THE GAMBIER LIMESTONE AND ITS FORAMINIFERAL FAUNA

by

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INTRODUCTION

GENERAL

The Gambier Limestone, partly Oligocene and partly Miocene in age, extends over an area of more than 10,000 square miles occupying the southeastern part of South Australia and the adjoining part of Victoria. This area is sometimes considered as the southern part of the Murray Basin, a region of Mesozoic and Tertiary sedimentation (Ludbrook, 1958). Outcrops of the Gambier Limestone are sparse, and the formation is largely covered by a comparatively thin mantle of Quaternary sediments. Map 1 shows the geographical location and text-fig.1 the approximate extent of the formation, both subsurface and in outcrop.

AIMS

The main aims of the present work were:

1. A study of the lithology, stratigraphy, paleoecology, conditions of deposition and diagenesis of the Gambier Limestone.

2. A detailed study of the Foraminifera and their distribution within the limestone.

3. Biostratigraphic zoning of the Gambier Limestone by means of the Foraminifera in order to elucidate the structure of the formation.

AREA

Study of the Gambier Limestone in outcrop was limited to the two areas shown on Maps 2 and 3 and indicated on Map 1. They are referred to as the Mount Gambier area and the Naracoorte area, respectively, in this thesis. In both areas, the Gambier Limestone is exposed at the surface or is covered by a thin layer of younger sediments and/or soil. The excellent exposures along the Glenelg River in Victoria were examined only superficially, since they are being investigated in detail by geologists of the Victorian Geologic Survey (Mr. P.R. Kenley, 1959, verbal communication).

MATERIAL

Outcrop samples

For both lithological and paleontological studies of the Gambier Limestone, samples from artificial exposures (quarries) and such natural exposures as sink holes and caves are most suitable and most easily obtainable. However, such exposures are not distributed sufficiently densely and uniformly for purposes of even moderately detailed biostratigraphic mapping. Hence a number of additional surface samples, which are commonly somewhat cemented, hardened and recrystallized, and auger samples, were also collected in the Mount Gambier area.

Two series of samples were collected by the writer in the

Mount Gambier and the Naracoorte areas. The D series consists of about 50 lithological and macropaleontological samples. Approximately 130 "soft" samples, belonging to the E series, were collected primarily for micropaleontological investigation. The numbers of the samples in the E series, as well as those of selected samples from the V series (in the collection of the Geology Department of the University of Adelaide) are plotted at their appropriate localities on Maps 2 and 3. The numbers of samples in both series from other strata than the Gambier Limestone were not plotted on the maps.

About 200 samples collected by Mr. E.J. Brock for Geosurveys of Australia Ltd., mostly to the west of Mount Schank (in the Mount Gambier area), were also available. Their localities were not plotted on Map 2, but biostratigraphic data resulting from their examination were plotted, together with data from the E series of samples, on Map 4.

Subsurface samples

The following subsurface samples from the Gambier Limestone were available for study:

Naracoorte no.1 bore. One sample, collected between 165 and 218 feet.

Naracoorte no.2 bore. Five samples, collected at depths 47 to 78 feet, 78 to 124 feet, 124 to 174 feet, 174 to 206 feet and 206 to 226 feet.

Comaum bore. Three samples, collected at depths 112 to 233 feet, 338 to 343 feet and 353 to 360 feet.

Allison's bore (near Wandillo). One sample, collected between 30 and 118 feet.

A number of subsurface samples from the Gambier Limestone, collected by the staff of Geosurveys of Australia Ltd. in the vicinity of Beachport, South Australia, were also available. The maximum depth at which a sample was obtained in this area is 280 feet.

DEPOSITORIES

Samples belonging to the E and D series, as well as foraminiferal slides and figured specimens (registered under numbers of the F series) from these samples, are deposited in the collection of the Geology Department of the University of Adelaide.

ACKNOWLEDGEMENTS

Thanks are expressed to Dr. M.F. Glaessner for advice and constructive criticism throughout the course of this work, and for the use of literature and material from his personal library and collection. Dr. M.J. Wade, and Mr. B. McGowran in part, read the manuscript and offered helpful suggestions; Dr. Wade also assisted with the photography. Dr. N.H. Ludbrook of the South Australian Mines Department lent foraminiferal material from the Gambier Limestone and presented a number of specimens figured in this thesis to the Department of Geology of the University of Adelaide. Dr. A.N.

Carter, formerly of the Victorian Mines Department, granted permission to photograph and refer to the illustrations of his unpublished thesis and discussed the Victorian microfaunas. Mr. E.D. Gill permitted the examination of foraminiferal material in the National Museum of Melbourne. Messrs. M. and F. Pritchard and Mr. H. James assisted the writer while in the field, and Mr. R.C. Sprigg of Geosurveys of Australia Ltd. gave financial help and permitted the use of data from one of his unpublished maps. Mr. C.R. Dalgarno photographed and reproduced the plates; Miss S. Sumner typed a part of the manuscript. Mr. R.E. Cooper assisted with the draughting, and other members of the Geology Department of the University of Adelaide helped in diverse ways. This work was carried out under the tenure of the Research Grant of the University of Adelaide during 1958 and the Commonwealth Postgraduate Scholarship during 1959 to 1961.

I PREVIOUS WORK

Only the more important references dealing with the Gambier Limestone are mentioned below. Such previous work is discussed more fully in the appropriate subsequent sections of this thesis. For a more complete bibliography, Sprigg (1952) and Teesdale-Smith (1959) should be consulted.

The bryozoal limestone outcropping near Mount Gambier was first described by Woods (1860). A more generalised and longer treatment was given by Woods (1862), in which these strata were referred to as the Mount Gambier stone (p.72), the Mount Gambier limestone (p.86), the Mount Gambier formation (p.255) or simply as Mount Gambier beds or deposits. Woods continued to use such variable terminology in his later papers, e.g. Woods, 1865a, b, c; 1867, 1876.

Sprigg (1952) was the first to formally introduce an abbreviated version of Woods' informal terminology. He referred to the bryozoal limestone in the vicinity of Mount Gambier and its equivalents elsewhere as "the Gambier limestones" on p.9 and as "the Gambier limestone" on p.27, while in fig.5 he used the name "Gambier formation". Victorian geologists have continued to use the non-abbreviated form of the name even after Sprigg's (1952) publication, e.g. Sprigg and Boutakoff (1953), correlation chart facing p.52.

Throughout the present thesis, the name "Gambier Limestone" (following Ludbrook, 1957, 1958) is used to refer to the formation as a whole, unless qualified with regard to locality or otherwise. The type locality of the Gambier Limestone is the Mount Gambier Town Hall sink hole (Ludbrook, 1961). The name "Gambier Limestone *sensu stricto*" (see table 2) refers to the formation exclusive of the Naracoorte Limestone Member, which was first differentiated by Ludbrook (1957). Its type locality is the H. James and Sons' quarry at Naracoorte (locality of sample E 1 and others - see Map 3).

The most comprehensive work to-date on the general geology of the southeastern part of South Australia, which includes the Mount Gambier and the Naracoorte areas, was published by Sprigg (1952). Glaessner (1953a, b) and Ludbrook (1957, 1958) discussed the Gambier Limestone within a broader tectonic framework. The structure of the southeastern part of South Australia and the adjoining part of Victoria was dealt with in more detail by Sprigg and Boutakoff (1953), while the correlation and age of the Gambier Limestone has been discussed most recently by Glaessner (1959).

The earliest references to the fossils within the Gambier Limestone are those of Busk (1860) and Parker and Jones (1860), listing some of the Bryozoa and the Foraminifera, respectively. Apart from some of the already mentioned papers by Woods, early works dealing with the fauna within the limestone include publications by Woods (1877), Etheridge (1876, 1878), Tate (1880, 1886, 1891) and Waters (1882).

Most of the generic nomenclature in these works has been subsequently revised or needs revision.

More recently, Ludbrook (1958) listed some of the most common fossils in the Gambier Limestone. Other recent works, describing and figuring selected macrofossils from the formation, are those of McGowran (1959), Brown (1958) and Glaessner (1955).

The physiography of the southeastern part of South Australia has been dealt with by Sprigg (1952), Hossfeld (1950) and, on a smaller scale, by Tindale (1933). For information concerning the hydrology of the Mount Gambier area, and the Murray Basin in general, O'Driscoll (1961), Ward (1941, 1946) and Shepherd (1959) should be consulted. Commercial uses of the Gambier Limestone were described by Jack (1923) and Dickinson (1951), while Cochrane (1952a, b) has written on the dolomitization of the limestone in the Mount Gambier area.

The most useful geological maps covering the area under consideration are the Gambier and Northumberland (1 mile Geological Series) sheet by Sprigg and Cochrane (1951) and the Penola (4 mile Geological Series) sheet by Sprigg, Cochrane and Solomon (1951).

The latest work of O'Driscoll (1961) and Ludbrook (1961), dealing with the general hydrology and stratigraphy, respectively, of the Murray Basin, was published too late to be considered fully by the present author. However, occasional references to these two publications are made in this thesis.

II TECTONIC FRAMEWORK

The tectonic framework of the area occupied by the Gambier Limestone is outlined to facilitate discussion in the subsequent sections of this thesis. The main features mentioned below are indicated on Map 1.

Sprigg (1952) was the first to formally divide the Murray Basin into a large northern part, the Murray Basin proper, and a smaller southern part, the Gambier Sunklands. An area of sporadically outcropping Paleozoic granites and relatively shallow bedrock intervenes between the two. This was named by Sprigg the Padthaway Horst or, since it extends in a southeasterly direction towards the Dundas Highlands in Victoria, as the Padthaway-Dundas Horst; O'Driscoll (1961) referred to it as the Padthaway Ridge. Boutakoff (1952) subdivided the Gambier Sunklands as defined by Sprigg into a northwestern, South Australian part - the Gambier Sunklands (sensu stricto) and a southeastern, Victorian part, named the Portland Sunklands. The two are separated by the Dartmoor Ridge. Apart from O'Driscoll (1961), the structure of the Murray Basin as a whole was most recently outlined by Ludbrook (1958), while Sprigg and Boutakoff (1953) have discussed the Gambier Sunklands in greater detail.

The Gambier Sunklands differ from the Murray Basin in containing a greater thickness of sediments, indicating more rapid subsidence during deposition. The sunklands represent a basin trough in the sense of Weeks (1952), while the Murray Basin proper corresponds with the basin shelf or foreland shelf, and the Padthaway Ridge with the basin hingebelt of Weeks.

Little is known about the structure of the Murray Basin proper. Its boundary with the Padthaway Ridge extends approximately along the Adelaide - Melbourne railway line. This boundary was inferred by Sprigg (1952, fig.3) to be faulted; O'Driscoll (1961) did not accept such a postulation. The boundary between the Padthaway Ridge and the Gambier Sunklands is considered to be faulted a little to the southwest of a line joining Kingston and Naracoorte (along the Lucindale Fault of O'Driscoll); further southeast in Victoria the boundary is formed by the Kanawinka Fault.

A major fault, referred to either as the Kanawinka Fault (Sprigg, 1952, fig.6) or the Naracoorte Fault (Sprigg, 1952, fig.3), cuts across the Padthaway Ridge to the northwest and southeast of Naracoorte. Until recently, this fault has been regarded as continuous with the Kanawinka Fault in Victoria; according to O'Driscoll (1961) it is truncated by the Lucindale Fault (as also indicated on the Tectonic Map of Australia, 1960). To avoid confusion, the fault passing near Naracoorte is referred to as the Naracoorte Fault in this thesis (see Map 1).

The structural pattern of the Gambier Sunklands is one of block faulting, warping and gentle folding along intersecting lines of weakness. Faults along such lines have been intermittently active, in some cases probably with reversal of movement, since at least the Mesozoic.

The majority of faults in the Gambier Sunklands have either an approximately northwest to southeast or northeast to southwest direction, with the former the more dominant. The most important faults affecting the position of the base of the Gambier Limestone are the Kanawinka Fault and the Tartwaup Fault. The latter belongs to the "Tartwaup - Swan Lake - Bridgewater relay system of step faults" (Sprigg and Boutakoff, 1953, p.48) with downthrow to the southwest. The Nelson Fault also belongs to this system; other faults in the Mount Gambier area are less prominent or only inferred. The northeast to southwest trending group of faults are not well developed in South Australia. In Victoria, the Kentbruck-Jones Ridge - Drik Drik line of faults form the boundary between the Normandy Platform to the east and the extensive coastal plain, the major part of which occupies the South Australian part of the Gambier Sunklands.

III LITHOLOGY

GENERAL

The following remarks apply only to the Gambier Limestone outcropping in the areas mentioned on p.ii . Larger scale lateral changes in the lithology of the formation are discussed on p. .

The Gambier Limestone consists of poorly bedded calcirudites, calcarenites and calcisiltites (terminology as in Pettijohn, 1957, pp.401, 408). Except in the case of the calcisiltites, the individual particles constituting the rock are mainly fossils or recognizable fossil fragments. An outstanding character is the usually very marked predominance of bryozoal skeletons over other fossil remains. The Bryozoa are abundant throughout the limestone, while other macrofossils, mainly pelecypods, echinoderms and brachiopods, are common in beds of restricted thickness. Variation in the relative proportion of Bryozoa to the larger macrofossils on one hand, and the comminuted, mostly unidentifiable calcite particles on the other, is associated with variation in the overall grain size of the rock constituents. Microfossils, of which the Foraminifera decisively outnumber the ostracods, are rather common throughout the limestone, but are more abundant in fine-grained rock.

MOUNT GAMBIER AREA

In a few quarries in this area (e.g. at localities E 50, E 54 and E 40) the Gambier Limestone is represented by beds not uncommonly containing abundant large macrofossils, including coarse Bryozoa. Generally such strata are rare, and the limestone consists of fine bryozoal calcirudites, calcarenites and calcisiltites. The lithology of the rock at the two extremes of the variation in average grain size is described below.

The coarse extreme (ignoring beds containing abundant large macrofossils) is exemplified by the limestone quarried as building stone in Pritchards' and adjoining quarries (e.g. at localities E 41, E 42, E 82 and E 83). The building stone is a white, fine calcirudite or coarse calcarenite composed mainly of fragmental bryozoal skeletons (plate 3, fig.2). The latter are predominantly of the arborescent, twig-like type, with a much smaller proportion of spreading Retepora and similar tests, and massive, sometimes branching Cellepora. Other macrofossils, chiefly pelecypods, brachiopods and echinoids, are considerably less common than the Bryozoa. The large macrofossils usually lie roughly parallel with the bedding planes, while the smaller bryozoal fragments show only a vague parallel orientation or none. The interstices between the bryozoal fragments are partly filled with smaller, mostly unidentifiable fossil fragments and Foraminifera. Only a very small fraction of the rock consists of particles, which are individually unrecognizable at a 100x magnification, i.e. are smaller than about 0.005mm, in thin section (plate 5, fig.2).

The building stone is moderately well sorted, and has a porosity of up to 50% or slightly more.

The building stone usually is not extensively recrystallised, but sufficient cementation has taken place to form a comparatively coherent rock. The angularity of the constituent fragments is partly the reason for the ability of the rock to withstand comparatively high compression stresses (up to more than 600 lbs/sq. inch; Sved, 1957). In thin section, the outlines of most of the bryozoal skeletons appear quite sharp, but they may be slightly blurred by the growth of small, anhedral calcite crystals. Growth of such crystals is somewhat more prominent inside fossil tests and in small interstices between particles. Sometimes the limestone is more extensively recrystallised and cemented.

The building stone is rather homogeneous, with poorly developed stratification. The latter can be traced in quarry walls by means of beds up to about a foot thick, which consist of roughly parallel, anastomosing thinner bands (plate 1, fig.2). Such thinner bands are characterised by streaks and blobs of recrystallised calcite, which are smooth in contrast to the generally rough surface of the bryozoal limestone in quarry walls. These beds often possess relatively abundant solution cavities and are sometimes brownish in colour due to iron-staining. They are also coarser, contain more of the larger macrofossils, and were at least originally more permeable than the rest of the limestone. In a continuous quarry wall such beds can be followed for a considerable length laterally, but if quarry walls are discontinuous or obscured, the identity of individual beds is lost.

The other extreme of the variation in average grain size in the Gambier Limestone is exemplified by the "chalky" calcisiltites and fine calcarenites typically exposed in quarries and sink-holes in the vicinity of Port Mac Donnell. Apart from the difference in grain size, this type of limestone differs from the building stone mainly in containing a considerably smaller proportion of recognizable bryozoal fragments as compared with comminuted unidentifiable skeletal particles and foraminiferal tests (plate 3, fig.1). Unfilled interstices between the constituent particles, which are orientated at random, are consequently smaller. The bulk of the fine calcite fragments can be recognized as individual particles at a 100x magnification, i.e. are larger than about 0.006mm, in thin section (plate 5, fig.1), and the limestone is not a calcilutite, as may appear to the naked eye. Large, relatively rare macrofossils are distributed at random within the rock or are more common in certain beds. Degree of recrystallisation and cementation is not notably different from that observed in the building stone, but commonly the fine-grained limestone is more friable than the latter. Stratification is generally poorly developed, but is sometimes well expressed by flint bands, extensively recrystallised layers or rows of solution cavities (plate 2, fig.2-4).

Limestone in different exposures or in different beds at the same exposure in the Mount Gambier area may represent any point within the range of continuous lithological variation between the two extremes described above. Few exposures exhibit only one or the other of the extreme types of the limestone. In most, relatively coarse beds alternate with fine beds, with interstratal boundaries usually transitional, rarely sharp. Lateral changes in average grain size and sometimes in thickness of individual beds can also be observed in horizontally extensive exposures.

The limestone outcropping in the vicinity of Mount Gambier and to the west and northwest of it is generally coarser than the outcrops in the coastal area, especially near Port Mac Donnell. However, different exposures within each area vary considerably as to which lithological extreme is predominant, and no mappable units can be established in the Gambier Limestone on purely lithological grounds.

In rare exposures, e.g. at locality E 53 (plate 2, fig.1), soft, friable layers alternate with thin, sharply differentiated laminae of hard recrystallised calcite. At locality E 27 certain beds are characterized by roughly spherical or more irregularly shaped calcite concretions, which vary up to about 10 cm in size.

NARACOORTE AREA

The Naracoorte Limestone Member consists of yellow to cream or whitish, often rubbly calcirudites and coarse calcarenites (plate 1, fig.4). While generally Bryozoa are predominant, other macrofossils (pelecypods, gastropods, brachiopods and echinoderms) are considerably more common than in the Gambier Limestone sensu stricto. Such other macrofossils and large Bryozoa, e.g. Cellepora and Retepora, are especially abundant in occasional beds of restricted thickness. Sometimes such fossils are the predominant rock constituent, as in the coarse bed of largely disarticulated Chlamys shells at the base of the Naracoorte Limestone Member in James' quarry at Naracoorte (plate 1, fig.3). The macrofossils usually occur as broken, large or small fragments without a noticeably parallel orientation (plate 4, fig.1). Spaces between the larger fossils are filled or partly filled with finer, broken Bryozoa and other fragments, with some, but often very little, finely comminuted, unidentifiable calcite particles.

The average grain size of fossil debris in different strata of the Naracoorte Limestone Member is rather variable. Generally the member is coarser and, unless extensively cemented, more permeable than the limestone in the Mount Gambier area; however, in some, often laterally variable beds, it approximates the Gambier Limestone sensu stricto in grain size. The finest strata of the Naracoorte Limestone Member are certainly finer than the coarsest limestone beds in the Mount Gambier area. Usually, however, the bryozoal fragments in such strata at Naracoorte are more broken and worn, and do not exhibit the often delicate, twig-like appearance of most of the Bryozoa in the building stone.

Stratification, due to differences in size of constituent particles of successive beds, is rather indistinctly developed. It may be emphasized by variation in the colour of the strata, caused by different degrees of iron-staining, and also by different degrees of recrystallization, cementation and resulting hardness of the rock. Generally the Naracoorte Limestone Member is considerably more iron-stained and recrystallized than the Gambier Limestone *sensu stricto*. On the whole, the coarser the grain size, the more iron-stained and recrystallized is the limestone. However, individual beds often vary laterally in these characteristics, which may be only partly correlated with each other, and may vary haphazardly with respect to bedding planes.

The Gambier Limestone *sensu stricto* at the lower level of James' quarry is generally finer-grained, more evenly textured, less recrystallized, less cemented, less iron-stained and softer than the Naracoorte Limestone Member at the upper level. On the whole, it is lithologically somewhat intermediate between the Naracoorte Limestone Member and the building stone in the Mount Gambier area.

DOLOMITE

The distribution, appearance and chemical composition of dolomite in the Mount Gambier area has been described by Jack (1923) and, in greater detail, by Cochrane (1952a, b). The chief occurrences are at the Up and Down Rocks (near Tantanoola), the large area to the north and south of the railway line near Burnda siding, and along the Nelson Fault in the southeastern corner of South Australia. Minor occurrences are more wide-spread. The dolomite varies from pink to yellowish, greyish or white in colour, and is commonly hard and dense. Chemical analyses (Cochrane, 1952b) show the amount of $MgCO_3$ present in extensively dolomitized rock to vary between 35% and 39%. In thin section, the fairly large dolomite crystals are anhedral or rhombohedral in shape.

The dolomitization usually appears to be associated with proved or inferred faults. It is not restricted to definite stratigraphical intervals, but has a haphazard distribution in the limestone with respect to the bedding.

CHERT

Chert has been observed only in the Mount Gambier area, never in the Naracoorte region. Almost black to light grey chert occurs in layers, which are usually up to about one foot thick (plate 2, fig.4). Such layers are parallel or roughly parallel with bedding planes in the limestone, and consist of separate nodules, often irregular in shape, or of a joined network of chert masses. The nodules are homogeneous or concentrically banded. In thin section, the lighter coloured bands appear to be less silicified than the darker. The central grey mass of a nodule often shows a sharp boundary with the surrounding white rock, which in the vicinity of the boundary appears to be only slightly less silicified than the inner part of the nodule. Sometimes another sharp, dark line surrounds both the grey central mass and its white "skin". The chert nodules commonly contain unsilicified fossils surrounded by, and sometimes infilled with, crystalline silica. The unsilicified fossil fragments exhibit the same mutual textural relationships as those in the surrounding limestone.

In the quarry at locality E 97 chert nodules up to about four feet in size and highly irregular in shape, often like tree-trunks with sawn-off limbs, are present. Not uncommonly they possess hollow middles, which may contain unsilicified bryozoal limestone.

Chert nodules were observed <u>in situ</u> only in calcisiltites and fine calcarenites. Their occurrence is not restricted within a certain stratigraphic interval in the Gambier Limestone.

INSOLUBLE RESIDUES

Three representative samples of the limestone were dissolved in hydrochloric and acetic acids. The percentage by weight of the insoluble residue is as follows (there is no appreciably significant difference between the values obtained for the two acids used):

Calcirudite (Naracoorte Limestone Member, sample E 2)

1.7%

Coarse calcarenite (building stone, sample D43, locality E 53)	1.0%
calcisiltite (sample E 43)	0.6%

Pale to dark brown or reddish-brown clay is the predominant constituent of the insoluble residue. The most common microscopically recognizable mineral grains are, in order of abundance, quartz, glauconite, felspar, mica and black ferromagnesian grains.

Quartz grains range up to about 1 mm, rarely more, in size. The larger grains, more common in the Naracoorte Limestone Member than in limestone in the Mount Gambier area, are fairly well rounded or subangular. They are often polished and translucent, but may be somewhat frosted or, rarely, iron-stained. The smaller grains are more angular than the larger.

Glauconite occurs mainly as small, dark to pale green grains, which are round, elongate or irregular in shape. Cracks are usually present on grain surfaces. A number of grains are obviously internal moulds of Foraminifera or parts of bryozoal skeletons. Very rarely larger lumps of glauconite, including unreplaced calcite tests and particles, occur in the limestone. In one instance, the glauconite is irregularly disseminated throughout a fragment of the rock. Sometimes the glauconite has been altered to limonite.

Felspar is present as small, whitish, angular grains. Thin flakes of mica and, very rarely, black particles of ferro-magnesian minerals also occur in the insoluble residues.

A few pale brown or yellowish, ovoid faecal pellets were found in undissolved limestone. They range up to about two millimetres in size, and possess no internal structure.

CHEMICAL COMPOSITION

Results of full or partial chemical analyses of samples of undolomitized Gambier Limestone have been published by Jack (1923), Reed (1957) and Madigan (1957). In all cases $CaCO_3$ + $MgCO_3$ exceeds 95%, sometimes being greater than 99%. Small amounts of SiO_2, Al_2O_3 and Fe_2O_3, and very small amounts of MnO, P_2O_5, SO_3, Na_2O, K_2O, TiO_2 and Cl are also present.

IV STRATIGRAPHY

LITHOSTRATIGRAPHY

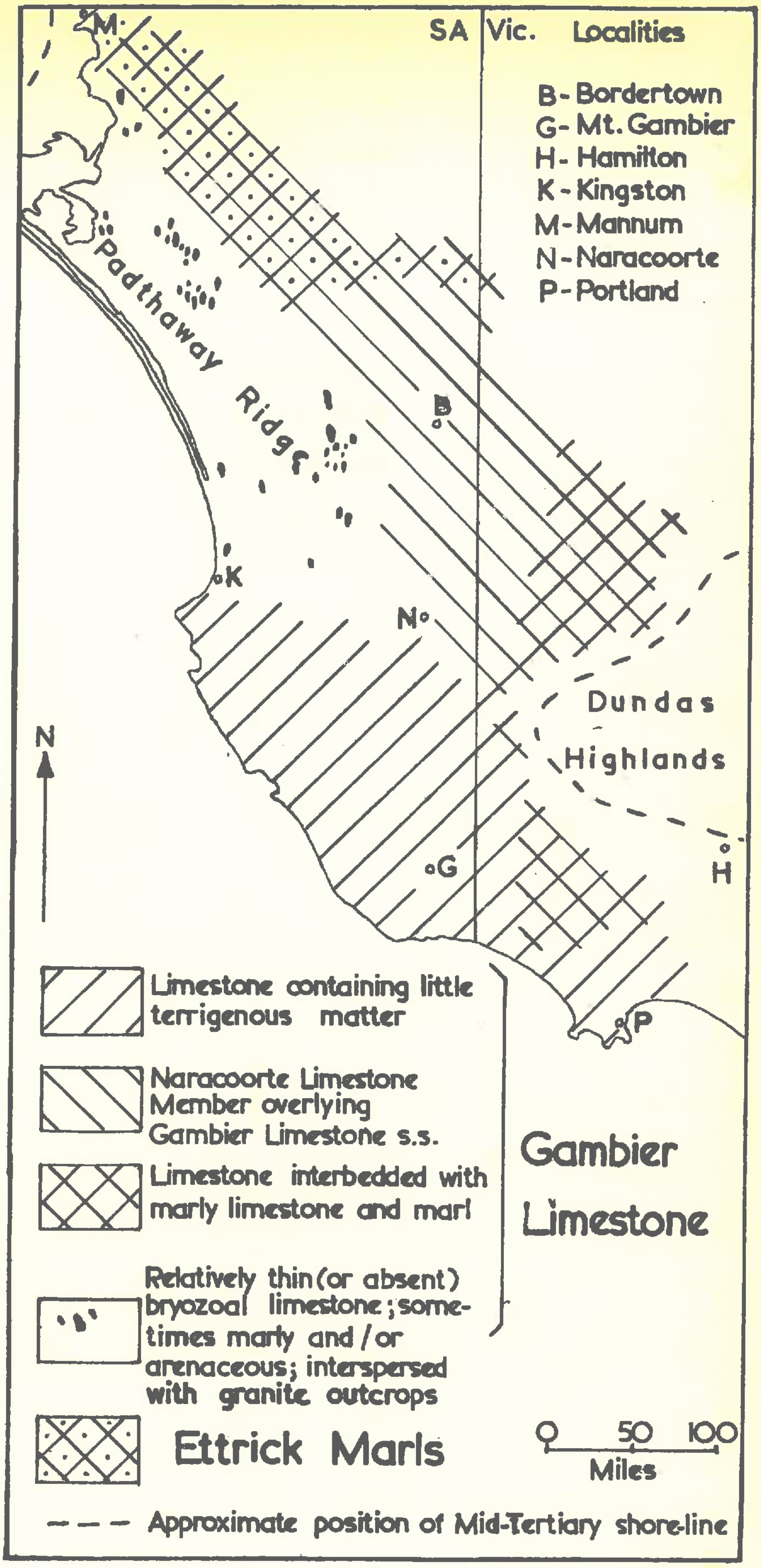
Base of the Gambier Limestone

The base of the Gambier Limestone in South Australia is exposed only in Knight's quarry near Compton, about four miles north-west from Mount Gambier (locality V 118). Here the Compton Conglomerate overlies, with a slight angular unconformity, the clays, sands and gravels of the Knight Group (plate 1, fig. 1). The Compton Conglomerate at its only exposure is a ferruginous, silicified conglomerate about one and a half feet thick. It passes upwards transitionally into the Gambier Limestone, which in Knight's quarry is comparatively coarse, considerably iron-stained and contains occasional large quartz grains. Equivalents of the Compton Conglomerate in bores elsewhere are from 10 to 30 feet thick and in some areas overlie the Buccleuch Beds (Ludbrook, 1957, p.177). Near Coonalpyn rather arenaceous lithological variants of the Gambier Limestone rest transgressively on outcrops of early Paleozoic granite (Chapman, 1943).

The base of the limestone in Victoria is exposed along the Glenelg River in the vicinity of Dartmoor and near Casterton (Kenley, 1951). At Dartmoor the limestone overlies lignitic sands and clays of the Dartmoor Formation (Sprigg and Boutakoff, 1953), equivalent to the upper part of the Knight Group, while near Casterton it rests on ferruginous grits and clays. In the Nelson bore, near the southwestern corner of Victoria, the Gambier Limestone passes downwards into the Nelson Sandstone, which consists of 174 feet of brown to green glauconitic sandstones and fossiliferous grits (Crespin, 1954). The Nelson Sandstone is considered to rest unconformably on lignitic strata belonging to the Knight Group.

Lateral extent

The lateral extent and changes in lithology of the Gambier Limestone are known mainly from the rather scant subsurface data available (see text-fig.1). "Its equivalents in the deeper parts of the Murray Basin proper are more clayey and probably less porous, and are distinguishable in bores from the overlying sediments (into which they grade upwards) by their microfauna and the presence of glauconite which increases in abundance towards the base." (Ludbrook, 1958, p.108). "On the western edge of the [Murray Basin]... from Mannum southeast to Coomandook a series of glauconitic marls and sandy marls, known only from borings, replaces the Gambier Limestone. With a normal thickness of between 70 and 100 feet, they are named the Ettrick Marls from their type subsurface section in Hundred of Ettrick, section 21." (Ludbrook, 1958, p.109). The most westerly area in which bryozoal limestones, considered to belong to the Gambier Limestone, have been recorded is near Lake Alexandrina (de Mooy, 1959, p.100).



Text-fig.1. Facies distribution within the Gambier Limestone

In the Naracoorte area, the upper part of the Gambier Limestone is formed by the Naracoorte Limestone Member, which is separated from the underlying Gambier Limestone sensu stricto by a diastem. The writer agrees with Ludbrook (1957, p.177) that "Neither the megafauna... nor the microfauna... nor the physical characters of the" Naracoorte Limestone Member warrant its recognition "as a separate formation from the Gambier Limestone." This member has not been observed as an individual rock unit to the south of the Kanawinka Fault. To the north, according to Ludbrook (1958, fig.21), the Gambier Limestone sensu stricto and the Naracoorte Limestone Member pass laterally into the Ettrick Marls and a "marly limestone", respectively, about halfway between Bordertown and Pinnaroo.

In Victoria, bryozoal limestones have been recorded in bores in the Wimmera region to the east of Bordertown and also near Horsham (Dennant, 1902). Detailed knowledge of their lithology and stratigraphy is lacking. In the Goroke-Edenhope district, some 30 to 40 miles east of Naracoorte marine limestones continuous with the bryozoal limestone in South Australia outcrop at isolated localities. "Over a large section of this district, it seems as though the polyzoal limestones... have been replaced, due to lateral variation, by clays and marls." (Stinear, 1948, p.23). Bryozoal limestone also outcrops in the vicinity of Dergholm and along the Glenelg River below Casterton. The equivalents of Gambier Limestone exposed in the Dartmoor area generally contain more terrigenous material than in the vicinity of Mount Gambier. They consist of bryozoal limestones, marls and clays, not uncommonly with flint beds.

Crespin (1954) divided the sequence of unaltered and altered bryozoal limestones penetrated in the Nelson bore into two unnamed members. "The lower member extends from 812 feet up to 635 feet and consists of grey and white, friable to hard, bryozoal marly limestone. The upper member is found from 625 up to 108 feet (the highest sample in the sequence...) and consists of crystalline lime-stone, grey flint, bryozoal limestone and marly limestone". (Crespin, 1954, p.25-26). These members can not be differentiated in the limestone outcropping in the Mount Gambier area.

At Portland, Victoria, the exposed limestone is mainly a bryozoal calcisiltite with thin coarser beds. In bores, limestone strata alternate with marly beds, and between 2,040 and 2,065 feet the limestone is rich in glauconite (Stinear, 1948, p.29). Bores at Heywood, about 15 miles to the north, have also penetrated bryozoal limestone and marl (Kenny, 1939). Near Hamilton at least 250 feet of Tertiary limestone are present, the lower part of which is presumably formed by equivalents of the Gambier Limestone.

Because of the lack of detailed subsurface data, the landward boundary of the Gambier Limestone cannot be accurately drawn. In South Australia it coincides approximately with the boundary between the

Padthaway Ridge and the Murray Basin. To the north of this line the Gambier Limestone is replaced by named and unnamed formations with a generally more terrigenous composition. Similar lithological changes in the Gambier Limestone have been observed as it approaches the Dundas Highlands in Victoria. As stratigraphical knowledge increases, argillaceous equivalents of Gambier Limestone may be assigned different formational or member names, as has been done in the case of the somewhat younger Muddy Creek beds, which were divided by Gill (1957a) into the Bochara Limestone and the overlying Muddy Creek Marl. There is no sufficient reason for assigning a different formational name to the bryozoal limestone at Portland, called Mount Gambier Formation by Victorian geologists (Sprigg and Boutakoff, 1953, correlation chart facing p.52).

Upper boundary

The upper boundary of the Gambier Limestone is marked by an unconformity, with the possible exception of the border area between the Padthaway Ridge and the Murray Basin. Where it does not outcrop at the surface, the limestone in the Mount Gambier and Naracoorte areas is covered by Pleistocene or Recent sediments. The Pleistocene sediments consist mainly of aeolianite dunes and associated deposits (Hossfeld, 1950; Sprigg, 1952). In a few bores near Kingston and Tintinara, Werrikooian (basal Pleistocene; Gill, 1957b) sediments are stated to overlie the Gambier Limestone (Sprigg and Boutakoff, 1953). According to Ludbrook (1958, fig.21), to the north of Bordertown the Naracoorte Limestone Member is covered unconformably by the Loxton Sands or conformably by the Morgan Limestone.

In Victoria, the equivalents of the Gambier Limestone in the vicinity of Dartmoor are overlain by the Werrikoo Member of the Whaler's Bluff Formation (Sprigg and Boutakoff, 1953). At Portland, the bryozoal limestone is covered by the Maretimo Member of the same formation. The Maretimo Member underlies the Werrikoo Member in this area. Gill (1957b) referred to both the Werrikoo and the Maretimo as formations, and considered their contact to represent the Pliocene-Pleistocene boundary. In the Hamilton district, the equivalents of the Gambier Limestone are presumably overlain by the Bochara Limestone (Gill, 1957a) in subsurface sections. (At its exposure, the Bochara Limestone rests partly on porphyry). Kalimnan (Lower Pliocene) sediments are known only from the vicinity of Hamilton. Further subsurface data may show them to be more widely distributed in the Gambier Sunklands.

Glenelg Group

Nelson Sandstone, Gambier Limestone (including the limestone at Portland) and the Muddy Creek beds (Bochara Limestone and Muddy Creek Marl) were included within the Glenelg Group by Sprigg and

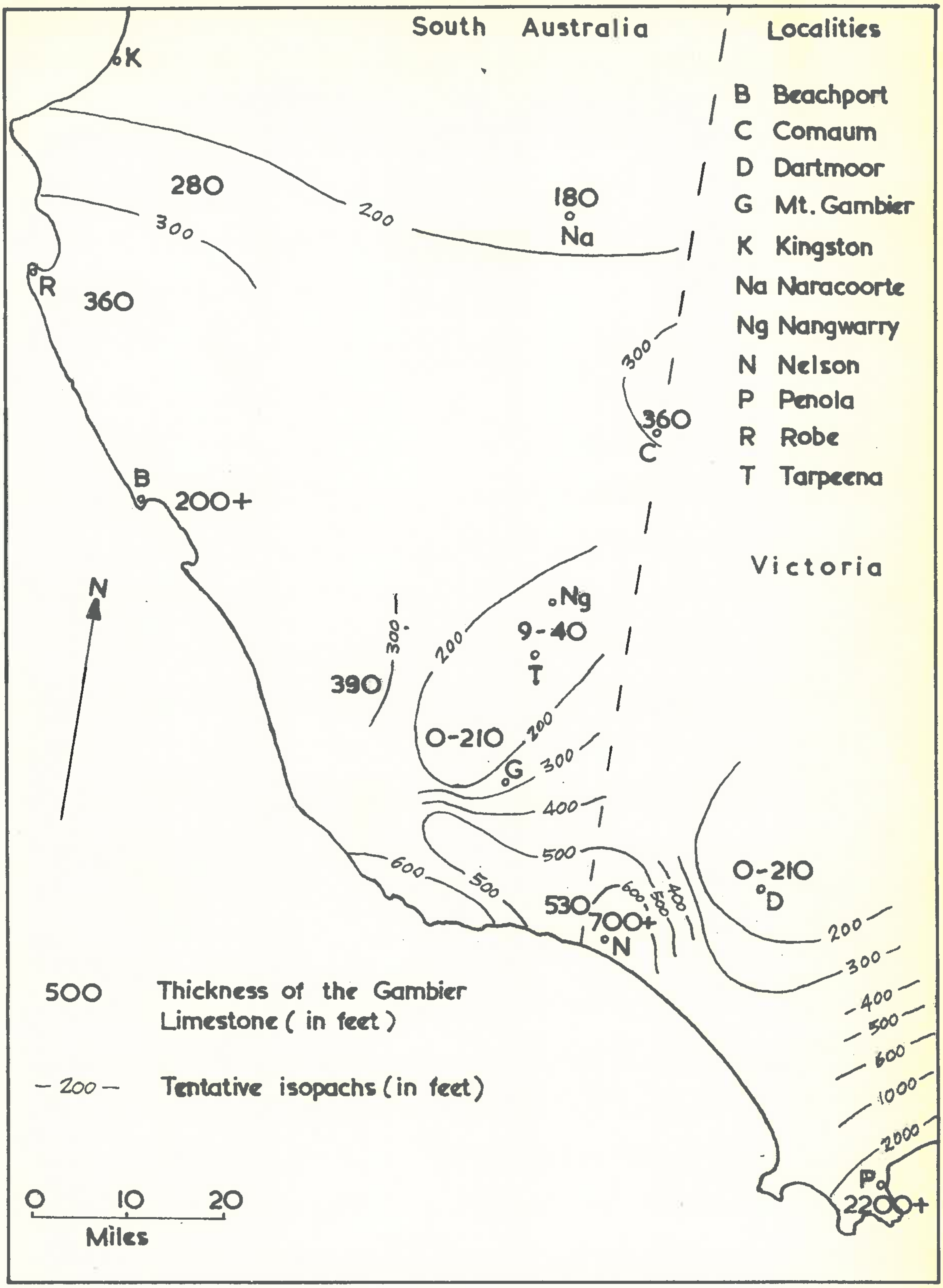
Boutakoff (1953). Subsequently the Compton Conglomerate and the Ettrick Marls were assigned to this group by Ludbrook (1957).

Thickness

The preserved thickness of the Gambier Limestone and its equivalents at different localities, as known from bore data, has been tabulated and briefly discussed by Sprigg and Boutakoff (1953). The available data are plotted in text-fig.2 of this thesis, and tentative contours indicating lateral variation in the preserved thickness of the Gambier Limestone are drawn.

The maximum thickness of the formation in South Australia is attained in the southeastern corner of the State, in the South Australian Oil Wells Co. no.1 bore in Hundred of Caroline, section 337, where bryozoal limestone was recorded between 0 and 533 feet. The limestone thins towards Mount Gambier and in the area a few miles to the northwest of it, where a number of bores have been drilled, the Gambier Limestone varies in thickness between 0 and slightly over 200 feet. The unit thickens again towards Millicent, reaching 392 feet in the South Australian Oil Wells Co. bore near Tantanoola, in Hundred of Hindmarsh, section 195. Further northwest it is more than 200 feet thick at Beachport, 363 feet thick in the Robe bore and 282 feet thick in a bore in Hundred of Bowaka, section 195.

To the north of Mount Gambier, the limestone varies in thick-



Text - fig. 2. Thickness of the Gambier Limestone ness between 9 and 40 feet in bores between Tarpeena and Mangwarry. The axis of this area of reduced thickness agrees with the approximately northeast trending axis of Quaternary upwarp discussed by Sprigg (1952, fig.9; see also p. 71 of this thesis). In the Comaum bore the limestone is about 360 feet and in the Naracoorte bores no.1 and 2, 179 feet thick.

Over the Padthaway Ridge the thickness of the Gambier Limestone does not approach the maximum values attained in the Gambier Sunklands. The formation is especially thin, sometimes absent, over the northwestern part of the ridge, the "shallow or outcropping horst" of Sprigg (1952, fig.3). Even in the southeastern part, the "buried horst" of Sprigg, its thickness has not been observed to exceed 200 feet.

In Victoria, the Gambier Limestone is more than 700 feet thick in both the Nelson bore and in the Pt. Addis Co. bore a few miles to the north. At Portland, the thickness of bryozoal limestones and marls exceeds 2,000 feet. The thickness of the limestone along the coast between these two localities is unknown, but the unit thins considerably towards Dartmoor, varying between 0 and 211 feet in thickness in that area. The Gambier Limestone and its equivalents generally thin, and eventually disappear, towards the Dundas Highlands in Victoria.

According to Ludbrook (1958, fig.21), the maximum thickness of the Naracoorte Limestone Member, as recorded in bores, is about

100 feet.

FAUNA

Only the Foraminifera in the Gambier Limestone were studied in detail, since an investigation of their distribution was considered as most likely to yield biostratigraphically important results in the time available. Systematic descriptions of the foraminiferal species occupy a subsequent part of this thesis.

A systematic study of the macrofossils and the ostracods was regarded as beyond the scope of this work. Some, including the more common of the macrofossils in the Gambier Limestone, are listed below. Their generic nomenclature has been revised in most cases, but not in all, by recent workers.

Phylum Bryozoa

The most conspicuous bryozoan present is Cellepora gambierensis Busk. A list of about thirty generically revised species occurring in the limestone in the Mount Gambier area is given by Brown (1958).

Phylum Echinodermata

Monostychia australis Laube, Echinolampas gambierensis Woods, Lovenia forbesi Woods, Eupatagus murrayensis Woods, Scutellina patella Tate, Scutellina morgani Cotteau, Holaster australiae Duncan, Micraster archeri (Woods).

Phylum Brachiopoda

Magellania crouchi (Woods), *Murravia catinuliformis* (Tate), *Magadina tenisoni* (Woods), *Magadina woodsiana* (Tate), *Waldheimia grandis* Woods, *Waldheimia imbricata* Woods.

Phylum Mollusca

Class Pelecypoda

Chlamys gambierensis (Woods), *Chlamys incerta* Woods, *Serripecten yahliensis* (Woods), *Limatula jeffreysiana* (Tate), *Glycimeris cainozoica* (Woods).

Class Gastropoda

Cypraea dorsata Tate, *Cypraea sphaerodoma* Tate, *Alcithoe heptagonalis* (Tate), *Pleurotomaria tertiaria* McCoy.

Class Cephalopoda

Aturia australis McCoy, *Eutrephoceras altifrons* (Chapman).

The whale *Squalodon gambierense* Glaessner occurs rarely in the Gambier Limestone. Penguin bones, sharks' teeth and crab appendages have also been found.

From the biostratigraphic viewpoint *L. forbesi* seems to be the most important among the macrofossils. It has been observed only in exposures belonging to either the intermediate or the uppermost zone in the Gambier Limestone (see p. 28).

BIOSTRATIGRAPHY

Foraminiferal zones

Since no continuous stratigraphic section in the Gambier Limestone is available for study, foraminiferal zones can be based only on species ranges established on a regional basis by Carter (1958a) and subsequently revised by Wade (1958). The presences or absences of four species serve as criteria for zones suitable for mapping and structural interpretation. These species are Victoriella conoidea (Rutten), Globoquadrina dehiscens (Chapman, Parr and Collins), Operculina victoriensis Chapman and Parr, and Globigerinoides bisphericus Todd. Other species with restricted time ranges (shown in table 1) are not sufficiently common for this purpose; they are useful as relative age indicators only for a few samples. The ranges of very rare species with stratigraphically restricted distribution are not shown in table 1.

Three foraminiferal zones are recognized in the Gambier Limestone (see tables 1 and 2). They are informally referred to as the lowest, the intermediate and the uppermost. The only conclusive criterion for referring limestone to the lowest zone is the presence of V. conoidea. The lowest zone corresponds with at least the upper part of the Victoriella plecte (= V. conoidea) zone of Carter (1959), which was first discussed by Glaessner (1951). Carter placed both

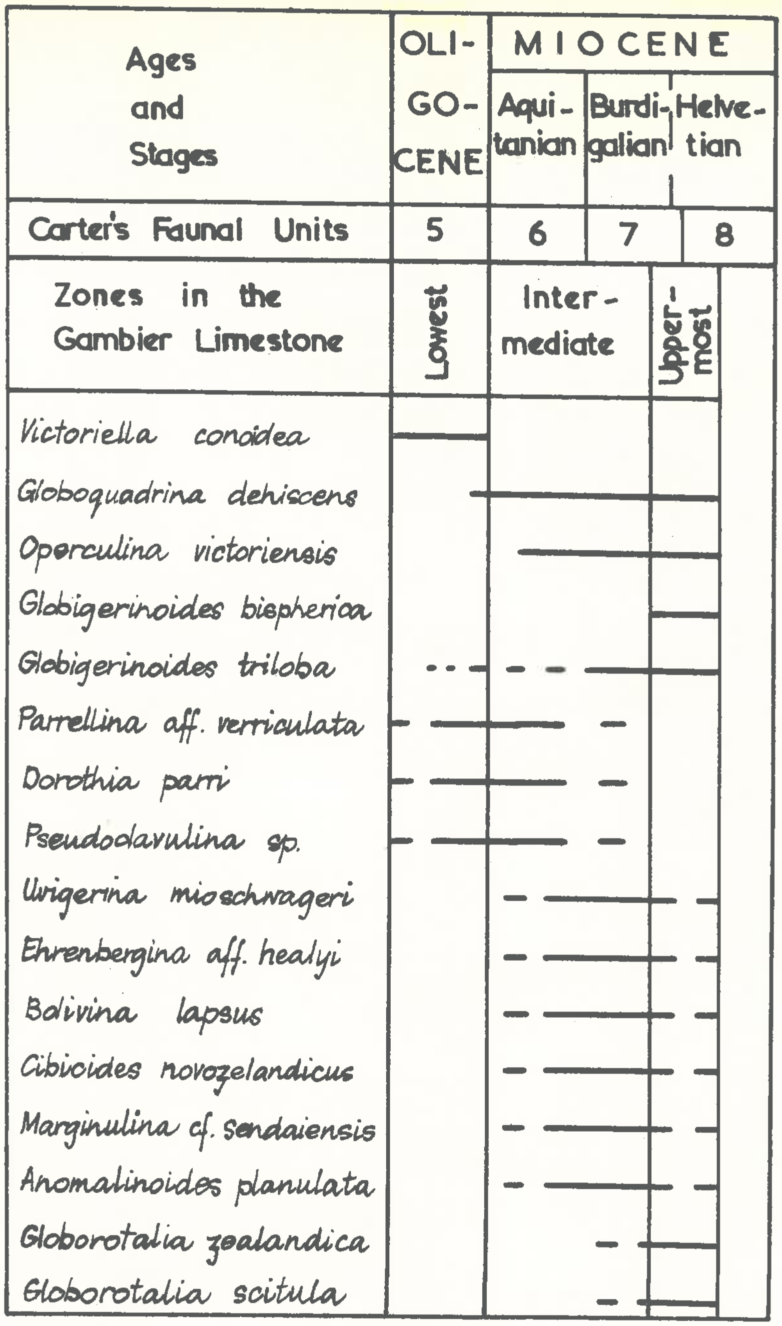


Table 1. Distribution of selected foraminiferal species in the Gambier Limestone

The zones in the Gambier Limestone are based on the observed distribution of the first four species (ranges in Carter's Faunal Units shown as revised by Wade) his Faunal Units 4 and 5 within this zone. Faunal Unit 4 cannot be distinguished in Gambier Limestone; the time of its deposition may be at least partly represented by the unconformity at the base of the Compton Conglomerate. The upper boundary of Faunal Unit 5 was considered by Carter to coincide with the top of the range of V. conoidea.

The intermediate zone is characterized by the presence of G. dehiscens and/or G. victoriensis in the absence of V. conoidea and distinctly developed G. bispherica. This zone corresponds to Carter's G. dehiscens zone and the lower part of his G. triloba zone, i.e. his Faunal Unit 6 and the lower part of 7, respectively.

The uppermost zone in the Gambier Limestone is recognised by the presence of distinctly developed G. bispherica, and corresponds to the upper part of Carter's G. triloba zone and, very likely, at least the lower part of his G. rubra zone (= Faunal Unit 8).

For the purpose of structural interpretation the foraminiferal zones are considered as time-stratigraphical units and their boundaries as synchronous or nearly synchronous horizons. Of the four species mentioned above only G. bispherica is considered as sufficiently common, and, because of its planktonic mode of life, unrestricted by differing ecological conditions, for its absence to be regarded as a reasonably safe indication that the strata are older than the beginning of the time range of G. bispherica. This horizon, as stated above, coincides by definition with the beginning of deposition of sediments of the uppermost zone.

The presence of the other species, but not their absence, serves as a fairly reliable age criterion, and even then it must be kept in mind that their local time ranges may be longer or shorter than is thought to be the case at present, and they may differ, due to different ecological conditions, from the corresponding ranges in other regions. V. conoidea is moderately rare, and its presence appears to have been controlled to a certain extent by ecological conditions, since it is absent in a number of samples considered for non-paleontological reasons (see below) to represent the lowest zone. It has been found together with G. dehiscens in a few samples, but never with O. victoriensis. Thus, some samples containing G. dehiscens, but not V. conoidea, may belong to the lowest and not to the intermediate zone, while this does not apply to samples containing O. victoriensis. Hence the boundary between outcrops representing the lowest and intermediate zones, respectively, can not be mapped as reliably as the boundary between the intermediate and the uppermost zones.

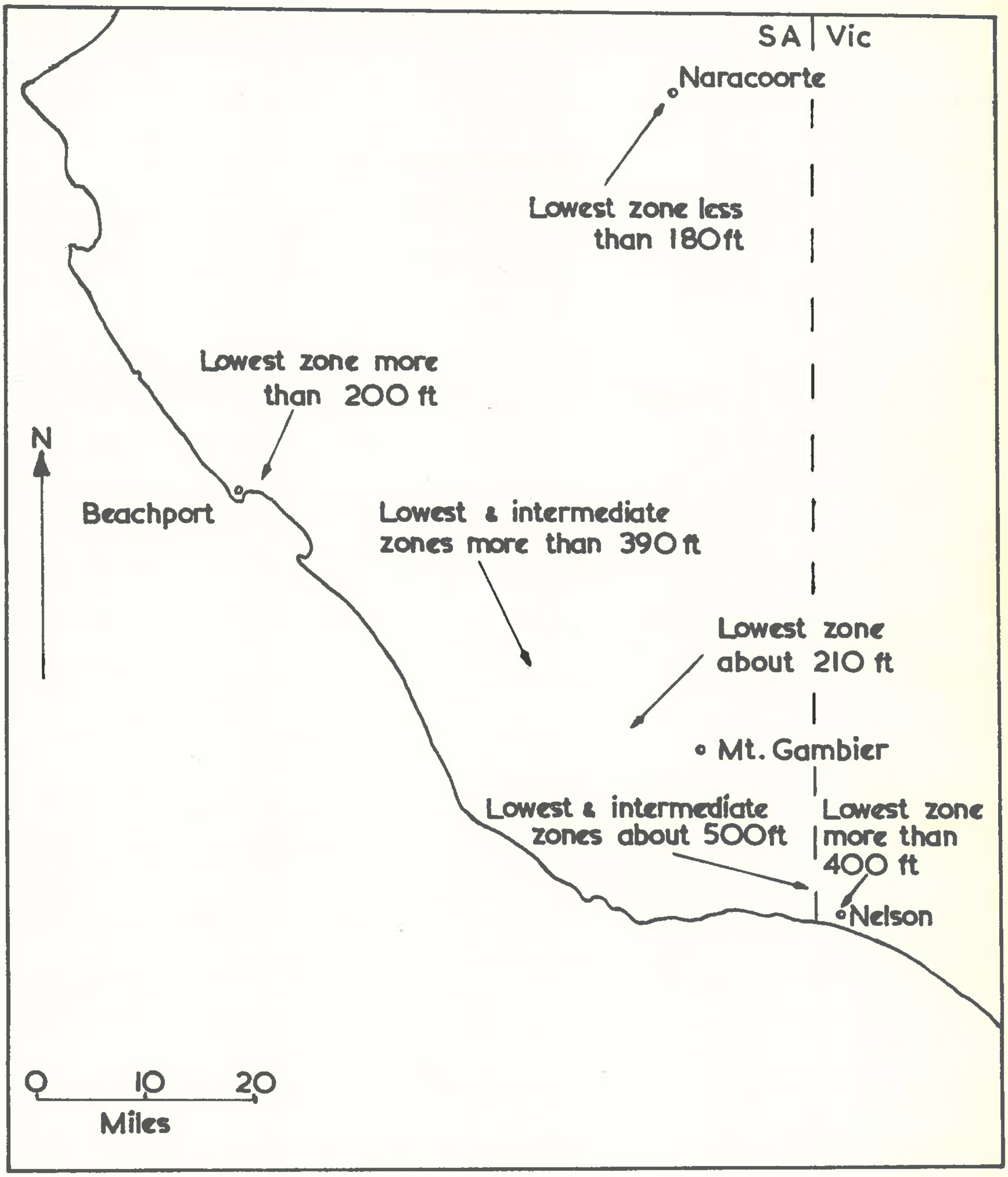
During mapping, a number of outcrop localities, represented by samples which cannot be allocated to any single one of the three zones on micropaleontological grounds, must be considered. They can be assigned to a zone, often with a high degree of probability, on the basis of their geographical location relative to neighbouring localities of determinable age.

The use of Carter's Faunal Units, rather than the three zones discussed above, is not a practical proposition for the Gambier Limestone. The upper boundary of the lowest zone coincides with the upper boundary of Faunal Unit 5 if the top of the range of V. conoidea is considered as the definitive criterion for the latter boundary. According to Carter, the lowest appearance of G. dehiscens occurs somewhat above the base of Faunal Unit 6. However, in the Gambier Limestone the time ranges of V. conoidea and G. dehiscens overlap slightly. Such overlap has also been noted in the case of the Port Campbell coastal section in Victoria by Wade (1958). The entry of G. triloba is stated by Carter to mark the boundary between Faunal Units 6 and 7. This boundary cannot be satisfactorily recognized in the Gambier Limestone, because the supplementary apertures of Globigerinoides are not uncommonly somewhat obscured, and no true distinction between variants of Globigerina ampliapertura Bolli and G. triloba can be made. Relatively few samples contain definite G. triloba while G. bispherica is absent, and the presence of at least a few distinctly developed G. bispherica is considered a more satisfactory criterion for the uppermost zone than the presence of G. triloba. According to Carter, G. bispherica makes its first appearance slightly above the middle of Faunal Unit 7. The boundary between Faunal Units 7 and 8 cannot be recognized in Gambier Limestone. G. rubra, the most important characteristic species of Faunal Unit 8, makes its entry only at about the middle of this unit. It does not occur in Gambier Limestone.

The subdivision of the three zones on the basis of presence or absence of other species with restricted ranges is not practical, since such species are not sufficiently common, and the extremities of their time-ranges not sufficiently well fixed. For example, the recognition of another zone, characterized by the presence of G. victoriensis in the absence of G. bispherica, does not add significant detail to structural interpretation.

Thickness of foraminiferal zones

The thickness of the individual foraminiferal zones can be estimated only very approximately, and they vary in different areas (see text-fig.3). The limestone outcropping at Naracoorte contains G. victoriensis and hence represents a stratigraphic interval some way above the base of the intermediate zone. Thus the thickness of the lowest zone at Naracoorte is considered to be less than the thickness of the Gambier Limestone recorded in the Naracoorte bores no.1 and 2 on the down-throw side of the Naracoorte Fault, namely, 179 feet. At Beachport a thickness of over 200 feet of Gambier Limestone has been penetrated by bores without reaching the base of the limestone.



Text - fig. 3. Thickness of foraminiferal zones in the Gambier Limestone

The presence of V. conoidea in the uppermost beds of the formation indicates that all the limestone belongs to the lowest zone.

In the Mount Gambier area, a thickness of 210 feet of Gambier Limestone was recorded in both the Springs bore (in Hundred of Blanche, section 150) and the Producers' Oil Wells Co. bore nearby. The nearest collected outcrop sample, from locality E 165 about a mile to the east, contains V. conoidea. Thickness of the limestone in the South Australian Oil Wells Co. bore (in Hundred of Hindmarsh, section 195) has been recorded as 392 feet. A surface sample from locality E 162, in the same section 195, contains Q. victoriensis, characteristic of the intermediate zone. Hence the thickness of the lowest zone in the area to the north-west of Mount Gambier is estimated to be at least about 210 feet and probably considerably less than about 390 feet. The latter figure can be regarded as being somewhat less than the minimum combined thickness of both the lowest and the intermediate zone in this area.

The Gambier Limestone is more than 500 feet thick in the South Australian Oil Wells Co. bores in the Hundred of Caroline, sections 336 and 337. The localities of these bores are close to the locality of outcrop sample E 46, belonging to the intermediate zone, and slightly further from locality E 45, where the uppermost zone is exposed. Thus it appears that the combined thickness of the intermediate and the lowest zones is about 500 feet in this area. The thickness of the Gambier Limestone in the Pt. Addis Co. bore about half a mile northwest of locality E 47, from which a sample representing the uppermost zone has been collected, has been recorded as 754 feet.

The highest sample of Gambier Limestone containing V. conoidea in the Nelson bore was collected at a depth between 360 and 390 feet (Crespin, 1954). Since the base of the limestone in the bore lies at 812 feet, or slightly deeper, the lowest zone is more than 400 feet thick. It cannot be determined from Crespin's foraminiferal lists whether the highest samples of Gambier Limestone collected in the bore belong to the intermediate or to the uppermost zone.

TIME-STRATIGRAPHY

Correlation

Glaessner has recently discussed the correlation of Tertiary strata in Australia and in the Indo-Pacific region, summarizing his conclusions in Table 1 (Glaessner, 1959). No additional data necessitating changes in those conclusions have come forth during the course of the present work, except that the base of the Naracoorte Limestone Member is placed somewhat above the base of Carter's Faunal Unit 6, since strata near the base of this member at James' quarry at Naracoorte contain O. victoriensis (see table I of this thesis). The time-stratigraphic relations of the Gambier Limestone in different areas are summarized in table 2.

Within the South Australian part of the Murray Basin, Glaessner correlated the base of the Naracoorte Limestone Member with the base of the Mannum Formation. The top of the latter was correlated with the top of the Gambier Limestone (in the Mount Gambier area), which is younger than the top of the Naracoorte Limestone Member. Glaessner did not refer to the Ettrick Marls in his Table 1. These marls were correlated with the whole of the Gambier Limestone sensu stricto and the lower part of the Naracoorte Limestone Member by Ludbrook (1957), who considered that all the limestone strata in the Mount Gambier area were older than the limestone at Naracoorte.

The Gambier Limestone in South Australia was correlated by Glaessner with the Port Willunga Beds in the St. Vincent Basin, the Clifton Formation and all but the uppermost part of the Gellibrand Clay in the Port Campbell section in Victoria, and the Calder River Limestone, the Upper Glen Aire Clay and all but the top part of the Fishing Point Marl in the Aire River district of Victoria.

The bryozoal limestone outcropping at Portland in Victoria contains Orbulina universa d'Orbigny, characteristic of Carter's Faunal Unit 11, and is thus considerably younger than the uppermost beds of the Gambier Limestone in South Australia. The lower strata of the thick bryozoal limestone and marl sequence pierced by bores at Portland con-

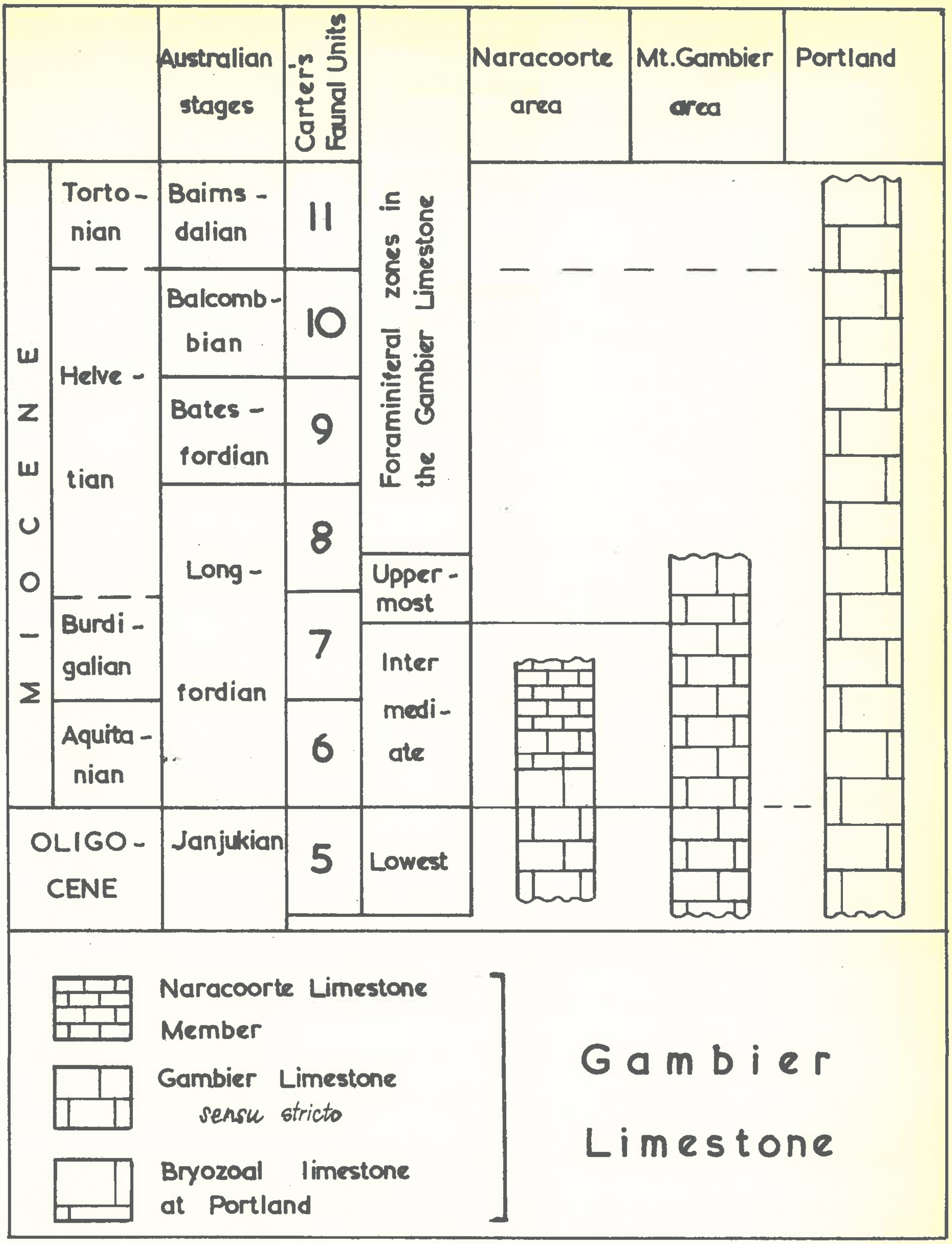


Table 2. Time-stratigraphic relations of the Gambier Limestone in different areas

(in the Portland bore the presence of faunal units 11 at the top and 5 at the bottom is known, but other faunal units have not been distinguished) tain V. conoidea (Crespin, 1954, p.33). Thus an undetermined thickness of this sequence is equivalent in time of deposition with the South Australian outcrops of the Gambier Limestone, but the equivalents of the upper part of the formation at Portland are missing in the type area.

Age

The interrelations of the Australian Tertiary Stages, established in various localities mainly in Victoria, have been the cause of considerable controversy. Carter (1959) defined all but the Upper Miocene and Pliocene Stages in terms of his Faunal Units. According to Carter's definitions, the Gambier Limestone in South Australia is equivalent to the Janjukian and the Longfordian Stages, perhaps with the exception of the basal part of the former and the uppermost part of the latter. The Naracoorte Limestone Member is approximately equivalent to the lower part of the bryozoal limestone sequence at Portland is equivalent to the Batesfordian, Balcombian and Bairnsdalian Stages.

The difficulties in relating Australian Tertiary beds to the standard time scale, based on European strata, for the purpose of world-wide correlation, have been discussed by Glaessner (1959). Apart from the problem as to whether the Aquitanian belongs to the Oligocene or to the Miocene, the age of the first appearance of G. bispherica, which is the most important event from the viewpoint of interregional correlation of the Gambier Limestone, is still controversial. The present writer follows Glaessner in tentatively accepting Drooger, Papp and Socin's (1957) placing of the *G. bispherica* zone in the Helvetian, and hence considering the Gambier Limestone (in South Australia) as equivalent in age to all but the lower part of the Oligocene, and the Aquitanian, the Burdigalian, and the lower part of the Helvetian Stages of the Miocene. The age of the Naracoorte Limestone Member falls within the Aquitanian and most of the Burdigalian. The uppermost beds of the bryozoal limestone at Portland are considered to be Tortonian in age.

V PALEOECOLOGY AND SEDIMENTATION

INTRODUCTION

Terrigenous material played a negligible role during the formation of the Gambier Limestone, at least as far as the strata outcropping in the Mount Gambier and the Naracoorte areas are concerned. In the case of such a predominantly biochemically formed rock unit, paleoecology and sedimentation are intimately related, since the skeletons of marine organisms constitute the source material.

Ecological factors controlled the production of the source material and determined the maximum size of rock constituents. The size of smaller particles, and sometimes the size of all particles, was controlled by the intensity of mechanical energy and the activity of benthonic organisms in the depositional environment. Water movement was responsible for selective transportation and comminution during such transportation of fossil tests, while organisms reduced the size of particles in the surface layer of sediment at rest. It is difficult to assess the relative importance of the last two factors in determining the observable grain size of the limestone.

All the above mentioned factors were in turn influenced by paleogeographic conditions, such as depth, distance from shore, land configuration and bottom topography.

PALEOECOLOGY

Foraminifera

Methods

The Foraminifera form the only fossil group which was subjected to a statistical paleoecological study. Thirty-seven samples were selected for such analysis. They were chosen to represent as fully as possible the areal distribution of outcrops belonging to each of the three foraminiferal zones. Five samples from the Naracoorte Limestone Member and one from the Gambier Limestone *sensu stricto* in the Naracoorte area were studied. The remainder were selected from the Mount Gambier area. Six of these represent the lowest zone, seventeen the intermediate zone and six the uppermost zones. Of the seventeen from the intermediate zone, at least ten represent its upper part (as indicated by the presence of *O. victoriensis*).

The washed samples were reduced to a suitable size by the cone-and-quarter method. In each case the resulting quantity of sediment was sieved, and the fraction finer than 0.026 inches discarded. The retained fraction was wholly or partly picked. Foraminifera unidentifiable because of fragmentation or bad preservation were ignored. The number of specimens picked from individual samples varies between 179 and 492, in most cases being between 200 and 300.

Subsequently the Foraminifera were sorted and the different groups counted separately in each sample.

Results

Only four of the foraminiferal groups recorded occur commonly as more than 5% of the total number of specimens. These are in order of abundance, the planktonic Foraminifera, Cibicides, Cassidulina subglobosa Brady, and Notorotalia howchini (Chapman, Parr and Collins). The species forming the first two groups were not considered individually, mainly because of the impossibility or difficulty of assigning the abundant juvenile specimens belonging to these groups to separate species. The relative abundances of these groups are plotted for different samples on Maps 5a-c, all covering only the Mount Gambier area. Samples from the lowest zone are plotted on Map 5a, while Map 5b represents those samples from the intermediate zone in which O. victoriensis is absent. Intermediate zone samples containing O. victoriensis are plotted on Map 5c and samples from the uppermost zone on Map 5d. No such map was prepared for the Naracoorte area because of the smaller areal spread of sampled localities.

The average relative abundances are also plotted collectively for samples from the Naracoorte Limestone Member and for the samples shown on Maps 5a-c, respectively. Foraminiferal groups, which usually occur as less than 5% of the total number of specimens were not considered significant in this study.

Foraminiferal assemblages in the Naracoorte Limestone Member differ as a whole from those within limestone in the Mount Gambier area as closely equivalent in age as at present determinable (containing Q. victoriensis in the absence of C. bispherica). The Naracoorte assemblages consist of relatively fewer planktonic Foraminifera, slightly more Cibicides, and significantly less C. subglobosa and more N. houchini than those from the vicinity of Mount Gambier. In the latter area, assemblages from the intermediate zone (with or without Q. victoriensis) show only slight statistical differences in relative abundance of Foraminifera from assemblages within the uppermost zone. Lowest zone assemblages are more variable than those from the two younger zones, especially with respect to abundances of C. subglobosa and N. houchini. Hence the average values of foraminiferal abundances in the six samples from the lowest zone are not as truly representative of the zone as a whole, and are not directly comparable with those for the younger zones.

The percentages of N. houchini and C. subglobosa are approximately indirectly proportional in individual samples, as is best exhibited in Map 5a. No such correlation between the abundances of other foraminiferal groups is apparent.

Generally, the coarser the limestone, the larger and numerically fewer are the Foraminifera per unit volume of rock. Such differences are largely explicable by selective transport (see p. 42) and the small size of most of the Foraminifera as compared with other fossil particles constituting the limestone. In the Mount Gambier area, no striking correlation between lithology and relative foraminiferal abundances was observed, except in the case of the building stone. This is characterized by assemblages rich in Parrellina aff. verriculata (Brady) and poor in the planktonic Foraminifera (plate 7, fig. 1).

Photographs of foraminiferal assemblages from selected samples, which indicate the range of variation in relative foraminiferal abundances within the Gambier Limestone, are figured on plates 6 and 7.

Discussion

The impossibility of distinguishing thinner stratigraphic intervals than the foraminiferal zones within the Gambier Limestone, together with the small number of samples investigated, are very likely the main reasons for the absence of significant patterns in the foraminiferal distributions plotted in Maps 5a-d. It is difficult to determine the relative importance of factors operating areally at the same time and changes in ecological conditions at the same locality through time. Hence the significance of apparent trends, such as best exemplified by the increase in relative abundance of N. howchini and decrease of C. subglobosa in a north-north-westerly direction in Map 5a, cannot be evaluated. Distribution data of C. subglobosa in Recent sediments at varying depth recorded by different authors do not agree closely, but most report this species to be more common at depths greater than 50 m than in shallower environments. Possibly the cause of the distribution pattern in Map 5a was variation in ecological factors associated with variation in distance from the shore (see p. 55).

Notwithstanding the difference in foraminiferal assemblages, it can not be concluded that the environmental conditions during the formation of limestone belonging to the lowest zone differed considerably, as a whole, from those existing during the time of deposition of the two younger zones. V. conoides, the only index fossil for the lowest zone, is absent from a considerable number of samples which very probably belong to the lowest zone (see p. 30). This species is usually found only in coarse or moderately coarse limestone. It is not unlikely that the lowest zone samples selected for paleoecological investigation are not truly representative of the zone as a whole, since they were chosen because they contained V. conoides.

A fairly large proportion of the genus Cibicides in Gambier Limestone consists of specimens with flat or concave dorsal sides, presumably adapted to an attached mode of life on sea-weeds. Such forms "indicate shallow water conditions, abundant plant life being limited to depths not exceeding 50 metres" (Glaessner, 1945, p.193). The Gambier Limestone foraminiferal assemblages agree in a general way with those considered by Lowman (1949, p.1956) to indicate a mid-continental shelf (mid-neritic) environment, which are characterized by "Great abundance of genera and species; dominance of Rotaliidae, especially Cibicides."

Summary of conclusions

In view of the abundance of flat- or concave-sided Cibicides and the scarcity of characteristically near-shore Foraminifera, such as Miliolidae, the depth of the depositional environment of the Gambier Limestone is estimated to have varied between about 20 and 50 fathoms. Differences between the assemblages in the Naracoorte Limestone Member and the limestone in the Mount Gambier area very probably indicate a shallower depth during sedimentation in the Naracoorte area than in the vicinity of Mount Gambier.

In the Mount Gambier area environmental conditions did not change notably during the time represented by the intermediate and the uppermost zones. There is no conclusive evidence that conditions during the formation of limestone belonging to the lowest zone differed considerably from subsequently prevailing conditions.

Bryozoa

Bryozoa live throughout a fairly wide range of depth (although they are most abundant in depths of the continental shelf regions), temperature and salinity. Their distribution is primarily controlled by texture of the substratum (Duncan, 1957). Shifting sand and mud, without larger debris, are not favourable for most Bryozoa. They attach to anything sufficiently firm and clean, e.g. rock bottom, tests of other animals and sea-weeds. Brisk currents and agitated water are favourable to vigorous bryozoal growth; however, forms can develop modifications for living in deeper, quieter waters. It seems that Bryozoa, contrary to past assumptions, can stand a certain amount of turbidity. Amount of light penetrating to the sea bed is important from the viewpoint of food of Bryozoa - diatoms, radiolarians etc., and organic algal substratum.

It is evident that most of the Bryozoa within the Gambier Limestone could not thrive attached directly to the sea-bed during deposition of the limestone. Although a certain number of them probably adhered to tests of larger organisms, such as found fairly commonly in the Naracoorte Limestone Member and less commonly in Gambier Limestone sensu stricto, most of the fossil particles constituting the depositional substratum were too small and too easily moved for such attachment. Because of the great abundance of Bryozoa in the Gambier Limestone, it is unlikely that they flourished directly attached to a more favourable, rocky sea-bottom outside the depositional environment of the outcropping limestone studied. It is concluded that, except for the relatively uncommon, large Cellepora, Retepora and similar types, some of which are probably preserved in growth positions, as well as the uncommon free-living Bryozoa, the predominant arborescent individuals lived attached mainly to algae, which have not been preserved. An analogous situation is often observed in Recent seas. As discussed on p. 44, the presence of algae in the depositional environment of the Gambier Limestone is also strongly suggested by the abundance of flat and concave-sided Cibicides in the limestone. Although algae thrive best on hard, rocky sea-bottoms, they are by no means uncommon on relatively soft sea-beds, where they live anchored by root-like processes.

It appears that most of the Bryozoa in limestone in the Mount Gambier area correspond to Stach's "vinculariform types" - arborescent forms with "erect, rigid, often narrow subcylindrical branches", (Stach, 1936, p.62), which were stated to be most common in moderately deep or sheltered waters. In Naracoorte Limestone Member there is a greater proportion of Stach's "reteporiform types", allegedly common in sublittoral environments.

SEDIMENTATION

General

The Gambier Limestone was deposited in an environment in which the intensity of mechanical energy, which controlled the submarine erosion, deposition and selective transport of particles differing in size and shape, varied considerably both in space and in time. The usually small lateral and vertical extent of individual exposures of the limestone, and the impossibility of relating accurately one exposure to another in a vertical, stratigraphic sense, make it difficult to determine the relative importance of areal, contemporaneous variation, contrasted to variation through time, as the underlying causes of lithological differences between different exposures.

Variation in space

The main agents of mechanical energy during the deposition of the limestone were wind-induced wave action and tidal currents. More persistent, permanent currents also may have existed, but nothing is known concerning their strength or direction. At any one time, mechanical energy decreased with increasing depth, which was at least approximately correlated with increasing distance from the shore. Although generally coarser sedimentation was predominant in areas nearer to the shore, a uniform gradient in average grain-size perpendicular to the coast line was probably not established, due to irregularities of bottom topography. Strongly winnowed, richly bryozoal sediments were laid down in relatively shallow areas or on low shoals of comparatively small lateral extent. Such sediments are exemplified by the Naracoorte Limestone Member and the building stone (in the Mount Gambier area), respectively. For reasons discussed on p.45 , bryozoal growth was vigorous in their environments of deposition. Fine sediment particles were carried away by selective transport and deposited in deeper, more quiet, bordering or surrounding parts of the environment. These fine, mostly unidentifiable particles are considered to owe their origin to fragmentation of fossils by water movement and/or the comminuting activities of benthonic organisms (see p.51). The fine material was incorporated within the sediment together with larger whole or broken fossil tests. A part of these were transported from neighbouring areas during brief, more than usually turbulent periods, while others were probably not shifted after the death of the organisms occupying the tests. The sediment formed in relatively quiet parts of the depositional environment of the Gambier Limestone is best exemplified by the calcisiltites and fine calcarenites outcropping in the vicinity of Port Mac Donnell.

Transport

While the constituent particles of the limestone were transported largely by traction along the sea-bed, some of the fine material was moved in suspension. Fine terrigenous particles may have been at least partly wind-borne. Rafting of fossils attached to floating sea-weeds undoubtedly also took place, but was probably not important quantitatively.

Variation in time

The main causes for the variation in the intensity of mechanical energy through time, represented by vertical variation in lithology at numerous quarries, were changes in climatic and oceanographic conditions. The absence of depositional rhythms or cycles indicates absence of eustatic oscillations of the sea-level or of frequently alternating subsidence and uplift of the sea-bed. The areas of coarse and fine sedimentation, which were mutually exclusive though laterally transitional, expanded and contracted correspondingly as the distribution of mechanical energy changed areally through time.

Discontinuity of sedimentation

Sedimentation was not continuous in any part of the depositional environment of the Gambier Limestone, but was interrupted by numerous short periods of local non-deposition and submarine erosion, due to fluctuation of the local base level alternately above and below the sea-bottom. Most of such periods have not left clearly discernable marks in the sedimentary record. Periodical storms were largely of too short a duration to do much more than effect a certain amount of selective transport of material from shallower to deeper areas and mix the surface layer on the sea-bottom. During considerably longer periods of continued strong water movement, diastems, such as best exemplified by the coarse bed at the base of the Naracoorte Limestone Member, resulted. Bryozoa, except the very coarse ones, were eroded from the sea-bed and transported to more quiet environments, while the larger macrofossils, being more resistant to transport, were concentrated, until they were sufficiently abundant to protect the underlying finer sediments from further erosion. When the intensity of mechanical energy decreased, deposition of the generally finer Bryozoa was resumed.

Comparison between different areas

As already mentioned (p. 11), limestone outcropping in the vicinity of Mount Gambier and to the west and northwest of it is generally coarser than the outcrops in the coastal area, especially near Port Mac Donnell. This may be due to the situation of the former area nearer to the ancient shore line (see p. 55), and presumably deposition at a shallower depth, than in the case of the Port Mac Donnell area. Alternately, it is also possible that deposition throughout the time represented by the lower foraminiferal zone, whose outcrops occur mainly in the area to the west and northwest of Mount Gambier, resulted in generally somewhat coarser limestone than the outcrops representing the intermediate or the uppermost zone.

The Naracoorte Limestone Member was deposited under shallower conditions, with water movement generally stronger, but similarly somewhat variable in intensity, than during the formation of the limestone outcropping in the Mount Gambier area.

Activities of organisms

A large variety of organisms may disturb and comminute the surface layer of sediment on the bottom of the sea by burrowing within it and/or passing the sediment through their alimentary tracts. Remains of recognizably burrowing organisms (e.g. echinoids) are not abundant in the Gambier Limestone. Various animals, such as worms, holothurians and others, may have been important as burrowers or scavengers, but have not left any identifiable skeletal parts or preserved sedimentary structures within the limestone.

Generally bottom scavengers prefer a fine-grained substratum because of its greater content of finely disseminated organic matter. It is not likely that they were common in the depositional environments of the relatively coarse Naracoorte Limestone Member and the building stone. The absence of well developed stratification and parallel orientation of elongate particles in such limestones is probably largely due to the coarseness of the sediment, mixing of the surface layer by periodical storms and gradual, rather than sudden, overall changes in the strength of water movement.

Benthonic scavengers were probably more common in the environments in which the fine calcarenites and calcisiltites were formed.

VI PALEOGEOGRAPHY

GENERAL

The Gambier Limestone was deposited over an area in which the continental shelf merged laterally with a shallow epicontinental sea (the "Murravian Gulf" of authors). Sedimentation during the Tertiary in southern Australia has been discussed by Glaessner (1953a, b), who stated: "The area of Tertiary deposits in southern Australia is essentially a "mobile shelf" in the sense of Bubnoff, which makes it a miogeosyncline in Stille's terminology." (Glaessner, 1953a, p.45). More recently, the history of sedimentation in the Murray Basin, involving alternating submergence and uplift since at least the Middle Mesozoic, has been outlined by Ludbrook (1958).

BEGINNING OF SEDIMENTATION

In the Murray Basin, "the beginning of the Tertiary was marked by partial uplift and rejuvenation of the land surface and ... sedimentation was comparatively rapid." (Ludbrook, 1958, p.105). During the Eocene and early Oligocene the paralic Knight sands were deposited; these are overlain in some areas by the marine Buccleuch Beds. Subsequently the sea retreated and a relatively short period of non-deposition and erosion followed. As the area became submerged again, a basal conglomerate, varying laterally both in thickness and in time of deposition, was laid down. As the depth of the transgressing sea increased, the formation of the Gambier Limestone was initiated.

INFLUENCE OF TECTONIC MOVEMENTS

Deposition of the Gambier Limestone was influenced to a certain extent by contemporaneous tectonic movements. Limestone in the Mount Gambier area was laid down in a more rapidly subsiding region than the limestone near Naracoorte, as indicated by the difference in thickness of strata representing the lowest foraminiferal zone in the two respective areas (see p. 32). A slight uplift of the Padthaway Ridge relative to the Gambier Sunklands may have been at least partly responsible for the increased average grain size of the Naracoorte Limestone Member as compared to the underlying Gambier Limestone sensu stricto. No corresponding change in lithology of strata of similar age can be observed in the Mount Gambier area.

The sea was generally shallower over the Padthaway Ridge than over the Gambier Sunklands. A number of the granite masses outcropping at present over the area occupied by the ridge probably existed as islands during the Oligocene and the Miocene (forming the "Padthaway Archipelago" of Sprigg, 1952, fig.7). These islands were sometimes at least partly covered by the transgressive sea, as evidenced by arenaceous limestone resting on granite (Chapman, 1943, p.39).

POSITION OF SHORE-LINE

The position of the shore-line in the southeastern part of the Murray Basin during the deposition of the Gambier Limestone can be estimated only very approximately. The clay content of the bryozoal limestone increases toward the Dundas Highlands in Victoria, but truly littoral deposits have been almost totally removed by subsequent erosion. There is no evidence that the position of the shore-line changed significantly during the formation of the Gambier Limestone, apart, of course, from the very early stages of the transgression.

Maximum extent of the transgression in the Murray Basin was reached during the deposition of the Mannum Formation (Ludbrook, 1958, p.109), i.e. during the time represented by the intermediate and the uppermost zones in the Gambier Limestone. Such an estimated maximum extent of Mid-Tertiary seas is shown by Sprigg (1952, fig.7). According to Sprigg's figure, the Naracoorte area was situated closer to the ancient shore-line than the Mount Gambier area.

LAND RELIEF

The small amount and fine grain size of the terrigenous material in the Gambier Limestone suggests that the relief of the land surface, occupying the area of the present Dundas Highlands, was at least moderately mature, and that no large rivers existed in this area during the Oligocene and the Miocene. There is no conclusive evidence that the land surface was a peneplane during that time.

CLIMATE

Little can be said about the climate of the southern part of Australia during the Tertiary. Recent work on oxygen isotope measurements in fossils by Dorman and Gill (1959, p.89) suggests "higher temperatures in the mid-Cainozoic, but falling away from this peak in both the earlier and later Cainozoic."

END OF SEDIMENTATION

Since an unknown, presumably laterally variable thickness of strata has been subsequently removed from the top of the Gambier Limestone by erosion, little is known about the sedimentation during the closing stages of its formation. The youngest Gambier Limestone beds in both the Mount Gambier and the Naracoorte areas are older than the uppermost bryozoal limestone strata at Portland in Victoria and also than both the Morgan Limestone and the Pata Limestone in the Murray Basin. It is impossible to say whether the absence of such younger sediments in the South Australian part of the Gambier Sunklands and on top of the Padthaway Horst is due to uplift and non-deposition during the Middle Miocene or due to relatively greater uplift and hence erosion of a greater thickness of sediment during Late or post-Miocene times.

VII DIAGENESIS AND WEATHERING

COMPACTION

The generally high porosity and moderately loose packing of uncrushed constituent particles indicate that the Gambier Limestone has not undergone severe compaction. The only direct evidence of compaction are compressed macrofossils, especially echinoids, which are occasionally present in the limestone. Probably a certain amount of cementation took place shortly after deposition, thus forming a rock capable of withstanding the low pressure resulting from comparatively shallow burial. Compaction, or lack of it, in limestones is still not fully understood (Weller, 1959).

CEMENTATION, RECRYSTALLIZATION AND IRON-STAINING

The porosity observable in hard specimens of the limestone and under the microscope is primary, since usually the outlines of fossil fragments in thin sections do not appear to be notably corroded. Secondary porosity, caused by solution on a large scale, is discussed on p. 64.

On the whole, the Gambier Limestone is not extensively recrystallized or cemented (see p. 9). Generally, the passage of ground water through the limestone must have been sufficiently rapid to prevent saturation of water with $CaCO_3$ and its subsequent precipitation, except near the very surface. However, some recrystallization and cementation has taken place throughout the rock, since none of the foraminiferal tests within it have fully retained their original glassy appearance, and the limestone is usually at least weakly coherent. The processes of granular cementation and drusy growth and, in more advanced cases, grain growth sensu stricto (Bathurst, 1958) have been the most important in affecting the fabric of the limestone. The extensive cementation, recrystallization and dolomitization observed in certain areas (p. 13), commonly associated with faults, may be due to the ground water supply not being constant enough to prevent precipitation within the highly permeable rock. As already mentioned on p. 13 , in less extensively altered exposures recrystallization, cementation and the more localised iron-staining appear to be roughly correlated with variation in average grain-size and the associated variation in original permeability of the limestone. However, these processes have taken place somewhat haphazardly with respect to bedding planes within the rock.

Although some recrystallization and cementation probably occurred fairly shortly after deposition, it is considered that both these processes and iron-staining were most active at a late stage of diagenesis in limestone uplifted above the water table. The rapid hardening of the Mount Gambier building stone after it has been quarried indicates that water loss and cementation take place readily in limestone exposed to air. However, hard, crystalline limestone has been penetrated in bores at depths well below the water table, e.g. in the Nelson bore (Crespin, 1954).

DOLOMITIZATION

The nature and age of dolomitization of the limestone in the Mount Gambier area has been discussed by Cochrane (1952a, b). Since the dolomite occurs mainly in areas associated with proved or inferred faults, most of the dolomitization is considered to have occurred at a rather late stage of diagenesis. Faulting and joint formation in the Gambier Limestone were most active during two main periods of uplift, an earlier one in Middle or Upper Miocene and a later one during late Pliocene and early Pleistocene (see p. 70).

The most likely source of magnesium necessary to replace the calcium are the fossil skeletons within the limestone itself. The tests of many Bryozoa and organisms belonging to other groups present in the Gambier Limestone may contain a relatively large amount of $Mg\ CO_3$ in solid solution with $Ca\ CO_3$ (Fairbridge, 1957). Very likely such tests were dissolved in certain parts of the limestone and the Mg ions in ground water migrated along faults and smaller fractures to replace the calcium or to be precipitated as dolomite in the interstices between the constituent particles of the rock in the vicinity of fractures. Probably much of the dolomitization has taken place near the surface; however, Crespin (1954) records dolomitic limestone at depths of 582 feet and 607 feet in the Nelson bore.

The dolomite in the Mount Gambier area is characterised by a comparatively coarse fabric, a usually extensive obliteration of fossils and the absence of thin, interbedded limestone. According to Fairbridge (1957, p.159), these properties are generally features of late diagenetic metasomatism.

Dolomitisation is a rather poorly understood process and can take place in a wide variety of ways (Fairbridge, 1957). It is not unlikely that the dolomites in the Mount Gambier area vary both in respect to the time and the exact method of their origin.

CHERT FORMATION

A post-depositional origin of the chert nodules and layers in the Gambier Limestone is strongly indicated. The boundary between the nodules and the surrounding rock is often transitional. The nodules are commonly irregularly shaped, sometimes very large and with hollow centres. The unreplaced or partly replaced fossil fragments within the chert possess the same mutual textural relationships as the fossils in the surrounding limestone.

The silica forming the nodules and bands is considered to have come from within the Gambier Limestone itself. Many authors, e.g.

Siever (1957), hold that the major source of epigenetic silica in limestones are the siliceous tests or parts of tests of various organisms, the most common being sponges, radiolarians and diatoms. Calcified sponge spicules have been observed rarely in the Gambier Limestone, while siliceous sponges occur abundantly in the slightly older (Upper Eocene) Blanche Point Marl in the neibouring St. Vincent Basin (Glaessner, 1953b, p.142). Radiolarian and diatom tests have not been seen in the Gambier Limestone; such may have been originally present, but subsequently dissolved, and the silica concentrated and precipitated to form chert layers. Other workers, e.g. Walker (1960) underline the importance of clastic quartz grains as at least partly the source of authigenic silica, in carbonate rocks. Clastic quartz is present in the Gambier limestone, though in limited quantities. Since it is unlikely that large rivers entered the sea in which the Gambier Limestone was deposited (see p. 55), inorganically precipitated silica, such as discussed by Bien et al. (1958), can/not be considered to have been important as source material for chert formation.

While most, though not all, workers on the geochemistry of silica agree that chert nodules are formed by diagenetic redistribution and later replacement of limestone by silica originally widely distributed throughout the rock, the exact nature and causes of these processes are not known. The theory postulated by Newell et al. (1953) to explain the simultaneous solution of silica and precipitation of calcite, and vice versa, in different beds of the same limestone unit, was based on solubility curves of silica and calcium carbonate given by Correns (1941, 1950). More recent work by Alexander et al. (1954), Krauskopf (1956) and Okamoto et al. (1957) invalidates Correns' results.

The time of formation of chert after the deposition of limestone is also subject to controversy. Probably chert nodules originated at somewhat different diagenetic stages in different, and perhaps in the same, rock units. Some authors hold that the formation of chert is mainly an early post-depositional process, since at that stage the migration of fluids within the rock is most active because the primary porosity has not been lost due to subsequent cementation. This limitation is probably of little importance in the case of a highly porous limestone, such as the Gambier Limestone. Rutten's (1957) main reason for postulating an early post-depositional origin for chert nodules was his observation that angular, broken chert fragments are sometimes associated with the nodules. Such an association has not been observed in the Gambier Limestone, and fossils within the nodules are not noticeably better preserved than those in the surrounding rock.

Other authors maintain that formation of chert is mainly a late diagenetic process. One of such is Sujkowski (1958), who considered that fine, disseminated silica in limestone goes into solution under pressure caused by the formation of gases due to oxidation of organic matter within the sediment. Pressure is reduced by the escape of such gases when joints and fractures develop in the rock during uplift of the latter, and the silica is precipitated at certain loci as a gel, which loses water and hardens. While it is not unlikely that the Gambier Limestone chert nodules came into existence after uplift of the limestone, there is no definite evidence for this, since the chert, unlike the dolomite, does not appear to be associated with faults.

Twenhofel (1950) considered that most of the replacement of calcite by silica occurs in the zone of weathering above the water table, due to migration of silica dissolved from the overlying soil. Since Crespin (1954, p.26) recorded chert from depths of up to 348 feet in the Nelson bore, at least some of the chert in the Gambier Limestone has been formed below the water table.

The concentric banding not uncommonly observed in chert nodules in the Mount Gambier area may have been caused by diffusion (the Liesegang phenomenon). A similar explanation has been advanced by different authors for the hollow centres of nodules. Sujkowski (1958) considered this feature to have been caused by contraction during dehydration.

WEATHERING

A notable feature of the Gambier Limestone is the large number of caves, sink holes and smaller underground cavities. These are the result of solution associated with movement of ground water. Such solution is a late diagenetic process occurring after uplift of the region under consideration, and is influenced by the fracture pattern formed within the limestone during or after such uplift. Some controversy exists as to whether underground cavities originate mainly above or below the water table (Davis, 1930; Swinnerton, 1932). From his study of caves in the Nullarbor region, King (1949) considered large, deep-seated caverns without or with poorly developed stalactites and stalagmites to have formed by solution below the water table during a former, less arid period, whereas smaller, shallower caves with well developed dripstones were thought to have originated more recently above the water table. The caves in the Mount Gambier and Naracoorte areas do not seem to be differentiable in this manner. Most of them contain plenty of stalactites and stalagmites.

A less notable feature of Gambier Limestone are the "sand pipes" or "clay pots" sometimes visible in quarry walls. These are narrow, approximately vertical, V-shaped cavities extending downwards from the surface into the limestone, and are usually filled with soil.

Unless it has been hardened by extensive dolomitization or cementation and recrystallization as, for example, at the Up and Down Rocks near Tantanoola and in other areas associated with faulting, the Gambier Limestone does not resist weathering. Formation of kunkar at or near the surface is wide-spread, but variable in intensity. Residual chert nodules or fragments are distributed in the soil or on the surface over large areas. The occurrence of such residual chert in County Grey has been described by Willington (1956).

VIII STRUCTURE

MOUNT GAMBIER AREA

The present investigation has yielded new information about the structure of the Gambier Limestone outcropping in the Mount Gambier area. Structural study in this region can not be based on mapping of units of different lithology, since there are no consistent, mappable changes at definite stratigraphic horizons. The slight dips measurable in the flat-lying strata do not add up to a comprehensive overall picture and only indicate local irregularities of the general structure. Where large dips are observed, faulting is obvious or inferred. Interpretation of structure during the present investigation has been based on recognition of the biostratigraphic zones already discussed.

The distribution of outcrops belonging to different zones (as far as it has been possible to determine this micropaleontologically) is plotted on Map 4. The structure of the Gambier Limestone shown on Map 4 has been traced, with minor modifications, from a somewhat interpretative, unpublished map by Mr. R.C. Sprigg, which incorporated both the biostratigraphic data of the present writer and the observed structural contours such as plotted on the 1 mile Gambier and Northumberland geological sheet. The two kinds of data agree rather well. Minor discrepancies are probably due to not all the structural contours representing bedding planes.

To the west-north-west of Mount Gambier, limestone belonging to the lowest zone is exposed over a considerable area, with the intermediate zone outcropping near Tantanoola. Lowest zone outcrops, surrounded by those belonging to the intermediate zone, indicate the presence of a "closed" structural high immediately southwest of the Mount Salt homestead a few miles west of Mount Schank. The north-eastern boundary of this structural high is formed by the Mount Salt Fault (named by Sprigg, unpublished map), the presence of which is suggested by the short distance separating limestone outcrops belonging to the lowest and the uppermost zones in this area, without intervening outcrops of the intermediate zone. Flatly dipping strata to the northwest, southwest and southeast of the high are indicated by comparatively wide areas separating limestone outcrops representing the lowest and uppermost zones respectively. Isolated lowest zone outcrops suggest a somewhat undulating structure.

A fairly large area extending from to the northeast of Mount Salt homestead in a roughly east-south-east direction towards the Victorian border is characterised by limestone outcrops belonging mainly to the uppermost zone. Intermediate zone strata are exposed directly to the south and east of Mount Schank and to the west of the South Australian part of the Glenelg River. Narrower areas of uppermost zone outcrops, separated by limestone representing the intermediate zone, extend in an approximately northwesterly direction from Port MacDonnell. Scattered uppermost zone outcrops occur also in the vicinity of Kongorong.

Intermediate zone outcrops are predominant in the neighbourhood of Mount Gambier, to the southeast of the structural high near Mount Salt homestead, and in the coastal area between Port Mac Donnell and Discovery Bay (near the State border).

While some faults in the Mount Gambier area are marked along at least a part of their extent by topographical breaks, steep dips or brecciation, the existence of others is inferred from linear zones of extensive dolomitization (Sprigg, 1952). The distribution of localities from which suitable micropaleontological samples were collected is not sufficiently dense, nor is the resolution afforded by the comparatively thick foraminiferal zones sufficiently sharp under conditions of low structural relief, to confirm observed or inferred faults or to delineate new, undiscovered faults. Hence it is difficult or impossible to ascertain the relative importance of faulting and folding, as causes of the observed structure, and to determine the exact relationship between these two intergrading processes. Folded structure, such as observed in the flat area a few miles northwest of Mount Schank, is related to the general interplay of stresses along approximately northwest and southwest trending intersecting lines of weakness. However, it is not the result of simple "drag" along faults, and should not be referred to as "fault-folding".

Jointing in the Gambier Limestone has been discussed by Sprigg (1952, p.38, fig.9), who constructed rosette diagrams on the basis of statistical measurements of joint directions in various parts of the Mount Gambier area. Joints are best seen on flat surfaces of outcropping limestone, and commonly stand out as ridges of more resistant secondary infillings of lime. They are evidently related to the general structural pattern of northwest and southwest trending lineaments.

NARACOORTE AREA

No additional information about the structure of the limestone in the Naracoorte area was obtained, since all the limestone samples collected from the latter belong to the same zone (the intermediate zone).

TECTONIC MOVEMENTS

The time and the relative effect of tectonic movements, which differed in time, on the structure of the Gambier Limestone, can be estimated only approximately. The occurrence of at least gentle movements during the deposition of the limestone is suggested by the difference in thickness of the lower zone of the Gambier Limestone in the Mount Gambier and the Naracoorte areas, respectively (see p. 32). More intense faulting probably occurred during Middle or Upper Miocene, when the Gambier Sunklands were uplifted and eroded. At approximately this time a large thickness of sediments was removed from the upthrow side of the Para Fault in the neighbouring St. Vincent Basin (Glaessner, 1953a, p.36). Tectonic movements also took place in the Murray Basin during the Pliocene and the Quaternary, but the evidence of their effect on the land surface in relation to the sea-level is rather scanty. For example, the extent of the Lower Pliocene transgression, during which the Kalimnan beds at Muddy Creek near Hamilton were laid down, is unknown. Towards the close of the Pliocene or early in the Pleistocene most of the Gambier Sunklands became submerged by the sea. Basal Pleistocene sediments are known from the Glenelg River and Portland areas in Victoria, and have been recorded in bores in the vicinity of Tintinara in South Australia (Sprigg and Boutakoff, 1953). According to Boutakoff (1952), the formation of the Normandy Platform in the southwestern corner of Victoria is Plio - Pleistocene in age.

As the land slowly emerged again during the Quaternary, successive standstills of the retreating strandline were marked by aeolianite dune ranges (Hossfeld, 1950; Sprigg, 1952). During this period the Mount Gambier region was subjected to gentle upwarping along an approximately northeast trending axis, which passed a few miles to the northwest of Mount Gambier (Sprigg, 1952, fig.9). Another indication of tectonic activity during the Pliocene and the Quaternary are the volcanic rocks in the vicinity of Mount Gambier and in the Victorian part of the Gambier Sunklands. Recent earthquakes indicate that some crustal adjusting to stresses is still going on in the area.

IX FORAMINIFERA

INTRODUCTION

General

The Gambier Limestone foraminiferal fauna has not been previously described as a whole, although certain species from this formation have been figured and described by earlier authors. A number of species have been listed as occurring in the Gambier Limestone, e.g. in Crespin (1954), Ludbrook (1957, 1958). Except where no doubt exists regarding the identification of species referred to, records of species unaccompanied by figures or description were not considered in the present work.

More than 160 species, including Notorotalia gambierense sp. nov., are described or recorded from the Gambier Limestone. Species not previously described in detail from Australian strata are described fully, with emphasis on their morphological variation and similarities with other species. Known species which have been adequately described from the Australian region, or which occur very rarely or are represented in the Gambier Limestone only by poorly preserved specimens, are recorded and discussed, in most cases briefly. With few exceptions, unidentified species represented by rare or only fragmental and poorly preserved tests are not mentioned in this thesis.

Some of the publications referred to under the selective synonymies in the subsequent systematic descriptions have not been seen in the original, but only fide Ellis and Messina (Catal. Foram., 1940 et seq.).

Specimens figured in the illustrations of this thesis have been registered under numbers F 15, 890 to F 16, 159 and are deposited in the collection of the Geology Department of the University of Adelaide.

Relationships of faunas

The Gambier Limestone faunas show close similarities with Victorian faunas of similar age, all possessing a considerable number of species in common. Carter's (1958a) work on the Oligocene and the Miocene faunas from the Aire district, Victoria, has been most useful for comparison. A copy of the illustrations (but not the text) of Carter's (1959) unpublished thesis on Tertiary Foraminifera from Gippsland, Victoria, was also available to the writer. Three of the species described by Carter are assigned to different genera by the present writer, namely, Hanzawaia scopos (Finlay) (=Rosalina scopos of Carter), Cavelinonion centroplax (Carter) and C. obesum (Carter) (=Astrononion centroplax and A. obesum of Carter). Cibicides perforatus (Karrer) of Carter is referred to C. pseudoungerianus (Cushman) in this thesis.

The Gambier Limestone faunas also show close similarities with faunas of equivalent age from New Zealand, described mainly by Finlay and Hornibrook. Representative specimens of species originally described from New Zealand, identified for the Geology Department of the University of Adelaide by N. deB. Hornibrook, were very useful for comparison.

Less close affinities exist between the Foraminifera in the Gambier Limestone and faunas described from the Oligocene and the Miocene of Europe and North and Central America.

Material studied

Foraminifera in samples belonging to the E series and selected samples of the V series, as well as in the bore samples mentioned in the general introduction to this thesis, were studied in detail. Samples collected by Geosurveys of Australia Ltd. from the Mount Gambier and Beachport areaswere examined superficially for purposes of biostratigraphic mapping.

Comparative material

Comparative material available during the course of this work included the following faunal and species slides:

Collection of the Geology Department of the University of Adelaide -

Slides V 26, V 27 (Dartmoor), V 33 (Caldwell's Cliff) and V 34 (Myaring Bridge); all from localities along the Glenelg River, Victoria. In exceptional cases, were no suitable specimens from the Mount Gambier area were available, specimens from sample V 34 are figured in the illustrations of this thesis.

Species slides containing selected South Australian and Victorian Tertiary Foraminifera.

Species slides containing New Zealand Tertiary Foraminifera.

Slides of Recent Foraminifera collected by the B.A.N.Z. Antarctic Research Expedition (1929-1931), including holotypes and paratypes described by Parr (1950). These slides are at present deposited in the Department of Geology of the University of Adelaide.

Collection of Dr. M.F. Glaessner - slides of European and North American Tertiary Foraminifera.

Collection of the South Australian Museum - the holotype of *Sigmomorphina subregularis* Howchin and Parr.

Collection of the National Museum of Melbourne, Victoria - holotypes, topotypes and representative specimens of Australian and New Zealand Foraminifera.

Collection of the South Australian Mines Department - Slides of Foraminifera from the Mount Gambier town hall sink hole and James' quarry, Naracoorte.

Preservation

Foraminifera in the Gambier Limestone are on the whole moderately well preserved, although all tests have undergone recrystallization to some extent. Because of this, and the limited amount of time available, study of the Foraminifera in this section was undertaken only when necessary to clarify their generic status.

Classification

A somewhat modified version of Pokorny's (1958) classification into families and superfamilies is followed in this thesis. This has been done mainly for the purpose of a convenient arrangement of the systematic descriptions; the classification of taxa within some of the superfamilies, especially the Rotaliidea, is at present in a state of flux due to recent work by Hofker (1951, 1956), Smout (1954, 1955), Reiss (1958, 1960) and other authors.

Terminology

"Distal" is used in the sense of more removed or subsequent in respect to direction of growth; "proximal" in the opposite sense. "Axial" (=inner) refers to the part of the test at or near the axis of coiling, and "peripheral" (=outer) to the part of test away from the axis of coiling. "Dorsal" and "ventral" are used as convenient terms of reference to the more evolute and more involute, respectively, sides of a trochospirally coiled test, without any ecological or phylogenetic implications (unlike Carter, 1958a).

Dimensions

Measurements of tests formed by a planispiral or a comparatively low trochospiral coil are expressed in terms of maximum diameter (D), minimum diameter (d) and thickness (t). Tests formed by a very high trochospiral coil or consisting of uniserially or biserially arranged chambers are measured in respect to length (l) in direction of growth, width (w) and thickness (t). In monolocular tests, length denotes the maximum dimension of elongation.

Distribution

In stating the time ranges of species occurring in the Australian and the New Zealand region in terms of the European Stages, Glaessner (1959) has been followed as far as possible. In most cases, the time ranges of species recorded from other strata than the Gambier Limestone are those stated by other authors in recent publications; for a few New Zealand species additional information concerning their distribution has been obtained from Hornibrook's remarks on slides in the collection of the Geology Department.

SYSTEMATIC DESCRIPTIONS

Superfamily LITUOLIDEA

Family TEXTULARIIDAE

Genus TEXTULARIA Defrance, 1824

TEXTULARIA LATERALIS Lalicker, 1935

Plate 8, fig. 1 - 3.

Textularia lateralis Lalicker, 1935, Smithsonian Misc. Coll., v. 91, no. 22, p.1, pl. 1, fig. 3-5

Description

Test triangular in side view, laterally compressed, with rather sharp edges; length approximately equal to, or a little greater than maximum width. Test tapers rapidly towards bluntly pointed proximal end in width, less so in thickness. Cross-section lenticular, strongly compressed in early part of test, less so distally; in some tests sides comparatively flat along median line, and distal part vaguely hexagonal in cross-section. Edges of test straight or somewhat curved in side view; compressed, marginal extremities of chambers project obliquely towards proximal end, making the edges strongly to moderately serrated. Chambers wider than long, up to about twenty in test, increasing fairly regularly and rapidly in size. In some specimens, rate of increase in width of chambers decreases in distal part of test, which has almost parallel edges. Upper, subtriangular surface of chambers separated from sides of chambers by a distinct angle of the wall; this surface is bent proximally towards edge of test, and may be slightly depressed in the apertual area. Sutures indistinct to fairly distinct, narrow and flush; they are oblique to axis of test in early part, becoming nearly perpendicular to axis distally. Sutures usually convex upwards.

Near edges of test sutures commonly distinct and may be slightly depressed. Wall rather finely arenaceous and smooth. Aperture a narrow, straight or slightly arched basal slit set in a shallow reentrant; its length is about one third or more of thickness of test.

Dimensions

Largest specimen (locality E 159): l = o.92 mm, w = 0.74 mm, t = 0.44 mm. Average l about 0.6 mm.

Distribution

Originally described from Recent sediments near Puerto Rico. Fairly rare throughout the Gambier Limestone.

Remarks

A rather similar species is T. marielensis Lalicker and Bermudez from the Upper Eocene of Cuba. It has more strongly compressed and spinose margins.

TEXTULARIA cf. MARSDENI Finlay, 1939

Plate 8, fig. 4.

Cf. Textularia marsdeni Finlay, 1939, Roy. Soc. New Zealand, Trans., v. 69, p. 90, pl. 14, fig. 67.

Description

Test elongate, straight, increasing gradually both in width and in thickness. Proximal end bluntly rounded in plan; it has been broken off in all but one or two specimens. Cross-section of test changes from strongly compressed, with subacute edges in early part, to moderately compressed, lenticular in middle part; distal part of test is oval to nearly round in cross-section. Up to about twenty-five chambers in test; they increase slowly and regularly in size. Sides of chambers slope fairly evenly in direction of growth, but are truncated at their basal extremities, which commonly appear as strongly raised, thick ridges, in some tests overhanging the preceding sutures.

These ridges may be rather irregular, but usually two, less commonly three, lobe-like proximally directed extensions of each chamber overlap the preceding chamber in the same series on each side of test. The largest of these lobes border the strongly depressed, indistinctly zig-zagging median suture; they may be knob-like in appearance in early part of test. Transverse sutures are similarly depressed, often obscured by surface sculpture; they are approximately perpendicular to axis of test or directed distally towards edges of test. Narrow, ridge-like extensions of chambers at edges of test commonly continue proximally to the raised basal extremities of preceding chambers; thus, at least in early part of test, margins are bluntly keeled, and irregularly serrated. In distal part of test, the surface sculpture of ridges and lobes is less conspicuously developed. Wall arenaceous, consisting of coarse grains set amongst fine grains and calcite cement. Aperture a narrow, straight or slightly arched basal slit, situated in an indistinct reentrant between two lateral lobes of last chamber. It is equivalent to about one third of maximum thickness of test in length.

Dimensions

Largest specimen (locality E 159) : l = 2.3 mm, w = 0.80 mm, t = 0.60 mm.

Distribution

Rare in the Gambier Limestone.

Remarks

The Gambier Limestone specimens, mostly fragmentary, are closely similar to *T. marsdeni*, described from the Miocene of New Zealand; the two may be conspecific, but the poor type figure of *T. marsdeni* does not permit a firm decision. *T. indenta* Galloway and Heminway from the Oligocene of Porto Rico is somewhat similar in respect to surface sculpture, but is less elongate than the Gambier Limestone specimens.

TEXTULARIA cf. PLUMMERAE Lalicker, 1935

Plate 8, fig. 5.

Cf. Textularia plummerae Lalicker, 1935, Cushman Lab. Foram. Res., Contr., v. 11, p. 50, pl. 6, fig. 10.

Dimensions

Largest specimen (locality E 37): l = 1.20 mm, w = 0.48 mm, t = 0.34 mm.

Distribution

Rare in the Gambier Limestone.

Remarks

The rather nondescript specimens in the Gambier Limestone have relatively shorter chambers and more narrowly rounded margins than is indicated in the type figure of T. plummerae.

TEXTULARIA sp. 1

Plate 8, fig. 6 - 9.

Description

Test elongate, tapering slowly both in width and in thickness towards proximal end; it is usually straight, sometimes gently twisted or bent, especially in early part. Rate of tapering uniform throughout or decreasing in distal part of test. Initial end of most tests bluntly pointed in side view. Margins gently curved or straight; they are finely serrated in early part, coarsely in late part, due to projecting lateral margins of chambers. Test commonly strongly compressed and lenticular in cross-section in early part; degree of compression decreases in direction of growth and late part of test is suboval or, rarely, subcircular in cross-section, with margins bluntly angular or rounded. Sometimes test vaguely six-sided in cross-section, due to raised chamber-surfaces on each side of median suture. Up to forty or more embracing chambers in test; they increase slowly and regularly in size. Visible parts of chambers preceding the last two are considerably wider than long, except in distal part of a few specimens. Early sutures indistinct; later sutures commonly distinct, depressed, approximately perpendicular to axis of test and straight or somewhat convex upwards. They join along the middle of each side of test to form a slightly zig-zagging and depressed median suture. In a number of specimens, sutures indistinct, flush or only slightly depressed throughout the test. It cannot be fully ascertained to what extent the variation in degree of depression of sutures represents original variation, as against subsequent modification by abrasion and diagenesis. Wall somewhat rough, consisting of fairly coarse grains set in calcite cement; it is rather smooth in last one or two chambers of some specimens. Aperture a narrow, straight or slightly arched basal slit situated in a slight reentrant between two lateral lobe-like extensions of last chamber. It is equal to about one third of thickness of test in length; in rare specimens apertual slit is longer.

Dimensions

Largest specimen (locality E 147): l = 2.4 mm, w = 1.10 mm, t = 0.90 mm. Most adult tests from 1.5 mm to 2 mm in length.

Distribution

Large specimens fairly rare; small, rather nondescript tests common throughout the Gambier Limestone.

Remarks

The Gambier Limestone specimens were compared with an individual from the Canopus bore (in the South Australian part of the Murray Basin), identified by Dr. N.H. Ludbrook as T. kerimbaensis Said (1949, new name for T. conica d'Orbigny var. corrugata Heron-Allen and Earland, 1915, a homonym of T. corrugata Costa, 1855). The Gambier Limestone specimens are considered conspecific with the Canopus bore individual, but none of them is very similar to the specimen figured by Heron-Allen and Earland, although some, especially smaller tests, show greater similarity with the more elongate forms referred to as *T. kerimbaensis* by Said. Since the variation of this species in Recent sediments has not been studied by the writer, the specimens described above are provisionally referred to as *Textularia sp. 1.*

TEXTULARIA sp. 2

Plate 8, fig. 10 - 12.

Description

Test elongate, arrowhead-shaped, rhomboidal in cross-section; usually strongly compressed, especially in early part. Test tapers evenly towards proximal end both in width and in thickness. Edges straight or slightly curved, finely and irregularly serrated. They are subacute and sharp, commonly becoming less acute and slightly blunter distally. Chambers considerably wider than long, increasing regularly and slowly in size; up to about twenty-five or more chambers in test. Subtriangular upper surfaces of chambers are separated from chamber sides by an angle in wall of test. Sutures fairly distinct, except along median lines of the sides of test, where the wall is thickened and sometimes gently raised; they are narrow, flush, occasionally slightly depressed near margins in distal part of test. Sutures oblique to axis of test, in some specimens becoming nearly perpendicular to axis distally; they are slightly recurved, especially in early part of test, or straight. Wall rather smooth, consisting of fine grains set in calcite cement. Aperture a narrow, straight or slightly arched basal slit, with its length equal to about a half or a little less of the thickness of test.

Dimensions

Largest specimen (locality E 170): l = 0.90 mm, w = 0.54 mm, t = 0.32 mm. Average l about 0.6 mm. Ratio l : t from 2.2 to 2.8.

Distribution

Rather rare in the Gambier Limestone.

Remarks

The Gambier Limestone specimens are somewhat similar to T. mississippiensis Cushman and some of its varieties, from the Oligocene of Texas, but lack the originally depressed and secondarily partly or wholly infilled and thickened sutures of these forms.

Some of the specimens in the Gambier Limestone differ from the majority of the tests described above in being lenticular rather than rhomboidal in cross-section, with blunter margins. Such tests are provisionally referred to Textularia sp. 2.

Genus SIPHOTEXTULARIA Finlay, 1939

SIPHOTEXTULARIA sp. 1

Plate 8, fig. 13.

Dimensions

Largest specimen (locality V119) : l = 0.62 mm, w = 0.40 mm, t = 0.30 mm.

Distribution

Very rare in the Gambier Limestone.

Remarks

The mostly damaged Gambier Limestone specimens bear a certain resemblance to S. concava (Karrer), but in the South Australian forms the sides of the test are not as concave, the margins are more rounded, and the aperture is nearer to one side of the test and at an angle to the plane of compression.

SIPHOTEXTULARIA sp. 2

Plate 8, fig. 14, 15.

Description

Test somewhat twisted, with the elongate aperture oblique to plane of compression. Wall very finely arenaceous.

Dimensions

Largest specimen (locality E 154) : l = 0.56 mm, w = 0.32 mm, t = 0.20 mm.

Distribution

Very rare in the Gambier Limestone.

Genus BOLIVINOPSIS Yakovlev, 1871

BOLIVINOPSIS cf. ATTENUATA (Cushman), 1939

Plate 8, fig. 16

Cf. Spiroplectoides attenuata Cushman, 1939, Cushman Lab. Foram. Res., Contr., v. 15, p. 62, pl. 10, fig. 47-49.

Description

Test elongate, compressed, club-shaped in side view. It consists of an early planispirally coiled portion, which is wider and slightly thicker than the subsequent straight part consisting of biserially arranged chambers. Outline of both parts of test is usually gently lobate. Margin of test bluntly to fairly sharply angular. Seven to nine chambers, arranged in about one whorl, are present in early coiled part; up to eighteen in the straight part. Chambers increase very slowly and regularly in size. Sutures distinct, short, straight and oblique; they make an angle of about 45° or less with axis of test in the straight part. Sutures limbate, slightly raised or flush. Wall very finely arenaceous, with fine pores passing between the grains. Aperture loop-shaped, extending at right angles to basal suture into the subterminal apertual face.

Dimensions

Largest specimen (locality E 166): length 0.48 mm, width 0.16 mm, thickness 0.08 mm.

Distribution

Occurs in very few samples from the lowest and the intermediate zones of the Gambier Limestone.

Remarks

The Gambier Limestone specimens are closely similar to *S. attenuata*, described from submarine cores of Eocene age collected off the Atlantic coast of North America; however, Cushman stated that his specimens were coarsely and conspicuously perforate and did not consider their wall structure to be arenaceous. The arenaceous nature of the wall in the Gambier Limestone tests is seen only in thin section under high magnification; there is no evidence that Cushman carried out such an examination.

Subsequently Cushman (1940) regarded *Spiroplectoides* as a synonym of *Bolivinopsis* and placed it within his family Heterohelicidae, characterized by "calcareous, perforate" walls. Although the wall of *B. capitata* Yakovlev, 1891, the type species of *Bolivonopsis*, was not stated to be arenaceous in the type description, most authors accept the opinion of later Russian workers that such is the case, e.g. Glaessner (1945, p. 98), Hofker (1956, p. 915), Pokorny (1958, p. 193). Hofker erected a new genus *Spirobolivina* to include non-arenaceous forms, similar in general morphology to *Bolivinopsis*; Cushman apparently considered *Spiroplectoides* and, subsequently, *Bolivinopsis* as based on and including such forms.

Since the wall structure of *S. attenuata* has not been examined by the writer because representative specimens were unavailable, the Gambier Limestone specimens cannot be considered as undoubtedly conspecific with the tests described by Cushman.

Genus VULVULINA d'Orbigny, 1826

VULVULINA sp.

Plate 8, fig. 17.

Description

Test elongate, compressed; proximal end pointed. Cross-section lenticular, less commonly rhomboidal; margin sharp, serrated.

Chambers considerably wider than long; up to about twenty present. Septal sutures fairly distinct near margins of test, slightly depressed or flush, slightly oblique, gently curved; median sutures indistinct. Wall rather smooth, consisting of fairly fine grains set in calcite cement. Aperture in most tests a small arch along the basal suture; in a few specimens aperture is elongate in plane of compression of test, and in one individual it is an oval, subterminal opening, which does not touch the basal suture.

Dimensions

Largest specimen (locality V 118) : l = 1.00mm, w = 0.64 mm, t = 0.34 mm.

Distribution

Very rare in the Gambier Limestone.

Family PLACOPSILINIDAE

Genus BDELLOIDINA Carter, 1877

BDELLOIDINA AGGREGATA Carter, 1877

Plate 8, fig. 18, 19.

Bdelloidina aggregata Carter, 1877, Ann. Mag. Nat. Hist., ser. 4, v. 19, p. 201, pl. 13, fig. 1 - 8; Brady, 1884, Rept. Voy. Challenger, Zool., v. 9, p. 319, pl. 36, fig. 4 - 6.

Bdelloidina aggregata Carter var. bradii Elias, 1950, Jour. Pal., v. 24, p. 301, pl. 4 - 6.

Description

Test attached, compressed. Attached side generally flat, somewhat variable depending on surface of attachment; unattached side convex. Numerous, close-set chambers, several times wider than long, are arranged uniserially in a flat series, which is irregularly curved or bent in plane of attachment. Successive chambers show no definite increase in size. Length of individual chambers is uniform or somewhat variable in relation to width; if test bends in plane of attachment, chambers lengthen away from axis of bending. Sutures on unattached side fairly distinct, slightly depressed, curved or wavy; sutures invisible on attached side. Wall thick, coarsely arenaceous; rough on unattached side, rather smooth on attached side. On inside, wall bears deep, irregular pits, which do not penetrate to outer surface. No apertual face preserved intact. Septa pierced by large, irregularly oval or circular pores; usually about half a dozen pores, arranged in a single row, are present; rarely pores occur in two rows. In dissected specimens, septa are seen to be connected by transverse partitions, which leave no trace on outside of wall of test.

Dimensions

Specimens range up to about 5 mm in size and 1 mm in thickness.

Distribution

Originally described from the Recent. Very rare in the Gambier Limestone.

Remarks

Transverse partitions between the septa are not mentioned in the type description of *B. aggregata*, and *B. aggregata* var. *bradii* was erected for tests with such partitions. Since the holotype of *B. aggregata* is apparently unavailable, the exact relationship between *B. aggregata* and its variety *bradii* cannot be ascertained.

Family VERNEUILINIDAE

Genus GAUDRYINA d'Orbigny, 1839

GAUDRYINA CRESPINAE Cushman, 1936

Plate 8, fig. 20 - 22

Gaudryina (Pseudogaudryina) crespinae Cushman, 1936, Cushman Lab. Foram. Res., Spec. Pub. 6, p. 14, pl. 2, fig. 15; Cushman, 1937, *ibid.*, Spec. Pub. 7, p. 91, pl. 13, fig. 10.

Description

Test elongate, tapering towards a fairly sharply pointed or blunt proximal end. Test may be slightly bent or twisted. Cross-section of early, triserial part of test triangular, with fairly sharp corners and flat sides, approximately equal in width. In the later, biserial part of test, two of the edges become increasingly rounded distally, with the third edge more persistent; hence cross-section changes gradually from roundedly triangular to roughly oval, with one end bluntly pointed. Biserial part constitutes up to about half the length of test, usually less. In outline, edges of the test are smooth or slightly indented, especially in biserial part of test. About twenty to thirty chambers, triangular in distal view, in the triserial part of test; up to four pairs of chambers in biserial part. In this, one series of chambers bluntly triangular, the other roundedly trapezoidal in distal view. Chambers increase gradually and slowly in size in triserial part, usually more rapidly in biserial part of test; sutures narrow, usually indistinct, flush or slightly depressed, especially in distal part of test. In triserial part, sutures perpendicular or slightly oblique to axis of test, straight or slightly bent near the median line of each side of test, where they meet in a zig-zag pattern. In biserial part, such pattern is confined to only two sides of test, with sutures on the remaining side transverse to axis of test and straight. Wall rather finely arenaceous, fairly smooth. Aperture of biserially arranged chambers a short, narrow, sometimes slightly arched slit along the middle part of basal suture. It is set in a slight reentrant between low, flat, lobe-like extensions of the last chamber.

Dimensions

Largest specimen (locality V 118) : l = 1.6 mm, w = 0.7 mm, Average l about 0.8 mm.

Distribution

Originally described from the Middle Miocene of Balcombe Bay, Victoria. Fairly common throughout the Gambier Limestone.

Remarks

Most of the Gambier Limestone specimens have less distinct chambers and sutures than is indicated in the type figure of G. crassipinae. Very rare specimens differing from those described above in having a very short triserial part and a more compressed, oval, biserial part, are also present in the Gambier Limestone.

GAUDRYINA cf. RUGOSA d' Orbigny, 1840

Plate 9, fig. 1, 2.

Cf. Gaudryina rugosa d'Orbigny, 1840, Soc. Geol. France, Mem., v. 4, p. 44, pl. 4, fig. 20, 21.

Gaudryina rugosa Chapman (non d'Orbigny), 1907, Linn. Soc. Lond., Jour., Zool., v. 30, p. 28, pl. 3, fig. 64.

Description

Test elongate, pyramidal in early, triserial part, subcylindrical in later, biserial part. Early part tapers rather rapidly towards bluntly pointed proximal end. Test often twisted at base of biserial part. Cross-section of triserial part of test triangular, with blunt or rounded corners and flat sides of equal width; cross-section of biserial part oval to nearly circular. Edges of test straight or somewhat curved, usually slightly indented. Biserial part consists of about two pairs of chambers and constitutes one half or more of the test. Sutures indistinct in triserial part; in biserial part poorly visible, depressed to almost flush, straight or slightly bent near the median line of each side, where they join in a zig-zag pattern. Wall fairly coarsely arenaceous and rough. Aperture a short, narrow, sometimes slightly arched slit along middle part of basal suture, usually set in a reentrant between two low, flat lobes of the last chamber.

Dimensions

Largest specimen (locality E 173) : l = 1.9 mm, w = 1.0 mm; l of most specimens between 1.0 mm and 1.5 mm.

Distribution

Rare throughout the Gambier Limestone.

Remarks

Various forms, probably belonging to more than one species, have been referred to as G. rugosa by different authors. Some of such forms are closely similar to the Gambier Limestone specimens; the type figure of G. rugosa shows a more elongate and compressed individual. According to Cushman (1937, p. 36), G. rugosa does not range above the top of the Cretaceous.

G. cf. rugosa generally differs from G. crespinae (p. 87) in the Gambier Limestone by possessing a more coarsely arenaceous wall, a relatively larger biserial part and a more rounded cross-section, while the test is larger and tapers more rapidly towards a blunter proximal end. Rare individuals morphologically intermediate between typical representatives of G. cf. rugosa and G. crespinae are, however, present, and it is possible that the specimens described above are megalospheric forms of G. crespinae.

Genus PSEUDOCLAVULINA Cushman, 1936

PSEUDOCLAVULINA sp.

Plate 9, fig. 3, 4.

Description

Test rod-shaped, straight or gently curved; it tapers slowly towards proximal end, less commonly sides roughly parallel. Apertual end bluntly pointed; proximal end bluntly pointed to rounded. Distal part of rare specimens slightly lobate in outline; cross-section round. Early chambers in triserial arrangement, distal chambers uniserial. Sutures usually invisible, and number, size and arrangement of chambers can be ascertained only in dissected specimens.

Wall coarsely arenaceous, rough. Aperture a round, terminal opening with a jagged circumference.

Dimensions

Largest specimen (locality E 108) : l = 2.9 mm, w = 0.95 mm. In most adult tests, ratio l : w is about 3. In very rare specimens this ratio is about 2. These possibly represent a different species.

Distribution

Rare in the lowest and intermediate zones of the Gambier Limestone.

Genus CLAVULINOIDES Cushman, 1936

CLAVULINOIDES VICTORIENSIS Cushman, 1936

Plate 9, fig. 5, 6.

Clavulina angularis Chapman (non d'Orbigny), 1907, Linn. Soc. London., Jour., Zool., v. 30, p. 29, pl. 4, fig. 68 - 73.

Clavulinoides szaboi (Hantken) var. victoriensis Cushman, 1936, Cushman Lab. Foram. Res., Spec. Pub. 6, p. 22, pl. 3, fig. 19, 22; Cushman, 1937, ibid., Spec. Pub. 7, p. 134, pl. 18, fig. 35, 36.

Description

Test of microspheric specimens straight or slightly bent, elongate. Cross-section triangular, with sides flat or concave. In side view edges gently curved, irregularly indented. Test tapers gradually towards the bluntly pointed proximal end; last chamber tapers rapidly in direction of growth. Megalospheric forms are thinner and generally smaller in size; the tests have straighter edges and taper less gradually towards a blunter proximal end. Chambers arranged triserially in early part of test, and are embracing in the late, uniserial part. Proximal sutures indistinct, distally flush with surface or slightly depressed, convex in direction of growth. Wall fairly coarsely arenaceous, generally rough, but rather smooth in rare tests. Aperture rounded, terminal, sometimes at the tip of an indistinct apertual neck.

Dimensions

Largest microspheric specimen (locality E 170) : l = 3.0 mm, w. = 1.3 mm; largest megalospheric specimen (locality E 154) : l = 2.4 mm, w = 0.7 mm.

Distribution

Occurs in Oligocene to Middle Miocene strata in the Balcombe Bay, Port Phillip and Torquay areas in Victoria. Rare in the Gambier Limestone.

Remarks

C. victoriensis differs from C. szabei in possessing a rougher surface, less distinct chambers and less strongly developed apertual neck (as stated by Cushman, 1936).

Genus DOROTHIA Plummer, 1931

DOROTHIA PARRI Cushman, 1936

Plate 9, fig. 7-10.

Dorothia parri Cushman, 1936, Cushman Lab. Foram. Res., Spec. Pub. 6, p. 29, pl. 4, fig. 19; Cushman, 1937, ibid., Spec. Pub. 8, p. 91, pl. 10, fig. 10.

Description

Test elongate, tapering towards a bluntly pointed, less commonly broadly rounded proximal end. Outline of test evenly curved, rarely slightly lobate in distal part. Cross-section round in early part, round or oval in later part of test. Adult chambers biserially arranged, last one or two pairs constituting most of the test, increasing regularly and rapidly in size. They are embracing, usually with somewhat compressed distal ends; less commonly subglobular, more inflated. Sutures indistinct in early part of test and poorly visible, rarely slightly depressed in later part, where they are oblique to axis of test. Wall coarsely arenaceous, rough.

Aperture a narrow, gently arched slit, extending along median part of basal suture, up to about one third or a little more of diameter of test in length. Apertual face flat, wide, low, horse-shoe-shaped in outline. Angle between apertual face and axis of test is commonly less than 45°; sometimes apertual face nearly vertical. In rare specimens with more rounded last chambers and less distinct apertual face, the angle between it and the axis of test is about 60° or more.

Dimensions

Largest specimen (locality E 158) : l = 2.0 mm, w = 1.2 mm, t = 1.1 mm. Average l about 1. 5 mm.

Distribution

Originally described from the Miocene near Geelong, Victoria. Fairly common throughout the Gambier Limestone.

Remarks

Most of the Gambier Limestone specimens have a more pointed proximal end than is indicated in the type figure of D. parri, but a number of tests with broadly rounded early part is also present.

Genus KARRERIELLA Cushman, 1933

KARRERRIELLA CHILOSTOMA (Reuss), 1852

Plate 9, fig. 11, 12.

Textularia chilostoma Reuss, 1852, Deutsch. Geol. Ges., Zeitschr., v. 4, p.18, text-fig. a, b.

Karreriella chilostoma (Reuss). Cushman, 1937, Cushman Lab. Foram. Res., Spec. Pub. 8, p. 126, pl. 15, fig. 1 - 8; Cushman and Stainforth, 1945, ibid., Spec. Pub. 14, p. 19, pl. 2, fig. 6, 7; Bermudez, 1949, ibid., Spec. Pub. 25, p. 90, pl. 5, fig. 17-20.

Dimensions

Largest specimen (locality E 154) : l = 0.82 mm, w = 0.38 mm, t = 0.16 mm.

Distribution

Occurs in the Oligocene of Europe and Central America. Very rare in the lowest and intermediate zones of the Gambier Limestone.

Remarks

K. chilostoma appears to be closely similar to the Recent K. bradyi (Cushman) and may be ancestral to it.

KARRERIELLA CUSHMANI Finlay, 1940

Karreriella cushmani Finlay, 1940, Roy. Soc. New Zealand, Trans., v. 69, p. 452, pl. 63, fig. 38 - 42.

Remarks

Very rare, fragmental tests in the Gambier Limestone agree with specimens of K. cushmani from New Zealand, with which they have been compared. This species occurs in the Oligocene and the Lower Miocene of New Zealand.

Superfamily NODOSARIIDEA

Family NODOSARIIDAE

Genus LAGENA Walker and Jacob, 1798

LAGENA LUCIAE Parr, 1938

Plate 9, fig. 13.

Lagena luciae Parr, 1938, Roy. Soc. Western Australia, Jour., v. 24, p. 78, pl. 1, fig. 13.

Description

Test elongate; it tapers gradually upwards and rapidly towards a rounded or bluntly pointed base, which may bear a short spine. Cross-section polygonal or rather rounded, with test thickest at about one third of its length from base. Test ornamented with five, very rarely six longitudinal costae, which are equidistant, distinct, sharp and thin. Costae join at base of a thin, tubular and gently tapering apertual neck and are relatively high and separated by fairly deep indentations near their apertual extremities. Costae are low near their mid-length, and increase to a maximum height downwards, becoming flange-like and often projecting slightly below base of test. Costae smoothly curved or slightly serrated in outline, and are regularly pierced by pores of moderate size. Pores directed obliquely upwards near upper extremities of costae; their direction gradually swings downwards in lower parts of costae until they are nearly parallel to axis of test near its base. Individual pores usually uniform in diameter, but may widen towards their outer ends, especially near base of test.

Dimensions

l from 0.22 mm to 0.38 mm; w from 0.14 mm to 0.18 mm.

Distribution

Originally described from the Eocene of Western Australia. Rare in the Gambier Limestone.

Remarks

Specimens similar to those described above, except in possessing eleven or twelve less distinctly developed costae, occur very rarely in the Gambier Limestone.

The South Australian specimens were compared with the holotype and other tests representing L. luciae from the King's Park bore, Perth. The holotype is rather worn, with a broken apertual neck; the other tests are well preserved and agree well with the Gambier Limestone specimens.

L. striatopunctata Parker and Jones var. renta-costa Pierce from the Miocene of Californica appears to be closely similar to L. luciae.

LAGENA CAUDATA (d'Orbigny), 1839

Plate 9, fig. 14.

Oolina caudata d'Orbigny, 1839, Voy. Amer. Merid., Foram., v. 5, pt. 5, p. 19, pl. 5, fig. 6.

Lagena caudata (d'Orbigny). Parr, 1950, B.A.N. Z.A.R.E. Repts., ser. B, v. 5, pt. 6, p. 301, pl. 8, fig. 2.

Description

Test spindle-shaped, circular in cross-section, with maximum diameter about one third of length of test from base. Test tapers more gradually upwards than towards base; at upper end, wall is thickened to form a conical apertual collar, which merges with a long and thin, tubular apertual neck. Base commonly bears a sharp spine which may be broken or absent. Wall ornamented with usually twenty to thirty, less commonly up to about fifty fine, longitudinal costae. Costae low, angular or rounded in cross-section; they extend from base of test to base of apertual collar or even to base of apertual neck. Costae decrease in number near apertual end of test, which in some specimens bears a few costae considerably higher than on remainder of test. Aperture ends as a fine, circular opening at tip of unlipped apertual neck.

Dimensions

l from 0.30 mm to 0.50 mm; w from 0.16 mm to 0.28 mm. Ratio l : w from 1.7 to 2.

Distribution

Occurs in the Recent of the Antarctic region. Fairly common in the Gambier Limestone.

Remarks

The Gambier Limestone specimens agree well with both the type figure of *L. caudata* and the specimens referred to this species by Parr, with which they have been compared.

LAGENA SPIRALIS Brady, 1884

Lagena spiralis Brady, 1884, Rept. Voy. Challenger, Zool.,

v. 9, p. 468, pl. 114, fig. 9; Cushman and Todd, 1945, Cushman Lab. Foram. Res., Spec. Pub. 15, p. 34, pl. 5, fig. 17.

Distribution

Occurs in the Tertiary and the Recent. Very rare in the Gambier Limestone.

LAGENA cf. ACUTICOSTA Reuss, 1862

Plate 9, fig. 15.

Cf. Lagena acuticosta Reuss, 1862, K. Akad. Wiss. Wien, Math. - Naturw. Cl., Sitzber., v. 44, p. 305, pl. 1, fig. 4.

Description

Test drop-shaped, with a tapering apertual end and a slightly truncated base. Cross-section of test circular. A conical apertual collar is present at distal end of test; its surface is flush with or slightly raised above general surface of test. Wall covered with eight to eighteen longitudinal costae. Costae usually thick compared with intercostal spaces, and rounded or somewhat flattened in cross-section. They extend from a basal disc or polygon, which may be up to about one fourth of maximum diameter of test across, to base of apertual collar. Tubular aperture opens at tip of apertual collar; there is no distinct apertual neck.

Dimensions

l. from 0.24 mm to 0.42 mm; w from 0.18 mm to 0.26 mm. Ratio l : w from 1.3 to 1.9.

Distribution

Rather rare in the Gambier Limestone.

Remarks

It appears that a number of specifically different forms, some of them rather similar to the specimens described above, have been referred to as L. acuticosta by different authors. The type figure of L. acuticosta shows a specimen from the Cretaceous of Holland, which is less elongate and has a less strongly developed apertual collar and thinner costae than the South Australian tests. The Recent L. subacuticosta Parr differs mainly in being considerably larger in size.

LAGENA sp.

Plate 9, fig. 16 - 18.

Description

Test drop-shaped, tapering towards apertual end, less so downwards. Base slightly truncated, with a basal disc or polygon, or bluntly pointed. Cross-section of test circular. Wall covered with twelve to twenty longitudinal costae, which extend from base of test to base of apertual neck. Intercostal spaces filled to a variable degree with shell matter, usually more so in top part of test. At one extreme are specimens with only their upper third, or less, possessing a smooth circumference; costae on remainder of test are steep-sided, flat-topped and considerably wider than the narrow intercostal spaces. In other specimens upper two thirds or more are smooth; lower boundary of smooth part is sharp, somewhat irregular and ragged, partly due to breakage. In some such specimens, intercostal spaces are not solidly filled near lower boundary of smooth part of test, but are covered by lateral thickening of only tops of costae, with empty spaces beneath; such "double-walled" structure of wall exists only near base of test. Sometimes such covering of intercostal spaces is incomplete, with costae T-shaped in cross-section. In rare specimens, whole test is smooth-surfaced; a thin, somewhat ragged flange surrounds, and extends below, base of test, imparting to it a strongly truncated appearance in side-view. Apertual neck tapers distally, usually short, broken at tip; in a few specimens fairly long. Aperture ends in a fine, terminal opening.

Dimensions

1 from 0.32 mm to 0.48 mm; w from 0.20 mm to 0.28 mm. Ratio 1 : w from 1.2 to 1.7.

Distribution

Fairly common in the Gambier Limestone.

Remarks

The specimens described above differ from L. cf. acuticosta (p. 97) in the Gambier Limestone mainly in possessing at least partly infilled intercostal spaces and a less distinctly developed apertual collar, but a number of specimens are present, which cannot be assigned with certainty to either one of these two species. The significance of the infilled, and in some cases "double-walled" intercostal areas is not understood; it may be a character of minor, perhaps infraspecific, taxonomic importance.

Genus NODOSARIA Lamarck, 1812

NODOSARIA SOLUTA (Reuss), 1851

Plate 9, fig. 19, 20.

Dentalina soluta Reuss, 1851, Deutsch. Geol. Ges., Zeitschr., v. 3, p. 60, pl. 3, fig. 4.

Nodosaria soluta (Reuss). Brady, 1884, Rept. Voy. Challenger, Zool., v. 9, p. 503, pl. 62, fig. 13-16; Chapman and Parr, 1926, Linn. Soc. Lond., Jour., Zool., v. 36, p. 383, pl. 19, fig. 40.

Distribution

Widespread in Cretaceous to Recent sediments. Rather rare throughout the Gambier Limestone.

Remarks

Almost all specimens in the Gambier Limestone are fragmentary.

Genus DENTALINA d'Orbigny, 1826

DENTALINA CONSOBRINA d'Orbigny, 1846

Plate 9, fig. 21.

Dentalina consobrina d'Orbigny, 1846, Foram. foss. bass tert. Vienne, p. 46, pl. 2, fig. 1 - 3.

Distribution

Widespread in Tertiary and Recent deposits. Very rare in the Gambier Limestone.

DENTALINA cf. COMMUNIS d'Orbigny, 1826

Plate 10, fig. 1 - 3.

Cf. Nodosaria (Dentaline) communis d'Orbigny, 1826, Ann. Sci. Nat., ser. 1, v. 7, p. 254.

Description

Test strongly elongate, gently curved, round or slightly oval in cross-section. Sutures nearly perpendicular to axis of test in lateral view, V-shaped on more concave side of tests. Usually base bluntly pointed or bearing a short spine; rarely rounded. Up to nine chambers in test. Wall finely perforate, smooth, except for one or two specimens with low costae on their proximal part. Aperture terminal at off-centre tip of tapering last chamber; radiate.

Distribution

Rather rare in the Gambier Limestone.

Remarks

The type description of D. communis is not accompanied by a type figure, and a large number of forms, probably belonging to more than one species, have been referred to d'Orbigny's species by different authors. Some of such forms are closely similar to the Gambier Limestone specimens. Since 1826 a number of species, differing in minor characters only, have been erected for tests generally similar to these described above, e.g. D. orbignyana Neugeboren, 1856, D. roemeri Neugeboren, 1856, and D. neugeboreni (Schwager), 1866.

DENTALINA cf. MUCRONATA Neugeboren, 1856

Plate 10, fig. 4.

Cf. Dentalina mucronata Neugeboren, 1856, K. Akad. Wiss. Math. - Naturw. Cl., Denkschr., v. 12, p. 83, pl. 3, fig. 8-11.

Distribution

Very rare in the Gambier Limestone.

Remarks

The Gambier Limestone specimens differ from those figured by Neugeboren in being less elongate and in lacking a basal spine. The South Australian forms are closely similar, perhaps conspecific with the Recent tests referred to Nodosaria mucronata by Brady (1884, p. 506, pl. 62, fig. 27-31).

DENTALINA sp. 1

Plate 9, fig. 22-26.

Description

Test long, gently curved, circular in cross-section. It tapers very gradually towards base (especially in microspheric forms), which usually bears a short, stout spine; rarely, base is rounded. In a number of (megalospheric) specimens, the proloculus is larger than the immediately succeeding chambers. Chambers increase slowly in size; up to about twelve present. In the early part of test chambers and sutures indistinct, outline of test smooth. In the distal part, chambers become inflated, usually more so on one side than on the other; sutures correspondingly depressed, perpendicular to strongly oblique to axis of test. Specimens rather variable with respect to length at which outline of test changes from smooth to lobate. Wall covered by about fifteen to twenty prominent, longitudinal, sometimes branching costae, which usually twist around test at a slight angle to its axis. Costae commonly slightly wavy, continuous across sutures. They are fairly low and wide; rounded or flat-topped, with steep sides, in cross-section. Usually the last chamber or only its distal part is smooth. Aperture a large, terminal, round and radiate opening, a little nearer to the less lobate side of test. No distinct apertual neck is present.

Dimensions

l ranges up to 10 mm; w up to 1.4 mm.

Distribution

Rather rare throughout the Gambier Limestone.

Remarks

The mostly fragmental Gambier Limestone specimens appear to be rather similar to Recent forms named Nodosaria flintii by Cushman, but do not taper as strongly towards the base.

DENTALINA sp. 2

Plate 10, fig. 5.

Description

Test long, gently curved, tapering slowly and gradually towards rounded base. Outline smooth, may be slightly lobate in distal part of test; cross-section round or slightly oval. Chambers and sutures rather indistinct. Chambers subcylindrical, close-set, increase slowly and gradually in size; up to more than nine chambers in test. Sutures approximately perpendicular or strongly oblique to axis of test, narrow or somewhat limbate, usually flush. Wall smooth. Last chamber tapers obliquely in direction of growth. Aperture a terminal, off-centre, large, round and radiate opening.

Dimensions

l up to 9 mm; w up to 1.6 mm.

Distribution

Rare in the Gambier Limestone.

Remarks

The specimens described above do not seem to be closely similar to any described species.

Genus MARGINULINA d'Orbigny, 1826

MARGINULINA HANTKENI Bandy, 1949

Plate 10, fig. 6 - 8.

Marginulina subbullata Hantken (non Gümbel, 1861), 1875,

K. Ungar. Geol. Anst., Mitt. Jahrb., v. 4, p. 46, pl. 4, fig. 9-10; Bermudez, 1949, Cushman Lab. Foram. Res., Spec. Pub. 25, p. 141, pl. 9, fig. 19, 20.

Marginulina hantkeni Bandy, 1949, new name, Bull. Amer. Pal., v. 32, no. 131, p. 46, pl. 6, fig. 9.

Description

Test of microspherical individuals elongate; formed by a coiled proximal part consisting of about three chambers, and a usually straight, less commonly curved, distal part; up to six chambers in test. Outline of test smoothly curved in early part, lobate in later part; cross-section subcircular. Later chambers subspherical or cylindrical, tapering rapidly distally, usually somewhat inflated; early chambers generally close-set. Early chambers increase more rapidly in size than later chambers. Sutures in proximal part of test indistinct, flush or slightly depressed; in distal part perpendicular or strongly oblique to axis of growth, commonly fairly distinct; usually depressed, less commonly flush. Later sutures narrow, or limbate, especially on one side of test, due to the thickened apertual regions of preceding chambers. Aperture a rather small, circular, radiate opening at tip of the obliquely tapering distal end of last chamber.

Dimensions

Largest specimen (locality E 24) : l = 1.48 mm, w = 0.58 mm. Average l about 0.8 mm.

Distribution

Widespread in Eocene to Miocene strata in Europe and in America. Rather rare throughout the Gambier Limestone.

Remarks

M. pediformis Bornemann from the Oligocene of Germany seems to be closely similar to M. hantkeni, differing in its proximal end being more curved.

MARGINULINA cf. SENDAIENSIS Asano, 1937

Plate 10, fig. 9 - 12.

Cf. Marginulina sendaiensis Asano, 1937, Geol. Soc. Japan, Jour., v. 44, p. 33, text-fig. 6.

Description

Test elongate, curved or nearly straight, sometimes slightly twisted. Cross-section circular or somewhat oval. Microspheric individuals taper gradually towards pointed base; in megalospheric forms, proximal end is less pointed; usually base bears a short, stout spine. Proximal part of test smooth or slightly lobate in outline, with chambers and sutures indistinct, except in well preserved specimens. Distal chambers somewhat inflated, more so in megalospheric individuals; sutures correspondingly depressed, perpendicular or strongly oblique to axis of growth. Sutures usually narrow on convex side of curved tests, somewhat limbate on opposite side. Up to nine chambers in test. Wall covered with longitudinal, sometimes branching costae, which are continuous across sutures and usually twist around the test at a slight angle to the axis of growth. Costae distinct, rather low and thick; rounded or somewhat flat-topped, steep-sided in cross-section. On adult chambers sixteen to twenty-four costae present; less on earlier chambers. Usually distal part of last chamber is smooth; rarely up to two and a half distal chambers are smooth. Wall, including costae, finely perforate; sparse, larger pores also may be present. Last chamber tapers obliquely to form a short, stout, usually rather indistinctly developed, apertual neck with thick walls. Aperture at tip of apertual neck.

Dimensions

Largest specimen (locality E 149) : l = 2.0 mm, w = 0.54 mm. Most specimens between 1 mm and 1.5 mm in length.

Distribution

Fairly common in the intermediate and uppermost zones of the Gambier Limestone.

Remarks

The Gambier Limestone specimens differ from M. sendaiensis, from the Miocene and the Pliocene of Japan, mainly in their less curved early part of the test.

MARGINULINA cf. INDICA LeRoy, 1944

Plate 10, fig. 13, 14.

Cf. Marginulina indica LeRoy, 1944, Colorado School Mines Quart., v. 39, p. 78, pl. 2, fig. 8 - 9.

Description

Early, planispirally coiled part of test consists of up to four or five chambers arranged in about half a whorl; later, uncoiled part is straight. Outline of test smoothly curved in early part; un-coiled part has parallel, sometimes slightly lobate sides. Early part lenticular in cross-section; distally test becomes less compressed, oval in cross-section, with chambers usually more compressed near the margin corresponding to periphery of coiled part of test. Last chamber tapers towards this margin. Up to ten chambers in test; they increase regularly in size. Sutures rather indistinct, oblique; in coiled part straight or weakly recurved, flush, in later part oblique, straight, flush or slightly depressed. Wall smooth, finely perforate. Aperture round, radiate, subterminal at bluntly pointed tip of last chamber.

Dimensions

Largest specimen (locality E 154) : l = 1.74 mm, w = 0.60 mm, t = 0.52 mm.

Distribution

Rare in the Gambier Limestone.

Remarks

The type figure of M. indica shows a slightly more compressed specimen from the Miocene of Java, with more chambers per unit length of test, than the Gambier Limestone specimens. Another similar species with more elongate and tapering chambers is Marginulinopsis wilcoxensis Toulmin from the Eocene of Alabama.

Genus VAGINULINA d'Orbigny, 1826

VAGINULINA cf. SUBLITUUS (Nuttall), 1932

Plate 10, fig. 15 - 17.

Cf. Cristellaria sublituus Nuttall, 1932, Jour. Pal., v. 6, p. 11, pl. 1, fig. 13, 14.

Description

In microspheric specimens, test elongate, compressed. Early part of test consists of up to four chambers arranged in a rapidly uncoiling planispiral coil; later part straight or gently curved, with sides parallel or tapering slightly towards base. Base of test asymmetrically rounded in plan; outline of straight part commonly smooth, sometimes slightly lobate. Last chamber tapers obliquely, with one side curved and the other straight. Some specimens oval in cross-section; usually test more compressed in cross-section and more curved in outline at the side corresponding with the periphery of the early, coiled part. Margin may be indistinctly keeled in early part of test. Proloculus spherical, slightly thicker than succeeding chambers, which are wedge-shaped in outline in early part and slice-shaped in later part of test. Not more than three succeeding chambers touch the proloculus with their lower extremities; up to eight close-set chambers in test. Early sutures recurved; later sutures straight, oblique at an angle of about 45° or more to axis of test. Sutures distinct; usually narrow and flush with surface near their more basal extremities, but thickening and becoming raised towards their more distal ends. Sometimes sutures narrow, or limbate and raised throughout their length. Wall smooth, finely perforate, with sparse, coarser pores also present. Aperture terminal, narrow and radiate, at tip of a short, bluntly pointed neck, which is situated at the more compressed side of last chamber.

Megalospheric specimens intergrade morphologically with the microspheric forms. Compared with the latter, megalospheric specimens have a larger proloculus and are uncoiled in early part of test, which is longer, more elongate and less strongly compressed; their sutures are generally at a larger angle to axis of test.

Dimensions

Largest megalospheric specimen (locality E 70) : l = 1.60, mm, w = 0.38 mm, t = 0.26 mm. Largest microspheric specimen (locality E 63) : l = 0.66 mm, w = 0.28 mm, t = 0.16 mm.

Distribution

Fairly common throughout the Gambier Limestone.

Remarks

The Gambier Limestone specimens are closely similar to *V. sublituus*, originally described from the Oligocene of Mexico; they differ mainly in being less compressed and in the thickening of the sutures near the loci of previous apertures.

VAGINULINA sp.

Plate 10, fig. 18-20.

Description

Test elongate, curved to almost straight; sides roughly parallel or tapering slowly towards rounded base. Cross-section compressed, oval; in rare specimens distal chambers inflated and round in cross-section. In early part, chambers increase slowly and regularly in size, and their visible parts are considerably wider than long; sometimes distal chambers increase more rapidly in length, and rarely last one or two chambers are smaller than the preceding one. Up to thirteen chambers in test; last chamber tapers obliquely. Sutures fairly distinct, strongly oblique to axis of test, convex upwards and flush; they are more limbate at the middle than towards marginal extremities. Wall smooth, bearing fairly coarse, sparse pores. Aperture terminal, round, radiate.

Dimensions

Specimens range up to 5 mm in length.

Distribution

Rare in the Gambier Limestone.

Remarks

V. faba Galloway and Himinway from the Oligocene of Porto Rico differs from the Gambier Limestone specimens in its considerably smaller size, greater degree of compression and more chambers per unit length of test. V. loeblichi McLean from the Paleocene of North America is also smaller and has almost narrow sutures.

Genus LENTICULINA Lamarck, 1804

LENTICULINA cf. GIBBA (d'Orbigny), 1839

Plate 10, fig. 21, 22.

Cf. Cristellaria gibba d'Orbigny, 1839, in R. de la Sagra, Hist. phys. nat. Cuba, p. 40, v. 8. pl. 7, fig. 20, 21.

Description

Test somewhat longer than wide, compressed, equally biconvex; it consists of an involute, planispiral coil. Specimens show a tendency towards uncoiling, though all chambers reach periphery of preceding whorl. Peripheral outline smoothly curved or, less commonly, bent at sutures, mainly in distal part of last whorl. Margin bluntly angular or with a poorly developed keel. The six to eight chambers in last whorl increase regularly in size. Sutures commonly distinct, recurved, flush; they are usually narrow, except at periphery, where test wall is thickened at loci of previous apertures. Wall smooth, finely perforate. Aperture round, radiate. Apertual face absent or indistinctly developed.

Dimensions

Largest specimen (locality E 154) : l = 1.16 mm, w = 0.84 mm, t = 0.44 mm. Ratio l : t from 1.7 to 2.7.

Distribution

Rather rare throughout the Gambier Limestone.

Remarks

A large number of forms, probably belonging to more than one species, have been referred to by d'Orbigny's specific name by different authors. Some of such forms are closly similar to the Gambier Limestone specimens, but the type figure of *L. gibba* shows a Recent specimen with distinctly developed apertual face and peripheral keel.

Genus ROBULUS Montfort, 1808

ROBULUS NIKOBARENSIS (Schwager), 1866

Plate 10, fig. 23, 24.

Cristellaria nikobarensis Schwager, 1866, Novara Exped., Geol. Theil, v. 2, p. 243, pl. 6, fig. 87.

Robulus nikobarensis (Schwager). Bermudez, 1949, Cushman Lab. Foram. Res., Spec. Pub. 25, p. 128, pl. 7, fig. 41, 42; Reu, 1951, Jour. Pal., v. 25, p. 432, pl. 64, fig. 4, 5.

Description

Test lenticular, compressed, equally biconvex; it consists of a planispiral, involute coil. A small central area, which is not covered by chambers of later whorls, is secondarily thickened and may project as a low, rounded boss. Peripheral outline subcircular, smoothly curved; margin sharply keeled or slightly blunted. Chambers increase regularly in size, six to eleven in last whorl. Sutures weakly oblique in distal part of last whorl, usually more strongly oblique in proximal part; they are gently recurved, narrow or slightly limbate along most of their length, strongly limbate at periphery due to thickened wall at positions of previous apertures. Sutures fairly distinct in small and medium sized specimens, less distinct in large tests. Wall smooth, finely perforate. Radiate aperture opens at laterally compressed distal-peripheral corner of last chamber.

An often well developed median slit extends into apertual face and is bordered by a raised margin, which is fairly high and plate-like at sides of slit. Apertual face rather low (as measured from apertual opening to periphery of previous whorl); it varies from indistinctly developed and rounded in cross-section to distinct and flat.

Dimensions

D ranges up to about 2 mm; most specimens about 1 mm or less. Rare, badly preserved specimens up to 4 mm in size may also belong to this species. Ratio D : t from about 2 to 2.5.

Distribution

Originally described from the Tertiary of Kar Nikobar; subsequently recorded from Oligocene to Pliocene strata in East and West Indies, United States and Japan. Common throughout the Gambier Limestone.

Remarks

Robulus intermedius (d'Orbigny) appears to be closely similar to R. nikobarensis.

ROBULUS cf. CLERICII (Fornasini), 1895

Plate 10, fig. 25.

Cf. Cristellaria clericii Fornasini, 1901, Mem. R. Accad. Sci. Bologna, ser. 5, v. 9, p. 65, pl. 1, fig. 17.

Cf. Robulus clericii (Fornasini) var. carinata Marks, 1951, Cushman Found. Foram. Res., Contr., v. 2, p. 32, pl. 5, fig. 9.

Description

Test lenticular, moderately biconvex, consisting of a planispiral, slightly evolute coil (the spherical proloculus is visible from the outside). Peripheral outline subcircular, smoothly curved; margin sharply keeled. Chambers increase regularly in size, five or six in last whorl. Sutures distinct, strongly bent near centre of test; towards periphery, they are oblique and gently recurved.

Sutures flush, sometimes slightly raised; limbate, especially near periphery at positions of previous apertures. Wall smooth, finely and densely perforate; it may also bear sparsely and irregularly distributed larger pores. A few pores of moderate size may also pierce the peripheral keel. A fine, tubular apertual opening passes through the solid distal-peripheral corner of last chamber; aperture radiate, with a median slit extending partly into apertual face. In well preserved specimens, the median slit has thin, plate-like ridges on both sides. Fairly distinct ridges usually mark the boundary between apertual face and lateral chamber walls.

Dimensions

Largest specimen (locality E 60) : D = 1.60 mm, d = 1.46 mm, t = 0.88 mm. D of most specimens less than 0.8 mm. Ratio D : t rather constant, slightly less than 2.

Distribution

Fairly common throughout the Gambier Limestone.

Remarks

The Gambier Limestone specimens are closely similar to, perhaps conspecific with some of the forms referred to by various authors as R. clericii, originally described from the Pliocene of Italy. The type figure of this species shows a specimen without a distinct median slit in the apertual face and with more chambers in the last whorl than in the South Australian teste.

ROBULUS cf. LIMBATUS (Bornemann), 1855

Plate 11, fig. 1 - 3.

Cf. Robulina limbata Bornemann, 1855, Deutsch. Geol. Ges., Zeitschr., v. 7, p. 335, pl. 15, fig. 4 - 6.

Description

Test compressed, equally biconvex, consisting of a slightly evolute, or involute planispiral coil. Some specimens show a slight tendency to uncoil in late part of last whorl. Peripheral outline smoothly curved, sometimes bent at sutures. Margin varies from keeled to blunt. Chambers increase regularly and rather rapidly in size; usually five or six, rarely up to eight chambers in last whorl. Spherical proloculi vary considerably in size. Sutures commonly distinct, less so in large specimens; they are oblique to nearly radial, especially in distal part of last whorl. Sutures gently recurved, less commonly straight, flush, narrow or somewhat limbate. Wall smooth, finely and densely perforate, with sparse larger pores also present. Radiate aperture passes through thickened wall at distal-peripheral corner of tapering last chamber. This corner is subconical or laterally compressed. A distinct median slit extends into apertual face and is bordered by plate-like lateral rims. In some specimens the aperture, while possessing the median slit, is indistinctly radiate. Loci of previous apertures can be seen as thickenings of wall at peripheral ends of sutures. Apertual face variable in size, sometimes indistinctly developed and usually smaller in microspheric forms. Commonly apertual face is flat and may be bordered laterally by raised margins.

Dimensions

Largest specimen (locality E 125) : D = 1.46 mm, d = 1.36 mm, t = 0.66 mm. Average D about 0.6 mm. Ratio D : t from 1.9 to 2.9.

Distribution

Fairly common throughout the Gambier Limestone.

Remarks

The megalospheric tests in the Gambier Limestone agree well with the type figures of R. limbatus from the Oligocene of Germany. However, neither the figures, nor the type description indicate the large variation in the size of the proloculus seen in the South Australian specimens.

ROBULUS cf. VENEZUELANUS (Hedberg), 1937

Plate 11, fig. 4.

Cf. Planularia venezuelana Hedberg, 1937, Jour. Pal., v. 11, p. 670, pl. 90, fig. 14.

Description

Test strongly compressed, consisting of a planispiral coil, which is moderately evolute on both sides, and has a tendency to uncoil in distal part of test. Sides subparallel, with fairly wide, shallow, often rather indistinct umbilici. Peripheral outline smoothly curved or bent at sutures, especially in later part of last whorl. Margin bears a sharp, low keel; less commonly, it is blunted. Septal sutures radial, straight or gently recurved. Distal sutures depressed near umbilici, widening and becoming flush or slightly raised near periphery; early sutures commonly limbate and raised along their whole lengths. Spiral suture bent where septal sutures join, usually thickened and somewhat indistinct in early part of test. Wall smooth, finely perforate. Aperture passes as a fine tube through the solid distal-peripheral corner of last chamber and opens at bottom of a narrow slit, which extends partly along the periphery and partly into the apertual face. Apertual face strongly elongate, narrowing gradually away from axis of coiling. It is flat in cross-section, or somewhat concave, due to raised ridges at contact between apertual face and lateral walls of last chamber.

Dimensions

Largest specimen (locality E 122) : D = 0.82 mm, d = 0.60 mm, t = 0.20 mm. Average D about 0.6 mm. Ratio D : t from about 3 to 4.

Distribution

Rare in the intermediate and the uppermost zones of the Gambier Limestone.

Remarks

The Gambier Limestone specimens differ from both R. venezuelanus and R. caribbeanus (Planularia caribbeana Bermudez) in having a less truncate margin, with a single instead of three peripheral keels. R. caribbeanus also possesses flatter sides than the South Australian tests. Both the above-mentioned species occur in the Oligocene of the Caribbean region. Another similar species is R. alvarezi (Planularia alverezi Limon-Gutierrez) from the Oligocene of Mexico; it is less compressed and less elongate than the Gambier Limestone specimens.

Genus AMPHICORYNE Schlumberger, 1881

This genus was revived by Parr (1950, p. 327) to include forms commonly referred to Lagenonodosaria Silvestri, 1900. Microspheric forms, with compressed chambers and oblique sutures in their proximal part, of A. cf. scalaris are present in the Gambier Limestone; A. hirsuta and A. cf. halkyardi are represented only by megalospheric specimens.

AMPHICORYNE HIRSUTA (d'Orbigny), 1826

Plate 11, fig. 5.

Nodosaria hirsuta d'Orbigny, 1826, Ann. Sci. Nat., v. 7, p. 252; Cushman and Todd, 1945, Cushman Lab. Foram. Res., Spec. Pub. 15, p. 23, pl. 4, fig. 1,2.

Nodosaria hispida d'Orbigny, 1846, Foram. foss. bass. tert. Vienne, p. 35, pl. 1, fig. 24, 25; Brady, 1884, Rept. Voy. Challenger, Zool., v. 9, p. 507, pl. 63, fig. 12-16; Chapman and Parr, 1926, Linn. Soc. London, Jour., Zool., v. 36, p. 379, pl. 18, fig. 25.

Description

Test elongate, straight, rarely slightly curved, round in cross-section; chambers separated by narrow constrictions or close-set, especially in proximal part of test. Base of initial chamber rounded, bluntly pointed or bearing a short spine. Chambers spherical or slightly ovoid, not notably tapering distally; up to five chambers in test, which increase slowly, somewhat irregularly in size. Sutures perpendicular to axis of growth, strongly to weakly depressed, rather indistinct. Wall ornamented with coarse to fine, short, blunt or sharpened spines; it varies from almost smooth to densely spinose. Spines distributed irregularly or in longitudinal rows. Aperture round, narrow, at the tip of a gently tapering neck, surrounded by a slight lip (in most specimens, the tip of the neck is broken off). Neck smooth or bearing one or two encircling collars or spines.

Dimensions

Largest specimens (locality E 16) : l = 0.96 mm, w = 0.24 mm.

Distribution

Widespread in Tertiary and Recent deposits. Rather rare throughout the Gambier Limestone.

AMPHICORYNE cf. HALKYARDI (Cushman), 1933

Plate 11, fig. 6, 7.

Cf. Dentalina halkyardi Cushman, 1933, Cushman Lab. Foram. Res., Contr., v. 9, p. 9, pl. 1, fig. 20.

Cf. Nodosaria halkyardi (Cushman) var. antillana Palmer and Bermudez, 1936, Soc. Cubana Hist. Nat. Mem., v. 10, p. 269, pl. 16, fig. 3.

Description

Test elongate, straight or gently curved; outline commonly strongly lobate, rarely non-lobate near base. Test approximately uniform in diameter throughout or slightly less at proximal end; cross-section circular. Base rounded, commonly bearing a number of short spines; rarely a single spine is present. Chambers increase slowly, often irregularly in size; up to five chambers in test. Early chambers usually more close-set and cylindrical than later chambers, which are inflated and sub-spherical. Early chambers added terminally; later chambers may be added somewhat obliquely, thus imparting slight curvature to the test. Sutures vary accordingly, from perpendicular to axis of growth and weakly to moderately depressed between early chambers to strongly depressed and oblique in later part of test. Wall ornamented with thin and low, longitudinal costae, about twelve to twenty-five on adult chambers. Costae rarely continue across sutures, where they are reduced in height. They may be longitudinal or (more commonly) oblique. The angle of obliquity may be constant for all chambers of a specimen, or vary; sometimes the direction of costae on the same chamber varies. Costae usually give way to spines near bases of chambers. Wall between costae finely perforate. Last chamber tapers distally to form an apertual neck with a slight terminal lip. Apertual neck smooth or ornamented with fine, annular ridges. Aperture round, at tip of apertual neck.

Dimensions

Largest speciment (locality E 163) : l = 0.88 mm, w = 0.20 mm. Average l about 0.5 mm.

Distribution

Rare in the Gambier Limestone.

Remarks

The Gambier Limestone specimens differ from *A. halkyardi* and its variety *antillena*, originally described from the Eocene of the United States and the Oligocene of Cuba, respectively, mainly in their smaller size and minor characters of surface ornamentation. *Dentalina halkyardi* var. *ponceana* Galloway and Heminway has a radiate aperture and appears to be generically unrelated to the forms discussed.

Specimens which cannot be readily assigned to either *A. cf. halkyardi* or *A. hirsuta* (p. 114) occur very rarely in the Gambier Limestone.

AMPHICORYNE cf. SCALARIS (Batsch), 1791

Plate 11, fig. 8 - 14.

Cf. *Nautilus (Orthoceras) scalaris* Batsch, 1791, Test. aren. marin. tab. sex, p. 1, 4, pl. 2, fig. 4.

Cf. *Amphicoryne scalaris* (Batsch). Pokorny, 1958, Grundzüge Zool. mikropaläont., v. 1, text - fig. 284.

Description

Test elongate, subcircular in cross-section, approximately uniform in diameter throughout or tapering slightly towards base. Outline even or slightly lobate in early part of test, lobate in later part. Base commonly bears a short spine, but may be bluntly pointed or rounded. Initial chamber subspherical, visible parts of later chambers cylindrical to somewhat inflated. Chambers increase slowly, sometimes irregularly in size; up to five chambers in test. Sutures perpendicular to axis of test, slightly to moderately depressed, narrow; distinct, except when obscured by costae. Wall covered with straight, longitudinal costae, which are thin, variable in height and sharp. Costae vary from six to about thirty in number. Some continue from base of test to base, or sometimes nearly to tip, of apertual neck without decreasing in height at sutures; others decrease in height between chambers or are confined to single chambers. Not uncommonly, all costae are uniformly strongly developed. Wall between costae finely perforate. Last chamber tapers distally to form a moderately long (when unbroken) apertual neck with a terminal lip. Apertual neck smooth or ornamented with slight annular costae. Aperture round, narrow, at tip of the neck.

Specimens vary considerably in size of initial chamber, which is closely correlated with size of whole test. Tests of megalospheric individuals are notably larger than those of microspheric forms; both intergrade morphologically, however. Commonly, costae of large specimens are fewer in number and higher than those of small tests.

In microspheric forms, last one or two chambers may be added obliquely to axis of growth; such chambers are sometimes slightly compressed laterally and costae on their surface are oblique to axis of test. Microspheric tests vary both in the degree of lateral displacement of distal chambers and in the number of non-displaced chambers preceding them.

Dimensions

Largest specimen (locality E 119) : l = 1.28 mm, w = 0.40 mm. Average l about 0.5 mm.

Distribution

Common throughout the Gambier Limestone.

Remarks

The Gambier Limestone specimens are similar to the Recent *A. scalaris*, but have less inflated chambers, increase more slowly in width and are less densely costate. A number of species, as well as varieties of *A. scalaris* have been erected by different authors for forms differing in minor characters from *A. scalaris*, e.g. *A. longicauda* (d'Orbigny), *A. striaticollis* (d'Orbigny), *A. variabilis* (Neugeboren), *A. proxima* (Silvestri) and *A. blanpiedi* (Ellis). The variation of these species cannot be ascertained in the absence of topotypes, but it is probable that at least some of them intergrade morphologically with each other and with the Gambier Limestone tests.

Genus LINGULINA d'Orbigny, 1826

LINGULINA METUNGENSIS Chapman and Crespin, 1930

Plate 11, fig. 15, 16.

Lingulina bartrumi Chapman var. *metungensis* Chapman and Crespin, 1930, Roy. Soc. Victoria, Proc., n.s., v. 43, p. 97, pl. 5, fig. 5.

Lingulina metungensis Chapman and Crespin. Carter, 1959, unpublished thesis, pl. 3, fig. 22, 23.

Description

Test elongate and compressed, consisting of up to five chambers arranged in a straight series. First one or two chambers circular, later chambers lenticular in cross-section. Outline of test roughly ovate, tapering rapidly distally and more gradually proximally towards rounded extremities; it is smoothly curved in early part of test, slightly lobate in later part, Chambers strongly embracing, increasing rapidly in size; last chamber constitutes about half of test. Sutures perpendicular to axis of test, straight or slightly bent backwards near margin, narrow; usually fairly distinct. Wall finely perforate; one or two proximal chambers covered with numerous (up to about thirty), costae. The straight, longitudinal costae do not radiate from base of initial chamber, but a set of three or four costae encircles the base in a plane parallel with maximum width of test. On later chambers, costae are confined along the margins of test. Aperture a terminal, long and narrow slit between two projecting semilunar lips.

Dimensions

Largest specimen (locality E 110) : l = 2mm, w = 1.5 mm, t = 1.1 mm.

Distribution

Originally described from Tertiary strata in the Parish of Bumberrah, Victoria; also from Gippsland. Very rare in the Gambier Limestone.

Remarks

L. metungensis differs from the closely similar L. bertrami from the Tertiary of New Zealand mainly in being smaller, having relatively wider chambers, a more compressed last chamber and less strongly developed surface ornamentation.

LINGULINA sp.

Plate 11, fig. 17, 18.

Description

Test elongate, compressed; outline suboval, generally smoothly curved; in some tests slightly lobate in distal part. In the more common microspheric forms early part consists of three or four chambers arranged in a planispiral coil; these are followed by chambers in a straight series. In megalospheric forms all chambers in a straight series. Test lenticular in cross-section; early part more compressed and with a keeled margin. Up to seven strongly embracing chambers in test; they increase rapidly, sometimes slightly irregularly in size. Sutures narrow, fairly distinct to poorly visible; flush in early part of test, flush or slightly depressed in later part. They are transverse and straight at middle of test, but commonly bent proximally near margins; in coiled part of specimens, sutures recurved. Wall smooth, finely perforate. Aperture a terminal, fairly long and narrow slit commonly bordered by two produced, crescent-shaped lips.

Dimensions

Largest specimen (locality E 122) : l = 2.1 mm, w = 1.34 mm, t = 0.84 mm. Ratio l : t from 1.8 to 2.6 in adult specimens.

Distribution

Rare in the Gambier Limestone.

Remarks

The Gambier Limestone specimens are somewhat similar to *L. mesonensis* Cole from the Oligocene of Mexico, but the chamber arrangement is apparently uniserial throughout in all representatives of this species.

Genus FRONDICULARIA Defrance, 1826

FRONDICULARIA LORIFERA Chapman, 1913

Frondicularia lorifera Chapman, 1913, Roy. Soc. Victoria, Proc., n.s., v. 26, p. 171, pl. 16, fig. 6; Howchin and Parr, 1938, Roy. Soc. South Australia, Trans., v. 62, p. 307, pl. 16, fig. 4.

Distribution

Occurs in Oligocene and Miocene strata in the Mallee district and the Muddy Creek, Torquay and Neumerella areas in Victoria. Very rare in the Gambier Limestone.

Remarks

All the Gambier Limestone specimens are fragmental.

Family POLYMORPHINIDAE

Genus GUTTULINA d'Orbigny, 1826

GUTTULINA PROBLEMA (d'Orbigny), 1826

Plate 11, fig. 19 - 23.

Polymorphina (Guttuline) problema d'Orbigny, 1826, Ann. Sci. Nat., v. 7, p. 266, no. 14.

Polymorphina (Guttuline) communis d'Orbigny, 1826, ibid., p. 266, pl. 12, fig. 1 - 4.

Guttulina problema d'Orbigny. Cushman and Ozawa, 1930, U.S. Nat. Mus., Proc., v. 77, p. 19, pl. 2, fig. 1 - 6, pl. 3, fig. 1; Parr and Collins, 1937, Roy. Soc. Victoria, Proc., v. 50, n.s., p. 191, pl. 12, fig. 1; Batjes, 1958, Inst. Roy. Sci. Nat. Belgique, Mem. 143, p. 121, pl. 4, fig. 10 - 12.

Guttulina frankei Cushman and Ozawa, 1930, U.S. Nat. Mus., Proc., v. 77, p. 28, pl. 4, fig. 1.

Description

Test greatly variable in shape due to variation in relative size, degree of overlapping and degree of removal from base of successive chambers. Usually apertual end tapers less rapidly than proximal end, which is bluntly pointed or fairly rounded. Outline of test lobate, since chambers somewhat inflated and projecting. Test roundedly triangular or compressed and suboval in cross-section; in some specimens cross-section even more irregular. Chambers drop-shaped or clavate in plan; they may be rather elongate and compressed laterally. Test consists of up to about ten chambers, which increase moderately rapidly in size. Sutures depressed, narrow to somewhat limbate; fairly distinct. Wall smooth; aperture terminal, radiate.

Distribution

Widespread in Cretaceous to Recent strata. Common throughout the Gambier Limestone.

Remarks

Some of the intergrading variants in the Gambier Limestone closely resemble the less elongate forms of both *G. austriaca* d'Orbigny and *G. yabei* Cushman and Ozawa, and also *G. irregularis* (d'Orbigny). Batjes (1958, *loc. cit.*) has previously stated that *G. frankei* and, to a smaller degree, *G. irregularis* cannot be distinguished from *G. problema* in the Oligocene of Belgium.

GUTTULINA REGINA (Brady, Parker and Jones), 1870

Plate 11, fig. 24.

Polymorphina regina Brady, Parker and Jones, 1870, Linn. Soc. Lond., Trans., v. 27, p. 241, pl. 41, fig. 32; Brady, 1884, Rept. Voy. Challenger, Zool., v. 9, p. 571, pl. 73, fig. 11 - 13.

Guttulina regina (Brady, Parker and Jones). Cushman and Ozawa, 1930, U.S. Nat. Mus., Proc., v. 77, p. 34, pl. 6, fig. 1, 2; Parr and Collins, 1937, Roy. Soc. Victoria, Proc., v. 50, n.s., p. 193, pl. 12, fig. 5, text - fig. 1 - 7.

Description

Test fusiform, sometimes rather elongate. It tapers fairly rapidly towards a bluntly pointed to, less commonly, sharply pointed or broadly rounded, base; tapering usually more gradual towards apertual end. Outline of test lobate; cross-section roundedly triangular to subcircular. Chambers increase rapidly in size, moderately inflated, roughly oval in side view, longer than wide. Each chamber more removed from base of test than the preceding one; up to about eight chambers in test. Sutures depressed, curved, somewhat obscured by ornamentation. Test covered with numerous, distinct, slightly anastomosing, longitudinal costae, which are generally equidistant and continuous across sutures. Costae moderately high, varying from fairly sharp to rounded in cross-section. They extend from base of test to base of a short, indistinctly developed, tapering apertual neck, which is oval to circular in cross section. Aperture terminal, round, radiate.

Dimensions

Largest specimen (locality E 26) : l = 1.04 mm, w = 0.40 mm. Average l about 0.7 mm; ratio l : w from 1.6 to 2.6.

Distribution

Occurs in Oligocene to Pliocene strata of Victoria, Tasmania and New Zealand, and in Recent sediments of the Australian and Philippines region. Rather rare in the Gambier Limestone.

GUTTULINA PACIFICA (Cushman and Ozawa), 1928

Plate 11, fig. 25.

Sigmoidella (Sigmoidina) pacifica Cushman and Ozawa, 1928, Cushman Lab. Foram. Res., Contr., v. 4, p. 19, pl. 2, fig. 13.

Guttulina (Sigmoidina) pacifica Cushman and Ozawa, 1930, U.S. Nat. Mus., Proc., v. 77, p. 50, pl. 37, fig. 3 - 5.

Distribution

Occurs in Recent sediments in the Pacific and in Miocene strata near Batesford, Victoria. Very rare in the Gambier Limestone.

GUTTULINA SILVESTRII Cushman and Ozawa, 1930

Plate 11, fig. 26.

Guttulina (Sigmoidina) silvestrii Cushman and Ozawa, 1930, U.S. Nat. Mus., Proc., v. 77, p. 51, pl. 37, fig. 6, 7.

Guttulina silvestrii Cushman and Ozawa. Parr and Collins, 1937, Roy. Soc. Victoria, Proc., v. 50, n.s., p. 197, pl. 12, fig. 11.

Distribution

Occurs in Recent sediments in the Pacific and in the Miocene near Batesford, Victoria. Rare in the Gambier Limestone.

GUTTULINA cf. SPICAEFORMIS (Roemer), 1838

Plate 11, fig. 27, 28.

Cf. Polymorphina (Guttulinen) spicaeformis Roemer, 1838, Neues Jahrb. Min. Geogn. Geol. Petref.-Kunde, p. 386, pl. 3, fig. 31.

Cf. Guttulina spicaeformis (Roemer). Cushman and Ozawa, 1930, U.S. Nat. Mus., Proc., v. 77, p. 31, pl. 5, fig. 1, 2.

Cf. Guttulina spicaeformis (Roemer) var. australis (d'Orbigny). Cushman and Ozawa, 1930, ibid., p. 32, pl. 5, fig. 3.

Description

Test elongate; cross-section roundedly subtriangular or irregular. Test tapers towards pointed apertual end and, usually more rapidly, towards bluntly pointed to rounded base. Outline of test lobate, chambers somewhat inflated and projecting. Chambers clavate or elongate drop-shaped in plan; often compressed laterally. They are arranged in a clockwise quinqueloculine series and increase moderately rapidly in size. Test consists of up to about eight chambers, which are successively further removed from base; early chambers sometimes only slightly removed distally. Sutures fairly distinct, depressed, narrow to somewhat limbate. Wall smooth or covered with numerous fine, longitudinal costae. Aperture terminal, radiate.

Dimensions

Largest specimen (locality E 70) : l = 0.74 mm, w = 0.36 mm. Average l about 0.5 mm.

Distribution

Common throughout the Gambier Limestone.

Remarks

The Gambier Limestone specimens differ from G. spicaeformis and its striated variety australis in having the chambers arranged in a clockwise instead of an anticlockwise series, and in the test being generally less fusiform.

Genus PYRULINA d'Orbigny, 1826

PYRULINA FUSIFORMIS (Roemer), 1838

Plate 12, fig. 1

Polymorphina (Globulinen) fusiformis Roemer, 1838, Neues Jahrb. Min. Geogn. Geol. Petref.-Kunde, p. 386, pl. 3, fig. 37.

Polymorphina angusta Chapman and Parr (non Egger), 1926, Linn. Soc. Lond., Jour., Zool., v. 36, p. 392, pl. 21, fig. 75.

Pyrulina fusiformis (Roemer). Cushman and Ozawa, 1930, U.S. Nat. Mus., Proc., v. 77, p. 54, pl. 13, fig. 3 - 8; Parr and Collins, 1937, Roy. Soc. Victoria, Proc., v. 50, n.s., p. 197, pl. 13, fig. 2, 3, pl. 14, fig. 5.

Distribution

Fairly widespread in Oligocene to Recent deposits. Rare in the Gambier Limestone.

Genus GLOBULINA d'Orbigny, 1826

GLOBULINA GIBBA (d'Orbigny), 1826

Plate 12, fig. 2 - 4.

Polymorphina (Globuline) gibba d'Orbigny, 1826, Ann. Sci. Nat., v. 7, p. 266, models 63.

Polymorphina globosa Münster, in Roemer, 1838, Neues Jahrb. Min. Geogn. Geol. Petref.-Kunde, p. 386, pl. 3, fig. 33.

Globulina inaequalis Reuss, 1850, Denkschr. K. Akad. Wiss. Wien, v. 1, p. 377, pl. 48, fig. 9; Cushman and Ozawa, 1930, U.S. Nat. Mus., Proc., v. 77, p. 73, pl. 18, fig. 2 - 4.

Globulina gibba d'Orbigny. Cushman and Ozawa, 1930, ibid., p. 60, pl. 16, fig. 1 - 4; Parr and Collins, 1937, Roy. Soc. Victoria, Proc., v. 50, n.s., p. 199, pl. 12, fig. 12; Batjes, 1958, Inst.

Roy. Sci. Nat. Belgique, Mem. 143, p. 121, pl. 4, fig. 9.

<u>Globulina gibba</u> d'Orbigny var. <u>globosa</u> (Münster). Cushman and Ozawa, 1930, U.S. Nat. Mus., Proc., v. 77, p. 64, pl. 17, fig. 8, 9; Parr and Collins, 1937, Roy. Soc. Victoria, Proc., v. 50, n.s., p. 199, pl. 12, fig. 13.

<u>Description</u>

Test globular to drop-shaped, circular to oval in cross-section. Base evenly rounded, apertual end slightly to distinctly pointed. Chambers few, strongly embracing, increasing rapidly in size. Sutures indistinct to moderately distinct, usually flush and narrow; in some specimens chambers project slightly from general surface of test and sutures are gently depressed. Wall smooth, pierced by sparse pores of medium size. Aperture terminal, radiate. Fistulose outgrowths are sometimes present in apertual region; commonly such have been broken and wall of last chamber originally covered by the outgrowths is seen to be pierced by large pores.

<u>Dimensions</u>

Largest specimen (locality E 107) : l = 1.9 mm, w = 1.3 mm, t = 1.2 mm. Average l about 0.8 mm.

<u>Distribution</u>

Widespread in Tertiary, less so in Recent deposits. Fairly common throughout the Gambier Limestone.

<u>Remarks</u>

Globular variants intergrade with somewhat compressed forms in the Gambier Limestone; less common, more elongate variants appear to be indistinguishable from <u>G. lacrima</u> (Reuss) or <u>G. rotundata</u> (Bornemann).

Genus SIGMOMORPHINA Cushman and Ozawa, 1928

SIGMOMORPHINA CHAPMANI (Heron-Allen and Earland), 1924

Plate 12, fig. 5.

Polymorphina chapmani Heron-Allen and Earland, 1924, Roy. Micr. Soc., Jour., p. 163, pl. 10, fig. 60-63.

Sigmomorphina chapmani (Heron-Allen and Earland). Cushman and Ozawa, 1930, U.S. Nat. Mus., Proc., v. 77, p. 124, pl. 32, fig. 4, 5; Parr and Collins, 1937, Roy. Soc. Victoria, Proc., v. 50, n.s., p. 204, pl. 15, fig. 2.

Description

Test compressed, subcircular or fan-shaped in side view, increasing in width distally; base of test may bear a short spine. Outline slightly lobate in early part of test; outline of last two chambers smoothly curved. Chambers arranged in an anticlockwise sigmoidal series, imparting to test a twisted appearance. Test thickest at a point between margin and the somewhat depressed median line. Margin usually bluntly angular; in less common, relatively thick tests, with rather inflated chambers, margin more rounded. Chambers roughly semilunar in side view, added at an angle to axis of test; up to ten chambers present, increasing fairly regularly and rapidly in size. Each successive chamber further removed from base of test, and overlapping strongly the preceding chamber in the same series on its anticlockwise side, i.e. on the right hand side of test in side view. In some specimens, small, proximally directed lobes of last one or two chambers overlap the preceding chambers also on opposite side of test near the middle. Sutures strongly recurved, flush or slightly depressed, limbate, usually distinct. Median suture gently depressed and curved. Wall smooth, finely perforate. Aperture a narrow, peripheral slit extending from contact between last and penultimate chambers for about one third of the length of the distal margin of last chamber.

Dimensions

Largest specimen (locality E 154) : l = 1.14 mm, w = 1.18 mm, t = 0.74 mm. Average l about 0.8 mm. Ratio l : t from 1.4 to 2.

Distribution

Originally described from Miocene strata near Batesford, Victoria. Rare in the Gambier Limestone.

SIGMOMORPHINA SUBREGULARIS Howchin and Parr, 1938

Plate 12, fig. 6 - 9.

Sigmomorphina subregularis Howchin and Parr, 1938, Roy. Soc. South Australia, Trans., v. 62, p. 308, pl. 18, fig. 2, 11.

Description

Test compressed; length varies from slightly greater than width to nearly twice as great. Outline slightly lobate to smoothly curved; test varies from subrhomboidal or roughly oval to fan-shaped in side-view, with base bluntly pointed or broadly rounded. Margin bluntly angular and slightly thickened or narrowly rounded. Cross-section of test in distal view lenticular, commonly with a broad, low, usually poorly defined median ridge. Chambers arranged in a clockwise, sigmoidal series; hence test often appears slightly twisted in basal view. In some specimens, the sigmoidal arrangement is poorly expressed. Chambers somewhat crescent-shaped or fairly straight in side view, narrowing towards margins of test and increasing fairly regularly in size. Angle made by chambers with axis of test varies between about 45° and 70°; similarly, the extent to which successive chambers are progressively further removed from base is rather variable. Each chamber strongly overlaps the preceding chamber in the same series on its clockwise side, i.e. on the left hand side of test; up to about sixteen chambers present. Sutures usually indistinct, especially near median line of test; usually slightly curved. Depending on degree of thickening of distal-peripheral margin of chambers, sutures on right-hand side of test vary from thickened and raised to narrow and flush, less commonly slightly depressed. Sutures on left-hand side of test are narrow and flush to slightly depressed. Wall smooth, finely perforate. Aperture terminal; radiate, round to oval.

Dimensions

Largest specimen (locality E 122) : l = 2.5 mm, w = 1.5 mm, t = 0.85 mm.

Distribution

Originally described from Miocene strata in the Metropolitan Abattoirs bore, Adelaide. Fairly common throughout the Gambier Limestone.

Remarks

Some of the intergrading variants described above agree well with the holotype of S. subregularis, with which they have been compared. The median ridge in the holotype is much less distinctly developed than is indicated in the type figure. The "pronounced median ridges" on chambers on the right hand side of test, mentioned by Howchin and Parr, are due to thickening associated with the distalperipheral margins of earlier chambers; such ridges coincide with the sutures or extend along their proximal sides.

S. subregularis is rather similar to S. pseudoregularis Cushman and Thomas from the Eocene of Texas, the chambers of which are arranged in an anticlockwise sigmoidal series and the median ridge of test is more strongly developed. Some variants in Gambier Limestone resemble S. flintii (Cushman).

SIGMOMORPHINA aff. BATESFORDENSIS Parr and Collins, 1937

Plate 12, fig. 10, 11.

Aff. Sigmomorphina batesfordensis Parr and Collins, 1937, Roy. Soc. Victoria, Proc., v. 50, n.s., p. 204, pl. 15, fig. 6.

Distribution

Adult tests very rare, juvenile specimens more common in the Gambier Limestone.

Remarks

Some of the specimens agree well with the type figure of S. batesfordensis from Miocene strata near Batesford, Victoria; other tests resemble more closely S. undulosa (Terquem).

Genus SIGMOIDELLA Cushman and Ozawa, 1928

SIGMOIDELLA ELENGANTISSIMA (Parker and Jones), 1870

Plate 12, fig. 12.

Polymorphina elengantissima Parker and Jones, 1865, Phil. Trans., v. 155, p. 438; Brady, Parker and Jones, 1870, Linn. Soc. Lond., Trans., v. 27, p. 231, pl. 40, fig. 15 b, c (non a).

Sigmoidella elengantissima (Parker and Jones). Cushman and Ozawa, 1929, Jap. Jour. Geol. Geogr., v. 6, p. 76, pl. 16, fig. 10, 11; Cushman and Ozawa, 1930, U.S. Nat. Mus., Proc., v. 77, p. 140, pl. 39, fig. 1; Parr and Collins, 1937, Roy. Soc. Victoria, Proc., v. 50, n.s., p. 206, pl. 14, fig. 9.

Sigmoidella bortonica Finlay, 1939, Roy. Soc. New Zealand, Trans., v. 69, p. 318, pl. 25, fig. 43, 44.

Description

Test compressed, commonly heart-shaped in outline. Distal end pointed, base slightly incurved or, less commonly, smoothly rounded. Cross-section lenticular, with margins angular to narrowly rounded. Up to about twelve chambers in test; they are arranged in a clockwise sigmoidal series and increase fairly rapidly in size. Chambers considerably elongate, roughly semilunar in shape; succeeding chambers overlap the preceding ones alternately on different sides of test. Sutures usually smoothly curved, flush and limbate; sutures of last two chambers on the sides of their overlap may be less evenly curved and narrow. Wall smooth, pierced by sparse medium sized pores. Aperture terminal, radiate.

Dimensions

Largest specimen (locality E 139) : l = 1.58 mm, w = 1.38 mm, t = 0.76 mm. Average l about 1 mm.

Distribution

Fairly widespread in Eocene to Recent sediments. Moderately common throughout the Gambier Limestone.

Remarks

In the Gambier Limestone, variants closely similar to the holotype of *S. bortonica* as figured by Finlay from the Eocene of New Zealand intergrade with less heart-shaped and distally less tapering forms resembling the specimen figured by Cushman and Ozawa (1930, *loc. cit.*). Finlay mentioned the above differences as distinguishing between *S. bortonica* and *S. elegantissima*; however Parker and Jones' original figure 15 b shows a specimen similar to *S. bortonica* in these respects.

Rare specimens similar to *S. kasaensis* Cushman and Ozawa are also present.

Genus GLANDULINA d'Orbigny, 1826

GLANDULINA LAEVIGATA (d'Orbigny), 1826

Plate 12, fig. 13.

Nodosaria (Glandulina) laevigata d'Orbigny, 1826, Ann. Sci. Nat., v. 7, p. 252, pl. 10, fig. 1 - 3; Chapman and Parr, 1926, Linn. Soc. London, Jour., Zool., v. 36, p. 378, pl. 17, fig. 20.

Glandulina laevigata (d'Orbigny). Cushman and Ozawa, 1930, U.S. Nat. Mus., Proc., v. 77, p. 143, pl. 40, fig. 1; Parr and Collins, 1937, Roy. Soc. Victoria, Proc., v. 50, n.s., p. 208, pl. 13, fig. 6; Batjes, 1958, Inst. Roy. Sci. Nat. Belgique, Mem. 143, p. 123, pl. 4, fig. 7, 8.

Description

Test, at least in microspheric forms, spindle-shaped, with sharply pointed extremities, tapering about equally rapidly towards both ends or somewhat more rapidly in direction of growth. In one or two specimens the initial end bears a short spine; rare megalospheric forms with rounded bases are also present. Cross-section of test circular. Test consists of up to about eight strongly embracing chambers, which increase rapidly in size. Sutures generally indistinct, flush, narrow; wall smooth. Aperture terminal, radiate.

Dimensions

Largest specimen (locality E 76) : l = 1.76 mm, w = 0.98 mm. Average l. about 0. 6 mm.

Distribution

Widespread in Tertiary to Recent deposits. Rather rare in the Gambier Limestone.

Remarks

G. laevigata occurs rather rarely in the Gambier Limestone. Well preserved specimens from V 27 and V 34 possess distinct sutures and in some of them a short entosolenian tube is visible.

It appears that the megalospheric forms of G. laevigata, with chambers arranged uniserially throughout the test, may have either bluntly pointed proximal ends, as mentioned by Cushman and Ozawa, or they may be sharply pointed, as figured by Chapman and Parr, and Batjes. The microspheric forms, with early chambers biserially arranged, are invariably sharply pointed proximally.

Superfamily BULIMINIDAE
Family BULIMINIDAE

Genus BULIMINELLA Cushman, 1911

BULIMINELLA MADAGASCARIENSIS (d'Orbigny), 1908

Plate 12, fig. 14, 15.

Bulimina madagascariensis d'Orbigny, 1826, Ann. Sci. Nat., v. 7, p. 270, no. 17; Fornasini, 1908, R. Accad. Sci. Ist. Bologna, Mem. Sci. Nat., ser. 6, v. 5, p. 47, pl. 1, fig. 13.

Bulimina elengantissima d'Orbigny var. apiculata Chapman (non Bulimina ovata d'Orbigny var. apiculata Egger, 1895), 1907, Linn. Soc. Lond., Jour., Zool., v. 30, p. 31, pl. 4, fig. 77.

Buliminella apiculata (Chapman). Cushman and Parker, 1937, Cushman Lab. Foram. Res., Contr., v. 13, p. 39, pl. 4, fig. 10.

Builiminella apiculata (Chapman) var. hebetata Cushman and Parker, 1937, ibid., p. 40, pl. 4, fig. 11, 12.

Buliminella madagascariensis (d'Orbigny). Cushman and Parker, 1946, U.S. Geol. Surv., Prof. Pap. 210-D, p. 68, pl. 17, fig. 15 - 17.

Buliminella madagascariensis (d'Orbigny) var. spicata Cushman and Parker. Cushman and Parker, 1946, ibid., p. 64, pl. 16, fig. 20.

Description

Test rather fusiform, approximately twice as long as wide, formed by a high trochospiral coil consisting of about two whorls. Base varies from bluntly rounded to bearing a short, pointed spine. Cross-section subcircular, outline smoothly curved. Chambers considerably wider than long, increasing regularly and fairly rapidly in size; six to eight present in last whorl, up to about twelve in the whole test. Periphery of last chamber bluntly angular in side view, smoothly curved in outline. Except in rare, well preserved specimens, sutures indistinct, especially near base of test, due to secondary deposition of shell matter associated with formation of the basal spine. Sutures oblique to axis of coiling, straight to slightly curved, flush, narrow to slightly limbate. Wall smooth, finely perforate. Apertual face semioval, with a shallow depression near the margin furthest removed from the base of test. Aperture lies in this depression; it is a narrow, arched slit around the edge of a semicircular tooth. Fine striations, radiating outwards from the apertual depression, are visible in a few, well preserved tests.

Dimensions

Largest specimen (locality E 149) : l = 0.60 mm, w = 0.32 mm. Average l about 0. 4 mm.

Distribution

Recorded from Recent sediments in the Indo-Pacific region and the Middle Miocene of Victoria. Rather rare throughout the Gambier Limestone.

Genus BULIMINA d'Orbigny, 1826

BULIMINA cf. BROWNI Finlay, 1939

Plate 12, fig. 16.

Cf. Bulimina browni Finlay, 1939, Roy. Soc. New Zealand, Trans., v. 69, p. 321, pl. 27, fig. 85, 86.

Dimensions

Largest specimen (Naracoorte no. 2 bore, sample between 124 and 174 feet) : l = 0. 24 mm, w = 0.18 mm.

Distribution

Very rare in the Gambier Limestone.

Remarks

The Gambier Limestone specimens differ from B. browni from the Eocene of New Zealand in having three instead of four chambers in the last whorl.

Genus VIRGULINA d'Orbigny, 1826

VIRGULINA cf. PONTONI Cushman, 1932

Plate 12, fig. 17.

Cf. Virgulina pontoni Cushman, 1932, Cushman Lab. Foram. Res., Contr., v. 8, p. 17, pl. 8, fig. 7.

Distribution

Very rare in the Gambier Limestone.

Remarks

The Gambier Limestone specimens are more elongate than is indicated by the type figure of V. pontoni from the Miocene of Florida.

Genus UVIGERINA d'Orbigny, 1826

UVIGERINA MIOSCHWAGERI Finlay, 1939

Plate 12, fig. 18 - 21.

Uvigerina pigmaea Chapman and Parr (non d'Orbigny), 1926, Linn. Soc. Lond., Jour., Zool., v. 36, p. 393, pl. 21, fig. 80.

Uvigerina mioschwageri Finlay, 1939, Roy. Soc. New Zealand, Trans., v. 69, p. 103, pl. 12, fig. 15-17.

Description

Test slightly to fairly elongate, bluntly triangular to subcircular in cross-section; it tapers subequally in both directions or more slowly towards either end than the other. Base bluntly, rarely rather sharply pointed to broadly rounded; thus general outline of test somewhat fusiform or oval or pear-shaped. Outline of test obscured by costae in early part, usually lobate in later part. Chambers arranged in a high trochospiral coil, with commonly about three chambers per whorl; in distal part of some specimens, about two and a half per whorl. Up to more than twelve chambers in test; they are rounded in side view and roughly triangular in plan, with pointed, truncated or lobe-like corners. Chambers rather flattened, overlapping and added at an angle to axis of test in proximal part; they often become inflated, longer and more terminally placed in distal part of test. Early sutures obscured by costae; later sutures fairly distinct, narrow to somewhat limbate, depressed and weakly to strongly curved. Wall finely perforate, ornamented longitudinally with gently curved to somewhat wavy costae, which commonly branch in direction of growth. Number, thickness, height, continuity and length of costae are highly variable. Commonly the number of costae decreases, while their thickness, height and roundness increases with increasing size of the test. Some costae continue across sutures, others are confined to a single chamber; up to ten costae per chamber may be present, but there are fewer in most tests. In some specimens, three approximately equidistant costae are more prominent, giving the test a somewhat triangular appearance in distal view; in other specimens the costae are uniform. Commonly, in proximally pointed specimens costae are highest near their middle; in specimens with less pointed base, costae reach maximum height and are flange-like near the base, which may have a jagged appearance. Costae sometimes irregularly pierced by fine to moderately large pores. Usually wall of last chamber is smooth, or bears costae only at its base, and preceding two chambers have costae confined to their lower parts; in some specimens, only the distal part of last chamber is smooth; in others the distal half of the whole test is smooth. Aperture round or elliptical, at the tip of a short, stout apertual neck with a flatly flaring lip. Commonly, the neck is in a slight depression, with a shallow groove extending from it to the base of the last chamber. In well preserved specimens, the apertual neck of the penultimate chamber is seen to be connected by a toothplate with the aperture of the last chamber.

Dimensions

Largest specimen (locality E 16) : 1 = 0.96 mm, w = 0.62 mm. Ratio 1 : w varies between about 1.2 and 2 in adult specimens.

Distribution

Occurs in the Miocene of New Zealand and Victoria, Common in the intermediate and uppermost zones in the Gambier Limestone.

Remarks

Different intergrading variants in the Gambier Limestone resemble closely not only U. mioschwageri from the Miocene of New Zealand, but also U. cubana Palmer and Bermudez from the Oligocene of Cuba, U. gallowayi Cushman var. basicordata Cushman and Renz from the Oligocene of Venezuela and, less commonly, U. curta from the Eocene of Trinidad. At the time of erection of their species, both Palmer and Bermudez and also Finlay remarked on the close similarity between some of the above-mentioned forms. Perhaps at least some of them are conspecific, but this cannot be determined in the absence of topotypes.

UVIGERINA STRIATISSIMA Perconig, 1955

Plate 12, fig. 22 - 24.

Uvigerina striatissima Perconig, 1955, Italy, Servizio Geol., Boll., v. 77, p. 187, pl. 3, fig. 1 - 4.

Description

Specimens agree with U. mioschwageri (p. 135) in all characters, except surface ornamentation. This consists of up to about fifty fine, longitudinal costae, which are absent or very faint on last three chambers, and sometimes confined to less than the proximal third of the test. Test consists of up to ten chambers.

Dimensions

Largest specimen (locality E 123) : 1 = 0.78 mm, w = 0.38 mm.

Distribution

Originally described from the Miocene of Italy. Occurs in very few samples from the intermediate and the uppermost zones of the Gambier Limestone.

Remarks

The Gambier Limestone specimens appear to be slightly more coarsely costate, with costae less strongly developed in the distal part of test, than is indicated in the type figures of U. striatissima.

UVIGERINA GRACILIS Reuss, 1851

Plate 13, fig. 1 - 3.

Uvigerina gracilis Reuss, 1851, Deutsch. Geol. Ges., Zeitschr., v. 3, p. 77, pl. 5, fig. 39; Cushman and Edwards, 1938, Cushman Lab. Foram. Res., Contr., v. 14, p. 74, pl. 13, fig. 3-6.

Angulogerina gracilis (Reuss). Batjes (pars), 1958, Inst. Roy. Sci. Nat. Belgique, Mem. 143, p. 134, pl. 6, fig. 1, 2.

Description

Test varies from fusiform, with a fairly even outline, to more elongate, strongly lobate in outline. Base bluntly pointed; cross-section subcircular to irregular. Chambers arranged in a very high trochospiral coil with commonly about three, in distal part of some tests about two and a half chambers per whorl; up to about twelve chambers in test. Chambers semicircular or somewhat fan-shaped in distal view and roughly drop-shaped, narrowing distally, in side view; last few chambers of some specimens are irregular, strongly compressed, with concave inner sides. In most specimens early chambers close-set, placed at an angle to axis of test; they commonly become more inflated, more removed from each other and more terminal in distal part of test. In some specimens all chambers close-set; in others even the early chambers are somewhat removed from each other, and test resembles an elongate cluster of grapes. Sutures vary accordingly; commonly indistinct, flush or slightly depressed in early part of test and moderately to strongly depressed in later part. Spiral suture usually indistinctly developed. Wall finely perforate, from fairly smooth, to densely covered with short, and fine spines; in some fusiform specimens spines may be arranged in vague longitudinal rows near base of test. Aperture opens at the tip of a thin, tubular and short apertual neck, which tapers slightly in direction of growth. In well preserved specimens, apertual neck bears a slight terminal lip. Not uncommonly, a shallow groove runs down the inner wall of last chamber from base of apertual neck to the basal suture. In well preserved specimens, the apertual neck of preceding chamber is visible through the inner wall of last chamber; it is connected by a toothplate with the aperture of last chamber.

Dimensions.

Largest specimen (locality E 17) : l = 0.60 mm, w = 0.20 mm. Average l about 0.4 mm. Ratio l : t from 1.9 to 3.5.

Distribution

Occurs in the Oligocene of Germany and Belgium. Fairly common throughout the Gambier Limestone.

Remarks

The Gambier Limestone specimens agree well with Cushman and Edwards' figures of topotypes of U. gracilis. In the Gambier Limestone, this species does not intergrade with distinctly triangular variants, such as figured by Batjes from the Oligocene of Belgium as Angulogerina gracilis (Reuss) varieties oligocaenica (Andreae) and germanica Cushman and Edwards.

A number of species closely similar to U. gracilis have been subsequently erected by different authors, e.g. U. proboscidea Schwager, U. farinosa Hantken and U. modeloensis Cushman and Kleinpell. Probably, at least some of these intergrade morphologically with U. gracilis.

UVIGERINA AUSTRALIS Heron-Allen and Earland, 1924

Plate 13, fig. 4, 5.

Uvigerina canariensis d'Orbigny var. australis Heron-Allen and Earland, 1924, Roy. Micr. Soc. Lond., Jour., p. 164, pl. 11, fig. 67 - 70.

Description

Test elongate, somewhat fusiform, tapering towards a bluntly pointed base; sometimes slightly bent or twisted. Outline of test smooth in early part, slightly lobate in later part. Cross-section bluntly triangular in early part, becoming more rounded distally. Except for last few chambers of a number of specimens, chambers increase regularly and slowly in size and are arranged in a high trochospiral coil with about three chambers per whorl. Up to about fifteen chambers, subtriangular in cross-section, somewhat embracing, with proximally directed corners. Last one or two chambers of a number of specimens are distorted, less embracing, with strongly excavate sides, and tending towards a terminal position. Sutures convex upwards to almost straight; limbate, flush and usually indistinct in early part of test, somewhat depressed and fairly distinct in later part. Sutures meet in a zig-zag pattern on each side of test; this pattern usually curves around the test at a slight angle to its axis. Spiral suture indistinctly developed. Wall smooth, finely perforate. Aperture opens at the tip of a thin tubular neck with a distinct, flaring lip; the neck is broken in most tests. A slight groove on inner face of last chamber is sometimes associated with the apertual neck.

Dimensions

Largest specimen (locality E 29) : l = 0.52 mm, w = 0.16 mm. Average l about 0.4 mm.

Distribution

Originally described from Miocene strata near Batesford, Victoria. Rather rare in the Gambier Limestone.

Remarks

U. canariensis var. *australis* does not appear to be closely similar to the Recent *U. canariensis*, and is considered specifically distinct.

UVIGERINA cf. CIPERANA Cushman and Stainforth, 1945

Plate 13, fig. 6 - 8.

Cf. *Uvigerina ciperana* Cushman and Stainforth, 1945, Cushman Lab. Foram. Res., Spec. Pub. 14, p. 49, pl. 7, fig. 19, 20.

Description

Test fusiform to rather elongate, tapering towards bluntly pointed to rounded base. Tapering towards apertual end may be gradual, involving several chambers, or it may be confined to last chamber and not well expressed. Position of maximum diameter of test relative to length varies. Outline of test lobate, in some elongate specimens only weakly so. Cross-section indistinctly triangular, rounded, sometimes subcircular in distal part of test. Chambers arranged in a very high trochospiral coil, commonly with three (in distal part of some specimens only slightly more than two) chambers per whorl. Size of initial chamber rather variable. Proximal chambers increase rapidly in size; rate of increase commonly slower in distal part of test and last chamber may be approximately equal in size to, or smaller than, penultimate chamber. Early chambers embracing, added at an angle to axis of test; distal chambers less embracing, more terminal. Degree of inflation of chambers rather variable; ratio length to breadth of individual chambers varies between about one and two. Chambers roughly semicircular in cross-section through their distal part; area of attachment to the preceding part of the test is asymmetrically subtriangular. Corners of chambers usually broadly rounded; sometimes the most distal corner is drawn out into a tapering lobe, which overlaps the preceding chamber slightly tò one side of its apex. Up to about twelve chambers in test. Sutures usually indistinct, sometimes distinct in distal part of test; they are depressed and narrow to somewhat limbate. Septal sutures commonly convex upwards; spiral suture fairly distinct, curving around test at approximately 60° to its axis. Wall finely perforate; ornamented with slightly curved, sometimes branching, longitudinal costae, which are commonly thin, sharp and low, and extend from base of test to base of apertual neck. Costae vary from interrupted at sutures and possessing jagged ends to smoothly continuous across sutures. In a few specimens, basal extremities of costae end as thin, spine-like flanges. Aperture round, terminal, at tip of a short, tubular neck with a flatly flaring lip (rarely preserved). The inner side of last chamber is commonly at a steep angle to axis of test and bears a shallow longitudinal groove. In well preserved specimens, outline of the apertual neck of penultimate chamber is visible at the bottom of this groove; it is connected by a toothplate to the aperture of the last chamber.

Dimensions

Largest specimen (locality E 64) : l = 0.68 mm, w = 0.30 mm. Average l about 0. 5 mm. Ratio l : w from 1.5 to 3.

Distribution

Fairly rare throughout the Gambier Limestone.

Remarks

The Gambier Limestone specimens appear to have less distinct sutures, due to better development of costae across them, than U. cinerana from the Oligocene of Trinidad, and are generally less elongate.

UVIGERINA cf. GERMANICA (Cushman and Edwards), 1938

Plate 13, fig. 9, 10.

Cf. *Angulogerina germanica* Cushman and Edwards, 1938, Cushman Lab. Foram. Res., Contr., v. 14, p. 85, pl. 15, fig. 14-16.

Description

Test commonly fusiform, thickest about midway between distal end and base, which is rounded to bluntly pointed. Outline of test rather jagged; cross-section bluntly triangular to rounded. Chambers arranged in a very high trochospiral coil, with proximally about three, distally about two and a half chambers per whorl. Test consists of up to about twelve chambers, which increase fairly regularly and rapidly in size. Chambers added at an angle to axis of test, somewhat semicircular in distal view, tapering in direction of growth. Distal chambers more elongate and more terminal than earlier chambers; their inner sides are flat or slightly concave. Proximal edges of chambers steeply truncated; hence sutures strongly depressed, somewhat obscured by costae in early part of test. Wall finely perforate, ornamented with thin and sharp costae, which usually end abruptly at bases of chambers. Costae commonly serrated in outline, approximately parallel with maximum elongation of chambers, which is usually at a low angle to axis of test. About fifteen to twenty costae around circumference of test; up to seven on single chambers. Aperture opens at the tip of a short tubular neck with a slight, terminal, flatly flaring lip. In well preserved specimens, apertual neck of penultimate chamber is seen to be connected by a toothplate with aperture of last chamber.

Dimensions

Largest specimen (locality E 96) : l = 0.56 mm, w = 0.28 mm.

Distribution

Rare in the Gambier Limestone.

Remarks

The Gambier Limestone specimens closely resemble U. germanica from the Oligocene of Germany, but differ in having a thinner and longer apertual neck, and showing no tendency to become smooth in the distal part of the test. Another closely similar species is U. jamaicensis (Cushman and Todd) from the Miocene of Jamaica, which has more terminally added distal chambers and is more distinctly triangular in cross-section. U. isidroensis Cushman and Renz from the Oligocene of Venezuela is smoother in outline and its apertual neck usually lacks a terminal lip.

Genus TRIFARINA Cushman, 1923

TRIFARINA BRADYI Cushman, 1923

Plate 13, fig. 11-13.

Rhabdogonium tricarinatum Brady (non Vaginulina tricarinata d'Orbigny), 1884, Rept. Voy. Challenger, Zool., v. 9, p. 525, pl. 67, fig. 1 - 3.

Trifarina bradyi Cushman, 1923, U.S. Nat. Mus., Bull. 104, p. 99, pl. 22, fig. 3 - 9; Chapman and Parr, 1926, Linn. Soc. Lond., Jour., Zool., v. 36, p. 386, pl. 20, fig. 52.

Angulogerina (Trifarina) tricarinata Hofker (non Vaginulina tricarinata d'Orbigny), 1951, Foram. Siboga Exped., pt. 3, p. 196, text-fig. 126 - 130.

Description

Test elongate; usually tapering more gradually towards bluntly pointed base than toward apertual end. Cross-section triangular, with concave or flat sides. Three keels extend from base or near base of test to base of apertual neck. Margins slightly lobate or smooth in outline. Commonly test somewhat twisted or bent. Early chambers arranged in a high, trochospiral coil with about three chambers per whorl; arrangement changes through roughly biserial to uniserial distally. Even uniserial chamber arrangement still exhibits traces of triseriality (as shown by Hofker, loc. cit.). Chambers increase fairly regularly and rapidly in size; up to about fifteen present. Adult chambers triangular in cross-section, tapering rapidly in direction of growth and embracing preceding chambers with their proximally directed corners. Sutures distinct, except in poorly preserved tests, and convex upwards; in early part flush and somewhat limbate, meeting in a zig-zag pattern along middles of sides of test; distal sutures narrow, often slightly depressed. Wall finely perforate; keels may also be pierced by pores. Wall generally smooth, but a number of specimens bear a few fine, longitudinal costae, commonly confined to their proximal part. Aperture terminal, at the tip of a short, round or oval apertual neck, which bears a slight lip in well preserved specimens.

Dimensions

Largest specimen (locality E 56) : l= 0.82 mm, w = 0.30 mm. Average l about 0. 5 mm. Ratio l : w from 2 to 4.

Distribution

Widespread in Eocene to Recent deposits. Common throughout the Gambier Limestone.

Genus STILOSTOMELLA Guppy, 1894

STILOSTOMELLA JEDLITSCHKAI (Thalmann), 1937

Plate 13, fig. 14-16.

Nodogenerina radicula var. annulata Brady (non Glandulina annulata Terquem et Berthelin), 1884, Rept. Voy. Challenger, Zool., v. 9, p. 496, pl. 62, fig. 1, 2.

Nodogenerina jedlitschkai Thalman, 1937, Eclogae Geol. Helv., v. 30, p. 341.

Description

Test elongate, straight or slightly curved, circular in cross-section; base rounded. Chambers subspherical or tapering distally, somewhat embracing, increasing irregularly in size; not uncommonly last one or two chambers are smaller than chambers in median part of test, which consists of up to six chambers. Sutures limbate, often slightly raised, at right angles to axis of test. Wall smooth, finely perforate. Aperture commonly somewhat obliterated; it is terminal, usually round, with or without a poorly developed rim; in rare tests, aperture compressed, elliptical.

Dimensions

Specimens range up to 1.42 mm in length and 0.60 mm in width. Average 1 about 1 mm.

Distribution

Originally described from Recent sediments near Papua. Rare in the intermediate and uppermost zones of the Gambier Limestone.

Remarks

S. rohri (Cushman and Stainforth) from the Oligocene of Trinidad has consistently more inflated chambers and S. laevigata (Bermudez) from the Oligocene of the Dominican Republic consistently less inflated chambers than the Gambier Limestone specimens. S. jedlitschkai also differs from both these species in its more irregular rate of increase in the size of the chambers.

STILOSTOMELLA SCULPTURATA (Cushman), 1939

Plate 13, fig. 17.

Nodogenerina sculpturata Cushman, 1939, Cushman Lab. Foram. Res., Contr., v. 15, p. 63, pl. 10, fig. 55.

Description

Test elongate, straight or slightly curved, circular in cross-section, weakly constricted at sutures; base rounded. Initial chamber spherical; succeeding chambers ovoid, tapering distally, weakly inflated and somewhat embracing. Up to seven chambers present, which increase slowly and irregularly in size. Sutures at right angles to axis of test, gently depressed, fairly distinct. Wall covered by numerous fine, longitudinal, anastomosing costae, which extend across sutures from base of test to near the tip of last chamber; in some specimens last chamber is smooth. Aperture terminal, round, surrounded by a thick, slightly flaring lip at the tip of last chamber or at the tip of a poorly developed apertual neck.

Dimensions

Largest specimen (locality E 61) : l = 0.82 mm, w = 0.22 mm.

Distribution

Originally described from a submarine core of Eocene age collected off the Atlantic coast of North America. Very rare in the Gambier Limestone.

Remarks

The Gambier Limestone specimens are slightly less elongate than is indicated in the type figure of S. sculpturata. A rather similar species is S. havanensis (Cushman and Bermudez) from the Eocene of Cuba, which has a better developed apertual neck, and more than one of the distal chambers may be smooth.

STILOSTOMELLA cf. MONILIS (Silvestri) var. LAEVIGATA (Silvestri), 1872

Plate 13, fig. 18 - 21.

Cf. Nodosaria monilis Silvestri var. laevigata Silvestri, 1872, Accad. Gioen. Sci. Nat. Catania, ser. 3, v. 7, p. 74, pl. 8, fig. 184-190.

Description

Test elongate, straight to gently curved, tapering very slowly towards rounded base. Outline smooth or nearly smooth in early part of test, lobate in distal part; cross-section circular. Initial chamber subspherical, early chambers subcylindrical; later chambers barrel-shaped, may be somewhat inflated. Chambers increase slowly, fairly regularly in size; up to twelve chambers in test. Sutures perpendicular to axis of test; limbate, and commonly flush, rarely slightly raised between early chambers; less limbate, depressed in distal part of test. Some tests have narrow or slightly limbate, flush sutures and more elongate chambers than the majority of specimens. Wall smooth, finely perforate. Aperture terminal, round, surrounded by a distinct lip, which is constricted at its base. An apertual tooth is present in well preserved specimens.

Dimensions

Largest specimen (locality E 139) : l = 1.00 mm, w = 0.14 mm. Average l about 0.5 mm.

Distribution

Rare in the Gambier Limestone.

Remarks

The Gambier Limestone specimens differ from those figured by Silvestri in the sutures being limbate and flush instead of narrow and depressed in the early part of the test. Another rather similar species, with a finely hispid surface, is S. fragilis (Todd).

Genus BOLIVINA d'Orbigny, 1839

BOLIVINA LAPSUS Finlay, 1939

Plate 13, fig. 22, 23.

Bolivina lapsus Finlay, 1939, Roy. Soc. New Zealand, Trans., v. 69, p. 98, pl. 11, fig. 9.

Description

Test elongate, compressed, usually straight, sometimes slightly twisted; it tapers slowly towards the proximal end, which is bluntly rounded in side view, and more rapidly in direction of growth. Outline generally smooth, sometimes slightly lobate in distal part of test. Cross-section lenticular to suboval, margins bluntly rounded. Up to about twenty chambers present, which increase regularly in size; spherical proloculus rather variable in size. Sutures fairly distinct, gently convex upwards to straight, oblique; usually at about 45° to axis of test; in some tests, especially in early part, this angle ranges to about 60°. Early sutures narrow throughout or slightly limbate at their inner extremities; later sutures commonly strongly limbate at their inner extremities, decreasing in thickness towards the margins. Sutures usually flush, rarely slightly depressed in distal part of test, sometimes raised near middle of the sides of test. Width of zig-zag pattern formed by the median sutures equals about one third or less of the width of test in its early part; width of zig-zag increases distally to up to one half the width of test, due to a slight tendency towards uniserial arrangement of chambers. Wall finely and densely perforate; generally smooth, but in rare, well preserved specimens, ornamented with very fine, longitudinal striations. Aperture approximately elliptical, extending at right angles from the basal suture to distal extremity of last chamber and bordered by a low, rounded rim of clear calcite. In a number of specimens, aperture does not touch the basal suture.

Dimensions

Largest specimen (locality E 70) : l = 1.00 mm, w = 0.26 mm, t = 0.14 mm. Average l about 0.5 mm.

Distribution

Occurs in the Oligocene and the Miocene of New Zealand. Fairly common in the intermediate and the uppermost zones in the

Gambier Limestone.

Remarks

The Gambier Limestone specimens agree well with topotypes of *B. lapsus* from Pakaurangi Point, New Zealand, with which they have been compared. Specimens occurring in the Miocene at Grange Burn, Victoria, which have been referred to as *B. hentyana* Chapman, are closely similar, perhaps conspecific with *B. lapsus*. The name *B. hentyana* as applied to a foraminiferal species is invalid, since the holotype is an echinoid spine (Jenkins, 1958, p. 335).

BOLIVINA VICTORIANA Cushman, 1936

Plate 13, fig. 24, 25.

Bolivina victoriana Cushman, 1936, Cushman Lab. Foram. Res., Spec. Pub. 6, p. 55, pl. 8, fig. 2; Cushman, 1937, Cushman Lab. Foram. Res., Spec. Pub. 9, p. 104, pl. 12, fig. 15.

Description

Test elongate, compressed, tapering slowly towards bluntly rounded proximal end; in some specimens, sides almost parallel, except in the earliest part. Outline smooth, sometimes slightly lobate in distal part of test. Cross-section oval, margins rounded. Not uncommonly test twisted or bent; it consists of up to fifteen chambers, which increase regularly and slowly in size. Sutures distinct, straight or slightly curved, oblique; usually at about 45° to the axis of test, less commonly at up to about 60°. They join along the middles of the sides of test to form a zig-zagging median suture; width of the zig-zag pattern is equal to about one third or less of the width of test. Sutures flush, sometimes slightly depressed in distal part of test, and narrow, except where transverse sutures join the median suture. Aperture elliptical, extending at right angles from the basal suture to distal extremity of last chamber and bordered by a low rim of clear calcite.

Dimensions

Largest specimen (locality E 166) : l = 0.54 mm, w = 0.16 mm, t = 0.10 mm. Average l about 0.4 mm.

Distribution

Originally described from Oligocene strata pierced by a bore near Geelong, Victoria. Fairly common throughout the Gambier Limestone.

Remarks

Some variants in the Gambier Limestone are rather similar to B. orta Macfadyen from the Miocene of Egypt, but are less compressed.

BOLIVINA PLICATELLA Cushman, 1930

Bolivina plicatella Cushman, 1930, Florida Geol. Surv., Bull. 4, p. 46, pl. 8, fig. 10; Cushman, 1937, Cushman Lab. Foram. Res., Spec. Pub. 9, p. 89, pl. 11, fig. 3, 4; Cushman and Todd, 1945, ibid., Spec. Pub. 15, p. 46, pl. 7, fig. 10.

Distribution

Occurs in Miocene to Recent sediments in the West and East Indies regions. Very rare in the Gambier Limestone.

BOLIVINA ANASTOMOSA Finlay, 1939

Plate 13, fig. 26, 27.

Bolivina anastomosa Finlay, 1939, Roy. Soc. New Zealand, Trans., v. 69, p. 320, pl. 27, fig. 75-77, 103, 111.

Description

Test elongate, compressed; outline leaf-shaped, smoothly curved. Sides usually taper more rapidly in direction growth than towards proximal end, which is broadly rounded to bluntly pointed. Cross-section lenticular; margin generally blunt, fairly sharp in distal part of some specimens. Up to twenty-two chambers present; they are semilunar in side view and increase regularly and moderately rapidly in size. Distal chambers of some specimens possess small, proximally pointed lobes next to the median suture. Sutures fairly distinct or obscured by ornamentation of the wall. They are slightly recurved or straight and form an angle between about 45° and 60° with axis of test. Median suture straight or indistinctly zig-zagging. Sutures generally limbate and raised, especially near middles of sides of test. Wall moderately coarsely perforate. Whole test or only its proximal part may be covered with longitudinal costae; in a few specimens costae absent. Costae vary from few and fairly high to numerous, lower and thinner; they may be continuous and anastomosing over several chambers or exist only as short branches at a steep angle to the raised sutures. Aperture elliptical, extending at right angles from the basal suture to the distal extremity of last chamber. It is bordered by a low, rounded rim of clear calcite.

Dimensions

Largest specimen (locality E17) : l = 0.48 mm, w = 0.28 mm, t = 0.13 mm.

Distribution

Occurs in the Upper Eocene to Lower Miocene of New Zealand. Rare in the Gambier Limestone.

Remarks

A number of the Gambier Limestone specimens agree well with the type figures and description of B. anastomosa, although the South Australian forms are rather variable in respect to the surface ornamentation. Some of the Gambier Limestone specimens appear to be closely similar to B. scalprata Schwager var. retiformis Cushman and, to a smaller degree, to B. scalprata var. miocenica Macfadyen, both originally described from the Miocene of Egypt. B. reticulata Hantken is more finely ornamented and B. byramensis Cushman more compressed, with sharper margins, than the specimens described above.

BOLIVINA Cf. FASTIGIA Cushman, 1936

Plate 13, fig. 28 - 30.

Cf. Bolivina fastigia Cushman, 1936, Cushman Lab. Foram. Res., Spec. Publ. 6, p. 51, pl. 7, fig. 17.

Description

Test elongate, leaf-shaped, compressed. In side view, test generally tapers more rapidly in direction of growth than towards the proximal end, which is broadly rounded in megalospheric forms, more pointed in microspheric specimens. Outline of test smoothly curved, sometimes slightly lobate in distal part of test. Cross-section lenticular; in strongly compressed specimens margins sharp, sometimes keeled; less compressed forms have blunted margins. Chambers increase regularly and moderately rapidly in size. Initial chamber spherical; later chambers semilunar in side view, about twice as wide as long. Up to seventeen chambers in test. Chambers, except a few early ones, possess a small but distinct proximally directed lobe next to the median suture; distal chambers may possess a second, less distinctly developed lobe next to the first one. Sutures usually distinct and recurved, more strongly so in early part of test, at an angle from about 45° to 60° to the axis of test. Median suture straight or indistinctly zig-zagging, limbate and raised. Transverse sutures generally slightly to distinctly raised and limbate near median suture, becoming less raised, sometimes flush, and less limbate towards margins of test. Wall finely perforate. Commonly wall of chambers appears opaque in contrast to the translucent sutures and margin of test. A number of specimens bear longitudinal, often irregular costae on their proximal parts. Aperture elliptical, extending at right angles from basal suture to distal extremity of last chamber. It is bordered by a rim of clear calcite.

Dimensions

Largest specimen (locality E 141) : l = 0.50 mm, w = 0.24 mm, t = 0.12 mm. Average l about 0.4 mm.

Distribution

Rare in the Gambier Limestone.

Remarks

The Gambier Limestone specimens are generally closely similar to B. fastigia, originally described from the Upper Oligocene of Germany, but appear to have a more finely perforate wall and lack the well-developed median ridge characteristic of the European specimens.

Smaller and commonly more elongate forms than those described above, possessing a very small initial chamber and up to more than twenty chambers in test, are also present in the Gambier Limestone. These may be extreme variants of B. cf. fastigia or represent a different species.

Genus OOLINA d'Orbigny, 1839

OOLINA TASMANICA Parr, 1950

Plate 14, fig. 1, 2.

Oolina tasmanica Parr, 1950, B.A.N.Z.A.R.E. Repts., ser. B, v. 5, pt. 6, p. 303, pl. 8, fig. 4.

Description

Test drop-shaped, apertual end moderately tapering; base slightly truncated, rarely bluntly pointed. Wall covered with longitudinal costae, which are low, thin and sharp. Six to ten major costae are present and an equal number of less prominent costae may extend between them; thus total number of costae, usually an even number, varies between six and twenty. In some specimens all costae uniformly strongly developed. Costae either join or die out at their extremities. Usually they start from a basal polygon or disc with a flat or slightly depressed central area; diameter of basal disc may be equivalent to up to about one fourth of the diameter of test. Costae join at the strongly indented base of a conical apertual collar. Its surface is flush with, or slightly raised above the general surface of test. Apertual collar may be smooth or covered with a finely to moderately coarsely reticulate pattern of ridges enclosing polygonal depressions or rounded indentations; in extreme cases, coarsely reticulate ornamentation extends over the whole upper half or more of the test. Wall between costae finely perforate. Tubular aperture ends as a small, round opening at top of apertual collar or at tip of a short apertual neck projecting slightly from the collar. A very short internal tube is visible in dissected, well preserved specimens.

Dimensions

l from 0.18 mm to 0.42 mm; w from 0.12 mm to 0.24 mm.

Distribution

Originally described from Recent sediments near Tasmania. Fairly common in the Gambier Limestone.

Remarks

The Gambier Limestone specimens agree well with the holotype and paratypes of O. tasmanica, with which they have been compared. It is probable that various forms referred to as Lagena williamsoni (Alcock), 1865, or its new name L. alcocki White, 1956, are conspecific with O. tasmanica. All the above-mentioned forms may be conspecific with the Recent Lagena guntheri Earland, 1934.

OOLINA HEXAGONA (Williamson), 1848

Plate 14, fig. 3, 4.

Entosolenia squamosa (Montagu) var. γ, hexagona Williamson, 1848, Ann. Mag. Nat. Hist., ser. 2, v. 1, p. 20, pl. 2, fig. 23.

Lagena hexagona (Williamson). Cushman and Todd, 1945, Cushman Lab. Foram. Res., Spec. Pub. 15, p. 33, pl. 5, fig. 14.

Description

Test subspherical to drop-shaped, circular in cross-section, with broadly rounded base. Aperture tubular; it passes through a thickened apertual collar at base of apertual neck, and ends as a small circular opening at tip of the neck. A short internal tube is visible in dissected specimens. Apertual neck is usually indistinctly developed or short in drop-shaped specimens; in subspherical forms, it is often distinct, moderately long (when unbroken) and with a rounded and thickened apertual lip. The neck may be smooth or bear annular ornamentation. Test ornamented with distinct ridges arranged in a honeycomb pattern. Ornamentation extends from a basal polygon or circle to base of apertual neck or, if latter indistinctly developed, right up to the apertual opening. Ridges are low in most of the subspherical tests, but may be rather high and sharp in more elongate specimens. The areas enclosed within the network of ridges vary from commonly regular hexagons to less regular polygons with sides of different length. Size of polygonal areas is rather constant for each individual, but varies considerably in different specimens; usually reticulation is coarser and less regular in drop-shaped forms. Wall of test between the ridges is finely perforate.

Dimensions

Largest specimen (locality E 160) : l = 0.78 mm, w = 0.52 mm. Average l about 0.3 mm. Ratio l : w from 1.2 to 1.6.

Distribution

Recorded as widespread from the Cretaceous to the Recent. Fairly common throughout the Gambier Limestone.

OOLINA LINEATA (Williamson), 1848

Plate 14, fig. 5.

Entosolenia lineata Williamson, 1848, Ann. Mag. Nat. Hist., ser. 2, v. 1, p. 18, pl. 2, fig. 18.

Lagena lineata (Williamson). Brady, 1884, Rept. Voy. Challenger, Zool., v. 9, p. 461, pl. 57, fig. 13.

Description

Test spherical or very slightly elongate, with a thin, short and blunt basal spine. Tubular aperture ends as a narrow, circular opening in the centre of a disk-like thickening. A straight entosolenian tube, extending about half-way into the test, is visible in well preserved specimens. Wall smooth or covered with fine, longitudinal costae, up to about thirty in number, which extend from the basal spine to the margin of apertual thickening.

Dimensions

l from 0.18 mm to 0.34 mm.

Distribution

Occurs in the Tertiary and in the Recent. Very rare in the Gambier Limestone.

OOLINA DESMOPHORA (Jones), 1874

Plate 14, fig. 6-8.

Lagena vulgaris Williamson var. desmophora Jones, 1874, Linn. Soc. Lond., Trans., v. 30, p. 54, pl. 19, fig. 23, 24.

Lagena desmophora Rymer-Jones. Cushman, 1933, U.S. Nat. Mus., Bull. 161, p. 29, pl. 7, fig. 11-14.

Description

Test elongate; main part straight or slightly curved, roughly cigar-shaped. Wall ornamented with nine to twelve longitudinal costae, which are finely and regularly perforate at frequent intervals. Costae straight, parallel and thin; they often have a finely serrated outline. In some specimens costae relatively uniform in height along their whole length, and base of test is bluntly pointed or rounded. Usually, however, costae are higher, flange-like and coalescing at their proximal extremities, imparting to base of test a truncated appearance in side view and a circular or polygonal appearance in basal view. Costae extend from base of test to base of apertual neck (or nearly so); they often join to give a finely reticulated ornamentation around distal end of test. Apertual neck is usually broken; in well preserved specimens, it is long, very thin, smooth, translucent and very slightly tapering, slightly thickened at the tip. Apertual neck and usually distal portion of main part of test are bent at an angle to the overall axis of test. A fine, short, median internal tube is visible in well preserved specimens.

Dimensions

l from 0.24 mm to 0.44 mm; ratio l : w from 2 to 3.5.

Distribution

Occurs in the Recent of the Indo-Pacific region. Very rare in the Gambier Limestone.

Remarks

In the type description, C. desmophora was stated to possess an internal tube. Lagena striatopunctata Parker and Jones var. excentricitas Cushman and McCulloch appears to differ from the species discussed in minor characters only.

COLINA aff. LAGENA CURVICOSTATA Heron-Allen and Earland, 1924

Plate 14, fig. 9 - 11

Aff. Lagena curvi-costata Heron-Allen and Earland, 1924, Roy. Micr. Soc. Lond., Jour., p. 148, pl. 9, fig. 36.

Description

Test elongate, straight, rarely slightly bent. Cross-section polygonal, sometimes subcircular. Base bluntly rounded, less commonly roundedly truncated. Sides in middle part of test parallel or tapering slightly towards the pointed apertual end. Test ornamented with five to seven straight, longitudinal costae, which usually extend along the whole length of test. In rare individuals, additional, less prominent costae are present; these are usually confined to basal part of test. Costae thin and sharp; commonly rather low, except near apertual end. In most specimens, costae distinct; some specimens are partly smooth. In rare specimens, costae are slightly twisted near apertual end of test. Base of some tests covered with very finely, irregularly reticulate ornamentation. Wall between costae very finely perforate, smooth; it may be considerably thickened at base of test. Apertual opening passes as a fine tube through the solid tip of test, which may constitute up to about one fourth of the test in length. A distinctly projecting, short apertual neck is present in one or two specimens. A very short internal tube is visible only in dissected, well-preserved specimens.

Dimensions

l from 0.22 mm to 0.42 mm; ratio l : w from 2.3 to 5.3.

Distribution

Rare in the Gambier Limestone.

Remarks

A few of the Gambier Limestone specimens are closely similar to L. curvicostata, originally described from the Miocene of Victoria. Variation of this species is poorly known, since Heron-Allen and Earland had only two specimens.

OOLINA cf. LAGENA FLEXA Cushman and Grey, 1946

Plate 14, fig. 12.

Cf. Lagena flexa Cushman and Grey, 1946, Cushman Lab. Foram. Res., Contr., v. 22, p. 68, pl. 12, fig. 18-21.

Dimensions

Largest specimen (locality E 182) : l = 0.32 mm, w = 0.11 mm.

Distribution

Very rare in the Gambier Limestone.

Remarks

In the Gambier Limestone specimens, a fine internal tube extends about half way towards the base of the test along one wall, and seven short costae coalesce to encircle an indistinctly polygonal depression at the base. The specimens appear to be identical with L. flexa from the Pliocene of California; however an internal tube is not mentioned in the type description of this species.

Genus FISSURINA Reuss, 1850

FISSURINA FLINTIANA (Cushman), 1923

Plate 14, fig. 13.

Lagena flintiana Cushman, 1923, U.S. Nat. Mus., Bull. 104, p. 18, pl. 3, fig. 11 - 13; Bermudez, 1949, Cushman Lab. Foram. Res., Spec. Pub. 25, p. 117, pl. 11, fig. 1.

Lagena orbignyana (Seguenza) var. caribaea Cushman, 1923, U.S. Nat. Mus., Bull. 104, p. 41, pl. 7, fig. 6 - 9.

Entosolenia flintiana (Cushman). Cushman and Stainforth, 1945, Cushman Lab. Foram. Res., Spec. Pub. 14, p. 42, pl. 6, fig. 13; Cushman and Todd, 1945, ibid., Spec. Pub. 15, p. 41, pl. 6, fig. 19.

Entosolenia flintiana (Cushman) var. caribaea (Cushman). Cushman and Stainforth, 1945, ibid., Spec. Pub. 14, p. 42, pl. 6, fig. 14.

Description

Test compressed, flask-shaped, weakly to moderately biconvex in peripheral view. Except in apertual region, test is encircled by three thin and sharp, flange-like peripheral keels, of which the median one is the most strongly developed. Two very slight, additional keels are sometimes present between the median keel and the other two keels. Keels usually parallel, rarely somewhat diverging towards base of test, and often have ragged margins, due to breakage. The circular or slightly oval areas on each side of test usually have slight, squarish, encircling margins. Apertual neck varies from short and poorly developed to distinct. Aperture opens at the tip of the neck into a short, slit-like depression, which is bordered by slight lips. These lips join laterally, and are continuous with median peripheral keel. A straight internal tube, extending for about half the length of the test towards the base, is visible in rare specimens. Wall smooth, very finely perforate or imperforate in appearance. Sparse pores of moderate size sometimes pierce the median keel.

Dimensions

Largest specimen (locality E 132) : l = 0.74 mm, w = 0.52 mm, t = 0.38 mm.

Distribution

Occurs in Oligocene to Recent sediments in the Caribbean region. Fairly common throughout the Gambier Limestone.

Remarks

Many varieties of F. orbignyana Seguenza have been erected by different authors to include forms with more than one peripheral keel. All of these are probably not conspecific; some are rather similar to the Gambier Limestone specimens. The type figure of F. orbignyana shows a specimen differing from those described above in having a single peripheral keel bordered on each side by a slight ridge, and in possessing a less produced apertual end.

FISSURINA BIFIDA (Heron-Allen and Earland), 1924

Plate 14, fig. 14.

Lagena orbignyana (Seguenza) var. *bifida* Heron-Allen and Earland, 1924, Roy. Micr. Soc. Lond., Jour., p. 152, pl. 9, fig. 46-50.

Description

Test rather strongly compressed, suboval in side view. A single peripheral keel extends from near the aperture for about half way towards base of test, where it divides into two thinner, flange-like keels, which continue around the basal half of test. The twin keels may be joined by a cross-ridge at the base of test. Margin of the single keel near aperture is smooth, while the twin basal keels usually have a ragged margin, due to breakage. Aperture opens at bottom of a terminal slit between thin lips of equal height, which join laterally and are continuous with the peripheral keel. Aperture extends as a fine, tubular passage through the solid tip of test. A straight internal tube, flaring slightly at its free end, extends to nearly the base of test, and is attached for most of its length along the median line of one wall. A squarish to rounded rim surrounds an oval, weakly convex, central area on each side of test. Wall smooth, very finely perforate on sides of test; slightly larger pores pierce the encircling rims and peripheral keels.

Dimensions

l from 0.20 mm to 0.30 mm; w from 0.16 mm to 0.24 mm, t from 0.05 mm to 0.12 mm.

Distribution

Originally described from the Miocene near Batesford, Victoria. Rather rare in the Gambier Limestone.

FISSURINA ANNECTENS (Burrows and Holland), 1895

Plate 14, fig. 15.

Lagena quadricostulata Brady (pars) (non Reuss), 1884, Rept. Voy. Challenger, Zool., v. 9, p. 486, pl. 59, fig. 15.

Lagena annectens Burrows and Holland, 1895, Monogr. Foram. Crag., pt. 2, Palaeontogr. Soc., p. 203, pl. 7, fig. 11; Chapman and Parr, 1926, Linn. Soc. Lond., Jour., Zool., v. 36, p. 376, pl. 17, fig. 11.

Description

Test flask-shaped, biconvex, slightly to moderately compressed. Peripheral outline drop-shaped, tapering towards a bluntly pointed apertual end; base of test rounded, sometimes slightly pointed. In marginal view, base broadly or narrowly rounded; apertual end compressed, tapering. Margin evenly rounded or very bluntly angular. Two arcuate bands, more opaque than bordering areas of test wall, are present on each side of test; they are usually fairly distinct, in some specimens less so. These bands are parallel with lateral margins of test, never joining at apertual end and very rarely at base. In a number of specimens, surface of bands is flush with surface of test; in others, it is very slightly depressed. Aperture opens at bottom of an elongate, terminal slit, which is bordered by rather prominent lips of equal height. An internal tube is visible in some specimens. Wall smooth, finely perforate; pores of medium size are sparsely and irregularly distributed in walls of some tests.

Dimensions

l from 0.14 mm to 0.36 mm; w from 0.12 mm to 0.30 mm, t from 0.08 mm to 0.20 mm. Ratio w : t from 1.1 to 1.5.

Distribution

Occurs in the Tertiary and the Recent. Rare in the Gambier Limestone.

Remarks

The Gambier Limestone specimens are generally less compressed than is indicated by the type figure of F. annectens.

FISSURINA SUBCIRCULARIS Parr, 1950

Plate 14, fig. 16.

Fissurina subcircularis Parr, 1950, B.A.N.Z.A.R.E. Repts., ser. B, v. 5, pt. 6, p. 311, pl. 8, fig. 15, pl. 9, fig. 1.

Dimensions

Largest specimen (locality E 139) : l = 0.38 mm, w = 0.38 mm, t = 0.30 mm.

Distribution

Originally described from Recent sediments near Tasmania. Rare in the Gambier Limestone.

Remarks

The Gambier Limestone specimens were compared with the holotype and paratypes of F. subcircularis. They agree well in every feature, except in not possessing an imperforate central area on each side of the test.

F. crassicarinata Bandy is externally closely similar to F. subcircularis; no internal tube is mentioned in Bandy's type description.

F. subcircularis is distinguished from F cf. globosa (p. 166) in the Gambier Limestone by having a hook-shaped internal tube and a more strongly developed marginal keel.

FISSURINA CLATHRATA (Brady), 1884

Lagena clathrata Brady, 1884, Rept. Voy. Challenger, Zool., v. 9, p. 485, pl. 60, fig. 4.

Distribution

Occurs in the Tertiary and the Recent. Very rare in the Gambier Limestone.

FISSURINA aff. TERRILLI (Parr), 1938

Plate 14, fig. 17.

Aff. Lagena terrilli Parr, 1938, Roy. Soc. South Australia, Jour., v. 24, p. 79, pl. 1, fig. 15.

Dimensions

l from 0.20 mm to 0.26 mm, w from 0.16 mm to 0.22 mm, t from 0.08 mm to 0.16 mm.

Distribution

Very rare in the Gambier Limestone.

Remarks

The Gambier Limestone specimens were compared with the holotype and paratypes of F. terrilli from the Eocene of Western Australia. They differ from the Western Australian tests in being smaller, having a more finely pitted surface and a somewhat more slit-like aperture. The margin of the Gambier Limestone specimens is concave or flat in cross-section and is pierced by sparsely distributed, fine, oblique pores.

FISSURINA cf. CARINATA Reuss, 1863

Plate 14, fig. 18.

Cf. Fissurina carinata Reuss, 1863, K. Akad. Wiss. Wien, Math. - Naturw. Cl., Sitzber., v. 46, p. 338, pl. 6, fig. 83, pl. 7, fig. 86.

Description

Test compressed, biconvex in peripheral view. Peripheral outline smoothly curved, oval to nearly circular, with a bluntly pointed apertual end. Margin bears a keel, which may be low and rounded or, especially around base of test, moderately high, thin and sharp. Aperture opens at bottom of an elongate slit bordered by lips of equal height, which join laterally and are continuous with peripheral keel. An internal tube, curved in a plane perpendicular to width of test, extends for about half the length of test. It is generally uniform in diameter, except at its flaring lower end, which is attached along the median line of one wall of test. Wall densely pierced by rather fine pores; sparse pores of larger size are scattered among the latter.

Dimensions

Largest specimen (locality V 34) : l = 0.52 mm, w = 0.46 mm, t = 0.32 mm. Average l about 0.4 mm. Ratio l : t rather constant, about 1.5.

Distribution

Fairly rare in the Gambier Limestone.

Remarks

The Gambier Limestone specimens are generally less compressed and with a less distinctly developed keel than is indicated in the type figures of F. carinata. An internal tube is not mentioned in the type description of this species.

A number of forms, some of them superficially closely similar to the South Australian specimens, have been referred to as F. marginata (Montagu) by different authors. The type figure of Vermiculum marginatum Montagu is very poor.

Except for very rare specimens, F. cf. carinata differs from F. cf. globosa (see below) in the Gambier Limestone in being distinctly more elongate and compressed.

FISSURINA cf. GLOBOSA Bornemann, 1855

Plate 14, fig. 19.

Cf. Fissurina globosa Bornemann, 1855, Deutsch. Geol. Ges., Zeitschr., v. 7, p. 317, pl. 12, fig. 4.

Description

At one extreme of morphological variation are almost perfectly spherical specimens, in which aperture is a short, narrow slit with bordering lips practically non-existent. Gently compressed specimens with a slightly keeled margin and a somewhat produced apertual end are at the other extreme. In these, length of apertual slit may be up to a little more than about one fifth of circumference of test; apertual slit widens slightly at its middle, and is bordered by slightly projecting lips of equal height.

Internal tube extends from bottom of apertual slit for about two thirds or a little more of length of test. Its lower half or less is attached along median line of one wall of test. Internal tube is uniform in diameter or widens very slightly towards base along most of its length; its lower end widens more rapidly and is directed obliquely inwards. Wall fairly densely and finely perforate; larger, more sparsely and less regularly distributed pores are also present. Apertual lips, marginal keel and sometimes a small, circular spot at base of test are imperforate. Wall imperforate or sparsely perforate where internal tube is attached to it.

Dimensions

l from 0.16 mm to 0.46 mm; w from 0.15 mm to 0.42 mm, t from 0.15 mm to 0.38 mm. Ratio l : t from 1.1 to 1.4; ratio w : t from 1 to 1.2.

Distribution

Rather rare in the Gambier Limestone.

Remarks

The Gambier Limestone specimens are generally larger and more spherical than F. globosa, originally described from the Oligocene of Germany. An internal tube was not mentioned in the type description of this species.

Family CASSIDULINIDAE

Genus CASSIDULINA d'Orbigny, 1826

CASSIDULINA SUBGLOBOSA Brady, 1881

Plate 15, fig. 1 - 3.

Cassidulina subglobosa Brady, 1881, Quart. Jour. Micr. Sci., n.s., v. 21, p. 60; Brady, 1884, Rept. Voy. Challenger, Zool., v. 9, p. 430, pl. 54, fig. 17; Norvang, 1958, Vidensk. Medd. Dansk naturh, Foren, v. 120, p. 36, pl. 8, fig. 17 - 19.

Description

Test subglobular or ovoid, often pear-shaped, since last chamber projects somewhat from the general, rounded outline of test; sometimes outline slightly lobate in specimens with inflated chambers. Chambers added alternately on each side of test in an involute planispiral arrangement, which may become somewhat irregular in distal part of last whorl. Chambers half-dome-shaped, placed against the last two preceding chambers and the previous whorl; they increase in size rather rapidly and regularly. Four or five pairs of chambers in last whorl of adult specimens. Sutures vary from indistinct to fairly distinct, and are straight or gently curved, flush to weakly depressed, narrow or slightly limbate. They bifurcate near the broadly rounded periphery. In specimens, which are regularly coiled throughout, the radially directed sutures join at the pole of the axis of coiling on each side of test; in specimens with less regular chamber arrangement, sutures do not join at a single point. Wall smooth, finely perforate. Aperture a loop-like slit in a shallow depression; it extends obliquely or approximately at right angles to basal suture into the semicircular apertual face. In well preserved specimens, a fairly prominent, plate-like lip is present along the more distal margin of the aperture; it becomes less prominent and gradually bends into the last chamber as it continues around the peripheral extremity and along the opposite side of the aperture.

Dimensions

Largest specimen (locality E 41) : D = 0.68 mm, d = 0.58 mm, t = 0.52 mm. Average D about 0.3 mm.

Distribution

Widespread in Tertiary and Recent sediments. Abundant throughout the Gambier Limestone.

Remarks

Variants similar to C. subglobosa, C. subglobosa var. horizontalis Cushman and Renz, 1941, and C. globosa Hantken, 1875, intergrade in the Gambier Limestone; rare specimens are rather similar to C. cuneata Finlay, 1940. Norvang (1958, op. cit.) considered C. globosa to be a synonym of C. oblonga Reuss, 1850, (Hantken thought this not unlikely already at the time of erection of C. globosa) and stated (p. 36) that "except for its considerable size....(C. subglobosa)....does not differ in any fundamental respects from ..C. oblonga..." Until a more detailed comparative study of these and similar species of Cassidulina has been completed, the specimens described above are referred to as C. subglobosa, because they reach a notably larger size than has been stated for C. oblonga and C. globosa.

CASSIDULINA CUSHMANI R.E. and K.C. Stewart, 1930

Plate 14, fig. 20, 21.

Cassidulina cushmani R.E. and K.C. Stewart, 1930, Jour. Pal., v. 4, p. 71, pl. 9, fig. 5; Martin, 1952, Cushman Found. Foram. Res., Contr., v. 3, p. 135, pl. 24, fig. 5; White, 1956, Jour. Pal., v. 30, p. 255, pl. 31, fig. 2.

Description

Test compressed, subequally and weakly to moderately biconvex; chambers added alternately on each side in an involute planispiral arrangement. Margin bluntly angular to weakly keeled. Peripheral outline oval to subcircular, slightly lobate. Each chamber overlaps the distal part of the preceding chamber in the same series and projects peripherally for up to about one third of its width past the last chamber in the other series. Chambers increase rapidly and regularly in size; usually four, sometimes five pairs of chambers in last whorl. Sutures strongly recurved; they bifurcate at about right angles near the periphery, giving rise to a short, slightly procurved or straight and radially directed branch and a long, oblique, proximally directed branch. Sutures distinct, slightly depressed and narrow, sometimes limbate at their axial extremities. Wall smooth, finely perforate. Aperture an elongate, narrow, gently curved slit along the basal suture; it lies in a shallow depression in the semilunar apertual face, and extends, parallel with the periphery, from near the distal extremity of the penultimate chamber for at least half the length of the last chamber. It lies partly beneath the peripheral margin of the penultimate chamber, which is often sharpened and lip-like due to secondary deposition of shell matter.

Dimensions

Largest specimen (locality E 147) : D = 0.50 mm, d = 0.42 mm, t = 0.22 mm. Average D about 0.3 mm. Ratio D : t from 1.7 to 2.3.

Distribution

Occurs in the Miocene and the Pliocene of California and the Pliocene of Panama. Fairly common throughout the Gambier Limestone.

Remarks

The Gambier Limestone specimens appear to be generally less sharply keeled than the Californian tests. C. delicata Cushman is a closely similar species; White (loc. cit.) states that C. delicata and C. cushmani "may be the same or varieties of a single species." C. tricamerata Galloway and Heminway from the Oligocene and the Miocene of Porto Rico has only three pairs of chambers in the last whorl, while C. asanoi Uchio from the Pliocene of Japan is more compressed, and has more strongly recurved sutures and a longer aperture than C. cushmani.

CASSIDULINA cf. ALABAMENSIS Bandy, 1949

Plate 15, fig. 4.

Cf. Cassidulina alabamensis Bandy, 1949, Bull. Amer. Pal., v. 32, p. 139, pl. 26, fig. 11.

Description

Test lenticular, compressed, subequally biconvex. Outline subcircular, smoothly curved; last chamber, with a rather straight distal-peripheral margin, projects from general outline of test. Margin of test fairly sharply to somewhat bluntly keeled. Chambers added alternately on each side of test in an involute planispiral arrangement; they increase regularly and fairly rapidly in size. Individual chambers elongate obliquely to direction of coiling; five or six pairs present in last whorl. Sutures fairly distinct near periphery, becoming indistinct in the secondarily thickened central area. They are generally flush and somewhat limbate; last one or two sutures in some specimens are narrow and slightly depressed. Sutures usually recurved near centre of test, but fairly straight peripherally from the point of bifurcation; the more proximal of the bifurcated branches are slightly longer and more oblique to direction of coiling than the others. Wall smooth, finely perforate. Aperture poorly preserved in most specimens; it is a short, comma - or wedge-shaped slit, which extends obliquely to basal suture into apertual face and is bordered by slight lips. Apertual face slightly depressed and bordered proximally by a bend in the wall of last chamber.

Dimensions

Largest specimen (locality E 83) : D = 0.54 mm, d = 0.48 mm, t = 0.28 mm. Average D about 0.3 mm. Ratio D : t from 1.6 to 2.3.

Distribution

Very rare in the lowest zone of the Gambier Limestone.

Remarks

The poorly preserved Gambier Limestone specimens appear to differ from C. alabamensis from the Upper Eocene and Lower Oligocene of Alabama only in the sutures being less distinct and less recurved in the axial region, and in the aperture extending obliquely, not parallel, to the plane of coiling in peripheral view.

CASSIDULINA cf. LATICAMERATA Voloshinova, 1939

Plate 15, fig. 5.

Cf. Cassidulina laticamerata Voloshinova, 1939, Neft. geol. Inst., Trudy, ser. A, fasc. 116, p. 88, pl. 2, fig. 6.

Description

Test lenticular, compressed, with a fairly sharply to bluntly angular margin. Peripheral outline slightly lobate, less commonly smoothly curved. Chambers added alternately on each side of test in a slightly to moderately evolute planispiral arrangement; however, chambers of the preceding whorl are commonly indistinctly visible, due to secondary thickening of central area. Chambers semicircular, roundedly quadrate or shaped like a widely open fan in side view. Four or five pairs of chambers in last whorl; they increase rapidly in size. Sutures distinct, generally narrow and flush or slightly depressed, especially near periphery; they are straight or gently curved, with spiral suture sharply bent where septal sutures join. Septal sutures bifurcate about half way between their contact with spiral suture and periphery; a short, radially directed branch is continuous with the axial part of the suture and a longer branch is directed obliquely backwards at nearly right angles to the other branch. Wall smooth, finely perforate. Aperture a short, loop-like or wedge-shaped slit, which is bordered by very slight lips and extends obliquely to basal suture into the gently depressed apertual face.

Dimensions

Largest specimen (locality E 46) : D = 0.32 mm, d = 0.30 mm, t = 0.16 mm. Average D about 0.25 mm. Ratio d : t from 1.7 to 2.

Distribution

Rather rare throughout the Gambier Limestone.

Remarks

The Gambier Limestone specimens differ from C. laticamerata from the Pliocene of the Kamchatka Peninsular, U.S.S.R., in having narrow instead of limbate sutures, and appear to possess a shorter aperture than is indicated in the type figure of this species.

CASSIDULINA cf. WILLIAMI Kleinpell, 1938

Plate 15, fig. 6.

Cf. Cassidulina williami Kleinpell, 1938, Miocene strat. California, p. 337, pl. 14, fig. 5, pl. 17, fig. 7, 8.

Description

Test compressed, subequally biconvex, with rounded margin. Peripheral outline subcircular, smoothly curved to very slightly lobate; last chamber projects somewhat from the general outline of test. Chambers added alternately on each side of test in an involute planispiral arrangement. Chambers compressed, fan-shaped to subquadrate in side view; four pairs in the last whorl.

Sutures fairly distinct, radial, straight to slightly curved, narrow to slightly limbate; usually flush, occasionally slightly depressed near periphery, where they bifurcate. Wall smooth, finely perforate. Aperture a narrow, wedge-shaped opening, occasionally shaped like a low, asymmetrical, concave-sided triangle with its longest side along the basal suture. Aperture situated in a shallow depression in the semilunar apertual face and bordered peripherally by a very slight lip.

Dimensions

Largest specimen (locality E 122) : D = 0.42 mm, d = 0.34 mm, t = 0.22 mm. Average D about 0.3 mm. Ratio D : t from 1.6 to 2.

Distribution

Rather rare in the Gambier Limestone.

Remarks

The Gambier Limestone specimens appear to differ from *C. williami* from the Miocene of California only in consistently having four rather than five pairs of chambers in the last whorl. *C. margareta* Karrer from the Miocene of Austria is similar to the South Australian tests in this respect, but is considerably larger in size; its type figure shows a more slit-like aperture parallel with the periphery.

Genus EHRENBERGINA Reuss, 1850

EHRENBERGINA aff. HEALYI Finlay, 1947

Plate 15, fig. 7, 8.

Aff. *Ehrenbergina healyi* Finlay, 1947, New Zealand Jour. Sci. Tech., v. 28, p. 284, pl. 7, fig. 106 - 115.

Description

Test fan-shaped or subtriangular in outline, not much longer than wide, compressed, somewhat curved in direction of growth at right angles to plane of compression. Test consists of up to about fifteen chambers; on ventral side, they partly overlap preceding chambers in the same series by means of small, proximally directed lobes, which form a median ridge. This ridge is generally rounded, sometimes rather flat-topped in cross-section; it widens and fades out distally, and is equal to about one third of the test in width. Ventral surface of test on each side of median ridge is concave, excavate; sides of ridge steep near its top, flattening towards its base. Both the height of median ridge and the concavity of the surfaces bordering it are rather variable. Distal margin of test sharply to bluntly keeled; lateral margins sharply angular in cross-section, and serrated, due to each chamber bearing a single, lateral spine; in some specimens early chambers bear two spines each. Spines vary from short, sharply or bluntly pointed to compressed, flange-like; their direction coincides roughly with direction of ventral sutures near margin of test. Ventral sutures indistinct on top of the median ridge and in early part of test; they bend proximally at base of the ridge, at an angle with the axis of test, which increases from about 30° in the early part to about 90° distally. Aperture a narrow, curved slit parallel with, and just inside, the distal margin of last chamber; it extends from contact between the last and the penultimate chambers for about one third of the length of distal margin of last chamber. Aperture partly overlapped along its proximal side by a flap with a curved, slightly thickened margin; this flap is continuous with the ventral wall of last chamber.

Dimensions

Largest specimen (locality E 168) : l = 0.56 mm, w = 0.46 mm, t = 0.24 mm. Average l about 0.4 mm. Ratio l : t from 1.7 to 2.3.

Distribution

Fairly rare in the intermediate and the uppermost zones of the Gambier Limestone.

Remarks

The Gambier Limestone specimens appear to be closely similar to E. healyi from the Upper Oligocene of New Zealand, but do not usually possess a large, conspicuous proloculus, stated to be characteristic of E. healyi. They differ from the two other closely related forms from the Upper Oligocene and the Miocene of New Zealand, E. willetti Finlay and E. marwicki Finlay, mainly in possessing a flatter, less distinctly developed median ridge.

Family ELLIPSOIDINIDAE

Genus PLEUROSTOMELLA Reuss, 1860

PLEUROSTOMELLA ELLIPTICA Galloway and Heminway, 1941

Plate 16, fig. 1, 2.

Pleurostomella elliptica Galloway and Heminway, 1941, N.Y. Acad. Sci., Sci. Surv. Porto Rico Virgin Islands, v. 3, p. 438, pl. 35, fig. 3; Cushman and Todd, 1945, Cushman Lab. Foram. Res., Spec. Pub. 15, p. 54, pl. 8, fig. 7.

Distribution

Occurs in the Oligocene and the Miocene of the Caribbean region. Very rare in the Gambier Limestone.

Genus NODOSARELLA Rzehak, 1895

NODOSARELLA sp.

Plate 16, fig. 3, 4.

Description

Test strongly elongate, slightly curved, round in cross-section, tapering slowly towards rounded base. Up to ten chambers in test; their rate of increase is irregular, varying in different specimens. Sutures at right angles to axis of test, flush in early part, slightly depressed distally. Wall smooth, finely perforate. Aperture a subterminal, short, straight or slightly curved slit, with wall on one side of it projecting slightly above the wall on the other side.

Dimensions

Largest specimen (locality E 53) : 1 = 1.44 mm, w = 0.20 mm. Fragmentary tests range up to 0.30 mm in width.

Distribution

Nodosarella sp. appears to be more elongate than the already described species of this genus.

Genus PARAFISSURINA Parr, 1947

PARAFISSURINA cf. LATA (Wiesner), 1931

Plate 16, fig. 5.

Cf. *Ellipsolagena lata* Wiesner, 1931, in Drygalski, Deutsche Südpolar - Exped., v. 20, p. 126, pl. 24, fig. k, l.

Dimensions

Largest specimen (locality E 164) : 1 = 0.38 mm, w = 0.30 mm, t = 0.18 mm.

Distribution

Very rare in the Gambier Limestone.

Remarks

The Gambier Limestone specimens differ from the Recent *P. lata* in possessing a generally less strongly developed marginal keel and a shorter, straight internal tube.

PARAFISSURINA sp.

Plate 16, fig. 6, 7.

Description

Test a moderately compressed sphaeroid. Margin bears a high, thin and sharp keel. Outline of test circular, slightly bulging at apertual end; it is usually even, sometimes ragged due to irregular breakage. Apertual slit subterminal, narrow, arcuate in side view and equal to about one fourth to one fifth of circumference of test in length. One of lips bordering apertual slit is distinctly thinner and lower than the other; both merge laterally into marginal keel. Internal tube rather uniform in diameter and extends from bottom of apertual slit towards the opposite side for about two thirds of the length of the test. Its lower one third to a half is attached to wall of test near the middle of that side which is continuous with the more prominent apertual lip. Lower end of internal tube sharply bent, hook-like. Wall smooth, very finely perforate; in well preserved specimens it is seen to be densely, slightly less finely perforate in two narrow, arcuate areas on each side of test. These areas lie along lateral margins of test and nearly join at base. The keel sometimes bears sparse, larger pores.

Dimensions

Largest specimen (locality E 154) : l = 0.34 mm, w = 0.32 mm, t = 0.18 mm.

Distribution

Rare in the Gambier Limestone.

Remarks

The most similar described species to the Gambier Limestone specimens is the Recent F. pseudomarginata (=Lagena pseudomarginata Buchner). Buchner's figured specimens indicate considerable variation in the shape and length of the internal tube, which is never as sharply bent near its free end as in the Gambier Limestone specimens. F. pseudomarginata has a thinner, more distinctly developed keel and lacks the arcuate, differently perforate areas near lateral margins of tests from the Gambier Limestone.

Family CHILOSTOMELLIDAE (?)

Genus PULLENIA Parker and Jones, 1862

PULLENIA BULLOIDES (d'Orbigny), 1826

Plate 16, fig. 8.

Nonionina bulloides d'Orbigny, 1826, Ann. Sci. Nat., v. 7, p. 293; d'Orbigny, 1846, Foram. Foss. Bass. Tert. Vienne, p. 107, pl. 5, fig. 9, 10.

Pullenia sphaeroides (non Nonionina sphaeroides d'Orbigny). Brady, 1884, Rept. Voy. Challenger, Zool., v. 9, p. 615, pl. 84, fig. 12, 13; Chapman, Parr and Collins, 1934, Linn. Soc. Lond., Jour., Zool., v. 38, p. 568, pl. 10, fig. 30.

Pullenia bulloides (d'Orbigny). Cushman and Todd, 1943, Cushman Lab. Foram. Res., Contr., v. 19, p. 13, pl. 2, fig. 15 - 18.

Description

Test subglobular or slightly compressed, planispirally coiled, involute. Margin evenly rounded; peripheral outline smoothly curved, sometimes very slightly lobate. Chambers increase regularly and slowly in size; last two or three sometimes approximately equal in size. Four or five, rarely six chambers in last whorl. Sutures radial, straight or very slightly recurved, narrow; they are flush, sometimes very weakly depressed in peripheral region. Wall smooth, very finely perforate. Aperture a narrow, evenly arched slit along basal suture, with a width equal to about one third of height of apertual face. Aperture usually uniform in width along most of its length, narrowing rapidly at extremities. Generally, extent of aperture is equal to about two thirds of the distance along circumference of test between the two poles of axis of coiling. In well preserved specimens peripheral margin of aperture is bordered by a very slight lip; often, however, the aperture is somewhat infilled, or enlarged by fragmentation of wall.

Dimensions

Largest specimen (locality E 134) : D = 0.60 mm, d = 0.54 mm, t = 0.50 mm. Average D, about 0.4 mm.

Ratio t : D (ratio A as consistently used, but conversely defined, by Cushman and Todd, 1943, loc. cit.) varies from 1 : 1 to 1 : 1.38.

Ratio height of apertual face to height of last chamber (ratio B of Cushman and Todd) varies from 1 : 2.2 to about 1 : 4.

Distribution

Widespread in Tertiary and Recent sediments. Fairly common throughout the Gambier Limestone.

Remarks

Cushman and Todd's ratios A and B and size ranges stated for different species of *Pullenia* seem to be, at least in a few cases, limiting values of arbitrarily chosen, intergrading variants. Most of the specimens in the Gambier Limestone fall within the limits of variation of ratio A as stated for *P. bulloides* (1 : 1 to 1 : 1.15); less common, more compressed specimens fall within the range given for *P. compressiuscula* Reuss. Probably a number of differently named species of *Pullenia* intergrade to a greater or lesser extent with *P. bulloides*.

PULLENIA QUINQUELOBA (Reuss), 1851

Nonionina quinqueloba Reuss, 1851, Zeitschr. deutsch. geol. Ges., v. 3, p. 71, pl. 5, fig. 31.

Pullenia quinqueloba (Reuss). Chapman, Parr and Collins, 1934, Linn. Soc. Lond., Jour., Zool., v. 38, p. 568, pl. 10, fig. 29; Cushman and Todd, 1943, Cushman Lab. Foram. Res., Contr., v. 19, p. 10, pl. 2, fig. 5, pl. 3, fig. 8; Carter, 1958, Geol. Surv.

Victoria, Bull. 55, p. 32, pl. 2, fig. 8, 9.

Pullenia quinqueloba (Reuss) var. angusta Cushman and Todd, 1943, Cushman Lab. Foram. Res., Contr., v. 19, p. 10, pl. 2, fig. 3, 4.

Distribution

Widespread in Tertiary and Recent sediments. Fairly common throughout the Gambier Limestone.

Dimensions

The size, the ratio t : D (= ratio A as consistently used, though defined as the converse of this, by Cushman and Todd, 1943), and the ratio of height of apertual face to height of last chamber (ratio B of Cushman and Todd) of the specimens in the Gambier Limestone, P. quinqueloba and P. quinqueloba var. angusta according to Cushman and Todd, and the specimen figured by Carter (loc. cit.) are compared below.

	Size	Ratio A	Ratio B
Specimens in the Gambier Limestone	0.28 - 0.70 mm	1:1.5 - 1:2	1:1.6 - 1:3
P. quinqueloba	0.38 - 0.50 "	1:1.3 - 1 :1.65	ca 1:2
P. quinqueloba var. angusta	0.25 - 0.50	1:1.45- 1:1.8	ca 1:2
Carter's values	0.54	1:1.8	1:2.75

Remarks

The Gambier Limestone specimens usually have five, less commonly four or six chambers in the last whorl.

Genus SPHAEROIDINA d'Orbigny, 1826

SPHAEROIDINA BULLOIDES d'Orbigny, 1826

Plate 16, fig. 9 - 11

Sphaeroidina bulloides d'Orbigny, 1826, Ann. Sci. Nat., v. 7, p. 267; mod. 65; Chapman, Parr and Collins, 1934, Linn.

Soc. Lond., Jour., Zool., v. 38, p. 568, pl. 10, fig. 31; Cushman and Todd, 1949, Cushman Lab. Foram. Res., Contr., v. 25, p. 15, pl. 3, fig. 10.

Description

Test varies from commonly subglobular or ovoid, with smoothly rounded outline, to, less commonly, somewhat compressed or strongly lobate. In subspherical forms last three or four chambers may be approximately planispirally arranged; in more strongly lobate forms, chamber arrangement irregular or vaguely trochospiral. Chambers increase rapidly, regularly to irregularly in size; last chamber constitutes from less than one third to more than one half of the test. Chambers vary from evenly rounded, hemispherical and strongly embracing in subspherical tests to smaller, dome-shaped or asymmetrical, strongly inflated and weakly embracing in lobate tests. In subspherical forms, early chambers are sometimes more projecting than the later ones. Four to seven chambers visible on surface of test. Sutures straight to strongly curved; flush to gently depressed. Wall smooth, finely perforate. Aperture a narrow, crescentic or horse-shoe-shaped arch, which touches or nearly touches the basal suture at its extremities and is bordered by a slight rim along its areal side. Aperture bends around a large, tongue-shaped tooth (often broken).

Dimensions

Largest specimen (locality E 61) : D = 0.62 mm, d = 0.50 mm. Average D about 0.3 mm.

Distribution

Widespread in Upper Eocene to Recent deposits. Common throughout the Gambier Limestone.

Remarks

Most of the Gambier Limestone specimens fall within the range of variation of S. bulloides as stated by Cushman and Todd (op. cit.). Such forms intergrade fully with specimens which, according to Cushman and Todd, should be referred to *S. austriaca* d'Orbigny, *S. haueri* (Czjek), *S. variabilis* Reuss, *S. chilostomata* Galloway and Morrey or *S. compressa* Cushman and Todd. This is in agreement with the view of Vasicek (1956), who regarded *S. bulloides* and *S. nitida* Cushman and Todd as the only distinct species of the genus.

Superfamily SPIRILLINIDEA

Family SPIRILLINIDAE

Genus SPIRILLINA Ehrenberg, 1843

SPIRILLINA DECORATA Brady, 1884

Spirillina decorata Brady, 1884, Rept. Voy. Challenger, Zool., v. 9, p. 633, pl. 85, fig. 22-25; Chapman, Parr and Collins, 1934, Linn. Soc. Lond., Jour., Zool., v. 38, p. 558, pl. 8, fig. 1; Carter, 1958, Geol. Surv. Victoria, Bull. 55, p. 33, pl. 3, fig. 22, 23.

Distribution

Occurs in Recent sediments; also in Oligocene and Miocene strata in Victoria. Very rare in the Gambier Limestone.

SPIRILLINA VIVIPARA Ehrenberg, 1843

Spirillina vivipara Ehrenberg, 1843, K. Akad. Wiss. Berlin, Physik. Abh., Teil 1, p. 323, 422, pl. 3,VII, fig. 41; Carter, 1958, Geol. Surv. Victoria, Bull 55, p. 39, pl. 4, fig. 32, 33.

Distribution

Widespread in Tertiary and Recent sediments. Very rare in the Gambier Limestone.

Genus PATELLINA Williamson, 1858

PATELLINA CORRUGATA Williamson, 1858

Patellina corrugata Williamson, 1858, Rec. Foram. Gt. Britain, Ray. Soc., p. 46, pl. 3, fig. 86 - 89; Parr and Collins, 1930, Roy. Soc. Victoria, Proc., v. 43, n.s., p. 90, pl. 4, fig. 1 - 5; Chapman, Parr and Collins, 1934, Linn. Soc. Lond., Jour., Zool., v. 38, p. 560, pl. 8, fig. 6.

Distribution

Widespread in Tertiary and Recent sediments. Rare, poorly preserved specimens in the Gambier Limestone.

Superfamily ROTALIIDEA

Family DISCORBIDAE

Genus DISCORBIS Lamarck, 1804

DISCORBIS BALCOMBENSIS Chapman, Parr and Collins, 1934

Plate 16, fig. 12, 13.

Discorbis balcombensis Chapman, Parr and Collins, 1934, Linn. Soc. Lond., Jour., Zool., v. 38, p. 562, pl. 8, fig. 10; Carter, 1959, unpublished thesis, pl. 21, fig. 266 - 268.

Description

Test compressed, formed by a low to fairly high trochospiral coil. Usually dorsal side more strongly convex than ventral side, which is flat in rare specimens; less commonly, test is subequally, biconvex. Dorsal side evolute; ventral side involute, with umbilical area infilled or projecting as a rounded boss, due to the coalescing of apertual flaps. This area is about one fourth to one third of the diameter of test in size. Margin acute, with a narrow and thin, somewhat blunted keel. Peripheral outline subcircular or somewhat oval, evenly curved or weakly lobate. The seven to nine chambers in last whorl increase regularly in size. Septal sutures dorsally oblique, recurved, limbate and flush (sometimes slightly depressed in distal part of last whorl); they are usually indistinct in whorls preceding the last one due to secondary thickening of test. Ventral sutures radial, straight or very slightly recurved, increasingly strongly depressed towards the umbilical area. Spiral suture evenly curved, limbate. Wall smooth, very finely perforate. Almost all specimens have broken last chambers; hence apertual characteristics can be observed only in very few. Arched aperture possesses a slight ventral rim or lip and extends along basal suture from a distance approximately equal to a third of the radius of test below periphery for a similar distance axially, when it suddenly narrows. It continues proximally, under a lobe-shaped apertual flap projecting into the umbilical area, along the entire ventral base of last chamber. Apertual flaps of chambers preceding the last are fused in the umbilical area; in well preserved specimens the central space under its covering can be observed to communicate with the exterior through elongate openings (the "posterior foramina" of Wade, 1958, unpublished thesis, p. 103), which are partly covered along their distal borders by proximal edges of apertual flaps of succeeding chambers. These openings coincide with the axial, deeply depressed ends of septal sutures. The division of aperture into a foraminal part and an umbilical part (Wade, op. cit., p. 101; the "septal foramen" and "spiral canal", respectively, of Carter 1959, loc. cit.) by the "proximal foot" of the penultimate chamber (Wade, p. 100), after addition of another chamber, can be seen fairly clearly in rare specimens (in which the last chamber has been broken).

Dimensions

Largest specimen (locality E 53) : D = 0.42 mm, d = 0.40 mm, t = 0.26 mm. Average D about 0.3 mm. Ratio D : t from 1.7 to 2.2

Distribution

Originally described from the Middle Miocene of the Port Phillip area; also occurs in Gippsland (both in Victoria). Rather rare throughout the Gambier Limestone.

Remarks

A closely similar species is D. finlayi Dorreen occurring in the Eocene and the Oligocene of New Zealand. It is, however, stated to be "medium to coarsely" perforate, and has only five to seven chambers in last whorl.

Species rather similar to D. balcombensis with respect to the structure in the umbilical area have been designated as the type species of Rotorbinella Bandy, 1944 (differing from Discorbis "in possessing an umbilical plug"), and Lamello-discorbis Bermudes, 1952 (exhibiting additional apertures under the edges of apertual flaps). According to Wade (op. cit., p. 107), the umbilical parts of the apertual lips are fused in adult specimens of the type species of Discorbis (D. vesicularis Lamarck) and specimens of D. dimidiatus (Parker and Jones), the type species of Lamellodiscorbis, do not always possess the additional apertures. Hence Wade's implied (in the case of Rotorbinella) and stated (in the case of Lamellodiscorbis) opinion, that these two "genera" are best regarded as synonyms of Discorbis, is accepted.

DISCORBIS aff. AUSTRALIS Parr, 1932

Aff. Discorbis australis Parr, 1932, Roy. Soc. Victoria, Proc., v. 44, n.s., p. 227, pl. 22, fig. 31.

Remarks

Poorly preserved specimens resembling the Recent D. australis occur rarely in the Gambier Limestone. They are generally smaller and not uncommonly formed by a higher trochopsiral coil than is shown in the type figure of D. australis.

DISCORBIS cf. MICENS Cushman, 1933

Plate 16, fig. 14.

Cf. Discorbis micens Cushman, 1933, Cushman Lab. Foram. Res., Contr., v. 9, p. 89, pl. 9, fig. 5.

Cf. Discorbis micens Cushman. Todd, 1957, U.S. Geol. Surv., Prof. Pap. 280 - H, pl. 90, fig. 7.

Description

Test compressed, consisting of a low trochospiral coil. Dorsal side evolute, weakly to moderately convex. Ventral side involute, usually gently concave due to presence of a shallow and wide umbilical depression. Margin rounded; peripheral outline roughly pear-shaped or oval, weakly lobate. Test consists of up to about ten chambers arranged in two or slightly more whorls, with four to five chambers in the last whorl. Chambers increase fairly rapidly in size. Dorsal sutures usually fairly distinct, slightly recurved, distally narrow and gently depressed, flush in early part of test. Ventral sutures less distinct, radial, straight to slightly recurved, depressed and narrow. Wall smooth; pierced by rather densely spaced pores of moderate size, which ventrally become sparse towards the umbilicus. Aperture extends along the basal suture from periphery into the umbilicus. Near the periphery it is bordered by a slight lip; in the umbilical region, aperture covered by a triangular flap, which usually makes a fairly sharp angle at its contact with the wall of last chamber at the most distal suture. This contact is marked by a shallow, notch-like depression in the wall. In some specimens apertual flaps bear small bosses of secondarily deposited shell matter.

Dimensions

Largest specimen (locality E 58) : D = 0.74 mm, d = 0.60 mm, t = 0.36 mm. Average D about 0.4 mm.

Distribution

Rare in the Gambier Limestone.

Remarks

The Gambier Limestone specimens appear to be closely similar to the Recent D. micens as figured by Todd (loc. cit.); the type figure of this species shows an individual with a less lobate peripheral outline and a less rounded margin.

Genus DISCORBINELLA Cushman and Martin, 1935

DISCORBINELLA BICONCAVA (Parker and Jones), 1862

Discorbina bi-concava Parker and Jones, 1862, in Carpenter, Intr. stud. foram., p. 201, text-fig. 32 g; Parker and Jones, 1865, Phil. Trans. Roy. Soc. Lond., v. 155, pl. 19, fig. 10.

Planulinoides biconcava (Jones and Parker). Parr, 1941, Min. Geol. Jour., Victoria, v. 2, p. 305, text-fig.

Discorbinella biconcava (Parker and Jones). Carter, 1959, unpublished thesis, pl. 7, fig. 80 - 83.

Distribution

Occurs in Recent sediments in the southern Australian region and in the Pliocene and the Miocene of Victoria, including Gippsland. Very rare in the Gambier Limestone.

DISCORBINELLA PAPILLATA (Chapman, Parr and Collins), 1934

Discorbis bertheloti (d'Orbigny) var. papillata Chapman, Parr and Collins, 1934, Linn. Soc. Lond., Jour., Zool., v. 38, p. 561, pl. 9, fig. 14.

Discorbinella papillata (Chapman, Parr and Collins). Carter, 1959, unpublished thesis, pl. 8, fig. 88-90.

Distribution

Occurs in the Miocene of the Port Phillip and Batesford areas, in the Tertiary of Gippsland (all in Victoria) and in Recent sediments in the southern Australian region. Very rare in the Gambier Limestone.

DISCORBINELLA PLANOCONCAVA (Chapman, Parr and Collins), 1932

Planulina biconcava (Jones and Parker) var. *planoconcava* Chapman, Parr and Collins, 1932, in Parr, Roy. Soc. Victoria, Proc., v. 44, n.s., p. 232, pl. 22, fig. 34.

Discorbis planoconcava (Chapman, Parr and Collins). Chapman, Parr and Collins, 1934, Linn. Soc. Lond., Jour., Zool., v. 38, p. 561, pl. 11, fig. 40.

Discorbinella planoconcava (Chapman, Parr and Collins). Carter, 1959, unpublished thesis, pl. 8, fig. 84 - 87.

Distribution

Occurs in Recent sediments off Victoria, in the Miocene of the Port Phillip and Hamilton areas, and in the Tertiary of Gippsland (all in Victoria). Very rare in the Gambier Limestone.

Genus PLANODISCORBIS Bermudez, 1952

PLANODISCORBIS IRREGULARIS Carter, 1959, (M.S.)

Planodiscorbis irregularis Carter, 1959, unpublished thesis, pl. 8, fig. 91 - 95.

Distribution

Originally described from the Tertiary of Gippsland, Victoria. Rare in the intermediate and the uppermost zones of the Gambier Limestone.

Genus VALVULINERIA Cushman, 1926

VALVULINERIA cf. TEXANA Cushman and Ellisor, 1931

Plate 16, fig. 15.

Cf. *Valvulineria texana* Cushman and Edwards, 1931, Cushman Lab. Foram. Res., Contr., v. 7, p. 56, pl. 7, fig. 7.

Cf. Valvulineria texana Cushman and Edwards. Todd, 1957, U.S. Geol. Surv., Prof. Pap. 280-H, pl. 68, fig. 6.

Description

Test compressed, consisting of a low, trochospiral coil. Dorsal side evolute, weakly to moderately convex; ventral side involute, with a small and shallow umbilical depression, which is sometimes only indistinctly developed. Peripheral outline roughly oval, commonly slightly lobate, rarely smoothly curved; margin rounded. Chambers increase rather rapidly in size, with last chamber commonly constituting about half of the test. Up to two or slightly more whorls with about ten chambers are present; five chambers in last whorl. Dorsally, septal sutures distinct, somewhat oblique, straight or gently recurved; they are narrow and slightly depressed, or flush, especially in early part of test. Spiral suture bent where septal sutures join. Ventral sutures less distinct, radial, straight or slightly curved, narrow and gently depressed. Wall smooth, finely perforate, monolamellid in structure. Aperture a straight or slightly arched slit extending from near periphery into the umbilical depression. In the umbilicus it is covered by a narrow flap, which is shaped like a low triangle. Apertual flap commonly joined at an angle to the general wall of the last chamber at the last suture; this contact may be marked by a shallow, notch-like depression. Flaps of succeeding chambers partly overlap those of preceding ones. In most specimens, umbilical depression is partly covered by apertual flaps; in some tests, the flaps are small and the umbilicus fairly deep.

Dimensions

Largest (figured) specimen (locality E 161) : D = 0.40 mm, d = 0.32 mm, t = 0.22 mm.

Distribution

Rare throughout the Gambier Limestone.

Remarks

The Gambier Limestone specimens are closely similar to *V. texana* as figured by Todd from the Eocene of Saipan. The type figure of this species shows a specimen with a considerably larger apertual flap extending over the umbilical depression.

Genus GYROIDINOIDES Brotzen, 1942

GYROIDINOIDES ZELANDICA (Finlay), 1939

Plate 17, fig. 1, 2.

Gyroidina zelandica Finlay, 1939, Roy. Soc. New Zealand, Trans., v. 69, p. 323, pl. 28, fig. 138 - 140.

Description

Test formed by a moderately low trochospiral coil. Dorsal side flat or slightly convex, rarely gently concave; ventral surface forms an obliquely truncated cone, hollowed at tip. Test evolute dorsally, with up to three whorls visible, although commonly early whorls are obscured by secondary thickening of test; ventrally involute, with a narrow and fairly deep umbilicus, which is commonly partly filled by apertual flaps and secondary shell matter. Margin bluntly angular; peripheral outline subcircular, smoothly curved, sometimes very slightly lobate in distal part of last whorl. Eight to ten chambers in last whorl; they increase regularly and rather slowly in size. Septal sutures ventrally radial, straight and narrow; they are depressed and distinct near the umbilicus, but become flush and, except between the last few chambers, indistinct near margin of test. Dorsal sutures short, oblique, slightly recurved or nearly straight, narrow and depressed, commonly with steep proximal sides. Spiral suture smoothly curved, narrow, depressed. Wall smooth, densely and finely perforate. Aperture a narrow, elongate slit around the entire ventral base of the last chamber. Near the margin it is bordered peripherally by a narrow rounded rim or flap, which gradually widens ventrally, to become prominent, triangular and bluntly pointed at its innermost corner in the umbilicus. Such umbilical flaps are gently curved and at an angle both to the axis of coiling and axis of growth of test. Each flap partly overlaps that of the preceding chamber; flaps of up to six last chambers can be seen in the umbilical region of well preserved specimens, though often apertual flaps of all but the last one or two chambers are indistinct. In well preserved specimens apertures opening into the umbilicus beneath the flaps of one or two chambers preceding the last one can be seen. A deep groove along the dorsal spiral suture is continuous with the aperture; it is interrupted by the attachment of septa between chambers of last whorl to peripheral margin of the preceding whorl. This groove may extend proximally for up to more than half the length of last whorl, but is often rather indistinctly developed. Apertual face somewhat bent, suptrapezoidal, usually with a prominent, bluntly angular ventro-peripheral corner (umbilical shoulder).

Dimensions

Largest specimen (locality V 119) : D = 0.88 mm, d = 0.76 mm, t = 0.56 mm. Average D about 0.5 mm.

Distribution

Occurs in Upper Eocene to Lower Oligocene strata of New Zealand. Common throughout the Gambier Limestone sensu stricto; not found in the Naracoorte Limestone Member.

Remarks

Rare specimens from near the base of the Gambier Limestone are somewhat similar to G. allani (Finlay) in having a rather rounded umbilical shoulder, prominent apertual flaps, a distinct groove extending backwards along the spiral suture and ten chambers in last whorl; however, they do not approach G. allani in maximum size, and intergrade fully with specimens identical with G. zelandica. G. subangulata (Plummer) from the Midway Group of Texas seems to be closely similar to G. zelandica. G. altispira (R.E. and K.C. Stewart) has a decidedly more rounded umbilical shoulder.

GYROIDINOIDES cf. SOLDANII (d'Orbigny), 1826

Plate 17, fig. 3 - 5.

Cf. Gyroidina soldanii d'Orbigny, 1826, Ann. Sci. Nat., ser. 1, v. 7, p. 278; modele 36.

Cf. Gyroidina soldanii d'Orbigny. Batjes (pars), 1958, Inst. Roy. Sci. Nat. Belgique, mem. 143, p. 147, pl. 7, fig. 13, 14.

Description

Test consists of a fairly low trochospiral coil. Dorsal side usually flat or nearly flat, less commonly gently convex or concave; ventral side strongly convex. Test involute ventrally, with a very narrow central umbilicus, which is often at least partly covered by apertual flaps of last one or two chambers. Dorsal side evolute, up to about three whorls present. Peripheral outline subcircular, smoothly curved, less commonly weakly lobate. Margin of test asymmetrically rounded, sometimes roundedly angular. The six to eight chambers in last whorl increase regularly in size. Septal sutures ventrally fairly distinct, radial, straight or gently recurved, narrow; they are usually slightly depressed near umbilicus, commonly becoming flush towards periphery. Septal sutures on dorsal side radial, short and straight; spiral suture bent where septal sutures join. Dorsal sutures usually distinct, narrow and depressed in last whorl, but slightly limbate, flush and often rather indistinct in early whorls. Wall smooth, finely perforate. Aperture a narrow, elongate and gently arched slit, which extends from peripheral margin along basal suture into the umbilicus. It is bordered by a slight lip along its outer margin in the region of apertual face; this lip widens to become a small, lobe-like flap partly covering the umbilicus. Apertual face suboval, usually somewhat arched in outline, with both ventral and dorsal extremities rounded.

Dimensions

Largest specimen (locality E 141) : D = 0.46 mm, d = 0.40 mm, t = 0.36 mm. Ratio D : t 1.3 or 1.4.

Distribution

Rather rare throughout the Gambier Limestone.

Remarks

A large number of forms, probably belonging to more than one species, have been referred to as *Gyroidina soldanii* (originally described from Recent sediments) by different authors. Some of such forms, with a *Gyroidinoides* - like aperture appear to be closely similar to the Gambier Limestone tests. D'Orbigny's model represents a form with more chambers in the last whorl and a less rounded umbilical shoulder than in the South Australian specimens.

Genus EPONIDES Montfort, 1808

EPONIDES LORNENSIS Finlay, 1939

Plate 17, fig. 6 - 12.

Eponides repandus (Fichtel and Moll). Chapman, Parr and Collins, 1934, Linn. Soc. Lond., Jour., Zool., v. 38, p. 565, pl. 9, fig. 18; Carter, 1958, Geol. Surv. Victoria, Bull. 55, p. 45, pl. 6, fig. 51-53; Wade, 1958, unpublished thesis, p. 116, pl. 9, fig. 5 - 8.

Eponides lornensis Finlay, 1939, Roy. Soc. New Zealand, Trans., v. 68, p. 521; Finlay, 1939, ibid., v. 69, p. 121, pl. 13, fig. 52,53; Carter, 1958, Geol. Surv. Victoria, Bull. 55, p. 44, pl. 5, fig. 48 - 50.

Eponides tethyeus Dorreen, 1948, Jour. Pal., v. 22, p. 295, pl. 39, fig. 3.

Dimensions

Largest specimen (locality E 116) : D = 2.0 mm, d = 1.7 mm, t = 0.9 mm. Most specimens less than 1 mm in size. Ratio D : t from 1.7 to 2.2 in adult specimens.

Distribution

Common throughout the Gambier Limestone.

Remarks

E. lornensis was originally described from Upper Eocene to Lower Oligocene beds of New Zealand. Finlay considered E. lornensis to be the ancestor of E. repandus (Fichtel and Moll), from which it was stated to differ in having a less pointed base, a distinctly open umbilical area formed by the great spread of the aperture ventrally, and especially in having fewer chambers; regularly five to a whorl, instead of seven to ten as in repandus. As an example of his concept of E. repandus, Finlay mentioned the forms described by Chapman, Parr and Collins (1934, loc. cit.) from Middle Miocene beds of Port Phillip, Victoria, agreeing with the authors that such forms seemed inseparable from Recent Indo-Pacific tests.

Carter (1958, loc. cit.) described and figured E. lornensis from Upper Eocene strata in Victoria and E. repandus from Victorian Oligocene and Miocene. He recorded that the Victorian specimens of E. lornensis have six (rather than five, as stated by Finlay) chambers in the last whorl and that "the ventral expansion of the aperture is never as great as in the specimens figured by Finlay." However, as partly mentioned by Carter, specimens of E. lornensis from New Zealand in the National Museum of Victoria agree with the forms described by Carter in these respects.

Wade (1958, loc. cit.) described E. repandus, with special emphasis on its internal structure, from the Miocene of the St. Vincent's Basin in South Australia. She concluded that the South Australian individuals are conspecific with specimens in the Upper Eocene of New Zealand, which were described as E. tethycus n.sp. by Dorreen (1948, loc. cit.)

Material from the Gambier Limestone was compared with the specimens of E. lornensis in the National Museum of Victoria and the forms described by Wade. Variants almost identical with both intergrade morphologically with tests agreeing well with the type figure of E. lornensis. The above variants cannot be distinctly separated from considerably less common individuals with up to eleven chambers in the last whorl and with the aperture extending for only about two thirds of the distance from the periphery to the ventral centre of specimens. In such specimens the central area ventrally may be covered by a fairly wide; but low calcite boss, and at least the lowest part of the ventral sutures may be limbate. Some of such forms closely resemble the E. repandus of Chapman, Parr and Collins (1934) and of Carter (1958). However, no specimens with large pores in the apertual face have been found in the Gambier Limestone.

Reiss' (1960, p. 1) statement that "The type - species of Eponides Montfort, 1808 (Nautilus repandus Fichtel and Moll) is a nomen dubium " is accepted, especially since differences of opinion exist concerning the significance of large pores in the apertual face of Eponides (such pores are not shown in the conventionalized type figure of E. repandus, but are present in the specimen figured as Pulvinulina repanda by Brady, 1884, pl. 104, fig. 18; many authors have based their concept of E. repandus on Brady's rather than on Fichtel and Moll's figure.) The presence or absence of such pores has been considered by some authors to be of more than specific significance, e.g. as the differentiating criterion between Eponides and Poroeponides Cushman, 1944; however, it appears to be a variable character within a single species (Chapman, Parr and Collins, Carter, auct.).

Reiss created a new genus Eponidopsis, with E. lornensis as the type species. Eponidopsis is a synonym of Eponides unless

Eponides is formally suppressed by the Committee for the Rules of Zoological nomenclature, because of the uncertainty concerning its type species.

Since tests agreeing well with the type figure of E. lornensis intergrade with forms similar to those referred to as E. repandus by Chapman, Parr and Collins throughout the Gambier Limestone, the two are not taxonomically separated. If such splitting is attempted in other sequences representing a greater interval of time, a new name to replace E. repandus is necessary.

Genus ALABAMINA Toulmin, 1941

ALABAMINA TENUIMARGINATA (Chapman, Parr and Collins), 1934

Plate 18, fig. 1, 2.

Pulvinulinella (?) tenuimarginata Chapman, Parr and Collins, 1934, Linn. Soc. Lond., Jour., Zool., v. 38, p. 565, pl. 9, fig. 19.

Alabamina tenuimarginata (Chapman, Parr and Collins). Carter, 1959, unpublished thesis, pl. 20, fig. 249 - 251.

Description

Test compressed, formed by a low, trochospiral coil. Dorsal side evolute, usually more convex than ventral side, which is involute and without umbilicus. Peripheral outline nearly circular to suboval, usually very slightly lobate. Margin acute, with a slightly projecting, unthickened keel. Five or six, rarely seven chambers in last whorl; up to fifteen chambers, arranged in about two and a half whorls, in the whole test. Septal sutures narrow and distinct in last whorl, commonly indistinct in earlier part of test dorsally. Dorsal sutures strongly oblique, slightly recurved, flush; ventral sutures radial, gently recurved, slightly depressed or flush. Wall smooth, densely and finely perforate; keel sometimes bears sparse larger pores. Aperture a slit extending ventrally from just below periphery (formed in this part by the "tectum" of Brotzen, 1948, p. 97) for about one third to two thirds of the distance along the basal suture, at an angle of about 10° to 40° to the periphery in ~~side~~ marginal view. Aperture fairly consistent in width or narrowing ventrally. The dorsal part of apertual face bordering periphery is folded inwards; this fold varies from a shallow to a distinct groove deepening rather gradually (the "scrobis septalis" and the "infundibulum" of Brotzen) towards the dorsal extremity of aperture. Outline of the proximal boundary of this fold visible through the dorsal wall of well preserved specimens, and is curved or nearly straight. In specimens with a short aperture at a low angle to periphery the ventro-distal boundary of the scrobis septalis and infundibulum, formed by a rather sharp, distally projecting fold (analogous to fold at e in text-fig. 4 c, Toulmin, 1941, p. 605), is continuous with a similarly folded ventral margin of the aperture. In specimens with a relatively long aperture, at a larger angle to periphery, this distally projecting fold becomes less distinct near the dorsal extremity of the aperture (which is sometimes bordered ventrally by a slightly raised lip) and continues, after bending, as a less tight fold ventral to and parallel with the aperture.

Dimensions

Largest specimen (locality E 101) : D = 0.64 mm, d = 0.58 mm, t = 0.28 mm. Average D about 0.4 mm. Ratio D : t from 1.3 to 2.3.

Distribution

Originally described from Middle Miocene strata in the Port Phillip area; also occurs in Gippsland (both in Victoria). Fairly common throughout the Gambier Limestone *sensu stricto*; not found in the Naracoorte Limestone Member.

Remarks

A. tenuimarginata has a more acute margin and a generally thinner and larger test than *A. westraliensis* (Parr) from the Eocene of Western Australia.

ALABAMINA AUSTRALIENSIS (Chapman, Parr and Collins), 1934

Discorbis tuberculata (Balkwill and Wright) var. australiensis Chapman, Parr and Collins, 1934, Linn. Soc. Lond., Jour., Zool., v. 38, p. 563, pl. 8, fig. 9.

Alabamina australiensis (Chapman, Parr and Collins). Carter, 1959, unpublished thesis, pl. 20, fig. 246 - 248.

Distribution

Originally described from Middle Miocene strata in the Port Phillip area; also occurs in Gippsland (both in Victoria). Very rare in the Gambier Limestone.

Genus SIPHONINA Reuss, 1850

SIPHONINA AUSTRALIS Cushman, 1927

Plate 18, fig. 3.

Siphonina australis Cushman, 1927, U.S. Nat. Mus., Proc., v. 72, p. 8, pl. 2, fig. 6, pl. 3, fig. 7, 8; Chapman, Parr and Collins, 1934, Linn. Soc. Lond., Jour., Zool., v. 38, p. 567, pl. 10, fig. 10; Carter, 1959, unpublished thesis, pl. 10, fig. 117-119.

Description

Test compressed, formed by a low, trochospiral coil, unequally or subequally biconvex. Ventral side evenly and usually less strongly convex than dorsal side, which bears a dome-shaped, somewhat eccentrically situated secondary thickening. This thickening usually obscures early whorls on the evolute dorsal side; in some specimens, however, more than two whorls are visible. Ventral side involute, without umbilicus. Margin acute, with a fairly wide, thin and crenulate keel, which usually has a finely serrated edge. The keel is least strongly developed along distal part of last chamber; not uncommonly, it is worn or broken. Peripheral outline subcircular, slightly lobate. Chambers increase regularly in size, each overlapping the distal third or more of the preceding chamber ventrally, while embracing only the peripheral part of preceding chamber dorsally. On ventral side septal sutures radial, straight or gently recurved; they are narrow and slightly depressed in distal part of last whorl, often somewhat limbate, flush and indistinct in proximal part. Dorsally septal sutures strongly oblique, recurved, approximately coinciding with axial edges of marginal keels of preceding chambers. Dorsal sutures usually indistinct in early part of last whorl, except near periphery. Spiral suture smoothly curved, commonly indistinct proximally. Wall coarsely perforate; pores, except near centre of test, are usually directed obliquely towards periphery. Ventrally pores are sparse in early chamber walls, to a certain extent concentrated in proximal parts of chambers and, to a lesser degree, near periphery; distal chambers more densely, often somewhat irregularly perforate. On dorsal side, pores concentrated near periphery of test, with only a few penetrating the central, thickened part. Peripheral keel pierced by rather densely spaced and radially directed, coarse pores. Aperture elliptical, surrounded by a usually well-developed, flaring, imperforate lip at the end of a short neck, which is situated peripherally near the distal extremity of last chamber. In some specimens indistinct, fine, subparallel striations, which are directed towards the aperture, are present on both sides of test.

Dimensions

Figured (largest) specimen : D = 0.66 mm, d = 0.60 mm, t = 0.28 mm. Average D. about 0.4 mm.

Distribution

Occurs in the Oligocene and the Miocene of Victoria, South Australia and New Zealand. Fairly common throughout the Gambier Limestone.

Genus GAVELINONION Hofker, 1951

GAVELINONION CENTROPLAX (Carter), 1958

Astrononion centroplax Carter, 1958, Geol. Surv. Victoria, Bull. 55, p. 61, pl. 9, fig. 95 - 97.

Description

Eight to twelve chambers in last whorl; periphery usually smoothly curved, sometimes slightly lobate in distal part of last whorl. Sutures commonly flush or gently raised; occasionally slightly depressed, especially near umbilicus, which is often partly filled by apertual plates and secondary shell matter. Wall bilamellid and granular in structure.

Dimensions

Largest specimen (locality E 61) : D = 0.90 mm, d = 0.76 mm, t = 0.38 mm. Average D about 0.6 mm. Ratio D : t from 2 to 2.7.

Distribution

Occurs in Oligocene to Miocene strata of the Aire district, Victoria. Rather rare in all the zones in the Gambier Limestone.

Remarks

The Gambier Limestone specimens agree well with topotypes of G. centroplax from the Calder River Limestone of Victoria, with which they have been compared.

Carter assigned this species to the genus Astrononion Cushman and Edwards, apparently because he regarded the large umbilical flaps of G. centroplax as analogous with the "supplementary chambers" of that genus. As mentioned in the remarks on Astrononion australe (p. 248), Hofker (1956, p. 136) considered

Ashton

Astrononion to be a synonym of _Nonion_ Montfort, and Reiss (1958, p. 67) placed both these genera within his superfamily Monolamellidea. _Gavelinonion_ was placed in the superfamily Bilamellidea by Reiss. Since the wall of _G. centroplax_ is bilamellid, this species is considered to be congeneric with _G. umbilicatulum_ (Walker and Jacob), the type species of _Gavelinonion_.

The specimen from the Eocene of Saipan, figured as _Nonion planatum_ Cushman and Thomas by Todd (1957, pl. 65, fig. 28) seems to be closely similar to _G. centroplax_. The type figure of _N. planatum_, however, shows a specimen without large umbilical flaps.

GAVELINONION OBESUM (Carter, M.S.), 1959

Astrononion obesum Carter, 1959, unpublished thesis, pl. 19, fig. 235, 236.

Distribution

Originally described from the Tertiary of Gippsland, Victoria. Very rare in the intermediate and the uppermost zones of the Gambier Limestone.

Remarks

G. obesum differs from _G. centroplax_ (p. 201) in the test being less compressed and the umbilical flaps smaller. It is assigned to the genus _Gavelinonion_ rather than to _Astrononion_ for reasons analogous to those stated in the case of _G. centroplax_.

Genus ANOMALINOIDES Brotzen, 1942

ANOMALINOIDES MACRAGLABRA (Finlay), 1940

Plate 18, fig. 4.

Anomalina glabrata Chapman, Parr and Collins (non Cushman), 1934, Linn. Soc. Lond., Jour., Zool., v. 38, p. 570, pl. 11, fig. 39.

Anomalina macraglabra Finlay, 1940, Roy. Soc. New Zealand, Trans., v. 69, p. 460, pl. 65, fig. 141 - 143; Carter, 1959, unpublished thesis, pl. 12, fig. 153 - 155.

Description

Test compressed, formed by a very low trochospiral coil, unequally and gently biconvex; dorsal side flatter than ventral side. Test dorsally evolute, with up to nearly three whorls visible, though often early whorls indistinct; ventrally involute, with a narrow, sometimes fairly deep, but usually partly closed umbilicus. Margin rounded; peripheral outline somewhat oval to sub-circular, smoothly curved, sometimes gently lobate in distal part of last whorl. Commonly nine to eleven, rarely eight chambers in last whorl; they increase regularly and rather slowly in size. Septal sutures radial, gently recurved, narrow or slightly limbate; they are flush, sometimes slightly depressed in distal part of last whorl, and distinct, except on dorsal side of early whorls of many specimens. Wall smooth, rather densely pierced by medium-sized pores; apertual face imperforate. Aperture a narrow, arched slit along entire base of last chamber, protected by a lip or narrow flap where it crosses the periphery and continuing under a similar or slightly wider flap backwards along the spiral suture. Apertures of up to four chambers preceding the last may remain open along spiral suture; often, however, development of apertures dorsally is obscured. Ventrally apertual flap increases gradually in width, ending in a bluntly triangular plate, which projects into the umbilicus, but is often broken. In some well preserved specimens small lobe-shaped flaps of a few chambers preceding the last one, each partly overlapped by the flap of the succeeding chamber, are visible in the umbilicus; sometimes the flaps have coalesced to form a more or less continuous shelf extending backwards along the rim of the umbilicus.

Dimensions

Largest specimen (locality E 129) : D = 0.82 mm, d = 0.76 mm, t = 0.40 mm. Average D about 0.5 mm.

Distribution

Occurs in Lower Oligocene to Lower Miocene strata in New Zealand; also in the Middle Miocene of the Port Phillip area and in Gippsland (both in Victoria). Common throughout the Gambier Limestone.

Remarks

The Gambier Limestone specimens agree well with specimens of A. macroglabra from All Day Bay, New Zealand, with which they have been compared. The Recent A. glabrata (Cushman) is rather similar; no representatives of this species were examined, but Finlay's remarks that A. glabrata differs from A. macroglabra in being "dorsally depressed, with wide umbilicus mostly plugged, coarser punctae, and a lobulate periphery" are accepted. A. orbiculus (Stache) [= A. eoglabra (Finlay), fide Hornibrook, 1953, written communication] from the Eocene and the Oligocene of New Zealand is smaller and has more chambers in the last whorl. A. parvumbilia (Finlay) from the Miocene of New Zealand is more compressed, with slightly more chambers in the last whorl.

ANOMALINOIDES PROCOLLIGERA Carter, 1958

Anomalina rotula Chapman, Parr and Collins (non d'Orbigny), 1934, Linn. Soc. Lond., Jour., Zool., v. 38, p. 570, pl. 11, fig. 38.

Anomalinoides procolligera Carter, 1958, Geol. Surv. Victoria, Bull. 55, p. 49, pl. 6, fig. 60 - 63.

Dimensions

Largest specimen (locality E 48) : D = 0.74 mm, d = 0.62 mm, t = 0.30 mm. Average D about 0.5 mm.

Distribution

Occurs in Oligocene and Miocene strata in the Aire district and in Miocene beds in the Port Phillip area (both in Victoria). Fairly common throughout the Gambier Limestone.

Remarks

The Gambier Limestone specimens agree well with topotypes of A. procolligera from Birregurra, Victoria, with which they have been compared.

ANOMALINOIDES PLANULATA Carter, 1959, (M.S.)

Anomalinoides planulata Carter, 1959, unpublished thesis, pl. 12, fig. 147 - 149.

Distribution

Originally described from the Tertiary of Gippsland, Victoria. Rare in the intermediate and the uppermost zones of the Gambier Limestone.

Genus CIBICIDES Montfort, 1808

CIBICIDES BREVORALIS Carter, 1958

Cibicides brevoralis Carter, 1958, Geol. Surv. Victoria, Bull. 55, p. 47, pl. 6., fig. 54 - 56.

Description

Seven to eleven chambers in last whorl of adult specimens. Rather fine pores are distributed densely in dorsal walls of chambers. On ventral side, chambers sparsely perforate in early part of last whorl (imperforate in small specimens), becoming progressively more densely perforate distally, but not as densely as on dorsal side. Peripheral keel pierced by sparse pores.

Dimensions

Largest specimen (locality E 53) : D = 0.62 mm, d = 0.58 mm, t = 0.30 mm. Average D about 0.5 mm. Ratio D : t from 1.6 to

2.5.

Distribution

Occurs in Oligocene to Middle Miocene strata in the Aire district, Victoria. Fairly common throughout the Gambier Limestone.

Remarks

The Gambier Limestone specimens agree well with topotypes of C. brevoralis from Birregurra, Victoria, with which they have been compared.

CIBICIDES PSEUDOUNGERIANUS (Cushman), 1922

Truncatulina ungeriana Brady (non Rotalina ungeriana d'Orbigny), 1884, Rept. Voy. Challenger, Zool., v. 9, p. 664, pl. 94, fig. 9).

Truncatulina pseudoungeriana Cushman, 1922, U.S. Geol. Surv., Prof. Pap. 129 - E, p. 97, pl. 20, fig. 9.

Cibicides perforatus (Karrer). Carter, 1958, Geol. Surv. Victoria, Bull. 55, p. 46, pl. 6, fig. 57 - 59.

Dimensions

Largest specimen (Comaum bore, sample from 112 to 233 feet) : D = 0.76 mm, d = 0.70 mm, t = 0.32. Average D about 0.6 mm. Ratio D : t from 1.9 to 2.6.

Distribution

Widespread in Oligocene to Recent sediments. Common throughout the Gambier Limestone.

Remarks

The Gambier Limestone specimens compare well with topotypes of C. pseudoungerianus from the Oligocene Byram Marl of the United States, although the available topotypes do not attain as large a size. The South Australian tests were also compared and agree well with specimens from the Middle Tertiary of New Zealand (in the National Museum of Melbourne) and from the Oligocene Calder River Limestone in Victoria, referred to as C. perforatus (Rotalia perforata Karrer) by Hornibrook and Carter, respectively. Rotalia perforata Karrer, 1865, is a homonym of Rotalia perforata Ehrenberg, 1840.

CIBICIDES MEDIOCRIS Finlay, 1940

Plate 18, fig. 5.

Cibicides mediocris Finlay, 1940, Roy. Soc. New Zealand, Trans., v. 69, p. 464, pl. 67, fig. 198, 199; Carter, 1959, unpublished thesis, pl. 11, fig. 135 - 137.

Description

Test consists of a low trochospiral coil, fairly strongly compressed; dorsally flat to slightly convex, ventrally more convex. Dorsal side evolute; central area usually filled and level or projecting as a very low boss (with a diameter equal to about one third of diameter of test). Ventral side involute; narrow central area slightly depressed, filled, or projecting as a small, low boss. Margin bluntly keeled; peripheral outline subcircular, commonly slightly lobate distally, but often smoothly curved in early part of last whorl. The ten or eleven chambers of the last whorl of adult specimens increase regularly in size. Last few chambers often added somewhat more dorsally, relative to the earlier part of test, than preceding chambers. Septal sutures usually distinct and gently recurved in last whorl. Ventrally they are radial, slightly depressed between distal chambers, commonly flush in proximal part of last whorl; dorsal sutures radial or slightly oblique, depressed between last few chambers, but usually flush and slightly limbate proximally.

Spiral suture smoothly curved, or slightly bent where septal sutures join. Dorsal walls of chambers coarsely perforate; pores sparse in central, secondarily thickened area constituted by early whorls. On ventral side early chambers of last whorl commonly imperforate and only in last few chambers density of perforation approaches that on the dorsal side. Aperture extends as a narrow slit from just below the periphery, which it crosses, along entire base of last chamber dorsally. It is continuous with a groove along spiral suture; the groove fades out proximally. Up to five chambers preceding the last open into this groove, which has a slightly raised rim along its peripheral border. The aperture bears a lip along its outer edge where it arches across periphery.

Dimensions

Largest specimen (locality E 65) : D = 0.80 mm, d = 0.72 mm, t = 0.34 mm. Average D about 0.5 mm. Ratio D : t from 2.2 to 2.9.

Distribution

Occurs in Middle Oligocene to Lower Miocene strata of New Zealand and in Gippsland, Victoria. Adult specimens rather rare throughout the Gambier Limestone.

Remarks

The Gambier Limestone specimens agree well with specimens from All Day Bay in New Zealand, with which they have been compared. C. mediocris is closely similar in many respects to C. pseudoungerianus (p. 206). Adult specimens of both species appear to be specifically distinct, but rare individuals, difficult to assign to either one or the other, do occur. The ratio of maximum diameter to thickness is not a decisive distinguishing criterion. Adult C. mediocris are best distinguished from C. pseudoungerianus by their flatter dorsal side, which possesses a smaller central area containing secondary shell matter (equivalent in size to about one third of diameter of test as compared with about one half in C. pseudoungerianus), by their somewhat less regularly added distal chambers and better development of the aperture along the spiral suture. Juvenile specimens of the two species are indistinguishable as the young individuals of C. pseudoungerianus usually have a flat dorsal side.

CIBICIDES CATILLUS Finlay, 1940

Plate 18, fig. 6, 7.

Cibicides catillus Finlay, 1940, Roy. Soc. New Zealand, Trans., v. 69, p. 465, pl. 67, fig. 200.

Description

Test strongly compressed, formed by a very low trochospiral coil. Dorsal side evolute, flat or slightly convex. Ventral side gently convex, involute or slightly evolute; in such specimens the small umbilical area is slightly depressed or, more commonly, level with the ventral surface. Peripheral outline subcircular to somewhat reniform, smoothly curved or slightly lobate, especially in late part of last whorl. Margin acute, keeled. Usually chambers increase regularly (sometimes irregularly in distal part of test) and rather slowly in size. Seven to ten chambers in last whorl; up to twenty-six, arranged in about three whorls, in whole test. On dorsal side, septal sutures limbate, moderately to fairly strongly recurved, flush in early part of last whorl and slightly depressed in distal part. They are distinct, except in early whorls of some specimens. On ventral side, early sutures limbate, flush or slightly raised; last few sutures may be narrow and slightly depressed, especially near centre of test. Ventral sutures strongly recurved. They are commonly radial and straight centrally, bending backwards near periphery; less commonly their curvature is more even. Spiral suture on dorsal side smoothly curved and limbate; it is flush or slightly raised in early part of test, but usually gently depressed in late part of last whorl. Wall smooth; on dorsal side it is moderately densely pierced by rather fine pores and a few irregularly scattered larger pores; ventrally only sparse, fairly large pores may be present on walls of some, especially the later, chambers. Aperture is a narrow slit with a slight lip along its outer edge; it arches across periphery from slightly below it, extending proximally along the entire base of last chamber on dorsal side. Up to four chambers preceding the last may remain open along spiral suture.

Dimensions

Largest specimen (locality E 115) : D = 0.88 mm, d = 0.76 mm, t = 0.34 mm. Average D about 0.6 mm. Ratio D : t from 2.2 (in small specimens) to 3.2.

Distribution

Occurs in Lower Oligocene to Upper Miocene strata in New Zealand. Rare throughout the Gambier Limestone *sensu stricto*; not found in the Naracoorte Limestone Member.

CIBICIDES NOVOZELANDICUS (Karrer), 1865

Plate 18, fig. 8, 9.

Rotalia novo-zelandica Karrer, 1865, Novara Exped. Geol. Theil, v. 1, p. 80, pl. 16, fig. 12.

Description

Test biconvex, formed by a fairly low trochospiral coil; either side may be higher than the other (in adult specimens the dorsal side is usually higher than ventral), or both approximately equal. Ventral side involute, uniformly and weakly, to moderately convex; dorsal side evolute, evenly convex or with central area consisting of early whorls projecting as a secondarily thickened, rounded dome. Peripheral outline subcircular, smoothly curved; it may be slightly lobate in distal part of last whorl. Margin acute, bearing a slightly thickened, blunted keel. Chambers increase regularly and fairly slowly in size; they are arranged in up to about three whorls, with seven to eleven chambers in last whorl. Septal sutures usually limbate, flush or somewhat raised. Ventrally they are distinct, radial near centre of test, strongly recurved near periphery; last one or two sutures sometimes slightly depressed. Dorsal sutures strongly oblique, recurved, usually indistinct in early whorls. Wall smooth; dorsal side bears fairly densely distributed, moderately large pores. Ventral side is similarly perforate, but in medium and small-sized specimens proximal chambers of last whorl are less densely perforate than distal chambers. Aperture is a narrow slit with a lip along its outer border; it extends ventrally along peripheral part of basal suture for up to about half its length, and just crosses periphery or continues for a short distance (up to about one third of the length of last chamber) proximally along spiral suture. Boundary between apertual face and the spiral wall of last chamber is usually marked by a distinct angle in the wall. Apertual face is imperforate; its outer part is proximally curved.

Dimensions

Largest specimen (locality E 137) : D = 1.22 mm, d = 1.02 mm, t = 0.54 mm. Average D about 0.9 mm. Ratio D : t from 1.7 to 2.2.

Distribution

Occurs in Middle Oligocene to Miocene strata of New Zealand. Rather rare in the intermediate and the uppermost zones of the Gambier Limestone sensu stricto; not found in the Naracoorte Limestone Member.

Remarks

The Gambier Limestone specimens agree rather well with specimens of C. novozelandicus from All Day Bay in New Zealand, with which they have been compared, although the South Australian forms are smaller and their sutures generally less limbate than in the New Zealand tests.

CIBICIDES THIARA (Stache), 1865

Plate 18, fig. 10.

Rosalina thiara Stache, 1865, Novara Exped. Geol. Theil, v. 1, p. 279, pl. 24, fig. 29.

Distribution

Occurs in the Upper Eocene and the Lower Oligocene of New Zealand. Very rare in the lowest zone of the Gambier Limestone.

Remarks

The Gambier Limestone tests agree well with specimens of C. thiara from the Whaingaroa Beds of New Zealand, with which they have been compared. The South Australian forms are, however, smaller.

CIBICIDES OPACUS Carter, 1959 (M.S.)

Cibicides opacus Carter, 1959, unpublished thesis, pl. 11, fig. 126 - 128.

Distribution

Originally described from the Tertiary of Gippsland, Victoria. Very rare in the Gambier Limestone.

CIBICIDES cf. LOBATULUS (Walker and Jacob), 1798

Plate 18, fig. 11 - 14.

Cf. Nautilus lobatulus Walker and Jacob, 1798, Adam's Essays, Kanmacher's ed., p. 642, pl. 14, fig. 36.

Cf. Cibicides lobatula (Walker and Jacob). Cushman, 1931, Smiths. Inst., U.S. Nat. Mus., Bull. 104, p. 118, pl. 21, fig. 3.

Description

Test strongly compressed, with a flat or concave dorsal side and slightly to moderately convex ventral side. Margin subacute and sharply keeled to less angular and bluntly keeled; uncommonly margin of last few chambers is roundedly angular, without a keel. Peripheral outline rather irregular. In early part of test chambers fairly regularly arranged in a very low trochospiral coil; later part of test usually irregularly coiled in the same or inverse direction. Distal part of some tests consists of biserially arranged chambers, which may be succeeded by chambers in a coiled arrangement. Relative size and number of chambers of the initial, regularly coiled part, as compared to size of whole test and total number of chambers (up to about twenty-five) varies greatly. Coiled part of test is evolute dorsally, involute ventrally. Sutures distinct, narrow or somewhat limbate, especially in early part of test. Dorsally they are oblique, gently to considerably recurved, flush; ventrally radial, recurved, flush or gently depressed. Sutures between biserially arranged chambers are curved and usually gently depressed. Wall smooth; rather finely and densely perforate on dorsal side. Ventrally chambers imperforate in early part of test, with progressive increase in density of perforation in later chambers, until pore frequency in ventral walls of last one or two chambers approaches closely that on dorsal side. Density of perforation of last chamber is not strictly correlated with number of chambers in test. Aperture is a fairly narrow slit, with a lip along its outer border; it extends along the basal suture from a short distance below periphery across it and along the entire base of the last chamber dorsally. In coiled tests up to four chambers preceding the last one may remain open along spiral suture.

Dimensions

Specimens range up to about 0.8 mm in size. Ratio D : t from about 2 to 4.

Distribution

Common throughout the Gambier Limestone.

Remarks

The type description and figures of C. lobatulus (seen in Catal. Foram.) are rather poor and it seems that different species of Cibicides with a strongly or fairly strongly compressed test and a lobate periphery have been included in C. lobatulus by various authors. Hence the Gambier Limestone specimens are referred to as C. cf. lobatulus.

C. mckannai Galloway and Wissler varieties arubena Drooger and oranjestadensis Drooger from the Miocene of Netherlands Antilles appear to be closely similar to the South Australian forms. Apparently a number of different species of Cibicides possess the ability to react to certain unknown environmental factors (Drooger, 1953, p. 147) by becoming irregularly coiled or biserial in the later part of test. Such irregular ecotypes of different species, even though morphologically inseparable, cannot be considered as conspecific.

CIBICIDES cf. REFULGENS Montfort, 1808

Plate 19, fig. 1 - 3.

Cf. Cibicides refulgens Montfort, 1808, Conch. syst. class. method. coquilles, v. 1, p. 123, text-fig. p. 122.

Cf. Cibicides refulgens Montfort. Cushman, 1931, Smiths. Inst., U.S. Nat. Mus., Bull. 104, p. 116, pl. 21, fig. 2.

Description

Test formed by a moderately high trochospiral coil. Dorsal side evolute, flat or slightly concave; ventral side involute, highly domed or subconical. Peripheral outline subcircular, smoothly curved or weakly lobate; margin bluntly keeled. Chambers increase regularly in size; about six to eight in last whorl. Septal sutures usually rather indistinct, recurved; last one or two narrow, earlier ones limbate. Dorsal sutures flush, weakly to moderately oblique; ventrally radial, usually flush, except near periphery, but last one or two sutures may be gently depressed along their whole length. Wall smooth, rather finely perforate. Pores distributed fairly densely in dorsal walls of chambers; on ventral side, early chambers of last whorl are much less densely perforate, with pores mainly concentrated near centre of test, and only in the last few chambers density of perforation approaches that on dorsal side. Aperture a narrow slit extending along basal suture for a short distance below periphery and along entire base of last chamber dorsally. It continues proximally as a shallow groove along spiral suture for up to about half the length of last whorl. The penultimate chamber sometimes opens into this groove.

Dimensions

Largest specimen (locality E 82) : D = 0.64 mm, d = 0.50 mm, t = 0.38 mm. Average D about 0.5 mm. Ratio D : t from 1.4 to 1.8.

Distribution

Common in only a few samples of the Gambier Limestone.

Remarks

Rare specimens, notably more flattened and with somewhat less regularly added distal chambers than in the specimens described above, but apparently conspecific with them, are also present.

The type description and figure of *C. refulgens* are poor, and different species of Cibicides with a flat dorsal side and strongly convex ventral side have been called *C. refulgens* by various authors. Hence the Gambier Limestone specimens are referred to as *C. cf. refulgens*.

CIBICIDES cf. SUBHAIDINGERI Parr, 1950

Plate 19, fig. 4.

Cf. *Cibicides subhaidingeri* Parr, 1950, B.A.N.Z.A.R.E. Repts., ser. B, v. 5, p. 364, pl. 15, fig. 7.

Remarks

Very rare specimens in the Gambier Limestone compare well, except for being smaller in size, with the holotype and topotypes of *C. subhaidingeri* from Recent sediments off Tasmania. They are possibly extreme variants of *C. pseudoungerianus* (p. 206)

CIBICIDES sp.

Plate 19, fig. 5, 6.

Description

Test compressed, formed by a low trochospiral coil. Dorsal side evolute, flat or somewhat concave; ventral side involute, moderately convex. Peripheral outline lobate; margin bluntly keeled, sometimes roundedly angular and without a keel in last few chambers. Early chambers increase fairly regularly in size and are arranged in a regular coil. Later chambers rather irregular; they are arranged in a coil, sometimes with reversed direction of coiling, or, more rarely, biserially. About five to nine chambers in last whorl; up to more than twenty in whole test. Sutures limbate in early part of test, usually somewhat depressed and narrow between distal chambers. Sutures in coiled part of test are recurved, dorsally somewhat oblique, ventrally radial; in biserial part they are curved and depressed. Wall smooth, pierced by fairly densely distributed, rather coarse pores. Aperture a fairly wide slit, bordered by a raised lip along its outer margin; it extends around entire base of last chamber dorsally and for a short distance along basal suture below periphery. A shallow groove, extending proximally along the dorsal spiral suture for up to more than half the length of last whorl, is continuous with the aperture. Rarely one or two chambers preceding the last open into this groove.

Dimensions

Largest specimen (locality E 83) : D = 0.76 mm, d = 0.58 mm, t = 0.34 mm. Average D about 0.6 mm. Ratio D : t from about 1.7 to 2.3.

Distribution

Fairly common in the Gambier Limestone.

Remarks

The specimens described above differ from C. cf. lobatulus (p. 213) mainly in being more coarsely perforate and generally less compressed. Irregular Cibicides generally similar to the forms under discussion have been occasionally figured in the literature, but without examination of the actual specimens and the size and distribution of pores in their walls no specific identification can be made.

Genus VAGOCIBICIDES Finlay, 1939

VAGOCIBICIDES MAORIA Finlay, 1939

Plate 19, fig. 7, 8.

Vagocibicides maoria Finlay, 1939, Roy. Soc. New Zealand, Trans., v. 69, p. 326, pl. 29, fig. 148-151, 158; Carter, 1959, unpublished thesis, pl. 9, fig. 99-103.

Description

Test club-shaped or irregularly bent and twisted; in rare specimens it is less elongate, more spreading and flattened. Early part of test formed by a low trochospiral coil, which is evolute dorsally and involute ventrally. Usually five to seven chambers, arranged in one to one and a half whorls, in the coiled part; thirteen chambers in one, exceptional specimen. In middle part of test (consisting of about six chambers) chamber arrangement is biserial, but becomes staggered distally; last part of test, with up to six chambers, is uniserial. Total number of chambers varies up to sixteen. Test compressed, plano-convex or concavo-convex in the coiled and biserial parts, with angular peripheral margin bearing a blunt rim or keel. Test in uniserial part more rounded in cross section; usually dorsal side is still somewhat flattened, but sometimes the distal chambers, which were apparently not in contact with surface of attachment, are quite round. Outline of test smoothly curved in proximal part, becoming lobate distally. Early chambers increase regularly in size, distal chambers less regularly. Proximal chambers close-set; each chamber in the uniserial part of test usually has two proximally directed lobes, which partly overlap the preceding chamber dorsally. A shallow to fairly deeply depressed groove lies between the two lobes; it decreases in depth and fades out distally, sometimes continuing right up to the aperture. In rare specimens, last chamber possesses a supplementary aperture opening at the bottom of this groove. Sutures in early, coiled part of test flush with surface. On dorsal side they are oblique, slightly recurved, narrow or somewhat limbate; ventrally radial, narrow. Sutures in later part of test are depressed, narrow, usually fairly distinct; ventrally they are straight or slightly curved, dorsally with distally directed indentations associated with the depressions in chamber walls already mentioned. Wall smooth, densely and very finely perforate; marginal keel bears more sparsely distributed pores. Aperture in adult chambers is an elliptical to circular opening, subterminal in position, situated in a shallow depression and surrounded by a low, rounded rim. Chambers in the coiled part of test have a Cibicides - like aperture (this was observed in Victorian representatives of this species by Carter, 1959, oral communication), not a terminal one, as stated by Finlay.

Dimensions

Largest specimen (locality E 19) : l = 1.22 mm, t = 0.48 mm. Average l about 0.7 mm.

Distribution

Occurs in Upper Oligocene to Pliocene strata in New Zealand; also in the Tertiary of Gippsland, Victoria. Common throughout the Gambier Limestone sensu stricto; not found in the Naracoorte Limestone Member.

Genus HANZAWAIA Asano, 1944

HANZAWAIA SCOPOS (Finlay), 1940

Plate 19, fig. 9, 10.

Discorbis bertheloti Chapman, Parr and Collins (non Rosalina bertheloti d'Orbigny), 1934, Linn. Soc. Lond., Jour., Zool., v. 38, p. 561, pl. 9, fig. 13.

Discorbis scopos Finlay, 1940, Roy. Soc. New Zealand, Trans., v. 69, p. 466, pl. 67, fig. 212, 213.

Rosalina scopos (Finlay). Carter, 1958, Geol. Surv. Victoria, Bull. 55, p. 41, pl. 4, fig. 34 - 36.

Description

The Gambier Limestone specimens are more variable than the forms described by Carter. Specimens with a prominent proloculus and strongly limbate and raised sutures intergrade with forms in which the proloculus is generally smaller and even the early sutures are only slightly limbate. These are on the whole thinner than tests with strongly limbate sutures, and do not reach as large a size. The number of chambers in the last whorl varies between seven and eleven, being nine in the majority of specimens. The wall is densely and finely perforate, with sparse larger pores sometimes piercing chamber walls and marginal keel. The aperture just crosses the periphery from the dorsal to the ventral side.

Dimensions

Largest specimen (locality E 115) : D = 0.84 mm, d = 0.68 mm, t = 0.24 mm. Average D about 0.5 mm. Ratio D : t from about 2.4 to 3.5 in adult specimens.

Distribution

Originally described from the Lower Miocene of New Zealand; occurs in the Middle Miocene of the Balcombe Bay area and in Oligocene to Middle Miocene strata in the Aire district (both in Victoria). Fairly common throughout the Gambier Limestone.

Remarks

The Gambier Limestone specimens do not reach as large a size as the New Zealand tests, and generally have more chambers in the last whorl (than six or seven, as stated by Finlay). Finlay observed that this number increases in the early whorls of specimens of H. scopos.

The Gambier Limestone tests are also closely similar to specimens of H. apposita (Discorbis appositus Finlay) from the Eocene of New Zealand, with which they have been compared. H. apposita, however, is generally more compressed and has fewer chambers in the last whorl. Some variants of H. scopos in the Gambier Limestone closely resemble, except for being smaller, topotypes of H. galera (Discorbis galerus Finlay) from the Lower Miocene of New Zealand.

H. scopos appears to be similar to a number of species described from Europe and America (and subsequently referred to the genus Hanzawaia by different authors), such as H. boueana (d'Orbigny), H. concentrica (Cushman), H. americana (Cushman) and H. choctawensis (Cushman and McGlamery). In the absence of a representative series of these species it cannot be determined whether and to what extent they intergrade with H. scopos. None of them, however, seems to possess as strongly limbate sutures as are present in common variants of H. scopos in the Gambier Limestone.

Although other authors besides Carter have recently revived the genus Rosalina d'Orbigny (e.g. Brotzen, 1948, p. 72; Pokorny, 1958, p. 318), the relation of this genus to Discorbis Lamarck, 1804, still appears to be rather uncertain. Forms with a generally Cibicides - like test, with commonly limbate and raised sutures and with apertual flaps, which extend into the dorsal central area, are best referred to as Hanzawaia. Some of such forms have been assigned by various authors to Cibicidina Bandy, 1949; this is a synonym of Hanzawaia (Bandy, 1956, p. 195).

Genus HERONALLENIA Chapman and Parr, 1931

HERONALLENIA LINGULATA (Burrows and Holland), 1895

Discorbina lingulata Burrows and Holland, 1895, in Jones, Monogr. foram. Crag, Palaeontogr. Soc., pt. 2, pl. 7, fig. 33.

Heronallenia lingulata (Burrows and Holland). Chapman, Parr and Collins, 1934, Linn. Soc. Lond., Jour., Zool., v. 38, p. 564, pl. 8, fig. 11; Carter, 1958, Geol. Surv. Victoria, Bull. 55, p. 42, pl. 5, fig. 40 - 42.

Description

Test strongly compressed, formed by a very low trochospiral coil. Ventral side usually concave to almost flat, dorsal side slightly convex; a number of tests are somewhat twisted. Adult specimens have a rounded, thickened margin; in young individuals the margin is more square. Chambers increase rapidly and regularly in size; usually seven chambers in last whorl, up to eleven in whole test. On ventral side each chamber possesses a proximally directed lobe, which overlaps the aperture of the preceding chamber. Slight ridges radiate from aperture on ventral side of last chamber. Short grooves, pointing towards the hollow, small, dome-shaped structure overlying the aperture on dorsal side of test, are rarely present near periphery of last chamber.

Dimensions

Largest specimen (locality E 74) : D = 0.76 mm, d = 0.64 mm, t = 0.14 mm. Average D about 0.5 mm.

Distribution

Occurs in the Pliocene of England and ranges from the Oligocene to the Recent in the southern Australian region. Rather rare throughout the Gambier Limestone.

HERONALLENIA PARRI Carter, 1958

Heronallenia wilsoni (non Discorbina wilsoni Heron-Allen and Earland). Chapman and Parr, 1931, Roy. Soc. Victoria, Proc., v. 43, n.s., pl. 9, fig. 7; Chapman, Parr and Collins, 1934, Linn. Soc. Lond., Jour., Zool., v. 38, p. 564, pl. 8, fig. 12.

Heronallenia sp. Parr, 1950, B.A.N.Z.A.R.E. Repts., ser. B, v. 5, p. 357.

Heronallenia parri Carter, 1958, Geol. Surv. Victoria, Bull. 55, p. 43, pl. 5, fig. 43 - 45.

Dimensions

Largest specimen (locality E 61) : D = 0.58 mm, d = 0.48 mm, t = 0.18 mm. Average D about 0.4 mm.

Distribution

Occurs in Lower Oligocene to Middle Miocene strata in Victoria (Aire district, Batesford area, Port Phillip area). Rather rare throughout the Gambier Limestone.

Remarks

The Gambier Limestone specimens agree well with topotypes of H. parri from the Calder River Limestone in Victoria, with which they have been compared. In some of the South Australian tests, the dorsal walls of chambers are strongly convex directly above the aperture (on opposite side of the test), but this convexity is not nearly as distinctly developed as in H. lingulata.

The separation of H. parri from H. wilsoni has been discussed by Parr (1950, loc. cit.).

HERONALLENIA WILSONI (Heron-Allen and Earland), 1922

Discorbina wilsoni Heron-Allen and Earland, 1922, British

Antarctic (Terra Nova) Exped., Nat. Hist. Rept., Zool., v. 6, p. 206, pl. 7, fig. 17 - 19.

Heronallenia wilsoni (Heron-Allen and Earland). Parr, 1950, B.A.N.Z.A.R.E. Rept., ser. B, v. 5, p. 357, pl. 14, fig. 5 - 7.

Distribution

Occurs in Recent sediments in the Antarctic region. Very rare in the Gambier Limestone.

Genus STOMATORBINA Dorreen, 1948

STOMATORBINA CONCENTRICA (Parker and Jones), 1864

Pulvinulina concentrica Parker and Jones, 1864, in Brady, Linn. Soc. Lond., Trans., v. 24, p. 470, pl. 48, fig. 14.

Eponides concentricus (Parker and Jones). Chapman, Parr and Collins, 1934, Linn. Soc. Lond., Jour., Zool., v. 38, p. 565, pl. 9, fig. 17.

Stomatorbina concentrica (Parker and Jones). Carter, 1958, Geol. Surv. Victoria, Bull. 55, p. 40, pl. 4, fig. 37 - 39, pl. 7, fig. 75.

Dimensions

Largest specimen (locality E 154) : D = 1.66 mm, d = 1.30 mm, t = 0.88 mm. Average D about 0.8 mm. Ratio D : t from 1.9 to 2.3.

Distribution

Widespread in Oligocene to Recent sediments in the Australian region. Fairly common throughout the Gambier Limestone.

Remarks

The Gambier Limestone specimens are unequally biconvex, with the ventral side varying from nearly flat to approximately as high as the dorsal side. The ventral apertual flaps of chambers of the last whorl may be distinct or the umbilicus may be secondarily somewhat infilled.

S. torrei (Cushman and Bermudez), originally described from the Eocene of Cuba and subsequently also from the Eocene of New Zealand (Dorreen, 1948, p. 295, pl. 39, fig. 4), is closely similar, perhaps conspecific with S. concentrica. The "supplementary apertures" of Dorreen appear to be fractures in the thinner parts of ventral chamber walls.

Genus MISSISSIPPINA Howe, 1930

MISSISSIPPINA ROWDONAE Carter, 1959 (M.S.)

Mississippina rowdonae Carter, 1959, unpublished thesis, pl. 6, fig. 65 - 67.

Distribution

Occurs in the Tertiary of Gippsland, Victoria. Very rare in the Gambier Limestone.

Genus GLABRATELLA Dorreen, 1948

GLABRATELLA CRASSA Dorreen, 1948

Glabratella crassa Dorreen, 1948, Jour. Pal., v. 22, p. 294, pl. 39, fig. 1.

Distribution

Originally described from the Upper Eocene of New Zealand. Very rare in the Gambier Limestone.

Remarks

The poorly preserved specimens in the Gambier Limestone agree well with a topotype of G. crassa in the National Museum of Victoria, with which they have been compared.

Family VICTORIELLIDAE

Genus VICTORIELLA Chapman and Crespin, 1930

VICTORIELLA CONOIDEA (Rutten), 1914

Carpenteria conoidea Rutten (pars), 1914, Nova Guinea, v. 6 (Geol.), p. 47, pl. 7, fig. 7 - 9.

Carpenteria proteiformis Goes var. plecta Chapman, 1921, Geol. Surv. Victoria, Rec., v. 4, p. 300, pl. 51, fig. 3.

Victoriella plecta (Chapman). Chapman and Crespin, 1930, Roy. Soc. Victoria, Proc., v. 42, p. 110, pl. 7, fig. 1 - 4; Crespin, 1950, Cushman Found. Foram. Res., Contr., v. 1, p. 74, pl. 10, fig. 15; Carter, 1959, unpublished thesis, pl. 21, fig. 269 - 277, pl. 29, fig. 342 - 347.

Victoriella conoidea (Rutten). Glaessner and Wade, 1959, Micropaleontology, v. 5, p. 194, pl. 1, fig. 1 - 5, pl. 2, fig. 1 - 5, 7 - 1 0, pl. 3, fig. 3.

Distribution

V. conoidea occurs in Upper Eocene to Lower Miocene strata in Australia and New Guinea. The upper time-boundary of the lowest foraminiferal zone in the Gambier Limestone coincides with the time of extinction of V. conoidea, at least in the area under consideration. When present, this species is usually common; however it is absent in a number of samples, which, because they do not contain the index species of the other two zones and were collected from localities within the areas of outcrops of the lowest zone, are considered to belong to it.

Genus CARPENTERIA Gray, 1858

CARPENTERIA ROTALIFORMIS Chapman and Crespin, 1930

Carpenteria proteiformis Chapman (pars) (non Goes), 1913, Roy. Soc. Victoria, Proc., v. 26, n.s., p. 171, pl. 16, fig. 7.

Carpenteria rotaliformis Chapman and Crespin, 1930, ibid., v. 43, n.s., p. 98, pl. 5, fig. 7, 8; Chapman, Parr and Collins, 1934, Linn. Soc. Lond., Jour., Zool., v. 38, p. 572, pl. 11, fig. 44; Glaessner and Wade, 1959, Micropaleontology, v. 5, p. 200, pl. 2, fig. 6.

Distribution

Widespread in Upper Eocene to Middle Miocene strata in southern Australia. Common throughout the Gambier Limestone.

Remarks

The majority of the tests in the Gambier Limestone are formed by a low to moderately high, often somewhat irregular, trochospiral coil, and range up to about 2 mm in size. Rare, more conical specimens resembling C. hamiltonensis Glaessner and Wade, and very rare specimens with chambers arranged in a biserial manner, similar to C. alternata Chapman and Crespin, are also present.

Family ?

Genus HOFKERINA Chapman and Parr, 1931

HOFKERINA SEMIORNATA (Howchin), 1889

Pulvinulina semiornata Howchin, 1889, Roy. Soc. S. Aust., Trans., v. 12, p. 14, pl. 1, fig. 12.

Hofkerina semiornata (Howchin). Chapman and Parr, 1931, Roy. Soc. Victoria, Proc., v. 43, n.s., p. 237, pl. 9, fig. 1 - 5;

Crespin, 1936, Australia, Dept. Interior, Pal. Bull. 2, p. 6, pl. 1, fig. 3; Carter, 1958, Geol. Surv. Victoria, Bull. 55, p. 58, pl. 9, fig. 88 - 90; Glaessner and Wade, 1959, Micropaleontology, v. 5, p. 203, pl. 1, fig. 12 - 15.

Distribution

Rather widespread in the Miocene of Victoria. Rare in the Gambier Limestone.

Remarks

The Gambier Limestone specimens agree well with the holotype and paratypes of H. semiornata from Muddy Creek, Victoria, with which they have been compared. One well preserved specimen differs from the others in having no tubercles on the dorsal side.

Family ORBULINIDAE

Genus GLOBIGERINA d'Orbigny, 1826

GLOBIGERINA BULLOIDES d'Orbigny, 1826

Plate 19, fig. 11 - 15.

Globigerina bulloides d'Orbigny, 1826, Ann. Sci. Nat., v. 7, p. 277, no. 1, modele 17, 76; Brady, 1884, Rept. Voy. Challenger, Zool., v. 9, p. 593, pl. 79, fig. 3 - 7; Cushman, 1941, Cushman Lab. Foram. Res., Contr., v. 17, p. 38, pl. 10, fig. 1 - 13; Drooger and Batjes, 1959, K. Nederl. Akad. Wetensch., Proc., ser. B, v. 62, p. 175, pl. 1, fig. 3; Carter, 1959, unpublished thesis, pl. 14, fig. 175 - 177.

Globigerina bulloides d'Orbigny (superspecies). Wade, 1958, unpublished thesis, pl. 12, fig. 3, 4, 6, 7.

Globigerina praebulloides Blow. Jenkins, 1960, Micropaleontology, v. 6, p. 352, pl. 2, fig. 1.

Description

Test formed by a low trochospiral coil. Dorsal side evolute, almost flat or gently convex; ventral side involute, with a narrow, commonly fairly deep umbilicus. Peripheral outline strongly lobate; margin broadly rounded. Chambers strongly inflated, subhemispherical, sometimes approaching subglobular shape; they increase rapidly in size. Test has up to fourteen chambers in slightly more than three whorls; usually three to four, uncommonly five chambers in last whorl. Septal sutures distinct, except in early whorls on dorsal side. They are radial and straight; strongly depressed ventrally and across periphery, less depressed dorsally. Spiral suture gently depressed, bent where septal sutures join. Wall covered with rather fine spines, which are usually broken; fairly fine pores occur between the spines. Aperture commonly a fairly low and wide arch, usually with a narrow, smooth and not distinctly raised ventral border.

Dimensions

Largest specimen (locality E 56) : D = 0.54 mm, t = 0.40 mm. Average D about 0.4 mm.

Distribution

Widespread in Tertiary and Recent sediments. Abundant throughout the Gambier Limestone.

Remarks

G. bulloides is rather variable morphologically due to several more or less correlated factors. One is the often irregular size relationship between chambers in the last whorl, especially the last two; another is the variation in position of the last chamber relative to penultimate and earlier chambers.

Variation in position of aperture relative to the axis of coiling influences the size of the aperture and size of umbilicus, and is closely correlated with the lastmentioned factor.

Wade (1958, op. cit., p. 145) included G. bulloides, G. concinna Reuss, G. ouachitaensis Howe and Wallace and G. parva Bolli in a single superspecies consisting of intergrading variants. Forms with the four chambers in the last whorl increasing fairly regularly in size, the aperture being a relatively low arch in a plane approximately parallel to the axis of coiling, are most common in the Gambier Limestone. These intergrade with variants possessing four approximately equal chambers in last whorl, similar to G. ouachitaensis. Large specimens with five or nearly five chambers in last whorl, with a large aperture opening not wholly into the umbilicus, but in a direction past one side of it, are rather similar to both G. obesa Bolli (especially as figured by Drooger and Batjes, op. cit., pl. 1, fig. 7) and G. concinna (though the type figure of the latter shows a specimen with the aperture opening into the umbilicus and the last chamber not as large relative to preceding chambers as in most of the comparable forms in the Gambier Limestone). Drooger and Batjes stated that the last two species are closely similar. Small South Australian specimens are closely similar to G. parva.

Variants closely resembling G. praebulloides Blow and G. parabulloides Blow intergrade with individuals similar to G. bulloides as restricted by Blow (1959, p. 175, 176). Without a study of abundant topotype material of these three forms (which is not available to the writer), their exact relationship cannot be ascertained, and a broader concept of G. bulloides is accepted.

None of the variants mentioned above becomes sufficiently distinctive and stratigraphically restricted in the Gambier Limestone, and hence they are not taxonomically separated.

GLOBIGERINA AMPLIAPERTURA Bolli, 1957

Plate 19, fig. 16 - 21.

Globigerina ampliapertura Bolli, 1957, U.S. Nat. Mus., Bull. 215, p. 108, pl. 22, fig. 4 - 7; Wade, 1958, unpublished thesis, pl. 12, fig. 13 - 15, 17, 18; Drooger and Magne, 1959, Micropaleontology, v. 5, pl. 1, fig. 2; Drooger and Batjes, 1959, K. Nederl. Akad. Wetensch., Proc., ser. B, v. 62, p. 174, pl. 1, fig. 1.

Globigerina euapertura Jenkins, 1960, Micropaleontology, v. 6, p. 351, pl. 1, fig. 8.

Globigerina woodi Jenkins, 1960, *ibid*., p. 352, pl. 2, fig. 2.

Description

Test formed by a low, compact, trochospiral coil. Dorsal side almost flat to gently convex, evolute; ventral side involute, with a commonly narrow and fairly deep umbilicus. Peripheral outline moderately to weakly lobate; margin broadly rounded. Chambers strongly inflated, subhemispherical, somewhat compressed laterally in later part of last whorl; they increase rapidly in size, sometimes irregularly in distal part of test. Three to four chambers in last whorl; up to about twelve chambers, arranged in about three whorls, in whole test. Septal sutures distinct, except in early part of test on dorsal side; they are approximately radial and fairly straight. Sutures gently depressed dorsally, more strongly peripherally and ventrally. Spiral suture bent where septal sutures join. Wall rather coarsely cancellate, with coarse pores at bottoms of pits. Aperture rather variable; usually it is a fairly wide and high arch, which opens into umbilicus or in a more ventral direction, and possesses a distinct, rather smooth, rounded rim along its ventral border.

Dimensions

Largest specimen (locality E 168) : D = o.7o mm, t = o.5o mm. Average D about o.5 mm.

Distribution

Originally described from the Oligocene of Trinidad; recorded also from the Oligocene of Europe and Northern Africa. Abundant throughout the Gambier Limestone.

Remarks

Morphological variation of G. ampliapertura is due to the same general factors as mentioned for G. bulloides (p. 228). The most common specimens possessing fairly high and wide apertures intergrade with forms characterized by short, low or arched apertures and more compact tests. These, except for lack of accessory apertures, closely resemble Globigerinoides triloba (Reuss) or Globigerinoides subquadrata Bronniman and Globigerinoides bispherica Todd. Such forms were referred to as Globigerina cf. ampliapertura by Wade (1958 op. cit., p. 161). Specimens with uncommonly high and wide, arched apertures are very similar to G. apertura Cushman. Rare individuals with the apertual rim of one or two most distal chambers widened into a narrow flap, which projects into the umbilicus, resemble G. venezuelana Hedberg. In a number of specimens the last few chambers are situated in a considerably more ventral position, relative to the preceding chambers, than in the typical forms; in other characters they are identical with the majority of tests. In some individuals, chambers ("bullae"), often smaller or more elongate and sometimes with a smoother, more finely perforate wall than typically, cover the umbilicus or, rarely, are placed over the junctions of sutures between the last few chambers on the dorsal side.

All the variants mentioned above intergrade with forms corresponding to the type figure of G. ampliapertura. These variants are not sufficiently distinctive or stratigraphically restricted for purposes of correlation in the Gambier Limestone, and are not taxonomically separated.

Forms, similar to G. ampliapertura, in the Oligocene of Europe have been referred to G. globularis Roemer, 1838, by various authors. G. ampliapertura may be a synonym of G. globularis, but this seems impossible to ascertain, since G. globularis was originally poorly described and figured and the type specimen has been lost. G. euapertura and G. woodi, described as new species from the Miocene of Victoria, intergrade with and are considered to be conspecific with G. ampliapertura.

GLOBIGERINA CIPEROENSIS Bolli, 1954

Plate 19, fig. 22.

Globigerina cf. concinna Reuss. Cushman and Stainforth, 1945, Cushman Lab. Foram. Res., Spec. Pub. 14, p. 67, pl. 13, fig. 1.

Globigerina ciperoensis Bolli, 1954, Cushman Found. Foram. Res., Contr., v. 5, p. 1, text-fig. 3, 4, 5, 6; Drooger and Batjes, 1959, K. Nederl. Akad. Wetensch., Proc., ser. B, v. 62, p. 179, pl. 1, fig. 10; Carter, 1959, unpublished thesis, pl. 14, fig. 178 - 180.

Globigerina ciperoensis ciperoensis Bolli, 1957, U.S. Nat. Mus., Bull. 215, p. 109, pl. 22, fig. 10.

Globigerina ciperoensis Bolli subsp. ciperoensis Bolli. Jenkins, 1960, Micropaleontology, v. 6, p. 350, pl. 1, fig. 5.

Description

Test formed by a low to moderately high trochospiral coil; dorsal side correspondingly convex, evolute. Umbilicus on involute ventral side varies from moderately wide and deep to shallow, poorly developed. Peripheral outline lobate; margin broadly rounded. Chambers subglobular, inflated; they increase rapidly in size in early part of test, more slowly in later part. Four to five chambers in last whorl; up to seventeen, arranged in about three whorls, in whole test. Septal sutures distinct in last whorl, less so in early whorls; they are depressed, ventrally and peripherally more than dorsally. Spiral suture gently depressed, bent where septal sutures join. Wall covered with fine spines between which fine pores occur. Aperture a low arch with a smooth, not notably raised ventral border. Variation in size and position of aperture is correlated with variation in width and depth of umbilicus. When umbilicus is well developed, apertures of all chambers in last whorl open into it; when it is indistinct and shallow, only aperture of last chamber is visible and opens towards one side of umbilicus.

Dimensions

Largest specimen (locality E 85) : D = 0.30 mm, t = 0.18 mm.

Distribution

Originally described from the Oligocene of Trinidad; also from the Miocene of the North Sea Basin, Europe. Occurs in the Oligocene and the Miocene of South Australia and in Gippsland, Victoria. Rare throughout the Gambier Limestone.

Remarks

The Gambier Limestone specimens do not show as wide an umbilicus as the type figure of G. ciperoensis. They are commonly more similar in this respect to G. ciperoensis angustiumbilicata Bolli, 1957, which Bolli subsequently came to regard as specifically distinct (*fide* Blow, 1959, p. 172). One or two specimens, with ventrally strongly depressed sutures, resemble *G. ciperoensis angulisuturalis* Bolli and are very similar to the forms figured as "*G. ciperoensis* Bolli subsp. *angustisuturalis* Bolli" by Jenkins (*op. cit.*, p. 350, pl. 1, fig. 4).

GOLIBIGERINA JUVENILIS Bolli, 1957

Plate 28, fig. 1, 2.

Globigerina juvenilis Bolli, 1957, U.S. Nat. Mus., Bull. 215, p. 110, pl. 24, fig. 5, 6; Jenkins, 1960, Micropaleontology, v. 6, p. 351, pl. 1, fig. 10, 11.

Description

Test formed by a moderately to fairly high, compact, trochospiral coil. Dorsal side weakly to strongly convex, evolute; ventral side involute. Peripheral outline lobate, margin broadly rounded. Chambers inflated, subglobular or slightly flattened and hemispherical; they increase rapidly in size in early part of test, more slowly in distal part. Four chambers in last whorl; up to fourteen, arranged in about three whorls, in whole test. Septal sutures fairly distinct, radial and depressed; they are generally straight, but may be curved in early whorls on dorsal side. Spiral suture gently depressed, bent where septal sutures join. Wall generally smooth or bearing fine spines, between which fine pores occur. Aperture a narrow slit, slightly arched or straight, somewhat variable in length; it usually has a thin, narrow, overhanging lip. Apertual slit faces third-to-last chamber across an indistinctly developed central depression.

Dimensions

Largest specimen (locality E 17) : D = 0.28 mm, t = 0.20 mm.

Distribution

Occurs in the Oligocene and the Miocene of the Caribbean region and in the Miocene of Gippsland, Victoria. Rare in the Gambier Limestone.

Remarks

One or two specimens, smaller, and formed by a higher trochospiral coil, than the more common tests, closely resemble *G. bradyi* Wiesner. Bolli considered *G. juvenilis* and *G. bradyi* as intergrading, whereas Blow (1959, p. 174) regarded them as distinct.

GLOBIGERINA sp.

Plate 20, fig. 3.

Distribution

Very rare in a few samples from the lowest and the intermediate zones in the Gambier Limestone.

Genus GLOBIGERINOIDES Cushman, 1927

Distribution and remarks

The occurrences and ranges of *G. triloba* (= *Globigerina triloba* Reuss, 1850), *G. bispherica* Todd, 1954, and *G. transitoria* Blow, 1956, in South Australian Tertiary beds have been discussed by Wade (1958, chapter 7). These forms occur abundantly in the uppermost zone (the presence of distinctly developed *G. bispherica* is the only decisive criterion for assigning a sample to this zone; see p. 29) in the Gambier Limestone; *G. triloba* is also very rarely present in older strata. Specimens similar to *G. glomerosa* Blow, 1956, in that the last chamber embraces about half of the preceding test, but with less than four apertures along the basal suture of the last chamber, occur less commonly in the uppermost zone. Wade's (1958, p. 162) assignment of such tests to G. bispherica rather than G. glomerosa is accepted.

All the above-mentioned forms intergrade in the Gambier Limestone and can be taxonomically separated, where they occur together, only on arbitrary grounds. Blow (1956), in discussing the evolution of the genus Orbulina d'Orbigny from G. triloba, erected such arbitrary boundaries, using the degree to which the last chamber embraces the earlier part of the test and the number of apertures along the basal suture of the last chamber as the main distinguishing characters. Bolli (1957, p. 112) stated that G. sacculifera (Brady) var. immatura Le Roy, 1939, intergrades with G. triloba, and treated the former as a subspecies of the latter. G. triloba immatura differs from G. triloba triloba mainly in the last chamber being smaller than the remainder of the test.

G. triloba and G. bispherica from the Miocene Fishing Point Marl of Victoria have been recently described and figured by Carter (1958a, p. 52 - 54, pl. 7, fig. 67 - 74). Jenkins (1960, p. 353, 354, pl. 2, fig. 4, 5, 7) also discussed and figured these forms from Miocene subsurface strata in Gippsland, Victoria. His concept of G. bispherica is more restricted than Carter's. For reasons already mentioned (p. 31), an exact taxonomic differentiation between G. triloba and G. bispherica is not necessary for biostratigraphic zoning of the Gambier Limestone.

G. triloba, G. bispherica and G. transitoria are widespread in Miocene sediments, and the first appearances of G. triloba and G. bispherica have been used in interregional correlation. Although decisive evidence is lacking (Glaessner, 1959), the earliest occurrences of G. bispherica are commonly regarded to signify a post-Aquitanian, probably Helvetian age (Drooger, Papp and Socin, 1957).

Genus GLOBOQUADRINA Finlay, 1947

GLOBOQUADRINA DEHISCENS (Chapman, Parr and Collins), 1934

Globorotalia dehiscens Chapman, Parr and Collins, 1934, Linn. Soc. Lond., Jour., Zool., v. 38, p. 569, pl. 11, fig. 36.

Globorotalia quadraria Cushman and Ellisor, 1939, Cushman Lab. Foram. Res., Contr., v. 15, p. 11, pl. 2, fig. 5.

Globoquadrina dehiscens (Chapman, Parr and Collins). Finlay, 1947, New Zealand Jour. Sci. Tech., ser. B, v. 28, p. 290; Bolli, Loeblich and Tappan, 1957, U.S. Nat. Mus. Bull. 215, p. 31, pl. 5, fig. 5; Bolli, 1957, *ibid.*, p. 111, pl. 24, fig. 3, 4; Carter, 1958, Geol. Surv. Victoria, Bull. 55, p. 56, pl. 8, fig. 85 - 87.

Globoquadrina quadraria (Cushman and Ellisor) var. *advena* Bermudez, 1949, Cushman Lab. Foram. Res., Spec. Pub. 25, p. 287, pl. 22, fig. 36 - 38.

Globoquadrina dehiscens dehiscens (Chapman, Parr and Collins). Blow, 1959, Bull. Amer. Pal., v. 39, p. 182, pl. 8, fig. 49.

Globoquadrina dehiscens advena Bermudez. Blow, 1959, *ibid.*, p. 182, pl. 8, fig. 50.

Globoquadrina dehiscens (Chapman, Parr and Collins) subsp. *dehiscens* (Chapman, Parr and Collins). Jenkins, 1960, Micropaleontology, v. 6, p. 354, pl. 3, fig. 3.

Globoquadrina dehiscens (Chapman, Parr and Collins) subsp. *advena* Bermudez. Jenkins, 1960, *ibid.*, p. 355, pl. 3, fig. 4.

Description

Wall rather coarsely cancellate, with pores at bottoms of pits; some tests bear short spines, mainly around the umbilicus. A few specimens possess last chambers which are smaller and more finely cancellate than penultimate chambers, and which may be situated in a more ventral position, relative to the earlier part of the test, than the preceding chambers. Apertual flaps usually longer than wide, with evenly curved umbilical margin; in some tests they are shaped like a triangular tooth projecting into the umbilicus. Apertual face imperforate near its base, becoming increasingly densely perforate away from it.

Dimensions

Largest specimen (locality E 139) : D = 0.62 mm, d = 0.52 mm, t = 0.48 mm. Average D about 0.4 mm.

Distribution

Occurs in the Miocene of the Balcombe Bay area, the Aire district and in Gippsland (all in Victoria); also in the Miocene of New Zealand, the Caribbean region, North America, North Africa and Europe. Fairly common throughout the uppermost and the intermediate zones of the Gambier Limestone; very rare in the upper part of the lowest zone.

Remarks

The Gambier Limestone specimens vary from indistinctly quadrate forms with moderately compressed chambers, which somewhat resemble G. larmeui Akers, to distinctly quadrate individuals with rather strongly compressed chambers narrowing ventrally and shaped like rounded wedges. Specimens referable to G. dehiscens dehiscens and to G. dehiscens advena intergrade in the Gambier Limestone. Rare individuals resemble G. subdehiscens Finlay.

Genus GÜMBELITRIA Cushman, 1933

GÜMBELITRIA sp.

Plate 20, fig. 4.

Distribution

A few specimens are present in one sample from the lowest zone and another from the intermediate zone in the Gambier Limestone.

Family GLOBOROTALIIDAE

Genus GLOBOROTALIA Cushman, 1927

GLOBOROTALIA OPIMA Bolli, 1957

Plate 20, fig. 5 - 9.

Globorotalia opima opima Bolli, 1957, U.S. Nat. Mus., Bull. 215, p. 117, pl. 28, fig. 1, 2.

Globorotalia opima nana Bolli, 1957, ibid., p. 118, pl. 28, fig. 3.

Globorotalia opima continuosa Blow, 1959, Bull. Amer. Pal., v. 39, p. 218, pl. 19, fig. 125.

Globigerina opima (Bolli). Drooger and Magne, 1959, Micropaleontology, v. 5, pl. 1, fig. 4.

Globorotalia opima Bolli subsp. opima Bolli. Jenkins, 1960, ibid., v. 6, p. 366, pl. 5, fig. 3.

Globorotalia opima Bolli subsp. continuosa Blow. Jenkins, 1960, ibid., p. 366, pl. 5, fig. 4, 5.

Description

Test formed by a low to very low trochospiral coil. Dorsal side flat or gently convex, evolute; ventral side more convex, involute, with umbilical depression poorly developed. Peripheral outline rather weakly lobate; margin broadly, commonly somewhat asymmetrically rounded. Chambers vary from subhemispherical with height, length and width approximately equal, to subovate, with height greater than length and width; they are usually, but not always, somewhat flattened dorsally, and increase rather rapidly in size. Four to five chambers in last whorl; up to about twelve, arranged in two and a half or less whorls, in whole test. Septal sutures ventrally radial, straight, rather weakly depressed; dorsally straight or gently recurved, approximately radial or somewhat oblique. They are even more weakly depressed dorsally than on ventral side, especially in early whorls, where sutures are often indistinct. Wall fairly coarsely cancellate, with pores at bottoms of pits. Aperture rather variable; it may be a fairly low arch extending from central depression on ventral side approximately to the peripheral margin of test, or a rather high, horse-shoe-shaped arch straddling the middle of basal suture. In some specimens aperture is an asymmetrical arch extending into the apertual face. Aperture usually has a distinct and somewhat rounded rim or lip along its ventral border.

Dimensions

Largest specimen (locality E 61) : D = 0.50 mm, t = 0.36 mm. Average D about 0.4 mm.

Distribution

Originally described from the Oligocene of Trinidad; occurs also in the Oligocene of North Africa and the Miocene of Venezuela and Gippsland, Victoria. Relatively rare throughout the Gambier Limestone.

Remarks

The Gambier Limestone specimens fall within the range of variation indicated by the type figures of the three subspecies of G. opima mentioned above. Relatively compressed specimens referable to G. opima continuosa occur very rarely only in the uppermost and the intermediate zones. The taxonomic distinction of the named subspecies in the present fauna could only be based on arbitrary boundaries within intergrading populations.

Some of the intergrading variants appear to be rather similar to G. obesa Bolli as figures by Jenkins (op. cit., p. 364, pl. 5, fig. 2) from the Miocene of Gippsland, Victoria. The type figure of G. obesa (Bolli, op. cit., p. 119, pl. 29, fig. 2, 3) indicates a somewhat different wall surface, covered with blunt spines, but type specimens have not been seen by the present writer. According to Drooger and Batjes (1959, p. 177), G. obesa is closely similar to Globigerina concinna Reuss. However, specimens in the Gambier Limestone, comparable with G. concinna (p. 230), have a distinctly smoother and more finely perforate wall than those referred to G. opima.

Other variants in the Gambier Limestone appear to be closely similar to G. mayeri Cushman and Ellisor as figured by Jenkins (p. 360, pl. 4, fig. 6). Bolli (1957, p. 118) mentioned the similarity between G. mayeri and G. opima nana. Some of the Gambier Limestone specimens resemble the species figured by Jenkins (p. 366, pl. 5, fig. 7) as G. siakensis Le Roy, except that the aperture in comparable South Australian tests generally extends more deeply into the apertual face.

GLOBOROTALIA ZEALANDICA Hornibrook, 1958

Plate 20, fig. 10 - 13.

Globorotalia zealandica Hornibrook, 1958, New Zealand Jour. Geol. Geoph., v. 1, p. 667, fig. 18, 19, 30; Jenkins, 1960, Micropaleontology, v. 6, p. 368, pl. 5, fig. 9.

Globorotalia aff. zealandica Hornibrook. Wade, 1958, unpublished thesis, pl. 13, fig. 1.

Description

Test formed by a low, trochospiral coil. Dorsal side evolute, flat to, less commonly, gently convex; ventral side rather strongly convex, involute, with a small or almost absent umbilical depression. Peripheral outline roundedly subquadrate, weakly lobate; margin asymmetrically rounded to bluntly angular, non-carinate. Chambers subtriangular in both axial and peripheral view; they increase fairly rapidly in size. Four or, less commonly, nearly five chambers in last whorl; up to about twelve in approximately two and a half whorls in whole test. Septal sutures weakly depressed; ventrally radial, straight or gently recurved; dorsally somewhat oblique, more recurved. Sutures fairly distinct in last whorl, less so proximally. Spiral suture gently depressed, bent where septal sutures join. Wall densely and fairly coarsely perforate; short spines are sometimes present, especially near centre of test, on ventral side of early chambers in last whorl. Aperture an arch straddling the basal suture, with a distinct rim or lip along its ventral border. Apertual arch commonly rather high, narrow and symmetrical; in some specimens it is fairly wide and low, asymmetrical, reaching maximum height towards its peripheral extremity. In a number of tests, aperture continues into the umbilical area, with its more axial extremity abutting against the penultimate instead of the first chamber in the last whorl. Apertual face suboval, with rounded boundary; it may be slightly concave in vicinity of aperture.

Dimensions

Largest specimen (locality E 122) : D = 0.56 mm, t = 0.38 mm. Average D about 0.4 mm. Ratio D : t from 1.3 to 1.6.

Distribution

Occurs in the Lower Miocene of New Zealand and in Gippsland, Victoria. Rather rare in the uppermost zone of the Gambier Limestone; also present in a few samples considered to come from the top strata of the intermediate zone.

Remarks

In the Gambier Limestone, specimens agreeing closely with the type figure of G. zealandica intergrade with more common forms possessing a less rounded margin and a more highly arched aperture, which does not extend into the umbilical area.

GLOBOROTALIA SCITULA (Brady), 1882

Plate 20, fig. 14 - 16.

Pulvinulina scitula Brady, 1882, Roy. Soc. Edinburgh, Proc., v. 11, p. 716; Banner and Blow, 1960, Cushman Found. Foram. Res., v. 11, p. 27, pl. 5, fig. 5.

Pulvinulina patagonica Brady (non Rotalina patagonica d'Orbigny), 1884, Rept. Voy. Challenger, Zool., v. 9, p. 693, pl. 103, fig. 7.

Globorotalia scitula scitula (Brady). Blow, 1959, Bull. Amer. Paleont., v. 39, p. 219, pl. 19, fig. 126.

Globorotalia scitula praescitula Blow, 1959, ibid., p. 221, pl. 19, fig. 128.

Globorotalia scitula (Brady) subsp. praescitula Blow. Jenkins, 1960, Micropaleontology, v. 6, p. 366, pl. 5, fig. 6.

Description

Test compressed, formed by a low, trochospiral coil. Dorsal side evolute, weakly to moderately convex; it may be more steeply, eccentrically convex in early part of test than in the last whorl. Ventral side involute, asymmetrically, flatly subconical and non-umbilicate, usually higher than dorsal side; sometimes test subequally convex. Peripheral outline slightly lobate; margin bluntly angular, without a distinctly developed keel. Chambers increase fairly rapidly in size, and are subtriangular both in axial and in peripheral view; they are about as long as wide, somewhat less in height. Usually five chambers in last whorl; up to fifteen, arranged in about two and a half whorls, in the whole test. Sutures distinct, rather weakly depressed and narrow. On ventral side they are radial, gently recurved to almost straight; dorsally oblique, moderately to fairly strongly recurved. Wall generally smooth, rather finely and densely perforate; sometimes short spines are present on ventral surface of early chambers of last whorl. Aperture a low arch, which extends along basal suture from near ventral centre of test to just below peripheral margin. Aperture usually has a slight lip along its ventral border.

Dimensions

Largest specimen (locality E 97) : D = 0.38 mm, d = 0.34 mm, t = 0.22 mm.

Distribution

Occurs in Recent sediments and in the Miocene of Venezuela and Gippsland, Victoria. Rare in a few samples considered to come from strata near the top of the intermediate zone in the Gambier Limestone.

Remarks

Specimens apparently indistinguishable from the Recent lectotype of G. scitula as figured by Banner and Blow or G. scitula praescitula as figured by Jenkins from the Miocene of Gippsland, Victoria, intergrade in the Gambier Limestone. Blow's figures of G. scitula scitula and G. scitula praescitula from the Miocene of Venezuela are rather poor. He mentioned that the latter subspecies differs from the former "in having more tangentially elongate chambers, a more convex umbilical side and a less finely perforate wall texture; the periphery [of G. scitula praescitula] is generally more acute but transitional forms occur....". Jenkins, after examining the type specimens of G. scitula scitula, stated that G. scitula praescitula differs from the former "in being about half its size, having a much thinner test wall, having a more convex umbilical side and a more acute periphery." Jenkins' concept of G. scitula scitula apparently differs from Blow's, since the lectotype of G. scitula as figured by Blow is only slightly larger, and its margin is not noticeably less acute than that of the specimen figured as G. scitula praescitula by Jenkins.

G. miozea Finlay (1939, p. 326, pl. 29, fig. 159 - 161; also Hornibrook, 1958, p. 33, pl. 1, figs. 6 - 10) from the Miocene of New Zealand is rather similar to the specimens in the Gambier Limestone, but differs mainly in its greater size and better development of pustules on ventral surfaces of early chambers of the last whorl. G. miozea is closely similar to G. scitula gigantea Blow (1959, op. cit., p. 220, pl. 16, fig. 127) from the Miocene of Venezuela and to G. scitula as figured by Bolli (1957, p. 120, pl. 29, fig. 11, 12) from the Miocene of Trinidad. The specimens figured by Bolli, although stated by Blow to be synonymous with G. scitula scitula, are nearly 0.6 mm in maximum diameter and should be referred to G. scitula gigantea, according to Blow's criteria for distinguishing between the two subspecies.

Family HETEROHELICIDAE

Genus CHILOGÜMBELINA Loeblich and Tappan, 1956

CHILOGÜMBELINA sp.

Plate 20, fig. 17.

Distribution

Two specimens were found in a sample from near the base of the Gambier Limestone.

Family NONIONIDAE

Genus NONION Montfort, 1808

NONION cf. PAUPERATUM (Balkwill and Wright), 1885

Plate 20, fig. 18.

Cf. Nonionina pauperata Balkwill and Wright, 1885, Roy. Irish Acad., Trans., Sci., v. 28, p. 353, pl. 13, fig. 25, 26.

Distribution

Very rare in the Gambier Limestone.

Remarks

The Gambier Limestone specimens have less depressed sutures and smaller infilled umbilical areas than is indicated in the type figure of the Recent N. pauperatum.

Genus ASTRONONION Cushman and Edwards, 1937

ASTRONONION AUSTRALE Cushman and Edwards, 1937

Astrononion australe Cushman and Edwards, 1937, Cushman Lab. Foram. Res., Contr., v. 13, p. 33, pl. 3, fig. 13, 14; Cushman, 1939, U.S. Geol. Surv., Prof. Pap. 191, p. 37, pl. 10, fig. 7, 8; Carter, 1958, Geol. Surv. Victoria, Bull. 55, p. 60, pl. 9, fig. 91, 92.

Dimensions

Largest specimen (locality E 182) : D = 0.52 mm, d = 0.44 mm, t = 0.30 mm. Average D about 0.4 mm.

Distribution

Widespread in Oligocene to Middle Miocene strata in Victoria. Fairly common throughout the Gambier Limestone.

Remarks

The Gambier Limestone specimens agree well with topotypes of A. australe from Muddy Creek, Victoria, with which they have been compared. In the Gambier Limestone, tests with a broadly rounded margin cannot be separated from others possessing a narrowly rounded margin, such as that figured by Carter (op. cit., pl. 9, fig. 93, 94) as Astrononion sp.; even more compressed forms are rarely present. The "supplementary chambers" formed by the apertual flaps vary from roughly rhomboidal to tubular in axial view and may extend peripherally for about two thirds of the length of the sutures.

After studying A. stelligera (d'Orbigny), the type species of Astrononion, and A. sidebottomi Cushman, Hofker (1956a, p. 136) considered Astrononion to be a synonym of Nonion Montfort. His figures of A. sidebottomi (especially fig. 6 on pl. 20, op. cit.) show specimens with the aperture restricted to the peripheral region. Reiss (1958, p. 67) placed both Astrononion and Nonion within his superfamily Monolamellidea. The aperture of A. australe extends around the entire base of last chamber, and the wall appears to be bilamellid in thin section. It is probable that generically unrelated species have been assigned to the genus Astrononion by various authors. Representatives of the type species were not available for study to the writer, and the generic name Astrononion is provisionally retained for the Australian species discussed above.

Family AMPHISTEGINIDAE

Genus AMPHISTEGINA d'Orbigny, 1826

AMPHISTEGINA cf. LESSONII d'Orbigny, 1826

Amphistegina lessonii d'Orbigny. Chapman, Parr and Collins, 1934, Linn. Soc. Lond., Jour., Zool., v. 38, p. 568, pl. 10, fig. 25; Crespin, 1936, Australia, Dept. Interior, Pal. Bull. 2, pl. 1, fig. 9; Carter, 1959, unpublished thesis, pl. 25, fig. 320 - 322.

Description

Test lenticular, strongly compressed, formed by a very low trochospiral coil; it is involute on both sides. Ventral side usually flatter than dorsal side, which may bear a small, central boss; sometimes test almost equally biconvex. Margin acute, sharp or somewhat rounded. Peripheral outline subcircular, evenly curved. Chambers much wider than long, twenty-four to thirty in last whorl; they increase slowly and regularly in size. Sutures radial axially, bent strongly backwards near periphery; they are flush and narrow, sometimes limbate near the bends. Short, curved sutures due to secondary septa, which divide chambers near the bends, are visible ventrally. Aperture a short, ventral slit along basal suture near periphery; it is indistinctly visible in only a few specimens.

Dimensions

D from 1.2 mm to 2.1 mm, t from 0.4 to 0.8 mm. Ratio D : t from 2.6 to 4.

Distribution

Widespread in Lower and Middle Miocene strata in Victoria. Rare in the intermediate and the uppermost zones of the Gambier Limestone.

Remarks

The Gambier Limestone specimens are worn and poorly preserved; they were probably transported into the depositional environment of the limestone from shallower areas.

A number of forms, probably belonging to more than one species, have been referred to A. lessonii by various authors, partly due to the confusion as to whether figures 1 - 4 on plate 17 (d'Orbigny, 1826, Ann. Sci. Nat., ser. 1, v. 7) were meant to represent A. lessonii or A. gueii d'Orbigny (as pointed out by Ellis and Messina, Catal. Foram.). D'Orbigny's model of A. lessonii portrays a test with a smaller number of chambers (fifteen) in the last whorl than in the South Australian specimens. A. hauerina d'Orbigny and A. campbelli Karrer are more similar in this respect to the Gambier Limestone specimens, but differ in the appearance of the sutures.

Family ELPHIDIIDAE

Genus NOTOROTALIA Finlay, 1939

NOTOROTALIA GAMBIERENSE sp. nov.

Plate 20, fig. 19, 20.

Description

Test compressed, consisting of a moderately high trochospiral coil; usually dorsal side more convex than ventral side, less commonly test subequally biconvex. Outline subcircular, smoothly curved to, rarely, slightly lobate; margin sharply keeled. Usually seven, less commonly six or eight chambers in last whorl; up to about three whorls present. Dorsal sutures distinct in last whorl, indistinct in early whorls due to secondary thickening of test-wall; strongly oblique, slightly curved, generally slightly raised, but faintly depressed between last two or three chambers of some specimens. Spiral suture smoothly curved, usually slightly raised. Ventral sutures marked by adjacent ridges, radial and straight axially and recurved peripherally, where they may be faintly depressed. Wall rotaliid (in the sense of Smout, 1954), finely and densely perforate. A poorly developed system of diverging canals ends at the surface as larger pores on both sides of the ridges marking the ventral sutures; these pores are commonly separated by weakly developed, oblique cross-bars. Larger pores also occasionally pierce the marginal keel. Aperture a low and short basal arch; in the last chamber it is always obstructed by shell matter. Unobstructed foramina of preceding chambers are visible in broken specimens and thin sections. Apertual face separated from spiral wall by a bend in the wall, marked by a ridge; it is commonly ornamented with fine ridges.

Dimensions

Holotype (F 16, 155; locality E 185) : D = 0.64 mm, d = 0.58 mm, t = 0.34 mm. Paratype (largest specimen, F 16, 156; locality E 185) : D = 0.68 mm, d = 0.58 mm, t = 0.36 mm. Ratio D : t rather constant, about 1.8 or 1.9.

Distribution

Present in only a few samples from the intermediate zone of the Gambier Limestone.

Remarks

About forty specimens were available for study. The Gambier Limestone specimens do not appear to be closely similar to any described species of *Notorotalia*, differing from most in possessing a smooth dorsal side and a weakly ornamented ventral side.

NOTOROTALIA HOWCHINI (Chapman, Parr and Collins), 1934

Rotalia howchini Chapman, Parr and Collins, 1934, Linn. Soc. Lond., Jour., Zool., v. 38, p. 566, pl. 9, fig. 20.

Notoratelia howchini (Chapman, Parr and Collins).
Wade, 1957, Washington Acad. Sci., Jour., v. 47, p. 334, 338; Carter, 1958, Geol. Surv. Victoria, Bull. 55, p. 65, pl. 10, fig. 104 - 106.

Description

Adult specimens have seven to ten chambers in the last whorl. Margin bluntly to rather sharply keeled. Ventral sutures moderately recurved to almost straight and radial; generally marked by adjacent ridges. Surface ornamentation highly variable. Usually from three to six ridges branch off the distal sides of the ridges along the sutures, and are directed obliquely towards the periphery. Sometimes these short ridges reach to the proximal side of the ridge along the succeeding suture. Central area ventrally covered by shell matter continuous with the ridges; this thickened central area varies in size and commonly bears scattered pits. In some specimens the last one or two sutures are slightly depressed and straddled by short cross-ridges. Dorsal side commonly covered by a reticulate, irregularly anastomosing pattern of ridges; in some specimens this pattern is more regular and similar to that on the ventral side. A bilateral canal system and internal retral processes are present (Wade, 1957).

Dimensions

Largest specimen (locality E 166) : D = 0.80 mm, d = 0.76 mm, t = 0.48 mm. Average D about 0.4 mm. Ratio D : t from 1.6 to 2.

Distribution

Common and widespread in the Oligocene and the Miocene, rare in the Pliocene, of Victoria and South Australia. Abundant throughout the Gambier Limestone, especially in the Naracoorte Limestone Member.

Genus PARRELLINA Thalmann, 1951

PARRELLINA aff. VERRICULATA (Brady), 1881

Plate 20, fig. 21, 22.

Aff. Polystomella verriculata Brady, 1881, Quart. Jour. Micr. Sci., v. 21, n.s., p. 66; Brady, 1884, Rept. Voy. Challenger, Zool., v. 9, p. 738, pl. 110, fig. 12.

Parrellina sp. Wade, 1957, Washington Acad. Sci., Jour., v. 47, p. 335, 338.

Description

Test strongly compressed, planispirally coiled, involute or slightly evolute. It is equally and weakly biconvex, with sides in central region rather flat. Peripheral outline reniform to subcircular, smoothly curved except for wide notch at base of apertual face. Margin narrowly rounded or more acute, bearing a low ridge, which is best developed in distal part of last whorl. Chambers considerably wider than long, increasing rather slowly in size; eleven to seventeen chambers in last whorl. Sutures moderately to fairly strongly recurved and marked by strongly raised ridges. Similarly raised cross-bars, six to ten per chamber in adult specimens, join the septal ridges. Cross-bars extend at about right angles to sutures and hence are generally somewhat peripherally directed. They vary from straight to somewhat bent; in latter case, surface ornamentation has a wavy appearance. Septal ridges commonly become irregular and disjointed in central region, where a few small bosses may be present. Apertual face narrowly triangular, with ridges forming its boundary with remainder of wall of last chamber. It is ornamented with finer ridges than on sides of test. These ridges lie approximately parallel to length of apertual face or radiate vaguely from mid-point of basal suture; sometimes ridges form a less regular pattern. Because of poor preservation, septal and apertual pores are not distinctly visible.

Dimensions

Largest specimen (locality E 5) : D = 1.04 mm, d = 0.86 mm, t = 0.34 mm. Average D about 0.6 mm. Ratio D : t from about 3 to 4 in adult specimens.

Distribution

Common and widespread in the Oligocene and the Lower Miocene in South Australia; also present in the Oligocene at Table Cape, Tasmania. Fairly common in the lower and the intermediate zones of the Gambier Limestone.

Remarks

According to Wade (1957), this species possesses septal canals and diverging canals, while the umbilical area contains anastomosing rather than clearly spiral canals. The septal canals appear to lead into one another in a dendroid fashion.

P. aff. verriculata differs from P. verriculata in being larger and in the ornamentation of the apertual face being finer than on the sides of the test.

Family NUMMULITIDAE

Genus OPERCULINA d'Orbigny, 1826

OPERCULINA VICTORIENSIS Chapman and Parr, 1938

Operculina victoriensis Chapman and Parr, 1938, Roy. Soc. Victoria, Proc., n.s., v. 50, p. 284, pl. 16, fig. 3 - 8, text-fig. 2; Howchin and Parr, 1938, Roy. Soc. South Australia, Trans., v. 62, p. 309, pl. 18, fig. 10; Carter 1959, unpublished thesis, pl. 25, fig. 317, 318.

Distribution

Widespread in the Miocene of Victoria and South Australia. Fairly common in the intermediate zone, except near its base, and in the uppermost zone in the Gambier Limestone.

INDEX

Foraminiferal species described or recorded from the Gambier Limestone in this thesis.

SUMMARY

The Mid-Oligocene to Lower Miocene Gambier Limestone extends over more than 10,000 square miles of the Gambier Sunklands and the Padthaway Ridge in southeastern South Australia and southwestern Victoria. With the underlying Compton Conglomerate, which rests unconformably on the Knight Group, it partly constitutes the Glenelg Group. The Gambier Limestone, as defined, includes the Naracoorte Limestone Member, and is up to 500 feet thick in South Australia. The top of the limestone, which was studied in outcrop near Mount Gambier and Naracoorte, has been eroded and remains undefined.

The formation consists of poorly bedded, porous calcirudites, calcarenites and calcisiltites. Constituent particles are largely organic in origin, with Bryozoa predominant. Chert occurs in the form of bands or nodules; recrystallization and dolomitization are not extensive. The Gambier Limestone becomes marly northwards and westwards. It is not divisible into lithological sub-units near Mount Gambier.

Deposition occurred on a continental shelf merging towards the Murray Basin with an epicontinental sea. Paleoecological evidence suggests a depth of 20 to 50 fathoms. Variation in mechanical energy and organic activity caused differences in lithology.

Three zones, based on the distribution of <u>Victoriella conoidea</u> (Rutten), <u>Globoquadrina dehiscens</u> (Chapman, Parr and Collins)

and *Operculina victoriensis* Chapman and Parr, and *Globigerinoides bispherica* Todd, have been used to elucidate the gently folded and faulted structure of the Gambier Limestone.

165 foraminiferal species, one of them new (*Notorotalia gambierense*), are described or recorded. The fauna shows close affinities with Victorian and New Zealand faunas of similar age; it has less in common with described faunas from Europe and North and Central America.

BIBLIOGRAPHY

ALEXANDER, G.B., HESTON, W.M. and ILER, R.K.

1954 The solubility of amorphous silica in water. Jour. Phys. Chem., v. 58, p. 453 - 455.

BANDY, O.L.

1956 Ecology of Foraminifera in northeastern Gulf of Mexico. U.S. Geol. Surv., Prof. Pap. 274 - G, p. 179 - 204.

BATHURST, R.G.C.

1958 Diagenetic fabrics in some British Dinantian limestones. Liverpool Manchester Geol. Jour., v. 2, p. 11 - 36.

BIEN, G.S., CONTOIS, D.E. and THOMAS, W.H.

1958 Removal of soluble silica from fresh water entering the sea. Geochim. Cosmochim. Acta, v. 14, p. 35 - 54.

BLOW, W.H.

1956 Origin and evolution of the foraminiferal genus Orbulina d'Orbigny. Micropaleontology, v. 2, p. 57 - 70.

1959 Age, correlation, and biostratigraphy of the upper Tocuyo (San Lorenzo) and Pozon formations, Eastern Falcon, Venezuela. Bull. Amer. Paleont., v. 39, no. 178, p. 59 - 251.

BOLLI, H.M.

1957 Planktonic Foraminifera from the Oligocene - Miocene Cipero and Lengua Formations of Trinidad, B.W.I. U.S. Nat. Mus., Bull. 215, p. 97 - 123.

BOUTAKOFF, N.

1952 The structural pattern of south-western Victoria. Mining Geol. Jour., Dept. Mines, Victoria, v. 4, p. 21 - 29.

BRADY, H.B.

1884 Report on the Foraminifera dredged by H.M.S. "Challenger", during the years 1873 - 1876. Challenger Exped. Rep., Zool., v. 9, 814 p., 115 pl.

BROTZEN, F.

1948 The Swedish Paleocene and its foraminiferal fauna. Sver. Geol. Unders., ser. C, no. 493, 140 p.

BROWN, D.A.

1958 Fossil cheilostomatous Polyzoa from south-west Victoria. Geol. Surv. Victoria, Mem. 20, 90 p.

BUSK, G.

1860 Note on the fossil Polyzoa collected by the Rev. J.E. Woods near Mount Gambier, South Australia. Quart. Jour. Geol. Soc. Lond., v. 16, p. 260 - 261.

CARTER, A.N.

1958 a Tertiary Foraminifera from the Aire district, Victoria. Geol. Surv. Victoria, Bull. 55, 76 p.

1958 b Pelagic Foraminifera in the Tertiary of Victoria. Geol. Mag., v. 95, p. 297 - 304.

1959 Guide Foraminifera of the Tertiary Stages in Victoria. Mining Geol. Jour., Dept. Mines, Victoria, v. 6, p. 48 - 54.

CHAPMAN, F.

1943 Notes on fossiliferous rocks from Tertiary outcrops to the south-west of Coonalpyn, South Australia. Roy. Soc. South Australia, Trans., v. 67, p. 39 - 41.

COCHRANE, G.W.

1952 a Dolomite deposits at Up and Down Rocks near Tantanoola. South Australian Dept. Mines, Mining Rev., 92, p. 71-78.

COCHRANE, G.W.

1952 b Dolomites of the lower South-East. South Australian Dept. Mines, Mining Rev., 93, p. 117 - 121.

CORRENS, C.W.

1941 Über die Löslichkeit von Kieselsäure in schwach sauren und alkalischen Lösungen. Chemie der Erde, v. 13, p. 92 - 96.

1950 Zur Geochimie der Diagenese. Geochim. Cosmochim. Acta, v. 1, p. 49 - 54.

CRESPIN, I.

1954 The Nelson Bore, south-western Victoria, micropalaeontology and stratigraphic succession. Australia, Dept. Nat. Devel., Bur. Min. Res., Geol. Geoph., 39 p.

CUSHMAN, J.A.

1937 A monograph of the foraminiferal family Verneuilinidae. Cushman. Lab. Foram. Res., Spec. Pub. 7, 157 p.

1940 Foraminifera, their classification and economic use. Harvard Univ. Press, Cambridge, Mass., 3rd ed., 535 p.

CUSHMAN, J.A. and ELLISOR, A.C.

1945 The foraminiferal fauna of the Anahuac formation. Jour. Paleont., v. 19, p. 545 - 572.

DAVIS, W.M.

1930 Origin of limestone caverns. Geol. Soc. America, Bull., v. 41, p. 475 - 628.

DENNANT, J.

1902 On the occurrence of Miocene strata at Horsham. Geol. Surv. Victoria, Rec., 1, p. 37.

DICKINSON, S.B.

1951 Mount Gambier building stone deposits. South Australian Dept. Mines, Mining Rev., 91, p. 92 - 94.

DORMAN, F.H. and GILL, E.D.

1959 Oxygen isotope palaeotemperature measurements on Australian fossils. Roy. Soc. Victoria, Proc., v. 71, n.s., p. 73 - 98.

DROOGER, C.W.

1953 Miocene and Pleistocene Foraminifera from Oranjestad, Aruba (Netherlands Antilles). Cushman Found. Foram. Res., Contr., v. 4, p. 116 - 147.

DROOGER, C.W. and BATJES, D.A.J.

1959 Planktonic Foraminifera in the Oligocene and Miocene of the North Sea Basin. K. Nederl. Akad. Wetensch., Proc., ser. B, v. 62, p. 172 - 186.

DROOGER, C.W., PAPP, A. and SOCIN, C.

1957 Über die Grenze zwischen den Stufen Helvet und Torton. Österreich. Akad. Wiss., Mat. Nat. Kl., p. 1 - 10.

DUNCAN, H.

1957 Bryozoans. Geol. Soc. America, Mem. 67, v. 2, p. 783 - 799.

ETHERIDGE, R.

1876 On some species of <u>Terebratulina</u>, <u>Waldheimia</u> and <u>Terebratella</u> from the Upper Tertiary deposits of Mount Gambier and the Murray River cliffs, South Australia. Ann. Mag. Nat. Hist., ser. 4, v. 17, p. 15 - 12.

1878 A synopsis of the known species of Australian Tertiary Polyzoa. Roy. Soc. New South Wales, Jour., v. 11, p. 129 - 143.

FAIRBRIDGE, R.W.

1957 The dolomite question. Soc. Econ. Paleont. Mineral., Spec. Pub. 5, p. 125 - 178.

FINLAY, H.J.

1939 New Zealand Foraminifera : key species in stratigraphy - No. 3. Roy. Soc. New Zealand, Trans., v. 69, p. 309 - 329.

GEOL. SOC. AUSTRALIA

1960 Tectonic map of Australia.

GILL, E.D.

1957 a The stratigraphical occurrence and paleoecology of some Australian Tertiary marsupials. Nat. Mus. Victoria, Mem. 21, p. 135 - 203.

1957 b Report of the ANZAAS Committee for the investigation of Quaternary strandline changes. Austr. Jour. Sci., v. 20, p. 5 - 9.

GLAESSNER, M.F.

1945 Principles of micropalaeontology. Melbourne Univ. Press, 296 p.

1951 Three foraminiferal zones in the Tertiary of Australia. Geol. Mag., v. 88, p. 273 - 283.

1953 a Some problems of Tertiary geology in southern Australia. Roy. Soc. New South Wales, Jour., v. 87, p. 31 - 45.

1953 b Conditions of Tertiary sedimentation in southern Australia. Roy. Soc. South Australia, Trans., v. 76, p. 141 - 146.

GLAESSNER, M.F.

1955 Pelagic fossils (Aturia, penguins, whales) from the Tertiary of South Australia. South Australian Mus., Rec., v. 11, p. 353 - 371.

1959 Tertiary stratigraphic correlation in the Indo-Pacific region and Australia. Geol. Soc. India, Jour., v. 1, p. 53 - 67.

HOFKER, J.

1951 The Foraminifera of the Siboga Expedition. Part III. E.J. Brill, Leiden, 513 p.

1956 a Foraminifera Dentata : Foraminifera of Santa Cruz and Thatch-Island, Virginia-Archipelago, West-Indies. Copenhagen, Univ., Zool. Mus., Spolia (Skrifter), v. 15, 237 p.

1956 b Tertiary Foraminifera of coastal Ecuador : Part II, additional notes on the Eocene species. Jour. Paleont., v. 30, p. 891 - 958.

HORNIBROOK, N. deB.

1958 New Zealand Upper Cretaceous and Tertiary foraminiferal zones and some overseas correlations. Micropaleontology, v. 4, p. 25 - 38.

HOSSFELD, P.S.

1950 The late Cainozoic history of the South-East of South Australia. Roy. Soc. South Australia, v. 73, p. 232-279.

JACK, R.L.

1923 The building stones of South Australia. Geol. Surv. South Australia, Bull. 10, 73 p.

JENKINS, D.G.

1958 The true nature of Bolivina bentyana Chapman, 1916. Micropaleontology, v. 4, p. 335 - 336.

JENKINS, D.G.

1960 Planktonic foraminifera from the Lakes Entrance oil shaft, Victoria, Australia. Micropaleontology, v. 6, p. 345 - 371.

KENLEY, P.R.

1951 Marine Eocene sediments near Casterton, Victoria. Austr. Jour. Sci., v. 14, p. 91 - 92.

KENNY, J.P.L.

1939 Limestone at Heywood. Mining Geol. Jour., Dept. Mines, Victoria, v. 2, p. 52 - 54.

KING, D.

1949 Geological notes on the Nullarbor cavernous limestone. Roy. Soc. South Australia, v. 73, p. 52 - 58.

KRAUSKOPF, K.B.

1956 Dissolution and precipitation of silica at low temperatures. Geochim. Cosmochim. Acta, v. 10, p. 1 - 26.

LOWMAN, S.W.

1949 Sedimentary facies in Gulf Coast. Amer. Assoc. Petr. Geol., Bull., v. 33, p. 1939 - 1997.

LUDBROOK, N.H.

1957 A reference column for the Tertiary sediments of the South Australian portion of the Murray Basin. Roy. Soc. New South Wales, Jour., v. 90, p. 174 - 180.

1958 The Murray Basin in South Australia. Geol. Soc. Australia, Jour., v. 5, p. 102 - 114.

1961 Stratigraphy of the Murray Basin in South Australia. Geol. Surv. South Australia, Bull. 36, 96 p.

McGOWRAN, B.
1959 Tertiary nautiloids (Eutrephoceras and Cimomia) from South Australia. Jour. Paleont., v. 33, p. 434 - 448.

MADIGAN, D.C.
1957 Preparation of precipitated chalk from Mount Gambier Limestone. South Australian Dept. Mines, Mining Rev., 104, p. 76 - 79.

de MOOY, C.J.
1959 Notes on the geomorphic history of the area surrounding Lakes Alexandrina and Albert, South Australia. Roy. Soc. South Australia, Trans., v. 82, p. 99-118.

NEWELL, N.D., RIGBY, J.K., FISCHER, A.G., WHITEMAN, A.J., HICKOX, J.E. and BRADLEY, J.S.
1953 The Permian reef complex of the Guadalupe Mountains region, Texas and New Mexico : A study in paleoecology. Freeman, San Francisco, 236 p.

O'DRISCOLL, E.P.D.
1961 The hydrology of the Murray Basin Province in South Australia. Geol. Surv. South Australia, Bull. 35, v. 1, p. 1 - 148; v. 2, p. 149 - 300.

OKAMOTO, G., OKURA, T. and GOTO, K.
1957 Properties of silica in water. Geochim. Cosmochim. Acta, v. 12, p. 123 - 132.

PARKER, W.K. and JONES, T.R.
1860 Note on the Foraminifera from the bryozoan limestone near Mount Gambier, South Australia. Quart. Jour. Geol. Soc. Lond., v. 16, p. 261.

PARR, W.J.

1950 Foraminifera. B.A.N.Z. Antarct. Res. Exped., Rep., ser. B, v. 5, pt. 6, p. 235 - 392.

PETTIJOHN, F.J.

1957 Sedimentary rocks. Harper, New York, 2nd ed., 718 p.

POKORNY, V.

1958 Grundzüge der zoologischen Mikropaläontologie. v. 1, 582 p. Deutsch. Verl. Wiss., Berlin.

READ, D.W.

1957 Suitability of Mount Gambier Limestone for the production of hydrated lime. South Australian Dept. Mines, Mining Rev., 103, p. 134 - 142.

REISS, Z.

1958 Classification of lamellar Foraminifera. Micropaleontology, v. 4, p. 51 - 70.

1960 Structure of so-called Eponides and some other rotaliiform Foraminifera. Geol. Surv. Israel, Bull. 29, 28 p.

RUTTEN, M.G.

1957 Remarks on the genesis of flints. Amer. Jour. Sci., v. 255, p. 432 - 439.

SHEPHERD, R.G.

1959 Underground drainage in the lower South-East. South Australian Dept. Mines, Mining Rev., 106, p. 20 - 26.

SIEVER, R.

1957 The silica budget in the sedimentary cycle. Amer. Mineralogist, v. 42, p. 821 - 841.

SMOUT, A.H.

1954 Lower Tertiary Foraminifera of the Quatar Peninsula. British Mus. (Nat. Hist.), London, 96 p.

1955 Reclassification of the Rotaliidea (Foraminifera) and two new Cretaceous forms resembling Elphidium. Washington Acad. Sci., Jour., v. 45, p. 201 - 210.

SPRIGG, R.C.

1952 The geology of the South-East Province, South Australia, with special reference to Quaternary coastline migrations and modern beach developments. Geol. Surv. South Australia, Bull. 29, 120 p.

SPRIGG, R.C. and BOUTAKOFF, N.

1953 Summary report on the petroleum possibilities of the Gambier Sunklands. South Australian Dept. Mines, Mining Rev., 95, p. 41 - 62.

SPRIGG, R.C. and COCHRANE, G.W.

1951 Gambier and Northumberland (1 mile geological series) sheet. Geol. Surv. South Australia.

SPRIGG, R.C., COCHRANE, G.W. and SOLOMON, M.

1951 Penola (4 mile geological series) sheet. Geol. Surv. South Australia.

STACH, L.W.

1936 Correlation of zoarial form with habitat. Jour. Geol., v. 44, p. 60 - 65.

STINNEAR, B.H.

1948 Compilation of geological and borehole data from S.-W. Victoria and the contiguous part of South Australia, with particular reference to Portland-Nelson-Mt. Gambier area. Bur. Min. Res., Geol. Geoph. Rep. 1948 - 82 and appendix.

SUJKOWSKI, Z.L.

1958 Diagenesis. Amer. Assoc. Petr. Geol., Bull., v. 42, p. 2692 - 2717.

SVED, G.

1957 Appendix to Whitten, G.F., Limestone deposit near Glencoe. South Australian Dept. Mines, Mining Rev., 104, p. 75.

SWINNERTON, A.C.

1932 Origin of limestone caverns. Bull. Geol. Soc. America, v. 43, p. 663 - 694.

TATE, R.

1880 On the Australian Tertiary palliobranchs. Roy. Soc. South Australia, Trans., v. 3, p. 140 - 170.

1886 The lamellibranchs of the older Tertiary of Australia. Part I. Roy. Soc. South Australia, Trans., v. 8, p. 96 - 158.

1891 A bibliography and revised list of the described echinoids of the Australian Eocene with descriptions of some new species. Roy. Soc. South Australia, Trans., v. 14, p. 270 - 282.

TEESDALE-SMITH, E.N.

1959 Bibliography of South Australian geology. South Australian Dept. Mines, Geol. Surv., 235 p.

TINDALE, N.B.

1933 Tantanoola Caves, South East of South Australia : geological and physiographical notes. Roy. Soc. South Australia, Trans., v. 57, p. 130 - 142.

TOULMIN, L.D.

1941 Eocene smaller Foraminifera from the Salt Mountain limestone of Alabama. Jour. Paleont., v. 15, p. 567 - 611.

TWENHOFEL, W.H.

1950 Principles of sedimentation. McGraw-Hill, New York, 2nd ed., 673 p.

WADE, M.J.

1958 Unpublished thesis.

WALKER, T.R.

1960 Carbonate replacement of detrital crystalline silicate minerals as a source of authigenic silica in sedimentary rocks. Bull. Geol. Soc. America, v. 71, p. 145 - 152.

WARD, L.K.

1941 The underground water of the south-eastern part of South Australia. Geol. Surv. South Australia, Bull. 19, 56 p.

1946 The occurrence, composition, testing and utilization of underground water in South Australia, and the search for further supplies. Geol. Surv. South Australia, Bull. 23, 281 p.

WATERS, A.W.

1882 On fossil chilostomatous Bryozoa from Mount Gambier, South Australia. Quart. Jour. Geol. Soc. Lond., v. 38, p. 257 - 276.

WEEKS, L.G.

1952 Factors of sedimentary basin development that control oil occurrence. Amer. Assoc. Petr. Geol., Bull., v. 36, p. 2071 - 2124.

WELLER, J.M.

1959 Compaction of sediments. Amer. Assoc. Petr. Geol., Bull., v. 43, p. 273 - 310.

WILLINGTON, C.M.

1956 Flint deposits - County Grey. South Australian Dept. Mines, Mining Rev., 100, p. 100 - 102.

WOODS, J.E. Tenison

1860 On some Tertiary rocks in the colony of South Australia. Quart. Jour. Geol. Soc. Lond., v. 16, p. 253 - 260.

1862 Geological observations in South Australia : principally in the district south-east of Adelaide. Longman, Green; London, 404 p.

1865 a The Tertiary rocks of South Australia. Part I. Introduction. Adelaide Philos. Soc., Ann. Rep. Trans., 3 p.

1865 b The Tertiary rocks of South Australia. Part II. The Mount Gambier fossils. Adelaide Philos. Soc., Ann. Rep. Trans., 2 p.

1865 c The Tertiary rocks of South Australia. Part III. Brachiopoda. Adelaide Philos. Soc., Ann. Rep. Trans., 2 p.

1867 The Tertiary rocks of South Australia. Part IV. Fossil Echinidae. Adelaide Philos. Soc., Ann. Rep. Trans., 2 p.

1876 On some Tertiary Australian Polyzoa. Roy. Soc. New South Wales, Jour., v. 10, p. 147 - 150.

1877 Palaeontological evidence of Australian Tertiary formations. Roy. Soc. New South Wales, Jour., v. 11, p. 113 - 143.

This thesis contains no material previously submitted for a degree in any University by myself or by any other person, except when due reference is made in the text.

PLATES 1 to 20

PLATE 1

Fig. 1. Approximately 1½ feet of Compton Conglomerate unconformably overlying clays, sands and gravels of the Knight Group, and passing upwards into the Gambier Limestone. Knight's quarry (locality V13) near Compton.

Fig. 2. Stratification in the Gambier Limestone (building stone) exhibited in vertically cut quarry wall. Locality E22 (about 5½ miles west of Mt. Gambier).

Fig. 3. Naracoorte Limestone Member overlying Gambier Limestone *sensu stricto*. James' quarry, Naracoorte (locality E1).

Fig. 4. Naracoorte Limestone Member. Locality E6 (east of Naracoorte).

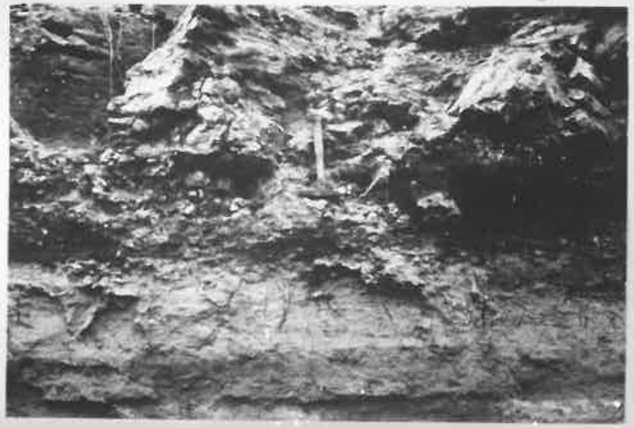


FIG. 1

FIG. 2

FIG. 3

FIG. 4

PLATE 1

PLATE 2

Fig. 1. Stratification in the Gambier Limestone indicated by thin, recrystallized layers approximately parallel with bedding planes. Locality E53 (about 1½ miles east of Mt. Gambier).

Fig. 2 - 4. Stratification in fine grained Gambier Limestone indicated by chert bands and rows of solution cavities. Sink hole at locality E21 (about 3 miles west of Mt. Schank).

PLATE 2

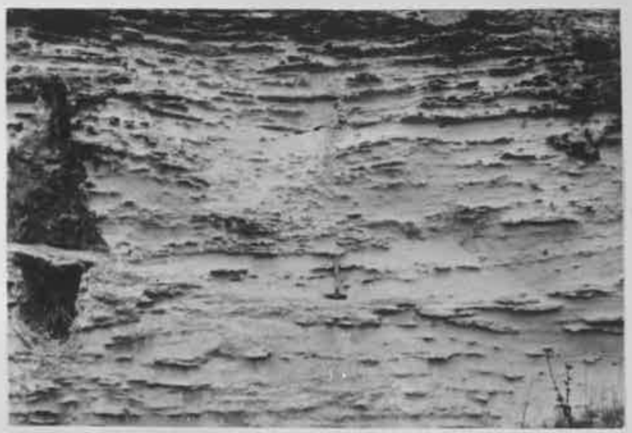


FIG. 1

FIG. 2

FIG. 3

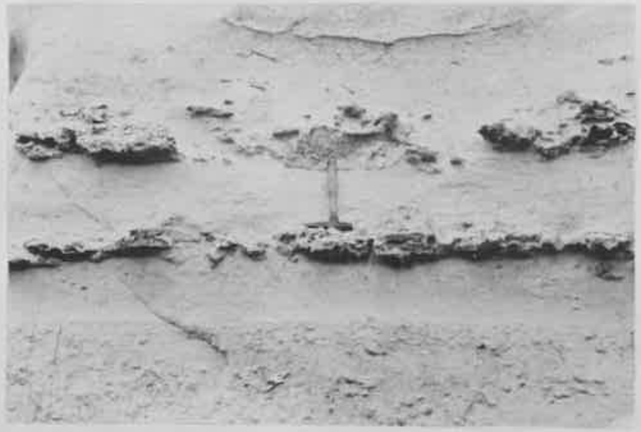


FIG. 4

PLATE 3

Fig. 1. Gambier Limestone (calcisiltite). Natural size. Specimen from locality E63.

Fig. 2. Gambier Limestone (building stone). Natural size. Specimen from Pritchards' quarry, near locality E42.

PLATE 3

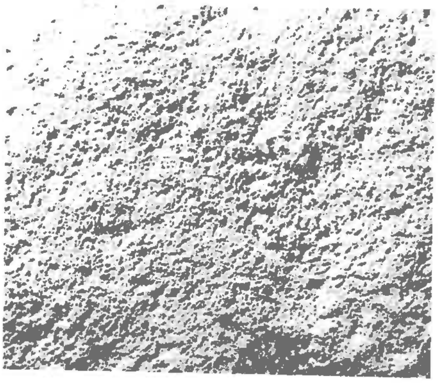


FIG. 1

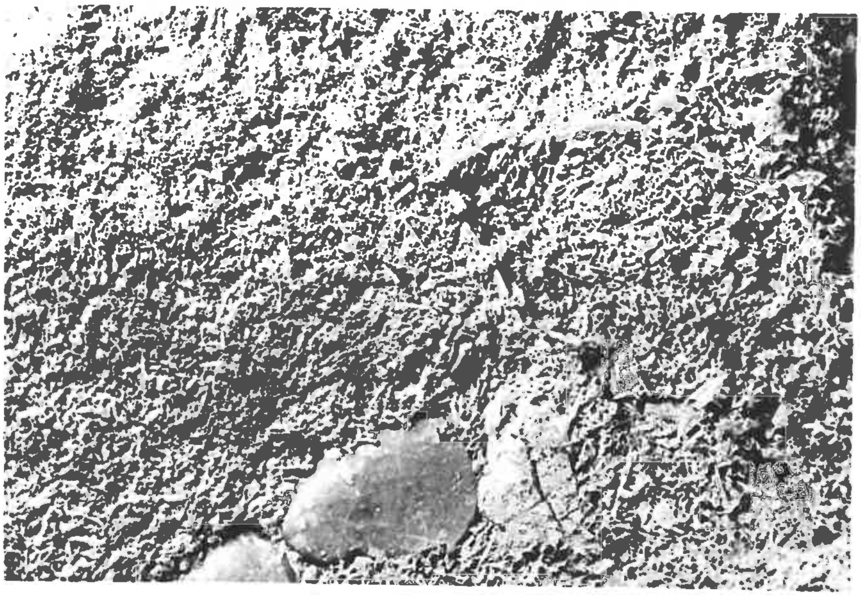


FIG. 2

PLATE 4

Fig. 1. Naracoorte Limestone Member. Natural size. Specimen from near the base of the member at James' quarry, Naracoorte (locality E1).

PLATE 4

FIG. 1

PLATE 5

Thin sections.

Magnification approximately 40 x.

Fig. 1. Gambier Limestone (calcisiltite). Specimen from locality E63.

Fig. 2. Gambier Limestone (building stone). Specimen from Pritchards' quarry, near locality E42.

PLATE 5

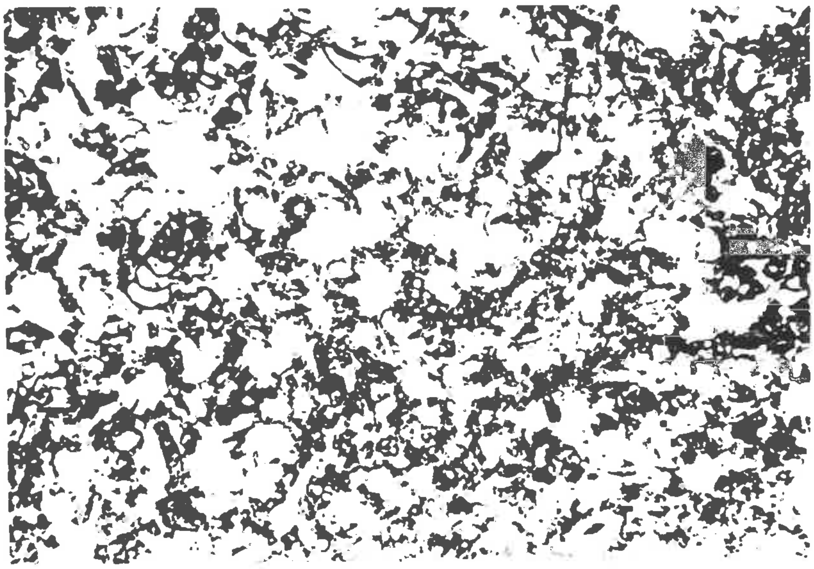


FIG. 1

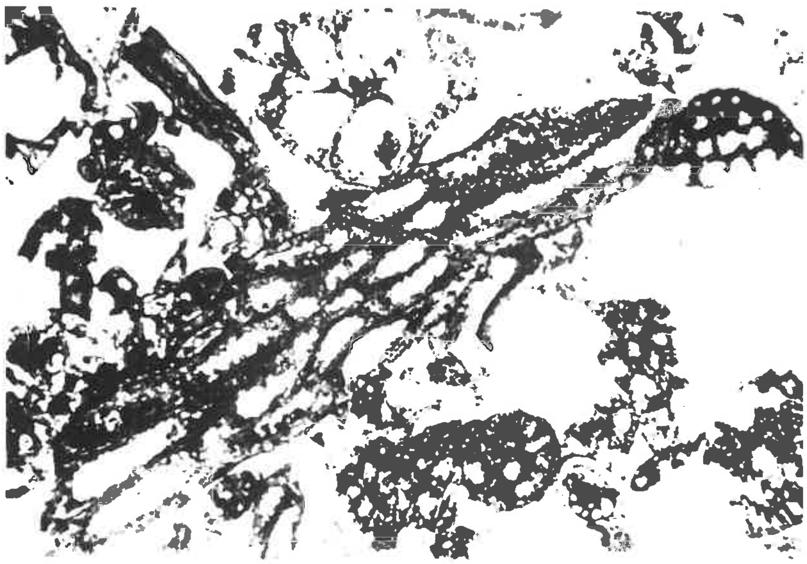


FIG. 2

PLATE 6

Foraminiferal assemblages.

Magnification approximately 30 x.

Fig. 1. Naracoorte Limestone Member. Intermediate zone. Locality E4.

Fig. 2. Gambier Limestone. Lowest zone. Locality E154.

Fig. 3. Gambier Limestone. Lowest zone. Locality E159.

PLATE 6

FIG. 1

FIG. 2

FIG. 3

PLATE 7

Foraminiferal assemblages

Magnification approximately 30 x.

Fig. 1. Gambier Limestone (building stone).
Locality E82.

Fig. 2. Gambier Limestone. Intermediate zone.
Locality E24.

Fig. 3. Gambier Limestone. Uppermost zone.
Locality E62.

PLATE 7

FIG. 1

FIG. 2

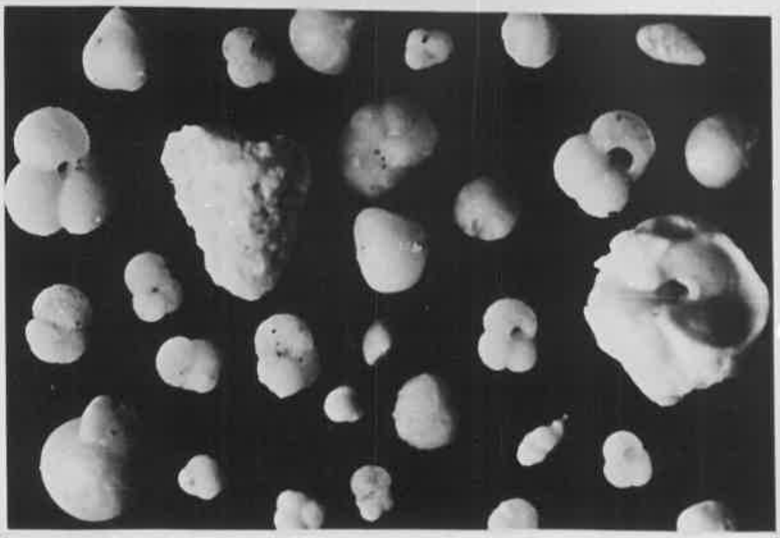


FIG. 3

PLATE 8

The magnifications stated for figures on plates 8 - 20 are approximate.

Fig. 1 - 3. Textularia lateralis Lalicker, p. 77. 40 x. (1 a, b) F15890; locality E182. (2) F15891; locality E182. (3) F15892; locality E159.

Fig. 4 a, b. Textularia cf. marsdeni Finlay, p. 78. 20 x. F15893; locality E159.

Fig. 5 a, b. Textularia cf. plummerae Lalicker, p. 80. 40 x. F15894; locality E37.

Fig. 6 - 9. Texularia sp. 1, p. 80. 20 x. (6 a, b) F15895; Mt. Gambier town hall sink hole. (7 a, b) F15897; locality E126. (8 a, b) F15896; Mt. Gambier town hall sink hole. (9) F15898; locality E147.

Fig. 10 - 12. Textularia sp. 2, p. 82. 50 x. (10 a, b) F15899; locality V119. (11 a, b) F15900; locality E159. (12) F15901; locality E64.

Fig. 13 a, b. Siphotextularia sp. 1, p. 83. 100 x. F15902; locality V119.

Fig. 14 - 15. Siphotextularia sp. 2, p. 83. 50 x. (14 a, b) F15903; locality E154. (15) F15904; locality E131.

Fig. 16. Bolivinopsis cf. attenuata Cushman, p. 84. 100 x. F15905; locality E182.

Fig. 17 a, b. Vulvulina sp., p. 85. 50 x. F15906; locality V118.

Fig. 18, 19. Bdelloidina aggregata Carter, p. 86. (18) 12 x. F15907; Mt. Gambier town hall sink hole. View of unattached side. (19) 20 x. F15908; locality E144. Distal view (last chamber broken).

Fig. 20 - 22. Gaudryina crespinae Cushman, p. 87. 20 x. (20 a, b) F15909; locality V118. (21 a, b) F15910; locality E124. (22) F15911; locality E124.

PLATE 8

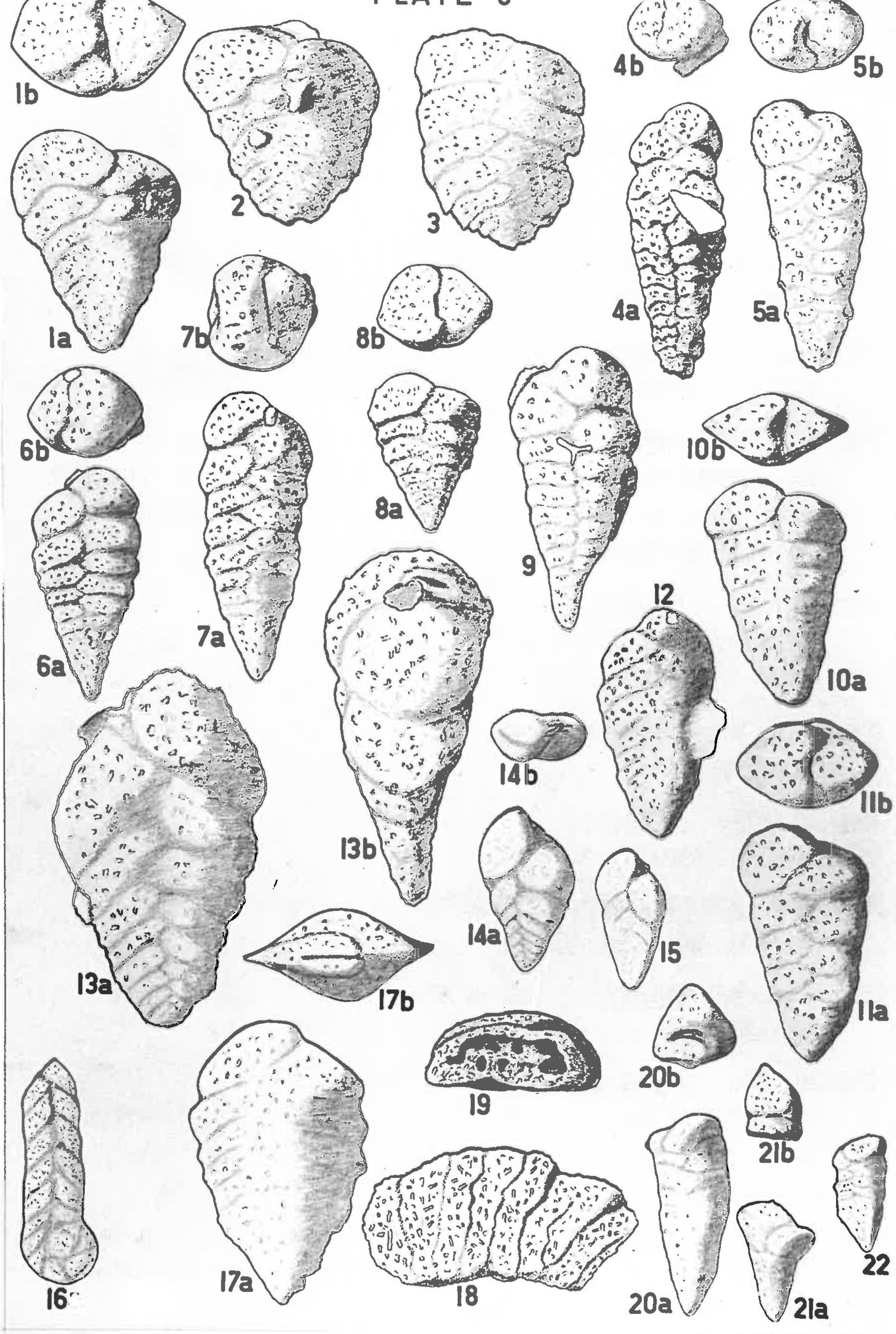


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PLATE 9

Fig. 1, 2. Gaudryina cf. rugosa d'Orbigny, p. 89. 20 x. (1 a, b) F15912; locality E170. (2 a, b) F15913; locality E159.

Fig. 3, 4. Pseudoclavulina sp., p. 90. 12 x. (3) F15914; locality E108. (4) F15915; locality E124.

Fig. 5, 6. Clavulinoides victoriensis Cushman, p. 91. 12 x. (5) F15916; locality V18. Microspheric form; a/ side view, b/ distal view. (6) F15917; locality E170. Megalospheric form.

Fig. 7 - 10. Dorothia parri Cushman, p. 92. 20 x. (7 a, b) F15918; locality E131. (8 a, b) F15919; locality E108. (9) F15920; locality E158. (10) F15921; locality E146.

Fig. 11, 12. Karreriella chilostoma (Reuss), p. 93, 50 x. Locality E154. (11 a, b) F15922. (12) F15923.

Fig. 13 a, b. Lagena luciae Parr, p. 94. 100 x. F15924; Naracoorte no. 2 bore, sample between 124 and 174 feet.

Fig. 14 a, b. Lagena caudata d'Orbigny, p. 96. 100 x. F15925; locality E154.

Fig. 15 a, b. Lagena cf. acuticosta Reuss, p. 97. 100 x. F15926; locality V120.

Fig. 16 - 18 Lagena sp., p. 98. 100 x. (16 a, b) F15927; locality E103. (17 a, b) F 15928; locality E120. (18) F15929; locality E61.

Fig. 19, 20. Nodosaria soluta (Reuss), p. 99. (19) 20 x. F15930; locality E21. (20) 40 x. F15931; from near locality E126.

Fig. 21. Dentalina consobrina d'Orbigny, p. 99. 40 x. F15932; locality E122.

Fig. 22 - 26. Dentalina sp. 1, p. 101. 12 x. (22) F15933; locality E25. (23) F15934; locality E86. (24) F15935; locality E26. (25) F15936; locality E108. (26) F15937; locality E147.

PLATE 9

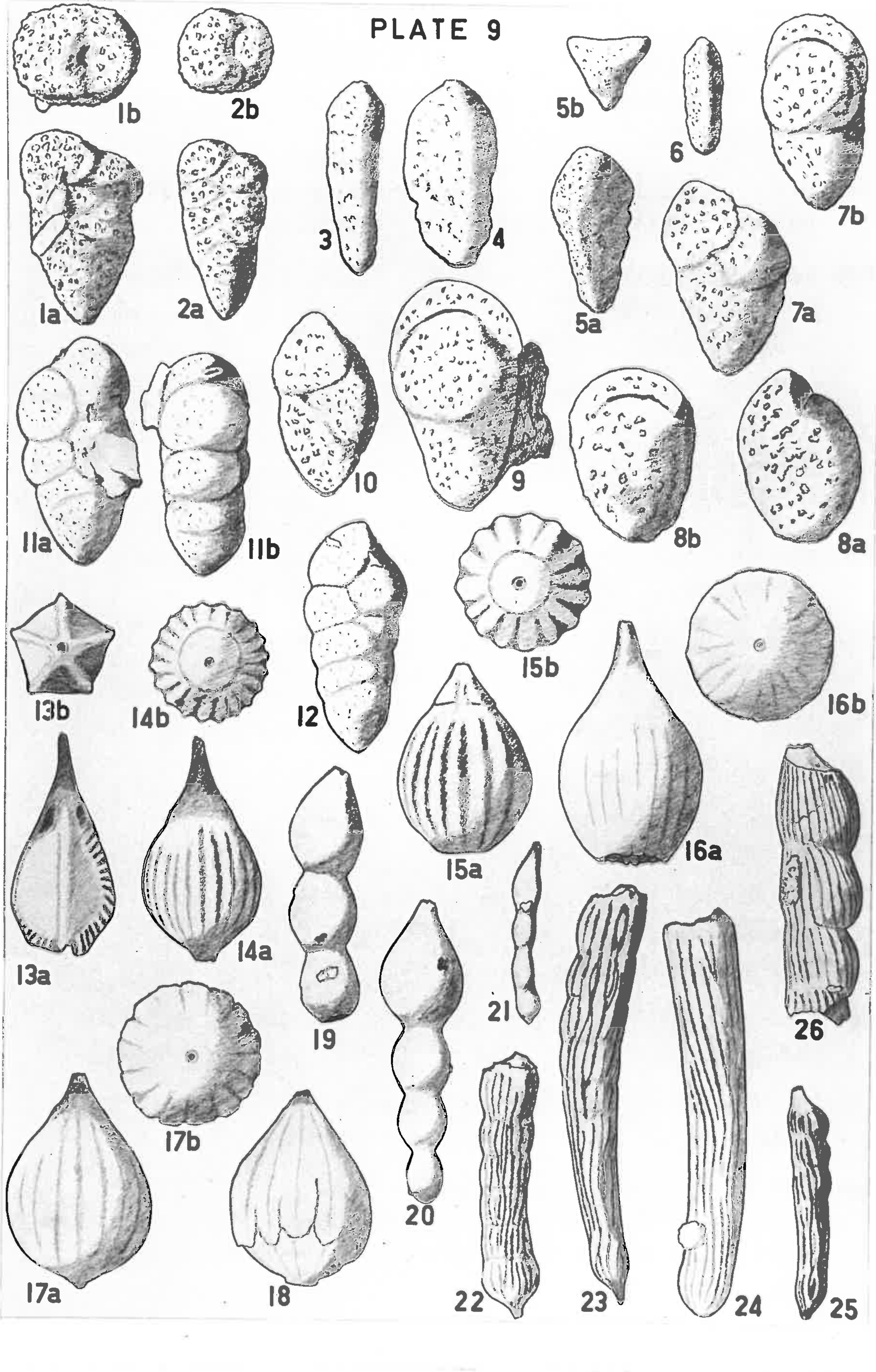
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PLATE 10

Fig. 1 - 3. Dentalina cf. communis d'Orbigny, p. 100. 40 x. (1) F15938; locality E154. (2) F15940; locality E53. (3) F15939; locality E154.

Fig. 4 a, b. Dentalina cf. mucronata Neugeboren, p. 100. 20 x. F15941; locality E67.

Fig. 5 a, b. Dentalina sp. 2, p. 102. 7 x. F15942; locality V18.

Fig. 6 - 8. Marginulina hantkeni Bandy, p. 102. 40 x. (6) F15943; locality E122. (7) F15944; locality E154. (8) F15945; locality E132.

Fig. 9 - 12. Marginulina cf. sendaiensis Asano, p. 104. 20 x. (9) F15946; locality E149. (10) F15947; locality E134. (11) F15948; Comcum bore, sample between 112 and 233 feet. (12) F15949; locality E114.

Fig. 13, 14. Marginulina cf. indica Le Roy, p. 105. 20 x. (13 a, b) F15950; locality E154. (14 a, b) F15951; locality E160.

Fig. 15 - 17. Vaginulina cf. sublituus (Nuttall), p. 106. 40 x. (15 a, b) F15952; locality E65. Microspheric form. (16) F15953; locality E65. Microspheric form. (17 a, b) F15954; locality E22. Megalospheric form.

Fig. 18 - 20. Vaginulina sp., p. 107. 12 x. (18 a, b) F15955; from near locality E128. (19) F15956; locality E65. (20 a, b) F15957; locality E139.

Fig. 21, 22. Lenticulina cf. gibba (d'Orbigny), p. 108. 40 x. (21 a, b) F15958; locality E154. (22 a, b) F15959; locality E170.

Fig. 23, 24. Robulus nikobarensis (Schwager), p. 109. 50 x. (23 a, b) F15960; locality E122. (24 a, b) F15961; locality E154.

Fig. 25 a, b. Robulus cf. clericii (Fornasini), p. 110. 40 x. F15962; locality E139.

PLATE 10

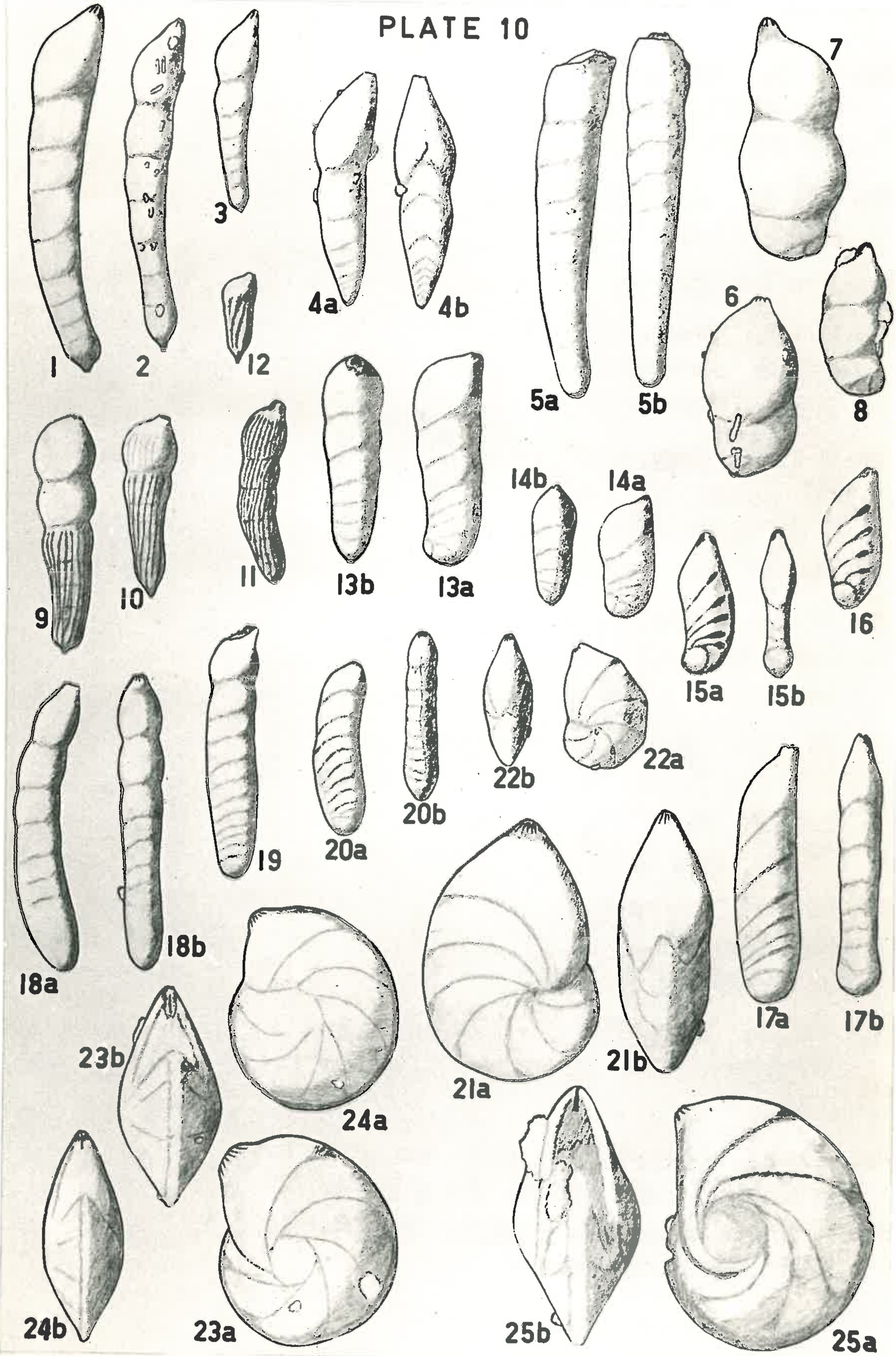
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PLATE 11

Fig. 1 - 3. *Robulus* cf. *limbatus* (Bornemann), p. 111. 40 x. (1 a, b) F15963; locality E125. (2 a, b) F15964; locality E22. (3 a, b) F15965; locality E26.

Fig. 4 a, b. *Robulus* cf. *venezuelanus* (Hedberg), p. 112. 50 x. F15966; locality E123.

Fig. 5. *Amphicoryne hirsuta* (d'Orbigny), p. 114. 50 x. F15967; locality E121.

Fig. 6, 7. *Amphicoryne* cf. *halkyardi* (Cushman), p. 115. 50 x. Naracoorte no. 2 bore, sample between 124 and 174 feet. (6) F15968. (7) F15969.

Fig. 8 - 14. *Amphicoryne* cf. *scalaris* (Batsch), p. 116. 50 x. (8) 15970; locality E119. (9) F15971; locality E119. (10) F15972; locality E106. (11) F15973; locality E106. (12) F15974; locality E87. (13) F15975; locality E122. (14) F15976; Naracoorte no. 2 bore, sample between 124 and 174 feet.

Fig. 15 - 16. *Lingulina metungensis* Chapman and Crespin, p. 118. 20 x. (15a, b) F15977; locality E110. (16 a, b) F15978; locality E140.

Fig. 17, 18. *Lingulina* sp., p. 119. 20 x. (17 a, b) F15979; locality E122. (18 a, b) F15980; locality E154.

Fig. 19 - 23. *Guttulina problema* (d'Orbigny), p. 121. 20 x. (19 a - c) F15981; locality E154. (20 a, b) F15982; locality E154. (21 a, b) F15983; locality E159. (22) F15984; locality E21. (23) F15985; locality E80.

Fig. 24. *Guttulina regina* (Brady, Parker and Jones), p. 122. 50 x. F15986; locality E26.

Fig. 25. *Guttulina pacifica* (Cushman and Ozawa), p. 123. 40 x. F15987; locality E139.

PLATE 11

(continued)

Fig. 26. Guttulina silvestrii Cushman and Ozawa, p. 123.
50 x. F15988; locality E65.

Fig. 27, 28. Guttulina cf. spicaeformis (Roemer), p. 124.
50 x. (27 a - c) F15989; locality E70. (28 a, b)
F15990; locality E64.

PLATE 11

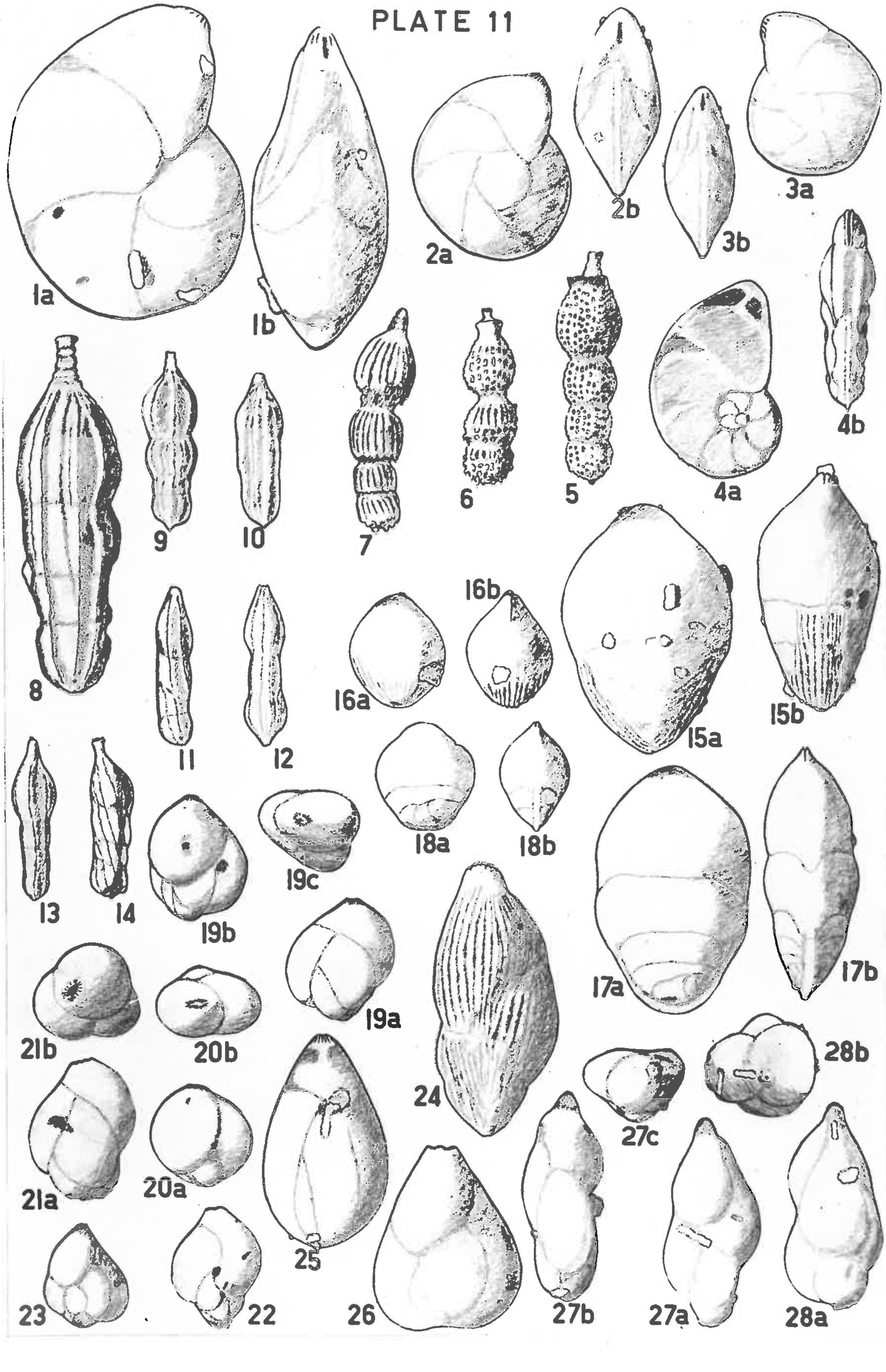

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PLATE 12

Fig. 1. *Pyrulina fusiformis* (Roemer), p. 125. 20 x. F15991; locality E56.

Fig. 2 - 4. *Globulina gibba* (d'Orbigny), p. 125. 20 x. (2 a, b) F15992; locality E159. (3a, b) F15993; locality E160. (4 a, b) F15994; locality E56.

Fig. 5 a - c. *Sigmomorphina chapmani* (Heron-Allen and Earland), p. 127. 40 x. F15995; locality E182.

Fig. 6 - 9. *Sigmomorphina subregularis* Howchin and Parr, p.128. 20 x. (6 a, b) F15996; locality E122. (7) F15997; locality E147. (8) F15998; locality E26. (9a, b) F15999; locality E65.

Fig. 10, 11. *Sigmomorphina* aff. *batesfordensis* Parr and Collins, p. 130. 50 x. (10 a - c) F16000; locality E154. (11 a - c) F16001; locality E41.

Fig. 12 a, b. *Sigmoidella elegantissima* (Parker and Jones), p. 130. 20 x. F16002; locality E139.

Fig. 13. *Glandulina laevigata* (d'Orbigny), p. 131. 50 x. F16003; locality E160.

Fig. 14 - 15. *Buliminella madagascariensis* (d'Orbigny), p. 133. 100 x. (14 a, b) F16004; locality E46. (15) F16005; locality E37.

Fig. 16a, b. *Bulimina* cf. *browni* Finlay, p. 134. 100 x. F16006; Naracoorte no. 2 bore, sample between 124 and 174 feet.

Fig. 17. *Virgulina* cf. *pontoni* Cushman, p. 135. 50 x. F16007; Naracoorte no. 2 bore, sample between 124 and 174 feet.

Fig. 18 - 21. *Uvigerina mioschwageri* Finlay, p. 135. 50 x. (18 a, b) F16008; locality E16. (19) F16009; locality E16. (20) F16010; locality E122. (21) F16011; locality E139.

Fig. 22 - 24. *Uvigerina striatissima* Perconig, p. 137. 50 x. Locality E123. (22 a, b) F16012. (23) F16013. (24) F16014.

PLATE 12

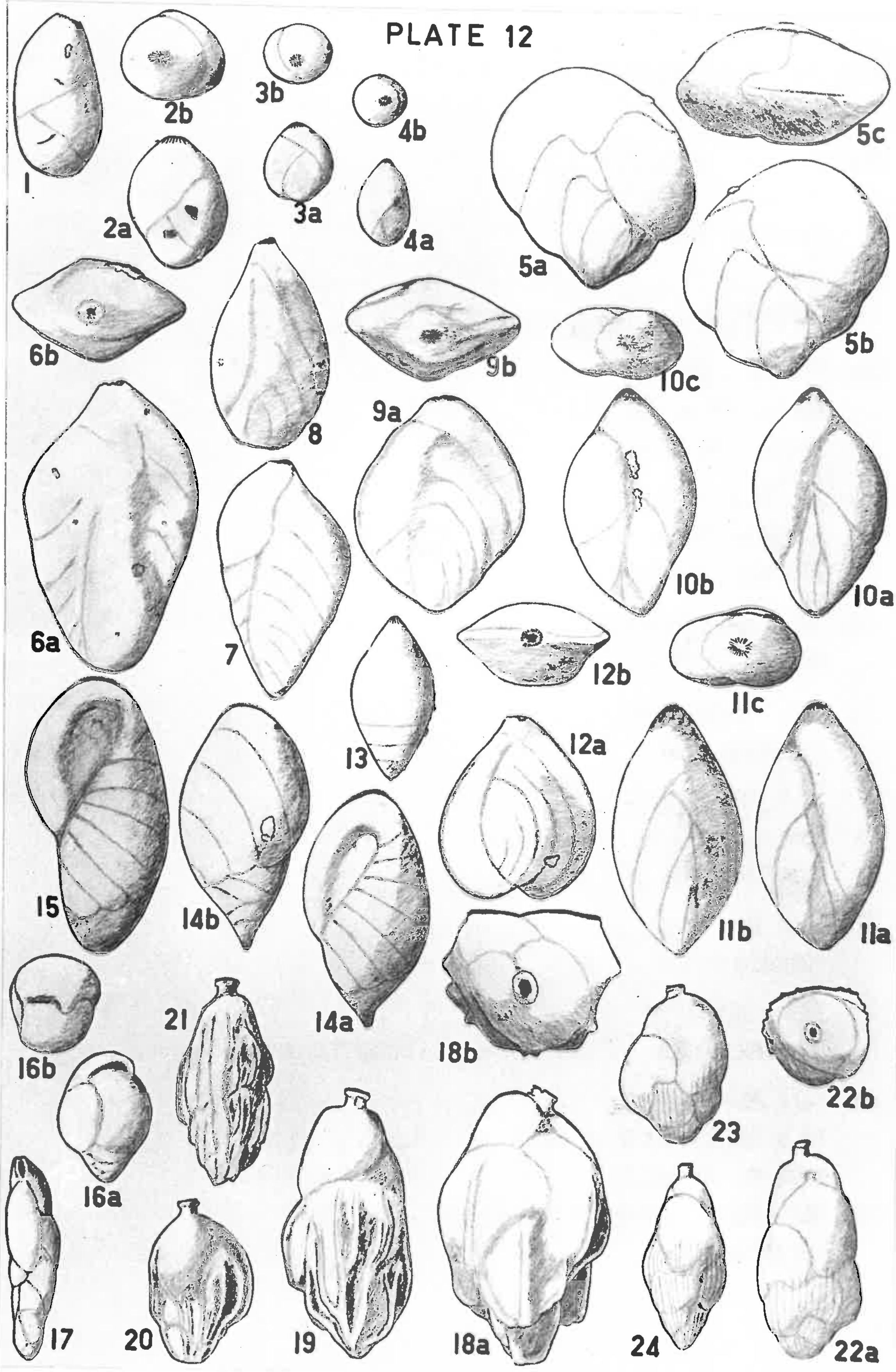
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PLATE 13

Fig. 1 - 3. Uvigerina gracilis Reuss, p. 138. 100 x. (1) F16015; Naracoorte no. 2 bore, sample between 124 and 174 feet. (2) F16016; locality E16. (3) F16017; locality E123.

Fig. 4, 5. Uvigerina australis Heron-Allen and Earland, p. 140. 100 x. (4 a, b) F16018; locality E58. (5) F16019; locality E29.

Fig. 6 - 8. Uvigerina cf. ciperana Cushman and Stainforth, p. 141. 100 x. (6 a, b) F16020; locality E45. (7) F16021; locality E45. (8) F16022; locality E106.

Fig. 9, 10. Uvigerina cf. germanica (Cushman and Edwards), p. 143. 100 x. (9). F16023; locality E141. (10 a, b) F16024; locality E96.

Fig. 11 - 13. Trifarina bradyi Cushman, p. 144. (11a, b) 100 x. F16025. Naracoorte no. 2 bore, sample between 124 and 174 feet. (12) 50 x. F16026; locality E 52. (13) 50 x. F16027; locality E103.

Fig. 14 - 16. Stilostomella jedlitschkai (Thalmann), p. 145. 40 x. (14) F16028; locality E119. (15) F16029; locality E16. (16) F16030; locality E121.

Fig. 17. Stilostomella sculpturata (Cushman), p. 146. 50 x. F16031; locality E61.

Fig. 18 - 21. Stilostomella cf. monilis (Silvestri) var. laevigata (Silvestri), p. 147. 50 x. (18) F16032; locality E119. (19) F16033; locality E123. (20) F16034; from near locality E129. (21) F16035; locality E139.

Fig. 22, 23. Bolivina lapsus Finlay, p. 148. 50 x. (22) F16036; locality E70. (23 a, b) F16037; locality E106.

Fig. 24, 25. Bolivina victoriana Cushman, p. 150. 100 x. (24 a, b) F16038; locality E166. (25) F16039; locality E43.

PLATE 13
(continued)

Fig. 26, 27. *Bolivina anastomosa* Finlay, p. 151. 100 x. (26) F16040; Comaum bore, sample between 112 and 233 feet. (27 a - c) F16041; locality E43.

Fig. 28 - 30. *Bolivina* cf. *fastigia* Cushman, p. 153. 100 x. (28 a - c) F16042; locality E141. (29) F16043; locality E141. (30) F16044; Naracoorte no. 2 bore, sample between 124 and 174 feet.

PLATE 13

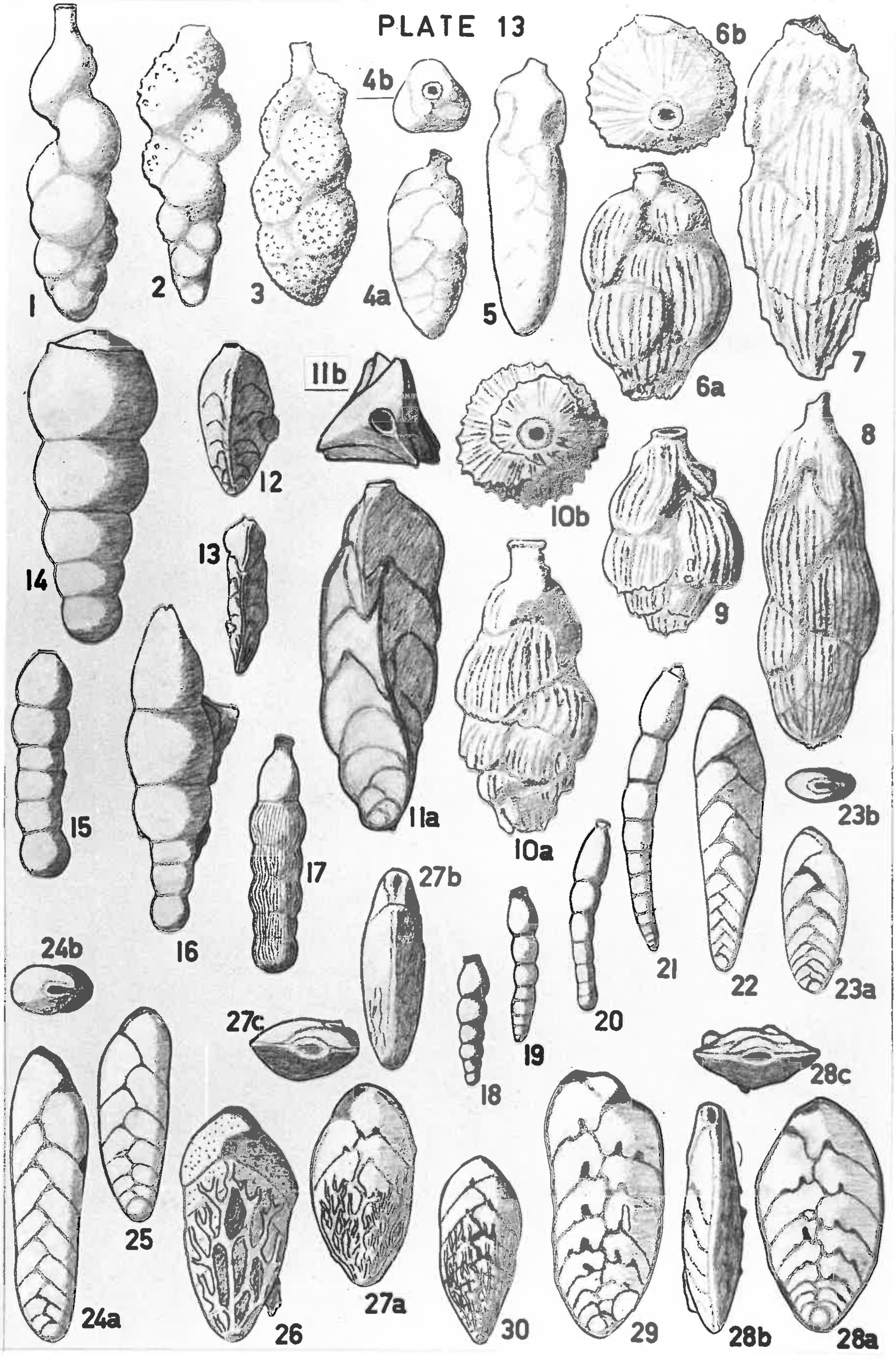
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PLATE 14

All figures magnified 100 x.

Fig. 1, 2. Oolina tasmanica Parr, p. 154. (1 a, b) F16045; locality E123. (2) F16046; locality E61.

Fig. 3, 4. Oolina hexagona (Williamson), p. 155. (3) F16047; Naracoorte no. 2 bore, sample between 124 and 174 feet. (4) F16048; locality E154.

Fig. 5. Oolina lineata (Williamson), p. 157. F16049; Naracoorte no. 2 bore, sample between 174 and 206 feet.

Fig. 6 - 8. Oolina desmophora (Jones), p. 157. Locality E182. (6) F16050. (7) F16051. (8) F16052.

Fig. 9 - 11. Oolina aff. Lagena curvicostata Heron-Allen and Earland, p. 158. (9 a, b) F16053; locality V120. (10 a,b) F16054; locality E139. (11) F16055; locality E182.

Fig. 12. Oolina cf. Lagena flexa Cushman and Grey, p. 160. F16056; locality E182.

Fig. 13 a, b. Fissurina flintiana (Cushman), p. 160. F16057; locality V34.

Fig. 14 a, b. Fissurina bifida (Heron-Allen and Earland), p. 162. F16058; Naracoorte no. 2 bore, sample between 124 and 174 feet.

Fig. 15 a, b. Fissurina annectens (Burrows and Holland), p. 163. F16059; Naracoorte no. 2 bore, sample between 124 and 174 feet.

Fig. 16 a, b. Fissurina subcircularis Parr, p. 164. F16060; locality E182.

Fig. 17 a - e. Fissurina aff. terrilli (Parr), p. 165. F16061; locality E61.

Fig. 18 a - e. Fissurina cf. carinata Reuss, p. 165. F16062; locality E61.

PLATE 14
(continued)

Fig. 19 a, b. *Fissurina* cf. *globosa* Bornemann, p. 166.
F16063; locality E164.

Fig. 20, 21. *Cassidulina cushmani* R.E. and K.C. Stewart, p. 169.
(20 a - e) F16064; locality E139. (21 a - e) F16065;
Naracoorte no. 2 bore, sample between 124 and 174 feet.

PLATE 14

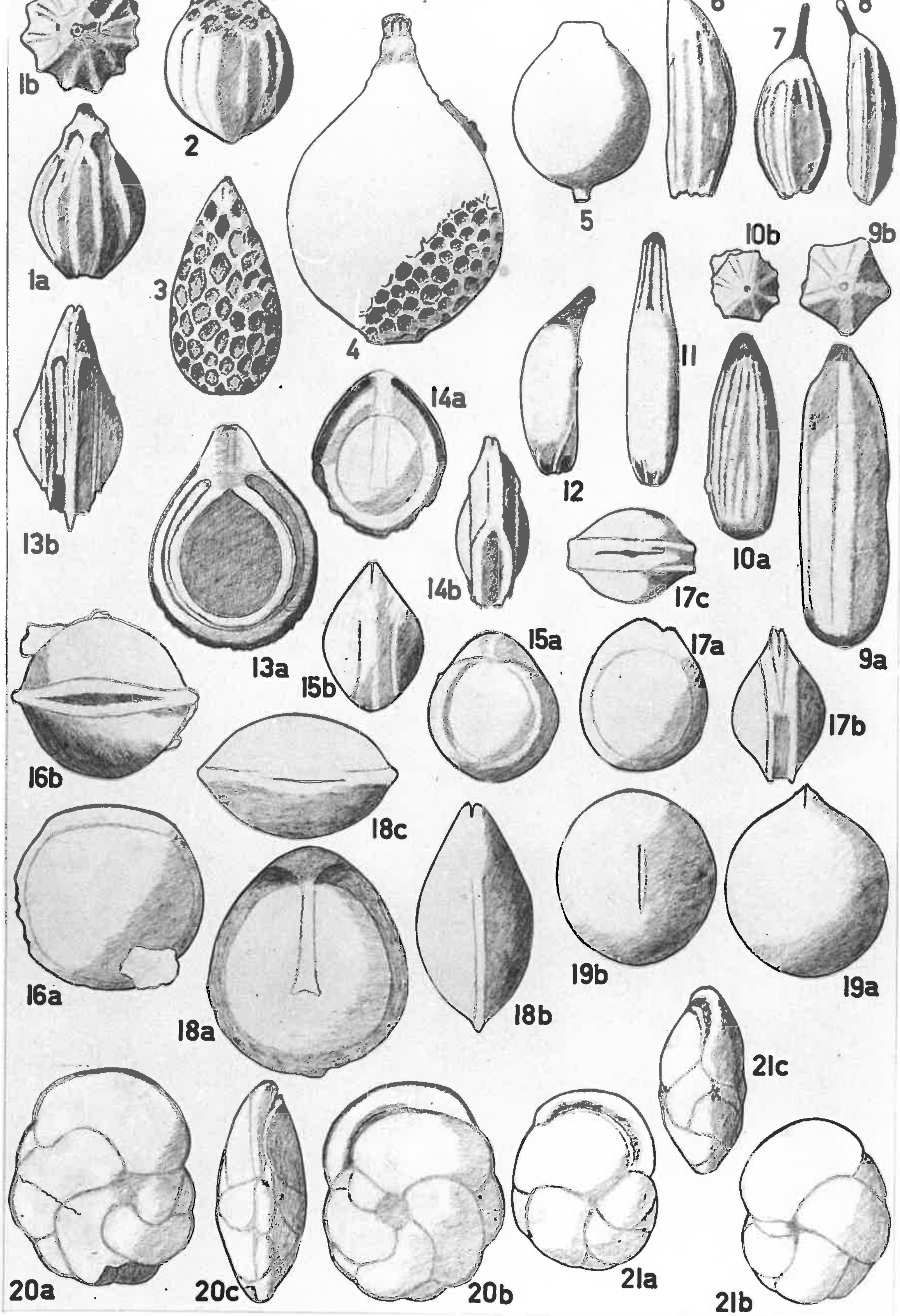

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PLATE 15

All figures magnified 100 x.

Fig. 1 - 3. Cassidulina subglobosa Brady, p. 168. (1 a - c) F16066; Naracoorte no. 2 bore, sample between 124 and 174 feet. (2) F16067; locality E54. (3 a - c) F16068; locality E154.

Fig. 4 a - c. Cassidulina cf. alabamensis Bandy, p. 171. F16069; locality E154.

Fig. 5 a - c. Cassidulina cf. laticamerata Voloshinova, p. 172. F.16070; locality E46.

Fig. 6 a - c. Cassidulina cf. williami Kleinpell, p. 173. F16071; locality E63.

Fig. 7, 8. Ehrenbergina aff. healyi Finlay, p. 174. Locality E168. (7 a - c) F16072. (8 a, b) F16073.

PLATE 15

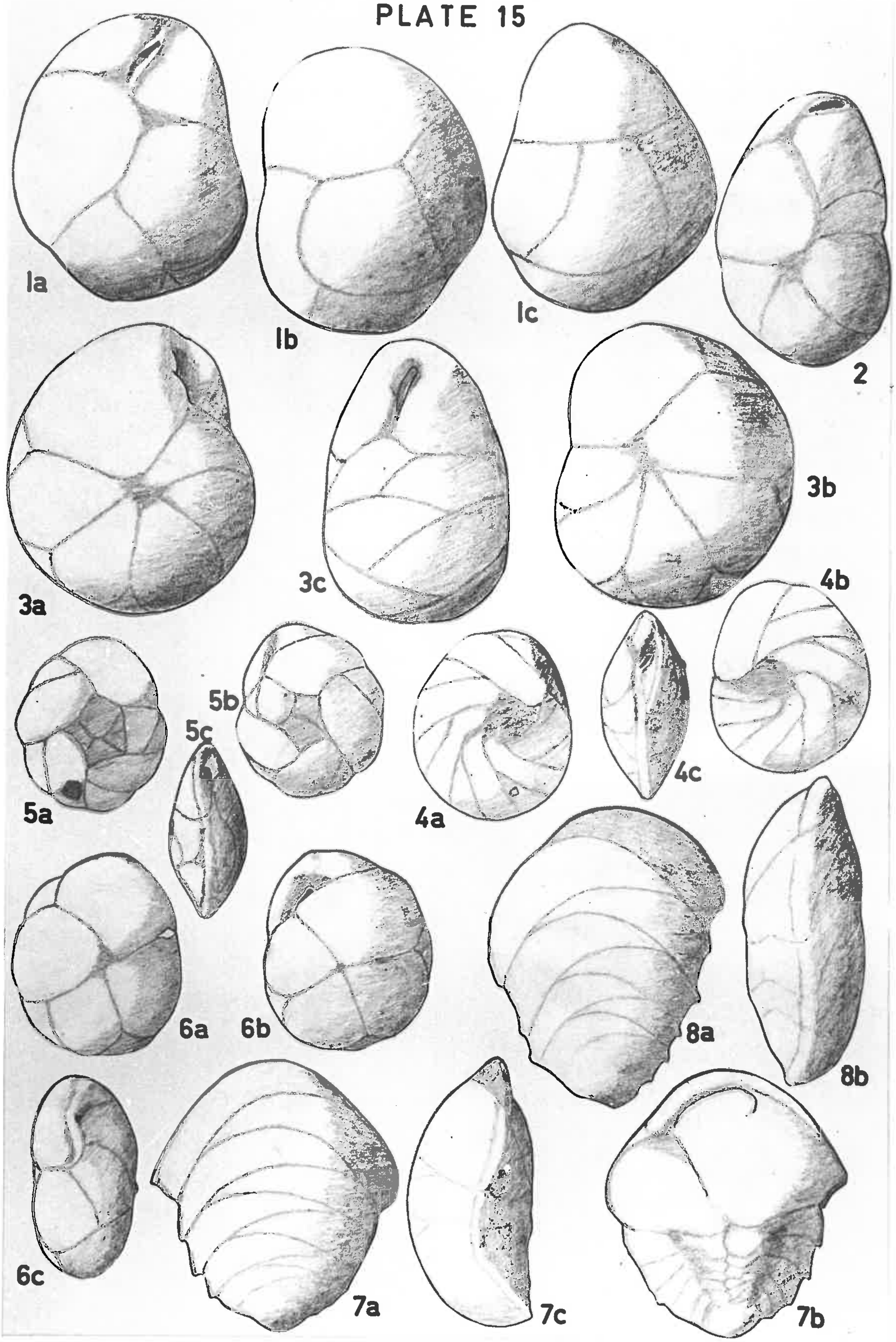

PLATE 16

Fig. 1, 2. Pleurostomella elliptica Galloway and Heminway, p. 176. 50 x. (1 a, b) F16074; locality E116. (2 a, b) F16075; locality E158.

Fig. 3, 4. Nodosarella sp., p. 176. 40 x. (3 a, b) F16076; locality E46. (4) F16077; locality E53.

Fig. 5 a, b. Parafissurina cf. lata (Wiesner), p. 177. 100 x. F16078; locality E164.

Fig. 6, 7. Parafissurina sp., p. 177. 100 x. (6 a, b) F16079; locality E154. (7) F16080; locality E61.

Fig. 8 a, b. Pullenia bulloides (d'Orbigny), p. 179, 100 x. F16081; locality E61.

Fig. 9 - 11. Sphaeroidina bulloides d'Orbigny, p. 181. (9) F16082; Naracoorte no. 2 bore, sample between 124 and 174 feet. (10) F16083; locality as for F16082. (11) F16084; locality E61.

Fig. 12, 13. Discorbis balcombensis Chapman, Parr and Collins, p. 184. 100 x. (12) F16085; locality E134. a/ dorsal view, b/ ventral view, c/ peripheral view. (13 a, b) F16086; locality E139.

Fig. 14. Discorbis cf. micens Cushman, p. 187. 50 x. F16087; locality E154. a/ dorsal view, b/ ventral view c/ peripheral view.

Fig. 15. Valvulineria cf. texana Cushman and Ellisor, p. 189. 100 x. F16088; locality E161. a/ dorsal view, b/ ventral view, c/ peripheral view.

PLATE 16

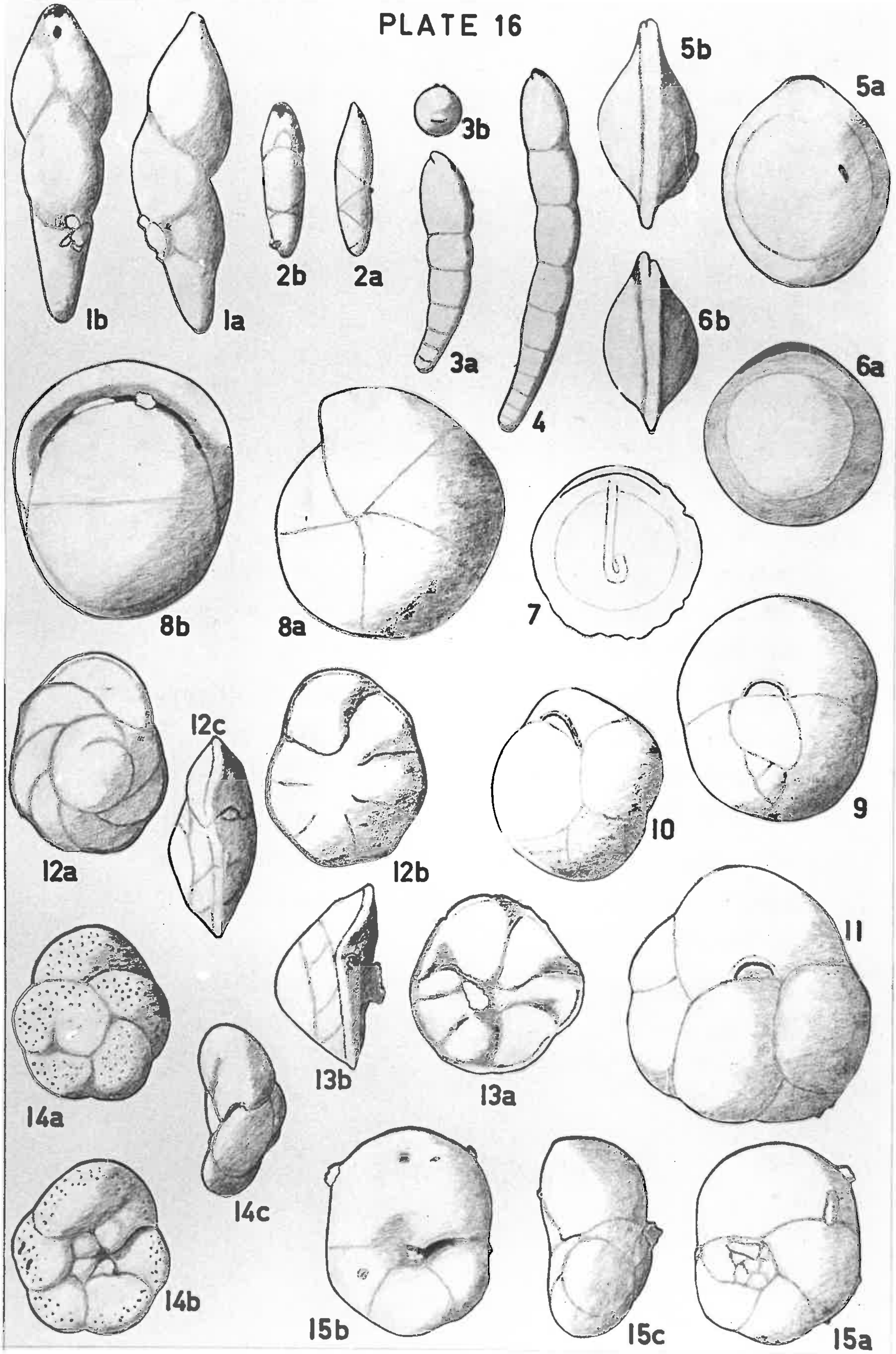

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PLATE 17

Fig. 1, 2. Gyroidinoides zelandica (Finlay), p. 191. (1) 100 x. F16089; locality E139. a/dorsal view, b/ ventral view, c/ peripheral view. (2 a - c) 50 x. F16090; locality V119.

Fig. 3 - 5. Gyroidinoides cf. soldanii (d'Orbigny), p. 193. 100 x. (3) F16091; locality E182. a/ dorsal view, b/ ventral view, c/ peripheral view. (4 a - c) F16092; locality E138. (5) F16093; locality E143.

Fig. 6 - 12. Eponides lornensis Finlay, p. 194. 20 x. (6) F16094; Mt. Gambier town hall sink hole. a/ ventral view, b/ peripheral view. (7) F16095; Mt. Gambier town hall sink hole. a/ dorsal view, b/ ventral view c/ peripheral view. (8 a - c) F16096; locality V18. (9 a, b) F16097; locality E159. (10 a, b) F16098; locality E116. (11 a, b) F16099; locality E16. (12) F16100; locality E46.

PLATE 17

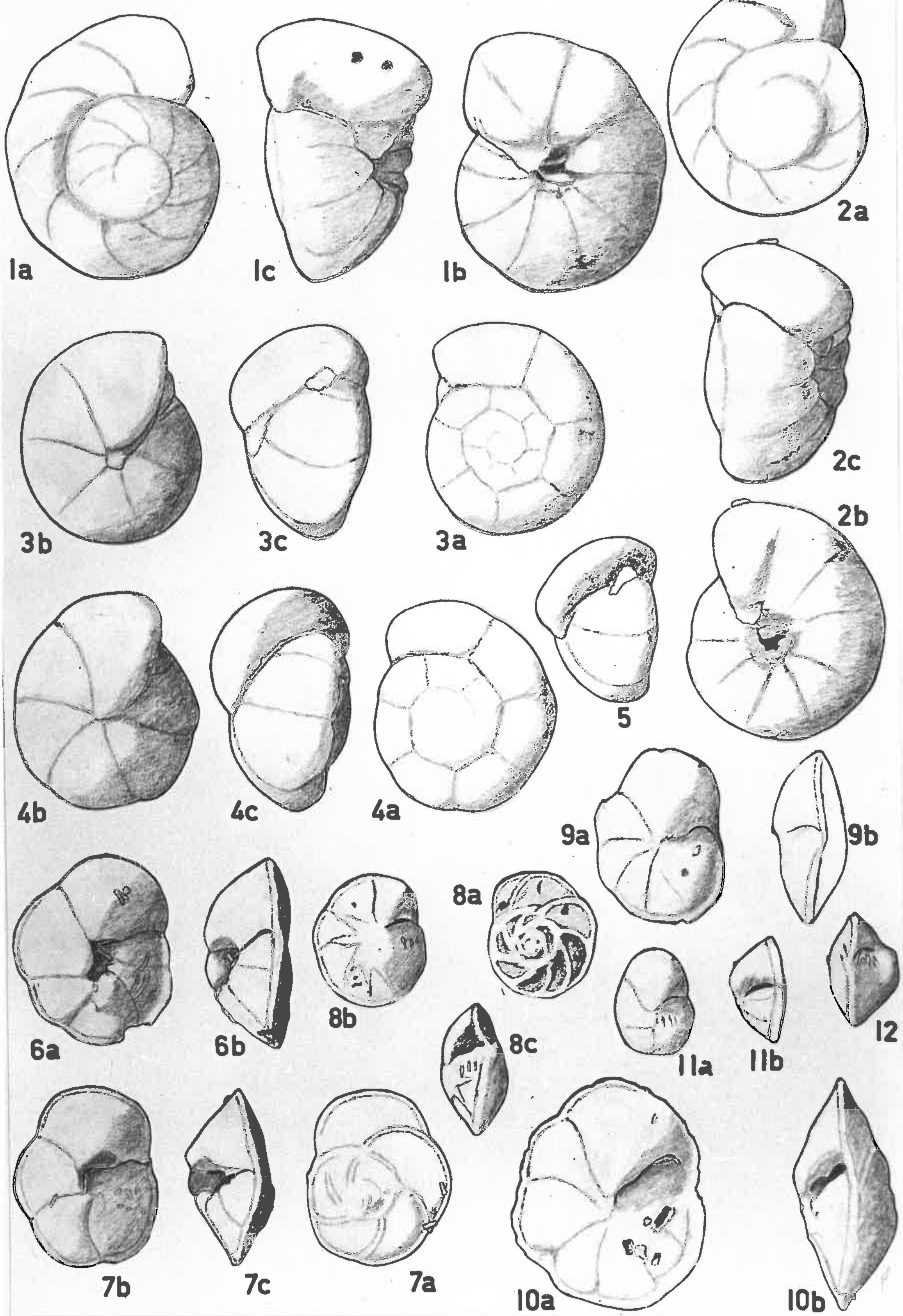
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PLATE 18

Fig. 1, 2. *Alabamina tenuimarginata* (Chapman, Parr and Collins), p. 197. (1) 100 x. F16101; locality E139. a/ dorsal view, b/ ventral view, c/ peripheral view. (2 a - c) 50 x. F16102; locality E50.

Fig. 3. *Siphonina australis* Cushman, p. 199. 50 x. F16103; locality E37. a/ dorsal view, b/ ventral view, c/ peripheral view.

Fig. 4. *Anomalinoides macraglabra* (Finlay), p. 202. 50 x. F16104; locality E61. a/ dorsal view, b/ ventral view, c/ peripheral view.

Fig. 5. *Cibicides mediocris* Finlay, p. 207. 50 x. F16105; locality E65. a/ dorsal view, b/ ventral view, c/ peripheral view.

Fig. 6, 7. *Cibicides catillus* Finlay, p. 209. 50 x. (6a) F16106; locality E163. a/ dorsal view, 6b/ F16159; locality E101. peripheral view. (7) F16107; locality E154. a/dorsal view, b/ ventral view, c/ peripheral view.

Fig. 8, 9. *Cibicides novozelandicus* (Karrer), p. 210. 50 x. Locality E143. (8) F16108. a/ dorsal view, b/ ventral view, c/ peripheral view. (9) F16109.

Fig. 10. *Cibicides thiara* (Stache), p. 212. 40 x. F16110; locality E154. a/ dorsal view, b/ ventral view, c/ peripheral view.

Fig. 11 - 14. *Cibicides* cf. *lobatulus* (Walker and Jacob), p. 213. 50 x. (11) F16111; locality E17. a/ dorsal view, b/ ventral view, c/ peripheral view. (12) F16112; locality E17. (13 a - c) F16113; locality E70. (14) F16114; Naracoorte no.2 bore, sample between 124 and 174 feet.

PLATE 18

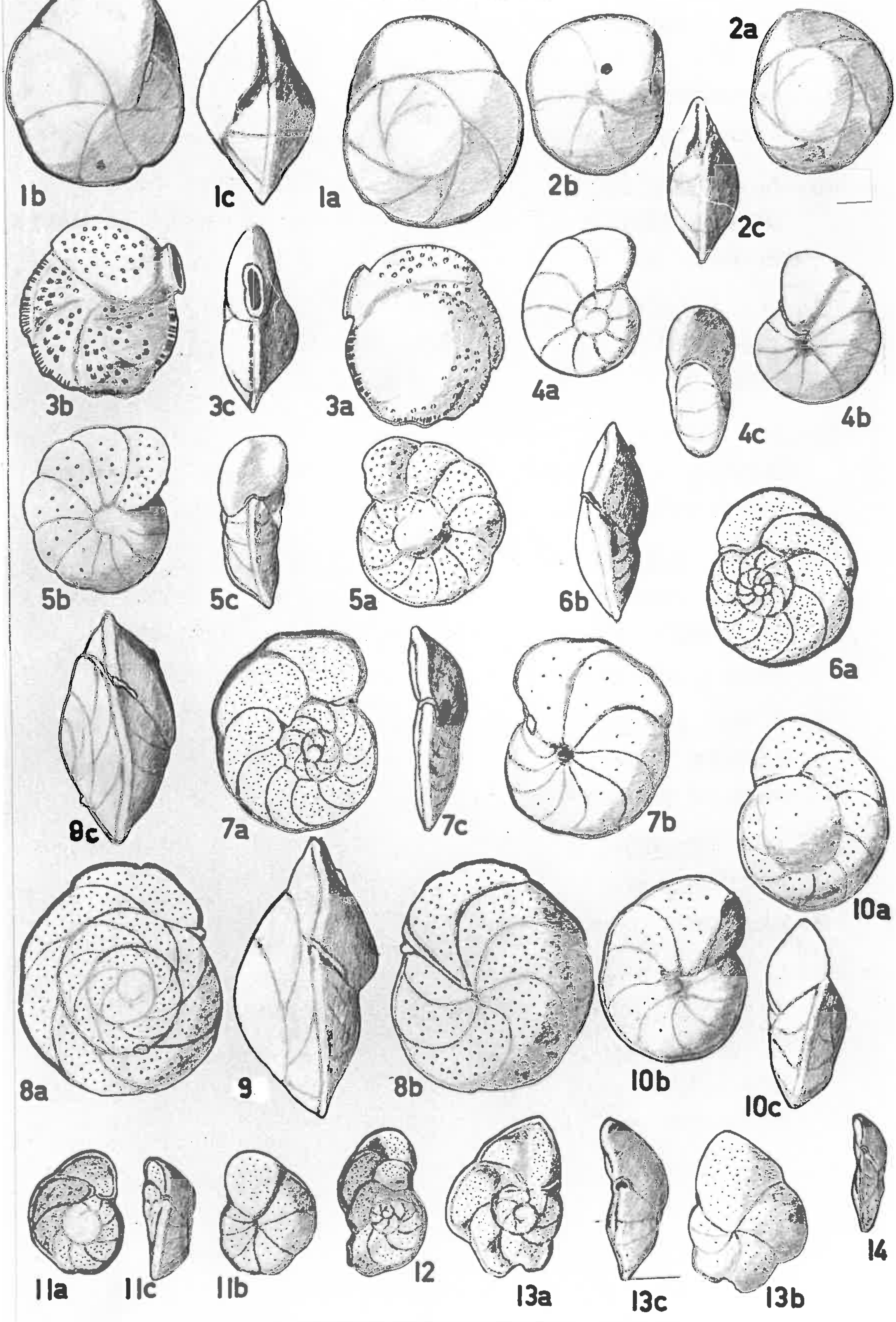
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PLATE 19

Fig. 1 - 3. Cibicides cf. refulgens Montfort, p. 215. 50 x. (1) F16115; locality E83. a/ dorsal view, b/ ventral view, c/ peripheral view. (2) F16116; locality E83. (3a, b) F16117; locality E82.

Fig. 4. Cibicides cf. subhaidingeri Parr, p. 216. 50 x. F16118; locality E53. a/ dorsal view, b/ ventral view, c/ peripheral view.

Fig. 5, 6. Cibicides sp., p. 216, 50 x. (5) F16119; locality E19. a/ dorsal view, b/ ventral view, c/ peripheral view. (6 a - c) F16120; locality E16.

Fig. 7, 8. Vagocibicides maoria Finlay, p. 218. 50 x. Locality E61. (7) F16121. Ventral view. (8) F16122. a/ dorsal view, b/ marginal view, c/ distal view.

Fig. 9, 10. Hanzawaia scopos (Finlay), p. 219. (9) 50 x. F16123; locality E61. a/ dorsal view (apertual flaps broken), b/ ventral view, c/ peripheral view. (10) 100 x. F16124; locality E119.

Fig. 11 - 15. Globigerina bulloides d'Orbigny, p. 228. 50 x. F16125, F16126 and F16127; Naracoorte no. 2 bore, sample between 47 and 78 feet. F16128, F16129; locality E56. (11) F16125. a/ dorsal view, b/ ventral view, c/ peripheral view. (12 a, b) F16126. (13) F16127. (14) F16128. (15) F16129.

Fig. 16 - 21. Globigerina ampliapertura Bolli, p. 231. 50 x. (16) F16130; locality E168. a/ dorsal view, b/ ventral view, c/ peripheral view. (17) F16131; locality E168. (18) F16132; locality E19. (19) F16133; locality E61. (20) F16134; locality E89. (21) F16135; locality E24.

Fig. 22. Globigerina ciperoensis Bolli, p. 233. 100 x. F16136; locality E108. a/ dorsal view, b/ ventral view, c/ peripheral view.

PLATE 19

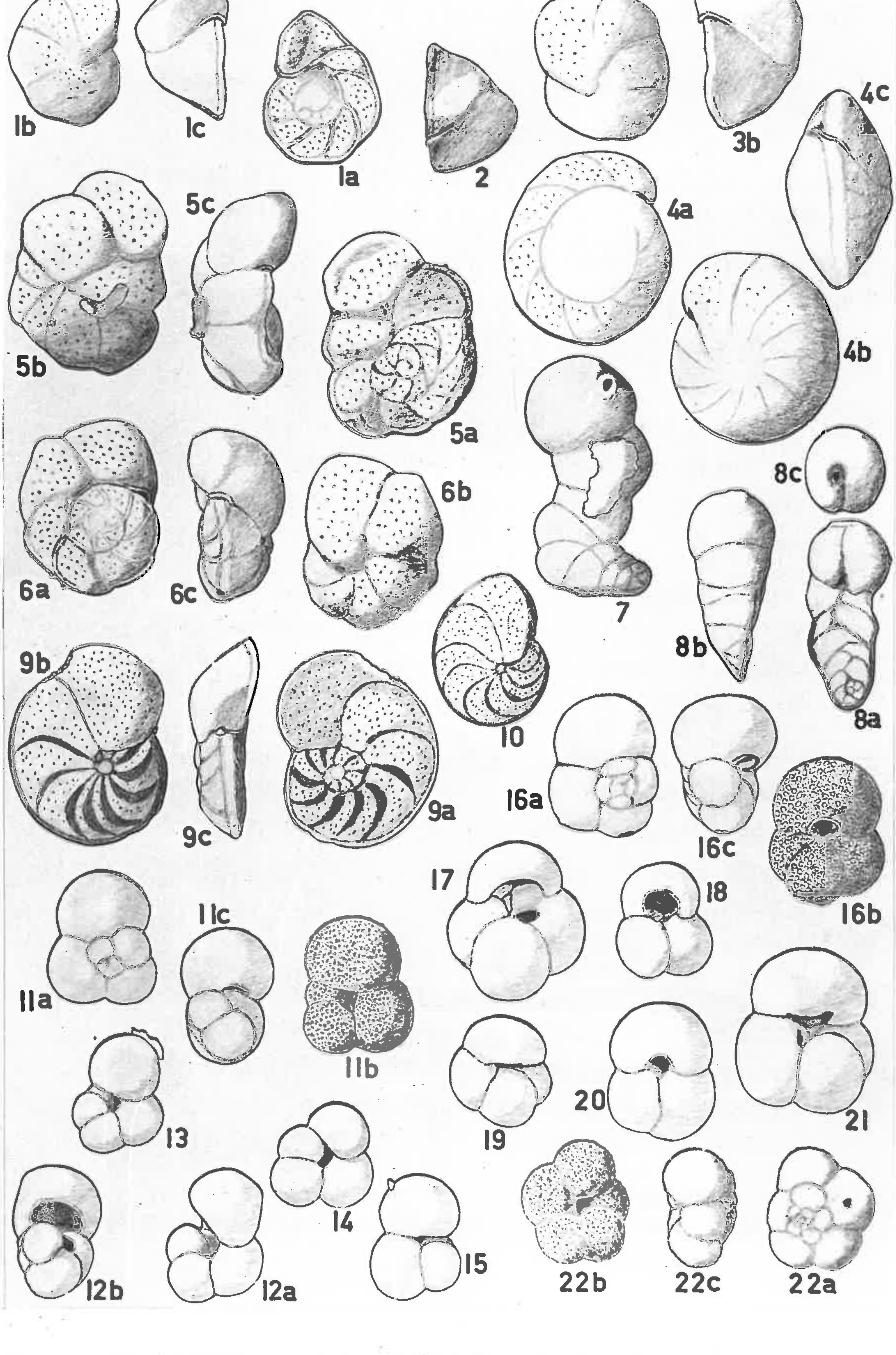
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PLATE 20

Fig. 1, 2. Globigerina juvenilis Bolli, p. 235. 100 x. (1) F16137; locality E22. a/ dorsal view, b/ ventral view, c/ peripheral view. (2) F16138; locality E58.

Fig. 3. Globigerina sp., 236. 100 x. F16139; locality E182. a/ dorsal view, b/ ventral view, c/ peripheral view.

Fig. 4 a, b. Gumbelitria sp., p. 240. 100 x. F16140; Comaum bore, sample between 338 and 343 feet.

Fig. 5 - 9. Globorotalia opima Bolli, p. 240. 50 x. (5) F16141; locality E78. a/ dorsal view, b/ ventral view, c/ peripheral view. (6 a - c) F16142; locality E123. (7) F16143; locality E123. (8) F16144; locality E79. (9) F16145; locality E54.

Fig. 10 - 13. Globorotalia zealandica Hornibrook, p. 242. 50 x. (10) F16146; locality E16. a/ dorsal view, b/ ventral view, c/ peripheral view. (11 a - c) F16147; locality E16. (12) F16148; locality E16. (13) F16149; locality E122.

Fig. 14 - 16. Globorotalia scitula (Brady), p. 244. 100 x. Locality E97. (14) F16150. a/ dorsal view, b/ ventral view, c/ peripheral view. (15) F16151. (16) F16152.

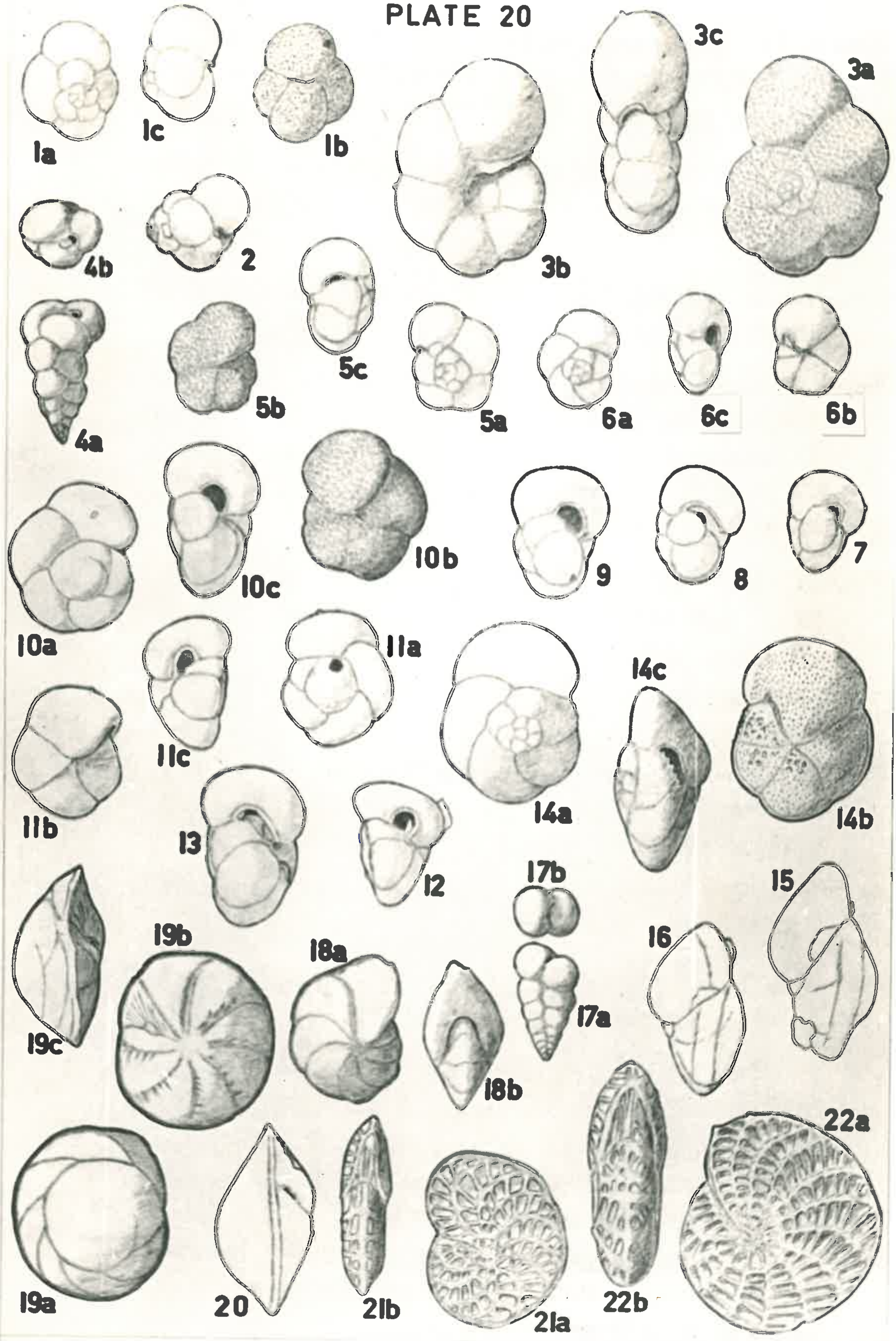
Fig. 17 a, b. Chilogumbelina sp., p. 247. 100 x. F16153; locality V120.

Fig. 18 a, b. Nonion cf. pauperatum (Balkwill and Wright), p. 247. 100 x. F16154; locality E70.

Fig. 19, 20. Notorotalia gambierense sp. nov., p. 250. 50 x. Locality E185. (19) Holotype, F16155. a/ dorsal view, b/ ventral view, c/ peripheral view. (20) Paratype, F16156. Peripheral view; last chamber is broken and foramen of penultimate chamber is visible.

Fig. 21, 22. Parrellina aff. verriculata (Brady), p. 253. (21) F16157; locality E58. (22) F16158; Naracoorte no. 2 bore, sample between 78 and 124 feet.

PLATE 20



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