and *Lasiograptus etheridgei* are the commonest species as, e.g. at loc. 176 and north-west of Turner's Quarry. A similar assemblage, with *D. nodosus* very rare, is found at Woodend (Allots. 95-99) and at Newham (Sect. 20).

Zone of Diplograptus (Glyptograptus) intersitus.

Typical localities—Locs. 196, 210 Strathfieldsaye; 298 Sedgwick.

Diplograptus (Glyptograptus) intersitus (v.c.) H. and T.
Lasiograptus etheridgei (v.c.) Harris.
Isograptus forcipiformis (Rued.).
,, caduceus varr.

Cardiograptus crawfordi (c) Harris.
Cryptograptus schaferi Lapw.
Glossograptus acanthus E. and W.
Trigonograptus ensiformis J. Hall.
Didymograptus compressus (c) H. and T.
,, spp.
Tetragraptus spp.
Pterograptus incertus (c) H. and T.
Phyllograptus sp.
Loganograptus cf. logani (v.r.).

Zone of DIPLOGRAPTUS AUSTRODENTATUS (D2).

Typical localities—Loc. 310 Sedgwick; Guildford-Strangways Road; Brisbane Ranges.

Characteristic Assemblage. (See list on page 321).

Isograptus Series.

Zone of CARDIOGRAPTUS MORSUS (D3).
Zone of CARDIOGRAPTUS and ONCOGRAPTUS (D4).
Zone of ONCOGRAPTUS (D5).
Zone of ISOGRAPTUS CADUCEUS varr. MAXIMA and MAXIMO-DIVERGENS (C1).
Zone of ISOGRAPTUS CADUCEUS var. VICTORIAE (C2).
Zone of ISOGRAPTUS CADUCEUS var. LUNATA (C3, C4).

Didymograptus proto-bifidus Passage Beds.

Zone of DIDYMOGRAPTUS PROTO-BIFIDUS and ISOGRAPTUS CADUCEUS varr. PRIMULA and LUNATA (C5).
Zone of DIDYMOGRAPTUS PROTO-BIFIDUS and TETRAGRAPTUS FRUTICOSUS (B1).

Tetragraptus fruticosus Series.

(Bendigonian zones).

XII. Correlation.

The correlation of Victorian graptolite zones with those of the other side of the world lies outside the scope of the present paper, but the subject cannot be altogether neglected. There can be little doubt that, as stated in an earlier paper(5), the Victorian *Diplograptus* series is the equivalent of the Llanvirnian, and it is probable that more detailed work will increase rather than lessen the resemblances of the assemblages. It should be noted, however, that in England *Diplograptus* enters on a lower horizon and that in Victoria the tuning-fork *Didymograpti* are absent from the Darriwilian. In fact, whether our common Victorian dependent *Didymograptus* is *D. bifidus* Hall or *D. proto-bifidus* Elles, its associations are not the same here as in either Europe or America.

The correlation of lower zones is more difficult and the opinion is expressed that it would be well to delay a revision of the correlation until a detailed and systematic study has been made of Victorian horizontal *Didymograpti*. Our knowledge of these forms is at present very limited, partly because their zonal value has not been stressed, and partly because as a rule Victorian forms which otherwise resemble those of the old world have lower angles of thecal inclination, and the value to be attached to this has not been decided. It is rare, as far as I have studied these forms, to find any with angles of over 35°, and the identity of even well-known forms such as *D. nitidus* and *D. nicholsoni* has not yet been definitely asserted.

XIII. Notes on the Map (Fig. 3.)

The map which accompanies this paper is intended chiefly to show the distribution in the Bendigo East district of the graptolite zones outlined. Fossiliferous outcrops are too scattered to enable it to represent detailed structure. It is probable that as faulting can be clearly demonstrated east and west of the mapped area (towards Heathcote and at Bendigo) it also affects the present area.

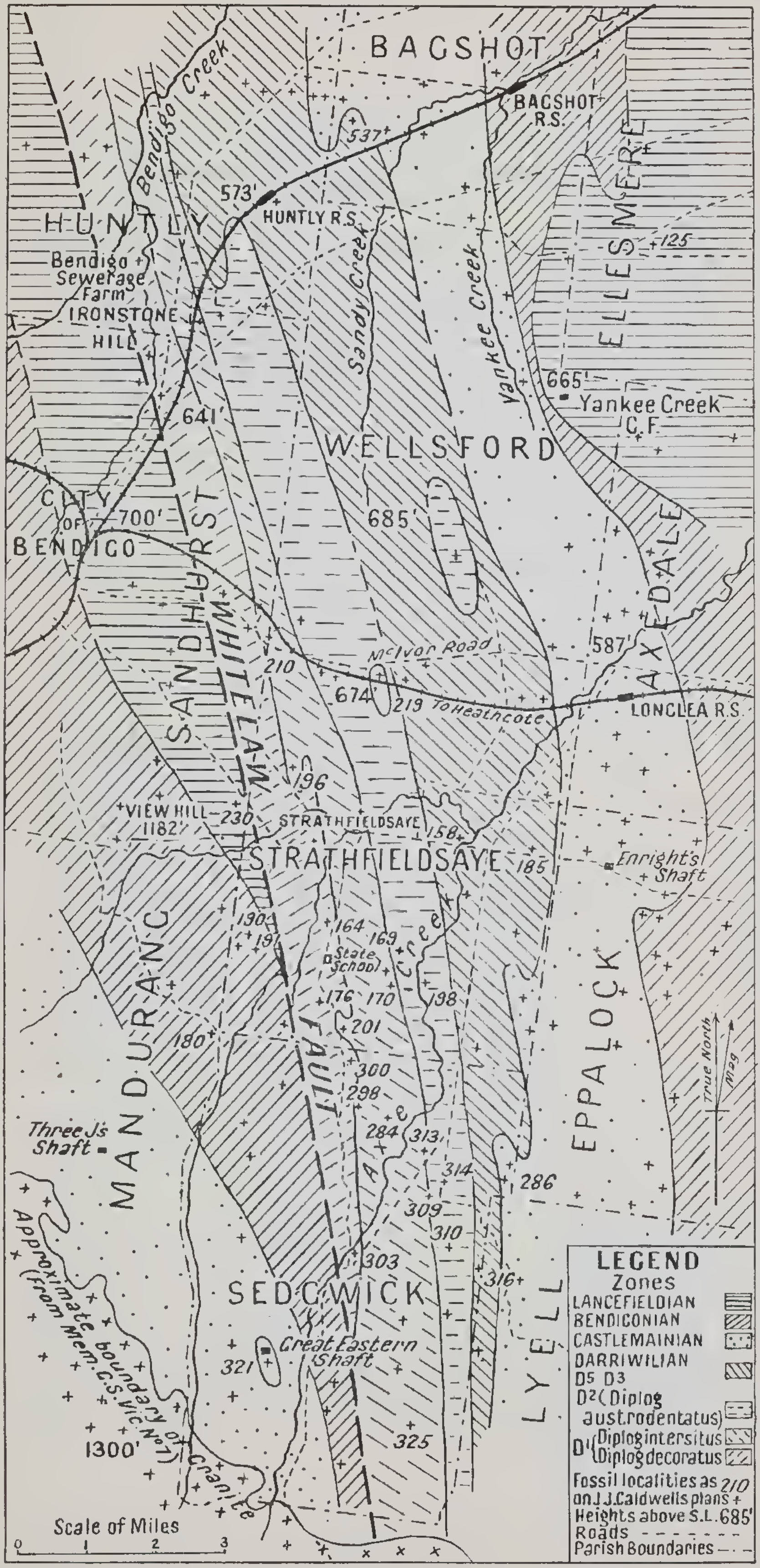
When the features marked on the map are shown on a larger scale, e.g., 2 inches to the mile, several interesting features, rather obscure on a smaller map, stand out.

(1) It is probable that the broad belts of Lancefieldian, Bendigonian, and Castlemainian west of the Whitelaw Fault enclose smaller areas or strips of one or other series. The detailed survey of the Bendigo Gold-field (15) shows that this is so in the central Bendigo area. If it is found not to be so south of Bendigo, the difference in folding may possibly be correlated with the less auriferous nature of the rocks in that direction.

(2) The belts of Darriwilian east of the fault are shown as long usually narrow strips, with some minor indentations in their outline due to pitch. It is certain that more detailed work will show that the number of indentations and inliers of other series is much greater than the present map indicates. With the increase of emphasis on assemblages of species and relative abundance rather than the mere occurrence of a "zonal" form, large collections are necessary for accurate zoning, especially when there is a tendency for species to be restricted locally to bands.

(3) The appearance of great width of the lower to middle Darriwilian in the parish of Wellsford may be partly due to lack of evidence to the contrary. Indefinite evidence of the presence of *Diplograptus austrodentatus* near the centre of the parish was obtained, but was insufficient to warrant alterations in the mapping. Here again, and in fact over the whole of this unsatisfactory parish, detailed work is much to be desired.

(4) The problem of the relationship of Lancefieldian to Bendigonian and Castlemainian in the north-east of the area has already been mentioned. A possible partial solution would be the placing of a fault running north and south almost along the western boundary of Eppalock and Axedale. This might help to account for the narrow strip of D3-D5 in Sedgwick, but as no positive evidence at all has yet been produced it does not seem wise to do more than suggest the possibility.



[Page 335.]

FIG. 3.

XIV. Index to Graptolite Localities.

Caldwell's Field No.

A.159. 28 chains west from south-east corner of Allot. 11, Sect. X., Strathfieldsaye (D5).

160. 23 chains west, 7 chains south from north-east corner of Allot. 12, Sect. X., Strathfieldsaye (D4).

164. Where water-race touches Emu Creek-road at south-east corner of Allot. 19, Sect. IV., Strathfieldsaye. (Zone of *Didymograptus nodosus*).

167. 21 chains east of Allot. 30, Sect. III., Strathfieldsaye (on road). (Zone of *Didymograptus nodosus*).

169. Across north-east corner of Allot. 26, Sect. III., Strathfieldsaye. (Outcrops on both roads) (D2—high).

170. Near north-east corner of Allot. 4, Sect. V., Strathfieldsaye (on east and west road—very limited outcrop). (Zone of *Diplograptus intersitus*).

173. On race at north-east corner of Allot. 1A, Sect. V., Strathfieldsaye. (Zone of *Diplograptus intersitus*).

176. On Sedgwick-road about half-way between water-race and the south-west corner of Allot. 4, Sect. V., Strathfieldsaye. (Zone of *Didymograptus nodosus*—low).

179. At south-west corner of Parish of Strathfieldsaye (B2).

180, 181. Near loc. 179.

196. 1 chain east from north corner of Allot. 3, Sect. XIX., Strathfieldsaye (an extensive surfaced area). (Zone of *Diplograptus intersitus*).

197. 10 chains east from Loc. 196. (Zone of *Didymograptus nodosus* —low).

198. On south side of road north of Allot. 8, Sect. VI., Strathfieldsaye, and just east of Axe Creek (D2).

201. 13 chains north, 8 chains west from south-east corner of Allot. 2A, Sect. V., Strathfieldsaye (in bed of watercourse). (Zone of *Diplograptus intersitus*).

202. In water-course in north-east corner of Allot. 27, Sect. III., Strathfieldsaye. (Zone of *Diplograptus intersitus*).

203. On small water-race in centre of same allotment as loc. 202. (Zone of *Diplograptus intersitus*).

205. On road south of Allot. 3A, Sect. VIII., Strathfieldsaye (D4-D5).

209. McIvor-road at south-east corner of Parish of Sandhurst. (Zone of *Didymograptus nodosus*—low).

210-211. In storm-water channel on south side of McIvor-road, between loc. 209 and railway crossing at 97 miles 36 chains. (Zone of *Diplograptus intersitus*).

226. On Axe Creek in Allot. 3, Sect. XVI., Strathfieldsaye (C2).

229. On Axe Creek in south-west of same allotment as loc .226 (C1).

230. At north-west corner of Allot. 9, Sect. XIX., Strathfieldsaye (on road) (L3).

244. In north of Allot. 41, Township of Strathfieldsaye (on water-race—badly cleaved material) (D2).

283, 284, 285. In road cutting west of Axe Creek, south-east of Sect. V., Sedgwick. (Zone of *Diplograptus intersitus*).

298-299. In watercourse 9 and 19 chains north respectively from the north-west corner of Allot. 1, Sect. IX., Sedgwick. (Zone of *Diplograptus intersitus*).

300. At north-east corner of dam in north-west corner of Allot. 1A, Sect. V., Sedgwick (just off Sedgwick-road). (Zone of *Didymograptus nodosus*).

303. On right bank of Axe Creek in south-west of Allot. 7, Sect. X., Sedgwick. (Zone of *Didymograptus nodosus*—probably).

309. 7 chains west from south-east corner of Allot. 8, Sect. X., Sedgwick. (Zone of *Diplograptus intersitus*—low, or D2 high).

310. 9 chains south, 13 chains west from north-east corner of Allot. 2, Sect. XI., Sedgwick (in tributary water-course) (D2).

313. 3 chains south, 3 chains west from north-east corner of Allot. 6, Sect. X., Sedgwick (on road). (Zone of *Diplograptus intersitus*—low).

314. In small watercourse in north of Allot. 2A, Sect. VIII., Sedgwick (D2).

316. 1 chain north from south-east corner of Sect. XI., Sedgwick (just south of dam) (D5).

325. 1 chain north, 3½ chains east from north-east corner of Allot. 1, Sect. XVII., Sedgwick. (Zone of *Diplograptus intersitus*).

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[Proc. Roy. Soc. Victoria **47** (N.S.), Pt. II., 1935.]

Art. XVIII.—*Victorian Lower Pliocene Bryozoa. Part I.*

By LEO W. STACH.

(With Plate XII.)

[Read 11th October, 1934; issued separately, 8th May, 1935.]

Introduction.

The Victorian Lower Pliocene Bryozoa, probably because of their comparative rarity and the overwhelming variety and extraordinary preservation of Victorian Lower Tertiary forms, have received but passing mention from previous workers. The Bryozoa form, however, a definite constituent of Lower Pliocene faunas and their stratigraphical application in borings has scarcely been utilized because of the lack of systematic treatment of the Lower Pliocene species. The present contribution lists the forms in an extensive series of sievings collected from the classic Macdonald's locality on Muddy Creek, Hamilton, during January, 1934.

The author (1933) stated that the Catenicellidae had not been found in the Lower Pliocene, his material being then confined to an extensive series of washings from Beaumaris, the upper section of No. 7 bore, Parish of Glencoe, and a small amount of material from Macdonald's. Further search has revealed their occurrence at the present locality, and it is hoped that further work on the Lower Pliocene Catenicellidae will materially assist the elucidation of the phylogeny of this interesting southern Australian group.

Previous Literature.

The earliest record of Victorian Lower Pliocene Bryozoa known to the author is that of Maplestone (1902) who records the occurrence of "*Schizoporella*" *flabeliata* Mapl., 1902, from Jemmy's Point (Lakes Entrance) and the Reeves River. Livingstone (1924) has shown this form to be an early zoarial growth stage of the Recent *Parmularia obliqua* (Macgillivray). The former author (1904, i.) later records several species of *Selenaria* from Jemmy's Point and *S. petaloides* from Beaumaris. It is doubtful whether the species recorded from Beaumaris by Maplestone in the latter paper and in his tabulated list (1904, ii.) were obtained from the series above or below the remanié nodule bed (Lower Pliocene and Lower Miocene respectively) at this locality.

Chapman (1916) has recorded Bryozoa from mixed Miocene-Pliocene faunas in the Mallee bores, and later (1928) a fairly extensive series consisting mainly of Cellariidae and "*Lunulites*" from the Lower Pliocene (Kalimnan) of the Sorrento bore.

List of Species.

Otionella grandipora, sp nov. P.
Arachnopusia acanthoceros (MacG.). P–R.
A. terminata (Waters). M–P.
Caleschara denticulata (MacG.). M–R.
?*Selenaria punctata* T.–Woods.
S. maculata (Busk). M–R.
Steganoporella magnilabris (Busk). M–R.
Cellaria australis MacG. M–R.
Cellaria setigera Pergens. P–R.
Caberea grandis Hincks. M–R.
Schizoporella conservata Waters. M–R.
Parmularia obliqua (MacG.). P–R.
Tubucellaria hirsuta (Lamx.). P–R.
T. cercoides gracilis Canu and Bassler. P–R.
Retepora porcellana MacG. M–R.
Adeonellopsis australis MacG. P–R.
Vittaticella elegans (Busk). M–R.
V. gracilenta (MacG.). P–R.
V. hannafordi (MacG.). M–R.
Cornuticella perforata (Busk). P–R.
Pterocella alata (Wyv.-Th.). M–R.
Claviporella aurita (Busk.) P–R.

M = Lower Miocene, P = Lower Pliocene, R = Recent.

Aspect of the Faunal Assemblage.

The abundance of *Lunulites*-form zoaria in this deposit is the most striking feature of the bryozoan fauna. Dartevelle (1933) notes that "*Lunulites*" are common on sandy bottoms subject to the influence of tides and currents, thus indicating moderately shallow-water conditions. The occurrence of abundant Catenicellidae also points to a similar bathymetric facies, the group, from available records, apparently flourishing at depths of five to forty fathoms and forming, together with *Cellaria setigera*, a conspicuous constituent of storm débris around the Victorian coast.

The fauna has an essentially Recent character, and the gap in the marine history of the Muddy Creek area from Lower Miocene to Lower Pliocene represented by the remanié nodule bed, accounts for the extinction of a large proportion of the Lower Miocene fauna of the underlying series represented at Clifton Bank. Many of the forms are recorded as fossil for the first time.

Systematics and Distribution.

Otionella grandipora, sp. nov.

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

Description.—Zoarium discoidal, slightly convex. The zooecia are roughly polygonal with the distal raised margins rounded. The opesium is oval and slightly broader at the proximal end, the free edge of the finely papillose cryptocyst being minutely denticulate. The asymmetrical interzooecial vibracula occur in the angle between the distal rims of neighbouring zooecia.

The radial ribs of the slightly concave inner face are minutely papillose and slightly convex, perforated by a longitudinal row of scattered pores and separated by narrow raised ridges.

Dimensions.—Zoarium, diameter 3-6 mm.; zooecium, length 0.43 mm., width 0.37; opesium, length 0.27, width 0.18; vibraculum, length 0.20, width 0.08.

Observations.—This species appears to belong to the genus *Otionella* Canu and Bassler (1920), but lacks the raised "collar" bordering the opesium, which feature seems to be a characteristic of the genus. The species is distinguished from the North American Tertiary forms by its larger dimensions and the greater proportionate area of the opesium.

Distribution.—Lower Pliocene: Macdonald's.

ARACHNOPUSIA ACANTHOCEROS (Macgillivray, 1887).

Cribrilina acanthoceros Macgillivray, 1887, p. 68, pl. ii., fig. 4.

Arachnopusia acanthoceros (Macgillivray), Livingstone, 1924, p. 204.

Distribution.—Recent: Port Phillip Heads, Portland (Macgillivray).

Lower Pliocene: Macdonald's.

ARACHNOPUSIA TERMINATA (Waters, 1881).

Cribrilina terminata Waters, 1881, p. 326, pl. xvii., fig. 68.

Arachnopusia terminata (Waters), Canu and Bassler, 1920, p. 313.

Observations.—A single specimen of this species agreeing in minute detail with the zooecia figured by Waters (1881) was found encrusting a shell fragment. This is one of the few extinct species common to both the upper and lower Tertiary of Victoria.

Dimensions.—Zooecium, length 0.80 mm., width 0.58; aperture, width 0.23, height 0.15.

Distribution.—Lower Pliocene: MacDonald's.

Lower Miocene: *vide* Maplestone (1904, ii.) and add: Sorrento bore, 1,320 feet.

CALESCHARA DENTICULATA (Macgillivray, 1869).

Eschara denticulata Macgillivray, 1869, p. 138.

Caleschara denticulata (Macgillivray), 1895, p. 51, pl. vi., figs. 8, 9. Livingstone, 1928, p. 112, text-fig. 31.

Observations.—This form is abundant at Macdonald's, occurring as bilaminate foliaceous fragments. The Lower Miocene specimens are generally of the type described as var. *tenuis* by Busk (1884), but whether it should be separated as a distinct species is doubtful. The lower Tertiary series has a deeper-water facies than that represented by the Lower Pliocene, and it is possible that the narrow bilaminate fronds with their more elongate zooecia constitute a growth variation correlated with the more equable conditions prevailing in deeper water than in the littoral zone within the limits of wave action, where zoarial growth would tend to dominate in the horizontal plane rather than in the vertical plane. Significant in this direction is the fact that var. *tenuis* was recorded from 38 fathoms, while Macgillivray's foliaceous specimens were obtained from storm débris and tidal scour.

Distribution.—Recent: Queenscliff, Mornington, Warrnambool (Macgillivray); off East Moncoeur Is. (Bass Str.) at 38 faths., Curtis Is. (Bass Str.) (Busk); South Australia 14-40 faths. (details, Livingstone, 1928).

Lower Pliocene: Macdonald's.

Lower Miocene: *vide* Maplestone (1904, ii.) and add: Batesford Tunnel marl, Curlewis marl, Forsyth's (below remanié nodule bed) on Grange Burn (Hamilton).

?SELENARIA PUNCTATA Tenison-Woods, 1880.

Selenaria punctata Tenison-Woods, 1880, p. 9, pl. ii., figs. 8 a-c.

Dimensions.—Zooecium, length 0.32 mm., width 0.25; opesium, diameter 0.08.

Observations.—A very much abraded zoarium was found with a single zooecium intact. The zooecium has the two opesiules characteristic of the above species, but its zooecial dimensions are greater than those given by Maplestone (1904, i.) and less than those of *S. magnipunctata* Maplestone, 1904, which is a lower Tertiary form. It is doubtfully referred here to the Recent species, but its relationship cannot be fully ascertained without further specimens.

SELENARIA MACULATA (Busk, 1852).

Lunulites maculata Busk, 1852, i., pl. i., figs. 15, 16.

Selenaria maculata (Busk), Macgillivray, 1895, p. 47, pl. vii., figs. 5-7.

Distribution. — Recent: Bass Strait (Busk); Holborn Is. (Queensland); Barnard Is. (N.E. Aust.) at 10 faths.

Lower Pliocene: Macdonald's, Sorrento bore, 660 ft.-730 ft.

Lower Miocene: *vide* Maplestone (1904, ii.) and add: Batesford Tunnel marl, Curlewis marl, quarry on Thompson's Ck. $\frac{1}{4}$ ml. E. of Torquay Road, Sorrento bore, to 1,525 ft.

STEGANOPORELLA MAGNILABRIS (Busk, 1854).

Membranipora magnilabris Busk, 1854, p. 62, pl. lxv., fig. 4.

Steganoporella magnilabris (Busk), Canu and Bassler, 1929, p. 144, pl. xv., figs. 1, 2.

Observations.—This well-known, widely-distributed species is represented throughout the greater part of the Victorian Tertiary sequence. Regarding its bathymetric occurrence, Canu and Bassler (1929) have stated that "Its presence in the fossils does not have a great bathymetric significance." A single abraded specimen with zooecia identical with Victorian Recent specimens was obtained. Contrary to the general habit of this species, the specimen is unilamellar and apparently had been encrusting an irregular substratum.

Distribution.—Recent: Atlantic Ocean 8-182 faths. (details, Canu and Bassler, 1928); Indo-Pacific Region 2-230 faths. (details, Canu and Bassler, 1928, 1929). Southern Australia: Bass Str., Lakes Entrance; Beachport 40 faths., 7 mls. S.W. Newland Head (Encounter Bay) 20 faths., 3 mls. S. Tunk Hds. 16 faths., Port Wallaroo 15 faths. (Livingstone).

Pliocene: Caloosahatchee marl (Florida).

Lower Pliocene: Macdonald's.

Miocene: Choctawhatchee marl (Florida).

Lower Miocene: *vide* Maplestone (1904, ii.) and add: Largon Ck. off Toorloo Arm (8 mls. E. of Lakes Entrance); Sorrento bore, 1,693 ft. (Chapman).

CELLARIA AUSTRALIS Macgillivray, 1880.

Cellaria fistulosa var. *australis* Macgillivray, 1880, dec. v., p. 48, pl. 49, fig. 1.

Cellaria australis Macgillivray, 1895, p. 29, pl. iii., fig. 19.

Distribution.—Recent: Bass Str. cable, Queenscliff, Portland (Vic.); off Port Morowie 14 faths. (South Aust.).

Lower Pliocene: Macdonald's, Glencoe No. 7 bore 160 ft.-200 ft., Sorrento bore 324 ft.-719 ft.

Lower Miocene: *vide* Maplestone (1904, ii.) and add: Sorrento bore, to 1,608 ft.

CELLARIA SETIGERA Pergens, 1887.

Salicornaria hirsuta Macgillivray, 1869, p. 128.

Cellaria hirsuta Macgillivray, 1880 (*non* Lamouroux, 1816 = *Tubucellaria hirsuta*), dec. v., p. 48, pl. 49, fig. 2.

Cellaria setigera Desmarest and Lesueur MS., 1829, pl. viii., fig. 6. Pergens, 1887, p. 89.

Observations.—This species is readily recognized in the fossil state by the perforations at the bases of the zooecia, indicating the points of attachment of the numerous chitinous, filiform appendages which suggested both the trivial names attached to this form.

Distribution.—Recent: Western Port, Torquay, Queenscliff, Portland, Bass Str. cable (Vic.).

Lower Pliocene: Macdonald's.

CABEREA GRANDIS Hincks, 1881.

(Pl. XII., Fig. 3.)

Caberea grandis Hincks, 1881, p. 50, pl. iii., fig. 4.

Observations.—Several very much abraded fragments referable to this species were found. The characters of the zooecia are made out with great difficulty, but the dorsal view of the vibracular grooves is quite distinctive. This species was recorded from the lower Tertiary of Victoria by Macgillivray (1895), who remarks that none of his specimens showed the large vicarious avicularia usually seen in the Recent forms. Maplestone, however, has written a note in his copy of the "Monograph" stating that he had seen specimens with that feature.

Distribution.—Recent: Bass Strait cable, Western Port, Lakes Entrance, Port Phillip Heads (Vic.); 22 mls. E. of Port Jackson at 80 faths., Darnley Is. (Torres Str.) at 10-30 faths.

Lower Pliocene: Sorrento bore 726 ft., Macdonald's.

Lower Miocene: *vide* Maplestone (1904, ii).

SCHIZOPORELLA CONSERVATA Waters, 1881.

(Pl. XII., Fig. 4.)

Schizoporella conservata Waters, 1881, p. 340, pl. xviii., fig. 81. Hincks, 1882, p. 165, pl. vii., fig. 2. Maplestone, 1904, ii., p. 207.

Schizoporella insignis Macgillivray (*non* Hincks, 1881), 1883, p. 132, pl. ii., fig. 11. Hincks, 1884, p. 281.

Schizoporella daedala Macgillivray, 1887, dec. xiv., p. 146, pl. 138, fig. 4; *idem*, 1895, p. 84, pl. xi., fig. 15. Maplestone, 1904, ii., p. 207.

Observations.—Hincks (1884) pointed out that *S. insignis* MacG. (1883) could be referred to *S. conservata* Waters, 1881. Macgillivray (1887) denied this (misquoting Waters' species as "*controversa*") and changed the trivial name to *daedala,* since his original name was preoccupied by Hincks (1881). Later (1895) Macgillivray admitted the conspecificity of the two forms and described the species under the name "*daedala,*" ignoring the priority of Waters' name "*conservata.*" Maplestone perhaps regarded them as separate species, but may have accidently listed them separately during the laborious mechanical assemblage of his catalogue (1904, ii.).

Distribution.—Recent: Off Port Phillip Heads (Macgillivray).

Lower Pliocene: Macdonald's.

Lower Miocene: *vide* Maplestone (1904, ii.).

PARMULARIA OBLIQUA (Macgillivray, 1869).

(Pl. XII., Fig. 5.)

Eschara obliqua Macgillivray, 1869, p. 137.

Schizoporella flabellata Maplestone, 1902, p. 68, pl. vii., figs. 10, 10A.

Parmularia obliqua (Macgillivray). Livingstone, 1924, p. 190, pl. xxiii., figs. 1, 2, pl. xxv., fig. 1, pl. xxvi., text-fig. 1.

Distribution.—Recent: Eastern and southern Australia at 5-100 fathoms (details, Livingstone, 1924, 1928).

Lower Pliocene: Jemmy's Point, Reeves River (Victoria) (Maplestone); Macdonald's.

TUBUCELLARIA HIRSUTA (Lamouroux, 1816).

(Pl. XII., Fig. 6.)

Cellaria hirsuta Lamouroux, 1816 (*non Cellaria hirsuta* (MacG., 1869)=*C. setigera* Pergens, 1887), p. 126, pl. ii., fig. 4.

Tubucellaria hirsuta (Lamouroux), Livingstone, 1928, p. 117.

Observations.—This species is readily distinguished in the fossil state by its similar zooecial arrangement to that of the genus *Tetraplaria* Tenison-Woods, and by the presence of the pits on either side of the peristome marking the insertion of the jointed, filiform, chitinous processes characteristic of this species. The fossil specimens are generally much worn, the peristome being usually completely abraded away. It is essentially a shallow-water form and is common around the Victorian coast amongst storm débris.

Distribution.—Recent: Queenscliff, Western Port, Cape Otway, Portland (Vic.) (Macgillivray); off Two Sisters' Is., Bass Str. cable (J. Gabriel coll.). South Australia: 12 mls. S.E. by S. from Newland Head (Encounter Bay) at 24 faths. (Livingstone).

Lower Pliocene: Macdonald's.

TUBUCELLARIA CEREOIDES GRACILIS Canu and Bassler, 1929.

(Pl. XII., Fig. 7.)

Tubucellaria cereoides (*non* Ellis and Solander), Macgillivray, 1885, p. 107, pl. i., fig. 4.

Tubucellaria cereoides gracilis Canu and Bassler, 1929, p. 355, pl. xliv., figs. 1, 2.

Observations.—The Lower Pliocene specimens agree with the Philippine specimens of Canu and Bassler (1929) in the more proximal position of the ascopore and the dimensions of the zooecia. Macgillivray's specimens from Port Phillip Heads also show these features, the typical *T. cereoides* (Ell. and Sol.) from Naples having the ascopore situated close to the peristome.

Distribution.—Recent: Port Phillip Heads (Macgillivray); various localities in the Philippine Is. at depths of 20-240 faths. (Canu and Bassler).

Lower Pliocene: Macdonald's.

RETEPORA PORCELLANA Macgillivray, 1869.

Retepora porcellana Macgillivray, 1869, p. 140; *idem,* 1895, p. 115, pl. xv., fig. 15.

Distribution.—Recent: Port Phillip Heads.

Lower Pliocene: Macdonald's.

Lower Miocene: *vide* Maplestone (1904, ii.) and add: Quarry on Thompson's Creek $\frac{1}{4}$ ml. E. of Torquay Road.

ADEONELLOPSIS AUSTRALIS Macgillivray, 1886.

Adeonellopsis australis Macgillivray, 1886, p. 134, pl. ii., figs. 2, 3.

Observations.—This species occurs abundantly in the deposit as abraded bilaminate fragments. The upwardly-directed avicularium and the three or four stellate ascopores are typical of the species.

Distribution.—Recent: Port Phillip Heads (Macgillivray).

Lower Pliocene: Macdonald's.

VITTATICELLA ELEGANS (Busk, 1852).

Catenicella elegans Busk, 1852, i., p. 361, pl. i., fig. 2.

Vittaticella elegans (Busk), Stach, 1934, ii., p. 19, pl. iii., figs. 1-4.

Distribution.—Recent: *vide* Stach (1934, ii.).

Lower Pliocene: Macdonald's.

Lower Miocene: Forsyth's (below remanié nodule bed) on Grange Burn (Hamilton).

VITTATICELLA GRACILENTA (Macgillivray, 1885).

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

Catenicella gracilenta Macgillivray, 1885, p. 106, pl. i., fig. 3.

Vittaticella gracilenta (Macgillivray), Maplestone, 1901, p. 202.

Description. — Zooecium elongate, subrectangular, tapering slightly at base; greatest width, at level of scapular compartments, equals one-third length of zooecium.

Proximal rim, equalling more than one-half width of zooecium, situated one-fifth of distance proximally from distal connecting-tube aperture. Aperture subcircular, transverse, extends two-thirds distance from proximal rim to distal connecting-tube aperture.

Scapular compartments, at level of distal half of aperture, face obliquely laterally; infrascapular compartments situated at level of proximal half of aperture; suprascapular compartments face obliquely forward and upward. The narrow vittae equalling four-fifths length of zooecium, face entirely laterally and have a single row of about twelve septulae.

Dorsal surface regularly convex. Axis of daughter zooecium inclined at about 35° to that of mother zooecium. Macgillivray (1885) notes that the ovicell has a central, smooth, longitudinally-elongate quadrate area.

Dimensions.—Zooecium from Macdonald's: Zooecium, length 0.75 mm., width 0.32; aperture, diameter 0.13; vittae, length 0.45. Recent zooecium from off Shoalhaven: Zooecium, length 0.87, width 0.30; aperture, diameter 0.14; vittae, length 0.51.

Observations.—The single fossil zooecium found has a portion of the proximal end broken off, thus accounting for the difference in the dimensions of the two zooecia recorded above.

No additional record of this species is known since 1885. It is readily distinguished by its extreme slenderness and long lateral vittae. The zoarium, seen macroscopically, has an etiolated appearance quite distinct from zoaria of the majority of the Catenicellidae. It may here be noted that the angle between the axes of the zooecia of a geminate pair is a fairly constant character of most species of the Catenicellidae and rarely varies more than 10°. It often gives a characteristic macroscopic feature enabling zoaria to be fairly accurately sorted specifically from bulk samples.

Distribution.—Recent: Port Phillip Heads (Macgillivray); Western Port (Vic.), off Eden and off Shoalhaven (N.S.W.) (J. Gabriel coll.).

Lower Pliocene: Macdonald's.

VITTATICELLA HANNAFORDI (Macgillivray, 1869).

Catenicella hannafordi Macgillivray, 1869, p. 127.

Vittaticella hannafordi (Macgillivray), Stach, 1933, p. 97.

Distribution.—*Vide* Stach (1933) and add, Lower Pliocene: Macdonald's.

CORNUTICELLA PERFORATA (Busk, 1852).

Catenicella perforata Busk, 1852, ii., p. 10, pl. viii., figs. 1, 2.

Vittaticella perforata (Busk), Maplestone, 1901, p. 202.

Catenaria perforata (Busk), Levinsen, 1909, p. 219.

Description.—Zooecium elongate-oval in outline; greatest width, at level of scapular compartments, equals about one-half length of zooecium.

Proximal rim, one-third width of zooecium in length, situated one-third distance proximally from distal connecting-tube aperture. The aperture is longitudinally oval, extending two-thirds of distance from proximal rim to distal connecting-tube aperture.

Scapular compartments, extending from level of proximal rim almost to summit of zooecium, face directly laterally and have one or more rounded uncalcified areas at their bases; infrascapular compartments reduced in extent; suprascapular compartments face upward. The narrow vittae, with a single row of seven to ten septulae, face directly laterally and equal two-thirds length of zooecium. The frontal has sparsely-scattered fine perforations.

Dorsal surface regularly convex, depressed behind scapular compartments. Axis of daughter zooecium inclined at about 45° to that of mother zooecium.

The smooth terminal ovicell, pertaining to the mother zooecium of a geminate pair, is pyriform and has a median longitudinal raised ridge.

Dimensions.—Recent zooecium from Torquay (Vic.): Zooecium, length 0.42 mm., width 0.26; aperture, diameter 0.09; vittae, length 0.23. Zooecium from Macdonald's: Zooecium, length 0.40, width 0.22; aperture, diameter 0.09; vittae, length 0.21.

Observations.—The position of the ovicell, noted by many authors, places this species in the genus *Cornuticella* Canu and Bassler, 1927, which appears to be further characterized by the laterally-directed vittae.

This species is readily recognized, in the absence of the ovicell, by the uncalcified areas at the bases of the scapular compartments and the narrow, laterally-directed vittae with a single row of seven to ten septulae.

C. perforata is abundant on the Victorian coast and this constitutes its initial record as a fossil.

Distribution.—Recent: Port Phillip Heads, Western Port, Torquay, Apollo Bay (Vic.); off Launceston and Devonport, Circular Head (Tas.), off Montagu Is. 50 faths. (N.S.W.) (Aust. Mus. coll.); St. Vincent Gulf (Sth. Aust. Mus. coll.); 10 mls. off Cape van Diemen at 50 faths., Three Kings' Is. at 65 faths. (New Zealand) (Livingstone).

Lower Pliocene: Macdonald's.

PTEROCELLA ALATA (Wyville-Thomson, 1858).

Catenicella alata Wyville-Thomson, 1858, p. 137, pl. xiii., fig. 4.

Pterocella alata (Wyv.-Th.), Levinsen, 1909, p. 246, pl. xii., figs. 6 a-b, pl. xxi., fig. 4A. Stach, 1934, i., p. 17, text-figs. 1 *a-c*.

Distribution. — Recent: Western Port, Torquay, Lakes Entrance, Warrnambool, Queenscliff (Vic.); New Plymouth at 8 faths. (New Zealand); off Launceston and Devonport (Tas.) (Aust. Mus. coll.).

Lower Pliocene: Macdonald's.

Lower Miocene: *vide* Maplestone (1904, ii.) and add: Glencoe No. 7 bore 580 ft., 650 ft., 790 ft., under railway bridge over Glenelg River at Dartmoor, Altona Bay coal shaft, Flinders, Nth. side of Armstrong's Ck. 10 chns. E. of Torquay Road, beach cliff at Ocean Grove, Batesford Tunnel marl, Prowse's marl pit (2 mls. W. of Mt. Moriac), Cochran's marl pit (near Ceres), Hamilton bore 80 ft.-85 ft.

CLAVIPORELLA AURITA (Busk, 1852).

Catenicella aurita Busk, 1852, ii., p. 8, pl. iv., figs. 1-3.

Claviporella aurita (Busk), Levinsen, 1909, p. 243, pl. xx., figs. 10 a-b.

Distribution.—Recent: Apollo Bay, Torquay, Lakes Entrance, Port Phillip Heads, Lorne, Western Port (Vic.); Encounter Bay, Port Elliot (South Aust. Mus. coll.); off Cape Maria van Diemen (New Zealand).

Lower Pliocene: Macdonald's.

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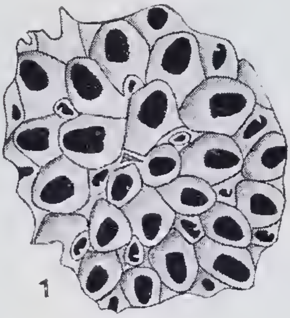
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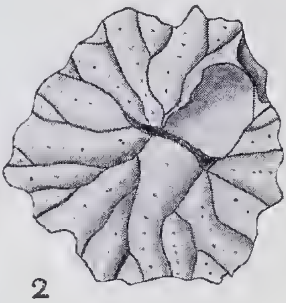
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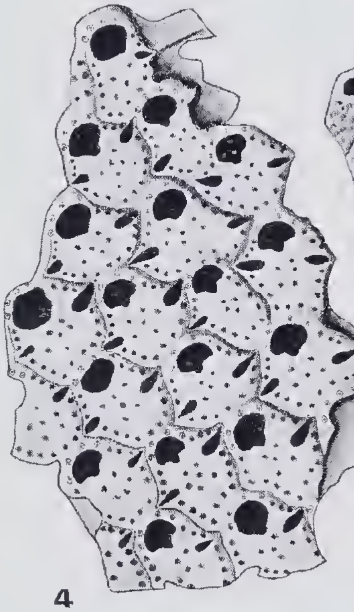
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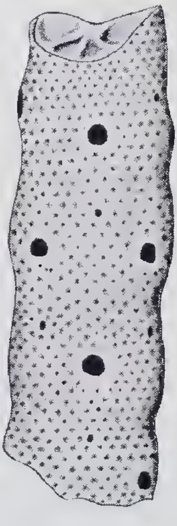
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Explanation of Plate XII.

Fig. 1. *Otionella grandipora*, sp. nov. Frontal view of holotype. × 20. Macdonald's. Nat. Mus. Coll., No. 14002.

Fig. 2. *O. grandipora*, sp. nov. View of inner face of holotype. × 20. Macdonald's. Nat. Mus. Coll., No. 14002.

Fig. 3. *Caberea grandis* Hincks. Dorsal view of plesiotype. × 20. Macdonald's. Nat. Mus. Coll., No. 14003.

Fig. 4. *Schizoporella conservata* Waters. Frontal view of plesiotype. × 20. Macdonald's. Nat. Mus. Coll., No. 14004.

Fig. 5. *Parmularia obliqua* (MacG.). Frontal view of plesiotype. × 20. Macdonald's. Nat. Mus. Coll., No. 14005.

Fig. 6. *Tubucellaria hirsuta* (Lamx.). Fragment of internode showing zooecial detail. × 20. Macdonald's. Nat. Mus. Coll., 14006.

Fig. 7. *Tubucellaria cereoides gracilis* Canu and Bassler. Fragment of internode showing zooecial detail. × 20. Macdonald's. Nat. Mus. Coll., No. 14007.

Fig. 8. *Vittaticella gracilenta* (MacG.). Frontal view of single zooecium. × 40. Macdonald's. Nat. Mus. Coll., No. 14008.

Fig. 9. *V. gracilenta* (MacG.). Frontal view of single recent zooecium. × 40. Off Shoalhaven (N.S.W.).

[Proc. Roy. Soc. Victoria **47** (N.S.), Pt. II., 1935.]

Art. XIX.—*An Account of the Cultural and Cytological Characteristics of a New Species of Mycogala.*

By KATHLEEN M. CROOKS, M.Sc.

[Read 8th November, 1934; issued separately, 8th May, 1935.]

I. Introduction.

During the isolation of several fungi from Jarrah (*Eucalyptus marginata*) timber, particular interest was taken in one form which appeared to be rather unusual. On investigation, this proved to be a species of *Mycogala*. Its characters did not agree with those of any previously described members of this genus, so that it has been given the specific name, *Mycogala marginata*. An account is given here of the main cultural and structural characteristics, including the development of the perithecium, from the observations made.

II. The Fungus in Culture.

The fungus grows readily on most of the media in ordinary use. On the solid media used an important characteristic of this form is the very pronounced colour change brought about in the medium by the fungus. Generally, the growth is mainly submerged with little superficial development. The optimum temperature for growth is about 19°C.

1. *Malt Agar.*

(*a*) *Macroscopic.*—The fungus grows quickly, but aerial growth is scanty, and is usually represented by only a small amount of white, flaky mycelium at the upper end of the malt slope. With the growth of the fungus over the agar, the latter changes in colour to a light yellowish-brown which soon deepens to a reddish-brown, and, in an old culture, the medium appears almost black. Perithecia are abundantly developed on the surface of the medium, and when mature are dark and carbonaceous in appearance, and easily visible to the naked eye.

(*b*) *Microscopic.*—The hyphae of the mycelium are generally uniform in size, and contain abundant oil. Septa are developed, although usually at fairly wide intervals (Fig. 1).

Fig. 1. Hypha of *Mycogala marginata*. × 545. (a) vacuole, (b) nucleus, (c) septum.

After about four days' growth, one type of asexual spore is found to be very abundant in the culture. These are formed on short branches of the aerial hyphae, and the branches appear to be transformed into closely septate, cylindrical, hyaline elements, which tend to break up into shorter elements—one or more septate (Fig. 2). The free cells appear, therefore, to be of the nature of "oidia" rather than of conidia, and will be discussed later.

Another type of asexual spore is soon apparent, namely chlamydospores. These may occur solitary or in chains and are formed in both intercalary and terminal positions in the hyphae (Fig. 3). At first these bodies are hyaline and appear as swollen cells, which are more closely septate than the ordinary cells of the hyphae, and they contain abundant oil globules, as shown by the red colour with Sudan III. As they mature, they increase in size, become dark brown in colour, and a thick wall is developed. They are approximately spherical in shape, and have a range in diameter of 6–18μ.

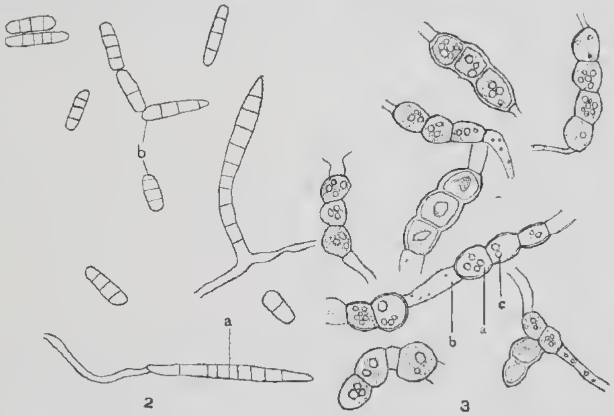


Fig. 2. Spores of oidia type, formed on aerial hyphae × 260. (a) aerial branch showing early stage in spore formation, (b) free spores. Fig. 3, Chlamydospores formed in an intercalary or terminal position in the hyphae, × 260. (a) chlamydospore, (b) hyphae, (c) oil globules.

After about five or six days at 19°C., the mycelium shows the first indications of sexual reproductive structures in the form of perithecium initials, and ripe perithecia are visible in three to four-weeks-old cultures. The fruiting-bodies are developed superficially on the medium, and may be solitary or two or three massed together. They are spherical in shape, with a range in diameter of 50–150μ, and are dark coloured when mature. No ostiole is developed, but the fruiting-body dehisces by an irregular splitting of the wall.

If the perithecia are crushed before they are quite ripe, colorless asci containing eight ascospores are apparent. The asci are sub-spherical and very delicate, and as they appear to rupture when the spores are ripe, one rarely sees asci on crushing the mature perithecium.

The ascospores are spherical, smooth and hyaline, with a diameter of 2–4.5μ. They are often seen massed together, when their shape is slightly modified, and they tend to be hexagonal in outline.

2. *Oatmeal Agar.*

The fungus causes a colour change in the medium similar to that noted on malt agar, and little aerial growth occurs. The microscopic characters of the fungus also agree with those already noted but the perithecia appear to mature somewhat more quickly.

3. *Maize-meal Agar.*

Growth is not as vigorous as on the previous media. At the end of three weeks oidia and chlamydospores were abundant in the culture, but perithecia were few and immature. Later on, these fruiting-bodies were more abundant, but not as plentiful as on malt or oatmeal agar.

4. *Dox's Agar.*

Very little mycelial development is found, and no colour change is brought about by the fungus. Neither asexual nor sexual spores develop in this case.

5. *Prune Juice.*

Growth is very sparse, and although a fine white mycelium develops, it does not form a dense mat as in turnip juice. Oidia and chlamydospores develop to a very limited extent. Perithecia are occasionally found and are easily visible as dark carbonaceous objects in the white mycelium.

6. *Turnip Juice.*

After a few days, a dense mat of hyphae is formed below the surface. Oidia are found but are not as abundant as on previous media. Chlamydospores were noted after some days. Perithecia do not seem to develop consistently in this medium, as in some cases only very few are developed, while in other instances, they are numerous.

III. Comparison with Related Forms.

From a study of the characters of the fungus, particularly from the nature of the perithecium with its asci and ascospores, it seems to be most closely allied to *Mycogala*, a genus of the Eurotiaceae. It differs largely, however, in its characteristics and habitat, from the species previously described. It is interesting to note that no other species of *Mycogala* has yet been recorded on *Eucalyptus*.

The main characters of the known species of *Mycogala* are given in the following table:—

SPECIES.	PERITHECIA. Diameter.	ASCOSPORES.	HABITAT AND LOCALITY.
M. porietinum (Schrad.) Sacc.	——	Globose, rough, 10–12μ diameter	Decaying wood in Britain, Germany, Lapland, Italy
M. minimum (Fr.) Karst.	1 mm. ..	10–12μ diameter	——
M. firmum Karst. 1896	0·3 mm.	3–4μ diameter	Leaves of living Palms, Leningrad, Russia
M. insigne Pat. 1900	3–6 mm.	Rough, 6μ diameter	Dead trunks of *Daniella* (Leguminosae) West Africa
M. guadalupense Pat. 1902	4–6 mm.	Ovoid or subglobose 6–7 x 4–5μ	Associated with *Lycogala Epidendri* on decaying wood
M. macrospora Jaap. 1910	0·5–1 mm.	18–25μ diameter	——
M. musciola Jaap. 1912	——	7–8μ diameter	—— Linglitz, Germany (Jaap.)
M. fimeti 1912 ..	200–300μ	8–10 x 6μ diameter	—— Hamburg (Jaap.) Dessan (Staritz)
Mycogala from *Eucalyptus*	50–150μ ..	2–4·5μ diameter	*Eucalyptus marginata* Melbourne, Australia

This table shows that *Mycogala firmum* is the only species approximating to the fungus in question, and it is with this form that a further comparison becomes necessary.

The size of the ascospores is approximately similar in both cases, but there is a wider variation in the Australian form, and the spores of the latter are hyaline, while those of *Mycogala firmum* are pale yellow. In addition the host and size of perithecia are different in the two forms. These points are considered sufficient to separate it from *Mycogala firmum,* and the name *Mycogala marginata* is proposed for it.

The asexual spores borne on the aerial branches of *Mycogala marginata* may be compared with the so-called "endo-conidia" of *Thielavia basicola* Zopf. According to Brierley (3), the conidia of *Thielavia basicola* Zopf. are endospores not formed by free cell division within an endo-conidial cell, but are "acrogenously abjointed from the conidiophore." The first conidium is liberated by the differentiation of its walls, into an inner wall and a sheath, and by the rupture of the latter at its apex. The later conidia grow out through the sheath of the first, and are set free by the splitting of their basal walls. The formation of the transverse walls is brought about by the ingrowth of a ring of cell-wall substance, which finally closes in the centre.

In *Mycogala marginata,* the method of spore-formation appears to be different. It was not possible in any instance to detect the sheath through which the conidia push their way out to the exterior—a feature which is readily observed in *Thielavia basicola.* The branches, however, seem themselves to break up into shorter elements—one or more septate—so these free cells appear to be of the nature of " oidia " rather than of conidia.

Thielavia basicola Zopf is a well-known parasite chiefly on tobacco, violet, and many Leguminosae. It was invariably placed in the Ascomycetes on the assumption that the chlamydospores, "endo-conidia," and perithecia belonged to the same fungus. McCormick (20) in 1924, obtained the perithecia in culture, and proved conclusively that all three spore stages belonged to the same form—*Thielavia basicola* Zopf.

It is interesting to note that *Mycogala marginata* also has three types of spores—chlamydospores, oidia—superficially resembling the endo-conidia of *Thielavia basicola* Zopf—and ascospores.

IV. Development of the Perithecium.

The ascospores germinate within twenty-four hours when incubated at 19°C. and soon produce abundant mycelium. After three or four days, the first signs of sexual reproductive organs are visible. The perithecium initial is a coiled septate hypha, the degree of coiling varying widely (Fig. 4).

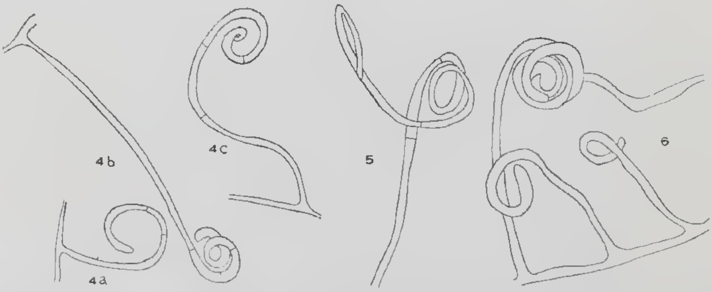


Fig. 4. Young ascogonial coils, representing initial stages in development of perithecia. Fig. 5. Ascogonial coil, showing free tip. Fig. 6. Young ascogonial coils. Note two hyphae intertwining. × 560.

Sometimes the coiling occurs at the apex of the filament (Fig. 4), while in some cases, it is found near the middle or base of the hypha, and the distal end may remain free (Fig. 5). When the distal end of the hypha is free, dichotomous branching frequently occurs (Fig. 8C), a feature also recorded in some members of the Ascobolaceae, where it has been compared to the branching trichogyne of *Lachnea cretea* (12). In *Lachnea cretea,* however, this terminal portion of the archicarp is constantly found protruding from the other coils, and it is so distinct as to be regarded morphologically as a trichogyne, and it is even suggested that the contents of the trichogyne may discharge themselves into the central part of the archicarp, and thus a form of pseudo-pogamy may replace fertilization. In *Mycogala marginata,* this free terminal portion is not such a constant feature. In *Lachnea cretea,* the terminal part consists of about eight or nine cells, but the cross-walls become broken down, so that a free passage occurs from cell to cell.

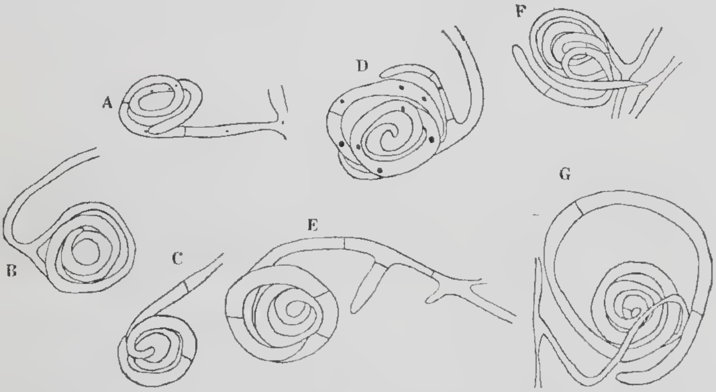


Fig. 7. Later stages in development of coils. B, D, and E show lateral branching at base of ascogonium. G shows long free tip. × 400.

Septa have not been observed in the free portion of the archicarp of *Mycogala marginata.* An antheridium is not developed, but hyphae grow out laterally from the stalk region of the ascogonium, and these often have the appearance of antheridial branches (Figs. 7B, D,E, 8E). Similar branching has been recorded by Gwynne-Vaughan and Williamson (16) in some members of the Ascobolaceae, and is regarded by them as contributing to the formation of the sheath.

Another feature showed by some members of the Ascobolaceae, e.g., *Saccobolus depauperatus* (16), is the fact that two coils are often found together (Fig. 6), suggesting that more than one may be concerned in the formation of an ascocarp.

Gwynne-Vaughan in discussing the Ascobolaceae describes the cells of the archicarp as being multi-nucleate. Fraser (12) describes the archicarp of *Lachnea cretea* as a multi-nucleate structure, and there is no evidence either when the ascogenous hyphae are first formed, or, at a later stage, of an arrangement in regular pairs. In *Mycogala marginata* the segments of the ascogonial coil are at first multi-nucleate, but later uninucleate segments are found (Fig. 8). In many cases, binucleate segments are observed, and these would represent a stage before the uninucleate condition is reached.

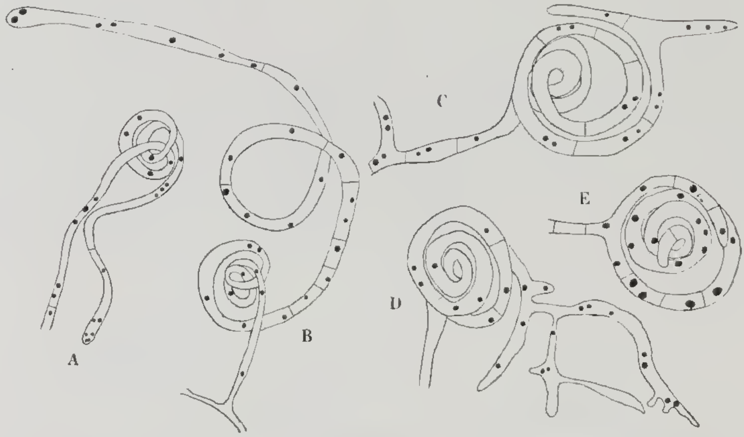
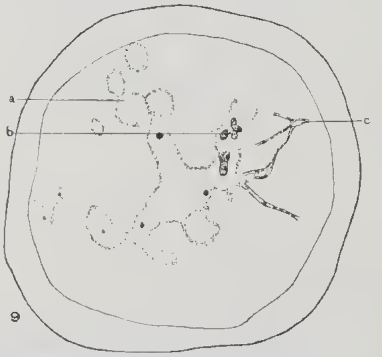


Fig. 8. Ascogonial coils in varying stages of development. In Figs. A and B, note multi-nucleate segment at tip of coil, and nuclei showing a tendency to associate in pairs. In Figs. B and E, note bi-nucleate and uninucleate segments. Figs. C and D show branching at tip of coil, and Fig. E shows a branch at base of coil. Fig. A. × 200; Figs. B, C, D, E. × 480.

As previously mentioned, the formation of the sheath is brought about by lateral branches given off from the stalk, but it is likely that the surrounding hyphae also contribute to its formation, as branches from the mycelium have been observed to pass up into the fruiting-body. The original ascogonium is visible in the young ascocarp, when cut in section, as large usually uninucleate segments only faintly stained and sometimes branched (Figs. 9, 10).



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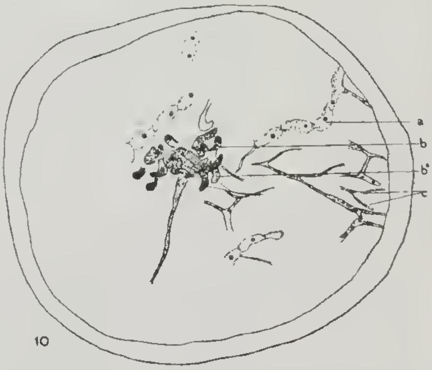

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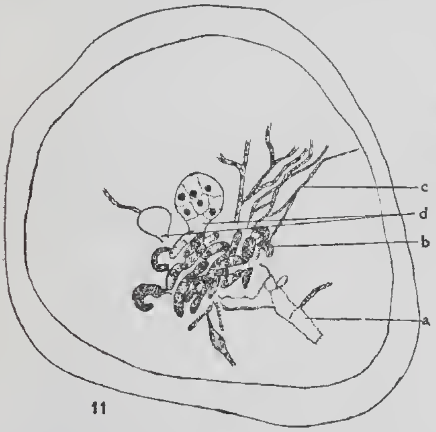
Fig. 9. Section of very young ascocarp. × 420. (a) original ascogonial coil, (b) ascogenous hyphae, deeply stained, (c) "nurse hyphae." Fig. 10. Section of ascocarp, at a slightly later stage. × 420. (a) segments of original ascogonial coil, (b) ascogenous hyphae, deeply stained—note recurved branches at b¹. (c) "nurse hyphae."

From the ascogonium, ascogenous hyphae arise and are visible as a mass of deeply stained hyphae, situated generally at about the centre of the ascocarp. These hyphae are very irregular in form and the branches are rather short. In many cases they are sharply recurved, resembling the crooks of a crosier system (Figs. 10, 11, 13). Asci arise from the ascogenous hyphae and appear to come from the penultimate cell of a crosier (Fig. 13), thus resembling *Thielavia terricola* (11). It was not possible to observe the nuclear detail of the ascogenous hyphae.

In the young ascocarp, one finds also a system of fine hyphae much branched and intertwined; nuclei are visible in these hyphae, but septa cannot be distinguished. They develop from the ascogenous hyphae and often seem to come from the cells of the ascogonial coil itself. They appear to correspond to Brefeld's digestive hyphae, although Dodge has shown that this is not their sole function, and he states that "the fine hyphae probably take no greater part in the digestion of the stromatic tissue than do the other elements occupying the cavity." Dodge found that these asci themselves frequently bear asci directly, and it was noted in one or two cases in *Mycogala marginata*.



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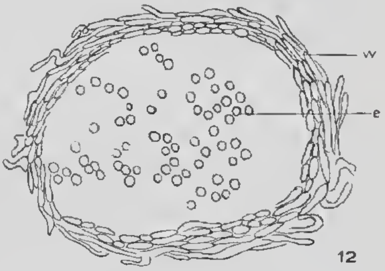

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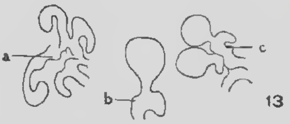

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Fig. 11. Section of young perithecium, showing beginning of ascus formation. × 485. (a) segments of original coil, (b) ascogenous hyphae, (c) "nurse hyphae," (d) asci.

Fig. 12. Section of mature perithecium, showing cavity filled with spores. × 300. w—perithecium wall, e—ascospores.

Fig. 13. (a) Ascogenous hyphae, showing recurved tips, (b), (c) recurved branches of ascogenous hyphae, showing asci arising from penultimate cell of crosier. × 485.

As the ascocarp matures, the contents of the interior disorganize and eventually the centre of the cavity is occupied by the darkly-stained mass of ascogenous hyphae, accompanied by the finer hyphae. In a ripe perithecium, the entire cavity is filled with ascospores (Fig. 12).

It is interesting to note the similarity that exists between *Penicillium Brefeldianum* and *Mycogala marginata* in the nature of the hyphae occupying the central region of the young ascocarp. In the latter, asci arise from a crosier system, but in *Penicillium Brefeldianum* Dodge (7) states that the asci arise as " short-side or terminal swellings from the thick primary ascogenous hyphae, and are formed in the same position as a branch "; and he believes that the formation of a crosier system may not be an impossibility in this case.

A striking resemblance also occurs between the young coils of *Mycogala marginata* and those of some members of the Ascobolaceae, which is rather surprising between such widely separated members of the Ascomycetes. Similarities also occur in the method of formation of the sheath in our species and in the Ascobolaceae.

V. Discussion.

The genus *Mycogala* is grouped in the family Aspergillaceae of the Plectascales on account of the nature of its sexual apparatus. Gäumann Dodge has traced out the development of the perithecium in the Aspergillaceae, and has classified the various members into five groups:—

(1) *Penicillium "crustaceum" Group, and occasionally also in Aspergillus nidulans.*

Two equal copulation branches are formed which coil around one another helically, come into communication, and the contents of one migrate into the other, after which the copulation branches are surrounded by a dense hyphal knot. Thus here, there is no distinction between the antheridium and ascogonium, a feature also found in the lowest family of the Plectascales—Gymnoascaceae.

(2) *Penicillium vermiculatum Group.*

This includes as yet only one species. This group differs from the previous one in the fact that both copulation branches are differentiated morphologically into antheridium and ascogonium, but the antheridium does not appear until a long time after the formation of the ascogonium, after the latter has become uninucleate. Although the antheridium comes into communication with the ascogonium, according to Dangeard's observation, its single nucleus is functionless. The ascogonium divides into numerous binucleate cells, each of which may develop ascogenous hyphae.

(3) *Aspergillus herbariorum-repens Group.*

There is developed a coiled, one or more septate ascogonium. The cells are multi-nucleate, the terminal one usually the longest. Before or after septation of the ascogonium, the antheridium arises and climbs along the ascogonial helix from either a different hypha, or a coil—usually the basal one of the ascogonium. The antheridium appears to be functionless, as it often does not grow to its full length, or may be entirely absent. In all cases, with or without antheridium, the ascogonium develops parthenogenetically, and divides into binucleate cells, some of which grown into ascogenous hyphae.

Thus here we get functional degeneration of the antheridium which forms often when the ascogonium has reached the stage when fertilization would occur.

(4) *Aspergillus flavus, A. fumigatus, and A. Fischeri.*

A coiled ascogonium is developed which divides into binucleate cells and develops ascogenous hyphae in the usual way, without any formation of an antheridium.

(5) *Penicilliopsis clavariaeformis.*

The formation of the fructification is no longer introduced by the formation of an ascogonium. Conidiophoric coremia radiate laterally or terminally without apparent reason, and change into perithecia in a still unknown manner.

Thus in these five groups, according to Gäumann Dodge, there is a gradual degeneration of sexuality, because of the retardation in the formation of the antheridium.

Mycogala marginata falls into the fourth group of this series, since an antheridium is not developed, but the ascogonium produce ascogenous hyphae from which asci are developed. A striking resemblance to *Thielavia* has already been noted both in the sexual apparatus, the development of the perithecium, which is of the same type as in *Thielavia terricola,* and also in the well-developed conidial apparatus.

Although *Mycogala* is a member of the Plectomycetes, it is interesting to note the resemblances found between this genus and some of the higher Discomycetous forms—namely, the Ascobolaceae—indicating that in spite of the different nature of the fructifications, the sexual apparatus is very similar in these widely separated groups.

VI. Latin Description.

Mycogala marginata.—Perithecia solitaria, vel bina, vel terna, in superficie sita, atro-rufa aut nigra quando matura sunt, non ostiolata, scissuris irregularibus dehiscentia; diametro a 50 ad 150μ. Asci subsphaerici, hyalini, tenerrimi, sporas octonas continentes. Ascosporae sphaericae, lenes, hyalinae, diametro a 2 ad 4.5μ, saepe conglomeratae.

Duo typi sporarum sine sexu:—

(*a*) Hyphae praebent chlamydosporas aut solitarias aut catenatas, atrorufas, parietibus crassis, situ aut intercalario aut terminali, forma prope sphaerica, diametro a 6 ad 8μ.

(*b*) Rami aerii producunt elementa spisse saeptata, cylindrica, hyalina, quae in elementa minora separantur, quorum unum aut plura saeptata sunt. Haec naturam oidiorum habere videntur.

VII. Summary.

1. A new species of *Mycogala* was obtained from Jarrah (*Eucalyptus marginata*) timber, and is described as *Mycogala marginata.*

2. The fungus was grown on various culture media, and the cultural characteristics are outlined.

3. There are two types of asexual spores:—

(*a*) Chlamydospores, occurring either singly or in chains, may be formed in either a terminal or intercalary position in the hyphae. They are approximately spherical in shape, $6–18\mu$ diameter, and dark brown in colour with a thick wall when mature.

(*b*) Spores of the nature of "oidia" are formed by the transformation of aerial branches into cylindrical, hyaline elements, which again break up into smaller segments one or more septate.

4. Comparison is made between these oidia and the so-called endo-conidia of *Thielavia basicola* Zopf, and the method of formation of the spores in the two cases is found to be different.

5. The perithecium initial is a coiled septate ascogonium, composed of segments at first multi-nucleate, but later becoming uninucleate. An antheridium is not developed.

6. The wall of the perithecium is formed from lateral branches arising from the basal port of the ascogonium. The surrounding hyphae are also considered to contribute towards the formation of the sheath.

7. The young ascocarp contains three kinds of hyphae:—

(*a*) Large, faintly staining hyphae, composed of uninucleate cells, which represent the ascogonial coil, and disappear as the ascocarp matures.

(*b*) Darkly-stained ascogenous hyphae, which arise from the ascogonium and branch irregularly, the branches being short and often recurved at the tips.

(*c*) Finer hyphae much branched, which correspond to the digestive hyphae of Brefeld, and arise from the ascogenous hyphae and also from the ascogonium itself. Occasionally they have been found to bear asci directly.

8. Asci arise from the ascogenous hyphae, and appear to come from the penultimate cell of a crosier, thus resembling *Thielavia terricola* (11). Ripe asci contain eight spores.

9. A mature fruiting body contains only ascospores, freed by rupture of the walls of the asci.

Acknowledgments.

Thanks are due to Professor Ewart of the Melbourne University Botanical Department for his helpful interest, and to Dr. McLennan for her help and guidance throughout.

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[Proc. Roy. Soc. Victoria **47** (N.S.), Pt. II., 1935.]

Art. XX.—*A Powdery Mildew of Boronia megastigma Nees.*

By KATHLEEN M. CROOKS, M.Sc.

(With Plate XIII.)

[Read 8th November, 1934; issued separately, 8th May, 1935.]

Introduction.

In September and October, 1933, *Boronia* grown at Healesville was found to be diseased. On investigation, it was found that the disease symptoms were caused by a species of *Oidium.*

In the family Rutaceae, to which *Boronia* belongs, there are a few members which are attacked by species of *Oidium,* namely:—

(1) *Ruta Buxbaumi* attacked by *Oidium Haplophylli.*

(2) *Citrus spec.* attacked by *Oidium fasciculatum.*

(3) *Citrus Aurantium* attacked by *Oidium Citri Aurantii* and *Oidium fasciculatum.*

(4) *Citrus limonum* attacked by *Oidium fasciculatum.*

Three other fungi have been recorded on *Boronia* spp., but, up to date, the forms described do not include any species of *Oidium.* It is proposed to give the fungus in question the specific name *Oidium Boroniae,* n.sp.

Symptoms.

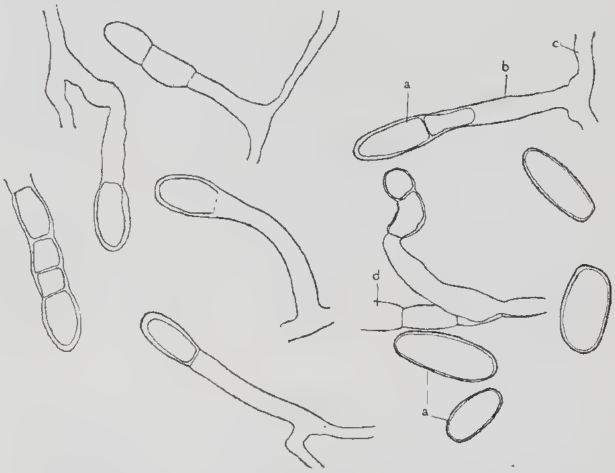
A noticeable feature of the disease was that the symptoms were confined to the petals only, while the stem and leaves appeared to be quite normal. The outer surface of the petals, which in the healthy plant is black, was found to be covered with a white felt of mycelium and was rather wrinkled and dry —cf. smooth surface of petals of healthy flowers—giving to the whole plant a withered appearance.

Description of Oidium Boroniae, n.sp.

The mycelium forms a white, dense network on the surface of the petals, and from the vegetative mycelium, aerial branches arise. At the apices of the fertile branches, oidia are constricted. The oidia are usually ovoid in shape, with an average size of $28\mu \times 13\mu$ and a range of $19\text{-}38\mu \times 11\text{-}18\mu$. The fertile hyphae are unbranched and from $6\frac{1}{2}\text{-}9\mu$ in diameter.

OIDIUM BORONIAE, n.sp.

Mycelium vegetale album, ex hypis ramosis formatum Hyphae fertiles erectae, sine ramis, diametro a 6.5 ad 9μ. Conidia plerumque ovalia, mensura a 19 ad 38 x 11 ad 18μ, mensura media 28 x 13μ.



Oidium Boroniae.—Formation of Oidia.—(a) Oidia × 625. (b) Aerial hypha bearing oidia. (c) Vegetative hyphae × 625. (d) Epidermis of petals.

Discussion.

In the case of the other members of Rutaceae, which are attacked by species of *Oidium,* the leaves or fruit were affected, while in the case under discussion, the attack was confined to the petals.

Comparing *Oidium Boroniae,* n.sp., with these other species, it is noted that *Oidium Haplophylli* has very elongated spores ($60 \times 13\mu$); *Oidium fasciculatum* has ovoid or globose oidia, while in *Oidium Citri Aurantii,* they may be globose (12μ diameter); ovoid ($12\text{-}13\mu \times 9\text{-}9\frac{1}{2}\mu$); or cylindrical ($14\frac{1}{2} \times 7\mu$).

Since these oidia do not correspond with those of the fungus on *Boronia,* in the absence of a perfect stage, this form may be described as a new species—*Oidium Boroniae.*

Boronia megastigma affected with Powdery Mildew.

Note that the fungus affects the petals only.

[Proc. Roy. Soc. Victoria **47** (N.S.), Pt. II., 1935.]

Art. XXI.—*An Account of Sclerote-forming Fungi causing Diseases in Matthiola, Primula, and Delphinium in Victoria.*

By ILMA G. BALFE, M.Sc.

(Government Research Scholar).

[Read 8th November, 1934; issued separately, 8th May, 1935.]

I. RHIZOCTONIA SOLANI ON MATTHIOLA SEEDLINGS.

Introduction.

Duggar (4) and Peltier (9) reviewed the early literature concerning diseases caused by *Rhizoctonia,* and the former made an extensive study of the genus, the outcome of which was the reduction of a large number of species to be included under either *Rhizoctonia solani* Kühn (*Corticium vagum* B. and C.) or *R. crocorum* (Pers.) DC. He also listed the synonyms of the two species. Different types of growth may occur on the same media even when the isolations are made from the same host. Thus macroscopic differences exist in culture, but microscopic differences are so slight as not to warrant the formation of new species.

Since 1915 several other species of parasitic Rhizoctonias have been described. J. Matz (5) reported several from Porto Rico. These are *R. alba, R. dimorpha, R. ferruginea, R. grisea, R. macrosclerotia, R. melongena, R. microsclerotia,* and *R. pallida.* K. S. Thomas (13) came to the conclusion that *R. microsclerotia* was synonymous with *R. solani,* and Briton-Jones (2) considered that the variations in different strains of *Rhizoctonia solani* and also in a single strain on different media were no greater than the differences between the species of *Rhizoctonia* created by Matz (5). As noted by Braun (1), in strains belonging to the species *R. solani* it is especially difficult to distinguish what we have to take as species, because in most cases they are sterile mycelia. Their classification is really more or less based on their vegetative growth, and it is possible that on the discovery of the perfect stage, closely related forms may be given far distant positions in the system. The disputed question as to whether we have to do with different species or only races therefore seems useless as long as the perfect fruiting stage is not obtained.

Recently a trinomial system of nomenclature in which the host name is indicated, e.g., *R. solani* Kühn *Brassicae* II, has been suggested by K. S. Thomas (13).

Records of Rhizoctonia solani in Australia.

In Victoria *R. solani* was first described on potato in 1903, and on turnips in 1911. In 1911 McAlpine (6) reported the fungus as occurring on potato in all the States of Australia. In an unpublished census of Australian fungi compiled by Mr. C. C. Brittlebank, formerly Biologist to the Department of Agriculture, Victoria, there are records of *R. solani* occurring on various hosts in Victoria. Among these are two Cruciferous hosts, Wallflower and Cabbage. In Western Australia W. M. Carne (3) records foot rot of *Lathyrus odoratus* due to *Corticium vagum*, also *Rhizoctonia* scab of potato. In South Australia Samuel and Garrett (12) record the attack of cereals in the Mallee district by *R. solani.*

Rhizoctonia solani from Matthiola incana in Victoria.

Stock seedlings in the seedling beds of the Footscray Gardens showed "damping off" symptoms in 1932 and 1933. The diseased plants appeared in patches which gradually spread out to larger circles. The young stock seeds germinated quite normally at first and showed no pathological symptoms until the first pair of true leaves were produced. At this stage "damping off" occurred, as the pathogen caused a collar rot, and the plants collapsed and died.

In some cases, usually in older and stronger plants, lesions were formed higher up on the stem but below the cotyledons. Microscopic examination showed the presence of numerous thin brown distributive hyphae in the lower stem and upper root regions of the diseased stocks, occurring as a web on the outside of the host tissue. Sections indicated that the fungus grew first in the cortical tissue of the stem near the ground and killed the cells as it proceeded. The cortical tissue was invaded and destroyed by the hyphae, the vascular strand remaining free from the fungus. Hyphae were not found extending into the roots. The weakening of the stem finally caused collapse, and when the soil was kept very moist the fungus formed a mat over the surface of the ground and covered the whole seedling. Lesions were brown in colour and in section were seen to be pocket-like cavities in the cortex, containing a compact mass of hyphae approximating to the density of a sclerote.

Malt agar plates were inoculated with portions of diseased tissue and *R. solani* was repeatedly isolated. *R. solani* has been recorded by Peltier (9) as causing "damping off" of greenhouse seedlings of *Matthiola incana* in Illinois in 1914.

Eight stock seedlings were grown in sterilized soil until the first pair of true leaves appeared. The fungus grown on agar was then introduced into the soil. After a few days "damping off" symptoms were noticeable and re-isolation of the fungus from diseased tissue was possible. Some weeks later fresh seedlings were transplanted to these same pots and showed disease symptoms in a few days.

Many seeds were also planted in soil obtained from the Footscray Garden seedling beds. The young plants were quite healthy until the first true leaves appeared, when many began to show "damping off" symptoms. The stronger plants all showed brown lesions on the lower stem region.

The discovery by Rolfs (11) of the perfect sporing stage shows that *R. solani* is a Basidiomycete, but what position the fungus occupies within this group is still a disputed question. The form found by Rolfs agreed with the fruiting layer of *Corticium vagum* B. and C., but owing to the appearance of the sporing mass and the parasitic life habit, he held it advisable to make it a variety of this fungus—*Corticium vagum* var. *solani*. Rolfs further estimated that it approached *Hypochnus solani* P. and D. and may prove to be identical with it. The *Corticium* stage, though common in nature, seems strictly parasitic, and has never been produced in artificial culture except perhaps by K. O. Müller (8).

The strain isolated from stock seedlings, and three others which will be referred to later, were subjected to the methods used by him to produce the basidial stage, but without success.

Comparison of Four Strains of Rhizoctonia solani K.

A culture of the strain parasitic on cereals in South Australia was obtained, so that it was possible for a comparison to be made between that form and the strain isolated from *Matthiola* in Victoria. Two cultures were also obtained from Baarn, Holland; *Rhizoctonia solani* Kühn from *Solanum tuberosum* sent to Baarn by Porte, and *R. solani* Kühn *Brassicae II* sent by K. S. Thomas.

The four strains were grown in triplicate on malt agar plates at various temperatures. The depth of the agar in the plates was equal, and care was taken to try to obtain similar sizes in the amount of inoculum used in each case. The cultures used were all of the same age and had been grown under the same conditions. For the sake of convenience the four strains will be referred to as follows:—

R1	..	From cereal, South Australia.
R2	..	*R. solani* Kühn, Holland.
R3	..	*R. solani* Kühn *Brassicae II*, Holland.
S11	..	From *Matthiola incana*, Victoria.

The experiments were conducted at 19°C., 22-26°C.*, 26-28°C.*, 30-32°C., and increases in the radii of the colonies were measured daily.

The figures in Table I. represent the area (in sq. cm.) covered by three days' growth. The first day's growth was not used because in all cases the fungus was slow in starting to grow.

TABLE I.—AREA OF GROWTH OF THE FOUR STRAINS IN SQUARE CM.

—	19°C.	23°C.–25°C.	26°C.–28°C.	30·5°C.–31°C.
S11	33·0	30·2	10·4	1·2
R1	11·9	12·6	17·1	2·0
R2	22·4	28·3	34·2	30·2
R3	13·3	8·0	5·0	0·14

The relation of temperature to increase in radius of the culture is represented graphically in Figs. 1–4. The optimum growth of S11 and R3 occurs at about 19°C., and that of R1 and R2 at 26–28°C. The growth of R3 at 30.5°–32°C. practically ceased.

From these results it appears that the isolations of *R. solani* from Cruciferous hosts have a lower optimum temperature than those from cereals and potato. At all temperatures tried the strain from potato had a greater growth rate than that from cereals. This is contrary to the results recorded by Monteith and Dahl (7), who dealt with strains from grasses and potato.

Variations in the Growth Characters of the Forms Studied.

S11.—A thick fluffy aerial mycelium with distinct concentric zonations was formed. At all temperatures tried except 30–32°C. a compact ring of sclerotes developed towards the outside of the plate, and sometimes an inner circle. The agar was discoloured to yellow ochre (Ridgway (10)) below the sclerotes. Scattered sclerotes also occurred mostly towards the centre, and these turned sudan brown and stained the agar beneath them.

R1.—The aerial mycelium was not as dense as in S11 but concentric zonations were very distinct. Scattered sclerotes were

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* These experiments were conducted in an incubating room where the temperature was not absolutely constant. The temperature recorded each morning has been indicated on the graphs.

formed, and after three weeks the agar showed a sudan brown discolouration with graduations to paler shades, giving a zoned effect.

R2.—The aerial mycelium was thick and fluffy but with no distinct concentric zonations. At 26–28°C. and 30–32°C. numerous scattered sclerotes were formed, but not at lower temperatures. The agar later showed a yellow ochre discolouration.

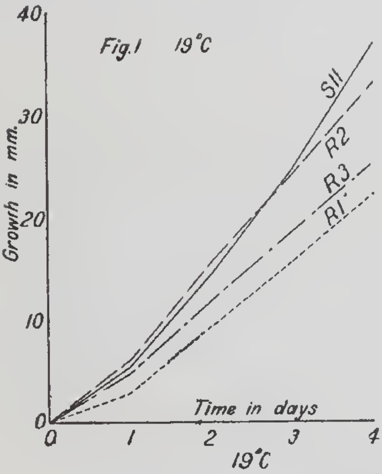
Fig. 1 19°C

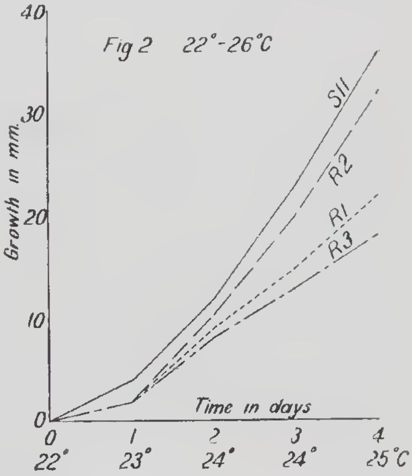
Fig 2 22°-26°C

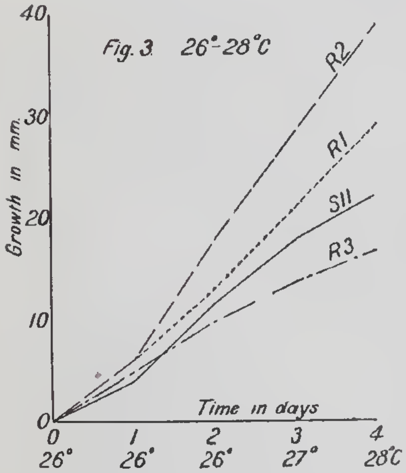
Fig. 3 26°-28°C

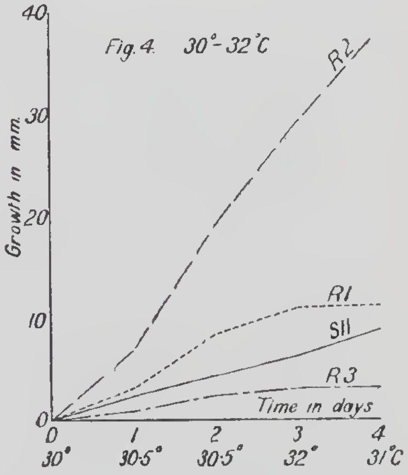
Fig. 4 30°-32°C

R3.—The aerial mycelium differs in being more compact and is mostly short and appressed to the surface of the medium. Concentric zonation is absent and the agar becomes discoloured a uniform sudan brown. Sclerotes were not formed at any temperature tried, and in this respect it differs markedly from the other three strains. This distinct macroscopic appearance is coupled with a difference in the width of the hyphae, which is 2μ less in R3 than in the other strains (Table II.).

TABLE II.

Strain.	Average width of Hyphae on Malt Agar.
S11	9·3μ
R1	9·0
R2	9·2
R3	7·3

Summary.

Although *R. solani* is an extremely widespread parasite, published accounts of its occurrence in Victoria are restricted to records on potato and turnip (McAlpine (6)).

The fungus flourishes with excess of moisture and has proved troublesome by causing "damping off" of *Matthiola* seedlings in the seedling beds at the Footscray Gardens.

Comparisons are made between the strain isolated from stocks with the cereal form from South Australia and *R. solani* Kühn and *R. solani* Kühn *Brassicae II* from Holland. Growth rates at different temperatures are represented graphically.

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II. SCLEROTINIA MINOR ON PRIMULA.

Introduction.

Sclerotinia minor Jagg., a fungus similar to *Sclerotinia libertiana* Fuckel but with smaller sclerotes, was first separated from the latter as a distinct species by Jagger (3) in 1920.

The fungus was isolated by him from lettuce in America, but has since been found on other hosts and in other localities, although not recorded for Australia.

Sclerotina minor from Primula in Victoria.

Primula plants in the Footscray Gardens, Victoria, were attacked in the collar region and soon collapsed and died. Small black sclerotes were found to be present at the bases of diseased plants and the pathogen was isolated and brought into pure culture on malt agar.

The appearance of the fungus in culture conforms with the description of *S. minor* given by Jagger (3). In the early stages of growth, abundant Roman green (Ridgway (6)) appressoria are formed where the mycelium comes into contact with the glass. These are very conspicuous and fan-like in appearance. Under the microscope the outer cells show a palisade arrangement (Fig. 5). Appressoria are only rarely seen on oatmeal agar.

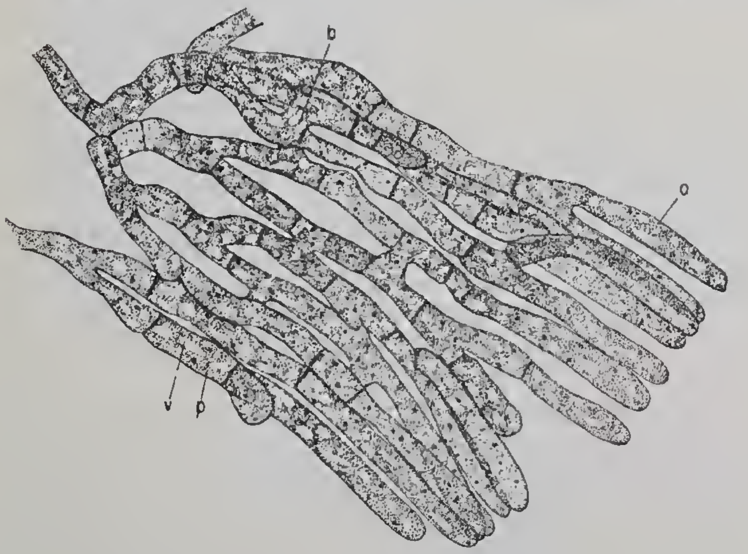

Fig. 5. Roman green appressoria of *S. minor* (× 300). (a) Palisade arrangement of outer cells of the hyphae. (b) Anastomosis between hyphae. (v) Vacuole. (p) Granular protoplasm. From culture on malt agar.

Jagger (3) in his original description of the species mentions the presence of abundant appressoria, but does not mention their conspicuous green colour, whereas Ramsey in his description of *Sclerotinia intermedia,* n.sp., a form intermediate in characters between *S. libertiana* and *S. minor,* describes the fungus as forming Roman green appressoria when coming in contact with foreign bodies.

The size of the sclerotes varies, decreasing with lower temperatures, which is in contrast to *Sclerotinia intermedia* which Ramsey (4) and Chivers (1) describe as showing an increase in size of sclerotes with decreasing temperatures.

The fungus was grown in sterile distilled water and on plain agar to induce the formation of microconidia which were not seen on malt nor oatmeal agars. After ten days a few microconidia were produced and after a month they became more abundant on plain agar. They were similar to those described by Jagger (3) for *S. minor,* being spherical and hyaline, and varying from 3–4.2μ. They were borne apically in series or clumps on short obclavate conidiophores (Fig. 6).

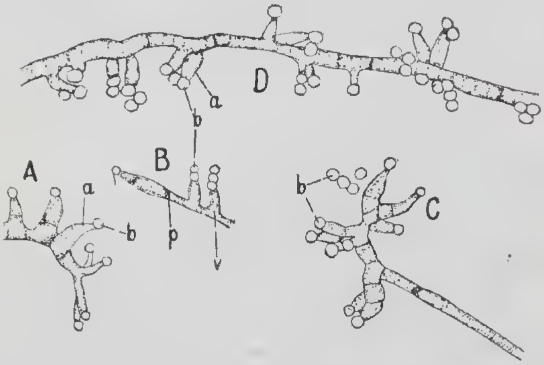

Fig. 6. Microconidia of *Sclerotinia minor* (× 300). A, B, C. Microconidia produced in distilled water. D. Microconidia produced on plain agar after oatmeal agar. (a) conidiophores, (b) conidia, (v) vacuole, (p) protoplasm.

As experiments for the development of apothecia were being conducted, large numbers of sclerotes were needed, and for this purpose the fungus was often grown on oatmeal agar, where sclerotial development was most prolific. It was observed that a culture on an oatmeal plate at 19°C. showed no development of sclerotes even after six weeks, the surface of the medium being covered with appressed white powdery patches, which is the characteristic appearance of the cultures just before sclerotes are developed. The powdery mycelium was examined under the microscope, and seen to bear numerous microconidia varying from 3–4.5μ, with an average diameter slightly higher than was found in water and on plain agar, which is to be expected on a richer medium. The inoculum used in this culture was a month-old sclerote taken from oatmeal agar, the previous transfer having been from malt agar. This appearance of abundant microconidia on oatmeal agar was unusual, as previous to this no microconidia had been observed on the oatmeal and malt plates, where only sclerotes were formed.

Transfers from this plate were made to malt, oatmeal and plain plates and slopes, and kept at 19°C. After five days characteristic green appressoria and numerous white clumps appeared. These powdery patches of appressed mycelium, in contrast to those produced on cultures where the transfers were from a colony bearing sclerotes, were more concentrated around the inoculum itself at first, and later spread out from that centre.

These tufts showed few microconidia after five days, but they increased in number and by the tenth day were very numerous, while no sclerotes developed even after three months.

Again three months later, a culture on an oatmeal slope at room temperature (about 23°C.) was seen to have produced no sclerotes. The inoculum was again a sclerote from a culture which had been on oatmeal agar for a considerable time. In this case the mycelium was short, light buff in colour and much denser in texture. Under the microscope the microconidia were seen to be extremely abundant.

Several malt and oatmeal slopes were inoculated from this tube, and after five days showed cottony aerial mycelium which soon disappeared. Green appressoria were present and powdery tufts around the inoculum. The whole surface of the medium was soon densely covered with powdery appressed mycelium.

A soil agar plate was also inoculated, and after seven days showed a rather sparse cottony aerial mycelium with no powdery white patches but fairly numerous microconidia around the inoculum. After two weeks the aerial mycelium bore numerous microconidia. A colony from a sclerotial culture on soil agar had a similar macroscopic appearance and the mycelia in both cases were the same, but after a week tiny black sclerotes were formed and no microconidia were present.

Ramsey (5) noticed that the formation of microconidia seemed to depend on a poor nutrient supply. He conducted experiments with *S. libertiana* and *S. intermedia* to determine whether there was any tendency to change from the normal. No change in the number of sclerotes nor in microconidial production was, however, observed.

Godfrey (2) working with *Sclerotina ricini* found that sometimes a culture produced numerous conidia (Botrytis stage) but no sclerotes. There was, however, a normal development of sclerotes if transfers from such cultures were put on oatmeal agar.

In the case of *Sclerotinia minor* saltation evidently occurs on rich media, and some inherent differences in the sclerotes cause some to produce mycelium with sclerotes, others with microconidia only. Transfers for several generations on to various media from these microconidial cultures have so far yielded no colonies producing sclerotes. Many workers have experimented with the microconidia of Sclerotinias and various functions have been suggested.

Unsuccessful attempts were made to germinate the microconidia of *S. minor* in sterile water and turnip juice.

Experiments for Apothecial Production.

An attempt was made to produce apothecia from the small sclerotes of *S. minor*. The methods employed were those used by Ramsey (5). Small porous pots were filled with pure sterile sand and placed in halves of petri dishes containing sterile distilled water. Some were placed under bell jars in strong diffuse light, others were covered with circular glass plates.

Sclerotes were also planted in pots containing sterilized garden soil. Various methods were used to try and induce germination. Sclerotes of ages varying between twelve months and two weeks were used, and planted during different months of the year. Some were from cultures on malt, others from oatmeal agar. They were planted at different levels in the sand from the surface to as deep as 1 cm.

Some sclerotes were specially treated before planting. They were subjected to:—

(1) Ether vapour for various periods between a half and two hours.

(2) Cold. Sclerotes in refrigerator for one week before planting.

(3) Water. Sclerotes soaked in sterile distilled water for one week.

(4) Drying. Sclerotes in desiccator from four days to one and a half months. Sclerotes were also allowed to remain on dry sand for two and three months before watering. This latter method was used by Jagger (3) for developing apothecia from sclerotes of *S. minor*.

(5) Heat. Sclerotes kept dry at 30°C. for three months.

RESULTS.

Only two results have so far been obtained from these experiments. One of the month-old sclerotes from malt agar which was subjected to ether vapour for one hour before putting on the surface of sterile sand, germinated, producing a pale yellowish, slightly curved, slender cylindrical body about $\frac{1}{4}$-in. long. When examined with a lens it was seen that the surface was not smooth but slightly roughened and had a frosted appearance.

The pot had been well watered and covered with a ground glass plate. The sclerote was planted in November, and germination occurred three months later in January, after three days of hot weather when the temperature had been over 100°F. During the next four weeks this structure was watched closely to see if a disc-shaped apothecium would develop. The tip, which was at first attenuated, broadened a little and seemed to indicate that an apothecium was forming. There was also a slight elongation in length and a deepening of colour, especially near the base. As light is necessary for the expansion of the apothecium, this was increased by replacing the ground glass with a bell jar, which also provided a greater humidity.

Godfrey (2) in his experiments with germinating sclerotes of *S. ricini* remarked on the necessity for high humidity and a warm temperature for the development of apothecia. Ramsey (5), however, found that more apothecia were produced between January and April, the summer months being unfavorable. Germination occurred between 18° and 22°C. but not between 22° and 30°C.

In February, four months after planting, a sclerote from a similar culture, which had been subjected to the same conditions, but in a different pot and with a plain glass cover, germinated, producing a short greyish cylindrical body with a lighter-coloured translucent tip. Germination again occurred after a spell of very hot weather. The glass plate was replaced with a bell jar and growth in length was noticeable within a few days.

From these results it seems that a high temperature is necessary to induce germination of sclerotes and as in both cases they had been subjected for one hour to ether vapour, the latter may have had some stimulatory effect. Both of the sclerotes which germinated were relatively large and anastomosing with others.

Summary.

(1) *Sclerotinia minor* Jagg. is recorded as causing a collar rot of *Primula malacoides* in Victoria.

(2) Saltation is found to occur on oatmeal agar so that sometimes a sclerote may produce a colony bearing microconidia only, instead of the usual development of abundant sclerotia.

Transfers were made from such cultures (and these were again transferred for several generations) on to various agars but no production of sclerotia followed.

(3) Experiments were carried out for the production of apothecia, and in two cases sclerotes germinated producing horn-like outgrowths. Development proceeded to a swollen tip.

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III. CORTICIUM CENTRIFUGUM ATTACKING DELPHINIUMS.

Introduction.

Sclerotium rolfsii has a wide distribution, occurring in most tropical and sub-tropical countries and causing the greatest damage during the wet seasons. The fungus is capable of attacking a large number of plants, the usual hosts being succulent annuals, although sometimes, under favorable conditions, it may cause disease in woody perennials. Weber (6) listed 189 host plants, including two species of Delphinium. Fajardo (4) reported a stem and root disease of annual Delphiniums due to *S. rolfsii* in the Philippine Islands. Birmingham (1) reported *S. rolfsii* from several hosts in New South Wales including a Delphinium plant from Goulburn.

Delphinium plants at Essendon, Victoria, were attacked by a fungus which caused yellowing and wilting of the leaves and finally drying up and death due to the rotting of root and collar regions. White mycelium with small brown sclerotia encircled these parts.

The pathogen was isolated by placing pieces of diseased tissue, mycelium and sclerotia on malt agar, and pure cultures were obtained.

Description of the Pathogen in Culture.

On malt agar the fungus grows in a fan-like manner and produces a dense fluffy mass of aerial mycelium. After about four days sclerotes begin to form, usually at the margin of the plate, and gradually extend inwards towards the inoculum. They generally arise singly in the aerial mycelium and appear first as irregular white knots of hyphae (Fig. 7c), which soon become compact and rounded, and a definite cortical layer develops (Fig. 8). They are uniform in size and almost quite globose. The colour gradually changes from white, through light buff, warm buff, cinnamon brown, and finally when old and dry, to clove brown (Ridgway (5)). Liquid is often exuded in droplets from the surface of the sclerotes and at first is colourless but later amber-coloured.

As the sclerotes mature the aerial mycelium collapses, and the sclerotes, which were formerly suspended, are left on the surface of the agar. Sclerotes produced by the mycelium on oatmeal, potato dextrose and malt agars show no significant differences in size but are more numerous and massed together on oatmeal. They vary in size from 0.5 to 2 mm. but are usually about 1.2 mm.

If an abundance of agar is not present the size and number of sclerotes are appreciably less. On malt agar the width of the septated hyphae varies from 2 to 12μ (generally 3 or 7μ), the narrower threads being more crooked. Anastomoses between hyphae are numerous, and clamp connexions are present (Fig. 7).

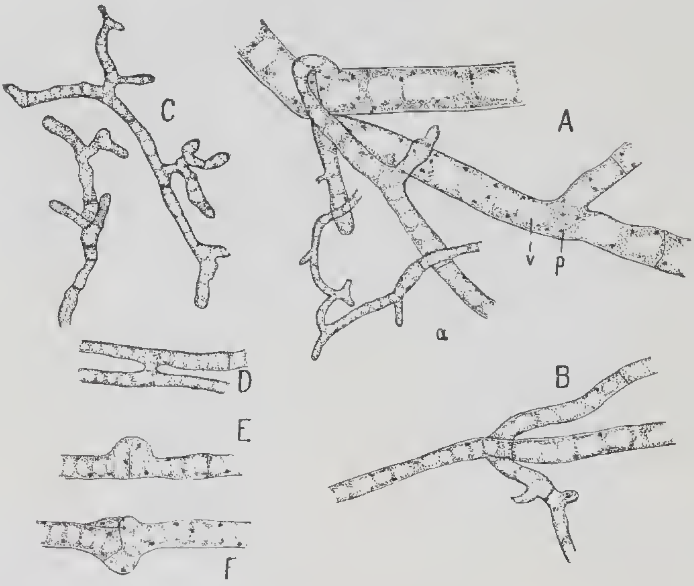

Fig. 7. Mycelium produced on malt agar. × 300. A. B. Hyphae of *C. centrifugum* showing variation in width. (a) Narrow crooked threads. C. Irregular hyphae from very young sclerote. D. Anastomosis between 2 hyphae. E. F. Clamp connections in aerial hyphae. (v) vacuole. (p) granular protoplasm.

Comparison with two other sclerotial forms.

The fungus isolated from Delphiniums in Victoria (D2) was compared with Whetzel's strain of *Sclerotium Delphinii* (SCI) obtained from Centraal-Bureau voor Schimmelcultures, Baarn, Holland. Comparison was made on malt agar, and microscopically the mycelium was quite similar except that in SCI there was sometimes a development of rounded irregular bodies occurring in an intercalary position on the hyphae (Fig. 9).

Macroscopic differences were, however, much greater. In D2 a dense fluffy aerial mycelium was produced. The numerous small sclerotes (0.5–2 mm. average 1.2 mm.) were formed first near the margin of the plate and gradually spread inwards. The liquid exuded from the sclerotes was amber-coloured. The final colour of the sclerotes was clove brown, and in section the outer brownish cortex (up to 50μ wide) was composed of compacted hyphae giving a parenchymatous appearance. The inner medullary region is composed of short and elongated colourless hyphae with numerous intercellular spaces (Fig. 8).

In SCI the aerial mycelium showed a more dendritic type of growth but greatest distinction was seen in the size, shape, number and colour of the sclerotes. The sclerotes were fewer and larger (1–6 mm. average 3.4 mm.) and in contrast to those of D2 were often found coalescing. They were irregular in shape, but convex or flattened above, and usually concave on the lower surface, where they were often attenuated into a stalk-like region. Sclerotes one week old were a conspicuous orange cinnamon colour and the final stage was warm sepia. At all stages they showed a more reddish tinge than those of D2. The colourless liquid was exuded from darker depressed

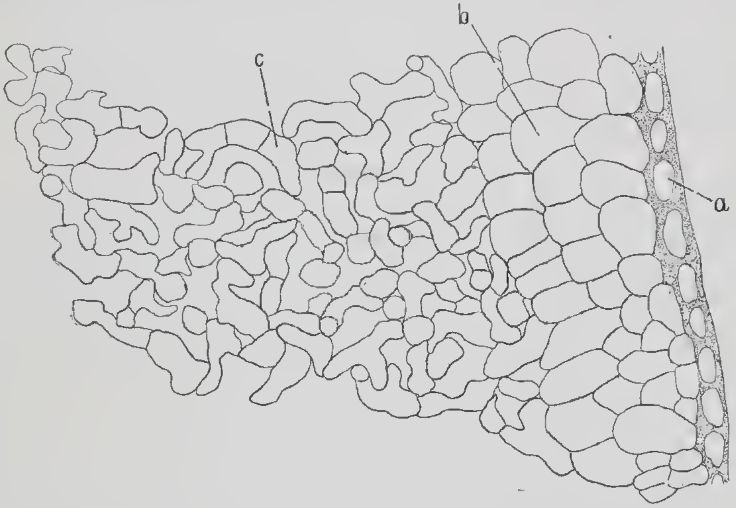

Fig. 8. Hand cut T.S. of portion of a mature sclerote of *Corticium centrifugum* (× 200) from malt agar. (a) Outer rind of compact cortex. Deep brown in colour. (b) Cortical tissue composed of false parenchyma and light brown in colour. (c) Inner lacunar medullary region composed of long and short irregular hyphae.

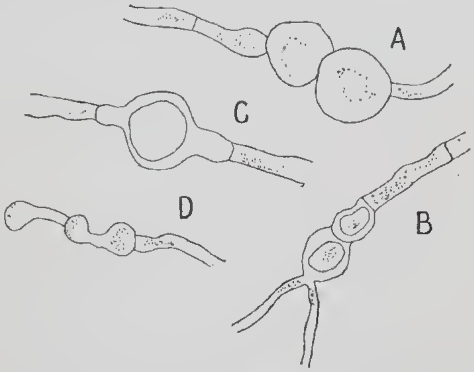

Fig. 9. A, B, C. Rounded chlamydospore-like bodies on the hyphae at the junction of SCI and D2 colonies. (× 300.) D. Irregular swellings on hyphae in the same region. (× 300.) Culture on malt agar.

spots. Sections of sclerotes showed that the cortex was if anything slightly wider but composed of smaller hyphae, while hyphae of the medullary region were distinctly wider than in D2. SCI also showed a development of felted white appressed mycelium around the inoculum.

This comparison indicates that the fungus isolated from Delphiniums in Victoria cannot be considered identical with *Sclerotium Delphinii.*

Comparison was also made with Wolf's strain of *Sclerotium rolfsii* which is known now as *Corticium centrifugum* (CI) obtained from Baarn, Holland.

CI on malt agar produced mycelium similar to that of D2 and the sclerotes were numerous and small (0.3–2 mm. average 1 mm.) but more irregular in shape and varied more in size than those of D2. Also in contrast to the initial marginal formation of sclerotes in the latter, they formed at first near the central inoculum (where masses of sclerotes were often found), and gradually spread out to the margin of the plate. The liquid exuded was colourless, but the colour changes of the developing sclerotes was practically the same as in D2, and the final colour again clove brown. Sections of sclerotes were very similar to those of D2. A felted white appressed mycelium was often developed around the inoculum. This was not seen in D2. The microscopic appearance of the hyphae of D2 and CI was identical.

D2, SCI and CI were plated against each other to determine whether any antagonising action existed between them. In each case there was a distinct line at the junction of the two colonies, and it was found that D2 was the fastest and SCI the slowest grower. If two colonies of one strain were started on the same plate there was free intermingling of the hyphae.

It was evident that a greater antagonistic action existed between SCI and D2, and between SCI and CI, than between D2 and CI, the agar in the two former cases being slightly stained along the junction. SCI developed numerous sclerotes along the line of junction, but this was not apparent with CI and D2. On microscopic examination it was found that there was a considerable development of rounded or irregular bodies up to 25μ diameter occurring in an intercalary position on the hyphae of SCI near the junction with CI and D2 (Fig. 9). It was evident that D2 was much more closely related to CI and the slight differences present could not be considered as specific.

Attempts were made to produce the fruiting stage by growing the three forms on various media (potato dextrose, malt, oatmeal, soil and plain agars) and on a solution of 1% Witte peptone + .5% potato starch + 50 cc. distilled water (CI and D2 formed thick conglomerated masses of sclerotes on the latter medium, but it was unsuitable for SCI) at 30°C., 19°C. and room temperature. No basidia or spores were observed although they were examined constantly.

Discussion.

Curzi (2) in Italy compared a sclerotial fungus isolated from aster with one from potato. Differences were found to exist in vegetative characters, the former producing a flocculent mycelium while in the latter the mycelium was arranged in strands and numerous stromata were present. The two were mutually antagonistic.

The aster fungus produced a loose aerial hymenium showing affinities with *Corticium centrifugum,* while the potato fungus had a dense crust-like hymenium which he considered was not identical with any known Basidiomycete. He named it *Corticium rolfsii,* n. comb., as he considered this latter fungus to correspond with that from which Saccardo described *Sclerotium rolfsii.* Wolf's strain, which is usually regarded as a typical strain of *Sclerotium rolfsii,* also has a loose hymenial stage similar to the aster *Corticium* and undoubtedly corresponds with it. Since *Corticium centrifugum* cannot be regarded as the perfect stage of the true *S. rolfsii,* it should be considered as a distinct species.

The study of various isolations of *S. rolfsii* therefore indicates that the name includes more than one species whose systematic positions should be determined by attempts to discover the perfect stage, or an accurate examination of the vegetative organs under various conditions.

Curzi (3) made three distinct groups for the strains examined by him:—

(1) Sclerotial stage of *Corticium rolfsii* (Sacc.) *Curzi.*
(2) Sclerotial stage of *Corticium centrifugum* (= *S. centrifugum* n. comb.).
(3) *Sclerotium Delphinii* Welch.

The perfect stage of the strain isolated from Delphinium was not obtained, but the vegetative characters under various external conditions showed a close resemblance to Wolf's *Corticum centrifugum* and Curzi's description of his aster strain, while the distinctive characters of his potato strain were not present.

Summary.

(1) *Corticium centrifugum* is recorded as causing a root and collar rot of Delphiniums in Victoria.

(2) A description of the pathogen in culture is given.

(3) Comparisons are made between the strain isolated from Delphinium, Wolf's strain of *Corticium centrifugum* and Whetzel's *Sclerotium Delphinii* (Welch).

Acknowledgments.

The writer wishes to express her gratitude for the helpful interest shown by Professor Ewart and also to thank Dr. McLennan, under whose direction the work was conducted, for her helpful criticism and suggestions.

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[Proc. Roy. Soc. Victoria 47 (N.S.), Pt. II., 1935.]

Art. XXII.—"*Sooty Mould*" *of the Tree-Fern Dicksonia.*

By EILEEN E. FISHER, M.Sc.

[Read 8th November, 1934; issued separately, 8th May, 1935.]

The fronds of a *Dicksonia* plant, growing in a fernery at Doncaster (approximately 11 miles east-north-east of Melbourne), were found covered by a dense black film, which so far as could be revealed by microscopic examination, was due entirely to the fungus *Teichospora salicina* (Mont.) Gau.

The perithecia, present in abundance, are dark, glabrous, roughly spherical bodies, of approximately 112μ in diameter. They contain ascospores which are brown in colour, muriformly septated with usually three transverse septa, and characteristically constricted in the median region. These fruit-bodies are in every way similar to those previously described in connexion with "sooty mould" of *Bursaria spinosa* (3), although the spores are slightly larger, measuring on an average $19.5\mu \times 9.5\mu$.

On the fronds examined by me, the imperfect stage of this fungus was not found occurring so commonly as the perithecial, but some dark, elongated, linear pycnidia, approximately 224μ long and averaging 32μ in width, were seen.

The pycnospores, which are very like the ascopores, differ, however, in certain points of detail; they are not waisted in shape, and also the longitudinal septa are frequently missing. The average dimensions of these spores may be given as $16.5\mu \times 8.2\mu$. Surrounding the pycnidium-mouth a fringe was visible in some cases, but otherwise this pycnidial form is identical with that already described and illustrated for *Teichospora salicina* constituent in "sooty mould" of *Bursaria spinosa* (3, fig. 4).

In 1892 Gaillard found *Meliola tortuosa* Wint., f. infecting plants of *Dicksonia* L'Her. in Brazil (4) and (6). Apparently the only other record of a "sooty fungus" occurring on any of the tree-fern genera was made in 1890 (2) when *Asterina* (*Asterella*) *Alsophilae* Cke. and Mass. was found growing on fronds of *Alsophilia rebeccae* F. Muell., collected by Mueller in north-eastern Queensland, Australia.

Both of the above mentioned fungi are ectoparasitic forms, penetrating the tissues of their host by means of haustoria, and it seems that no prior record has been made of a true "sooty mould," which as clearly defined by Neger (5), is characteristically epiphytic in nature.

Within the limits of the writer's experience "sooty mould" has never been found attacking tree-ferns growing in their natural habitat, and its development on this particular specimen is possibly due to the rather confined atmospheric conditions of the fern-house, which, however, it should be noted, was not artificially heated in any way. *Teichospora salicina,* which is responsible for the sootied condition in this instance, is a normal constituent of "sooty moulds" in temperate climates. On the other hand, the observations of Neger (5) and van Beyma Thoe Kingma (1) show that the "sooty mould" of European hothouse plants is almost invariably due to the fungus *Caldariomyces fumago* Wor. (*Fumago vagans* Pers.), a form which is adapted to high temperature conditions.

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[Proc. Roy. Soc. Victoria 47 (N.S.), Pt. II., 1935.]

Art. XXIII.—*The Genera of Catenicellidae.*

By LEO W. STACH.

[Read 13th December, 1934; issued separately, 8th May, 1935.]

Introduction.

The preparatory work on a revision of the Recent species of Catenicellidae has shown the necessity for a survey of the status of the generic names which have been used in connexion with the group. The conclusions arrived at are summarized below, and a systematic synopsis is appended in which new sub-families and genera are described.

Discussion of Genera.

Alysidium Busk, 1852, 2, p. 13. Busk (1852) placed this genus, comprising two species, in the Catenicellidae. One (*A. lafontii*) was later transferred to "*Catenaria*" by Busk (1884) and made the type of that genus, in which d'Orbigny (1851) had also included the species. *A. parasiticum* became the type by elimination of the Anascan genus *Alysidium*, thus removing the genus from the Catenicellidae.

Caloporella Macgillivray, 1895, p. 18. Synonym of *Vittaticella*. This genus was erected for vittate species, no type being selected. Preoccupied by Ulrich (1882, *Journ. Cincinnati Soc. Nat. Hist.*, vol. v., p. 154) and replaced by *Vittaticella* Maplestone, 1901.

Calpidium Busk, 1852, p. 364. Monotypical genus with *C. ornatum* Busk, 1852 as type.

Carinatocella, gen. nov. Erected for the Catenicellinid *Catenicella carinata* Busk, 1852. Characters as for *Pterocella*, but the suprascapular compartments are not calcified.

Catenaria Authors. Levinsen uses this name for vittate species, claiming that Savigny's figure establishes the genus (1909, p. 213, foot-note), but this is contrary to the definition of "indication" as applied to genera (Opinion 1, Inter. Rules Zool. Nomen.). *Catenaria* was regularized by d'Orbigny (1851) and included *Eucratea lafontii* Audouin, 1826, while *E. contei* was placed in *Catenicella*. The name *Catenaria* is, however, preoccupied by Zeder, 1800 and Strand (*Zool. Rec.*, vol. lxv., p. 37) has replaced it with *Catenariella*, but this name is invalidated by *Savignyella* (Levinsen, 1909) with the same genotype, *E. lafontii*. Thus *Catenaria* was removed from the Catenicellidae by d'Orbigny and has, as its type, *E. lafontii*, but *Catenaria* being preoccupied, the next synonym, *Savignyella*, replaces it. *Catenaria* Levinsen is a synonym of *Vittaticella*.

CATENICELLA Blainville, 1834, p. 462. Blainville erected this genus for *Hippothoa divaricata* Lamouroux, 1821, and *Catenicella savignyi* (1834) which is a synonym of *Eucratea contei* Aud., 1826. The meagre description and its apparent application solely to *H. divaricata* would seem to place it as a synonym of *Hippothoa* Lamx., 1821, but *Catenicella* was regularized and well-described by d'Orbigny (1851) and included *C. contei* which, by the selection of *H. divaricata* as type of *Hippothoa*, becomes type of *Catenicella* Blainville. D'Orbigny (1851) furnished the first adequate description of the genus. *Catenicella* Blainville is a restricted Catenicellinid genus with the single species *C. contei*, which is an aberrant form distinguished from other vittate species by its ovicell which pertains to the mother zooecium of a triglobulus. The name *Catenicella* (*sensu lato*, i.e. in the manner of subsequent authors) may also be used as a group name for species of uncertain affinity in the same manner as *Lunulites* and others are employed (Canu and Bassler, 1929; Harmer, 1933; Stach, 1933).

CATENICELLOPSIS Wilson, 1880, p. 64. Based on an unusual mode of branching which, however, is found in many widely-separated species (*Vittaticella* spp., *Claviporella* spp.) and constitutes a minor secondary character of little systematic value. Two species, *C. delicatula* and *C. pusilla*, were included, the former being referred to *Catenicella* (vittatae) by Macgillivray (1887, 2) and the latter to *Claviporella* by Levinsen (1909), thus eliminating the genus. The systematic value of the feature proposed by Canu and Bassler (1929) as a distinction between *Vittaticella* and *Catenicellopsis* is doubtful and *C. delicatula* is at present regarded by the author as belonging to the former genus.

CLAVIPORELLA Macgillivray, 1887, p. 65. One of the Catenicellinid genera with aberrant sternal structures and clithridiate aperture.

CORNUTICELLA Canu and Bassler, 1927, p. 9. Proposed for the reception of vittate species with the ovicell pertaining to a terminal mother zooecium of a geminate pair.

CORNUTICELLINA, gen. nov. Established for *"Pterocella" mathewsi* Bale, 1922 which has an ovicell of the Cornuticellinid type, but a sternal area similar to *Cribricellina*.

COSTATICELLA Maplestone, 1899, p. 9. Erected by Maplestone for *Catenicella lineata* MacG., 1895, and *Costaticella escharoides* Mapl., 1899, which have been shown to be conspecific (Stach, 1934). Levinsen's later genus *Costicella* with type *Catenicella hastata* Busk, 1852, has been merged with *Costaticella* by Canu and Bassler (1927, p. 21) and the author (1934).

COSTATICELLINA Stach, 1934, p. 39. Subgenus of *Costaticella* erected for *Catenicella latifrons* MacG., 1895, which has uncalcified suprascapular compartments.

COSTICELLA Levinsen, 1909, p. 233. Synonym of *Costaticella.* Erected by Levinsen, who apparently did not know of Maplestone's *Costaticella,* since he suggests that *C. lineata* MacG., 1895, and *C. latifrons* belong to his genus.

COTHURNICELLA Thomson, 1858, p. 141. Synonym of the Anascan genus *Chlidonia* Lamouroux, 1824. Thomson erected this genus for the reception of *Cothurnicella daedala,* which he placed in the Catenicellidae. Macgillivray regards *C. daedala* as a synonym of *Chlidonia cordieri* (Audouin, 1826) which Harmer (1923, p. 305) has shown to be synonymous with *Chlidonia pyriformis* (Bertolini, 1810).

CRIBRICELLA Levinsen, 1909, p. 238. Synonym of *Cribricellina.* Levinsen's name is preoccupied by Canu (1904).

CRIBRICELLINA Canu and Bassler, 1927, p. 9. One of the Scuticellinid genera, replacing the preoccupied *Cribricella* Levinsen.

DIGENOPORA Maplestone, 1899, p. 6. Monotypical Scuticellinid genus erected for *D. compta* Mapl., 1899, which is, however, a synonym of *Catenicella retroversa* MacG., 1895.

DITAXIPORA Macgillivray, 1895, p. 22. Monotypical genus erected for *Catenicella internodia* Waters, 1881. Multizooecial internodes.

DITAXIPORINA, gen. nov. Erected for *Catenicella septentrionalis* Waters, 1891, which has multizooecial internodes, but lacks the longitudinal median band of *Ditaxipora.*

EUCRATEA Lamouroux, 1812, p. 183. Audouin (1826) referred both *Savignyella lafontii* and *Catenicella contei* to this genus. Its status is discussed by Harmer (1923, p. 307).

EUNICEA Desmarest and Lesueur MS., 1829. This MS. generic name was given to twelve illustrated species which have been referred to species of the Catenicellidae by Pergens (1887).

HINCKSIELLA Levinsen, 1909, p. 241. Synonym of *Strongylopora.* Levinsen was apparently ignorant of the existence of the Catenicellinid genus *Strongylopora* since he describes the single species *Catenicella pulchella* which is taken as the type.

MICROSTOMARIA Macgillivray, 1895, p. 18. An examination of two partly-damaged specimens of the single species, *M. tubulifera,* from the type locality and from below the remanié nodule bed at Forsyth's on the Grange Burn Creek, Hamilton (Lower Miocene), suggests that the species is a member of the cyclostomatous family Crisiidae. The development of the calcareous layer is characteristically cyclostomatous, in that wavy lines of deposition cross the zooecia at right angles to the long axis, giving the typical undulose appearance particularly well seen in such genera as *Entalophora* and *Tubulipora,* but absent from the Cheilostomata. The characters of the pores are those of the

Crisiidae, while the circular aperture is produced into a peristome with an unthickened edge. The smaller apertures are the apertures of the connecting tubes of the articulated colony. The longitudinal ridge represented in Macgillivray's figure is merely an edge produced by the sides of the zooecia meeting at a very obtuse angle; no trace of thickening can be observed. The generic affinity cannot be established without further specimens. Canu and Bassler (1927, p. 21) regarded *Microstomaria* as a sub-genus of *Strophipora.*

PTEROCELLA Levinsen, 1909, p. 246. One of the Catenicellinid genera characterized by its calcified suprascapular compartments and fenestrate sternal area.

SCUTICELLA Levinsen, 1909, p. 221. Type of the sub-family Scuticellinae Stach, 1934.

STENOSTOMARIA Macgillivray, 1895, p. 16. Ovicell of the Catenicellinid type and thus distinct from the Scuticellinid genus *Strophipora* of which Canu and Bassler (1927, p. 21) regarded it as a subgenus.

STRONGYLOPORA Maplestone, 1899, p. 4. Levinsen (1909) unknowingly duplicated this genus by describing the type as the sole species of his genus *Hincksiella.*

STROPHIPORA Macgillivray, 1895, p. 17. Monotypical genus with ovicell of the Scuticellinid type; sternal area represented by a thickened longitudinal ridge.

VITTATICELLA Maplestone, 1901, p. 201. Introduced to replace the preoccupied *Caloporella.*

Systematic Synopsis.

Family CATENICELLIDAE.

Sub-family CATENICELLINAE, sub-fam. nov.

Description.—Internodes of a single zooecium or a geminate pair; in ovicelligerous internodes, where the ovicell pertains to the mother zooecium of a geminate pair, a trizooecial internode is formed by the adherence of the ovicell to the distal zooecium.

Genus **Catenicella** Blainville, 1834 (*sensu stricto*).

Type (by elimination): *C.* (*Eucratea*) *contei* (Audouin, 1826).

Description.—Ovicell pertains to mother zooecium of a triglobulus. Zooecia vittate with small scattered frontal pores; suprascapular compartments uncalcified.

Genus **Pterocella** Levinsen, 1909.

Type (by subsequent designation, Canu and Bassler, 1929): *P.* (*Catenicella*) *alata* (Thomson, 1858).

Genus **Carinatocella,** gen. nov.

Type: *C. harmeri,* nom. nov. (for *Catenicella carinata* Busk, 1852).

Description.—Ovicell pertains to mother zooecium of a triglobulus. Sternal area ornamented with oval fenestrae; suprascapular compartments uncalcified.

Observations.—D'Orbigny has described a species *Catenicella carinata* (1851, p. 44), but no figure is given. In the description, he states that the " cellules " are " non enlargées en arrière " and therefore the species is certainly not the *C. carinata* of Busk (1852). D'Orbigny's species must be regarded as a *nomen nudum* and Busk's trivial name is here replaced by " *harmeri* " in appreciation of the great assistance rendered by Sir Sidney F. Harmer in my study of the Recent Catenicellidae.

Genus **Claviporella** Macgillivray, 1887.

Type (by subsequent designation, Canu and Bassler, 1929): *C.* (*Catenicella*) *geminata* (Thomson, 1858).

Genus **Strongylopora** Maplestone, 1899.

Type (by subsequent designation, Canu and Bassler, 1929): *S.* (*Catenicella*) *pulchella* (Maplestone, 1880).

Genus **Stenostomaria** Macgillivray, 1895.

Type (by monotypy): *S.* (*Catenicella*) *solida* (Waters, 1881).

Sub-family VITTATICELLINAE Stach, 1933.

Genus **Vittaticella** Maplestone, 1901.

Type (here designated): *V.* (*Catenicella*) *elegans* (Busk, 1852).

Observations.—Canu and Bassler (1929, p. 438) have selected *Eucratea contei* Audouin, 1826, as the type of the genus, but since this form is not included in Maplestone's list of species of the genus (1901), the choice is not valid. *Vittaticella elegans* is here selected because of its abundance and extraordinarily wide distribution.

Sub-family CORNUTICELLINAE, sub-fam. nov.

Description.—Internodes of a single zooecium or a geminate pair. The ovicell pertains to a terminal mother zooecium of a geminate pair. Suprascapular compartments not calcified.

Genus **Cornuticella** Canu and Bassler, 1927.

Type (by original designation): *C.* (*Catenicella*) *cornuta* (Busk, 1852).

Genus **Cornuticellina,** gen. nov.

Type: *C.* (*Pterocella*) *mathewsi* (Bale, 1922).

Description.—Sternal area perforated by numerous large pores as in *Cribricellina,* with short radiating fissures. Scapular compartments in the form of long, narrow, lateral projections at the level of the aperture.

Sub-family SCUTICELLINAE Stach, 1934.

Genus **Scuticella** Levinsen, 1909.

Type (by subsequent designation, Canu and Bassler, 1929): *S.* (*Catenicella*) *plagiostoma* (Busk, 1852).

Genus **Cribricellina** Canu and Bassler, 1927.

Type (by subsequent designation, Canu and Bassler, 1927): *C.* (*Catenicella*) *rufa* (Macgillivray, 1868).

Genus **Costaticella** Maplestone, 1899.

Type (by subsequent designation, Canu and Bassler, 1929): *C.* (*Catenicella*) *lineata* (Macgillivray, 1895).

Sub-genus **Costaticellina** Stach, 1934.

Type (by original designation): *Costaticella* (*Costaticellina*) *latifrons* (Macgillivray, 1895) (= *Catenicella* do.).

Genus **Strophipora** Macgillivray, 1895.

Type (by monotypy): *S.* (*Catenicella*) *harveyi* (Thomson, 1858).

Genus **Calpidium** Busk, 1852.

Type (by monotypy): *Calpidium ornatum* Busk, 1852.

Genus **Digenopora** Maplestone, 1899.

Type (by monotypy): *D.* (*Catenicella*) *retroversa* (Macgillivray, 1895) (*vide* Stach, 1934).

Sub-family DITAXIPORINAE, sub-fam. nov.

Description.—Multizooecial internodes with ovicells adherent to the zooecium distal to the ovicelligerous zooecium. Avicularia at one or both of the upper angles of the zooecia. Sternal area with longitudinal median band or with scattered pores.

Genus **Ditaxipora** Macgillivray, 1895.

Type (by monotypy): *D.* (*Catenicella*) *internodia* (Waters, 1881).

Observations.—Waters' Italian Tertiary species, *Catenicella continua* Waters, 1891, is included here.

Genus **Ditaxiporina,** gen. nov.

Type: *D.* (*Catenicella*) *septentrionalis* (Waters, 1891).

Description.—Multizooecial internodes; the sternal area with scattered pores.

Observations.—*Catenicella subseptentrionalis* Canu and Bassler, 1920, also appears to belong to this genus.

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Fisher, Miss E. E., M.Sc., 1 Balwyn-road, Canterbury, E.7	1930
Fraser, Colin K., B.C.E., 136 Wellington-street, Kew, E.4	1934
Frostick, A. C., 9 Pentland-street, N. Williamstown, W.16	1933
Gabriel, C. J., 293 Victoria-street, Abbotsford, C.1	1922
Grieve, Brian J., B.Sc., 194 Osborne-street, Williamstown, W.16	1929
Hanks, W., 10 Holroyd-street, Coburg, N.13	1930
Hardy, A. D., Forests Department, Melbourne, C.2	1903
Hauser, H. B., M.Sc., Geology School, University, Carlton, N.3	1919

Head, W. C. E., 22 The Esplanade, Williamstown, W.16	1931
Hill, Gerald F., Council for Scientific and Industrial Research, Box 109, Canberra City, Canberra, F.C.T.	1924
Hills, E. S., M.Sc., Ph.D., Geology School, University, Carlton, N.3	1928
Hoette, Miss Shirley, M.Sc., 23 Moorhouse-street, Armadale, S.E.3	1934
Holland, R. A., 126 Kooyong-road, Caulfield, S.E.7	1931
Holmes, W. M., M.A., B.Sc., Observatory, South Yarra, S.E.1	1913
Honman, C. S., B.M.E., 3 Fairy-street, Ivanhoe, N.21	1934
Howitt, A. M., Department of Mines, Treasury Gardens, East Melbourne, C.2	1910
Huelin, F. E., University, Carlton, N.3	1933
Jack, A. K., M.Sc., 49 Aroona-road, Caulfield, S.E.7	1913
Jessep, A. W., B.Sc., M.Ag.Sc., Dip. Ed., Horticultural Gardens, Burnley, E.1	1927
Jona, J. Leon, M.D., M.S., D.Sc., Lister House, 61 Collins-street, Melbourne, C.1	1914
Keartland, Miss B., M.Sc., Cramer-street, Preston, N.18	1919
Kilvington, Mrs. T. B., 95 Kooyongkoot-road, Hawthorn, E.2	1929
Kubale, J. C., 167 Power-street, Hawthorn, E.2	1929
Lambert, C. A., Carlyon's Hotel, Spencer-street, Melbourne, C.1	1919
Leeper, G. W., M.Sc., Chemistry School, University, Carlton, N.3	1931
Luly, W. H., Esplanade, Altona, Vic.	1896
McCance, D., M.Sc., 144 Gatehouse-street, Parkville, N.2	1931
MacDonald, B. E., "The Heights," 127 Banksia-street, Heidelberg, N.22	1920
McLennan, Assoc. Prof. Ethel, D.Sc., University, Carlton, N.3	1915
Melhuish, T. D'A., M.Sc., Adelaide Chemical and Fertilizer Co., Box 7, Port Adelaide, S.A.	1919
Mollison, Miss E., M.Sc., Royal-crescent, Camberwell, E.6	1915
Moon, A., Ramsay, c/o Murex Welding Processes, Ferry-lane, Walthamstow, England	1929
Moore, F. E., O.B.E., Chief Electrical Engineer's Branch, P.M.G.'s Department, Treasury Gardens, East Melbourne, C.2	1920
Morris, P. F., National Herbarium, South Yarra, S.E.1	1922
Newman, B. W., Meteorological Bureau, Adelaide, S.A.	1927
Nicholls, Miss A., B.Sc., 633 Inkerman-road, Caulfield, S.E.7	1929
Nye, E. E., College of Pharmacy, 360 Swanston-street, Melbourne, C.1	1932
Nye, Rev. Edward, B.A., Wesley College, St. Kilda-road, Prahran, S.1	1934
Oke, C., 4 Raleigh-street, Prahran, S.1	1922
Orr, D., B.Sc., 860 Mount Alexander-road, Essendon, W.5	1927
Osborne, N., 3 Dean-street, East Malvern, S.E.5	1930
Parr, W. J., 17 Bokhara-road, Caulfield, S.E.8	1927
Paterson, Miss Helen T., 19 Power-street, Hawthorn, E.2	1933
Petersen, Miss K., B.Sc., 56 Berkeley-street, Hawthorn, E.2	1919
Phillipson, Mrs. L. J., M.Sc., 78 Glyndon-road, Camberwell, E.6	1930
Pretty, R. B., M.Sc., Technical School, Wonthaggi, Vic.	1922
Raff, Miss J. W., M.Sc., F.R.E.S., University, Carlton, N.3	1910
Rayment, Tarlton, Bath-street, Sandringham, S.8	1929
Richardson, Sidney C., 2 Geelong-road, Footscray, W.11	1923
Ripper, Miss E. A., 8 Mitchell-street, St. Kilda, S.2	1930

Rosenthal, Newman H., B.A., B.Sc., 10 Oulton-street, Caulfield, S.E.7	1921
Sayce, E. L., B.Sc., A.Inst.P., Research Laboratories, Maribyrnong, W.3	1924
Scott, T. R., 7 Garden-avenue, Hawthorn, E.3	1934
Shaw, Dr. C. Gordon, 75 Clendon-road, Toorak, S.E.2	1931
Shaw, F. H., M.Sc., 41 Prospect Hill-road, Camberwell, E.6 ..	1933
Sherrard, Mrs. H. M., M.Sc., 43 Robertson-road, Centennial Park, N.S.W.	1918
Smith, J. A., 25 Collins-place, Melbourne, C.1	1905
Stach, L. W., 78 Herbert-street, Albert Park, S.C.6	1932
Stickland, John, 433 Brunswick-street, Fitzroy, N.6	1922 .
Sutherland, Miss Jean L., M.Sc., Zoology Dept., University, N.3 ..	1934
Thomas, L. A., B.Sc., c/o Council for Scientific and Industrial Research, Stanthorpe, Queensland	1930
Traill, J. C., B.A., B.C.E., 630 St. Kilda-road, Melbourne, S.C.3 ..	1903
Trüdinger, W., 27 Gerald-street, Murrumbeena, S.E.9	1918
Turner, A. H., M.Sc., Natural Philosophy Dept., University, Carlton, N.3	1927
Turner, A. W., D.V.Sc., Animal Health Research Institute, Oonomba, via Townsville, Queensland	1925
Wilcock, A. A., 294 The Avenue, Parkville, N.2	1934
Wilcock, E. L., B.Sc., University High School, Parkville, N.2 ..	1925
Wilson, F. E., F.E.S., 22 Ferncroft-avenue, E. Malvern, S.E.5 ..	1921
Wilson, Major H. W., O.B.E., M.C., C. de G., B.Sc., 630 Inkerman-road, Caulfield, S.E.7	1923
Withers, R. B., B.Sc., Dip. Ed., Higher Elementary School, Yallourn, Vic.	1926
Wood, Assoc. Prof. G. L., M.A., Litt. D., University, Carlton, N.3 ..	1933
Woodburn, Mrs. Fenton, 21 Bayview-crescent, Black Rock, S.9 ..	1930

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

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