DEPARTMENT OF MINERALS AND ENERGY
BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

BULLETIN 140

PALAEONTOLOGICAL PAPERS, 1970-71

AUSTRALIAN GOVERNMENT PUBLISHING SERVICE
CANBERRA 1973

DEPARTMENT OF MINERALS AND ENERGY
MINISTER: THE HON. R. F. X. CONNOR, M.P.
SECRETARY: SIR LENOX HEWITT, O.B.E.

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS
DIRECTOR: N. H. FISHER
ASSISTANT DIRECTOR, GEOLOGICAL BRANCH: J. N. CASEY

Published for the Bureau of Mineral Resources, Geology and Geophysics by the Australian Government Publishing Service

ISBN 0 64200328 9

Manuscript received: 1971
Issued: August 1973

Printed by Graphic Services Pty Ltd, 60 Wyatt Street, Adelaide 5000

CONTENTS

TERTIARY LARGER FORAMINIFERA FROM NEW BRITAIN, PNG

by J. G. BINNEKAMP

SUMMARY

Ages of three formations from New Britain are discussed. Dating is based on larger and some diagnostic smaller Foraminifera. Tb faunas include species of *Biplanispira, Pellatispira, Nummulites, Spiroclypeus,* and *Halkyardia;* lower Te faunas include species belonging to *Lepidocyclina* (subgenera *Eulepidina* and *Nephrolepidina*), *Cycloclypeus,* and *Halkyardia,* and faunas dated from upper Te to upper Tf comprise species of *Lepidocyclina* (subgenus *Nephrolepidina*), *Cycloclypeus* (subgenus *Cycloclypeus* and *Katacycloclypeus*), *Austrotrillina,* and *Flosculinella.* Twenty-one species are discussed and figured.

INTRODUCTION

From 1966 to 1967 geologists of the Bureau of Mineral Resources (BMR) and of the Geological and Volcanological Branch of the Department of Lands, Surveys and Mines, Port Moresby, carried out regional geological mapping of New Britain. Several hundred samples of sedimentary rocks collected for palaeon-

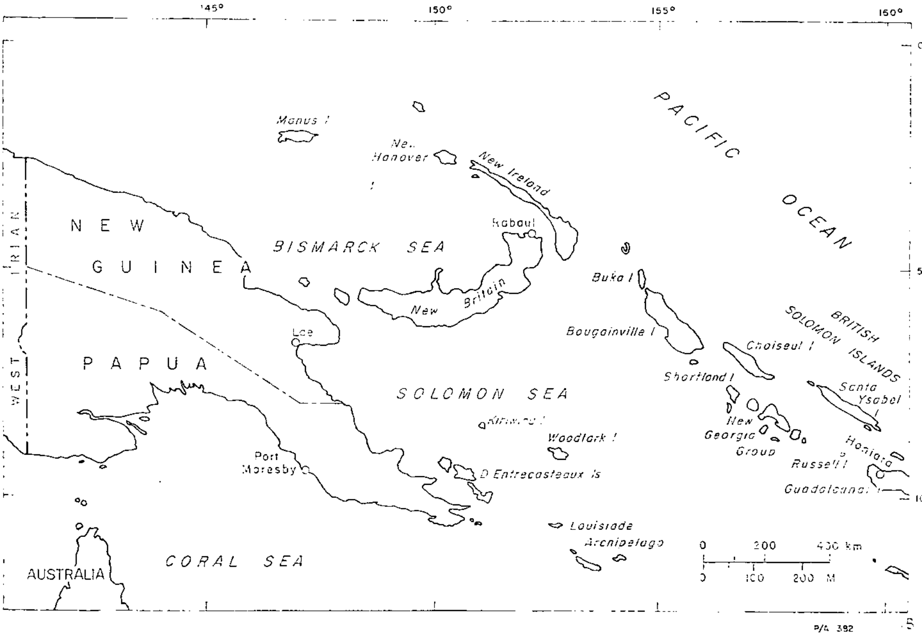


Fig. 1. Locality map.

tological examination were examined by the writer. The associations of Foraminifera indicated ages of Tb, lower Te, and upper Te through to upper Tf for the three oldest lithological units found on the island. The larger Foraminifera and some diagnostic smaller Foraminifera are recorded and illustrated.

Previous investigations

Schubert (1911, pp. 28-29) mentioned *Lepidocyclina* cf. *verbeeki, Operculina complanata, Amphistegina lessoni,* and *Miogypsina complanata?* from a limestone sample from the Baining Mountains, Gazelle Peninsula.

Between November 1938 and February 1939, L. C. Noakes made a reconnaissance survey of parts of New Britain (Noakes, 1942); the fauna of Noakes' samples was studied by I. Crespin (Appendix II *in* Noakes, 1942). Noakes recognized a basement of metamorphosed sediments ('Baining Series') overlain by at least two Tertiary units ('Neogene Series' and 'Lamogai Series') each unconformable on the preceding unit. From the 'Neogene Series', formed predominantly by limestones, Crespin recorded:

Lepidocyclina cf. *sumatrensis*
L. ferreroi
Miogypsina sp.
M. cf. *kotoi*
M. polymorpha
Cycloclypeus cf. *carpenteri*
Trillina howchini
Alveolinella bontangensis
Neoalveolina
Operculinella
Planorbulinella larvata

On the occurrence of these faunas the limestones were dated as Tf stage. The material available to Crespin is now in the BMR palaeontological collections and has been checked by the writer. The determinations were based mainly on random sections and the specific determinations are therefore in many cases doubtful. Most age determinations appear correct, except for the specimens from a locality '3 miles W to SW of Ramasaka Village, 25 miles SW of Rabaul'. From this sample, Crespin recorded as characteristic larger Foraminifera:

Lepidocyclina (*Eulepidina*) *richtofeni* (microspheric)
L. aff. *rutteni* forma *globosa*
L. aff. *spatiosa*
L. tournoueri
Cyclocypeus annulatus
Amphistegina lessoni
Operculina sp.

From the occurrence of *L.* (*E.*) *richtofeni* Crespin regarded the age of the rock as Te. The identification, however, is incorrect; Crespin's slides show a microspheric form which does not belong to the subgenus *Eulepidina,* but is probably close to such forms as *L. gigantea* (Martin), recorded by Caudri (1939) from upper Tf. No specific determination of the megalospheric form is possible on the available material, but it certainly belongs to the subgenus *Nephrolepidina.* This association together with *Cycloclypeus* (*Katacycloclypeus*) indicates Tf, most likely upper Tf.

Hanzawa (1947) recorded *Pellatispira reticularis* sp. nov. together with other Eocene species from a limestone pebble found in the Nakanai region. This species has since then been put in the synonymy of *P. rutteni* (see discussion of *P. madaraszi*). Small collections made during hydrological surveys in the Gazelle Peninsula have since been examined (Belford, 1968), but larger Foraminifera were determined only to subgeneric level. Some of these samples have been re-examined and are included in this paper.

From 1966 to 1969 geologists from BMR and from the Geological and Volcanological Branch of the Department of Lands, Surveys and Mines, Port Moresby, carried out reconnaissance geological mapping of the whole of New Britain. During these surveys several hundred samples of sedimentary rocks were collected and examined by the writer; they form the basis for this study. The first results of the geological mapping were presented by Macnab (1970) in a report on the geology of the Gazelle Peninsula, accompanied by a preliminary edition of a 1:250 000 geological map of this area. The palaeontological collections are housed in BMR.

Nature of the material

Except for five samples which could be broken up by repeated freezing and thawing, all the samples containing larger Foraminifera were hard limestones from which no free specimens could be obtained. Examination usually began with preparation of some random sections. Additional specimens of a particular species were then selected on polished slices of the sample. Grinding another plane at right angles to the polished surface and just touching the periphery of the selected specimen showed its orientation and allowed preparation of oriented sections. Although slow and laborious, this is the only way to prepare such sections. Unfortunately, this method cannot be used for asymmetrical forms such as *Miogypsina,* and although this genus is among the most common in the Miocene limestones in New Britain, no specific determinations have been made.

INTERPRETATION OF THE AGE OF THE FAUNAS

The primary aim of the study was to establish the ages of the different lithological units distinguished in New Britain. The main handicap in doing this has been the lack of continuous exposed sections: virtually the whole island is covered by thick tropical forest and exposure is poor. Also, the older rocks are strongly faulted and folded, and the younger ones are mostly flat-lying and only well exposed in cliffs too steep to climb, the outcrop on less steep slopes being sparse and overgrown. The main source of material has been spot samples, either from outcrop, the approximate position of which within the sedimentary succession was sometimes known, or quite often from 'float' samples of unknown origin. The problem thus became one of arranging the samples according to their faunal content, thus determining the stratigraphic range of the formations.

For this purpose the Foraminifera were the most suitable fossils as they are quite common in the sediments found in New Britain and their succession in the Tertiary of the Indo-Pacific region is fairly well known. The Foraminifera found in New Britain are larger benthonic Foraminifera and planktonic and benthonic smaller Foraminifera. Samples containing larger Foraminifera were initially arranged using the East Indian letter stages based on the associations of genera, subgenera, and in some cases species. Although valuable for generalized correlations this system is insufficient for detailed correlations and, as has also been pointed out, it does not take into account the fact that occurrences of some genera are facies-controlled. Other methods have been developed using the evolutionary changes of some genera and their value in stratigraphy (e.g. *Miogypsina, Cycloclypeus,* and *Lepidocyclina*).

Miogypsina is one of the most abundant larger Foraminifera in New Britain, but it occurs mostly in massive limestone. Drooger's method (1952) of analysis could therefore not be followed as this requires well preserved, free specimens. *Cycloclypeus* is uncommon in New Britain samples and equatorial sections, necessary for identification, are hard to prepare.

From three samples only one equatorial section per sample was obtained; a fourth sample yielded several sections, prepared from free specimens. As Tan's method (1932) is based on statistical measurements of a great number of sections, the results from these sections can be taken only as indications of the stratigraphic positions of the samples. However, the results seem to fit in well with other evidence.

Lepidocyclina, subgenus *Nephrolepidina* (s.l.), occurs quite commonly in the New Britain samples. In various publications van der Vlerk has been able to prove an evolutionary development of the nucleoconch of this subgenus. From older to younger strata the average curvature of the common wall between protoconch and deuteroconch of a number of specimens increases, thus changing the shape of the nucleoconch from an isolepidine via nephrolepidine to a trybliolepidine form. These changes can be expressed numerically as the so-called grade of enclosure of the protoconch by the deuteroconch or the degree of curvature of the common wall between the two. Van der Vlerk has given these values for a number of samples for which the stratigraphic position in terms of the letter stages was also known.

It appears that the correlation between these values and the letter stages is, approximately:

lower Te	36-40% grade of enclosure
upper Te	40-50%
lower Tf	50-59%
upper Tf	59% and higher

Several samples yielded sufficient sections to determine these average values; in others, preparation of some sections provided indications of the stratigraphic position of the sample. By combining all evidence the stratigraphic position of some of the samples from the three oldest formations could be determined. Figure 2 summarizes the results and a discussion follows. Descriptions of the lithological units in the Gazelle Peninsula are taken from Macnab (1970).

Eocene (Baining Volcanics)

The oldest associations of larger Foraminifera occur in the Gazelle Peninsula in the Baining Volcanics, which Macnab (1970) described as a thick pile of undifferentiated, hard and indurated, volcaniclastic marine sedimentary rocks with lava flows; volcanic conglomerates and greywackes dominate the succession. Small limestone lenses are exposed at several localities and limestone clasts have been found in volcaniclastic rocks; the limestone generally contains much volcanic detritus.

In the Nakanai region similar limestones have been found as far west as the Melkoi River. Limestones in a similar setting farther west were found to be unfossiliferous or contained a fauna which could not be identified precisely enough to allow an age determination (e.g. *Heterostegina*).

The association found in 22 samples includes the following genera and species: *Spiroclypeus vermicularis* Tan Sin Hok, *Nummulites* sp. (in some cases referred to cf. *pengaronensis* Verbeek), *Biplanispira hoffmeisteri* (Whipple), *B. mirabilis*

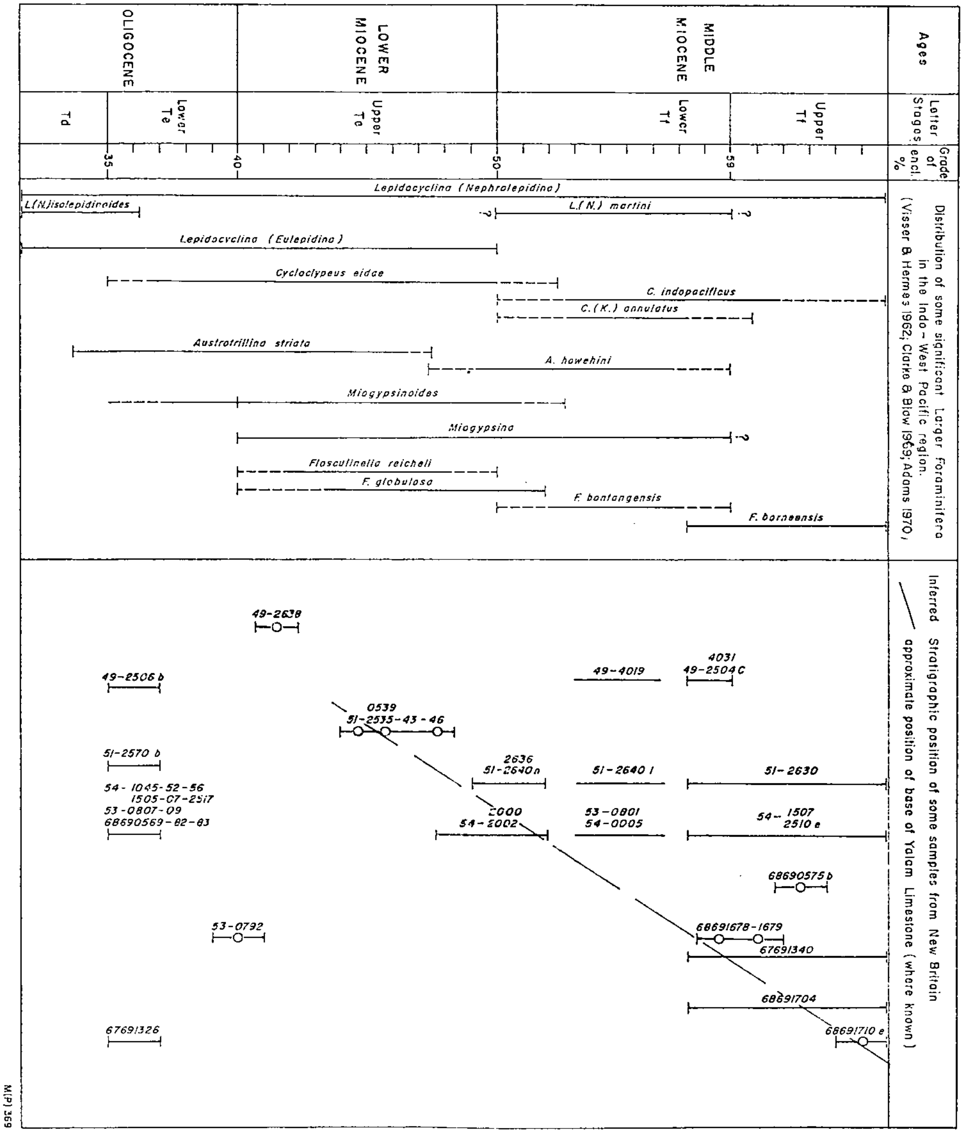


Fig. 2. Inferred stratigraphic positions of some samples determined by grade of enclosure and stratigraphic ranges of some significant larger Foraminifera.

Umbgrove, *Pellatispira madaraszi* (Hantken) (=*P. fulgeria* Whipple), *Halkyardia* sp., *Heterostegina* sp., *Cycloclypeus* sp., and *Discocyclina* (s.l.) sp. Identical associations have been reported from numerous localities in the Indo-Pacific region assigned to the Tb (upper Eocene).

Hanzawa (1947) recorded a fauna consisting of *Pellatispira reticularis* sp. nov. (placed in synonymy with *P. provaleae* by Cole, 1970), *Discocyclina* sp., and *Heterostegina* sp. from an impure limestone from an undescribed locality in the Nakanai region.

Oligocene (Merai Volcanics and equivalents)

A younger fauna is present in limestone associated with less indurated volcanics and volcanogenic sediments, which have been found on the Gazelle Peninsula to the east of the headwaters of the Via River. In the Gazelle Peninsula Macnab has called these sediments Merai Volcanics. The association includes: *Lepidocyclina (Eulepidina) ephippioides* (Jones & Chapman), *Lepidocyclina (Nephrolepidina) isolepidinoides* van der Vlerk, *L. (N.) augusticamera* Cole, *Cycloclypeus eidae* Tan Sin Hok (very rare), *Heterostegina* sp., and *Halkyardia* sp.

In terms of letter stages the age of this fauna is lower Te. Specimens identified as *Lepidocyclina (Nephrolepidina) isolepidinoides* are rare in these samples; this scarcity and their small size make the preparation of equatorial sections quite difficult; such sections were made from 5 samples, with a maximum of 3 sections from any one sample. The grade of enclosure of these sections (10 in all) varies between 29.7 percent and 37.4 percent. These values strongly indicate a level close to the base of the lower Te. From one sample (6869 0569e) an equatorial section of a specimen of *Cycloclypeus* was prepared, which showed some 20 nepionic septa; this confirms a position low in the lower Te.

South of Riebeck Bay samples 49NG 2605, 2608, and 2610, taken from a series of unindurated volcanogenic sediments, yielded some poorly preserved planktonic and larger Foraminifera. The planktonic Foraminifera of 2605 probably indicate zone N.1; in 2608 some younger species (zone N5-N6) were determined in association with older species also found in 2605. The poor preservation, however, made a definite determination difficult. Larger Foraminifera in 2610 include *Eulepidina,* a primitive *Nephrolepidina,* and *Spiroclypeus,* and this seems equivalent to the association found in the Merai Volcanics. The presence of *Spiroclypeus* in this sample is remarkable, since this is the only sample from New Britain in which this genus is common. On the combined evidence of these three samples it seems best to regard these sediments as lower Te, about planktonic zone N1.

A sample of impure limestone, found in association with volcanogenic sediments near Pondo Plantation, west coast, Gazelle Peninsula (53NG 0792), contains *Lepidocyclina (Eulepidina) ephippioides* together with *Lepidocyclina (Nephrolepidina) verbeeki* (Newton & Holland). Twenty-four equatorial sections of specimens of *verbeeki* showed an average grade of enclosure of 40.3 percent, which puts the position of this sample near the boundary between the lower and upper Te, considerably younger than the *L. (E.) ephippioides—L. (N.) isolepidinoides* fauna.

Miocene

Subhorizontal limestone with minor interbedded calcareous sediments overlies these volcanic rocks in many parts of the island. It crops out extensively in the Whiteman Range, Nakanai Mountains, the North Baining Mountains, and south of Ataliklikun Bay, in the Gazelle Peninsula. It is a bioclastic limestone, mainly coralline and algal calcarenites containing a few larger Foraminifera. Smaller Foraminifera occur also, mainly in the lower part of the sequence. Several associations can be distinguished, indicating a range in age of these sediments, with the base gradually becoming younger from west to east. In the Gazelle Peninsula the limestone has been called the Yalam Limestone (Macnab, 1970).

In the Whiteman Range the oldest fauna occurs in sample 49NG 2683 from the Lamogai area. Larger Foraminifera in this sample are *Miogypsina* spp., *Lepidocyclina (Nephrolepidina) japonica* Yabe, and *Cycloclypeus eidae* Tan Sin Hok. The average grade of enclosure of 14 specimens of *L. (N.) japonica* is 41.4 percent; this value corresponds to values found by van der Vlerk (van der Vlerk & Postuma, 1970) for samples from east Java, southwest France, and Corfu (Greece), all of which contain planktonic Foraminifera characteristic of the *Globorotalia kugleri* Zone, as defined by Bolli (1969), which is approximately equal to zone N4 of Blow. Clarke & Blow (1969) correlate this zone with the base of the upper Te stage. Planktonic Foraminifera from the same sample were identified by D. J. Belford as: *Globigerinoides quadrilobatus, G. immaturus, Globorotalia (T.) siakensis, G. (T.) obesa,* and *Globoquadrina altispira.* All these forms are long-ranging, but the association cannot be older than zone N4.

Other samples from the Whiteman Range to which an age could be assigned are 49NG 4019 and 4031. The first contains lepidocyclinids belonging to the group of species identified as *L. (N.) radiata* (Martin) and *L. (N.) martini* Schlumberger, which are known from the upper part of the lower Tf and the upper Tf; Sample 4031 contains *Flosculinella borneensis* Tan Sin Hok and *Austrotrillina howchini* Schlumberger. These two species have been reported to occur together near the top of the Lower Tf (Visser & Hermes, 1962, encl. 7). Unfortunately the position of these samples in relation to the base or the top of the sequence is unknown. Samples from near the base collected in the headwaters of the Johanna River did not contain diagnostic fauna.

Limestone cropping out near Rudiger Point and the lower reaches of the Via River yielded abundant planktonic faunas (samples 49NG 0010-0024 and 2601-2602), which range in age from zone N.10-N.13. This limestone is therefore equivalent to the coralline-algal limestone with larger Foraminifera which forms the bulk of the formation further inland.

In the headwaters of the Iglik River, just east of the Whiteman Range, thin limestone overlies volcanic rocks. In ten samples an association was found comprising *L. (N.) japonica* Yabe, *Miogypsina* spp., and *Austrotrillina* sp. Measurements of the grade of enclosure of *japonica* gave the following results:

Sample No.	*Number of sections*	*Variation*	*Average*
51NG 0539	9	42.1-50.0%	44.6%
51NG 2535	5	38.6-47.4%	45.0%
51NG 2543	10	40.0-59.0%	47.6%
51NG 2546	10	40.6-50.7%	45.8%

These values appear to be quite consistent and indicate a position somewhat above the middle of the upper Te. The representatives of *Austrotrillina* include specimens that are morphologically intermediate between *A. striata* and *A. howchini,* as well as true *A. howchini,* also indicating a horizon in the upper half of the upper Te. In this area the limestone is not very thick. All ages determined fall in a small interval, and no distinction in age between the top and the bottom seems possible.

In the western part of the Nakanai Mountains samples collected from the base of the limestone sequence (51NG 2636 and 2640n) contain *L. (N.) japonica, A. howchini,* and *Flosculinella globulosa* (Rutten). This association occurs near the boundary between the upper Te and the lower Tf or in the lower part of the lower Tf. Sample 51NG 26401, about 480 m above 2460n, contains representatives of the *L. radiata-martini* group, indicating upper part of the lower Tf to upper Tf. Sample 49NG 2630, containing *Flosculinella borneensis* Tan Sin Hok, probably represents a higher level in the sequence, as this species is characteristic of the upper Tf.

In the eastern part of the Nakanai Mountains and the region between Wide Bay and Open Bay, no ages could be assigned to samples near the base of the sequence. The oldest fauna is found in samples 54NG 2000 and 2002, where *Flosculinella globulosa* occurs with specimens of *Austrotrillina* which are intermediate between *A. howchini* and *A. striata,* indicating a level high in the upper Te. Younger faunas were found in sample 54NG 0005 (*L.* (*N.*) *radiata-martini* group, upper part of lower Tf to upper Tf) and in samples 54NG 1507j-k and 54NG 2510e, which contain *Miogypsina* with *Flosculinella borneensis* (upper Tf). A float specimen, sample 6869 0575b, contains lepidocyclinids belonging to the group of *radiata* and *martini*. The grade of enclosure of 16 specimens averages 61.7 percent, which indicates upper Tf.

Near Yalam village in the North Baining Mountains a sequence of some 1000 m of limestone is exposed in prominent cliffs. A sample from the base (6769 1340) contains *F. borneensis,* indicating upper Tf. In samples from the lowest 200 m the following were identified: *L.* (*N.*) *radiata-martini* group, *Cycloclypeus* (*C.*)*indopacificus* Tan, *C.* (*K.*) *annulatus* Martin, *Alveolinella* sp., and *Marginopora vertebralis* Blainville. This association indicates also an upper Tf age, which is confirmed by the value of the grade of enclosure of the lepidocyclinids from two of the samples (6869 1678a and 1679), which averages 58.5 percent and 59.9 percent respectively. The samples from the other 800 m of the section did not contain any diagnostic Foraminifera.

Farther to the east near Vudal River a sample from the base of the limestone (6869 1710e) yielded lepidocyclinids with an average degree of enclosure of 64.6 percent. Other characteristic faunas from this area include *F. borneensis. Austrotrillina,* a genus common in the limestones in other parts of New Britain, has not been found in the North Baining area. It disappears at the top of the lower Tf, and its absence supports the conclusion that the limestone sedimentation in this area did not start until upper Tf times.

The upper limit of the limestone is difficult to date because of lack of measured and sampled sections, and also the absence of diagnostic fauna in specimens that were collected from the upper surface of the limestone. Lower Tf and upper Tf faunas of larger Foraminifera occur in most areas. In the Yalam section, the upper Tf beds are overlain by some 800 m of coralline limestone from which no Foraminifera were obtained, and its age is therefore unknown. Younger formations of clastic and volcanogenic sediments have been dated as upper Miocene to basal Pliocene. Large-scale limestone sedimentation therefore must have ended in upper middle Miocene and upper Miocene times; since the limestones were largely formed as reefs, it seems likely that they did not cease to form simultaneously in all areas.

DISCUSSION OF SPECIES

Twenty-one species are discussed and figured. The classification given in the Treatise on Invertebrate Paleontology (Loeblich & Tappan, 1964). is followed. No detailed synonymies are given, only relevant references, which usually give such synonymies. All illustrated specimens have a number with the prefix CPC as well as the sample number: they are stored in the Commonwealth Palaeontological Collections kept in the BMR, Canberra. Other sections prepared for this study are kept in the palaeontological section of the BMR and carry the sample number given by the field geologists.

Suborder MILIOLINA

Superfamily MILIOLACEA

Family MILIOLIDAE

Subfamily FABULARIINAE

Genus AUSTROTRILLINA Parr, 1942

Specimens belonging to *Austrotrillina* are quite common in samples from the the Jacquinot Limestone from the Whiteman Range and Nakanai Mountains. Adams (1968) redescribed and compared the known species of the genus. As the most important characters for species identification he used the structure of the inner wall and the type of surface ornament. Since all the specimens from New Britain occur in massive limestone and therefore had to be studied in thin sections only, the latter character could not be used. All the sections were random, and most contained quite a number of specimens; poor preservation and recrystallization often obscure the wall structure. Wherever it was possible to make a specific identification and to verify the age of the sample on the evidence of other Foraminifera, the results fit in well with the stratigraphical distribution of the species of *Austrotrillina* as given by Adams.

AUSTROTRILLINA HOWCHINI (Schlumberger, 1893)

(Pl. 1, figs 1-4)

1968 *Austrotrillina howchini* (Schlumberger); Adams, p. 86, pl. 2, figs 1-7; pl. 6, figs 1-5, 7.

All the specimens referred to *A. howchini* have rounded chambers and bifurcating alveoli, characters mentioned by Adams as typical of many advanced Tf forms from New Guinea and other regions.

Representative samples. 51NG 2640n, in association with *Lepidocyclina* (*Nephrolepidina*) *japonica* and *Miogypsina* sp. Top of upper Te to base of lower Tf. 49NG 2504c, in association with *Flosculinella* sp. cf. *F. borneensis, Lepidocyclina* (*Nephrolepidina*) sp., and *Miogypsina* sp. Top of lower Tf.

AUSTROTRILLINA sp.

(Pl. 1, figs 5-6)

These specimens have rounded chambers but the alveoli do not bifurcate, or bifurcate at the chamber angles only. In some the alveoli appear fine as in *A. asmariensis,* in others coarse as in *A. striata.* No definite determinations are possible as only random sections are available.

Representative samples. 51NG 2543c, in association with *Lepidocyclina* (*Nephrolepidina*) *japonica.* 54NG 2000a, in association with *Flosculinella globulosa.*

Family ALVEOLINIDAE

Genus FLOSCULINELLA Schubert, 1910

FLOSCULINELLA GLOBULOSA (Rutten, 1917)

(Pl. 2, figs 1-2)

1957 *Flosculinella globulosa* L. Rutten; Cole, p. 767, pl. 240, fig. 1.
1969 *Flosculinella globulosa* L. Rutten; Cole, p. C7, pl. 4, figs 24, 26.

Flosculinella globulosa was definitely determined in one sample (54NG 2000a) from the Jacquinot Limestone. It was observed in random sections only. The specimens in this sample are affected by recrystallization but show a subspherical test with a diameter between 1.1 and 1.6 mm and chamberlets in two rows with the upper ones small. It occurs in association with *Austrotrillina* sp.; these specimens are also recrystallized and specific identification is not possible. By analogy with other occurrences the age of this sample is upper part of the upper Te to lower part of the lower Tf.

FLOSCULINELLA BORNEENSIS (Tan Sin Hok, 1936)

(pl. 2, figs 3-6)

1929 *Alveolinella bosci* Van der Vlerk (*non* Defrance), p. 16, fig. 24.
1936 *Alveolinella borneensis* Tan Sin Hok, p. 178.

Mohler (1949), describing *Flosculinella reicheli,* mentioned four representatives of *Flosculinella* in Borneo that form a morphogenetic series differentiated by their size and length-width (l/w) ratio. The oldest form, *F. reicheli,* small and globular (l/w ratio 0.9-1.2), occurs in the upper Te, followed by the bigger and globular to fusiform group of *F. globulosa-bontangensis* (l/w ratio 1.0-1.8) in the lower Tf, and the biggest and most elongate representative *F. borneensis* (l/w ratio 1.7-3.2) in the upper Tf. Brouwer (*in* Bär, Cortel, & Escher, 1961) recorded *borneensis* in two samples from the Star Mountains, Central Range, West Irian, in association with *Austrotrillina howchini,* and referred them to probably upper Tf. Visser & Hermes (1962, encl. 7) show *borneensis* ranging from the upper part of the lower Tf to the top of the upper Tf.

In 11 samples from New Britain elongate specimens referable to *F. borneensis* have been found. Axial to near-axial sections were prepared from five samples; l/w ratio of the specimens sectioned ranges from 2.8 to 4.0, length from 2.4 to 3.2 mm. In two samples it was found in association with *A. howchini*; as this well established species has not been recorded from upper Tf strata, the association appears to indicate that *F. borneensis* first appeared near the end of the lower Tf. In other samples the associated faunas (*Miogypsina* sp., *Lepidocyclina* (*Nephrolepidina*) sp., miliolids, and soritids) do not provide any further information on the age of these samples.

Representative samples. 49NG 2504c, 49NG 4031, 51NG 2630, 54NG 1507j-k, 54NG 2510e, 6769 1340, and 6869 1704.

Suborder ROTALIINA
Superfamily ROTALIACEA
Family NUMMULITIDAE
Subfamily NUMMULITINAE
Genus NUMMULITES Lamark, 1801
NUMMULITES PENGARONENSIS Verbeek, 1871

(Pl. 2, figs 7-9)

1970 *Camerina pengaronensis* (Verbeek); Cole, p. 4, pl. 3, figs 10-11, 13-16 (references and synonymy).

Nummulites pengaronensis has been tentatively identified in random sections of a number of Eocene samples from New Britain. It occurs only rarely and in only one case was it possible to prepare some oriented vertical and equatorial sections, all of megalospheric specimens. The vertical section shows a specimen identical with one of Cole's specimens from Eniwetok (Cole, 1957, pl. 231, fig. 6); these specimens are slightly less robust than others which have been illustrated, but show clearly the distinct axial plug. The equatorial sections show between 3½ and 5 whorls with about 25 chambers in the last volution.

Both Rutten (*in* van Bemmelen, 1949, p. 85, table 12) and Clarke & Blow (1969, fig. 1) give the range of this species from Ta to Td stage (Eocene to Oligocene). Cole (loc. cit.) gives 11 references, all of Eocene occurrences. In New Britain the species was tentatively identified in samples containing *Discocyclina* (s.l.) sp., *Spiroclypeus vermicularis, Pellatispira madaraszi, P. 'fulgeria'*, and *Biplanispira mirabilis;* the specimens illustrated are from a sample which did not contain any other characteristic Foraminifera.

Representative sample. 6869 0567b.

Genus PELLATISPIRA Boussac, 1906

PELLATISPIRA MADARASZI (Hantken, 1876)

(Pl. 3, figs 1-5; pl. 4, figs 1-3)

1970 *Pellatispira madaraszi* (Hantken); Cole, p. 6, pl. 1, figs 1-13; pl. 2, figs 19-23 (references and synonymies).

Cole (1970), reviewing the eight species of *Pellatispira* recognized in the upper Eocene of the Indo-Pacific up to 1957, pointed out that only two species, *orbitoidea* and *provaleae,* could be regarded as valid. Among the abundant matrix-free specimens of *Pellatispira* from Eua (Tonga), Cole found two groups of specimens which could be referred to these two species, and other specimens intermediate in all respects between the two supposedly valid species. He therefore concluded that only one species of *Pellatispira* is represented in the Indo-Pacific upper Eocene, and apparently under the influence of ecological factors it shows a considerable morphological variation. In Cole's opinion the *provaleae*-type specimens of this continuous gradational series are similar to the European *P. madaraszi.* All eight Indo-Pacific species thus become junior synonyms of *P. madaraszi.*

Specimens of *Pellatispira* found in New Britain do not show the full range of shapes and sizes described by Cole. Specimens of the *crassicolumnata* type with a well developed fibrous keel, often broken off, occur together with *Discocyclina* (s.l.) spp. and *Nummulites* sp. cf. *N. pengaronensis.* Most specimens have a slightly inflated umbonal area and large pillars (Pl. 3, fig. 1); compressed lenticular specimens occur also (Pl. 3, fig. 2).

One limestone pebble (sample 6869 1327) from the Lat River, Gazelle Peninsula, consists almost entirely of specimens of *Pellatispira* and *Discocyclina.* The specimens of *Pellatispira* occur in two sizes. The small specimens (up to 2.5 mm across) are of the *crassicolumnata* type (Pl. 3, fig. 3). The other form is large (up to 6 mm across), and strongly papillate with an inflated periphery (Pl. 3, figs 4-5); the central area has the same internal structure as *crassicolumnata,* but the inflated periphery resembles the structure of *P. fulgeria* Whipple, but more strongly developed and papillate. These forms resemble the specimen figured by Cole (1970, pl. 1, fig. 10) except for the more strongly inflated periphery in the New Britain material.

To Cole such forms suggest an interconnexion between *P. madaraszi* and *P. fulgeria;* 'typical' *fulgeria,* as figured by Cole (1970, pl. 1, fig. 11), and also the types figured by Whipple, and Umbgrove's type-material of *Biplanispira absurda,* a junior synonym of *fulgeria,* appear to be larger and thinner. Specimens of this kind occur in other samples from New Britain (Pl. 4, fig. 2), but are rare in the sample from the Lat River. It is possible, as Cole suggests for the *P. madaraszi* group, that ecological factors influence the shape and size of the specimens, causing a wide morphological diversity.

Two samples from New Britain contain *P. madaraszi* only, in two others it occurs in association with *'P. fulgeria',* and three samples contain *'P. fulgeria'* but no *madaraszi,* in one case together with *Biplanispira mirabilis.*
Representative samples. 51NG 1082, 54NG 0013, 54NG 1063, 54NG 1518a, 6769 0200, 6769 1327, and 6769 1330.

PELLATISPIRA HOFFMEISTERI Whipple, 1932

(Pl. 4, fig. 4)

1958 *Biplanispira hoffmeisteri* (Whipple); Cole, p. 334, pl. 100, figs 1-3.

Cole described the morphological variation of specimens of *Pelatispira hoffmeisteri* from Saipan as ranging from compressed lenticular specimens, thick lenticular with or without rim, and umbonate with a pronounced rim, all linked by gradational forms. The material from New Britain does not allow observations of this kind; only five random transverse sections are available from three samples. A compressed lenticular specimen identical with Cole's plate 100, figure 1 is figured; other sections seemingly show more inflated forms. All sections show only *Biplanispira*-like chambers surrounding the embryonic apparatus.

Representative samples. 51NG 2653, 54NG 0013, and 54NG 2502b.

Subfamily CYCLOCLYPEINAE

Genus CYCLOCLYPEUS W. B. Carpenter, 1856

CYCLOCLYPEUS (CYCLOCLYPEUS) EIDAE Tan Sin Hok, 1932

(Pl. 5, figs 1-3)

1953 *Cycloclypeus* (*Cycloclypeus*) *eidae* Tan; Cole, p. 27, pl. 5, figs 13-19.
1958 *Cycloclypeus* (*Cycloclypeus*) *eidae* Tan; Cole, p. 334, pl. 101, fig. 15.
1963 *Cycloclypeus* (*Cycloclypeus*) *eidae* Tan; Coleman, p. 34, pl. 9, fig. 12.
1964 *Cycloclypeus eidae* Tan; Ujiié, p. 311, pl. 2, figs 1-5; pl. 3, figs 1-6.

From three samples a single equatorial section could be prepared. All three were hard limestones, and preparation of sections of the undulating equatorial plane was extremely difficult. A specimen with 20 nepionic septa in 2¼ whorls was found in sample 6869 0560e in association with *Lepidocyclina* (*Nephrolepidina*) *isolepidinoides, L.* (*Eulepidina*) *ephippioides,* and *Heterostegina* sp., indicating lower Te stage.

In sample 49NG 2638 a specimen with 16 nepionic septa in two volutions was found in association with *L.* (*N.*) *japonica* and *Miogypsina* sp. This sample was dated as basal upper Te stage. A specimen in sample 51NG 0539 has 15 nepionic septa arranged in 1¾ volutions. Specimens with similar characteristics have been assigned to *posteidae* (e.g. Cole, 1963, p. 18); other workers, however, regard this species as being within the range of variation of *eidae,* to which it is very similar (MacGillavry, 1962, p. 437), thereby extending its stratigraphic range into lower Tf stage (see range chart by Clarke & Blow, 1969). The specimen from sample 51NG 0539 occurs with *L.* (*N*) *japonica, Miogypsina* sp., and *?Austrotrillina* sp. This fauna has been dated as upper part of upper Te stage.

CYCLOCLYPEUS spp.

A sample (6869 1678) collected from the cliff section of Yalam Limestone near Yalam village, North Baining Mountains, Gazelle Peninsula, was disintegrated by repeated freezing and boiling. Several cycloclypeids occurred among the free specimens. As the specimens were all worn, with the rims and flanges broken away, only tentative identifications could be made from the features of the median sections.

CYCLOCLYPEUS (s.l.) cf. C. (CYCLOCLYPEUS) INDOPACIFICUS Tan Sin Hok, 1932

(Pl. 5, fig. 4)

cf. 1932 *Cycloclypeus* (*Cycloclypeus*) *indopacificus vandervlerki* Tan, p. 67-78, pl. 17, figs 5-6; pl. 18, figs 5-6.

Three sections are assigned to *C.* cf. *C. indopacificus.* They show an almost circular protoconch (diameters 175 × 160, 200 × 200, 178 × 200) partly enveloped by the reniform deuteroconch. The first nepionic chamber (ana-nepionic) is large and not divided; five or six nepionic septa follow in just over one whorl (in the third specimen too many irregularities occur). These sections are very similar to the illustrations cited above, especially those of *C. 'hexaseptus'* (formerly *C. posteidae hexaseptus*) as given by Cole (1963). In a later study (which was, however, published in 1960) he changed his opinion and regarded this species as a synonym of *indopacificus.*

CYCLOCLYPEUS (s.l.) sp. cf. C. (KATACYCLOCLYPEUS) ANNULATUS Martin, 1880

(Pl. 5, fig. 5)

cf. 1880 *Cycloclypeus* (*Katacycloclypeus*) *annulatus* Martin, p. 157, pl. 28, figs 1a-i.

Six equatorial sections are compared with *C.* (*K.*) *annulatus.* They were obtained from sample 6869 1678a and their measurements are:

Slide	Diameters of protoconch	Diameters of deuteroconch	nepionic whorls	nepionic chambers
13	275 × 250μ	400 × 175μ	—	—
18	375 × 310μ	500 × 180μ	—	—
19	325 × 325μ	525 × 225μ	0.9	2
23	310 × 275μ	425 × 175μ	0.8	2
25	250 × 250μ	350 × 150μ	0.7	1

The large embryonic chambers with the almost spherical protoconch about half-enveloped by the reniform deuteroconch and one or two nepionic chambers make these specimens very similar to those figured by Cole.

Genus SPIROCLYPEUS Douvillé, 1905

SPIROCLYPEUS VERMICULARIS Tan Sin Hok, 1937

(Pl. 5, figs 6-7)

1957 *Spiroclypeus vermicularis* Tan Sin Hok; Hanzawa, p. 47, pl. 4, figs 2-7; pl. 5, fig. 15.
1970 *Spiroclypeus vermicularis* Tan Sin Hok; Cole, p. 10, pl. 2, figs 6-12.

S. vermicularis, widely distributed in the Indo-Pacific area, is characteristic of the Tb stage. Tan (1937) and Hanzawa (1957) described the vermicular outline of the lateral chambers in vertical sections as its diagnostic feature.

It occurs commonly in the limestones found with the volcanics and volcanogenic sediments of the Baining Volcanics in the Nakanai Mountains and Gazelle Peninsula; specimens found in association with it belong to *Discocyclina* (s.l.). *Pellatispira, Biplanispira, Nummulites* and *Halkyardia.*

Superfamily ORBITOIDACEA

Family CYMBALOPORIDAE

Genus HALKYARDIA Heron-Allen & Earland, 1918

HALKYARDIA sp.

(Pl. 5, figs 8-10)

The genus *Halkyardia* was for a long time thought to be restricted to the Eocene (Cushman, 1948, p. 309, and Treatise). Glaessner (1945, p. 152) gave the range as middle Eocene to Oligocene. Bursch (1947) found *Halkyardia* in upper Eocene and Oligocene deposits on Great Kei, Molucca Islands. He referred these specimens to *H. minima* Liebus. Cole (1954) noted similarities between them and a probable upper Eocene representative from New Zealand named *H. bartrumi* by Parr (see Cole, 1954, pp. 572, 585).

Cole (1954) described a new species *H. bikiniensis* from Bikini Well 2B; it occurred in beds that were thought to be of Tc age. As no other species were found with them the age determination was only tentative. After examining material from Eniwetok Atoll drill holes, Cole revised the subdivision of the strata in Bikini Well 2B and stated that the section which contained *H. bikiniensis* probably has to be included in the lower section of Te (Cole, 1957, p. 748, and table 2).

In 1958 Cole reported *H. bikiniensis* from undoubtedly Eocene samples from Saipan, where it is extremely rare. In the Melinau Limestone, Sarawak, Adams (1965) found *Halkyardia* sp. sporadically in upper Eocene strata; *H.* cf. *bartrumi* is fairly common in some samples from Tc strata, and occasional specimens of *H.* sp. were found in Td strata.

In New Britain rare specimens have been found in four samples, all from the Gazelle Peninsula. One random section occurs in sample 6869 1328 together with *Discocyclina* (s.l.) sp. and *Spiroclypeus vermicularis;* the sample is a limestone pebble from the Lat River, probably derived from the Baining Volcanics. Two other limestone pebbles from the Marambu River just to the west of 6869 1328 yielded three random sections unaccompanied by any other fauna; on lithological grounds these pebbles are also believed to be derived from the Eocene Baining Volcanics. Finally, two sections were found in slides from sample 6869 0583a, again a limestone pebble, found just northeast of Matanakunei Plantation near Open Bay. This sample contains abundant specimens identified as *L.* (*N.*) *augusticamera* Cole and *Heterostegina* sp.; the first species has been recorded from lower Te beds by Cole. This sample is thought to be derived from the Merai Volcanics, which have been dated as lower Te.

The specimens are illustrated without specific identification; identification would require more material and a revision of existing species, whose differences are not very well defined. Whether or not these species have distinct stratigraphic ranges is not to the author's knowledge indicated in the literature.

Family LEPIDOCYCLINIDAE

Subfamily LEPIDOCYCLININAE

Genus LEPIDOCYCLINA Gumbel, 1868

Subgeneric classification

Ever since Douvillé introduced a subgeneric classification of the lepidocyclinids opinions have differed on its validity and basis. All the New Britain species except one could be assigned either to *Nephrolepidina* (with *Trybliolepidina* regarded as a variant within it) or *Eulepidina,* using the diagnosis as given by Eames, Banner, Blow, Clarke, & Smout (1962). Specimens from float samples from the Open Bay/ Wide Bay area, probably derived from the Merai Volcanics (lower Te stage) show a transition from a typical nephrolepidine nucleoconch to (in the writer's opinion) a eulepidine type. These observations seem to support Cole's opinion that 'as embryonic chambers of the nephrolepidine and eulepidine shape intergrade and both shapes are found in specimens assigned to a single species, these two subgenera are combined' (Cole, *in* Cole, Todd, & Johnson, 1960, p. 101).

It is beyond the scope of this paper to decide whether or not such rare cases invalidate the subgenera, otherwise easily distinguished, as it would require an evaluation of all the arguments used by Cole, Eames et al., and others, and any new evidence available. For the moment the observations made on the New Britain specimens are therefore presented without any conclusions on their subgeneric assignment.

Specific distinction

It is generally acknowledged that specific assignment of lepidocyclinids is greatly hampered by the large number of species, many of which are inadequately described. In addition, variation among individuals of one population is often so wide that end-members of a series may appear to belong to different species, but can be linked by a complete set of specimens with intermediate characters.

A wide variation was observed also in New Britain species wherever it was possible to examine and section a large number of specimens. When arranged in a gradational series the specimens appear to centre on an intermediate form which occurs most frequently. One of the variable characteristics which can be measured is the degree of enclosure of the protoconch by the deuteroconch. On a histogram, these values show a normal Gaussian distribution. In such cases all the specimens have been put under the species name most applicable to the intermediate and most common form. In the description of each 'species' the variation is described and illustrated.

LEPIDOCYCLINA (NEPHROLEPIDINA) ISOLEPIDINOIDES van der Vlerk, 1929
(Pl. 6, figs 1-7)

1929 *Lepidocyclina (Nephrolepidina) isolepidinoides* van der Vlerk, p. 23, figs 20, 45a-b, 48a-c.

1939 *Lepidocyclina isolepidinoides* van der Vlerk; Caudri, p. 244.

Van der Vlerk and Caudri give the characteristic features of *isolepidinoides* as: small size, equatorial chambers rhombic and arranged in a fan shape, nucleuconch nephrolepidine, but deuteroconch hardly enclosing protoconch as in *Lepidocyclina* s. str. (*'Isolepidina'*); there is little difference in shape and size between deuteroconch and protoconch, and the lateral chambers are high and rectangular.

Cole (1953, p. 30) stated after examining specimens from Saipan, initially identified as *Lepidocyclina (Nephrolepidina) parva* Oppenoorth and *L. (N.) isolepidinoides,* that these two groups showed a rather complete gradation, representing only two species. He therefore concluded that *L. (N.) isolepidinoides* should be combined with *L. (N.) parva.*

In 1953 and 1957 Cole reported a gradation between specimens thought to represent *L.* (*N.*) *parva, L.* (*N.*) *verrucosa* Scheffen, and *L.* (*N.*) *sumatrensis* (Brady), and placed these species in synonymy with *L.* (*N.*) *atjehensis* Oppenoorth, *L.* (*N.*) *melanesiana* Hanzawa, and *L.* (*N.*) *brouweri* Rutten. In the references and synonymies to these species *L.* (*N.*) *isolepidinoides* is not mentioned.

According to van der Vlerk (van der Vlerk & Postuma, 1967) *L.* (*N.*) *isolepidinoides* dominates the oldest zone of the Tertiary in east Java and Madura in which *Lepidocyclina* occurs. At a higher level it is replaced by *L.* (*N.*) *parva,* but 'all sorts of transitions occur between the typical representatives, both in synchronous and in successive assemblages'. Illustrations of horizontal sections of the nucleoconchs of typical specimens of both species show a rather marked difference in the curvature of the wall between deuteroconch and protoconch.

It appears therefore that these two species belong to a single lineage, which can be divided into several species, delimited mainly by the differences in the shape of the nucleoconch. As they can be shown to have stratigraphic value the distinction should be maintained.

Specimens from New Britain identified as *L.* (*N.*) *isolepidinoides* agree in all their characteristics with the descriptions given by van der Vlerk and Caudri. Equatorial sections of megalospheric specimens from six samples were prepared. The degree of enclosure of the ten sections varies between 29.7 and 37.4 percent, values of about 36 percent being most common; similar values were obtained by van der Vlerk from samples from the lower part of the lower Te stage.

L. (*N.*) *isolepidinoides* has been found in two assemblages: (i) with *L.* (*E.*) *ephippioides* (Jones & Chapman), *Cycloclypeus* sp. (in one sample identified as *C. eidae* Tan Sin Hok), and *Heterostegina* sp.
Representative samples: 6869 0569, 49NG 2506b, 53NG 0009, and 54NG 1045.
(ii) with *L.* (*N.*) *augusticamera* Cole and *Heterostegina* sp.

Representative samples. 54NG 1056, and 6869 0583e.

LEPIDOCYCLINA (NEPHROLEPIDINA) VERBEEKI (Newton & Holland, 1899)
(Pl. 7, figs 1-4)

1922 *Lepidocyclina verbeeki* Newton & Holland; van der Vlerk, p. 44, pl. 2, fig. 3.

1953 *Lepidocyclina* (*Nephrolepidina*) *verbeeki* Newton & Holland; Cole, p. 33, pl. 11, figs 6-14; pl. 12, figs 7, 12, 13.

1957 *Lepidocyclina* (*Nephrolepidina*) *verbeeki* Newton & Holland; Cole, p. 344, pl. 106, figs 1-3, 6-7, 9-10; pl. 107, figs 1-12, 16; pl. 109, figs 7-8.

1963 *Lepidocyclina* (*Nephrolepidina*) sp. cf. *L. verbeeki* (Newton & Holland); Coleman, p. 24, pl. 7, figs 11-13.

L. (*N.*) *verbeeki* was observed, in thin sections only, in a sample from the west coast of the Gazelle Peninsula (53NG 0792). All specimens show an inflated central area gradually passing into a wide and thin rim, often broken away; the central portion has a diameter of 3 mm and complete specimens would possibly be up to 7 mm in diameter. Embryonic apparatus is nephrolepidine and relatively thick-walled; the grade of enclosure of 24 specimens averaged 40.3 percent (variation between 33.3 and 48.6 percent). The equatorial chambers are rhombic to ogival, with a radial diameter slightly greater than tangential, and are arranged in regular circles. Lateral chambers are rectangular with straight floors and roofs and are arranged in regular tiers. Pillars occur irregularly over the whole of the central area.

Occurrence. In a tuffaceous calcarenite, found in association with tuffaceous sediments just south of Pondo Plantation, west coast, Gazelle Peninsula. *L. (N.) verbeeki* occurs commonly in this sample in association with *L. (E.) ephippioides,* which indicates Te stage. The degree of enclosure averages 40 percent, which van der Vlerk reported in samples of upper Te stage. Van der Vlerk (1963) reported maximal values between 45 and 50 percent for specimens belonging to *verbeeki* from near the boundary between Te and Tf in Sumatra.

LEPIDOCYCLINA (NEPHROLEPIDINA) JAPONICA Yabe, 1906

(Pl. 7, figs 5-8; pl. 8, figs 1-8)

1939 *Lepidocyclina japonica* Yabe; Caudri, p. 209 and 243, figs 50-56.
1963 *Lepidocyclina (Nephrolepidina) japonica* Yabe; Cole, p. 21, pl. 10, figs 1-9, 11, 13, 14, 18.
1963 *Lepidocyclina (Nephrolepidina) japonica* Yabe; Coleman, p. 17, pl. 6, figs 1-6.
1967 *Nephrolepidina japonica* (Yabe); Matsumaru, p. 134, pl. 7, figs 1-9; pl. 8, figs 1-8.

Specimens from a number of samples from the Whiteman Ranges have been identified as belonging to *L. (N.) japonica.* They show a wide variation in the shape of the embryonic chambers. Some specimens seem to represent *Lepidocyclina (Nephrolepidina) sumatrensis* (Brady): the equatorial chambers are predominantly rhombic with a slight increase in size and elongation towards the periphery; they are arranged rather precisely in concentric circles and the nucleoconch is nephrolepidine (Pl. 7, figs 5-6). Others appear identical with *Lepidocyclina (Nephrolepidina) verrucosa* Scheffen: the equatorial chambers are short spatulate to hexagonal, becoming more elongate towards the periphery; they are arranged in irregular circles or polygons without marked development of rays and the nucleoconch is nephrolepidine (Pl. 7, figs 7-8). A third group is identical with *L. (N.) japonica*: the equatorial chambers are spatulate near the centre, grading to elongate and hexagonal near the periphery; the rays are somewhat more pronounced by the greater elongation of the chambers along them. The nucleoconch is nephrolepidine, tending towards a trybliolepidine shape in some cases (Pl. 8, figs 3-4). All these specimens show in cross-section a lenticular shape with a well developed rim. In some specimens pillars are weak to absent, in others they are moderately to strongly developed. Lateral chambers are arranged in regular tiers and are open, rectangular and relatively high, with curved roofs and floors.

Because of the continuous gradation between the various types in the equatorial sections, and the similarity of their vertical sections, the populations as a whole have been assigned to *L. (N.) japonica,* as this form seems to dominate. Cole (1963) has placed *Lepidocyclina (Nephrolepidina) angulosa* Provale in the synonymy of *L. (N.) japonica*; Hanzawa included in his synonymy *Lepidocyclina (Nephrolepidina) nipponica* Hanzawa.

Cole (1957) concluded that *L. (N.) verrucosa* and *L. (N.) parva* Oppenoorth have to be placed in the synonymy of *L. (N.) sumatrensis* Brady, after showing a gradation in cross-sectional shape, number of lateral chambers, and degree of pillaring of specimens thought to belong to these species. He pays little attention to the taxonomically more important equatorial section. Comparing the original descriptions and the other literature there seems to be reason to retain *verrucosa* as a separate name for forms intermediate between *sumatrensis* and *japonica.* Specimens identified here as *japonica* occur in association with *Miogypsina* sp., *Cycloclypeus eidae, Austrotrillina howchini,* and *A. howchini striata.*
Representative samples. 49NG 2630, 51NG 0539, 51NG 2535, 51NG 2543, 51NG 2546, and 51NG 2640n.

LEPIDOCYCLINA (NEPHROLEPIDINA) MARTINI Schlumberger, 1900

(Pl. 9, figs 1-8; pl. 10, figs 1-4)

1939 *Lepidocyclina martini* Schlumberger; Caudri, pp. 212, 243, figs 57-60.
1960 *Lepidocyclina (Eulepidina) martini* Schlumberger; Cole *in* Cole, Todd, & Johnson, p. 102, pl. 12, figs 1-3.
1962 *Lepidocyclina (Nephrolepidina) martini* Schlumberger; Eames et al., p. 303, pl. 6, figs 2-4.
1963 *Lepidocyclina (Nephrolepidina) martini* Schlumberger; Cole, p. 22, pl. 10, figs 10, 12, 15-17; pl. 11, figs 9-17.
1963 *Lepidocyclina* (s.l.) *martini* Schlumberger; Coleman, p. 14, pl. 3, figs 7-14.

L. (*N.*) *martini* is quite common in samples from the Jacquinot Limestone and Yalam Limestone from the Nakanai Mountains and the Gazelle Peninsula. Typical specimens show spatulate to hexagonal equatorial chambers, strongly elongated along the rays, of which there are usually six. The nucleoconch varies from nephrolepidine to trybliolepidine (Pl. 9). Individual specimens with less clearly defined rays, smaller elongation of the equatorial chambers near the periphery, and a nephrolepidine nucleoconch (Pl. 9, figs 1-4) are identical with some illustrations of *Lepidocyclina* (*Nephrolepidina*) *japonica* Yabe (compare pl. 10, figs 9 and 14 *in* Cole, 1963). Other specimens with a trybliolepidine nucleoconch and elongated hexagonal chambers (Pl. 10, fig. 1) show a strong resemblance to the specimens identified as *Lepidocyclina orientalis* and *L. talahabensis* by van der Vlerk (1929). The maximum diameter of the nucleoconch in some extremely trybliolepidine specimens reaches 0.6 mm, which is about the size of the nucleoconch in 'normal' representatives of *martini.*

Measurements of the grade of enclosure:

Sample No.	Number of specimens	Variation %	Mean value %
6969 0575b	16	42.8-75.0	61.7
6869 1678a	15	49.3-73.9	58.5
6869 1679	24	45.0-71.6	59.5
6869 1710e	36	48.6-81.1	64.6

From some samples free specimens were obtained. The specimens have a lenticular shape, moderately to strongly inflated, with a small flange, sometimes a flattened top. Outline is subcircular to polygonal. True pillars occur, often five or six in a polygonal arrangement around the edge of the elevated centre, in others scattered over the whole surface. Some specimens do not appear to be pillared.

Of the four samples for which measurements are given above, only 6869 1678a contains larger Foraminifera other than *L. martini*: specimens of the *Cycloclypeus* which have been identified as *C.* (*C.*) *indopacificus* and *C.* (*K.*) *annulatus.*

Values of 59 percent and higher have been reported by van der Vlerk (1929) for the average grade of enclosure of upper Tf faunas. The range given for *L. martini* in various range charts varies greatly; Adams (1970) shows it restricted to lower Tf, whereas Clarke & Blow (1969) show the main range in upper Tf.
Representative samples. 51NG 26501, 6869 0575b, 6869 0575b, 6869 1678, 6869 1679, 6869 1693, and 6869 1710e.

LEPIDOCYCLINA (NEPHROLEPIDINA) AUGUSTICAMERA Cole, 1954

(Pl. 10, figs 5-9; pl. 11, figs 1-2)

1954 *Lepidocyclina (Nephrolepidina) augusticamera* Cole, p. 585, pl. 217, figs 1-5.
1957 *Lepidocyclina (Nephrolepidina) augusticamera* Cole; Cole, p. 772, pl. 239, figs 7-8.

L. (*N.*) *augusticamera* has been described by Cole as characterized by nephrolepidine embryonic chambers, short spatulate to hexagonal equatorial chambers, and low oppressed lateral chambers in regular tiers. He remarks that but for the definitely nephrolepidine embryonic chambers these rare specimens might well belong to *Lepidocyclina* (*Eulepidina*) *formosa* (now regarded (Cole, 1957) as a junior synonym of *L.* (*E.*) *ephippioides*) because of the similarity of the pattern of the equatorial chambers.

In seven samples collected from these localities in New Britain, specimens assigned to Cole's species are common and a number of equatorial sections were prepared. The shape and arrangement of the equatorial chambers appears to be very regular and to have little variation. They are arcuate to short spatulate near the centre and short hexagonal near the periphery and are arranged in concentic rings. The relatively thick-walled embryonic apparatus varies from typical nephrolepidine to forms in which the deuteroconch almost completely surrounds the flattened spheroidal protoconch. The part of protoconch not surrounded by the deuteroconch clearly bulges out of the spheroidal deuteroconch. These forms approach very closely specimens identified as *L.* (*E.*) *formosa* by Cole (1954, pl. 218, fig. 3). Maximum diameter of the nucleoconch is about 470 μ. Periembryonic chambers could not be observed.

The vertical sections show a stronger development of pillars than Cole's specimens. Near the periphery the equatorial chambers show pectinations on the distal side of the kind that Eames et al. (1962) claimed as characteristic of *Eulepidina*. In many cases the flange is broken off. All seven samples in which this species was found are float, thought to be derived from the Merai Volcanics. Other samples from this formation contain *L.* (*E.*) *ephippioides, L.* (*N.*) *isolepidinoides, Cycloclypeus eidae,* and *Heterostegina* sp., indicating lower Te age. *L.* (*N.*) *isolepidinoides* is the only characteristic species found in association with *augusticamera;* it was found in two samples. Specimens of *Heterostegina,* which occur in all seven samples, could not be identified specifically, nor could two specimens of *Halkyardia* which were found in random sections of one sample. *L.* (*N.*) *augusticamera* has been reported from 'the lower section of Te' in Bikini drill hole 2B and Eniwetok E1 and F1.

Representative samples. 6769 1326, 6869 0582, 6869 0583a, 6869 0583e, and 54NG 1056.

LEPIDOCYCLINA sp. cf. L. (N.) AUGUSTICAMERA Cole, 1954

(Pl. 11, figs 3-10; pl. 12, fig. 1)

Of five limestone pebbles found behind Matanakunei village, Open Bay area, Gazelle Peninsula, four contained specimens assigned to *L.* (*N.*) *augusticamera.* The fauna of the fifth consists of numerous lepidocyclinids, obviously very closely related to this species. These specimens differ in that the walls of the equatorial and embryonic chambers are thicker; in most cases the wall of the nucleoconch has a fibrous structure. The shape of the equatorial chambers, somewhat obscured by the thick walls and what appears to be a fibrous structure of the whole test, varies from arcuate near the centre to spatulate near the periphery.

The embryonic chambers show a complete gradation from a subspherical deuteroconch (typically nephrolepidine), to a cuboidal protoconch surrounded completely by a cuboidal deuteroconch; in these latter forms the protoconch causes hardly any bulging of the cuboidal shape of the nucleoconch. This configuration cannot be regarded as anything but eulepidine. Maximum diameter of the nucleoconch is 470 μ. Except for an occasional bigger primary auxiliary chamber, the nucleoconch is surrounded by a complete ring of equal-sized, relatively small periembryonic chambers.

The vertical sections are indistinguishable from those of the specimens assigned to *augusticamera*. Several specimens have wide, well preserved flanges. Equatorial chambers near the periphery show the so-called pectinations on the distal side. Differences between these specimens and *augusticamera* are the greater thickness of the chamber walls, the fibrous structure of the test, and the more eulepidine development in some specimens. Further study of Cole's specimens may prove that these differences fall within the normal variation of this species.

LEPIDOCYCLINA (EULEPIDINA) EPHIPPIOIDES (Jones & Chapman, 1900)

(Pl. 12, figs 2-8; pl. 13, figs 1-4)

1952 *Lepidocyclina (Eulepidina) ephippioides* Jones & Chapman; Grimsdale, p. 240, pl. 23, figs 8, 17, 18.

1957 *Lepidocyclina (Eulepidina) ephippioides* Jones & Chapman; Cole, p. 346, pl. 108, figs 4-13; pl. 109, figs 11-15.

1963 *Lepidocyclina (Eulepidina) ephippioides* (Jones & Chapman); Coleman, p. 15, pl. 4, figs 6-12; pl. 5, figs 1-3.

Megalospheric specimens from New Britain vary in shape from lenticular to sellate with a moderately inflated centre sloping gradually towards the periphery. Numerous pseudopillars occur scattered over the whole surface.

Description. The nucleoconch is eulepidine, and the deuteroconch (thickwalled) partly (Pl. 12, fig. 3) to completely (Pl. 12, fig. 7) embraces the protoconch, which usually has a subrectangular outline in equatorial sections. The periembryonic chambers are not clearly differentiated; in one section the nucleoconch seems to be surrounded by a complete ring of equal-sized chambers. The equatorial chambers are thick-walled, spatulate to hexagonal, usually slightly more elongated near the periphery, and arranged in circles, often with irregularities.

Microspheric specimens were observed in one sample. The central area is slightly more inflated; there are more lateral chambers and the pillaring is somewhat stronger. The equatorial chambers are of similar shape and arrangement to those in the megalospheric specimens.

Occurrence. All specimens occur in detrital limestones, often with a high tuffaceous content, in association with volcanogenic sediments. Many specimens are worn and broken, probably by movement during or immediately after burial. There is no evidence of derivation. *L. (N.) isolepidinoides, Cycloclypeus eidae,* and *Heterostegina* sp. were found in association with *ephippioides;* this fauna indicates lower Te stage. In sample 53NG 0792 from the west coast of the Gazelle Peninsula it occurs with *L. (N.) verbeeki* in a sample thought to be of basal upper Te stage.

Representative samples. 49NG 2506b, 51NG 2570b, 54NG 1045, 54NG 1052f, 54NG 1505, 54NG 1507b, 54NG 2517i, 6869 0569a,b,e, 53NG 0792, and 53NG 1809.

LEPIDOCYCLINA GLABRA Rutten, 1911

(Pl. 13, figs 5-6)

1947 *Lepidocyclina glabra* Rutten: Bursch, p. 50, pl. 3, fig. 10; pl. 4, fig. 1 (references).

Description (microspheric species). The test is moderately inflated and no umbo is developed. The outline is circular and numerous pillars are scattered over the whole surface. The equatorial chambers are arcuate to short spatulate near the centre to elongate spatulate to short hexagonal near the periphery. They are arranged in circles and in some a hexagonal pattern is discernible immediately around the centre. Vertical section shows the numerous pillars and the fine lateral chambers.

These specimens are identical with Rutten's species. Several species described since Rutten erected this species possess rather similar characteristics. *L. flexuosa* Rutten, 1911, *L. subradiata* Douvillé, 1916 (originally a subspecies of *glabra*), *L. papulifera* Douvillé, 1916, and *L. ngampalensis* Caudri, 1939, differ only in the development of pillars and the polygonal arrangement of the equatorial chambers. It is doubtful whether these differences allow a specific distinction. In New Britain *L. glabra* occurs together with megalospheric specimens identified as *L.* (*N.*) *martini*. Usually the megalospheric specimens dominate, but in one sample the microspheric specimens are much more numerous.

Representative samples. 6869 1693.

LIST OF SAMPLES AND LOCALITIES

49NG 2504c	Limestone, float from Kapuluk River.
49NG 2506b	Limestone from large displaced block in Via River.
49NG 2638	Brown impure calcarenite from track between Mokukli Village and New Bulawatne Village, Lamogai area.
49NG 4019	White bioclastic calcarenite from west branch, Johanna River.
49NG 4031	Bioclastic calcarenite pebble from headwaters of west branch, Johanna River.
51NG 0539	Limestone from tributary of the Iglik River between Ziek and Ranguigui.
51NG 1002	Limestone, float from Melkoi River.
51NG 1091b	Large fragment of limestone from volcanic rudite (float), from Som River, a tributary of the Melkoi River.
51NG 2535	Limestone, float from headwaters of Iglik River.
51NG 2543	Limestone pebbles, float from the headwaters of the Awio River.
51NG 2546	Cream massive limestone from the Iglik River.
51NG 2570b	Compact pinkish limestone in association with volcanic rock (float) from Tavalo River.
51NG 2630	Limestone from Ivule River where river emerges from the hills.
51NG 2636	Limestone from base of Yalam Limestone in Ivule River.
51NG 2640d-n	11 limestone samples from section of Yalam Limestone in the headwaters of Ivule River.
51NG 2653	Limestone, float from Obutabu River, 15 km east of Uasilau.
53NG 0792	Grey detrital limestone from south of Pondo Plantation, east coast of Gazelle Peninsula.
53NG 0801	Limestone float from south of Sai River.
53NG 0807-09	Detrital limestones from volcanic sediments near Baia Village, Open Bay area.
54NG 0005	Limestone from Ip River.
54NG 0013	Limestone occurring as clasts in volcanic rudites near Ip River.
54NG 1045	Limestone, float from headwaters of Ikoi River.
54NG 1052f	Limestone occurring as fragments in volcanic rudites (float) from headwaters of Ikoi River.
54NG 1056	Limestone with volcanic detritus, float from Lemkong River.
54NG 1063	Volcanic rudite with fragmental limestone, float from Lemkong River.
54NG 1505	Grey tuffaceous calcareous sandstone, float in Berg Berg River.
54NG 1507	Limestone pebbles, float from Berg Berg River.
54NG 1518a	Limestone found *in situ* in volcanically derived sediments in Upper Iso River.
54NG 2000-02	Limestone from the west branch of Rak River.
54NG 2510e	Limestone from headwaters of Berg Berg River.
54NG 2517i	Volcanic breccia with limestone fragments (float) from Ikoi River.
54NG 2520b	Limestone, float from Ip River.
6769 0200	Limestone found *in situ* as little pods in Baining Volcanics in the headwaters of Usavit River.
6769 1326	Limestone from Merai Volcanics in Merai River.

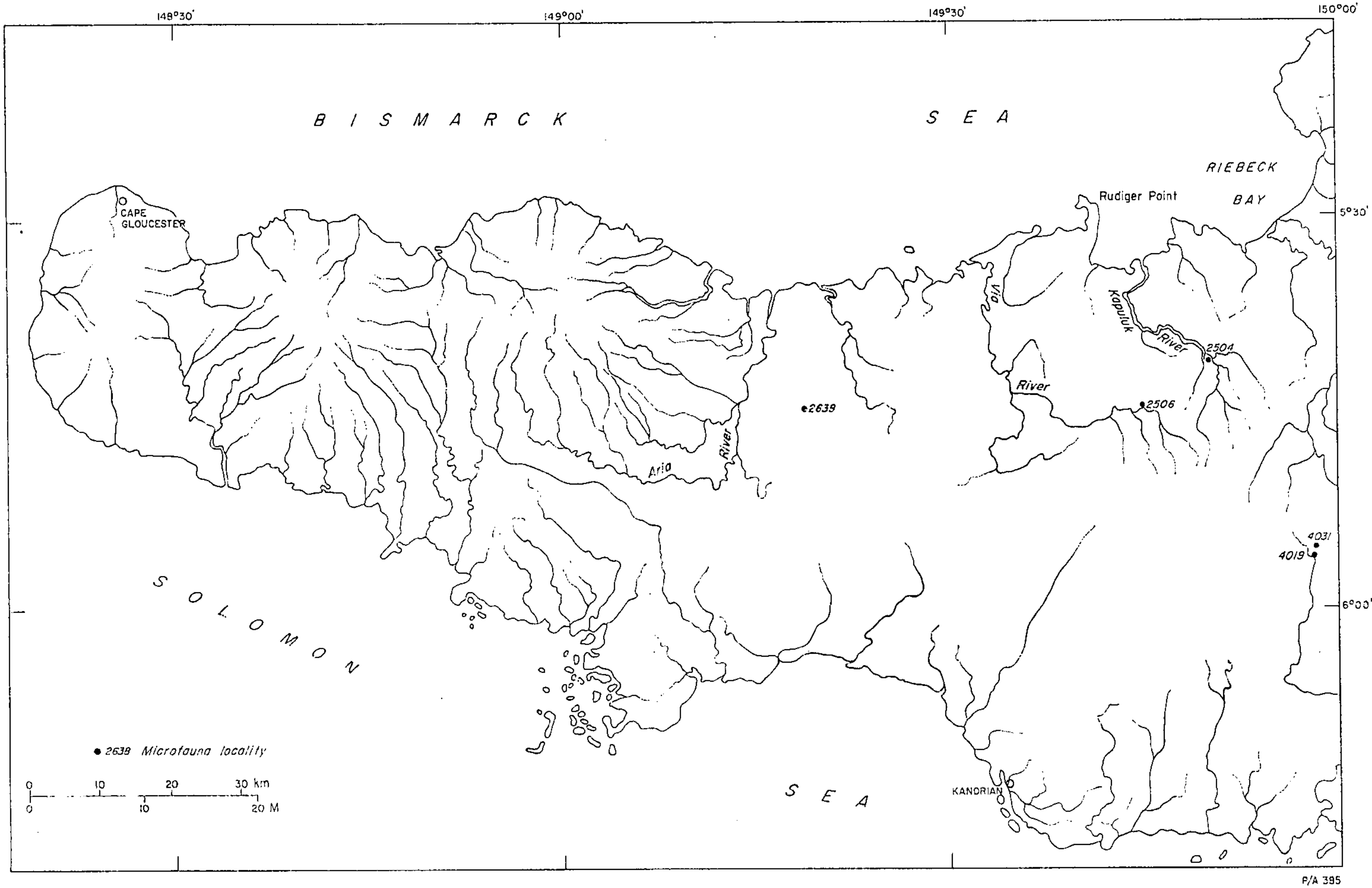


Fig. 3a. Microfauna localities, western New Britain.

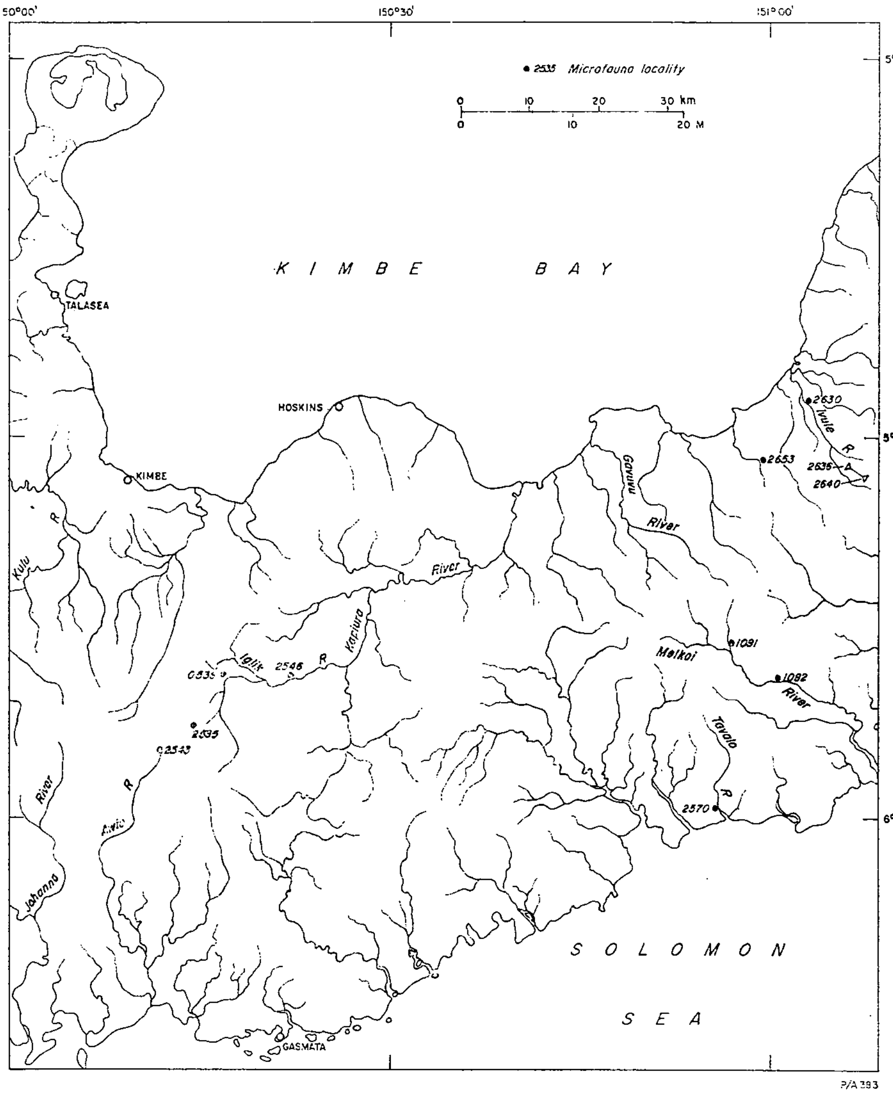


Fig. 3b. Microfauna localities, central New Britain.

6769 1327-30	Limestone float from Lat River.
6769 1331	Limestone float from Marambu River.
6769 1340	Limestone from base of Yalam Limestone northeast of Yalam Village.
6869 0567b	Limestone float from Bera River headwaters.
6869 0569	Limestone float from Mumus Creek, southern tributary of Mevlo River.
6869 0575b	Limestone float from southern tributary of Sai River.
6869 0582-83	Limestone float samples from behind Matanakunei Village, east coast of the Gazelle Peninsula.
6869 1678-79	Limestone samples from Yalam Limestone section above Yalam Village.
6869 1693	Limestone from Yalam Limestone near Puktas Village, Gazelle Peninsula.
6869 1704	Limestone float from upper Vudal River.
6869 1708	Limestone float from creek west of Rangoulit Village.
6869 1710e	Sandy limestone sample from base of Yalam Limestone along Valili Road beyond Vudal Agricultural College.

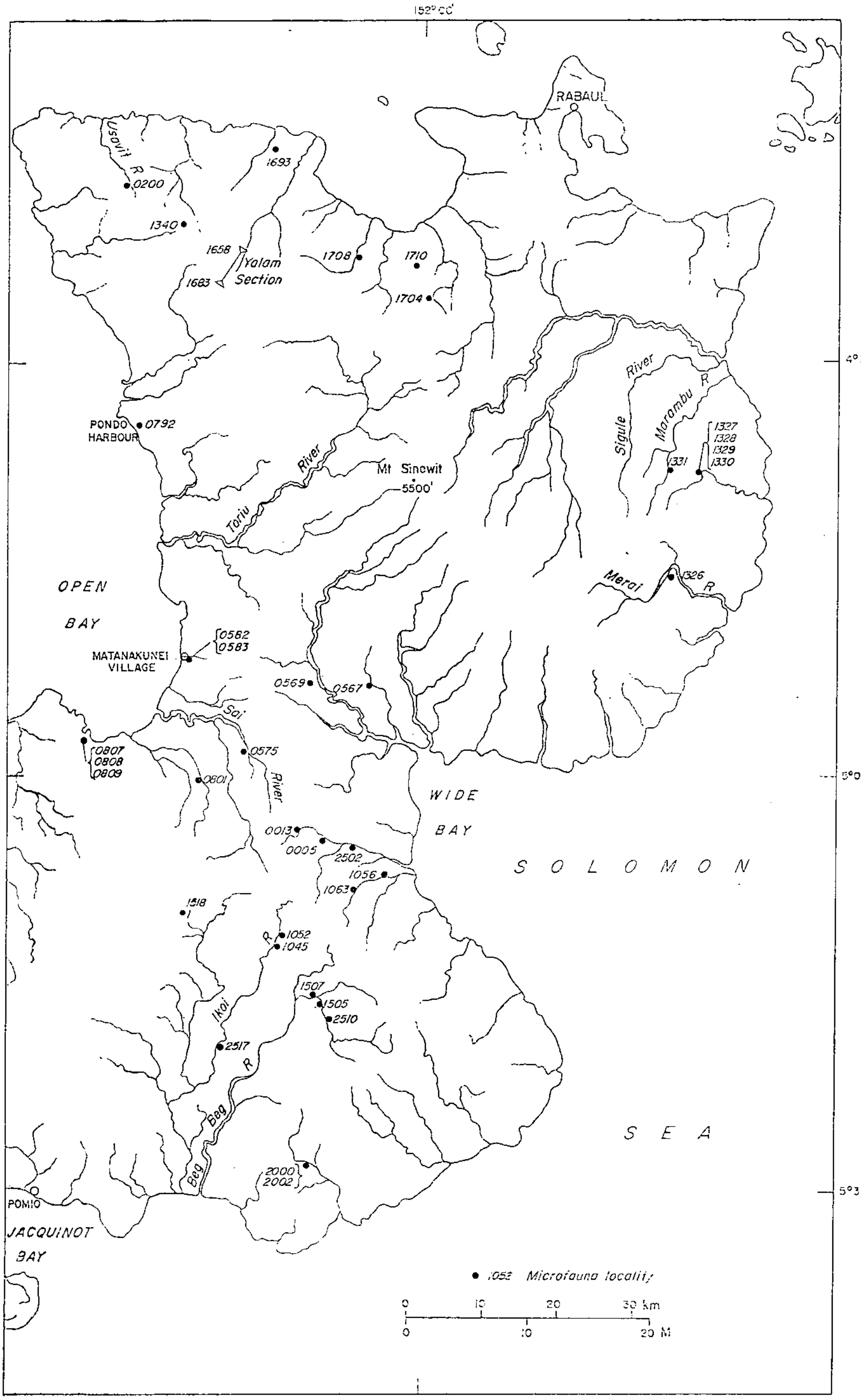


Fig. 3c. Microfauna localities, eastern New Britain.

REFERENCES

ADAMS, C. G., 1965—The Foraminifera and stratigraphy of the Melinau limestone, Sarawak, and its importance in Tertiary correlation. *Quart. J. geol. Soc. Lond.*, 121, 283-338, pls 21-30.

ADAMS, C. G., 1968—A revision of the foraminiferal genus *Austrotrillina* Parr. *Bull. Brit. Mus. (nat. Hist.) Geol.*, 16(2), 73-97.

ADAMS, C. G., 1970—A reconsideration of the East Indian letter classification of the Tertiary. *Bull. Brit. Mus. (nat. Hist.) Geol.*, 19(3), 85-137.

BAR, C. B., CORTEL, H. J., and ESCHER, A. E., 1961—Geological results of the Star Mountains ('Sterrengebergte') expedition (Central Range, Netherlands New Guinea). *Nova Guinea, Geol.*, 4, 39-99.

BELFORD, D. J., 1968—The foraminiferal fauna and age of samples from the Wide Bay-Open Bay area, East New Britain. *Bur. Miner. Resour. Aust. Rec.* 1965/233 (unpubl.).

BEMMELEN, R. W. VAN, 1949—THE GEOLOGY OF INDONESIA. *The Hague: Government Printing Office.*

BURSCH, J. G., 1947—Mikropaläontologische Untersuchungen des Tertiärs von Gross Kei (Molukken). *Abh. schweiz. palaeont. Ges.*, 65, 1-69, pls 1-10.

CAUDRI, C. M. B., 1939—Lepidocyclinen aus Java. *Verh. geol. mijnbouwk. Genoot.*, 12, 135-228, pls 1-10.

CLARKE, W. J., and BLOW, W. H., 1969—The inter-relationships of some late Eocene, Oligocene, and Miocene Larger Foraminifera and planktonic biostratigraphic indices. *Proc. 1st int. Conf. planktonic Microfossils (Geneva,* 1967), 2, 82-97.

COLE, W. S., 1954—Larger Foraminifera and small diagnostic Foraminifera from Bikini Drill Holes. *U.S. geol. Surv. prof. Pap.* 260-0, 569-608, pls 204-222.

COLE, W. S., 1957—Larger Foraminifera and smaller diagnostic Foraminifera from Bikini Drill Holes. *U.S. geol. Surv. prof. Pap.* 260-V, 743-84, pls 231-249.

COLE, W. S., 1958—Larger Foraminifera of Saipan Island. *U.S. geol. Surv. prof. Pap.*, 280-I, 321-360, pls 94-118.

COLE, W. S., 1960—Variability in embryonic chambers of *Lepidocyclina. Micropaleontology*, 6, 133-44, pls 1-4.

COLE, W. S., 1962—Embryonic chambers and the subgenera of *Lepidocyclina. Bull. Amer. Paleont.*, 44, 29-60, pls 1-8.

COLE, W. S., 1963—Tertiary Larger Foraminifera from Guam. *U.S. geol. Surv. prof. Pap.* 403-E, 1-28, pls 1-11.

COLE, W. S., 1969—Larger Foraminifera from deep drill holes on Midway Atoll. *U.S. geol. Surv. prof. Pap.* 680-C, 1-15, pls 1-5.

COLE, W. S., 1970—Larger Foraminifera of Late Eocene age from Eua, Tonga. *U.S. geol. Surv. prof. Pap.* 640-B, 1-17, pls 1-5.

COLE, W. S., and BRIDGE, J., 1953—Geology and larger Foraminifera from Saipan Island. *U.S. geol. Surv. prof. Pap.* 253, 1-45, pls 2-15.

COLE, W. S., TODD, R., and JOHNSON, C. G., 1960—Conflicting age determinations suggested by Foraminifera on Yap, Caroline Islands. *Bull. Amer. Paleont.*, 41(186), 77-112, pls 11, 12.

COLEMAN, P. J., 1963—Tertiary larger Foraminifera of the British Solomon Islands, Southern Pacific. *Micropaleontology,* 9(1), 1-38, pls 1-9.

CUSHMAN, J. A., 1948—FORAMINIFERA, THEIR CLASSIFICATION AND ECONOMIC USE, 4th edn. *Harvard Univ. Press.*

DROOGER, C. W., 1952—STUDY OF AMERICAN MIOGYPSINIDAE. *Vonk & Co. (Zeist).*

EAMES, F. E., BANNER, F. T., BLOW, W. H., CLARKE, W. J., and SMOUT, A. H., 1962—Morphology, taxonomy, and stratigraphic occurrence of the Lepidocyclininae. *Micropaleontology,* 8(3), 289-322, pls 1-8.

GLAESSNER, M. F., 1945—PRINCIPLES OF MICROPALAEONTOLOGY. *Melbourne Univ. Press.*

GRIMSDALE, T. F., 1952—Cretaceous and Tertiary Foraminifera from the Middle East. *Bull. Brit. Mus. (nat. Hist.) Geol.,* 1(8), 221-248, pls 20-25.

HANZAWA, S., 1947—Note on an Eocene foraminiferal limestone from New Britain. *Jap. J. Geol. Geogr.*, 20(2-4), 59-61, pls 14, 15.

HANZAWA, S., 1957—Cenozoic Foraminifera of Micronesia. *Mem. geol. Soc. Amer.*, 66.

LOEBLICH, A. R., and TAPPAN, Helen, 1964—TREATISE ON INVERTEBRATE PALEONTOLOGY. PART C. SARCODINA, CHIEFLY 'THECAMOEBIANS' AND FORAMINIFERA. *Geol. Soc. Amer.* and *Univ. Kansas Press.*

MACGILLAVRY, H. J., 1962—Lineages in the genus *Cycloclypeus* Carpenter (Foraminifera). *Prod. Acad. Sci. Amst.*, ser. B, 65, 429-58.

MACNAB, R. P., 1970—Geology of the Gazelle Peninsula, T.P.N.G. *Bur. Miner. Resour. Aust. Rec.* 1970/63 (unpubl.).

MARTIN, K., 1880—Die Tertiärschiten auf Java nach den Entdeckungen von Fr. Junghuhn. *Leiden, E. J. Brill.*

MATSUMARU, K., 1967—Geology of the Tomioka Area, Gunma Prefecture, with a note on *Lepidocyclina* from the Abuta Limestone Member. *Sci. Rep. Tohoku Univ., 2nd Ser. (Geol.)*, 39(2), 113-47, pls 7-8.

MOHLER, W. A., 1949—*Flosculinella reicheli* sp. nov. aus dem Tertiär von Borneo. *Ecl. geol. Helv.*, 42, 521-7.

NOAKES, L. C., 1942—Geological report on the island of New Britain; *in* FISHER, N. H., and NOAKES, L. C., Geological reports on New Britain. *Geol. Bull. N. Guinea*, 3, 3-39.

TAN SIN HOK, 1932—On the genus *Cycloclypeus* Carpenter. Pt 1. On the heterostegines of Tjimanggoe, S. Bantam, Java. Appendix. *Meded. Dienst Mijnb. Ned. -O.-Ind.*, 19, 3-194, pls 1-24.

TAN SIN HOK, 1936—Over verschillende palaeontologische criteria voor de geleding van het Tertiair. *Ing. Ned. Ind.*, 3(4), 173-9.

TAN SIN HOK, 1937—On the genus *Spiroclypeus* H. Douvillé with a description of the Eocene *Spiroclypeus vermicularis* sp. nov. from Koetai in East Borneo. *Ing. Ned. Ind.* 4(4), 177-93, pls 1-4.

UJIIE, H., 1964—Larger Foraminifera from a guyot in the Cocos-Keeling basin, eastern Indian Ocean. *Bull. Tokyo nat. Sci. Mus.*, 7(3), 307-21, pls 1-9.

VISSER, W. A., and HERMES, J. J., 1962—Geological results of the exploration for oil in Netherlands New Guinea. *Verh. geol.-mijnbouwk. Genoot.*, 20, 1-265.

VLERK, I. M. VAN DER, 1922—Het genus *Lepidocyclina* in het Indo-Pacifische gebied. *Meded. Dienst Mijnb. Ned. -O.-Ind.*, 8, 7-51, (also *Ecl. geol. Helv.*, 21, 182-221, pls 6-23).

VLERK, I. M. VAN DER, 1929—Groote Foraminifera van N. O. Borneo. *Meded. Dienst Mijnb. Ned. -O.-Ind.*, 9, 1-44.

VLERK, I. M. VAN DER, 1959—Problems and principles of Tertiary and Quaternary stratigraphy. *Quart. J. geol. Soc. Lond.*, 115, 49-63.

VLERK, I. M. VAN DER, 1959b—Modification de l'ontogénèse pendant l'évolution des Lépidocyclines (Foraminifères). *Bull. Soc. géol. Fr.*, 7e sér., 1, 669-73.

VLERK, I. M. VAN DER, 1963—Biometric research on *Lepidocyclina*. *Micropaleontology*, 9(4), 425-6.

VLERK, I. M. VAN DER, 1964—Biometric research on European Lepidocyclinas. *Proc. Acad. Sci. Amst., ser. B*, 67(5), 425-34.

VLERK, I. M. VAN DER, 1966a—Stratigraphie du Tertiaire des domaines Indo-Pacifique et Mesogéen. Essai de correlation. *Proc. Acad. Sci. Amst.*, ser. B, 69(3), 336-44.

VLERK, I. M. VAN DER, 1966b—*Miogypsinoides, Miogypsina, Lepidocyclina* et *Cycloclypeus* de Larat (Moluques). *Ecl. geol. Helv.*, 59(1), 421-9.

VLERK, I. M. VAN DER, 1968—Evolutie van een embryo. *Geol. Mijnb.*, 47(2), 121-5.

VLERK, I. M. VAN DER, and GLOOR, H., 1968—Evolution of an embryo. *Genetica*, 39, 45-63.

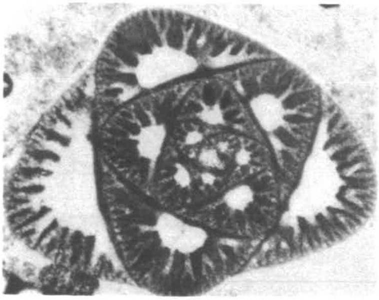
VLERK, I. M. VAN DER, and POSTUMA, J. A., 1967—Oligocene-Miocene Lepidocyclinas and planktonic Foraminifera from East Java and Madura, Indonesia. *Proc. Acad. Sci. Amst.*, ser. B, 70(4), 392-9.

PLATE 1

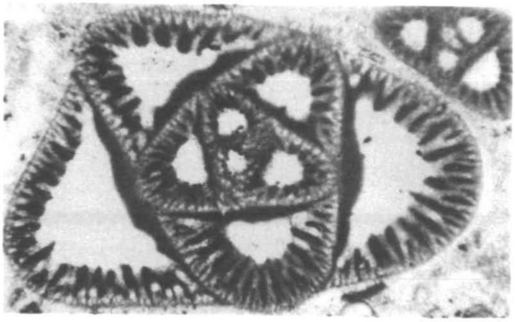
Figures 1-4 *Austrotrillina howchini* (Schlumberger)
1, random section x45, sample 51NG 2640n, slide 7 (CPC 12001).
2, random section x45, sample 49NG 2504c, slide 1 (CPC 12002).
3, enlargement x70 of specimen shown in fig. 2 showing the bifurcating alveoli.
4, random section x45, sample 49NG 2504c, slide 3 (CPC 12003).

Figures 5-6 *Austrotrillina* sp.
5, random section of specimen intermediate between *A. striata* and *A. howchini* x45. Sample 54NG 200a, slide 4 (CPC 12004).
6, random section of specimens intermediate between *A. asmariensis-striata* and *A. howchini* x45. Sample 54NG 2543c, slide 3 (CPC 12005).

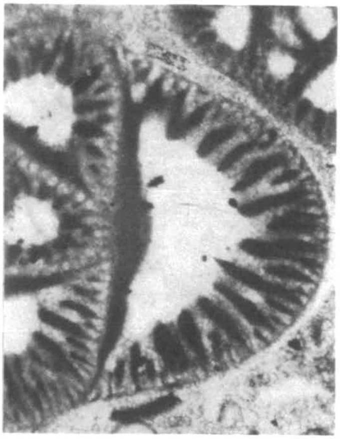
Austrotrillina



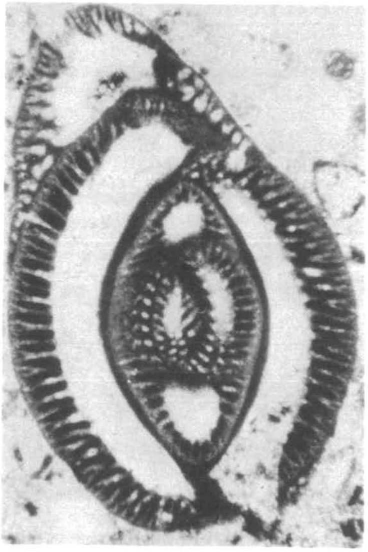
1



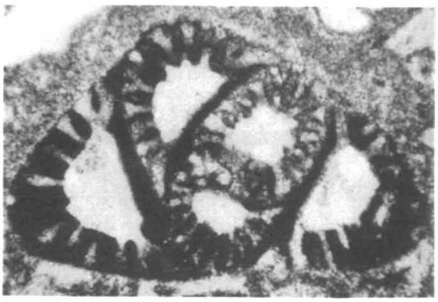
2



3



4

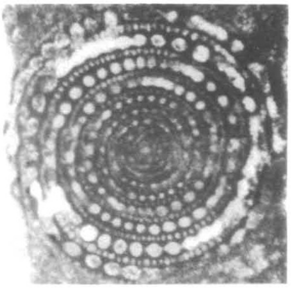


5

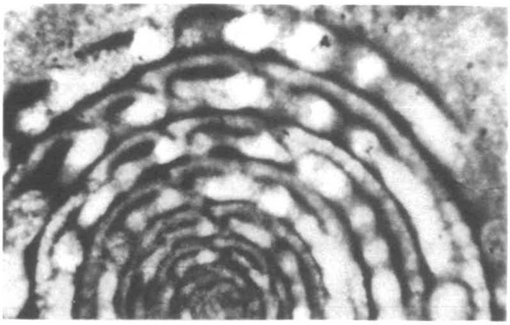
6

PLATE 2

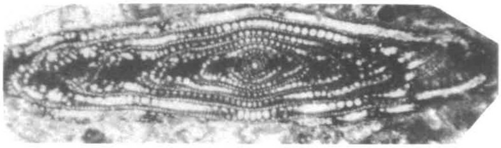
Figures 1-2	*Flosculinella globulosa* (Rutten) 1, random section close to axial plane x25. Sample 54NG 2000a, slide 6 (CPC 12006). 2, detail of random section close to equatorial plane x70. Sample 54NG 2000a, slide 4 (CPC 12007).
Figures 3-6	*Flosculinella borneensis* (Tan Sin Hok) 3, axial section x20, sample 54NG 1507i, slide 5 (CPC 12008). 4, axial section x70, sample 54NG 1507k, slide 6 (CPC 12009). 5, equatorial section x70, sample 54NG 1507k, slide 9 (CPC 12010). 6, detail of equatorial section shown in fig. 5, x200.
Figures 7-9	*Nummulites pengaronensis* Verbeek 7, transverse section of megalospheric specimen x25, sample 6869 0567b, slides 1 and 3 (CPC 12011). 8-9, equatorial sections of megalospheric specimens x25, sample 6869 0567b, slide 1 (CPC 12012), and slide 3 (CPC 12013).



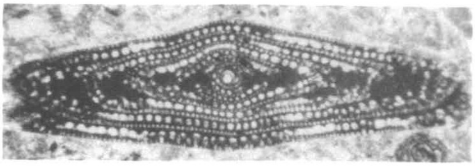
1



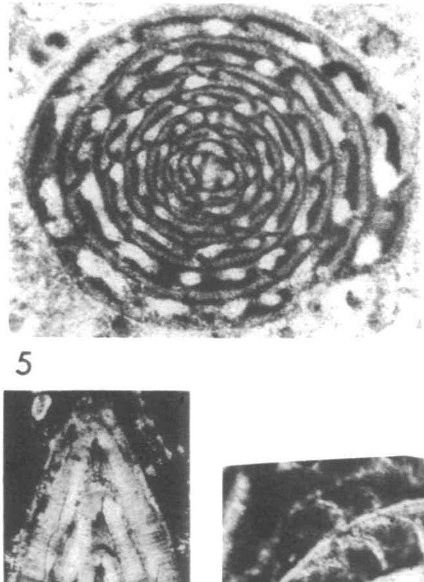
2



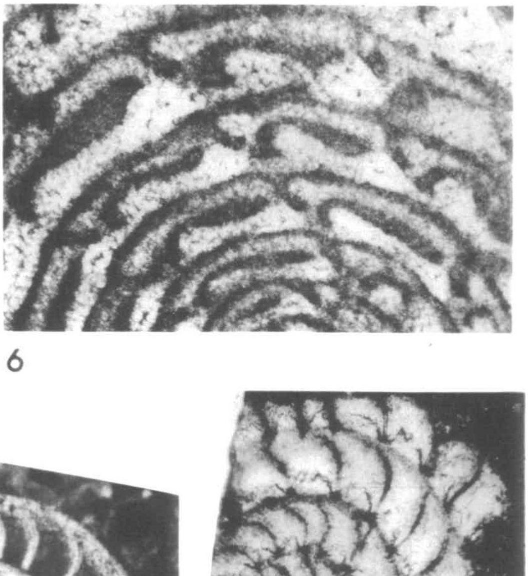
3



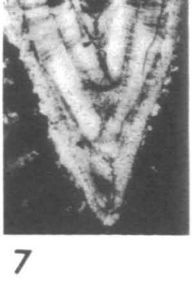
4



5



6



7

8

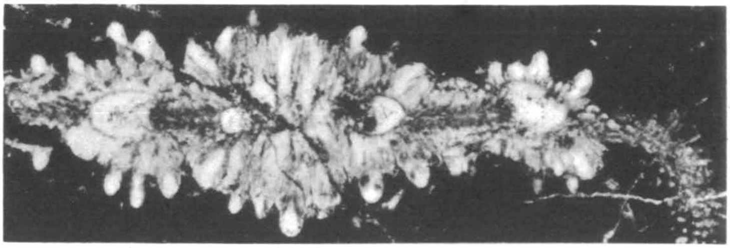
9

PLATE 3

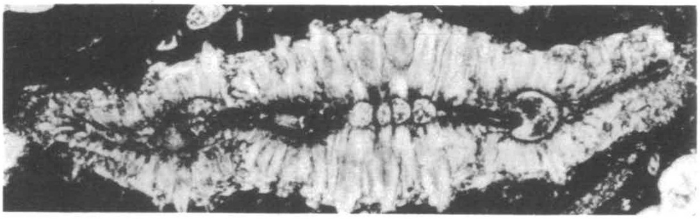
Pellatispira madaraszi (Hantken)
Transverse sections x20

Figure 1	Specimen having inflated umbonal area, large pillars and fibrous keel (*crassicolumnata*-type). Sample 54NG 1518a, slide 6 (CPC 12014).
Figure 2	Compressed lenticular specimen, sample 54NG 1518a, slide 5 (CPC 12016).
Figure 3	Small specimen of *crassicolumnata*-type, sample 6769 1327, slide 5 (CPC 12016).
Figures 4-5	Large, thick specimens showing strongly pillared centre and inflated periphery. Sample 6769 1327, slide 3 (CPC 12017) and slide 4 (CPC 12018).

Pellatispira madaraszi

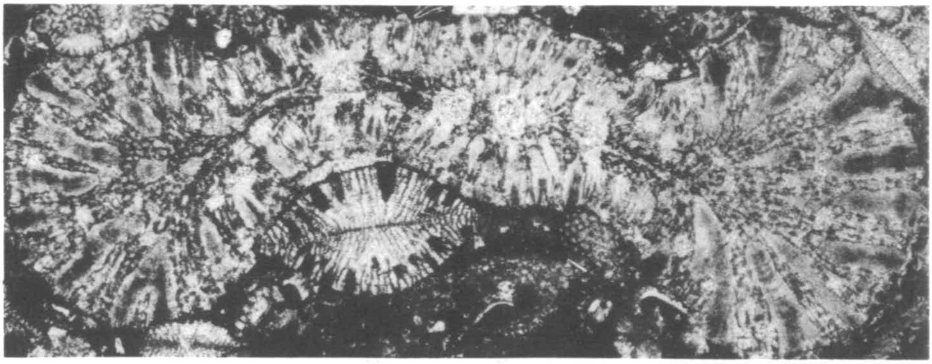


1

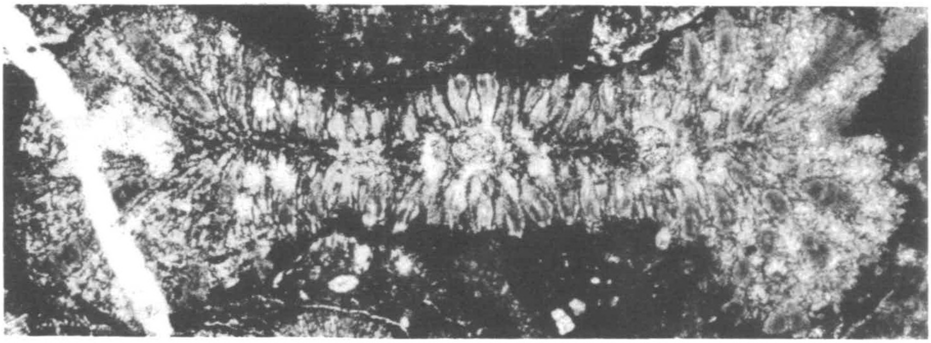


2

3



4



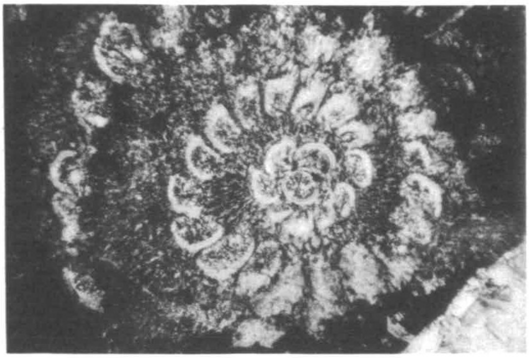
5

PLATE 4

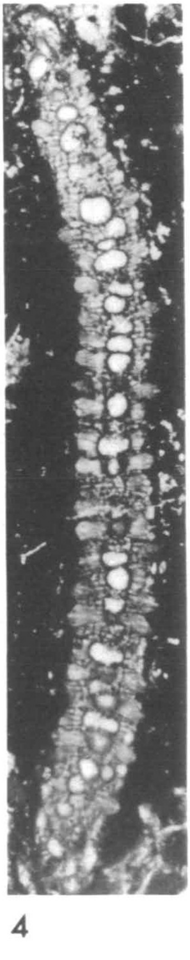
Figures 1-3	*Pellatispira madaraszi* (Hantken) 1, transverse section x20 of thinner specimen, intermediate between specimen figured in Pl. 3, figs 4-5, and 'typical' *P. fulgeria.* Sample 6769 1327, slide 5 (CPC 12019). 2, transverse section of 'typical' *P. fulgeria,* sample 54NG 0013, slide 4 (CPC 12020). 3, median section x20 of a specimen as figured in Pl. 3, figs 4-5. Sample 6769 1327, slide 4 (CPC 12021).
Figure 4	*Pellatispira hoffmeisteri* Whipple Transverse section x20, sample 51NG 1091b, slide 4 (CPC 12022).
Figure 5	*Biplanispira mirabilis* (Umbgrove) Transverse section x20, sample 54NG 0013, slide 2 (CPC 12023).

1

2



3

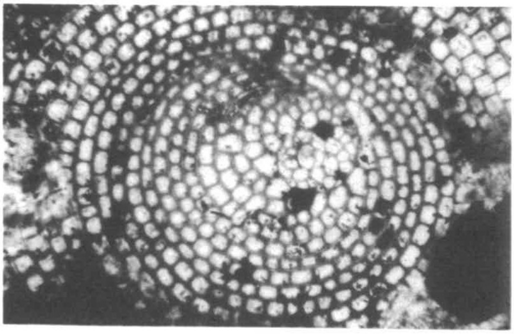


4

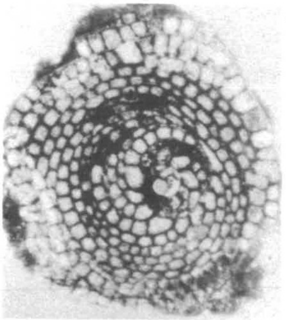
5

PLATE 5

Figures 1-3	*Cycloclypeus* (*Cycloclypeus*) *eidae* Tan Sin Hok 1, equatorial section x25, sample 6869 0569e, slide 5 (CPC 12024). 2, equatorial section x25, sample 49NG 2638, slide 28 (CPC 12025). 3, vertical section x25, sample 49NG 2638, slide 35 (CPC 12026).
Figure 4	cf. *Cycloclypeus* (*Cycloclypeus*) *indopacificus* Tan Sin Hok. Detail x45 of equatorial section, sample 6869 1678a, slide 15 (CPC 12027).
Figure 5	cf. *Cycloclypeus* (*Katacycloclypeus*) *annulatus* Martin Detail x45 of equatorial section, sample 6960 1678a, slide 19 (CPC 12028).
Figures 6-7	*Spiroclypeus vermicularis* Tan Sin Hok 6, vertical section x15, sample 6769 1708, slide 1 (CPC 12029). 7, vertical section x15, sample 6769 1330, slide 1 (CPC 12030).
Figures 8-10	*Halkyardia* sp. 8, sample 6769 1331, slide 1 (CPC 12031). 9-10, sample 6869 0583a, slide 4 (CPC 12032-33).

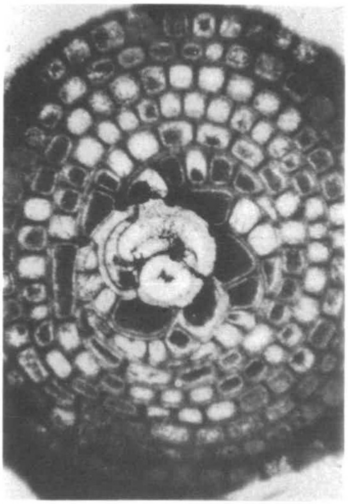


1

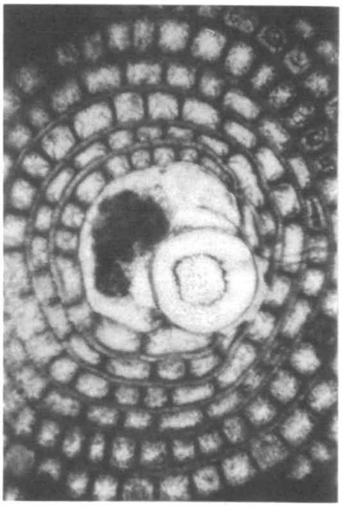


2

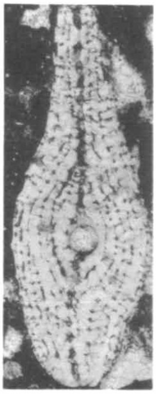
3



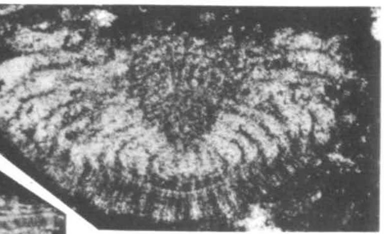
4



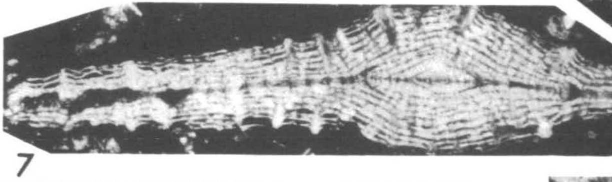
5



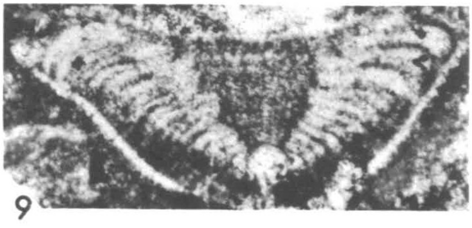
6



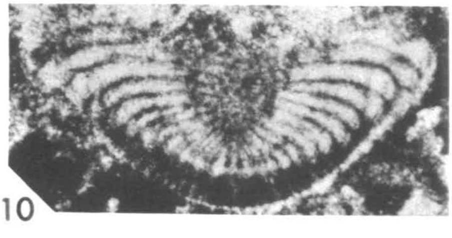
8



7



9



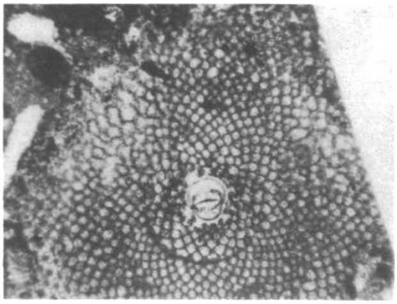
10

PLATE 6

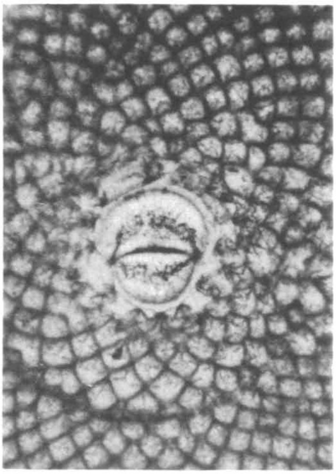
Lepidocyclina (*Nephrolepidina*) *isolepidinoides* van der Vlerk

Figure 1	Equatorial section x25, sample 54NG 1056, slide 30 (CPC 12034).
Figure 2	Nucleoconch x70 of specimen shown in fig. 1.
Figure 3	Detail x45 of equatorial section showing nucleoconch and equatorial chambers, sample 53NG 0807, slide 4 (CPC 12035).
Figure 4	Vertical section x25 of pillared specimen, sample 54NG 1056, slide 31 (CPC 12036).
Figure 5	Vertical section x25 of specimen without pillars, sample 6869 0569e, slide 2 (CPC 12037).
Figure 6	Equatorial section x25 of a microspheric specimen, sample 6869 0569a, slide 3 (CPC 12038).
Figure 7	Detail of specimen shown in fig. 6, x45.

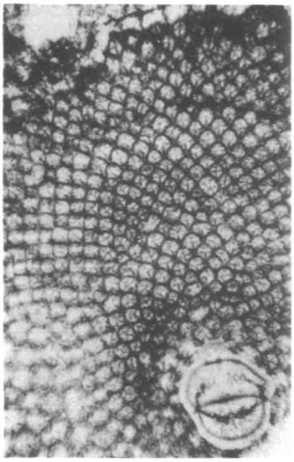
Lepidocyclina (Nephrolepidina) isolepidinoides



1

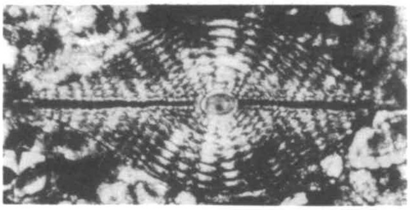


2

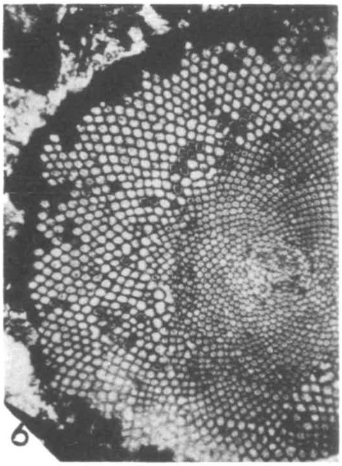


3

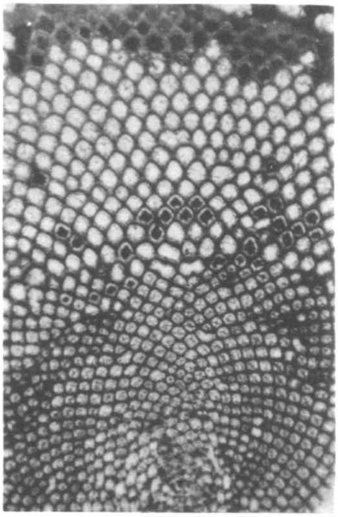
4



5



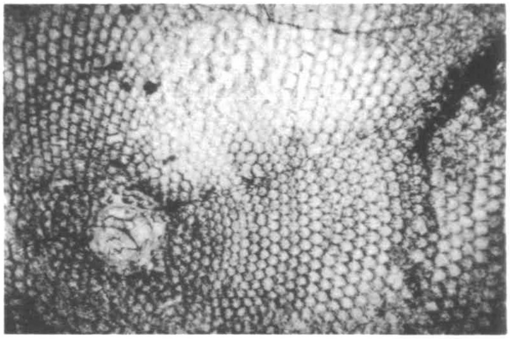
6

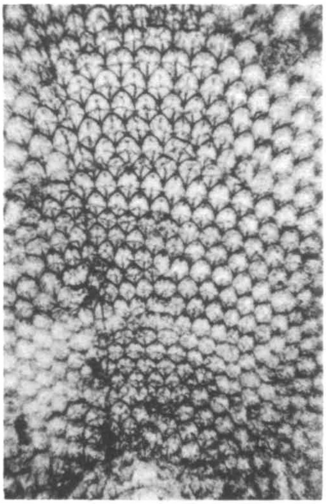


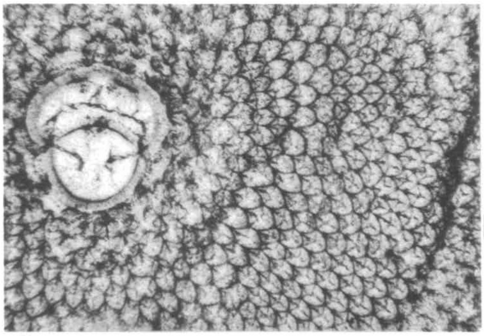
7

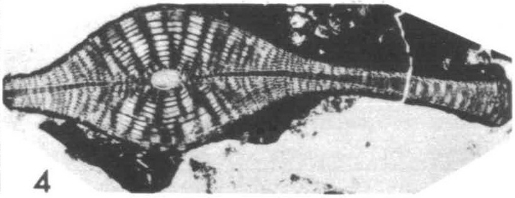
PLATE 7

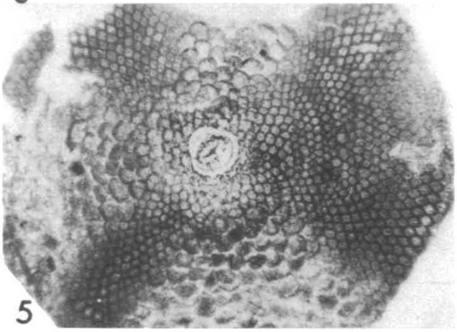
Figures 1-4	*Lepidocyclina* (*Nephrolepidina*) *verbeeki* Newton & Holland. All specimens from sample 53NG 0792. 1, equatorial section x25, slide 26 (CPC 12039). 2, detail of specimen shown in fig. 1, x45. 3, nucleoconch and equatorial chambers of megalospheric specimen, slide 2 (CPC 12040). 4, slightly oblique vertical section x10, slide 35 (CPC 12041).
Figures 5-8	*Lepidocyclina* (*Nephrolepidina*) *japonica* Yabe 5, equatorial section of a *sumatrensis*-type specimen x25, sample 49NG 2638, slide 1 (CPC 12042). 6, detail x45 of specimen shown in fig. 5. 7, equatorial section x25 of a *verrucosa*-type specimen, sample 51NG 2543a, slide 5 (CPC 12043). 8, detail x45 of the specimen shown in fig. 7.

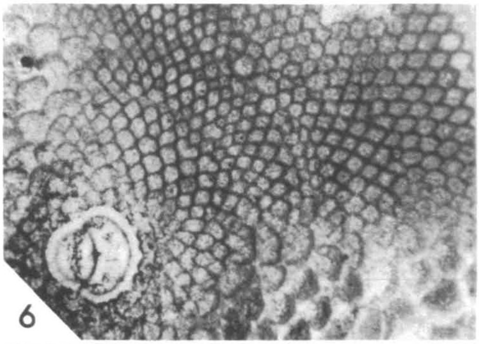

1

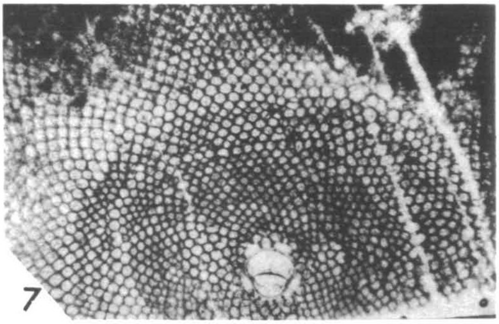

2


3


4


5


6


7

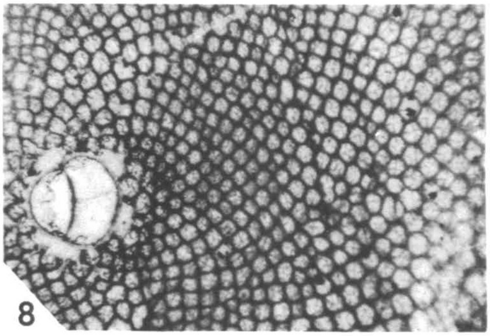
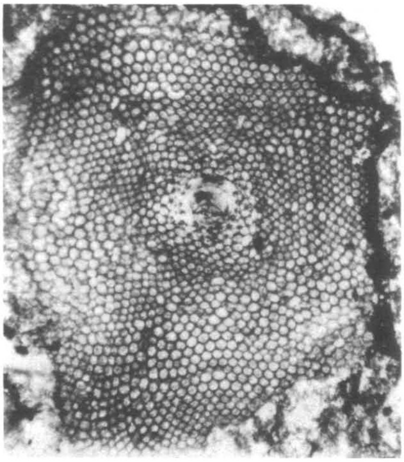

8

PLATE 8

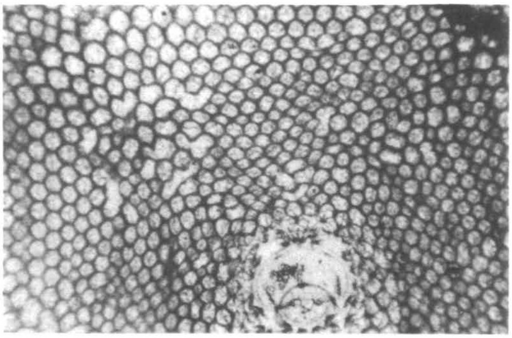
Lepidocyclina (Nephrolepidina) japonica Yabe

Figure 1	Equatorial section x25 of a *verrucosa*-type specimen, sample 51NG 0539, slide 1 (CPC 12044).
Figure 2	Detail x45 of a specimen shown in fig. 1.
Figure 3	Equatorial section x25 of a *japonica*-type specimen, sample 51NG 2535, slide 3 (CPC 12045).
Figure 4	Detail x45 of specimen shown in fig. 3.
Figures 5-7	Vertical sections x25. 5, sample 51NG 2535, slide 6 (CPC 12046). 6, sample 51NG 0539, slide 21 (CPC 12047). 7, sample 51NG 2543a, slide 19 (CPC 12048).
Figure 8	Vertical section x45 of young specimen, sample 51NG 0539, slide 22 (CPC 12049).

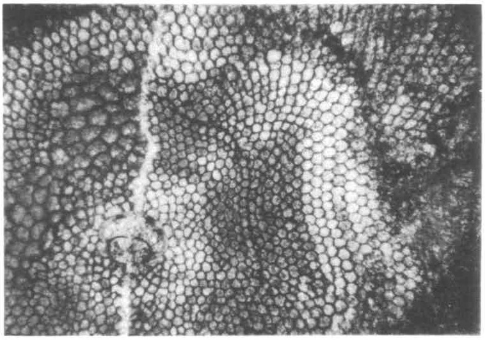
Lepidocyclina (Nephrolepidina) japonica



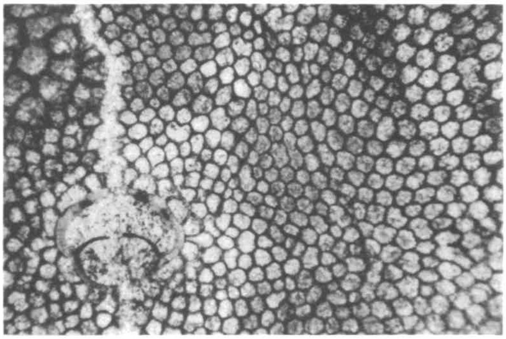
1



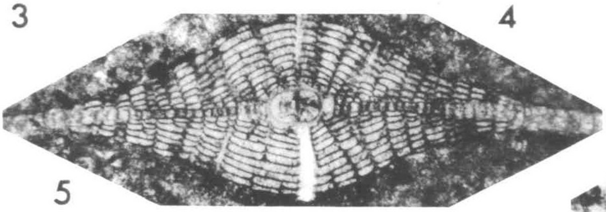
2



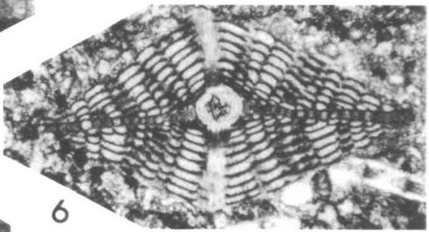
3



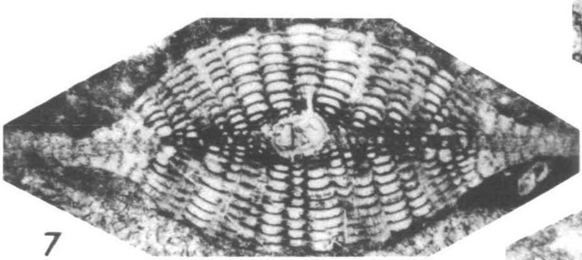
4



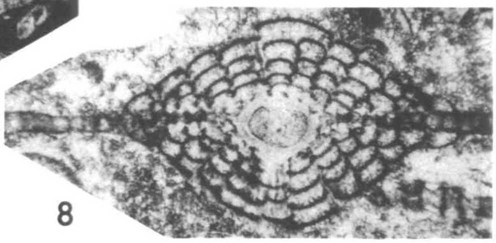
5



6



7



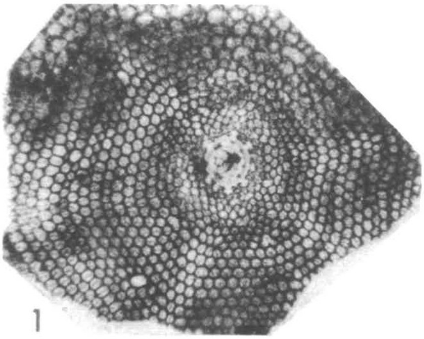
8

PLATE 9

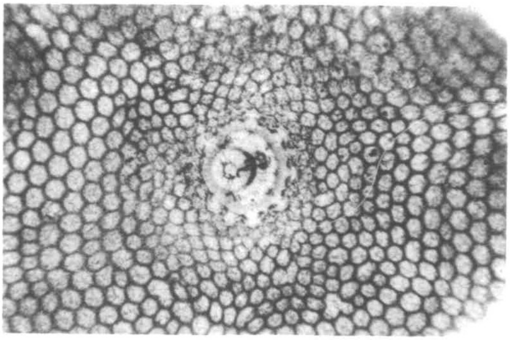
Lepidocyclina (*Nephrolepidina*) *martini* Schlumberger

Figure 1	Equatorial section x25, sample 6869 0575b, slide 3 (CPC 12050).
Figure 2	Detail x45 of specimen shown in fig. 1.
Figure 3	Equatorial section x25, sample 6869 0575b, slide 17 (CPC 12051).
Figure 4	Detail x45 of specimen shown in fig. 3.
Figure 5	Equatorial section x25, sample 6869 0575b, slide 2 (CPC 12052).
Figure 6	Detail x45 of specimen shown in fig. 5.
Figure 7	Equatorial section x25, sample 6869 1710e, slide 15 (CPC 12053).
Figure 8	Detail x45 of specimen shown in fig. 7.

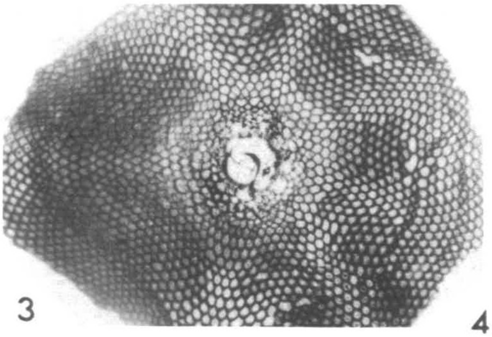
Lepidocyclina (Nephrolepidina) martini



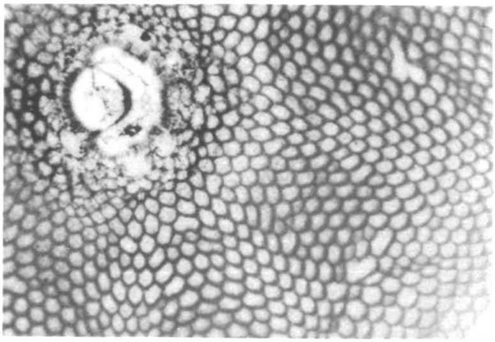
1



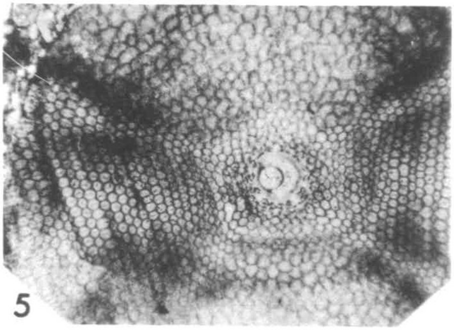
2



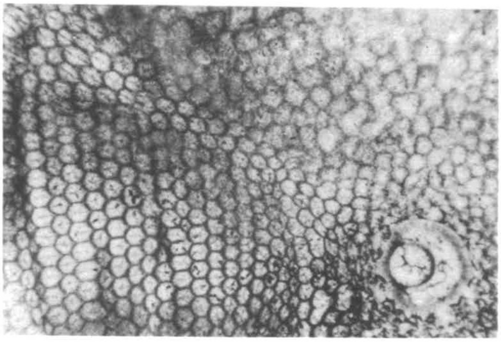
3



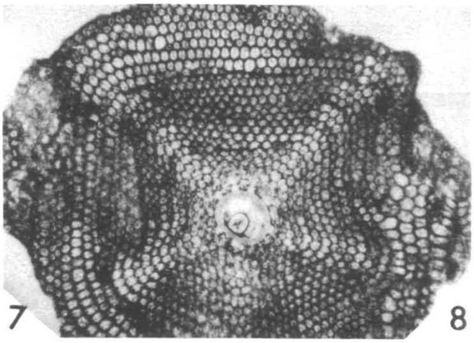
4



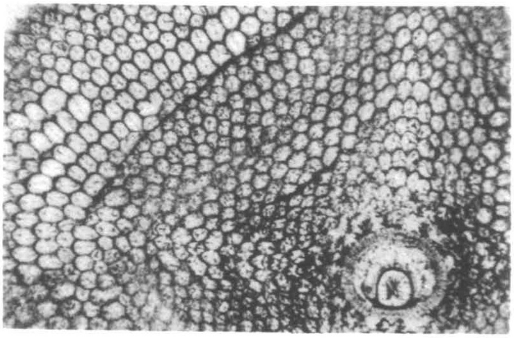
5



6



7



8

PLATE 10

Figures 1-4 *Lepidocyclina (Nephrolepidina) martini* Schlumberger

1, part of equatorial section of specimen with a typical trybliolepidine nucleoconch. Sample 6869 1710e, slide 33 (CPC 12054).

2, large trybliolepidine nucleoconch x70. Sample 6869 1710e, slide 35 (CPC 12055).

3-4, vertical sections x25, sample 6869 1710e, slide 39 (CPC 12056) and slide 46 (CPC 12057).

Figure 5-9 *Lepidocyclina (Nephrolepidina) augusticamera* Cole

5, equatorial section x20, sample 6769 1326, slide 13 (CPC 12058).

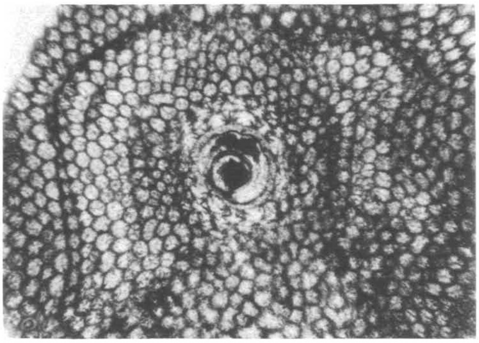
6, detail of specimen shown in fig. 5 showing the shape and pattern of equatorial chambers, x70.

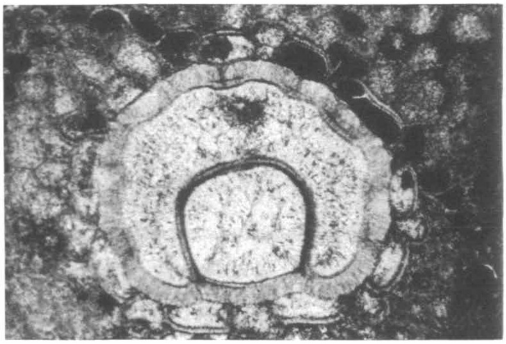
7-9, enlargements x45 of embryonic apparatuses of three specimens of sample 54NG 1056.

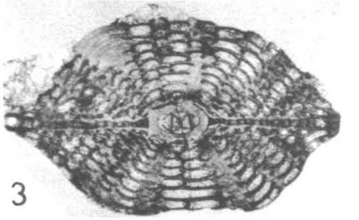
7, slide 9 (CPC 12059).

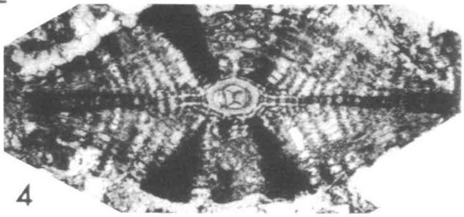
8, slide 14 (CPC 12060).

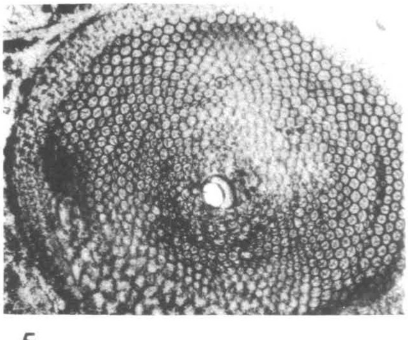
9, slide 5 (CPC 12061).

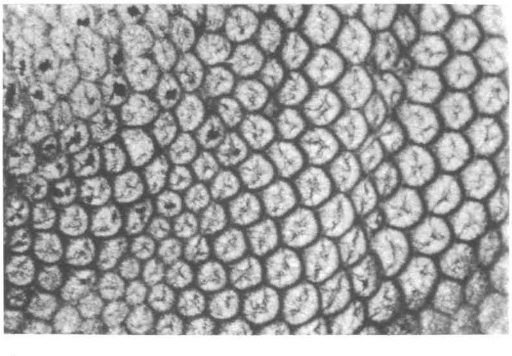

1

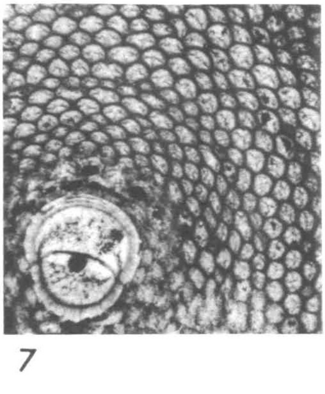

2

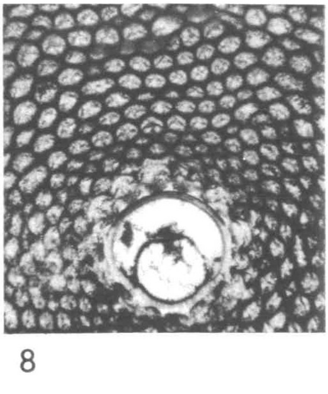

3


4


5


6


7


8

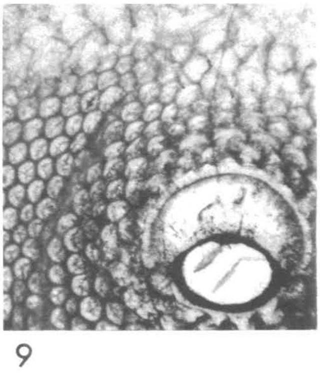
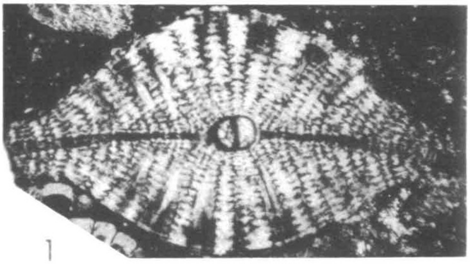

9

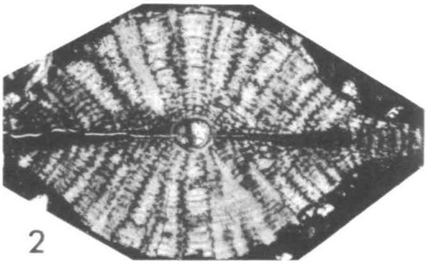
PLATE 11

Figures 1-2 *Lepidocyclina* (*Nephrolepidina*) *augusticamera* Cole
1, sample 6869 0582c, slide 7 (CPC 12062).
2, sample 54NG 1056, slide 20 (CPC 12063).

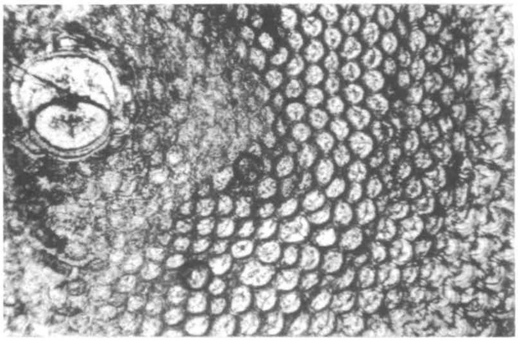
Figures 3-10 *Lepidocyclina* sp. cf. *L.* (*N.*) *augusticamera* Cole
All specimens from sample 6869 0582a.
3, part x45 of equatorial section showing nucleoconch and equatorial chambers, slide 9 (CPC 12064).
4-7, enlargements of embryonic apparatuses.
4, slide 15 (CPC 12065).
5, slide 24 (CPC 12066).
6, slide 11 (CPC 12067).
7, slide 5 (CPC 12068).
8-9, vertical sections x15.
8, slide 1 (CPC 12069).
9, slide 2 (CPC 12070).
10, vertical section x45 through flange, showing the pectinations of the distal side of the equatorial chambers, slide 1 (CPC 12072).



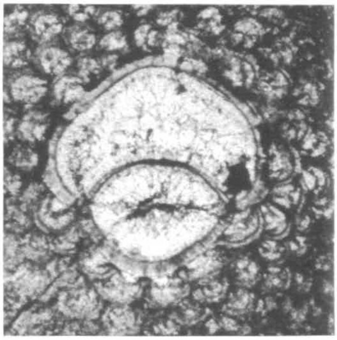
1



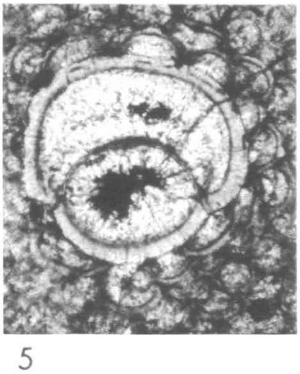
2



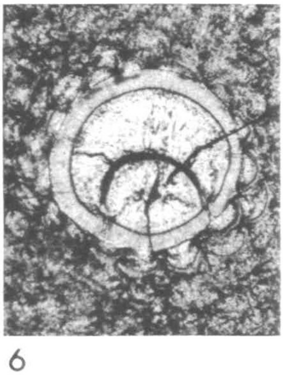
3



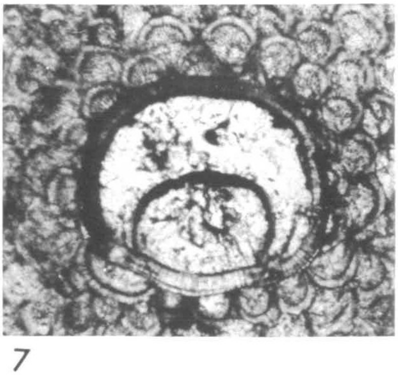
4



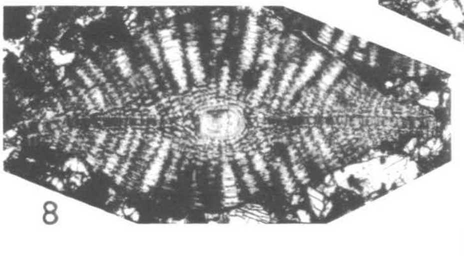
5



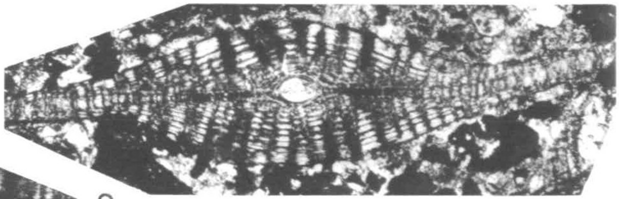
6



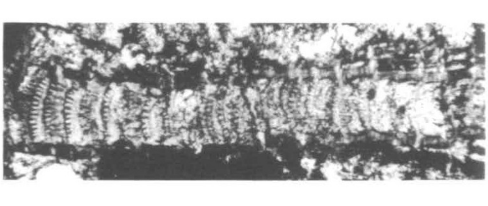
7



8



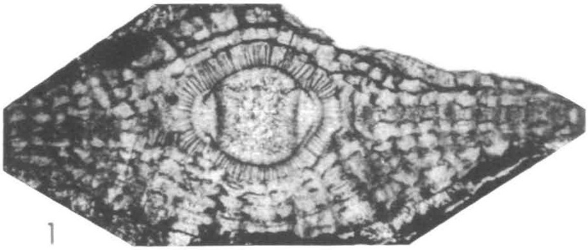
9

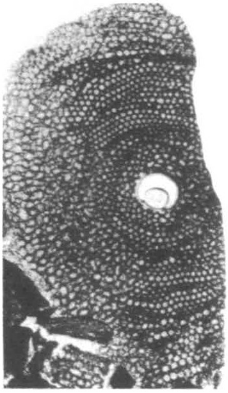


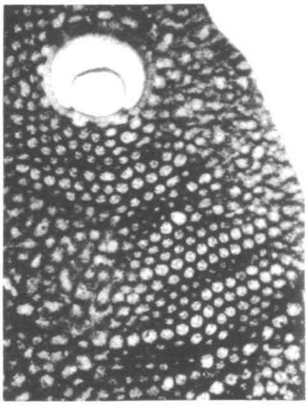
10

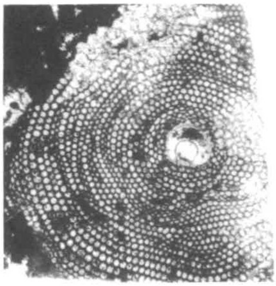
PLATE 12

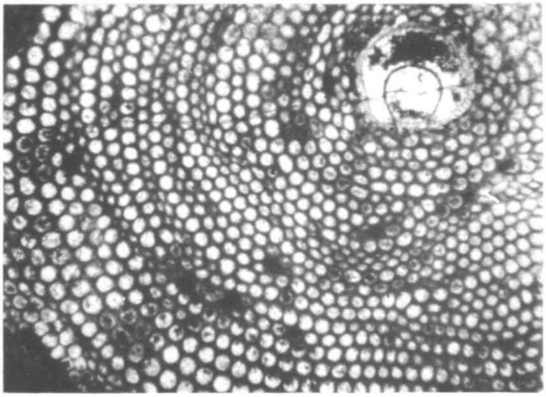
Figure 1	*Lepidocyclina* sp. cf. *L.* (*N.*) *augusticamera Cole* Vertical section x45 through a young specimen showing the fibrous structure of the wall of the nucleoconch, sample 6869 0582a, slide 2 (CPC 12071).
Figures 2-8	*Lepidocyclina* (*Eulepidina*) *ephippioides* (Jones & Chapman). 2, equatorial section x10, sample 54NG 2517i, slide 1 (CPC 12073). 3, detail x25 of a specimen shown in fig. 2. 4, equatorial section x10, sample 54NG 1045a, slide 16 (CPC 12074). 5, detail x25 of specimen shown in fig. 4. 6, equatorial section x10, sample 6869 0569b, slide 6 (CPC 12075). 7, detail x20 of specimen shown in fig. 6. 8, vertical section x10 of lenticular specimen, sample 53NG 0792, slide 34 (CPC 12076).

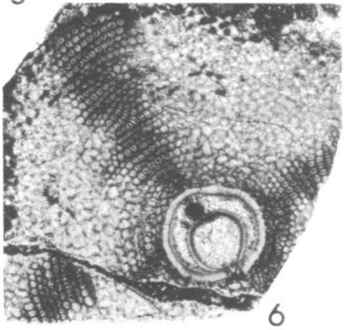

1

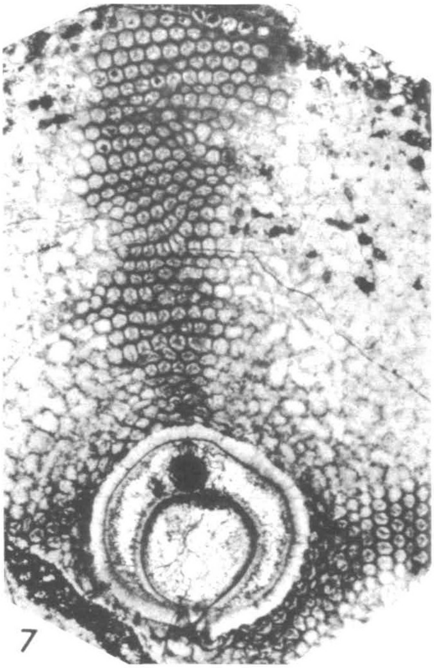

2


3


4


5


6


7

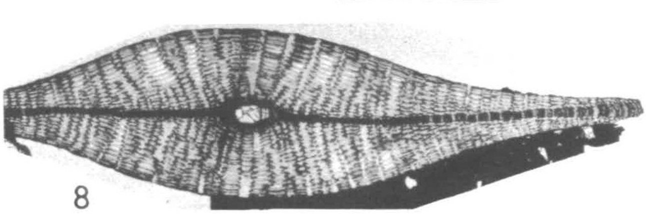

8

PLATE 13

Figures 1-4 *Lepidocyclina* (*Eulepidina*) *ephippioides* (Jones & Chapman)

1, vertical section x10 of worn specimen, sample 54NG 1045a, slide 13 (CPC 12077).

2, oblique vertical section x10 of sellate specimen, sample 53NG 0792, slide 29 (CPC 12078).

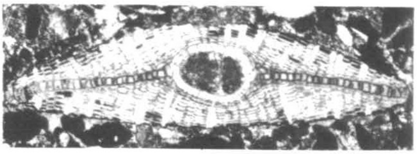
3, equatorial section x8 of a microspheric specimen, sample 6869 0569a, slide 6 (CPC 12079).

4, vertical section of a microscopic specimen, sample 6869 0569a, slide 4 (CPC 12080).

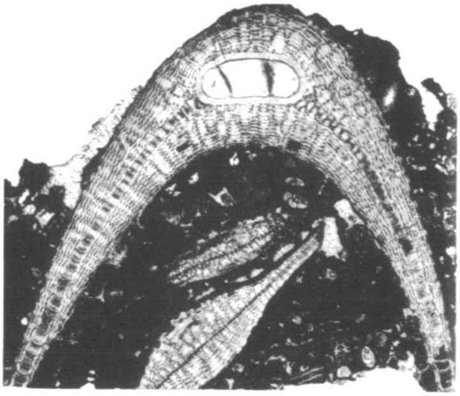
Figures 5-6 *Lepidocyclina glabra* (Rutten)

5, equatorial section x13, sample 6869 1693, slide 6 (CPC 12081).

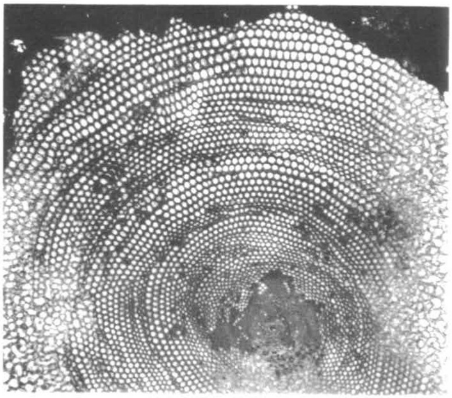
6, vertical section x13, sample 6869 1693, slide 1 (CPC 12082).



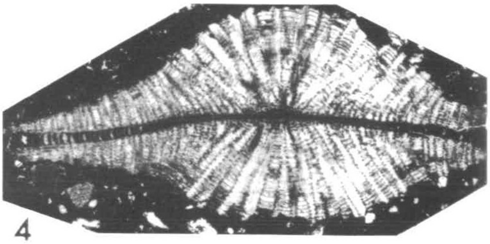
1



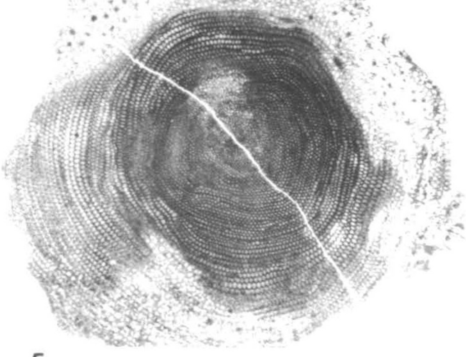
2



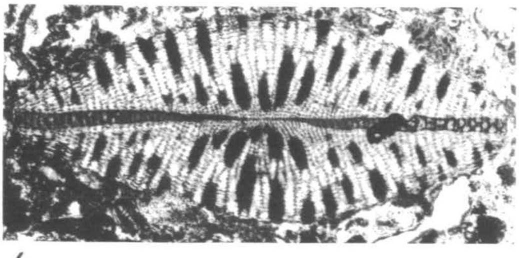
3



4



5



6

PALYNOLOGICAL OBSERVATIONS IN THE CARPENTARIA BASIN, QUEENSLAND

by D. BURGER

SUMMARY

From analysis of core and cuttings samples from four oil exploration wells, Mornington Island No. 1, Burketown No. 1, Karumba No. 8, and Wyaaba No. 1, five palynological intervals are recognized in the Cretaceous sequence, based on restricted ranges of selected spore and pollen species.

The earliest interval, corresponding to part of spore unit K 1a (Burger's *Murospora florida* Zone), is associated with the lower Aptian Gilbert River Formation. The second interval, unit K 1b-c, occurs in the lower (Aptian) part of the Wallumbilla Formation; the succeeding (Albian) unit K 1d is connected with the upper part of the Wallumbilla Formation. The fourth interval, of Albian age, is here referred to as unit K 2b and is associated with most of the Allaru Mudstone. The youngest microfloral assemblages from the upper part of the Mudstone and the overlying Normanton Formation (formerly upper Normanton Formation) are provisionally grouped into a fifth interval, unit K 2c. This unit is also Albian in age and forms an intermediate interval between the Albian spore sequence in the Eromanga Basin and the Cenomanian sequence in Bathurst Island, Northern Territory.

None of the samples served to establish the presence of spore unit K 2a, which lies between K 1d and K 2b and is present in the Eromanga Basin, associated with (approximately) the Toolebuc Limestone.

On the basis of its pollen content, the Gilbert River Formation is correlated with the upper part of the Hooray Sandstone in the central Eromanga Basin. The Wallumbilla Formation and Toolebuc Limestone are palynologically equivalent in the southern Carpentaria Basin and Eromanga Basin. The Allaru Mudstone is probably comparable to the Allaru Mudstone plus the Mackunda Formation in the eastern, central and northern Eromanga Basin, and the Normanton Formation should probably be correlated with the lower part of the Winton Formation.

The microplankton record, although poor, indicates withdrawal of the sea following deposition of the Wallumbilla Formation and Toolebuc Limestone, culminating in brackish to non-marine environments, with possibly a brief incursion of the sea during deposition of the Normanton Formation.

INTRODUCTION

This paper describes the preliminary results of palynological examination of strata in the Carpentaria Gulf area, in order to correlate the sediments there with those in the Eromanga Basin. The results will be incorporated in a more extensive paper on the Carpentaria Basin with the aid of further field work and sampling during future stratigraphic drilling in the Cape York Peninsula. It is realized that the boundary between the Eromanga and Carpentaria Basins is difficult to define (H. F. Doutch, pers. comm.). For the purpose of this paper the region from which spore information was obtained (Figs 1, 2, 4) is taken as part of the southern Carpentaria Basin.

The available material shows the existence of Cretaceous spores, pollen grains, and microplankton in part of the sequence. The occurrence of marine Lower Cretaceous micro-organisms in the Cape York Peninsula has been known since Eisenack & Cookson (1960) described Aptian dinoflagellates and acritarchs from a bore in the Archer River area at latitude 14°S approximately. They also reported Lower Cretaceous microplankton from the basal marine sandstone in Wyaaba No. 1 Well (Fig. 1). Evans (*in* Terpstra & Evans, 1962) recovered Cretaceous spore and pollen assemblages from samples from Mornington Island No. 1 and Karumba No. 8 Wells farther south (Fig. 1). Evans (1966b) reported similar spores and dinoflagellates from seismic shothole samples and cuttings in the Archer River area. He established the presence of spore unit K 1a, as well as the Lower Cretaceous dinoflagellate Zone of *Dingodinium cerviculum/Scriniodinium attadalense,* the Zone of *Dingodinium cerviculum,* the Zone of *Muderongia tetracantha/ Odontochitina operculata,* and the Zone of *Odontochitina operculata,* all in sediments which he referred to as the 'Mein Formation'.

Re-examination of the Karumba and Mornington Island samples, plus additional examination of cores and cuttings from Burketown No. 1 and Wyaaba No. 1 Wells, yielded sufficient data to permit recognition of the essential features of the Lower Cretaceous spore sequence as known in the Eromanga and Surat Basins and treated in Evans (1966a) and Burger (1968a and b, 1973). Valuable information was obtained from the upper sandy sequence, i.e. the Normanton Formation. The microfloral assemblages from this sequence appear to be intermediate in stratigraphic position between the microfloras from the Albian Allaru Mudstone in the Eromanga Basin (unit K 2b) and those from the Cenomanian of Bathurst Island, Northern Territory (unit K 3, see Fig. 4).

Palynological evidence of Jurassic sedimentation exists in the Laura and Papuan Basins (Evans, 1966b), but in the Carpentaria Basin, north of about Latitude 19°S, Jurassic spores are known only in Weipa No. 1 Well (Meyers, 1969).

STRATIGRAPHY

The Carpentaria Basin is the northernmost part of the Great Artesian Basin. Its geology has been reviewed by Whitehouse (1955), Laing & Power (*in* Hill & Denmead, 1960), Meyers (1969), and Smart, Ingram, Doutch, & Grimes (1971). Further regional studies of the southernmost part of the Carpentaria Basin were carried out by Reynolds (1960) and Woods (1961). Furthermore, oil companies have carried out seismic, geological, and gravity surveys and have drilled exploratory and stratigraphic wells. The following account is based largely on the results of recent field work by the Bureau of Mineral Resources and the Geological Survey of Queensland.

Mesozoic and Cainozoic sediments rest unconformably on older, mostly metamorphic and igneous, rocks of which the age is uncertain and could range from Proterozoic to Upper Palaeozoic (Meyers, 1969). In the southern Carpentaria Basin, where the geology is best known, five sedimentary formations of Cretaceous age have been distinguished in outcrop and subsurface in an uninterrupted sequence. These formations are, in stratigraphic order, the Gilbert River Formation, Wallumbilla Formation, Toolebuc Limestone, Allaru Mudstone, and Normanton Formation. The Wallumbilla, Toolebuc and Allaru are also known to extend across most, if not all, of the Eromanga Basin. Four oil exploration wells

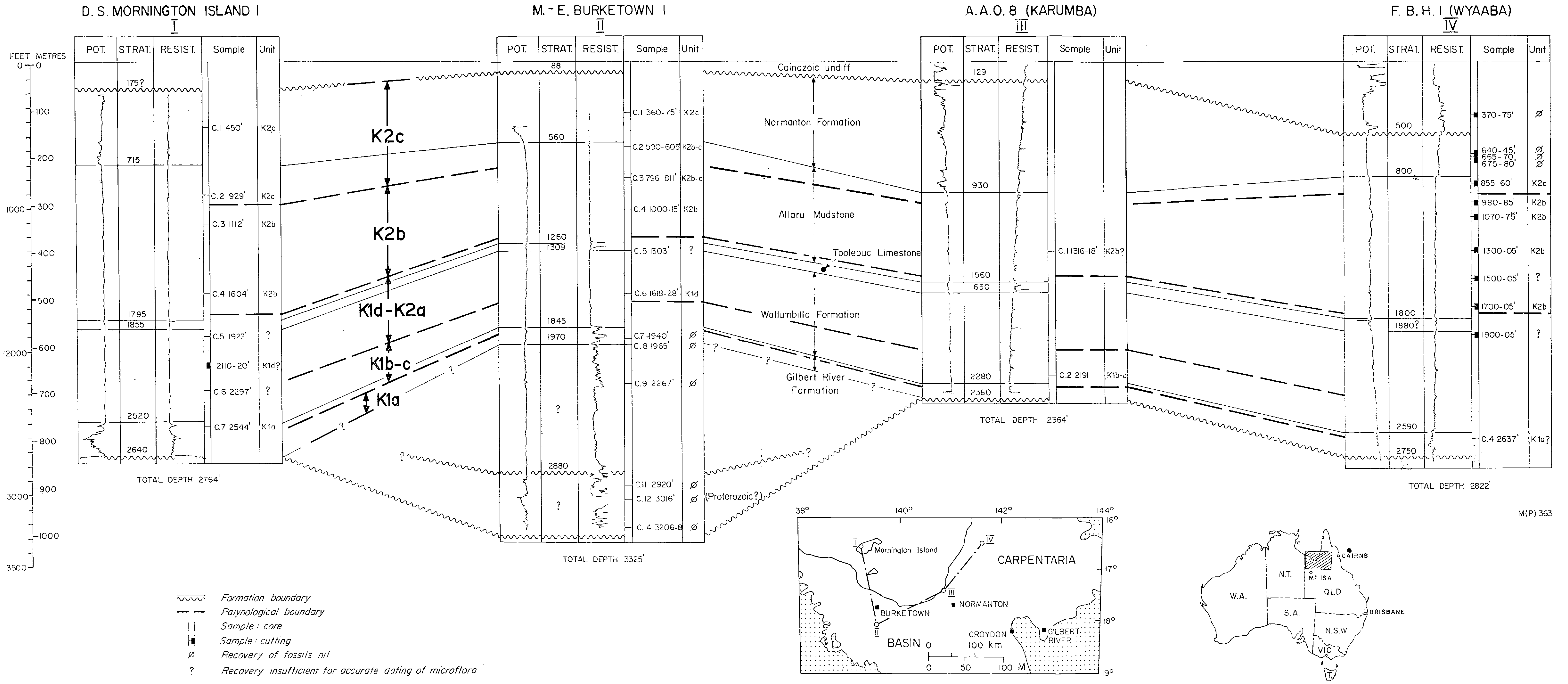


Fig. 1. Relationship of formations to spore units in the southern Carpentaria Basin.

were sunk through this sequence in the southern part of the Carpentaria Basin (see also Fig. 1):

Well	Reference	Location		Year drilled
Delhi-Santos Mornington Island 1	Harrison, Greer, & Gibson, 1961	16°32′44″	139°15′27″	1961
Mid-Eastern Burketown 1	Perryman, 1964	18°03′30″	139°31′00″	1964
Associated Australian Oilfields 8 (Karumba)	Laing, 1960	17°24′36″	140°52′21″	1958
Frome-Broken Hill 1 (Wyaaba)	Derrington, 1957	16°29′30″	141°37′22″	1957

Part of the sequence beneath the Gilbert River Formation in Burketown No. 1 Well (Fig. 1) represents the Eulo Queen Group (named by Smart et al., 1971), of presumably Jurassic age (Burger *in* Grimes & Smart, 1970). No other spore data are available from the Group in the southern Carpentaria Basin.

The Gilbert River Formation has been described in outcrop mainly from near Croydon, where it consists of coarse to medium-grained sandstone with interbedded conglomerate and siltstone (Smart et al., 1971). Laing & Power (*in* Hill & Denmead, 1960) distinguished two members which also proved to be mappable units in outcrops; they were formally defined by Smart et al. (1971). The lower, the Yappar Member, originated apparently in non-marine conditions and is thought to be of Upper Jurassic to Lower Cretaceous age. The upper, the Coffin Hill Member, contains marine fossils which were collected near Croydon. Whitehouse (1955) dated these as lower Aptian. Dickins (1960) reported, among other species, *Maccoyella barklyi, 'Rhynchonella' croydonensis, Cyrenopsis* cf. *C. meeki, Fissilunula clarkei, Trigonia* sp. cf. *T. nasuta,* and *Peratobelus* sp.; he related this assemblage to the lower Aptian 'Roma' faunas. Plant fossils determined by White (1957) included *Cycadites, Cladophlebis, Phyllopteris,* and *Linguifolium.*

The Gilbert River Formation was recognized in Wyaaba No. 1 between 2750 ft (838 m) and 2590 ft (789 m), in Karumba No. 8 between 2360 ft (719 m) and 2280 ft (694 m), in Burketown No. 1 between 1970 ft (600 m) and 1845 ft (562 m), and in Mornington Island No. 1 between 2640 ft (804 m) and 2520 ft (768 m).

The Wallumbilla Formation (Laing & Power's (1959) Blackdown Formation) is widespread in subsurface and consists mainly of silty and calcareous mudstone deposited in a restricted marine environment (Meyers, 1969). Near the base, as elsewhere, some sandstones may be present. The thickness of the formation remains fairly constant. Marine 'Roma' faunas collected from near Gilberton, south of the Gilbert River, included, according to Dickins (1960), *Maccoyella umbonalis, M.* cf. *M. corbiensis, Australiceras* sp., *Peratobelus* sp. Fossils determined by Whitehouse include *Pachydomella chutus, Australiceras irregulare, Cinulia hochstetteri?, Dentalium wallumbillaensis, Macrocallista* sp. nov., and *'Cyrenopsis' elongata*; they indicate a lower Aptian age (Laing & Power *in* Hill & Denmead, 1960). Further fossil discoveries near Wrotham Park are listed in Woods (1961).

Day (1969) regarded the 'Roma' faunas from the Wallumbilla Formation in the Surat, Eromanga, and Carpentaria Basins as late, rather than early, Aptian. He gave an early Aptian age to faunas collected from the Minmi Member below the formation in the Surat Basin, and compared them on stratigraphic grounds with the Gilbert River faunas. Although the latter contain many species which are lacking in the Minmi faunas, he thought that this was due to provincialism rather than to difference in age.

From the Wrotham Park area Crespin (1963) reported the presence of Lower Cretaceous Foraminifera, such as *Ammobaculites fisheri, A. minimus, Ammodiscus cretaceus, Trochammina minuta,* and *T. raggatti.* Belford (1957) suggested a possible Albian age for assemblages in Wyaaba, 1900-2200 ft (579-670 m), in the upper part of the formation, and based this mainly on the presence of *Hedbergella planispira* (Tappan) and *H.* (al. *Globigerina*) *infracretacea* (Glaessner). This agrees well with an Albian age for the upper part of the Wallumbilla Formation (Coreena Member) in the Eromanga Basin (Vine & Day, 1965; Day, 1969). In the northern Eromanga Basin *H. planispira* appears to have a similar (Albian) lower range limit (Terpstra, 1970); however, Crespin (*in* Laing, 1960) recovered the species also from the basal (Aptian) part of the formation in Karumba No. 8 Well (core 2). *H. infracretacea* may be an equally unreliable marker, as Ludbrook (1966) recovered it from strata equivalent to the lower part of the Wallumbilla Formation in the Eromanga Basin, South Australia.

The top of the Wallumbilla Formation lies probably at 1880 ft (573 m) in Wyaaba No. 1, at 1630 ft (496 m) in Karumba No. 8, at 1309 ft (399 m) in Burketown No. 1, and at 1855 ft (565 m) in Mornington Island No. 1.

The Toolebuc Limestone (Needham & Doutch, 1972; Ingram, 1972), Laing & Power's Kamileroi Limestone, occurs in the southern part of the Carpentaria Basin. It extends farther to the north (Doutch, pers. comm.); Meyers (1969) did not recognize it in the Weipa well. It consists mainly of limestone and calcareous mudstone. Fossil fragments include fish scales, *Inoceramus* sp., *Dimitobelus diptychus,* and vertebrate fragments. The top of the Toolebuc Limestone lies in Wyaaba at 1800 ft (548 m), in Karumba at 1560 ft (475 m), in Burketown at 1260 ft (385 m) and in Mornington Island at 1795 ft (547 m).

The Allaru Mudstone, the equivalent of Meyers' lower Normanton Formation (Smart et al., 1971), is predominantly argillaceous and was mapped in outcrop in the Dobbyn and Millungera Sheet areas, south of Croydon and Normanton (Doutch, pers. comm.). It was also identified in petroleum exploration wells and water bores. Very few fossils are known from the formation in outcrop (Doutch, pers. comm.). Crespin (*in* Laing, 1960) reported *H. planispira* from the formation in Karumba No. 8 Well. Belford (1957) reported, among other species, *Trochammina raggatti, Haplophragmoides chapmani, Lenticulina* sp., *Neobulimina* cf. *N. canadensis, Hedbergella planispira,* and *H. infracretacea* from the formation in Wyaaba No. 1 Well.

The top of the Allaru Mudstone lies in Wyaaba at 800 ft (243 m), in Karumba at 930 ft (283 m), in Burketown at 500 ft (171 m), and in Mornington Island at 715 ft (218 m).

The Normanton Formation *sensu stricto* (Smart et al., 1971), equivalent to Meyers' upper Normanton Formation, consists of sandstone, siltstone, and mudstone. Smart et al. mapped it in the southern part of the basin. They pointed out that the name should refer only to the upper sandy sequence of Laing & Power's Normanton Formation (*sensu lato*). At the type area, 65 km southwest of Normanton (Little Bynoe Crossing) ammonites were collected, among which Whitehouse (see Meyers, 1969) determined *Cymatoceras hendersoni, Beudanticeras flindersi, Cophinoceras* (?) *daintreei, C. ogilviei, Myloceras* sp. nov., and *Appurdiceras* sp., a fauna of upper Albian age.

The formation is in places unconformably overlain by lateritized, leached, and deeply weathered Cainozoic (and Upper Cretaceous?) sediments. The contact lies in Wyaaba at 500 ft (152 m). In Karumba the Mesozoic-Cainozoic contact lies at 129 ft (39 m), in Burketown at 88 ft (27 m), and in Mornington Island probably at 175 ft (53 m).

DISTRIBUTION OF SPORES AND POLLEN GRAINS

Of the samples examined, only those from the Cretaceous sequence yielded recognizable microfossils. The sequence between the Gilbert River Formation and the basement in Burketown No. 1 Well did not yield any information. The sequence above the Normanton Formation was not investigated in any detail, as it lies outside the scope of this paper.

The Mesozoic sediments gave a reasonably good yield of palynomorphs. Details of successfully examined samples are given in Table 1, and their position in the sequence is shown in Figure 1. The occurrence is given of 33 selected species of pollen and spores; these are useful index fossils for the Lower Cretaceous in the Great Artesian Basin. They are:

Camarozonosporites cf. *C. amplus* (Stanley, 1965) Dettmann & Playford, 1968
Cicatricosisporites australiensis (Cookson, 1953) Potonié, 1956
C. cuneiformis Pocock, 1964
C. hughesi Dettmann, 1963
C. ludbrooki Dettmann, 1963
C. pseudotripartitus (Bolkhovitina, 1961) Dettmann, 1963
Clavatipollenites sp.
Clavifera triplex (Bolkhovitina, 1953) Bolkhovitina, 1966
Cooksonites variabilis Pocock, 1962
Coptospora paradoxa (Cookson & Dettmann, 1958a) Dettmann, 1963
Couperisporites tabulatus Dettmann, 1963
Crybelosporites striatus (Cookson & Dettmann, 1958b) Dettmann, 1963
C. stylosus Dettmann, 1963
C. sp.
Cyclosporites hughesi (Cookson & Dettmann, 1958a) Cookson & Dettmann, 1959a
Dicolpopollis sp.
Dictyotosporites speciosus Cookson & Dettmann, 1958a
Foraminisporis asymmetricus (Cookson & Dettmann, 1958a) Dettmann, 1963
F. wonthaggiensis (Cookson & Dettmann, 1958a) Dettmann, 1963
Hoegisporis uniforma Cookson, 1965

Kraeuselisporites jubatus Dettmann & Playford, 1968
Kuylisporites sp.
Laevigatosporites ovatus Wilson & Webster, 1946
Microfoveolatosporis canaliculatus Dettmann, 1963
Murospora florida (Balme, 1957) Pocock, 1961
Peromonolites peroreticulatus Brenner, 1963
Pilosisporites notensis Cookson & Dettmann, 1958a
P. parvispinosus Dettmann, 1963
Psilatricolpites sp.
Rouseisporites radiatus Dettmann, 1963
Tricolpites augathellaensis Burger, 1970
Tricolporopollenites cf. *T. distinctus* Groot & Penny, 1960
Trilobosporites trioreticulosus Cookson & Dettmann, 1958a

The genus *Appendicisporites* Weyland & Krieger, 1953, is present also, but separate species have not yet been distinguished. These will be studied further. Specimens with close affinity to *A. tricornitatus* Weyland & Greifeld, 1953, and *A. distocarinatus* Dettmann & Playford, 1968, were found. Likewise, specimens belonging to the genus *Tricolpites* (Cookson, ex Couper) emend. Belsky, Bolt., & Pot., 1965 have not yet been distinguished at specific level; they require closer examination.

Megaspores, many of them torn and fragmented (cf. *Balmeisporites* Cookson & Dettmann, 1958b) occurred in a number of samples; they could not be fully identified and are therefore not shown in Table 1.

The restricted ranges of various species are the basis for palynological comparison of the formations in the Eromanga and Carpentaria Basins; the spore intervals or spore units recognized have been repeatedly identified in the Surat and Eromanga Basins (Evans, 1966a; Burger, 1968a and b, 1969, 1973; Terpstra & Burger, 1969). The age given for the various units is based on faunal evidence of associated sediments in outcrop and subsurface.

Spore unit K 1a

Evans' (1966a) unit K la is the equivalent interval of Burger's (1973) *Murospora florida* Zone. Here the upper part of the range of *Murospora florida* overlaps the lower part of the ranges of *Cyclosporites hughesi* and *Cicatricosisporites australiensis.* These three species are present in the upper part of the Gilbert River Formation in Mornington Island No. 1 Well (core 7). A microflora (MFP 5644) was recovered from the top of the formation in Wyaaba No. 1 Well (core 4), at approximately the same stratigraphic level. The assemblage is poor in species and lacks *Murospora florida,* but the presence of *Couperisporites tabulatus* and *Cooksonites variabilis* strongly suggests that the microflora is referable to the *Murospora florida* Zone. Eisenack & Cookson (1960) recovered from the same core an organism of unknown affinity ('Gen. et sp. indet. forma A'). This fossil (BMR species 405) has been identified in Queensland exclusively in the Zone of *Murospora florida* (Burger, 1973). Although it was not found in microflora MFP 5644, Eisenack & Cookson's record indicates that core 4 from Wyaaba No. 1 Well is within the Zone.

Foraminisporis asymmetricus is present in the assemblages from the Wyaaba and Mornington Island wells; the Wyaaba microflora contains in addition *Pilosisporites notensis*. These species first appear in the upper part of the *Murospora florida* Zone, the Subzone of *Foraminisporis asymmetricus,* of late Neocomian and early Aptian age (Burger, op. cit.). The Subzone occurs in the uppermost part of the Hooray Sandstone in most of the northern and eastern Eromanga Basin; and in the Gilbert River Formation in the northern part of the basin (Gilberton and Hughenden Sheet areas). In much of the northern Eromanga Basin the upper limit of the Subzone lies close to the base of the Wallumbilla Formation. This also appears to be the case in the southern Carpentaria Basin, as in Karumba No. 8 Well a younger microflora was recovered from immediately above the base of the formation.

The Subzone of *Foraminisporis asymmetricus* is the equivalent interval of Dettmann & Playford's (1969) lower *Dictyotosporites speciosus* Zone, or, more specifically, the lower part of the *Cyclosporites hughesi* Subzone, which ranges in age from Valanginian to late Aptian. Thus the age estimates of the Subzone of *Foraminisporis asymmetricus* and its correlates in eastern Australia appear to be in reasonably approximate agreement.

Spore unit K 1b-c

Unit K 1b-c is the interval in the spore sequence that commences at the upper range limit of *Murospora florida* and ends with the introduction of *Crybelosporites striatus*. It contains, among other species, *Cyclosporites hughesi, Cicatricosisporites australiensis, C. hughesi, Pilosisporites notensis, Dictyotosporites speciosus,* and *Foraminisporis asymmetricus;* it lacks *Murospora florida* and, except perhaps in the lowermost part, also *Crybelosporites stylosus*. The unit is closely associated with the (late) Aptian 'Roma' faunas (Vine & Day, 1965; Day, 1969). In view of this, and the age of the previous unit, a post-early Aptian age is suggested for unit K 1b-c.

Seven samples from cores and cuttings were examined from the Wallumbilla Formation. The yield was disappointing for the purpose of locating the boundaries of the units. However, the presence of unit K 1b-c was established in the lower part of the formation in Karumba (core 2); this part of the formation can therefore be correlated with the Doncaster Member in the Eromanga Basin.

Unit K 1b-c is equivalent to the upper part of Dettmann & Playford's (1969) *Cyclosporites hughesi* Subzone (Burger, 1972).

Spore unit K 1d

Microfloras succeeding unit K 1b-c are mainly characterized by the presence of *Crybelosporites striatus* and *Laevigatosporites ovatus*. Burger (1968a) thought that *Pilosisporites parvispinosus* also entered the sequence at the same level as the other two species, but specimens of *parvispinosus* have since been recovered from the Hooray Sandstone and Bungil Formation in the Eromanga and Surat Basins (Burger, 1973). The presence of the species in the Gilbert River Formation of Wyaaba No. 1 confirms that the range of the species includes most of the Aptian.

Unit K 1d ends with the first appearance of *Coptospora paradoxa* and *Microfoveolatosporis canaliculatus;* it has been recognized in the early Albian Coreena and Ranmoor Members of the Wallumbilla Formation (Burger, 1968a; also uncommunicated information). A representative assemblage was recovered from the middle part of the Formation in Burketown (core 6). This microflora (MFP 5284) contained also specimens resembling *Cicatricosisporites hughesi* and *C. ludbrooki;* these species are common in units K 1 and K 2 microfloras in Queensland, especially *C. hughesi,* which occurs in most samples from units K 1a to K 1d of the Eromanga and Surat Basins.

The presence of *Appendicisporites* spp. is unusual, as in the Eromanga Basin the earliest specimens of this genus do not appear before spore unit K 2b, and coincide with the first appearance of tricolpate angiosperms (Burger, 1968a). Dettmann & Playford (1969) also observed synchronous appearance of angiosperms and *Appendicisporites* in Victoria and South Australia, so that an earlier appearance of the genus to the north may perhaps be connected with a milder climate at lower latitudes.

Samples from the Wallumbilla Formation in Mornington Island No. 1 were poor in pollen and spores. Cuttings from the middle of the formation yielded a poorly preserved microflora (MFP 1790) which contained, among other species, *Cicatricosisporites australiensis, Laevigatosporites ovatus,* cf. *Crybelosporites striatus* (1 specimen), *Appendicisporites* spp., angiospermous pollen grains (*Tricolpites* spp.), and *Microfoveolatosporis canaliculatus.* In view of its stratigraphic position, microflora MFP 1790 might be of approximately similar age to microflora MFP 5284 from Burketown, core 6. The presence of cf. *Crybelosporites striatus* might be genuine; otherwise, the microflora appears to include a fair amount of contaminants. Tricolpate angiosperms are unknown from the Wallumbilla Formation: they only occur in unit K 2b, associated with the Allaru Mudstone, in the Eromanga Basin (Burger, 1970); the specimens in microflora MFP 1790 are therefore clearly derived from caving of higher parts of the well during sampling. The presence of *Microfoveolatosporis canaliculatus* is also suspect, as elsewhere in the Great Artesian Basin the species is only known in association with *Coptospora paradoxa* (Burger, 1968a and b, 1970). The microflora can therefore not be dated accurately; it is considered to lie somewhere in units K 1b-d, and by the presence of cf. *Crybelosporites striatus* it may represent unit K 1d.

The lower limit of unit K 1d lies between Karumba, core 2, and Burketown, core 6, within the Wallumbilla Formation; the position of its upper limit is uncertain. The unit is equivalent to the *Crybelosporites striatus* Subzone of Dettmann & Playford's (1969) *Dictyotosporites speciosus* Zone. Dettmann & Playford gave an upper Aptian age to the Subzone in South Australia, based on associated Foraminifera (Ludbrook, 1966). However, an Albian age for unit K 1d, based on fossil evidence of the Coreena and Ranmoor Members in Queensland (Vine & Day, 1965; Day, 1969; Terpstra, 1970; Terpstra & Burger, 1969) is too firmly established to be dismissed. Evans & Hawkins (1967), noticing this discrepancy, commented on Ludbrook's placing of the Aptian-Albian boundary in Innamincka No. 1 well at 2770 ft (844 m), within her Zone of *Verneuilina howchini-Trochammina flosculus.* They based their comments on Evans' report of microfloras equivalent to units K 1d and K 2 from below 2770 ft (Evans, *in* McPhee, 1963) and similar discoveries in the Cretaceous of the Murray Basin. For those reasons they preferred to place the Aptian-Albian boundary at the top of Ludbrook's *Herrgottella jonesi* Zone, at 3526 ft (1074 m), in the lower part of the marine mudstone sequence. Further study is under way to investigate this problem with the aid of Terpstra's

(1969, 1970) recent datings of Foraminifera in palynologically controlled sections of the Wallumbilla Formation in Queensland.

Spore unit K 2a

The lower limit of unit K 2a is characterized by the first appearance of *Coptospora paradoxa* and *Microfoveolatosporis canaliculatus.* In this part of the sequence a narrow interval occurs in which *Dictyotosporites speciosus* and *Cyclosporites hughesi* are still present. The association of these four species defines the unit. The unit is approximately equivalent to Dettmann & Playford's *Coptospora paradoxa* Zone. It has been recognized in the Cretaceous of Victoria (Evans, 1966c) and the Great Artesian Basin, Queensland (Burger, 1968a, b). The first specimens of *Coptospora paradoxa* and *Microfoveolatosporis canaliculatus* in the Allaru Mudstone of Mornington Island (core 4) and Karumba (core 1), together with angiospermous pollen grains, indicates the association of the Mudstone with the unit K 2b. Unit K 2a must therefore lie below the Mudstone; in the Eromanga Basin it is certainly associated approximately with the Toolebuc Limestone. Unfortunately, the available samples from that interval (Mornington Island, core 5; Burketown, core 5; Wyaaba, cuttings from 1900 ft (590 m)) yielded extremely poor assemblages. Unit K 2a must occur above Burketown, core 5, and below the basal Allaru Mudstone in Wyaaba and Mornington Island, i.e. within the upper Wallumbilla Formation or Toolebuc Limestone. The upper limit of unit K 2a lies therefore probably near the base of the Allaru Mudstone, as in the Eromanga Basin (Figs 1-2).

Spore unit K 2b

Burger (1968a; 1970; *in* Terpstra & Burger, 1969) reported the incoming of the first angiospermous (tricolpate) pollen grains as a persistent horizon close to the base of the Allaru Mudstone. Lack of information from the sediments that contained angiosperms prevented him from delineating further workable spore divisions and he defined this part of the spore sequence as 'spore units K 2b+'. On the basis of samples from the Allaru Mudstone and Normanton Formation in the southern Carpentaria Basin, some analogies at least can now be made with Dettmann & Playford's (1969) palynological work in the mid-Cretaceous and with unpublished data on the Cenomanian in Bathurst Island, Northern Territory.

In the upper part of the Allaru Mudstone (Table 1) the last occurrence of *Coptospora paradoxa* seems to coincide approximately with the introduction of *Clavifera triplex* (assemblage MFP 1783). This level is here chosen to mark the upper limit of an interval, referred to as spore unit K 2b, which contains the earliest (tricolpate) angiospermous pollen grains in association with *Coptospora paradoxa, Appendicisporites* spp., *Microfoveolatosporis canaliculatus,* and *Trilobosporites trioreticulosus.* Unit K 2b may be equivalent to Dettmann & Playford's (op. cit.) *Tricolpites pannosus* Zone, which contains the last occurrence of *Coptospora paradoxa* (Fig. 3). The unit was recognized in the Allaru Mudstone of Mornington Island No. 1, Burketown No. 1, and Wyaaba No. 1 Wells (Fig. 1). Similar microfloras occur in the Allaru Mudstone and Mackunda Formation of the Eromanga Basin. *Cicatricosisporites cuneiformis* and *Kraeuselisporites jubatus* make their first appearance within the unit; this agrees with the ranges of the species given by Dettmann & Playford (1969; Table 4). *Hoegisporis uniforma* seems to occur in the Aptian-Albian of Western Australia (Cookson, 1965); in Queensland it has been recovered only in the Albian, together with the angiosperm group.

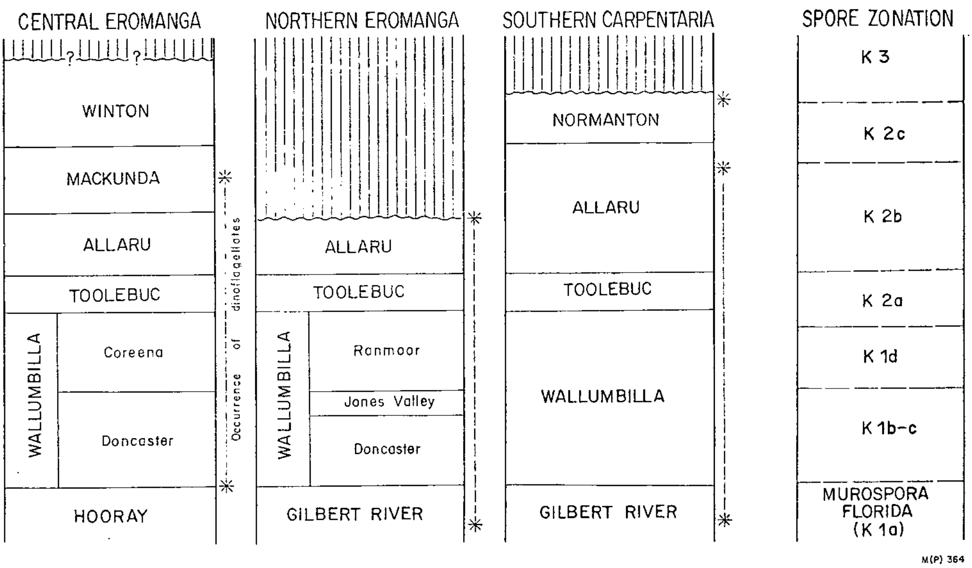


Fig. 2. Palynological comparison of formations in the Great Artesian Basin.

In Karumba, core 1, the Allaru Mudstone yielded a microflora poor in number of species, and containing *Coptospora paradoxa, Microfoveolatosporis canaliculatus, Camarozonosporites* sp. (BMR 1128), *Kraeuselisporites jubatus, Crybelosporites striatus, Appendicisporites* spp., and one possible tricolpate pollen specimen. This assemblage is part of the unit K 2 interval; the presence of *Kraeuselisporites jubatus* suggests that it is within unit K 2b, despite the absence of distinct angiosperms.

The unit is dated as upper Albian in view of the occurrence of similar assemblages in the Albian Allaru Mudstone, Eromanga Basin. This agrees with Ludbrook's (1966) dating of Foraminifera in the reference section of the *Tricolpites pannosus* Zone, Santos Oodnadatta No. 1 Well, South Australia as upper Albian-?Cenomanian.

Spore unit K 2c

The upper part of the Allaru Mudstone and the Normanton Formation yielded microfloras which contain species such as *Clavifera triplex, Crybelosporites* sp. (BMR 1129), and *Tricolporopollenites* sp. (BMR 1120), common forms in the Cenomanian of Bathurst Island. Other species such as *Crybelosporites striatus, Foraminisporus wonthaggiensis,* and *Pilosisporites parvispinosus* continue from the Albian; these species are absent from the Cenomanian in Bathurst Island. The spore interval which contains Clavifera triplex and some species from the preceding sequence (Fig. 3) in combination with *Crybelosporites striatus* is here defined as unit K 2c. The unit must still be of upper Albian age, because it lacks a number of trilete spore species and angiospermous pollen grains, which are common in the Bathurst Island microfloras (Burger, 1973). Faunal evidence for the Normanton Formation reviewed above confirms an Albian age for the unit.

The earliest specimens of *Clavifera triplex* were found in Mornington Island, core 2, and Wyaaba, cuttings from 855-860 ft (260-262 m). The lower limit of unit K 2c is thus restricted to the upper part of the Allaru Mudstone. Core 3 in

Burketown yielded a microflora (MFP 5290) which could still be part of unit K 2b, as it did not contain distinct specimens of *Clavifera triplex*. The presence of *Crybelosporites striatus,* and the few angiosperms recovered show that the assemblage is not younger than unit K 2c.

The assemblages from Mornington Island (core 1) and Burketown (core 1) show the continued presence of *Crybelosporites striatus* and *Foraminisporis wonthaggiensis* in the Normanton Formation; they also contain *Crybelosporites* sp. (BMR 1129) and *Dicolpopollis* sp. (BMR 1121), which are common forms in the Bathurst Island microfloras. This shows that the assemblages from the Normanton Formation are similar to those from Bathurst Island; the Normanton Formation in Mornington Island and Burketown is hence considered to have been formed in the uppermost part of the Albian.

Unit K 2c microfloras are not known from the Allaru Mudstone and Mackunda Formation in the Eromanga Basin. Burger (1968a, also unreported information) recovered microfloras of not higher than unit K 2b from these formations. Microfloras comparable to those from unit K 2c were found in the Winton Formation. This means that the Mackunda Formation is not traceable to the north and that contemporaneous strata are incorporated in the Allaru Mudstone in the southern Carpentaria Basin. Here the Normanton Formation is very probably equivalent to (the lower) part of the Winton Formation (Fig. 2).

The probable relationship of unit K 2c to Dettmann & Playford's Cretaceous Zones is shown in Figure 3. Dettmann & Playford regarded the *Coptospora paradoxa* Zone as Albian; they thought that the *Appendicisporites distocarinatus* Zone could also be, in part, of Albian age. The disappearance of *Coptospora paradoxa* below the *Appendicisporites distocarinatus* Zone suggests that the lower limits of the Zone and of unit K 2c coincide. Dettmann & Playford noticed a partial overlap in the ranges of *Clavifera triplex* and *Crybelosporites striatus* within their *Clavifera triplex* Zone. Here the absence of *Appendicisporites distocarinatus* and *Trilobosporites trioreticulosus* and the presence of *Triorites minor, Stephanoporopollenites obscurus,* and *Phyllocladidites minor* date that Zone as much younger than unit K 2c. *Clavifera triplex* must range farther downwards in northern Australia than Dettmann & Playford assumed. Unit K 2c is therefore to be compared with (the lower part of) the *Appendicisporites distocarinatus* Zone.

DISTRIBUTION OF MICROPLANKTON

Dinoflagellates were recovered from most of the Cretaceous samples. These organisms are sensitive to environment as their growth is dependent on degree of salinity in the sea. Table 1 shows the distribution of the following dinoflagellate species:

Canningia colliveri Cookson & Eisenack, 1960
Chlamydophorella nyei Cookson & Eisenack, 1958
Cribroperidinium edwardsi (Cookson & Eisenack, 1958) Davey, 1969
Cyclonephelium compactum Deflandre & Cookson, 1955
Diconodinium multispinum (Deflandre & Cookson, 1955) Eisenack & Cookson, 1960
Dingodinium cerviculum Cookson & Eisenack, 1958
Fromea amphora Cookson & Eisenack, 1958
Muderongia mcwhaei Cookson & Eisenack, 1958
Muderongia tetracantha (Gocht, 1957) Alberti, 1961
Odontochitina operculata (Wetzel, 1933) Deflandre & Cookson, 1955

Other species are also present, particularly in the lower part of the sequence. They are being studied in detail, but they are not included in Table 1 as their stratigraphic occurrence is not significant for the purpose of this paper.

The Gilbert River Formation and the lower part of the Wallumbilla Formation in Mornington Island No. 1, Wyaaba No. 1, and Karumba No. 8 Wells yielded *Dingodinium cerviculum,* the index species of Evans' Lower Cretaceous *D. cerviculum* Zone. Criteria for marking the lower limit of the Zone have been proposed, but they are not satisfactory. Approximately following Evans' concept, Burger (1973) proposed that the Zone should include only that interval in which *Dingodinium cerviculum* ranges above *Scriniodinium attadalense* and *Cannosphaeropsis mirabilis*. Difficulties arise in pinpointing the last occurrence of the last two species; further study of the marine Lower Cretaceous in Papua may give more data. It seems that neither species occurs in the Wallumbilla Formation. Evans (1966b) listed *Scriniodinium attadalense* among other species in what he referred to as the 'Mein Formation' near the Archer River, within sport unit K 1a. Burger (1973) recovered *Cannosphaeropsis mirabilis* from the Gilbert River Formation near Hughenden in the upper part of unit K 1a, his *Foraminisporis asymmetricus* Subzone. Neither *C. mirabilis* nor *Scriniodinium attadalense* have been found in the southern Carpentaria Basin. The plankton assemblages from the Gilbert River Formation are therefore not committed to any of the dinoflagellate Zones. In comparison with the Eromanga Basin sequence (Evans, 1966a), the dinoflagellate assemblage in Karumba, core 2, is, because of the association of *Dingodinium cerviculum* with spore unit K 1b-c, taken as part of the *D. cerviculum* Zone.

The succeeding interval is characterized for stratigraphic purposes by the *Odontochitina operculata* group (including perhaps *Odontochitina striatoperforata* Cookson & Eisenack, 1962). It is equivalent to Evans' *Muderongia tetracantha/ O. operculata* Zone and his *O. operculata* Zone. *Muderongia tetracantha* was not recovered above the range of *Dingodinium cerviculum,* probably because there is a marked decrease in the abundance of microplankton towards the top of the Wallumbilla Formation. The Zones could therefore not be recognized separately. Up to this point, the number of dinoflagellates in the microfloras indicates open marine environments for the Gilbert River Formation to the Allaru Mudstone in the southern Carpentaria Basin (Fig. 2). In the upper part of the Allaru Mudstone and the Normanton Formation dinoflagellates are virtually absent. At the same time the freshwater algal genus *Botryococcus* enters the sequence (Table 1). Brackish to non-marine environments must have existed in the area, at least temporarily. Burger (1968a, unwritten information) also noticed the disappearance of dinoflagellates towards the upper part of the Mackunda Formation, Eromanga Basin. These events are apparently related, so it seems that the sea withdrew from the Eromanga and southern Carpentaria Basins at the end of unit K 2b and during unit K 2c. The subsequent increase of dinoflagellates in the Normanton Formation of Mornington Island (core 1) indicates a return to marine conditions in the southern Carpentaria Basin towards the end of unit K 2c.

The dinoflagellate assemblage from the Normanton Formation in Mornington Island No. 1 (core 1, MFP 1780) is entirely Albian in character. There was no sign of *Ascodinium parvum,* the index species of Evans' (1966c) *A. parvum* Zone. The species is common in the Cenomanian of Bathurst Island. This is significant, as Evans regarded the *A. parvum* Zone in the Otway Basin as lower Upper Creta-

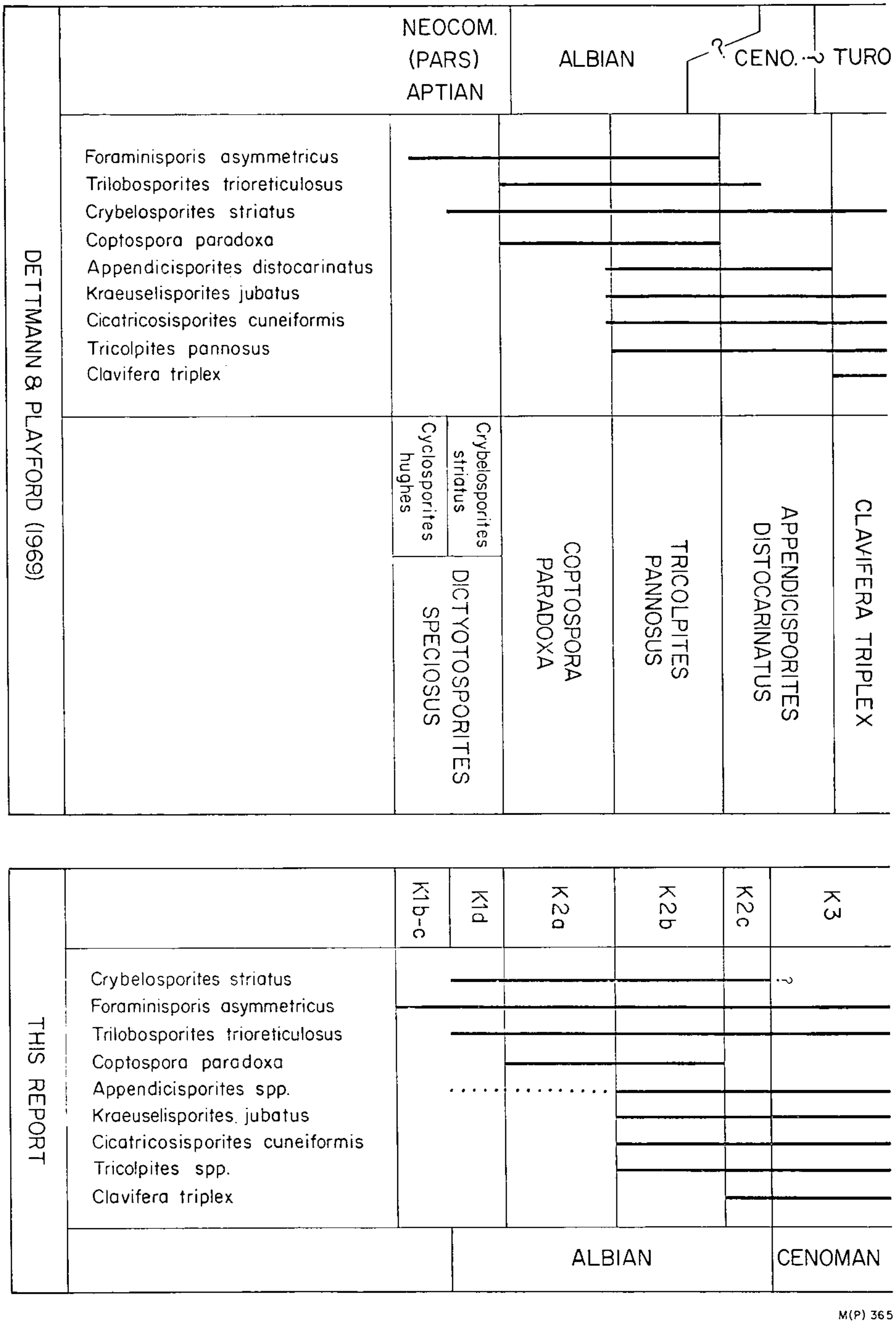


Fig. 3. Comparison of Albian-Cenomanian spore zonations in eastern Australia.

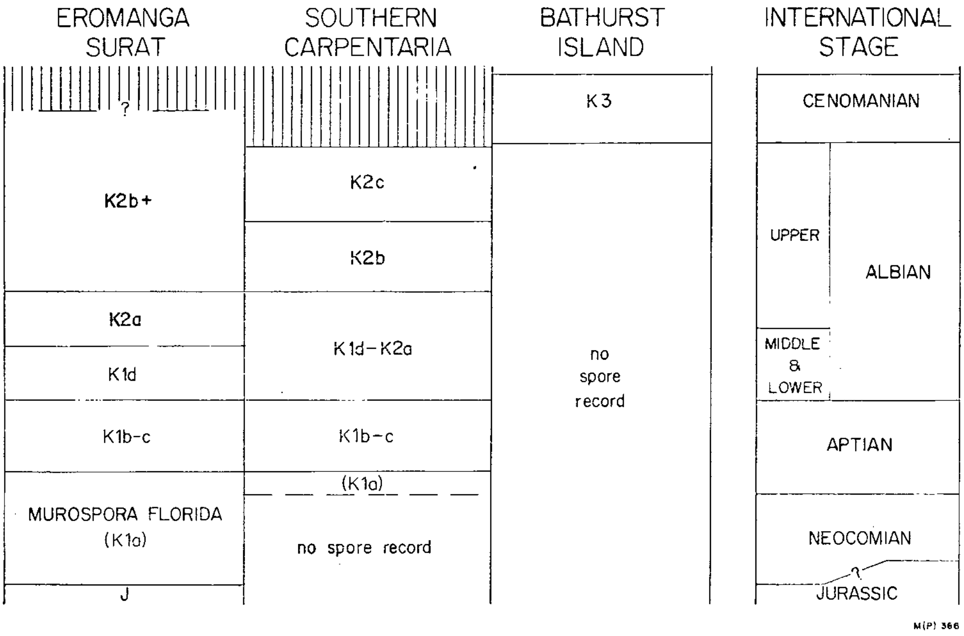


Fig. 4. Distribution of spore units recognized in northern Australia.

ceous (Cenomanian) in age. Evans (*in* Harrison et al., 1961) found the species in Mornington Island No. 1 between 310 feet (91.7 m) and 520 feet (158.5 m). The absence of the species in core 1 might indicate that its presence in deeper horizons (cuttings) is contaminated from higher in the section. However, the presence of the species, and the faunal evidence discussed above, suggest that the Normanton Formation is locally of Upper Albian to (lower?) Cenomanian age.

CONCLUSIONS

There is good agreement between palynological and other palaeontological studies of the Lower Cretaceous in the Eromanga and Carpentaria Basins. In the southern Carpentaria Basin the lowermost Cretaceous (Neocomian) was apparently not developed in large areas. At this time coarse- and fine-grained non-marine clastics were laid down in most of the Surat and Eromanga Basins. The major transgression which started in late unit K 1a time resulted in deposition of the Gilbert River Formation. Initially, when the Aptian sea had not reached its maximum extent, deposition of non-marine sands and muds continued in the central and southern Eromanga Basin, whereas fine-grained glauconitic sand and mud of the Doncaster Member began to accumulate in large areas further north (Burger, 1973). Shallow conditions prevailed, and land and sea must have been divided in a complex geographical pattern. Detailed palynological comparison of strata laid down in this phase still poses a difficult problem.

At the beginning of unit K 1b-c the sea had in places advanced as far as the present Queensland/New South Wales border; deposition of muds (Doncaster Member) prevailed (Burger, 1973). Shallow marine conditions continued to exist throughout the interval of units K 1b-d in the Carpentaria Basin. Evidence of withdrawal of the sea in the early Albian unit K 1d with sandy developments and near absence of dinoflagellates (Coreena Member) in the Surat and Eromanga Basins, and evidence of non-deposition in the region of Tambo (Day, 1969) are entirely lacking further north. The well logs in the southern Carpentaria Basin show a preponderance of mudstone throughout the Wallumbilla Formation and the microfloras so far recovered contain appreciable fractions of marine forms.

This relatively quiet period was followed, in unit K 2a times, by a new invasion of the sea from the north. Conditions remained favourable for microplankton, but curbed animal life. Increased carbonate precipitation (Toolebuc Limestone) may have been caused by higher evaporation in a large inland sea of which the access to the open ocean was temporarily blocked (Exon et al., 1966).

A second withdrawal of the sea occurred at the beginning of unit K 2b, when angiosperms reached northern Australia; it also affected the Carpentaria Basin. Dinoflagellates in the Allaru Mudstone microfloras diminished notably. At the onset of unit K 2c, microplankton disappeared from the sequence towards the top of the Mudstone and further south in the Mackunda Formation. Paralic conditions were followed by non-marine deposition (Normanton and Winton Formations) at the close of the Albian. Towards the end of unit K 2c a new oscillation of the sea level occurred during deposition of the Normanton Formation, but the transgression did not reach the Eromanga Basin and may have been only brief.

ACKNOWLEDGEMENTS

I am indebted to Dr Mary Dettmann of the University of Queensland for her valuable comments on the microfossil zonation; I also wish to thank Messrs H. F. Doutch and J. Smart for instructive discussions on stratigraphic problems in the Carpentaria and Eromanga Basins and their criticism during the preparation of this paper; Drs D. J. Belford and J. M. Dickins kindly commented on the text of the manuscript.

REFERENCES

ALBERTI, G., 1961—Zur Kenntnis mesozoischer und alttertiärer Dinoflagellaten und Hystrichosphaerideen von Nord- und Mitteldeutschlands sowie einigen anderen europäischen Gebieten. *Palaeontographica,* A116, 1-58.

BALME, B. E., 1957—Spores and pollen grains from the Mesozoic of Western Australia. *CSIRO Aust. Coal Res. Sect.,* T.C. 25.

BELFORD, D. J., 1957—Micropalaeontological examination of samples from FBH No. 1 Well, Wyaaba, Queensland. *Bur. Miner. Resour. Aust. Rec.* 1957/109 (unpubl.).

BELSKY, C. Y., BOLTENHAGEN, E., and POTONIE, R., 1965—Sporae dispersae der Oberen Kreide von Gabun, Äquatoriales Afrika. *Paläont. Z.* 39(1-2), 72-83.

BOLKHOVITINA, N. A., 1953—Spores and pollen typical of Cretaceous deposits of central regions of the U.S.S.R. *Tr. Inst. geol. Nauk SSSR, Moscow,* 145 (*geol. Ser.* 61), 1-184. (In Russian.)

BOLKHOVITINA, N. A., 1961—Fossil and Recent spores in the Schizaeaceae. *Tr. Inst. geol. Nauk SSSR, Moscow* (*geol. Ser.*), 40, 1-176.

BRENNER, G. J., 1963—The spores and pollen of the Potomac Group of Maryland. *Maryland Dept. Geol. Min. Bull.,* 27, 1-215.

BURGER, D., 1968a—Palynology of marine Lower Cretaceous strata in the northern and eastern Eromanga Basin, Queensland. *Bur. Miner. Resour. Aust. Rec.* 1968/62 (unpubl.).

BURGER, D., 1968b—Relationship of palynology to stratigraphy in the Lower Cretaceous of the Surat Basin in Queensland. *Bur. Miner. Resour. Aust. Rec.* 1968/125 (unpubl.).

BURGER, D., 1969—Palynological observations of Jurassic and Cretaceous strata at the border of Queensland and New South Wales. *Bur. Miner. Resour. Aust. Rec.* 1969/94 (unpubl.).

BURGER, D., 1970—Early Cretaceous angiospermous pollen grains from Queensland. *Bur. Miner. Resour. Aust. Bull.* 116, 1-16.

BURGER, D. 1973—Spore zonation and sedimentary history in the Neocomian and early Aptian of the Great Artesian Basin, Queensland. *In Isabel Cookson Comm. Vol., J. geol. Aust. Spec. Publ.* 4.

BURGER, D. (in prep.)—Cenomanian spores and pollen grains from Bathurst Island, Northern Territory. *Bur. Miner. Resour. Aust. Bull.*

COOKSON, Isabel C., 1953—Difference in microspore composition of some samples from a bore at Comaum, South Australia. *Aust. J. Bot.*, 1, 462-473.

COOKSON, Isabel C., 1965—On a new species of *Hoegisporis* Cookson. *Palaeontology,* 8(1), 39-40.

COOKSON, Isabel C., and DETTMANN, Mary E., 1958a—Some trilete spores from Upper Mesozoic deposits in the eastern Australian region. *Proc. Roy. Soc. Vic.,* 70, 95-128.

COOKSON, Isabel C., and DETTMANN, Mary E., 1958b—Cretaceous 'megaspores' and a closely associated microspore from the Australian region. *Micropaleontology,* 4, 39-49.

COOKSON, Isabel C., and DETTMANN, Mary E., 1959a—*Cyclosporites,* Cretaceous microspore: corrected name. *Aust. J. Sci.,* 21, 260.

COOKSON, Isabel C., and DETTMANN, Mary E., 1959b—On *Schizosporis,* a new form genus from Australian Cretaceous deposits. *Micropaleontology,* 5, 213-216.

COOKSON, Isabel C., and EISENACK, A., 1958—Microplankton from Australian and New Guinea Upper Mesozoic sediments. *Proc. Roy. Soc. Vic.,* 70(1), 19-79.

COOKSON, Isabel C., and EISENACK, A., 1960—Upper Mesozoic microplankton from Australia and New Guinea. *Palaeontology,* 2(2), 243-61.

COOKSON, Isabel C., and EISENACK, A., 1962—Additional microplankton from Australian Cretaceous sediments. *Micropaleontology,* 8(4), 485-507.

CRESPIN, Irene, 1963—Lower Cretaceous arenaceous Foraminifera of Australia. *Bur. Miner. Resour. Aust. Bull.* 66, 1-69.

DAY, R. W., 1964—Stratigraphy of the Roma-Wallumbilla area. *Geol. Surv. Qld Publ.* 318, 1-23.

DAY, R. W., 1969—The Lower Cretaceous of the Great Artesian Basin; *in* CAMPBELL, K. S. W. (ed.)—STRATIGRAPHY AND PALAEONTOLOGY. ESSAYS IN HONOUR OF DOROTHY HILL, 140-73. *Canberra, A.N.U. Press.*

DAVEY, R. J., 1969—Non-calcareous microplankton from the Cenomanian of England, northern France and North America. Part I. *Bull. Brit. Mus. (nat. Hist.) Geol.,* 17(3), 105-180.

DEFLANDRE, G., and COOKSON, Isabel C., 1955—Fossil microplankton from Australian late Mesozoic and Tertiary sediments. *Aust. J. mar. freshw. Res.,* 6(2), 242-313.

DERRINGTON, S. S., 1957—Completion Report, F.B.H. No. 1 (Wyaaba) Well (unpubl.).

DETTMANN, Mary E., 1963—Upper Mesozoic microfloras from southeastern Australia. *Proc. Roy. Soc. Vic.,* 77(1), 1-148.

DETTMANN, Mary E., and PLAYFORD, G., 1968—Taxonomy of some Cretaceous spores and pollen grains from eastern Australia. *Proc. Soc. Vic.,* 81(2), 69-94.

DETTMANN, Mary E., and PLAYFORD, G., 1969—Palynology of the Australian Cretaceous: a review; *in* CAMPBELL, K. S. W. (ed.)—STRATIGRAPHY AND PALAEONTOLOGY. ESSAYS IN HONOUR OF DOROTHY HILL, 174-210. *Canberra, A.N.U. Press.*

DICKINS, J. M., 1960—Cretaceous marine macrofossils from the Great Artesian Basin in Queensland. *Bur. Miner. Resour. Aust. Rec.* 1960/69 (unpubl.).

EISENACK, A., and COOKSON, Isabel C., 1960—Microplankton from Australian Lower Cretaceous sediments. *Proc. Roy. Soc. Vic.,* 71(2), 1-11.

EVANS, P. R., 1966a—Mesozoic stratigraphic palynology in Australia. *Aust. Oil Gas J.,* 12(6), 58-63.

EVANS, P. R., 1966b—Contribution to the palynology of northern Queensland and Papua. *Bur. Miner. Resour. Aust. Rec.* 1966/198 (unpubl.).

EVANS, P. R., 1966c—Mesozoic stratigraphic palynology of the Otway Basin. *Bur. Miner. Resour. Aust. Rec.* 1966/69 (unpubl.).

EXON, N. F., GALLOWAY, M. C., CASEY, D. J., and KIRKEGAARD, A. G., 1966—The geology of the Tambo, Augathella and Blackall 1:250 000 Sheet areas, Queensland. *Bur. Miner. Resour. Aust. Rec.* 1966/89 (unpubl.).

GOCHT, H., 1957—Mikroplankton aus dem nordwestdeutschen Neokom 1. *Paläont. Z.* 31(3-4), 163-85.

GRIMES, K. G., and SMART, J., 1970—Shallow stratigraphic drilling in the southern Carpentaria Basin 1969. *Bur. Miner. Resour. Aust. Rec.* 1970/38 (unpubl.).

GROOT, J. J., and PENNY, J. S., 1960—Plant microfossils and age of non-marine Cretaceous sediments of Maryland and Delaware. *Micropaleontology*, 6(2), 225-36.

HARRISON, J., GREER, W. J., and GIBSON, A. R., 1961—Delhi-Santos Mornington Island Nos 1 and 2, Queensland, Well Completion Report (unpubl.).

HILL, Dorothy, and DENMEAD, A. K., 1960—The geology of Queensland. *J. geol. Soc. Aust.*, 7.

INGRAM, J. A., 1972—Burketown, Queensland—1:250 000 Geological Series. *Bur. Miner. Resour. Aust. explan. Notes* SE/54-6.

LAING, A. C. M., 1960—Karumba A.A.O. No. 8 Bore, northern Queensland, of Associated Australian Oilfields N.L. *Bur. Miner. Resour. Aust., Petrol. Search Subs. Acts Publ.* 9.

LAING, A. C. M., and POWER, P. E., 1959—New names in Queensland stratigraphy. *Aust. Oil Gas J.*, 5(8), 35-6; 5(9), 28.

LUDBROOK, N. H., 1966—Cretaceous biostratigraphy of the Great Artesian Basin in South Australia. *Geol. Surv. S. Aust. Bull.* 40.

MCPHEE, I., 1963—Conorada Ooroonoo No. 1, Queensland, of Conorada Petroleum Corporation. *Bur. Miner. Resour. Aust., Petrol. Search Subs. Acts Publ.* 23.

MEYERS, N. A., 1969—Carpentaria Basin. *Geol. Surv. Qld Rep.* 34.

NEEDHAM, S., and DOUTCH, H. F., 1972—Galbraith, Queensland—1:25 000 Geological Series. *Bur. Miner. Resour. Aust. explan. Notes* SE/54-3.

PERRYMAN, J. C., 1964—Completion Report, Mid-Eastern Oil N.L. Burketown No. 1 Well, Queensland (unpubl.).

POCOCK, S. A. J., 1961—The microspore genus *Cingulatisporites* Thomson, 1953. *J. Paleont.*, 35(6), 1235-6.

POCOCK, S. A. J., 1962—Microfloral analysis and age determination of strata at the Jurassic-Cretaceous boundary in the western Canada Plains. *Palaeontographica*, B111, 1-95.

POCOCK, S. A. J., 1964—Pollen and spores of the Chlamydospermidae and the Schizaeaceae from Upper Mannville strata of the Saskatoon area of Saskatchewan. *Grana Palynologica*, 5(2), 129-209.

POTONIE, R., 1956—Synopsis der Gattungen der Sporae dispersae. I-Sporites. *Beih. geol. Jb.*, 69, 1-103.

REYNOLDS, M. A., 1960—Mesozoic and younger sediments of the Gilberton and Georgetown 4-mile Sheet areas, Queensland. *Bur. Miner. Resour. Aust. Rec.* 1960/68 (unpubl.).

SMART, J., INGRAM, J. A., DOUTCH, H. F., and GRIMES, K. G., 1971—Recent geological mapping in the Carpentaria Basin. New stratigraphic names. *Qld Govt Min. J.*, 72, 3-8.

STANLEY, E. A., 1965—Upper Cretaceous and Paleocene plant microfossils and Paleocene dinoflagellates and hystrichosphaerids from northwestern South Dakota. *Bull. Amer. Paleont.*, 49(222), 179-384.

TERPSTRA, G. R. J., 1969—Micropalaeontological examination of samples from A.O.G. Scout Bores No. 1 and No. 2 Talbalba, Thallon Basin, Queensland. *Bur. Miner. Resour. Aust. Rec.* 1969/55 (unpubl.).

TERPSTRA, G. R. J., 1970—Micropalaeontology of core and cuttings samples from water bores and shallow stratigraphic holes in the northern Eromanga Basin, Queensland. *Bur. Miner. Resour. Aust. Rec.* 1970/34 (unpubl.).

TERPSTRA, G. R. J., and BURGER, D., 1969—Micropalaeontology and palynology of samples from BMR Bulloo No. 1 Scout Hole, Queensland. *Bur. Miner. Resour. Aust. Rec.* 1969/39 (unpubl.).

TERPSTRA, G. R. J., and EVANS, P. R., 1962—Palaeontological examination of samples from Delhi-Santos Mornington Island No. 1 Well, Carpentaria Basin, Queensland. *Bur. Miner. Resour. Aust. Rec.* 1962/177 (unpubl.).

VINE, R. R., and DAY, R. W., 1965—Nomenclature of the Rolling Downs Group, northern Eromanga Basin, Queensland. *Qld Govt Min. J.*, 66(767), 417-21.

WETZEL, O., 1933—Die inorganischer Substanz erhaltenen Mikrofossilien des Baltischen Kreide-Fauersteins. *Palaeontographica,* 77, 141-88.

WEYLAND, H., and GREIFELD, G., 1953—Über strukturbietende Blätter und pflanzliche Mikrofossilien aus den Untersenonen Tonen der Gegend von Quedlinburg. *Palaeontographica,* B95 (1-3), 30-52.

WEYLAND, H., and KRIEGER, W., 1953—Die Sporen und Pollen der Aachener Kreide und ihre Bedeutung für die Charakterisierung des mittleren Senons. *Palaeontographica,* B95(1-3), 6-29.

WHITE, Mary E., 1957—Fossil plants from the Georgetown district, Western Queensland, from the Blythesdale Formation. *Bur. Miner. Resour. Aust. Rec.* 1957/70 (unpubl.).

WHITEHOUSE, F. W., 1955—The geology of the Queensland portion of the Great Australian Artesian Basin. Appendix G *in* Artesian Water Supplies in Queensland. *Dept Coord. Gen. Public Works, Parl. Pap. A,* 56-1955 *(Brisbane).*

WILSON, L. R., and WEBSTER, R. M., 1946—Plant microfossils from a Fort Union Coal of Montana. *Amer. J. Botany,* 33, 271-278.

WOODS, J. T., 1961—Mesozoic and Cainozoic sediments of the Wrotham Park area. *Geol. Surv. Qld Publ.* 304.

WELL	SAMPLE	DEPTH		MFP	FOSSIL RECOVERY	FORMATION	SPORE UNIT	SPORES AND POLLEN GRAINS																																			MICROPLANKTON										REST	
								Murospora florida	Crybelosporites stylosus	Cyclosporites hughesi	Cicatricosisporites australiensis	Foraminisporis asymmetricus	Foraminisporis wonthaggiensis	Cooksonites variabilis	Cicatricosisporites ludbrooki	Couperisporites tabulatus	Pilosisporites notensis	Pilosisporites parvispinosus	Dictyotosporites speciosus	Crybelosporites striatus	Cicatricosisporites hughesi	Laevigatosporites ovatus	Appendicisporites spp.	Coptospora paradoxa	Camarozonosporites cf. C. amplus	Tricolpites augathellaensis	Trilobosporites trioreticulosus	Tricolpites spp.	Microfoveolatosporis canaliculatus	Kuylisporites sp.	Clavatipollenites sp.	Hoegisporis uniforma	Cicatricosisporites cuneiformis	Kraeuselisporites jubatus	Peromonolites peroreticulatus	Tricolporopollenites cf. T. distinctus	Cicatricosisporites pseudotripartitus	Psilatricolpites sp.	Rouseisporites radiatus	Clavifera triplex	Dicolpopollis sp.	Crybelosporites sp.	Muderongia mowhaei	Muderongia tetracantha	Dingodinium cerviculum	Chlamydophorella nyei	Cyclonephelium compactum	Canningia colliveri	Cribroperidinium edwardsi	Odontochitina operculata	Diconodinium multispinum	Fromea amphora	Schizosporis reticulatus	Botryococcus spp.
MORNINGTON I	core 1	450′	137.2 m	1780	moderate	NORMANTON	K 2c				x	?	x							x		x	x					?	x		x		x	?							x	x					x		x	x	x			
BURKETOWN	core 1	360–75′	109.7–114.3	5285	fair						x	x						x		x	x	x	x		x	x	x		x			x						x		?	?												x	x
BURKETOWN	core 2	590–605′	179.8–184.4	5289	fair						x	x								?	x	x	x		x		x	x				x	x		x																			
WYAABA	cutt	855–60′	260–2	5618	fair	ALLARU					x	x										x	x		x	x		?	x	?	x				x					x	c	c												
MORNINGTON I	core 2	929′	283.2	1783	good		K 2b				x		?					x		x		x	x	x	x	x	x	x	x		x	x		x						x								x	x					x
BURKETOWN	core 3	796–811′	242.6–247.2	5290	moderate						x	?								x		x	x			x		x					?				?									x					x	x		
WYAABA	cutt	980–85′	298–300	5619	fair							x								?	x	x	x		x	x			x	?			?						x								x							
WYAABA	cutt	1070–75′	326–327.5	5621	poor						x	x									x	x	x		x		x		x				?					x																
MORNINGTON I	core 3	1112′	338.9	1784	poor						x	x			?							x	x						x			x																	x	x	x		?	
WYAABA	cutt	1300–05′	396.8	5627	moderate															?		x	x			?	x	x	x		?							x																
BURKETOWN	core 4	1000–15′	304.8–309.4	5287	moderate						x	?								x	x	x	x		?			x	x		x					x	x														x			
KARUMBA	core 1	1316–18′	401.1	1344	moderate						x	?			x					x		x	x	x	x		x	?	x					x	x												x		x		x			
MORNINGTON I	core 4	1604′	488.9	1787	good						x	x	x							x		x	x		x		x	x	x	x	x	x	x	?												x	x			x	x			
WYAABA	cutt	1700–05′	518–519.5	5629	good						?	x	x							x		x	x	x	x	x	x	x	x			c																?			x			
						TOOLEBUC	K 2a																																															
BURKETOWN	core 6	1618–28′	493.2–496.2	5284	moderate	WALLUMBILLA	K 1d				x	x	?		?			x		x	?	x	x																							x	?	?	?	x		?		
MORNINGTON I	cutt	2110–20′	643.6	1790	poor		K 1d ?				x	?								?	?	c	c			c	c		c		c														?	x	x	x	x	x	x			
KARUMBA	core 2	2191′	667.8	1348	good		K 1b– c		?	x	x				x		?		x																									x	x	x		?		x			x	
WYAABA	core 4	2637′	803.8	5644	fair	GILBERT RIVER	K 1a ?			x	x	x	x	x		x	x	x	?																										x	?							x	
MORNINGTON I	core 7	2544′	865.4	1792	fair		K 1a	x	x	x	x	x	x	?	?																												x	x	x	x	x	?	?					
BMR species catalogue number								472	714	489	403	386	381	1077	1074	614	411	1083	424	423	490	740		1126	1128	802	732		1132	1131	1124	1125	1122	1130	812	1120	1123	803	1134	1127	1121	1129	1101	893	892	1047	745	1087	957	894	974	1133	428	1092

x	positive identification of species
?	identity of species uncertain
c	secondary presence of species by contamination from higher levels
MFP	palynological sample catalogue number

M(P)362

Table 1. Details of samples and distribution of microfossils in the Carpentaria Basin.

THE MICROPLANKTON GENUS *DISPHAERIA* COOKSON & EISENACK EMEND.

by M. NORVICK

ABSTRACT

The genus *Disphaeria* is emended and attention is drawn to its dinoflagellate affinities. *Disphaeria* is shown to be congeneric with and to have priority over *Thalassiphora*.

INTRODUCTION

During a study of the mid-Cretaceous microplankton from Oil Development N.L. Bathurst Island Nos 1 and 2 Wells, Northern Territory, a number of specimens of the dinoflagellate cyst species *Disphaeria macropyla* Cookson & Eisenack, 1960, were found. The holotype of this species was examined in the Victorian Museum, Melbourne. These investigations show that *Disphaeria macropyla* has definite dinoflagellate features, such as cingular folds and a possible archaeopyle. It is certainly not an acritarch, as suggested by Downie, Evitt, & Sarjeant (1963), who placed it in their new morphological subgroup Disphaeromorphitae.

Disphaeria has a structure which is identical with that of the dinoflagellate cyst genus *Thalassiphora* Eisenack & Gocht, 1960. If the two forms are in fact congeneric then the name *Disphaeria,* published in January 1960, has priority over *Thalassiphora,* which was published on an unknown date in 1960 but certainly after March. The genus *Disphaeria* is therefore emended and several species previously placed in *Thalassiphora* are transferred.

Genus DISPHAERIA Cookson & Eisenack, 1960, emend.

1960 *Disphaeria* Cookson & Eisenack, p. 11.

1960 *Thalassiphora* Eisenack & Gocht, p. 512.

Type species: *Disphaeria macropyla* Cookson & Eisenack, 1960.

Emended diagnosis. Pterate cyst with the endophragm and periphragm in contact on the dorsal surface only. Inner capsule ellipsoidal or spherical, granular or without surface ornament. The periphragm may be smooth, granular, or echinate and is expanded into a lamellar wing, which is attached on the dorsal side to the inner capsule. The ventral side of the inner body may or may not be partially overlapped by the recurved margin of the lamellar wing. Traces of the cingulum and of the tabulation may or may not be represented by lines of periphragmic folds. The archaeopyle is formed by the loss of a single reflected precingular plate area, either P or P/P.

Other species. A number of species which have previously been attributed to *Thalassiphora* (including the type species) are here reallocated to *Disphaeria* because they have a dorsally attached, lamellar periphragm.

Disphaeria pelagica (Eisenack, 1954) Norvick comb. nov.
=*Bion pelagicum* Eisenack, 1938 (*nomen nudum*), p. 187.
=*Pterospermopsis pelagica* Eisenack, 1954, p. 71, pl. 12, figs 17-18 (transferred to *Thalassiphora* by Eisenack & Gocht, 1960, p. 513, text-figs 1-3).
to *Thalassiphora* by Eisenack & Gocht, 1960, p. 513, text-figs 1-3).

Disphaeria delicata (Williams & Downie, 1966) Norvick comb. nov.
=*Thalassiphora delicata* Williams & Downie, 1966, p. 235, pl. 26, fig. 8.

Disphaeria reticulata (Morgenroth, 1966) Norvick comb. nov.
=*Thalassiphora reticulata* Morgenroth, 1966, p. 6, pl. 2, figs 1-2.

Disphaeria succincta (Morgenroth, 1966) Norvick comb. nov.
=*Thalassiphora succincta* Morgenroth, 1966, p. 7, pl. 2, figs 7-9.

There is some doubt about the taxonomic position of *Pterocystidiopsis velata* Deflandre & Cookson, 1955 (transferred to *Thalassiphora* by Eisenack & Gocht, 1960). Gocht (1968) considers it to be a juvenile stage in his 'ontogeny' of *Disphaeria pelagica*. Drugg (1970) points out that at least some of Gocht's figures (pl. 26, figs 5-6) are identical with the former's new genus and species *Muratodinium fimbriatum* and should not belong in *Disphaeria*.

REFERENCES

COOKSON, I. C., and EISENACK, A., 1960—Microplankton from Australian Cretaceous sediments. *Micropalaeontology,* 6(1), 1-18.

DEFLANDRE, G., and COOKSON, I. C., 1955—Fossil microplankton from Australian late Mesozoic and Tertiary sediments. *Aust. J. mar. freshw. Res.,* 6(2), 242-313.

DOWNIE, C., EVITT, W. R., and SARJEANT, W. A. S., 1963—Dinoflagellates, Hystrichospheres and the classification of acritarchs. *Stanford Univ. Publ., geol. Sci.,* 7(3), 1-16.

DRUGG, W., 1970—Some new genera, species and combinations of phytoplankton from the Lower Tertiary of the Gulf Coast, U.S.A. *Proc. N. Amer. paleont. Convention, Sept. 1969,* pt G, 809-43.

EISENACK, A., 1938—Die Phosphoritknollen der Bernsteinformation als Überlieferer tertiären Planktons. *Schr. phys.-okon. Ges. Königsberg,* 70, 181-8.

EISENACK, A., 1954—Mikrofossilien aus Phosphoriten des samländischen Unteroligozäns und über die Einheitlichkeit der Hystrichosphaerideen. *Palaeontographica,* Abt A, 105, 49-95.

EISENACK, A., and GOCHT, H., 1960—Neue Namen für einige Hystrichosphären der Bernsteinformation Ostpreussens. *N. Jb. Geol. Paläont.,* Mh., 11, 511-8.

GOCHT, H., 1968—Zur Morphologie und Ontogenie von *Thalassiphora* (Dinoflagellata). *Palaeontographica,* Abt. A, 129, 149-56.

MORGENROTH, P., 1966—Neue inorganischer Substanz erhaltene Mikrofossilien des Oligozäns. *N. Jb. Geol. Paläont., Abh.,* 127(1), 1-12.

WILLIAMS, G. L., and DOWNIE, C., 1966—Further dinoflagellate cysts from the London Clay; *in* DAVEY, R. J., DOWNIE, C., SARJEANT, W. A. S., and WILLIAMS, G. L., Studies on Mesozoic and Cainozoic dinoflagellate cysts. *Bull. Brit. Mus. nat. Hist.* (*Geol.*), Suppl. 3, 215-36.

UPPER CRETACEOUS PLANKTONIC FORAMINIFERA FROM PAPUA NEW GUINEA

by M. Owen

Abstract

Nineteen samples from the Western Highlands, New Guinea, and one from eastern Papua contain rich Upper Cretaceous foraminiferal faunas ranging in age from Turonian to upper Maestrichtian. Thirty-eight planktonic species from these faunas are figured and comments made on the age of the samples. A new species, *Globotruncana wabagensis*, is described.

Introduction

During a survey of the Wabag area, Western Highlands of New Guinea, by the Bureau of Mineral Resources, Geology and Geophysics (BMR) in 1963, several samples containing abundant free Foraminifera of Upper Cretaceous age were collected. This paper records the planktonic Foraminifera from this fauna, and comments on the age of the samples. Faunas from some samples from the Lai River area, to the east of the Wabag area, and from an isolated sample from eastern Papua are also recorded. The location of the three areas is shown in Text-figure 1.

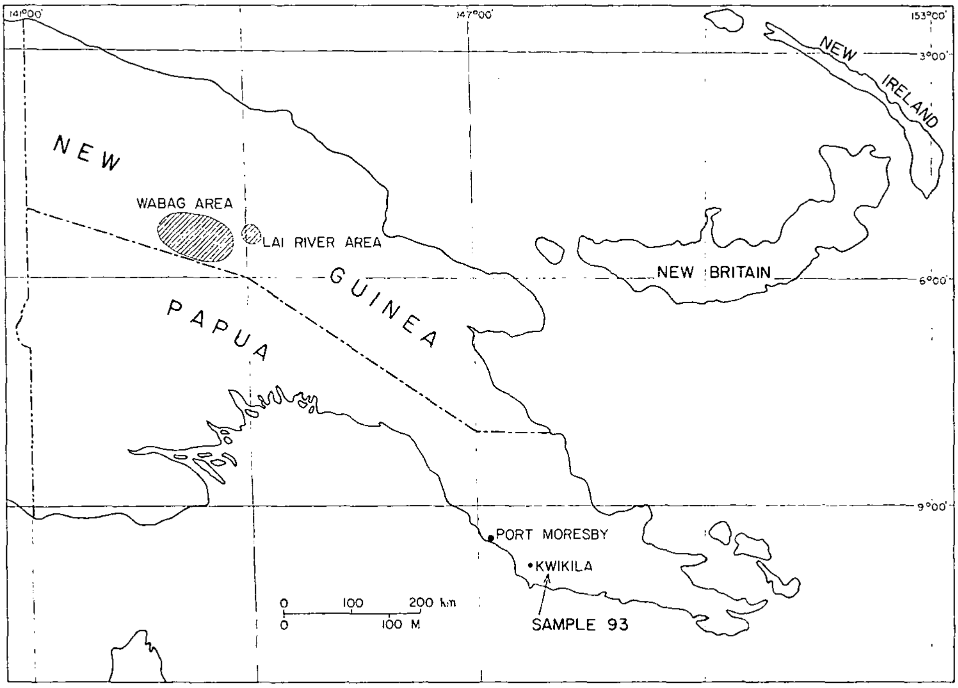


Fig. 1. Locality map.

There is little published work on Upper Cretaceous Foraminifera from Papua New Guinea and no free specimens of planktonic Foraminifera have been figured. The nearest Upper Cretaceous Foraminifera fauna described in detail is that recorded by Belford (1960) from the Carnarvon Basin, Western Australia, about 4000 km away. However, a brief record of Cretaceous Foraminifera from West Irian is mentioned by Visser & Hermes (1962), and papers by Glaessner (1952), Rickwood (1955), and the Australasian Petroleum Company (1961) record occurrences of Upper Cretaceous Foraminifera from Papua New Guinea, though none are figured.

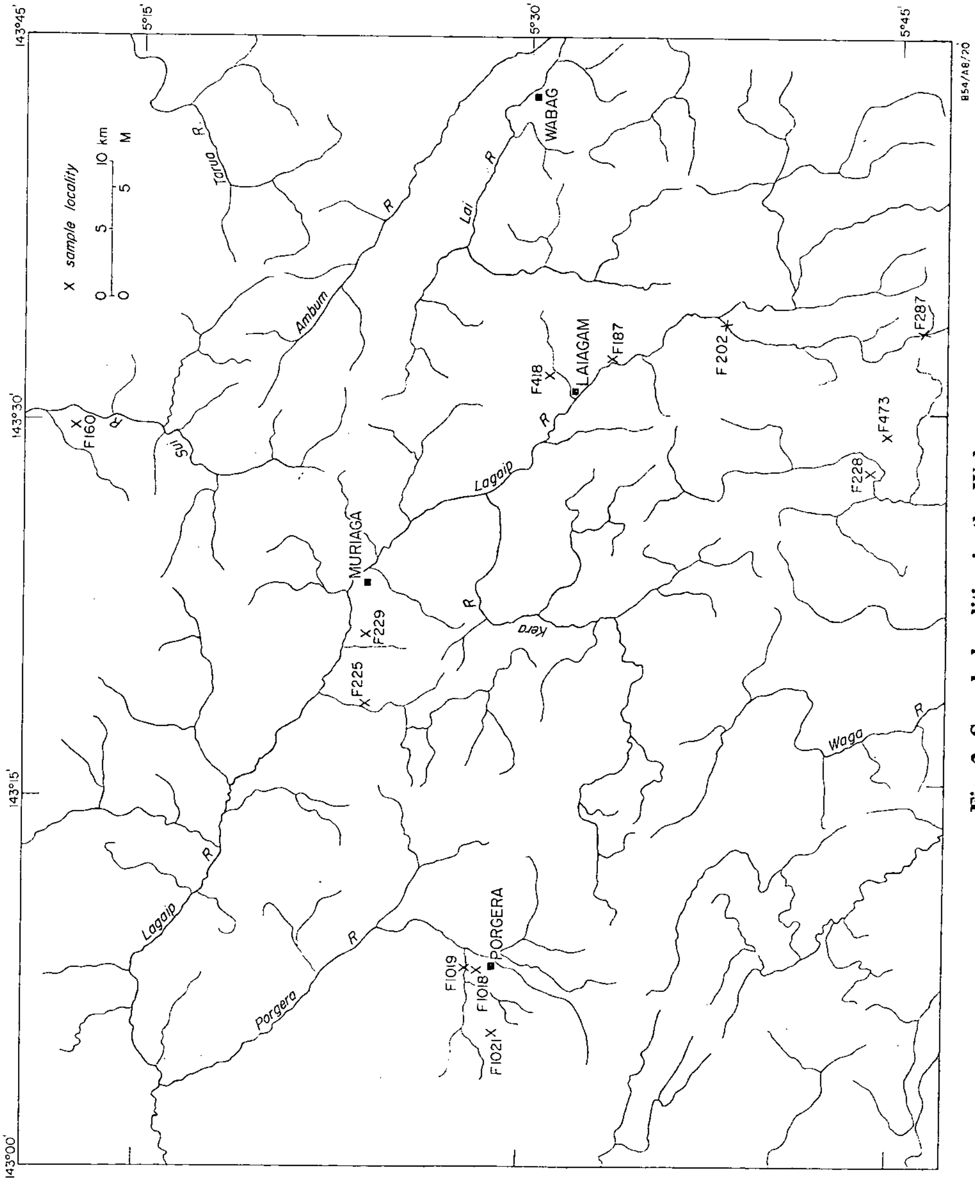


Fig. 2. Sample localities in the Wabag area.

Fourteen samples from the Wabag area were found to contain Cretaceous Foraminifera; planktonic Foraminifera occur in all but one. Their location is shown in Text-figure 2. Unfortunately no continuous section in the Cretaceous was collected during the survey of the area because of the structural complexity of the region, its inaccessibility, and the reconnaissance nature of the survey. It is unlikely that collections from continuous sections will be made for many years.

The geology of the Wabag area was summarized by Dekker & Faulks (1964, unpubl.) and has been revised by Dow, Smit, Bain, & Ryburn (1972). The Cretaceous samples are all from a series of mainly grey, calcareous, fine-grained, laminated shales with interbedded massive to flaggy limestones. This series was termed the Lagaip Beds by Dekker & Faulks (1964) and a formal definition is given by Dow (*in* Belford, 1967, p. 5). The Lagaip Beds are now thought to range in age from the Middle Jurassic to the Paleocene and possibly lower Eocene. Subdivision of the Lagaip Beds has proved impossible in view of the monotonous lithology and complex structure. The Paleocene planktonic Foraminifera from the Lagaip Beds have been described by Belford (1967).

Six samples collected by D. E. Mackenzie during a BMR survey of the Lai (or Gai) River area, about 35 km east-northeast of Wabag, were also found to contain planktonic Upper Cretaceous Foraminifera. The samples are all from Waia Creek (Text-fig. 3) just south of Linganas, and appear to be from a continuous section ranging from Campanian to lower Maestrichtian in age. Unfortunately, the Foraminifera are not abundant and are poorly preserved, so few specimens were obtained. The stratigraphic nomenclature of this area is unsatisfactory, and in need of revision in the light of new information.

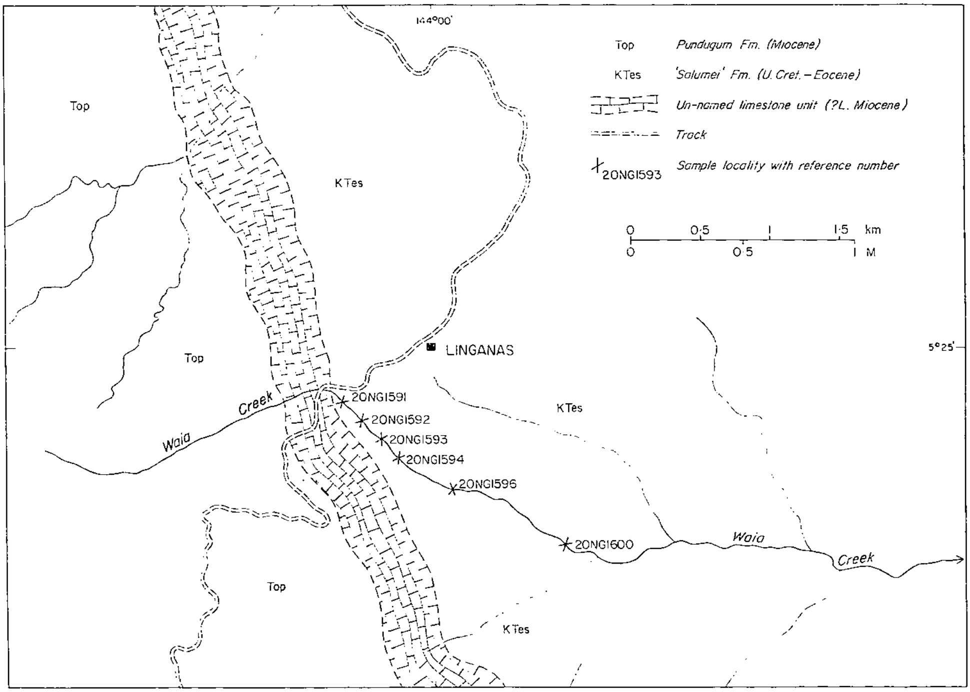


Fig. 3. Sample localities in the Lai River area.

The samples are from the 'Salumei Formation', an informally named unit, said to range from Upper Cretaceous to Eocene, and the lateral equivalent of the Lagaip Beds to the west. In the area of Waia Creek, the youngest part of the 'Salumei Formation' is of lower Maestrichtian age and is overlain by an unnamed limestone formation of possible lower Miocene age. However, elsewhere the youngest beds placed in the 'Salumei Formation' are known to be of Lower Tertiary age. No adequate account of the geology of this area has been published.

In addition, an isolated sample from eastern Papua has yielded free Upper Cretaceous Foraminifera. It was collected by D. H. Blake in 1969 from a locality 33 km east-southeast of Kwikila, about 70 km east-southeast of Port Moresby (lat. 9°56′S; long. 147°58′E). The sample is from an unnamed calcilutite formation. No account of the geology of this area has been published.

AGE OF SAMPLES

Several excellent zonal schemes based on planktonic Foraminifera have been proposed in recent years for the Upper Cretaceous. Probably the most detailed and best documented is that proposed by Pessagno (1967, 1969) for the western Gulf Coast area of the U.S.A. and Mexico. Since many of the species occurring in Papua New Guinea also occur in the area studied by Pessagno, it is proposed to use his zonation when discussing the age of the Papua New Guinea samples. Pessagno's zonation is reproduced in Text-figure 4. No changes are proposed except for minor nomenclatural changes at the generic level, although in some instances it proved impossible to reconcile faunal evidence from individual samples with the criteria for the zones and subzones laid down by Pessagno. Cases where this problem arises are discussed in the comments on individual samples.

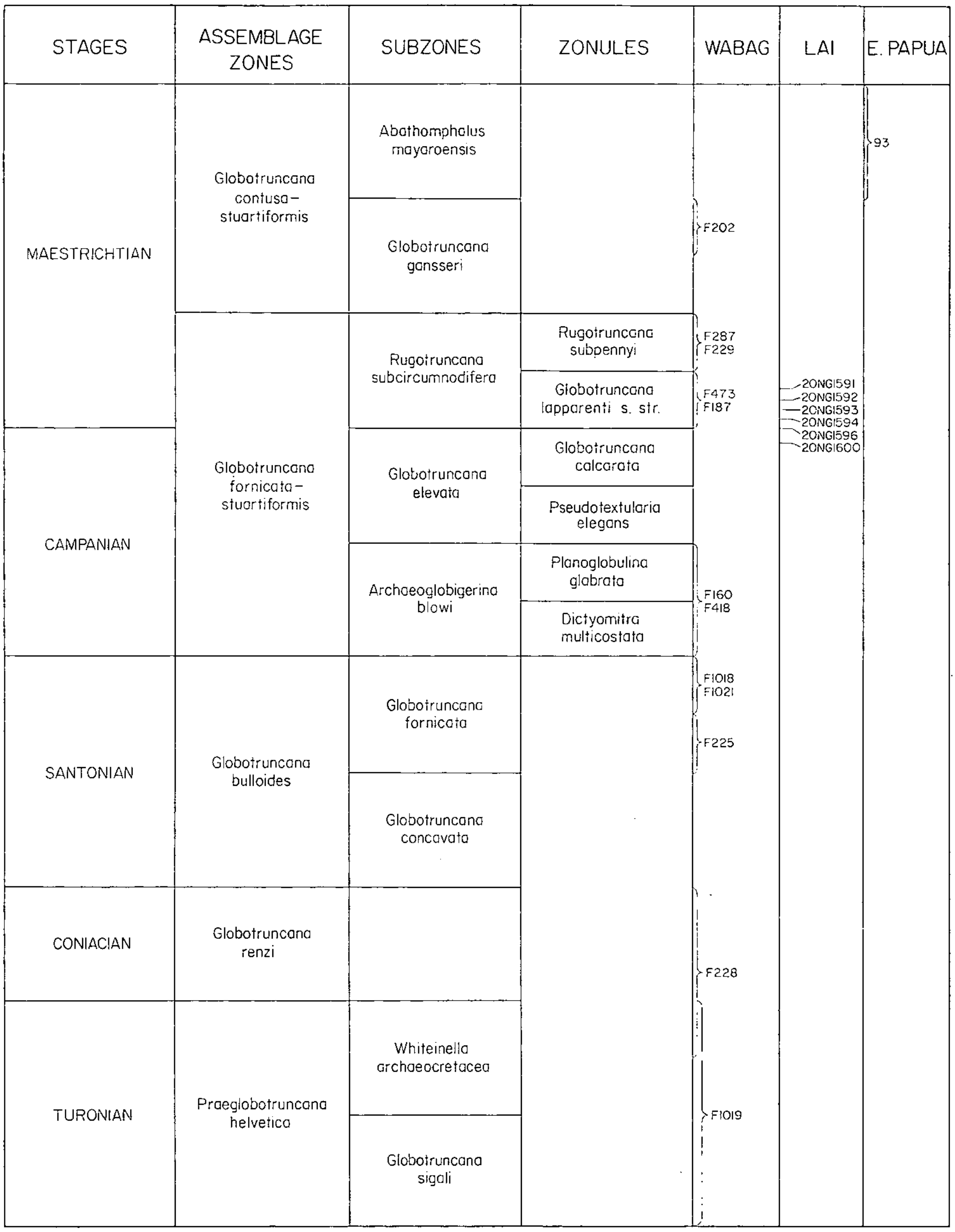
The ages of the samples from each area in turn are now discussed, taking the samples within each area in their assumed stratigraphic order. The total planktonic fauna in each sample is shown in Text-figure 5.

Wabag area

Sample F1019. Preservation in sample F1019 was very poor; however, two specimens were tentatively identified as *Praeglobotruncana helvetica* (Bolli) and *Globotruncana sigali* Reichel, indicating a Turonian age. The sample therefore correlates with the *P. helvetica* Zone of Pessagno. The benthonic fauna also accords with a Turonian age and includes *Gavelinella berthelini* (Keller), which is present in the Turonian of the Carnarvon Basin (Western Australia), and southern England.

Sample F288. Preservation in this sample was poor, and only *Globotruncana coronata* Bolli and *G. renzi* Gandolfi were tentatively identified, indicating a range in age from the middle of the *P. helvetica* Zone (middle Turonian) to the *G. bulloides* Zone (Santonian). An age at the lower end of this range is more likely, since the benthonic fauna has more similarities with that from F1019 than with those higher in the succession. An upper Turonian or Coniacian age is therefore indicated.

Sample 225 produced a relatively rich and well preserved planktonic fauna, which does, however, pose some problems in correlation. These are caused by the association of *Globotruncana concavata* (Brotzen), *G. coronata* Bolli, *G. renzi* Gandolfi, and *G. pseudolinneiana* (Pessagno) with *G. elevata* (Brotzen) and *G. ventricosa* White. The first four species are said by Pessagno (1967) to die out at the top of the *G. concavata* Subzone (middle Santonian), while *G. ventricosa* White



STAGES	ASSEMBLAGE ZONES	SUBZONES	ZONULES	WABAG	LAI	E. PAPUA
MAESTRICHTIAN	Globotruncana contusa–stuartiformis	Abathomphalus mayaroensis				93
		Globotruncana gansseri		F202		
	Globotruncana fornicata–stuartiformis	Rugotruncana subcircumnodifera	Rugotruncana subpennyi	F287 F229		
			Globotruncana lapparenti s. str.	F473 F187	20NG1591 20NG1592 20NG1593 20NG1594 20NG1596 20NG1600	
CAMPANIAN		Globotruncana elevata	Globotruncana calcarata			
			Pseudotextularia elegans			
		Archaeoglobigerina blowi	Planoglobulina glabrata	F160 F418		
			Dictyomitra multicostata			
SANTONIAN	Globotruncana bulloides	Globotruncana fornicata		F1018 F1021 F225		
		Globotruncana concavata				
CONIACIAN	Globotruncana renzi			F228		
TURONIAN	Praeglobotruncana helvetica	Whiteinella archaeocretacea				
		Globotruncana sigali		F1019		

M(P) 367

Fig. 4. Upper Cretaceous zonation (after Pessagno, 1967), with age of samples from Papua New Guinea indicated.

does not appear until the base of the *A. blowi* Subzone (basal Campanian) and *G. elevata* (Brotzen) does not appear until the base of the *G. elevata* Subzone (middle Campanian). All samples were collected as spot samples from one horizon, and are not channel samples, hence it is most probable that all these species were associated together. No reworking is thought to have occurred since preservation of the various species is identical. Specimens of *G. concavata* (Brotzen) and *G. elevata*

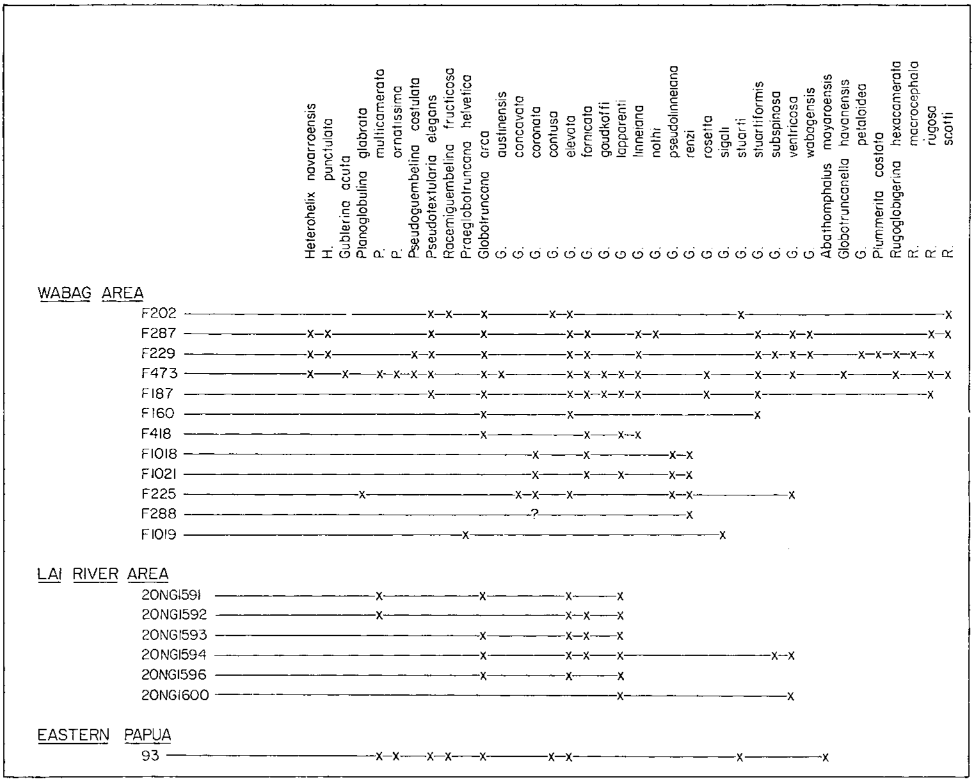


Fig. 5. Distribution of planktonic Foraminifera in Upper Cretaceous samples from Papua New Guinea.

(Brotzen) from this sample are illustrated on Plate 15 (figs 7-9) and Plate 16 (figs 3-4). It is apparent that the ranges of *G. ventricosa* White and *G. elevata* (Brotzen) must, in the Papua New Guinea area, be extended down into the upper Santonian, while the ranges of the remaining species mentioned earlier must be extended upwards, at least into the lower part of the upper Santonian, since Scheibnerova (1969) recorded an upper Santonian occurrence for both *G. concavata* and *G. elevata* from the west Carpathian Klippen Belt, Czechoslovakia.

This means that the Subzones *G. fornicata* and *G. concavata* proposed by Pessagno (1967, 1969) for the Santonian cannot be applied satisfactorily in the Papua-New Guinea region, and the sample can only be referred to the *G. bulloides* Assemblage Zone. However, it is considered that the sample is from the upper half of the *G. bulloides* Zone (upper Santonian).

Sample F1021 contained well preserved *Globotruncana coronata* Bolli, *G. renzi* Gandolfi, and *G. fornicata* Plummer with other species. This fauna indicates a horizon in the upper half of the *G. bulloides* Zone (upper Santonian). It is thought to be slightly younger than sample F225 as *G. concavata* (Brotzen) is absent.

Sample F1018 has a fauna similar to, though rather poorer than, that of sample F1021. The fauna includes *Globotruncana coronata* Bolli, *G. renzi* Gandolfi, and *G. fornicata* Plummer. It is therefore correlated with the upper part of the *G.*

bulloides Assemblage Zone (upper Santonian). Its age relative to F1021 is unknown.

Sample F418 contained a poor planktonic fauna, which included *Globotruncana arca* (Cushman), *G. fornicata* Plummer, *G. lapparenti* Brotzen, and *G. linneiana* (d'Orbigny). This fauna is inadequate for detailed correlation since all the species have relatively long ranges, and the sample can only be said with certainty to belong to the *G. fornicata-stuartiformis* Assemblage Zone (basal Campanian-lower Maestrichtian). However, since all planktonic foraminiferal faunas of definite upper Campanian to lower Maestrichtian age from New Guinea are abundant and well preserved, sample F418 is thought likely to be from the lower part of the Campanian, possibly from the *A. blowi* Subzone.

Sample F160 contained a poor fauna, with only *Globotruncana arca* (Cushman), *G. elevata* (Brotzen), and *G. stuartiformis* Dalbiez being identified. As with F418, this fauna is not sufficient to indicate an exact age; it could range from lower Campanian to upper Maestrichtian. Since the fanua is poor, a similar line of argument to that used for the previous sample may be applied, and a possible lower Campanian age may be suggested.

Sample F187 contained a rich and varied fauna with eleven species of planktonic Foraminifera. Many of these species range throughout much of the Campanian and Maestrichtian; however the occurrence of *Globotruncana fornicata* Plummer, *G. lapparenti* Brotzen, *G. rosetta* (Carsey), and *Globotruncanella havanensis* (Voorwijk), together with the absence of *Globotruncana calcarata* Cushman, indicates a lower Maestrichtian age. Further, the occurrence of *G. lapparenti* Brotzen indicates that the sample is from the *G. lapparenti* Zonule of the *R. subcircumnodifera* Subzone of Pessagno (1967, 1969).

Sample F473 provided the richest planktonic fauna, with twenty species. The presence of *Globotruncana lapparenti* Brotzen and *G. ventricosa* White, together with *Rugoglobigerina hexacamerata* Bronnimann and *R. scotti* (Bronnimann), is taken to indicate that the sample is from the *R. subcircumnodifera* Subzone. The presence of *G. lapparenti* Brotzen enables the age to be further refined down to the *G. lapparenti* Zonule. Both *R. hexacamerata* Bronniman and *R. scotti* have previously been considered by authors such as Pessagno (1967) and Olsson (1964) to be restricted to the middle and upper Maestrichtian; however, their occurrence with *G. lapparenti* Brotzen and *G. ventricosa* White is taken to indicate that their earliest occurrence is in the lower Maestrichtian.

Sample F229 contained a rich fauna of seventeen species. A lower Maestrichtian age is indicated by the occurrence of *Globotruncana subspinosa* Pessagno, *G. ventricosa* White, *Rugoglobigerina hexacamerata* Bronnimann, and *R. macrocephala* Bronniman. The absence of *G. lapparenti* Brotzen is taken as indicating that the sample is from the *R. subpennyi* Zonule of the *R. subcircumnodifera* Subzone.

Sample F287 is of similar age to sample F229. *Globotruncana lapparenti* Brotzen is absent and *Globotruncana ventricosa* White and *Rugoglobigerina scotti* (Bronnimann) are present, indicating the sample is from the *R. subpennyi* Zonule of the *R. subcircumnodifera* Subzone (lower Maestrichtian).

Sample F202 has a moderately rich fauna of seven species. *Pseudotextularia elegans* (Rzehak), *Racemiguembelina fructicosa* (Egger), *Globotruncana contusa* (Cushman), and *G. stuarti* (de Lapparent) indicate that the sample is from the *G. gansseri* Subzone (middle Maestrichtian).

Lai River area

Sample 20NG 1600 contained a poor fauna; only *Globotruncana lapparenti* Brotzen and *G. ventricosa* White were identified. These two species indicate an age between the upper Santonian and lower Maestrichtian. However, from the stratigraphic relationships with the other samples in this section, a Campanian age is likely since sample 20 NG 1600 is stratigraphically the oldest in the section.

Sample 20NG 1596 contains five species, of which *Globotruncana nothi* and *G. lapparenti* indicate an upper Campanian or lower Maestrichtian age.

Sample 20NG 1594 contains the diagnostic species *Globotruncana subspinosa, G. lapparenti,* and a form intermediate between *G. fornicata* and *G. contusa.* They indicate that the sample is probably from the lower part of the lower Maestrichtian, since typical specimens of *G. contusa* do not appear until the middle Maestrichtian, while *G. lapparenti* dies out in the middle of the lower Maestrichtian.

Samples 20NG 1591-3 all contain a planktonic fauna indicating an age from lower Campanian to the lower part of the lower Maestrichtian. However, the benthonic foraminiferal faunas are similar to those from samples in the Wabag area of lower Maestrichtian age. They are therefore thought to be from the *G. lapparenti* Zonule.

Eastern Papua

Sample 93 contains a rich, fairly well preserved fauna including nine species of planktonic Foraminifera. The presence of *Abathomphalus mayaroensis* (Bolli) shows that the sample is from the *A. mayaroensis* Subzone (upper Maestrichtian). Associated species include *Racemiguembelina fructicosa* (Egger), *Globotruncana contusa* (Cushman), and *G. stuarti* (de Lapparent).

SYSTEMATIC DESCRIPTIONS

All figured specimens are deposited in the Commonwealth Palaeontological Collections, held by the Bureau of Mineral Resources, Canberra, Australia under the numbers CPC 12129-12167. The collection numbers of individual specimens are included in the plate explanations.

Synonymies have been kept brief, but include a reference wherever possible to a recent paper containing a complete synonymy for the species concerned. In many instances the concept of individual species held by Pessagno (1967) has been followed to facilitate the application of his system of zonation of Upper Cretaceous and reference to a complete synonymy has usually been given by Pessagno. Instances of disagreement with Pessagno are noted under the remarks for relevant species.

Superfamily GLOBIGERINACEA Carpenter, Parker, & Jones, 1862

Family HETEROHELICIDAE Cushman, 1927

Genus HETEROHELIX Ehrenberg, 1843

HETEROHELIX NAVARROENSIS Loeblich, 1951

(Pl. 14, figs 1-2)

1951 *Heterohelix navarroensis* Loeblich, pp. 107-108, pl. 12, figs 1-3b, text-fig. 1.
1967 *Heterohelix navarroensis* Loeblich; Pessagno, p. 261, pl. 69, figs 8-9.

Remarks. Some specimens appear to be intermediate between *Heterohelix striata* (Ehrenberg) and *H. navarroensis,* with a rather more inflated test and coarser costae than are typical of *H. navarroensis.* Since the occurrences of *H. navarroensis* recorded here are all from the lower Maestrichtian, it seems possible that the species evolved from *H. striata* early in the Maestrichtian.

Known range. Lower to upper Maestrichtian.

Occurrence. Samples F229, F287, and F473.

HETEROHELIX PUNCTULATA (Cushman, 1938)

(Pl 14, figs 3-4)

1938 *Guembelina punctulata* Cushman, p. 13, pl. 2, figs 15-16.
1967 *Heterohelix punculata* (Cushman); Pessagno, pp. 262-263, pl. 86, figs 7-10.

Remarks. Pessagno (1967) noted that many species of *Heterohelix,* including *H. punctulata,* may possess accessory apertures. No accessory apertures were noticed in the New Guinea material.
Known range. Campanian and Maestrichtian.
Occurrence. Samples F229 and F287.

Genus GUBLERINA Kikoine, 1948

GUBLERINA ACUTA de Klasz, 1953

(Pl. 14, fig. 5)

1953 *Gublerina acuta* de Klasz, p. 246, pl. 8, fig. 3.

Remarks. The specimens of *Gublerina acuta* found in this study are identical with the holotype as figured by de Klasz. They differ from *Gublerina robusta* de Klasz in being more compressed with less globular chambers.
Known range. Upper Campanian and Maestrichtian.
Occurrence. Sample F473.

Genus PLANOGLOBULINA Cushman, 1927

PLANOGLOBULINA GLABRATA (Cushman, 1938)

(Pl. 14, fig. 6)

1938 *Ventilabrella eggeri* var. *glabrata* Cushman, p. 26, pl. 4, figs 15-17.
1957 *Planoglobulina glabrata* (Cushman); Gallitelli, pp. 141-142, pl. 32, figs 10-12.
1967 *Planoglobulina glabrata* (Cushman); Pessagno, p. 272, pl. 88, figs 12, 13, 17.

Remarks. The New Guinea specimens of *Planoglobulina glabrata* tend to have rather coarser costae on the earlier chambers than is normal, but they are otherwise typical of the species.
Known range. Upper Santonian and Campanian.
Occurrence. Sample F225.

PLANOGLOBULINA MULTICAMERATA de Klasz, 1953

(Pl. 14, fig. 7)

1953 *Planoglobulina multicamerata* de Klasz, p. 230, pl. 5, figs 1a-b.
1967 *Planoglobulina multicamerata* de Klasz; Pessagno, pp. 272-273, pl. 89, fig. 15.

Known range. Upper Campanian and Maestrichtian.
Occurrence. Samples F473, 93, 20NG 1591, and 20NG 1592.

PLANOGLOBULINA ORNATISSIMA (Cushman & Church, 1929)

(Pl. 14, fig. 8)

1929 *Ventilabrella ornatissima* Cushman & Church, p. 112, pl. 39, figs 12-14.
1969 *Planoglobulina ornatissima* (Cushman & Church); Douglas, pp. 160-161, pl. 11, figs 1-2.

Remarks. The taxonomic position of *Planoglobulina ornatissima* has been discussed by Douglas (1969), whose conclusions are accepted. The specimens here placed in *P. ornatissima* are virtually all broken along the line of weakness noted by Douglas and hence are biserial forms similar to that in his illustration (1969, pl. 11, fig. 2). A few specimens, however, show the initial stage of chamber proliferation after the biserial portion of the test.

P. ornatissima has previously only been recorded from California in strata of Campanian and lower Maestrichtian age. This record extends the stratigraphic range of the species to the upper Maestrichtian.
Known range. Upper Campanian and Maestrichtian.
Occurrence. Samples F473 and 93.

Genus PSEUDOGUEMBELINA Bronnimann & Brown, 1953
PSEUDOGUEMBELINA COSTULATA (Cushman, 1938)
(Pl. 14, figs 9-10)

1938 *Guembelina costulata* Cushman, p. 16, pl. 3, figs 7-9.
1957 *Pseudoguembelina costulata* (Cushman); Gallitelli, p. 139, pl. 31, figs 21-22.
1967 *Pseudoguembelina costulata* (Cushman); Pessagno, p. 266, pl. 79, fig. 1; pl. 88, figs 8-9; pl. 90, fig. 3.

Known range. Middle Campanian to upper Maestrichtian.
Occurrence. Samples F229 and F473.

Genus PSEUDOTEXTULARIA Rzehak, 1891
PSEUDOTEXTULARIA ELEGANS (Rzehak, 1891)
(Pl. 14, figs 11-12)

1891 *Cuneolina elegans* Rzehak, p. 2.
1967 *Pseudotextularia elegans* (Rzehak); Pessagno, p. 268, pl. 75, figs 12-17; pl. 85, figs 10-11; pl. 88, figs 14-16; pl. 89, figs 10-11; pl. 97, fig. 18; pl. 98, figs 19-20.

Remarks. Forms similar to, and gradational between, Pessagno's (1967) varieties *Pseudotextularia elegans* s. str. and *P. elegans* s.l. occur in the New Guinea material. There appears to be a tendency for *P. elegans* s.l. to become relatively more abundant than *P. elegans* s. str. in samples thought to be from higher horizons; however, the present material is not suitable for a quantitative study.
Known range. Campanian and Maestrichtian.
Occurrence. Samples F187, F202, F229, F287, F473, and 93.

Genus RACEMIGUEMBELINA Gallitelli, 1957
RACEMIGUEMBELINA FRUCTICOSA (Egger, 1899)
(Pl. 14, fig. 13)

1899 *Guembelina fructicosa* Egger, p. 35, pl. 14, figs 8-9, 24.
1967 *Racemiguembelina fructicosa* (Egger); Pessagno, pp. 270-271, pl. 90, figs 14-15.

Known range. Upper part of middle Maestrichtian and upper Maestrichtian.
Occurrence. Samples F202 and 93.

Family ROTALIPORIDAE Sigal, 1958
Genus PRAEGLOBOTRUNCANA Bermudez, 1952
PRAEGLOBOTRUNCANA ?HELVETICA (Bolli, 1945)
(Pl. 14, figs 14-16)

1945 *Globotruncana helvetica* Bolli, pp. 226-227, pl. 9, figs 6-8, text-figs 1, 9-12.
1967 *Marginotruncana helvetica* (Bolli); Pessagno, p. 306, pl. 53, figs 9-13; pl. 54, figs 1-3; pl. 99, fig. 4; pl. 100, fig. 4.

Remarks. A single very poorly preserved specimen from sample F1019 bears a distinct resemblance to *Praeglobotruncana helvetica* (Bolli). Because of its possible stratigraphic importance, the specimen is included in this account, despite its poor preservation. The typical hemispherical chamber shape and small umbilicus of *P. helvetica* are apparent, but it is uncertain if a single keel is also present. In view of the preservation of the specimen, it is only tentatively referred to *P. helvetica.*
Known range. Turonian.
Occurrence. Sample F1019.

Family GLOBOTRUNCANIDAE Brotzen, 1942

Genus GLOBOTRUNCANA Cushman, 1927

GLOBOTRUNCANA ARCA (Cushman, 1926)

(Pl. 14, figs 17-19)

1926 *Pulvinulina arca* Cushman, p. 23, pl. 3, figs 1a-c.

1967 *Globotruncana arca* (Cushman); Pessagno, pp. 321-323, pl. 79, figs 5-8; pl. 90, figs 6-8; pl. 96, figs 7-8, 17.

Known range. Campanian and Maestrichtian.

Occurrence. Samples F160, F187, F202, F229, F287, F418, F473, 93, 20NG 1591, 20NG 1593, 20NG 1594, and 20NG 1596.

GLOBOTRUNCANA AUSTINENSIS Gandolfi, 1955

(Pl. 15, figs 1-3)

1955 *Globotruncana marginata austinensis* Gandolfi, p. 29, pl. 1, figs 6a-c.

1967 *Globotruncana austinensis* Gandolfi; Pessagno, pp. 323-324, pl. 82, figs 12-15; pl. 94, fig. 9.

Remarks. The specimens found in the present study agree closely with the description of Pessagno (1967). They possess vaulted chambers dorsally, with a convex ventral side and a double keel which narrows and merges in later chambers and is positioned along the dorsal margin of the test.

Known range. Upper Santonian to lower Maestrichtian.

Occurrence. Sample F473.

GLOBOTRUNCANA CONCAVATA (Brotzen, 1934)

(Pl. 15, figs 7-9)

1934 *Rotalia concavata* Brotzen, p. 66, pl. 3, fig. b.

1955 *Globotruncana ventricosa carinata* Dalbiez, p. 168, text-figs 8a-c.

1967 *Marginotruncana concavata* (Brotzen); Pessagno, pp. 304-305, pl. 58, figs 1-9; pl. 95, figs 6-7; pl. 99, figs 1, 3.

Remarks. Specimens typical of *Globotruncana concavata* (Brotzen) were found in material from the Wabag area. They correspond to the subspecies *Globotruncana ventricosa carinata* Dalbiez of various authors, which is here considered a junior synonym of *G. concavata,* following Pessagno (1967). Pessagno (1967) shows *G. concavata* to be restricted to the uppermost Coniacian and the lower Santonian; however, various authors have recorded an upper Santonian occurrence for the species, sometimes in association with the supposedly Campanian and Maestrichtian *Globotruncana elevata* (Brotzen) (Scheibnerova, 1969, pp. 75, 77). This association was found in the Wabag area in sample F225. It seems likely that *G. concavata* ranges up to near the top of the Santonian, and that *G. elevata* also occurs in the upper Santonian.

Known range. Uppermost Coniacian and Santonian.

Occurrence. Sample F225.

GLOBOTRUNCANA CONTUSA (Cushman, 1926)

(Pl. 15, figs 4-6)

1918 *Rosalina linnei* d'Orbigny 'mutation calciforme' de Lapparent, p. 8, text-fig. 2, fig. j (=*nomen nudum*).

1926 *Pulvulina arca* Cushman var. *contusa* Cushman, p. 23.

1941 *Globotruncana linnei* d'Orbigny *caliciformis* Vogler, p. 288, pl. 24, fig. 23.

1967 *Globotruncana contusa* (Cushman); Pessagno, pp. 330-333, pl. 75, figs 18-20; pl. 77, figs 1-9; pl. 78, figs 6-11; pl. 92, figs 10-12; pl. 96, figs 11, 13-16.

Remarks. Typical specimens of *Globotruncana contusa* (Cushman) were found in the present study. A form intermediate between *G. contusa* and *G. fornicata* was found in sample 20NG 1594.

Occurrence. Samples F202, and 93.

GLOBOTRUNCANA CORONATA Bolli, 1945
(Pl. 15, figs 10-12)

1945 *Globotruncana lapparenti* Brotzen subsp. *coronata* Bolli, p. 233, text-figs 1, 21-22, pl. 9, fig. 15.

1967 *Marginotruncana coronata* (Bolli); Pessagno, pp. 305-306, pl. 65, figs 11-13; pl. 100, fig. 6.

Known range. Middle Turonian to upper Santonian.

Occurrence. Samples F225, F1018, F1021, and tentatively from sample F288.

GLOBOTRUNCANA ELEVATA (Brotzen, 1934)
(Pl. 16, figs 3-5)

1934 *Rotalia elevata* Brotzen, p. 66, pl. 3, fig. C.

1967 *Globotruncana elevata* (Brotzen); Pessagno, pp. 336-338, pl. 78, figs 12-14; pl. 80, figs 1-6; pl. 81, figs 9-14; pl. 93, figs 1-5, 8; text-fig. 44.

1969 *Globotruncana elevata* (Brotzen); Scheibnerova, pp. 76-77, pl. 16, figs 5a-c, 2a-c; text-fig. 25.

Remarks. Many of the samples examined contained typical *Globotruncana elevata* (Brotzen), the species being abundant in several. The figured specimen is of interest, since it occurs in association with *Globotruncana concavata* (sample F225). Pessagno (1967) indicated that *G. concavata* became extinct in the middle of the Santonian whereas *G. elevata* did not appear until the middle Campanian. However, the two species have previously been recorded together from upper Santonian horizons (Scheibnerova, 1969, pp. 75, 77); hence it seems likely that *G. elevata* first appeared during the upper Santonian. The specimen illustrated is not entirely typical of the species since it has a rather more convex dorsal side than is normal. However, the specimen has a T'X/TX value of about 1.6 (using the methods of Pessagno, 1967, p. 251, text-fig. B), which is well above the lower limit of 1.25, used by Pessagno to distinguish *G. elevata* from the dorsally more convex *Globotruncana stuartiformis.*

Known range. Upper Santonian to Maestrichtian.

Occurrence. Samples F160, F187, F202, F225, F229, F287, F473, 93, 20NG 1591, 20NG 1592, 20NG 1594, and 20NG 1596.

GLOBOTRUNCANA FORNICATA Plummer, 1931
(Pl. 15, fig. 13; pl. 16, figs 1-2)

1931 *Globotruncana fornicata* Plummer, pp. 198-199, pl. 13.

1967 *Globotruncana fornicata* Plummer; Pessagno, pp. 338-341, pl. 63, figs 1-9; pl. 80, figs 7-9; pl. 96, figs 3-4.

Remarks. Several specimens found are transitional between *Globotruncana fornicata* and *G. contusa,* particularly in lower Maestrichtian samples.

Known range. Middle Santonian to lower Maestrichtian.

Occurrence. F187, F229, F287, F418, F473, F1018, F1021, 20NG 1592, 20NG 1593, and 20NG 1594.

GLOBOTRUNCANA GOUDKOFFI Martin, 1964
(Pl. 16, figs 6-8)

1964 *Globotruncana goudkoffi* Martin, p. 80, pl. 10, fig. 1.

1969 *Globotruncana goudkoffi* Martin; Douglas, pp. 179-180, pl. 8, fig. 3.

Remarks. Typical specimens of *G. goudkoffi* were found in two samples from the Wabag area, New Guinea. The author has also observed the species in Campanian and lower Maestrichtian samples from the Carnarvon Basin, Western Australia.

Known range. Campanian to lower Maestrichtian.

Occurrence. Samples F187 and F473.

GLOBOTRUNCANA LAPPARENTI Brotzen, 1936

(Pl. 16, figs 9-11)

1936 *Globotruncana lapparenti* Brotzen, pp. 175-176.

1967 *Globotruncana lapparenti* Brotzen; Pessagno, pp. 344-346, pl. 71, figs 6-13; pl. 97, figs 8-9.

Remarks. *Globotruncana lapparenti* has been separated from *G. linneiana* (d'Orbigny) by the criteria used by Pessagno (1967), i.e. the sum of the keel heights at the anterior and posterior chambers. This proved an easy method for distinguishing the two species.

Known range. Lower Santonian to lower Maestrichtian.

Occurrence. Samples F187, F418, F473, F1021, 20NG 1591, 20NG 1592, 20NG 1593, 20NG 1594, 20NG 1596, and 20NG 1600.

GLOBOTRUNCANA LINNEIANA (d'Orbigny, 1839)

(Pl. 16, figs 12-14)

1839 *Rosalina linneiana* d'Orbigny, p. 110, pl. 5, figs 10-12.

1967 *Globotruncana linneiana* (d'Orbigny); Pessagno, pp. 346-349, pl. 72, figs 1-4, 7-9; pl. 97, figs 11-13.

Known range. Campanian to lower Maestrichtian.

Occurrence. Samples F187, F229, F287, F418, and F473.

GLOBOTRUNCANA PSEUDOLINNEIANA (Pessagno, 1967)

(Pl. 17, figs 4-6)

1967 *Marginotruncana pseudolinneiana* Pessagno, p. 310, pl. 65, figs 24-27; pl. 76, figs 1-3.

1969 *Globotruncana pseudolinneiana* (Pessagno); Douglas, p. 185, pl. 3, figs 2-4, text-fig. 6.

Known range. Middle Turonian to lowermost Campanian.

Occurrence. Samples F225, F1018, and F1021.

GLOBOTRUNCANA RENZI Gandolfi, 1942

(Pl. 17, figs 7-9)

1942 *Globotruncana renzi* Gandolfi, p. 124, pl. 3, fig. 1; pl. 4, fig. 16.

1957 *Globotruncana coldreriensis* Gandolfi, p. 64, pl. 9, fig. 7 (=Gandolfi, 1942, pl. 3, fig. 1).

1969 *Globotruncana renzi* Gandolfi; Caron & Luterbacher, p. 27, pl. 9, fig. 12.

1969 *Praeglobotruncana renzi* (Gandolfi); Douglas, pp. 172-173, pl. 2, fig. 8.

Remarks. The varied taxonomic history of *Globotruncana renzi* has been reviewed by, amongst others, Caron & Luterbacher (1969), Douglas (1969), and Pessagno (1967), and need not be repeated here. Pessagno's conclusions, different from those of most workers, are apparently based on an immature, poorly preserved syntype specimen and are not accepted by the author. The concept of the species followed here is that based on the specimen illustrated by Gandolfi (1942, pl. 3, fig. 1). Typical specimens of *G. renzi* were found during this study.

Known range. Middle Turonian to Santonian.

Occurrence. Samples F225, F288, F1018, and F1021.

GLOBOTRUNCANA ROSETTA (Carsey, 1926)

(Pl. 17, figs 10-12)

1926 *Globigerina rosetta* Carsey, p. 44, pl. 5, figs 3a-c.

1967 *Globotruncana rosetta* (Carsey); Pessagno, pp. 352-354, pl. 70, figs 9-12; pl. 73, figs 5-8; pl. 97, figs 19-23; pl. 98, fig. 14.

Known range. Campanian to lower Maestrichtian.

Occurrence. Samples F187, and F473.

GLOBOTRUNCANA ?SIGALI Reichel, 1950

(Pl. 17, figs 13-15)

1950 *Globotruncana (Globotruncana) sigali* Reichel, pp. 610-612, pl. 16, fig. 7; pl. 17, fig. 71, text-figs 5-6.

1967 *Marginotruncana sigali* (Reichel); Pessagno, pp. 313-314, pl. 54, figs 4-6; pl. 56, figs 1-3; pl. 57, figs 1-2; pl. 98, figs 6-7.

Remarks. A single poorly preserved specimen from sample F1019 appeared identical with *Globotruncana sigali* in general characteristics. In particular, it possessed a single keel and the shape of the biconvex test was very similar to that of *G. sigali*; the specimen is accordingly tentatively identified as *G. sigali.*

Known range. Turonian.

Occurrence. Sample F1019.

GLOBOTRUNCANA STUARTI (de Lapparent, 1918)

(Pl. 18, figs 1-3)

1918 *Rosalina stuarti* de Lapparent, p. 11, pl. 1, figs 5-7, text-figs 4 (p. 12), 5a-c (p. 13).

1967 *Globotruncana stuarti* (de Lapparent); Pessagno, pp. 356-357, pl. 81, figs 1-6; pl. 93, figs 9-11; pl. 94, fig. 7.

Known range. Middle and upper Maestrichtian.

Occurrence. Samples F202, and 93.

GLOBOTRUNCANA STUARTIFORMIS Dalbiez, 1955

(Pl. 18, figs 4-6)

1955 *Globotruncana (Globotruncana) elevata stuartiformis* Dalbiez, p. 169, text-figs 10a-c.

1967 *Globotruncana stuartiformis* Dalbiez; Pessagno, pp. 357-359, pl. 80, figs 3-6; text-fig. 44, fig. 17.

Known range. Campanian and Maestrichtian.

Occurrence. Samples F160, F187, F229, F287, F473, and 20NG 1596.

GLOBOTRUNCANA SUBSPINOSA Pessagno, 1960

(Pl. 18, figs 7-9)

1960 *Globotruncana subspinosa* Pessagno, pp. 101-102, pl. 1, figs 1-9; pl. 5, fig. 5.

Remarks. G. subspinosa, as noted by Pessagno (1967, p. 337), appears to be transitional between *G. elevata* and *G. calcarata,* and it could well be regarded as a subspecies of *G. elevata.* However, the species with its crenulate dorsal chamber surface and poorly developed peripheral chamber extensions has a distinctive appearance, can be clearly distinguished from both *G. elevata* and *G. calcarata,* and has a more restricted range than *G. elevata.* It is therefore treated as a distinct species. Pessagno (1967, p. 337) considered *G. subspinosa* to be a junior synonym of *G. elevata*; however, in the material examined by the author no intermediate forms were observed.

G. subspinosa differs from *G. elevata* in having crenulate dorsal chamber surfaces, and from *G. calcarata* in having much less well developed peripheral extensions of the chambers. The specimens found in the New Guinea material tend to have a more convex ventral side than the type for the species.

Known range. Upper Campanian and lower Maestrichtian.

Occurrence. Samples F229, and 20NG 1594.

GLOBOTRUNCANA VENTRICOSA White, 1928

(Pl. 19, figs 4-6)

1928 *Globotruncana canaliculata* var. *ventricosa* White, p. 284, pl. 38, figs 3a-c.

1967 *Globotruncana ventricosa* White; Pessagno, pp. 362-364, pl. 75, figs 21-26; pl. 79, figs 9-14; pl. 95, figs 10-11; pl. 99, fig. 2.

Remarks. Pessagno (1967, p. 363) considered *G. ventricosa* to be restricted to the Campanian; however, typical specimens were found in samples from both the upper Santonian and lower Maestrichtian in New Guinea. In the upper Santonian occurrence, *G. ventricosa* is associated with *G. concavata* (Brotzen) (sample F235), and in the lower Maestrichtian *G. ventricosa* occurs with such forms as *Rugoglobigerina hexacamerata* Bronnimann and *R. scotti* (Bronnimann) (sample F473).

Known range. Upper Santonian to lower Maestrichtian.

Occurrence. Samples F225, F229, F287, F473, 20NG 1594, and 20NG 1600.

GLOBOTRUNCANA WABAGENSIS sp. nov.

(Pl. 18, figs 10-12; pl. 19, figs 1-3)

Diagnosis. Test trochospiral, dorsally convex, ventrally flat to concave; narrow double keel merging on later chambers, dorsal sutures curved, raised, ventral sutures depressed, straight.

Description. Test trochospiral, spiroconvex, and truncated by a narrow double keel which merges to form a single keel in the last one or two chambers. Chambers arranged in three whorls, which increase gradually in size, with six to seven chambers in last whorl. Chambers dorsally petaloid, separated by curved, raised, beaded sutures; ventrally wedge-shaped, separated by straight, depressed sutures. Umbilicus fairly small, moderately deep, and covered by a tegilla with infralaminal and intralaminal accessory apertures. Primary aperture interiomarginal and umbilical in position. Surface of chambers smooth except for scattered, non-aligned rugosities on ventral side.

Dimensions. Maximum diameter 0.62 mm; thickness 0.33 mm. Average diameter 0.57 mm; thickness 0.30 mm.

Remarks. Globotruncana wabagensis is a distinctive species characterized by a markedly convex dorsal side, a flat to concave ventral side, and a narrow double keel which merges on the last one or two chambers. It has many similarities with *Globotruncana conica* White, but the double keel of *G. wabagensis* allows a ready separation of the two forms. *Globotruncana stephensoni* Pessagno is also similar to *G. wabagensis*; however, the double keel of *G. stephensoni* is more strongly reflected ventrally, and the test of *G. wabagensis* is dorsally more convex and ventrally less concave.

G. wabagensis was found in two samples; it was fairly common in F229 and rare in F287. Both samples have been dated by their planktonic foraminiferal fauna as belonging to the *Rugotruncana subpennyi* Zonule (upper part of the lower Maestrichtian). About 25 specimens of the species were found.

Origin of name. The village of Wabag, New Guinea.

Type locality. The type specimens are from sample F229, at a locality on the Muriaga to Timundan track about 3 km from Muriaga and about 40 km west-northwest of Wabag airstrip (lat. 5°22′S, long. 143°20′,30″E).

Type horizon. The type sample is from the Lagaip Beds; the sample has been dated from the planktonic foraminiferal fauna as being from the upper part of the lower Maestrichtian.
Known range. Upper part of lower Maestrichtian.
Occurrence. Samples F229, and F287.

Genus ABATHOMPHALUS Bolli, Loeblich & Tappan, 1957
ABATHOMPHALUS MAYAROENSIS (Bolli, 1951)
(Pl. 19, figs 7-9)

1951 *Globotruncana mayaroensis* Bolli, p. 198, pl. 35, figs 10-12.
1967 *Abathomphalus mayaroensis* (Bolli); Pessagno, p. 372, pl. 92, figs 4-9; pl. 95, fig. 5.
Known range. Upper Maestrichtian.
Occurrence. Sample 93.

Genus GLOBOTRUNCANELLA Reiss, 1957
GLOBOTRUNCANELLA HAVANENSIS (Voorwijk, 1937)
(Pl. 19, figs 13-15)

1937 *Globotruncana havanensis* Voorwijk, p. 195, pl. 1, figs 25-26, 29.
1951 *Globotruncana citae* Bolli, p. 197, pl. 35, figs 4-6.
1967 *Globotruncanella havanensis* (Voorwijk); Pessagno, p. 373, pl. 84, figs 1-3.
Known range. Maestrichtian.
Occurrence. Samples F187 and F473.

GLOBOTRUNCANELLA PETALOIDEA (Gandolfi, 1955)
(Pl. 20, figs 1-3)

1955 *Globotruncana (Rugoglobigerina) petaloidea petaloidea* Gandolfi, p. 52, pl. 3, figs 13a-c.
1967 *Globotruncanella petaloidea* (Gandolfi); Pessagno, pp. 374-375, pl. 82, figs 6-9.
Known range. Maestrichtian.
Occurrence. Sample F229.

Genus PLUMMERITA Bronnimann, 1952
PLUMMERITA COSTATA (Bronnimann, 1952)
(Pl. 19, figs 10-12)

1952 *Rugoglobigerina (Plumerella) hantkeninoides costata* Bronnimann, p. 39, pl. 3, figs 4-6, text-fig. 18.
1952 *Rugoglobigerina (Plumerella) hantkeninoides inflata* Bronnimann, p. 40, pl. 3, figs 7-9, text-fig. 19.
1956 *Plummerita hantkeninoides inflata* (Bronnimann); Bronnimann & Brown, p. 556, pl. 21, figs 4-6.

Remarks. The two subspecies of Bronnimann (1952), here placed in synonymy, were separated by Bronnimann on the basis of the more inflated end chambers and the reduction in the number of spinose chambers in the subspecies *R. hantkeninoides inflata*. A comparison of the figures presented by Bronnimann (1952) shows little significant difference between the two forms. In addition, the specimens examined from New Guinea show sufficient variation to include all morphological varieties included by Bronnimann in the two subspecies. They are therefore considered synonymous, with the name *costata* being preferred over *inflata,* since the subspecies *costata* is described before the subspecies *inflata* in the type descriptions of Bronnimann (1952).

The ornamentation of meridionally arranged rugosities characteristic of the genus is poorly developed in the New Guinea specimens. A few specimens show an indistinct alignment of rugosities on the early chambers of either the dorsal or ventral sides, but many show no alignment. However, all specimens have a well developed unaligned rugose ornamentation. *P. costata* was stated by Bronnimann to occur in upper Maestrichtian; it was found in a sample from New Guinea thought to be of late lower Maestrichtian age.

Genus RUGOGLOBIGERINA Bronnimann, 1952

RUGOGLOBIGERINA HEXACAMERATA Bronnimann, 1952

(Pl. 20, figs 4-6)

1952 *Rugoglobigerina reicheli hexacamerata* Bronnimann, pp. 23-25, pl. 2, figs 10-12, text-fig. 8.

1967 *Rugoglobigerina hexacamerata* Bronnimann; Pessagno, pp. 364-365, pl. 74, fig. 4; pl. 91, figs 5-7.

Known range. Upper part of lower Maestrichtian to upper Maestrichtian.

Occurrence. Samples F229 and F473.

RUGOGLOBIGERINA MACROCEPHALA Bronnimann, 1952

(Pl. 20, figs 7-9)

1952 *Rugoglobigerina macrocephala macrocephala* Bronnimann, p. 25, pl. 2, figs 1-3, text-fig. 9.

1964 *Rugoglobigerina macrocephala* Bronnimann; Olsson, p. 172, pl. 6, fig. 9.

Remarks. Many of the specimens here placed in *R. macrocephala* appear to be transitional from *Rugoglobigerina rugosa* (Plummer). Olsson (1964, p. 172) noted that *R. macrocephala* probably arose from *R. rugosa* in the lower Maestrichtian.

Known range. Maestrichtian.

Occurrence. Sample F229.

RUGOGLOBIGERINA RUGOSA (Plummer, 1927)

(Pl. 20, figs 10-12)

1927 *Globigerina rugosa* Plummer, p. 38, pl. 2, fig. 10.

1967 *Rugoglobigerina rugosa* (Plummer); Pessagno, pp. 366-367, pl. 75, figs 2-3; pl. 101, figs 8-9.

Known range. Middle Campanian to Maestrichtian.

Occurrence. Samples F187, F229, F287, and F473.

RUGOGLOBIGERINA SCOTTI (Bronnimann, 1952)

(Pl. 20, figs 13-15)

1952 *Trinitella scotti* Bronnimann, p. 57, pl. 4, figs 4-6, text-fig. 30.

1967 *Rugoglobigerina scotti* (Bronnimann); Pessagno, p. 367, pl. 74, figs 9-14; pl. 76, figs 4-6.

Known range. Upper part of lower Maestrichtian to upper Maestrichtian.

Occurrence. Samples F202, F287, and F473.

REFERENCES

AUSTRALASIAN PETROLEUM COMPANY, 1961—Geological results of petroleum exploration in western Papua, 1937-1961. *J. geol. Soc. Aust.*, 8(1), 1-133.

BELFORD, D. J., 1960—Upper Cretaceous Foraminifera from the Toolonga Calcilutite and Gingin Chalk, Western Australia. *Bur. Miner. Resour. Aust. Bull.* 57, 1-198.

BELFORD, D. J., 1967—Paleocene planktonic Foraminifera from Papua and New Guinea. *Bur. Miner. Resour. Aust. Bull.* 92, 1-33.

BOLLI, H. M., 1945—Zur Stratigraphie der Oberen Kreide in den hoheren helvetischen Decken. *Ecl. geol. Helv.*, 37(2), 217-328.

BOLLI, H. M., 1951—The genus *Globotruncana* in Trinidad, B.W.I. *J. Paleont.*, 25(2), 187-99.

BRONNIMANN, P., 1952—Globigerinidae from the Upper Cretaceous (Cenomanian-Maestrichtian) of Trinidad, B.W.I. *Bull. Amer. Paleont.*, 34(140), 1-70.

BRONNIMANN, P., and BROWN, N. K., 1956—Taxonomy of the Globotruncanidae. *Ecl. geol. Helv.*, 48(2), 503-62.

BROTZEN, F., 1934—Foraminiferen aus dem Senon Palästinas. *Dtsch. Ver. Palästinas,* Z-o., 57, 28-72.

BROTZEN, F., 1936—Foraminifera aus dem Schwedischen untersten Senon von Eriksdal in Schonen. *Sverig. geol. Unders.*, Ser. C. (396), 1-206.

CARON, M., and LUTERBACHER, H. P., 1969—On some type specimens of Cretaceous planktonic Foraminifera. *Contr. Cushman Fdn,* 20(1), 23-9.

CARSEY, D. O., 1926—Foraminifera of the Cretaceous of central Texas. *Bull. Univ. Texas,* 2612, 1-56.

CUSHMAN, J. A., 1926—Some Foraminifera from the Mendez Shale of eastern Mexico. *Contr. Cushman Lab.*, 2(1), 16-26.

CUSHMAN, J. A., 1938—Cretaceous species of *Guembelina* and related genera. *Contr. Cushman Lab.*, 14(1), 2-28.

CUSHMAN, J. A., and CHURCH, C. C., 1929—Some Upper Cretaceous Foraminifera from near Coalinga, California. *Proc. Calif. Acad. Sci.*, Ser. 4, 18, 497-531.

DALBIEZ, F., 1955—The genus *Globotruncana* in Tunisia. *Micropaleontology,* 1(2), 161-71.

DEKKER, F. E., and FAULKS, I. G., 1964—The geology of the Wabag area, New Guinea. *Bur. Miner. Resour. Aust. Rec.* 1964/137 (unpubl.).

DOUGLAS, R. G., 1969—Upper Cretaceous planktonic Foraminifera in northern California, Part I—Systematics. *Micropaleontology,* 15(2), 151-209.

DOW, D. B., SMIT, J. A. J., BAIN, J. H. C., and RYBURN, R. J., 1972—Geology of the South Sepik Region, New Guinea. *Bur. Miner. Resour. Aust. Bull.* 133.

EGGER, J. G., 1899—Foraminifera und Ostrakoden aus den Kreidemergeln der oberbayerischen Alpen. *K. Bayer. Acad. Wiss. München Abh.* Cl. II, 21(1), 3-230.

GALLITELLI, E. M., 1957—A revision of the foraminiferal family Heterohelicidae. *U.S. nat. Mus. Bull.* 215, 135-154.

GANDOLFI, R., 1942—Ricerche micropaleontologiche e stratigrafiche sulla Scaglia e sul Flysch Cretacici dei dintorni de Balerna (Canton Ticino). *Riv. ital. Paleont.*, 48(4), 1-160.

GANDOLFI, R., 1955—The genus *Globotruncana* in northeastern Columbia. *Bull. Amer. Paleont.*, 36(155), 1-188.

GANDOLFI, R., 1957—Notes on some species of *Globotruncana. Contr. Cushman Fdn,* 8(2), 59-65.

GLAESSNER, M. F., 1952—Geology of Port Moresby, Papua. *In Sir Douglas Mawson Anniversary Volume, Univ. Adelaide,* 63-86.

KLASZ, I. DE, 1953—Einige neue oder wenig bekannte Foraminiferen aus der helvetischen Oberkreide der bayerischen Alpen südlich Traunstein (Oberbayern). *Geol. Bavarica,* 17, 223-44.

LAPPARENT, J. DE, 1918—Etude lithologique des terrains Crétacés de la région d'Hendaye. *Carte géol. France Mém.*, 1-153.

LOEBLICH, A. R., 1951—Coiling in the Heterohelicidae. *Contr. Cushman Fdn,* 2(3), 106-111.

MARTIN, L., 1964—Upper Cretaceous and lower Tertiary Foraminifera from Fresno County, California. *Geol. Bundesanst. Wien, Jb.*, 9, 1-128.

OLSSON, R. K., 1964—Late Cretaceous planktonic Foraminifera from New Jersey and Delaware. *Micropaleontology,* 10(2), 157-88.

PESSAGNO, E. A., 1960—Stratigraphy and micropaleontology of the Cretaceous and lower Tertiary of Puerto Rico. *Micropaleontology,* 6(1), 87-110.

PESSAGNO, E. A., 1969—Upper Cretaceous stratigraphy of the Western Gulf Coast Area of Mexico, Texas and Arkansas. *Mem. geol. Soc. Amer.*, 111, 1-138.

PLUMMER, H. J., 1927—Foraminifera of the Midway Formation in Texas. *Bull. Univ. Texas,* 2644, 1-206.

PLUMMER, H. J., 1931—Some Cretaceous Foraminifera in Texas. *Bull. Univ. Texas,* 3101, 109-203.

REICHEL, M., 1950—Observations sur les *Globotruncana* du gisement de la Breggia (Tessin). *Ecl. geol. Helv.*, 42(2), 596-617.

RICKWOOD, F. K., 1955—The geology of the Western Highlands of New Guinea. *J. geol. Soc. Aust.*, 2, 63-82.

RZEHAK, A., 1891—Die Foraminiferenfauna der alttertiären Ablagerungen von Bruderndorf in Niederösterreich, mit Berücksichtigung des angeblichen Kreidevorkommens von Leitzensdorf. *Naturh. Hofmus. Ann., Wien,* 6, 1-12.

SCHEIBNEROVA, V., 1969—Middle and Upper Cretaceous Microbiostratigraphy of the Klippen Belt (West Carpathians). *Acta Geol. Geogr. Univ. Comenianae, Geol.,* 17, 5-98.

VISSNER, W. A., and HERMES, J. J., 1962—Geological results of the exploration for oil in Netherlands New Guinea. *Netherlands Government.*

VOGLER, J., 1941—Beiträge zur Geologie von Niederlandisch-Indien: Ober Jura und Kreide von Misal. *Palaeontographica, suppl. Bd* 4, *Abt.* 4, 245-93.

VOORWIJK, G. H., 1937—Foraminifera from the Upper Cretaceous of Habana, Cuba. *Proc. Kon. Akad. Wetensch. Amst.*, 40(2), 190-198.

WHITE, M. P., 1928—Some index Foraminifera of the Tampico Embayment area of Mexico, part 2. *J. Paleont.*, 2(4), 280-317.

PLATE 14

Figures 1-2	*Heterohelix navarroensis* Loeblich. 1, side view; 2, edge view, x100. From sample F229, Wabag area, New Guinea. CPC 12129.
Figures 3-4	*Heterohelix punctulata* (Cushman). 3, edge view; 4, side view, x80. From sample F229, Wabag area, New Guinea. CPC 12130.
Figure 5	*Gublerina acuta* de Klasz. Side view, x80. From sample F473, Wabag area, New Guinea. CPC 12131.
Figure 6	*Planoglobulina glabrata* (Cushman). Side view, x80. From sample 225, Wabag area, New Guinea. CPC 12132.
Figure 7	*Planoglobulina multicamerata* de Klasz. Side view, x66. From sample F473, Wabag area, New Guinea. CPC 12133.
Figure 8	*Planoglobulina ornatissima* (Cushman and Church). Side view, x80. From sample 93, eastern Papua. CPC 12134.
Figures 9-10	*Pseudoguembelina costulata* (Cushman). 9, edge view; 10, side view, x100. From sample F229, Wabag area, New Guinea. CPC 12135.
Figures 11-12	*Pseudotextularia elegans* (Rzehak). 11, side view; 12, edge view, x100. From sample F229, Wabag area, New Guinea. CPC 12136.
Figure 13	*Racemiguembelina fructicosa* (Egger). Side view, x80. From sample F202, Wabag area, New Guinea. CPC 12137.
Figures 14-16	*Praeglobotruncana ?helvetica* (Bolli). 14, dorsal view; 15, peripheral view; 16, ventral view, x75. From sample F1019, Wabag area, New Guinea. CPC 12138.
Figures 17-19	*Globotruncana arca* (Cushman). 17, dorsal view; 18, peripheral view; 19, ventral view, x75. From sample F473, Wabag area, New Guinea. CPC 12139.

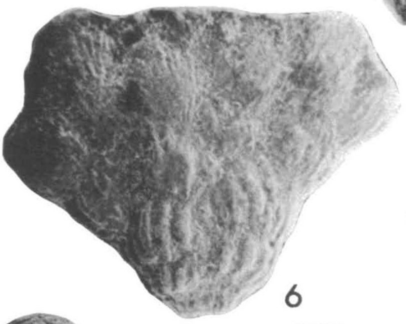

1

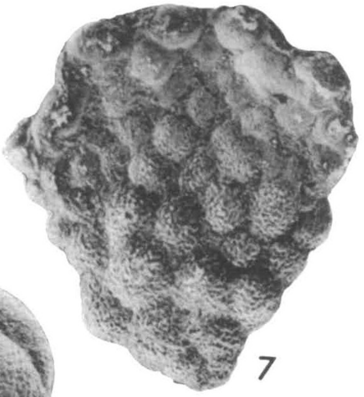

2


3


4


5


6


7

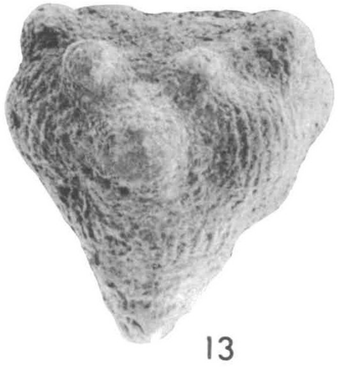

8

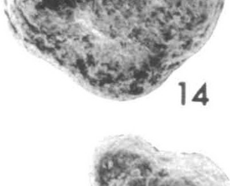

11

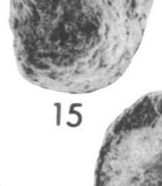

12

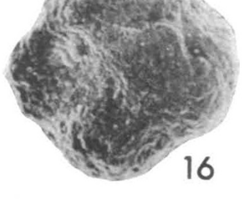

9


10


13


14


15


16


17


18

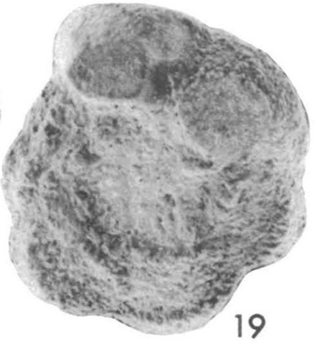
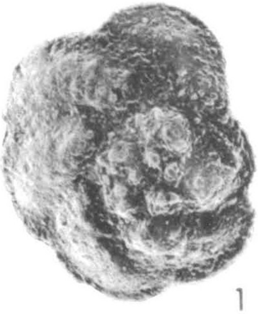

19

PLATE 15

Figures 1-3	*Globotruncata austinensis* Gandolfi. 1, dorsal view; 2, peripheral view; 3, ventral view, x75. From sample F473, Wabag area, New Guinea. CPC 12140.
Figures 4-6	*Globotruncana contusa* (Cushman). 4, dorsal view; 5, ventral view; 6, peripheral view, x50. From sample F202, Wabag area, New Guinea. CPC 12142.
Figures 7-9	*Globotruncana concavata* (Brotzen). 7, dorsal view; 8, peripheral view; 9, ventral view, x75. From sample F225, Wabag area, New Guinea. CPC 12141.
Figures 10-12	*Globotruncana coronata* Bolli. 10, ventral view; 11, dorsal view; 12, peripheral view, x66. From sample F225, Wabag area, New Guinea. CPC 12143.
Figure 13	*Globotruncana fornicata* Plummer. Dorsal view, x75. From sample F229, Wabag area, New Guinea. CPC 12145.

Globotruncana


1


2

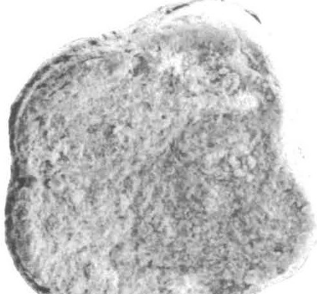

3

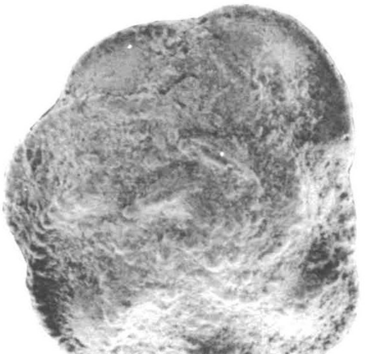

6


4


5

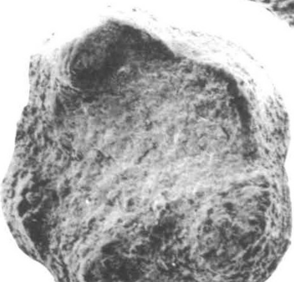

10


7


11


12


8


9

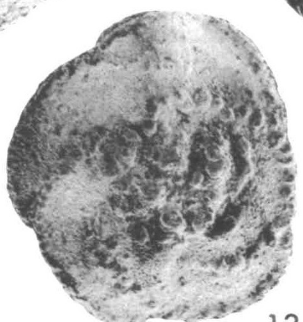

13

PLATE 16

Figures 1-2 *Globotruncana fornicata* Plummer. 1, ventral view; 2, peripheral view, x75. From sample F229, Wabag area, New Guinea. CPC 12145.

Figures 3-5 *Globotruncana elevata* (Brotzen). 3, dorsal view; 4, ventral view; 5, peripheral view, x66. From sample F225, Wabag area, New Guinea. CPC 12144.

Figures 6-8 *Globotruncana goudkoffi* Martin. 6, dorsal view; 7, ventral view; 8, peripheral view, x75. From sample F473, Wabag area, New Guinea. CPC 12146.

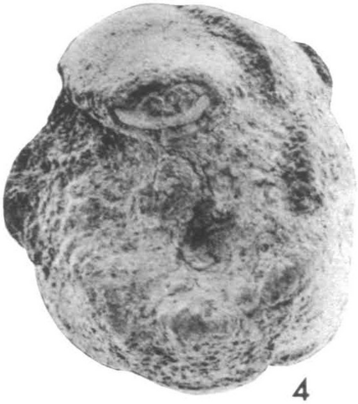
Figures 9-11 *Globotruncana lapparenti* Brotzen. 9, dorsal view; 10, peripheral view; 11, ventral view, x75. From sample F473, Wabag area, New Guinea. CPC 12147.

Figures 12-14 *Globotruncana linneiana* (d'Orbigny). 12, dorsal view; 13, peripheral view; 14, ventral view. From sample F473, Wabag area, New Guinea. CPC 12148.

Globotruncana


1


3


4


2

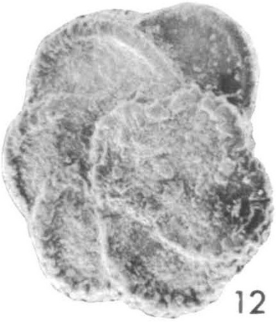

6

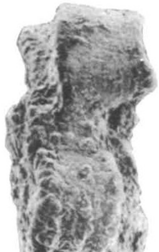

7


5

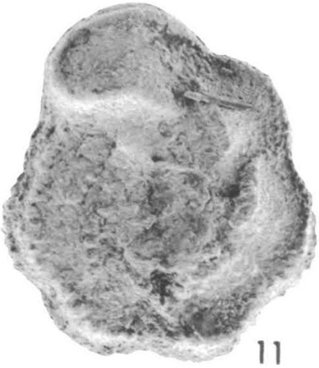

9


8


12


13


10


11

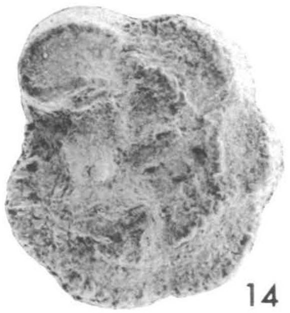

14

PLATE 17

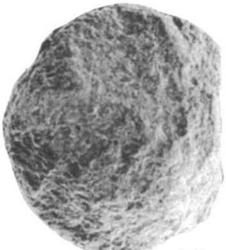
Figures 1-3	*Globotruncana nothi* (Bronnimann & Brown). 1, dorsal view; 2, peripheral view; 3, ventral view, x75. From sample F287, Wabag area, New Guinea. CPC 12149.
Figures 4-6	*Globotruncana pseudolinneiana* (Pessagno). 4, dorsal view; 5, peripheral view; 6, ventral view, x75. From sample F225, Wabag area, New Guinea. CPC 12150.
Figures 7-9	*Globotruncana renzi* Gandolfi. 7, dorsal view; 8, peripheral view; 9, ventral view, x66. From sample F225, Wabag area, New Guinea. CPC 12151.
Figures 10-12	*Globotruncana rosetta* (Carsey). 10, dorsal view; 11, peripheral view; 12, ventral view, x75. From sample F473, Wabag area, New Guinea. CPC 12152.
Figures 13-15	*Globotruncana ?sigali* Reichel. 13, dorsal view; 14, ventral view; 15, peripheral view, x75. From sample F1019, Wabag area, New Guinea. CPC 12153.

Globotruncana


1


2

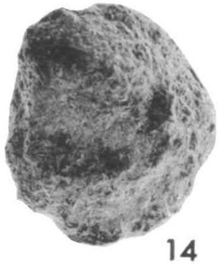

3

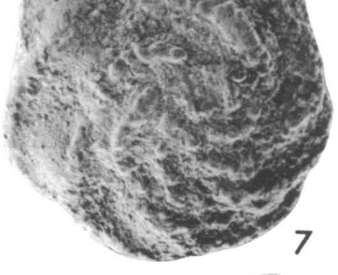

13


4

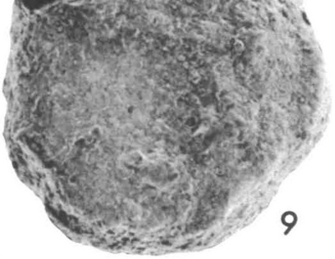

5


6

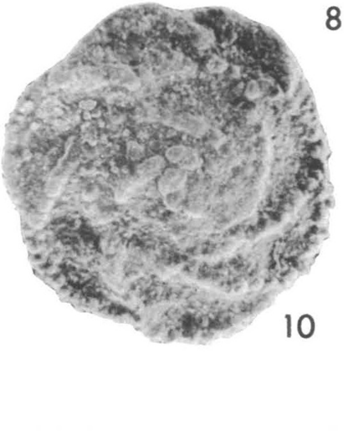

14


7


8


9


15


10


11

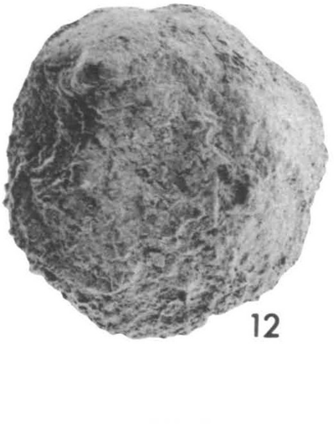
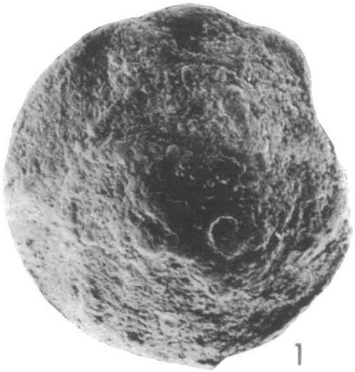

12

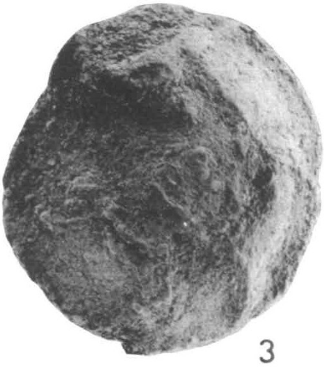
PLATE 18

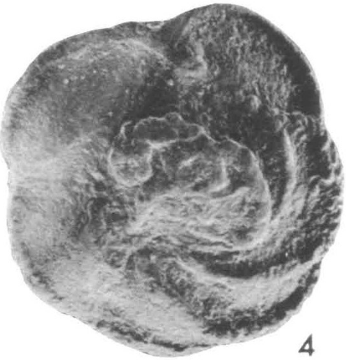
Figures 1-3	*Globotruncana stuarti* (de Lapparent). 1, dorsal view; 2, peripheral view; 3, ventral view, x66. From sample F229, Wabag area, New Guinea. CPC12154.
Figures 4-6	*Globotruncana stuartiformis* Dalbiez. 4, dorsal view; 5, peripheral view; 6, ventral view, x66. From sample F229, Wabag area, New Guinea. CPC 12155.
Figures 7-9	*Globotruncana subspinosa* Pessagno. 7, dorsal side; 8, peripheral view; 9, ventral view, x75. From sample F229, Wabag area, New Guinea. CPC 12156.
Figures 10-12	*Globotruncana wabagensis* sp. nov. Paratype. 10, dorsal view; 11, peripheral view; 12, ventral view, x75. From sample F229, Wabag area, New Guinea. CPC 12159.

Globotruncana


1


2


3


4


5


6


7


8


9


10


11


12

PLATE 19

Figures 1-3	*Globotruncana wabagensis* sp. nov. **Holotype.** 1, dorsal view; 2 peripheral view; 3, ventral view, x75. From sample F229, Wabag area, New Guinea. CPC 12158.
Figures 4-6	*Globotruncana ventricosa* White. 4, dorsal view; 5, peripheral view; 6, ventral view, x75. From sample F229, Wabag area, New Guinea. CPC 12157.
Figures 7-9	*Abathomphalus mayaroensis* (Bolli). 7, dorsal view; 8, peripheral view; 9, ventral view, x75. From sample 93, Eastern Papua. CPC 12160.
Figures 10-12	*Plummerita costata* (Bronnimann). 10, dorsal view; 11, peripheral view; 12, ventral view, x150. From sample F229, Wabag area, New Guinea. CPC 12163.
Figures 13-15	*Globotruncanella havanensis* (Voorwijk). 13, peripheral view; 14, dorsal view; 15, ventral view. From sample F473, Wabag area, New Guinea. CPC 12161.

Globotruncanidae


1


2


3


4

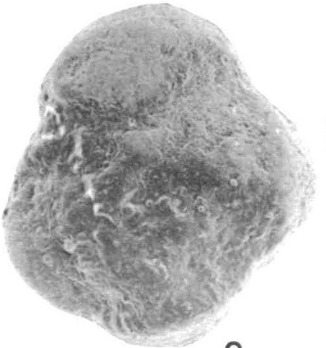

5


6


13


7

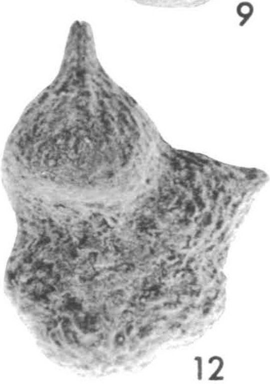

8


9


14


10


11


12

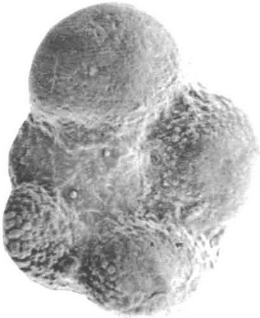

15

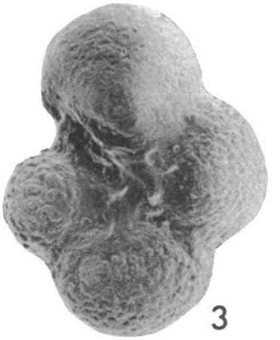
PLATE 20

Figures 1-3	*Globotruncanella petaloidea* (Gandolfi). 1, dorsal view; 2, peripheral view; 3, ventral view, x150. From sample F229, Wabag area, New Guinea. CPC 12162.
Figures 4-6	*Rugoglobigerina hexacamerata* Bronnimann. 4, dorsal view; 5, peripheral view; 6, ventral view, x100. From sample F229, Wabag area, New Guinea. CPC 12164.
Figures 7-9	*Rugoglobigerina macrocephala* Bronnimann. 7, dorsal view; 8, peripheral view; 9, ventral view, x100. From sample F229, Wabag area, New Guinea. CPC 12165.
Figures 10-12	*Rugoglobigerina rugosa* (Plummer). 10, dorsal view; 11, peripheral view; 12, ventral view, x100. From sample F229, Wabag area, New Guinea. CPC 12166.
Figures 13-15	*Rugoglobigerina scotti* (Bronnimann). 13, dorsal view; 14, peripheral view; 15, ventral view, x100. From sample F229, Wabag area, New Guinea. CPC 12167.

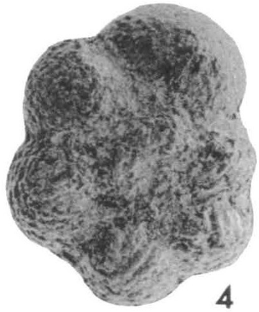
Globotruncanidae

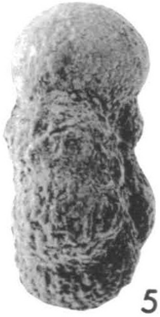

1

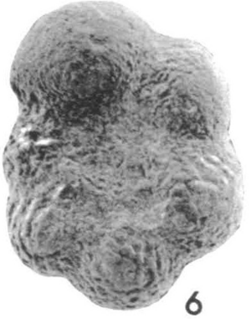

2


3


13


4


5

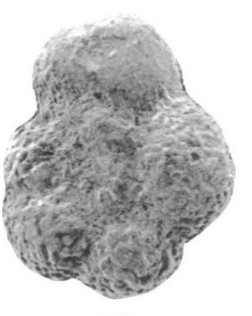

6

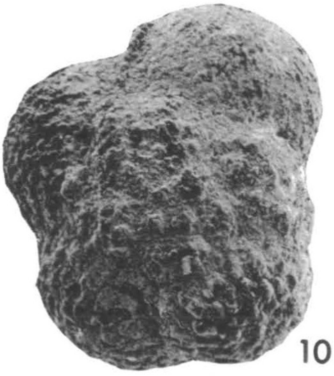

14


7


8


9


15


10


11


12

BIBLIOGRAPHY AND INDEX OF AUSTRALIAN CAMBRIAN TRILOBITES

by J. H. SHERGOLD

INTRODUCTION

This paper is a bibliography and specific index of Australian Cambrian trilobites. The upper limit of the Cambrian is considered to lie at the boundary between the Paytonian and Datsonian Stages, and thus excludes rocks of Tremadocian age equivalence.

The bibliography contains papers in which Australian Cambrian trilobites are mentioned, listed, described, or illustrated in the general body of the Australian geological literature and text books. It excludes references found in treatises, theses, encyclopaedias, and dictionaries. The index of species which follows the bibliography is drawn from the references cited. It is up to date at the time of writing (June 1971) and includes taxa from manuscripts which are presently in press but which should be published within the near future.

Eventually it is hoped to compile a synonymy index for the Cambrian trilobites described from this continent. When completed it will be published as a report or bulletin in conjunction with the bibliography and index presented here.

Neither the bibliography nor the index is considered to be fully comprehensive and it is hoped that papers missed in this survey or subsequently published will be included in supplements appended from time to time.

In the bibliography the following symbols are used:
* denotes papers containing systematic descriptions and illustrations.
† denotes papers with illustrations but lacking descriptions.
In the remainder of the papers trilobites are merely listed or mentioned.

BIBLIOGRAPHY

†ANDERSON, C., 1935—Trilobites. *Aust. Mus. Mag.*, 4(5), 178-9.

BANKS, M. R., 1956—The Middle and Upper Cambrian Series (Dundas Group and its correlatives) in Tasmania. *In* Cambrian Symposium, 2, 165-212. *20th int. geol. Congr., Mexico.*

BANKS, M. R., 1957—As above, *reprinted in* The Cambrian geology of Australia. *Bur. Miner. Resour. Aust. Bull.* 49, 165-212.

BANKS, M. R., 1961—Age and relationship of Tasmanian fossil faunas and floras. *Proc. 9th Pacif. Sci. Congr., Bangkok,* 12.

BANKS, M. R., 1962—Cambrian System. *In* SPRY, A., and BANKS, M. R., The geology of Tasmania. *J. geol. Soc. Aust.,* 9(2), 127-45.

BARNES, T. A., and KLEEMAN, A., 1934—Notes on fossiliferous Cambrian near Kulpara, South Australia. *Trans. Roy. Soc. S. Aust.,* 58, 7-9.

BASEDOW, H., 1909—Beiträge zur Kenntnis der Geologie Australiens. *Z. dtsch. geol. Gesell., Abh.,* 61(3), 306-79.

BLATCHFORD, T., 1927—The geology of portions of the Kimberley Division, with special reference to the Fitzroy Basin and the possibilities of the occurrence of mineral oil. *Geol. Surv. W. Aust. Bull.* 93, 5-56.

BLISSET, A. H., 1962—Geology of the Zeehan Sheet. *Dep. Min. Tas.*

BLISSET, A. H., and GULLINE, A. B., 1961a—Tin mineralization near Mt Razorback, Dundas. *Rep. Dep. Min. Tas.,* 5(1960), 136-54.

BLISSET, A. H., and GULLINE, A. B., 1961b—The Proterozoic-Upper Cambrian succession in west Tasmania. *Aust. J. Sci.,* 337-9.

BRYAN, W. H., and JONES, O. A., 1945—The geological history of Queensland. A stratigraphical outline. *Pap. Univ. Qld Dep. Geol.,* 2(12), iii-vi, 1-103.

BURNS, K. L., 1964—Explanatory report, one-mile geological map K/55-6-29, Davenport. *Dep. Min. Tas.*

CAMPANA, B., 1957—The Mt Lofty-Olary region and Kangaroo Island. *In* GLAESSNER, M. F., and PARKIN, L. (eds)—The geology of South Australia. *J. geol. Soc. Aust.,* 5, 3-28.

CARTER, E. K., and ÖPIK, A. A., 1961—Lawn Hill—4-mile geological series sheet E/54-9. *Bur. Miner. Resour. Aust. explan. Notes* 21.

CARTER, E. K., and ÖPIK, A. A., 1963—Duchess, Qld—4-mile geological series sheet F/54-6. *Bur. Miner. Resour. Aust. explan. Notes* 23.

CASEY, J. N., 1968—Boulia, Qld—1:250 000 geological series sheet SF/54-10. *Bur. Miner. Resour. Aust. explan. Notes.*

CASEY, J. N., and GILBERT-TOMLINSON, Joyce, 1956—The Cambrian geology of the Huckitta-Marqua region, Northern Territory. *In* Cambrian Symposium, 2, 55-74. *20th Sess. int. geol. Congr. Mexico* (reprinted in *Bur. Miner. Resour. Aust. Bull.* 49, 1957).

†CHAPMAN, F., 1908—Preliminary notes on a collection of trilobite remains from Dolodrook River, N. Gippsland. *Proc. Roy. Soc. Vic.,* 21, 268-9, pl. XI.

*CHAPMAN, F., 1911—New or little known Victorian fossils in the National Museum, Pt XIII. On the trilobite fauna of the Upper Cambrian (Olenus Series) in northeastern Gippsland. *Proc. Roy. Soc. Vic.,* 23, 305-24, pls LVIII-LXI.

†CHAPMAN, F., 1914—AUSTRALIAN FOSSILS. A STUDENT'S MANUAL OF PALAEONTOLOGY. 341 pp., 150 figs. *Melbourne, Geo. Robertson & Co.*

CHAPMAN, F., 1917a—Report on Cambrian fossils from Knowsley East, near Heathcote. *Rec. geol. Surv. Vic.,* 4(1), 87-9.

*CHAPMAN, F., 1917b—The Heathcote fauna. *Rec. geol. Surv. Vic.,* 4(1), 89-102, pls VI-VII.

CHAPMAN, F., 1923—Appendix 1 *in* HOWITT, A. M.—Report on fossils from an Upper Cambrian horizon at Loyola, near Mansfield. *Bull. geol. Surv. Vic.,* 46, 34-44.

CHAPMAN, F., 1924a—On the age and contents of limestone specimens from the Negri Series, Kimberley division. *Progr. Rep. geol. Surv. W. Aust.,* 1923, 31.

CHAPMAN, F., 1924b—Appendix A. *in* WADE, A.—Petroleum prospects: Kimberley district of Western Australia and Northern Territory. *Northern Territory of S. Aust. parl. Pap.,* 142, 5-63.

CHAPMAN, F., 1929—On some trilobites and brachiopods from the Mt Isa district, northwestern Queensland. *Proc. Roy. Soc. Vic.,* 41, 206-16, pls XXI-XXII.

CLARKE, E. DE C., PRIDER, R. T., and TEICHERT, C., 1944—ELEMENTS OF GEOLOGY FOR WESTERN AUSTRALIAN STUDENTS, 3rd edn. *Nedlands, Univ. W. Aust. Press.*

CLARKE, M. J., 1966a—Trilobites from the north bank of the Que River, Murchison Highway. *Dep. Min. Tas. tech. Rep.* 12(1967), 146.

CLARKE, M. J., 1968b—Cambrian and Ordovician fossils from the Macquarie Harbour area. *Dep. Min. Tas. tech. Rep.* 12(1967), 146-9.

CRESPIN, Irene, 1954—Catalogue of type and figured specimens in the Commonwealth Palaeontological Collection, Canberra. *Bur. Miner. Resour. Aust. Rep.* 54, 7-92.

DAILY, B., 1956—The Cambrian of South Australia. *In* Cambrian Symposium, 2, 91-147. *20th Sess. int. geol. Congr., Mexico.*

DAILY, B., 1957—As above, *reprinted in* The Cambrian geology of Australia. *Bur. Miner. Resour. Aust. Bull.* 49, 91-147.

DAILY, B., 1966—Appendix 3, Palaeontology *in* HARRIS, W. K., and DAILY, B., Delhi-Santos Gidgealpa No. 1 Well South Australia. *Bur. Miner. Resour. Aust., Petrol. Search Subs. Acts Publ.* 73, 87-111.

DAVID, T. W. E., 1914—The geology of the Commonwealth. Ch. 7 *in* Commonwealth of Australia, Federal Handbook (KNIBBS, G. H., ed.). *84th Sess. Brit. Assoc. Adv. Sci.,* 241-325.

DAVID, T. W. E., 1927—Notes on the geological horizons of Archaeocyathinae. *Trans. Roy. Soc. S. Aust.,* 51, 410-3.

DAVID, T. W. E., 1932—Explanatory notes to accompany a new geological map of the Commonwealth of Australia. *Coun. sci. ind. Res. Aust., Sydney. Edward Arnold & Co.*

†DAVID, T. W. E., and BROWNE, W. R., 1950—THE GEOLOGY OF THE COMMONWEALTH OF AUSTRALIA. *Vol.* 1. *London, Arnold.*

†DAVID, T. W. E., and TILLYARD, R. J., 1936—MEMOIR ON FOSSILS OF THE LATER PRE-CAMBRIAN (NEWER PROTEROZOIC) FROM THE ADELAIDE SERIES, S. AUSTRALIA. *Angus & Robertson and Roy. Soc. N.S.W.*

DAVIDSON, A. A., 1905—Journal of exploration in central Australia by the Central Australian Exploration Syndicate Ltd. *S. Aust. parl. Pap.,* 27, 1-76.

DUN, W. S., 1914—Notes on the palaeontology of Australia. Sec. 7 *in* DAVID, T. W. E., Geology of the Commonwealth. Ch. 7 *in* Commonwealth of Australia, Federal Handbook (KNIBBS, G. H., ed.). *84th Sess. Brit. Assoc. Adv. Sci.,* 291-7.

ELLISTON, J., 1954—The geology of the Dundas district, Tasmania. *Proc. Roy. Soc. Tas.,* 88, 161-84.

*ETHERIDGE, R., JNR, 1890—see FOORD, A. H., 1890.

*ETHERIDGE, R., JNR, 1896a—Official contributions to the palaeontology of South Australia. No. 9—On the occurrence of *Olenellus* in the Northern Territory. *S. Aust. parl. Pap.* (1896), 13-16, pl. 1.

*ETHERIDGE, R., JNR, 1896b—Evidence of the existence of a Cambrian fauna in Victoria. *Proc. Roy. Soc. Vic.,* 8, 52-64, pl. 1.

*ETHERIDGE, R., JNR, 1898—A further Cambrian trilobite from Yorke Peninsula. *Trans. Proc. Roy. Soc. S. Aust.,* 22, 1-3, pl. IV.

*ETHERIDGE, R., JNR, 1902—Official contributions to the palaeontology of South Australia. No. 12—Evidence of further Cambrian trilobites. *S. Aust. parl. Pap.* (1902), 3-4, pl. II.

*ETHERIDGE, R., JNR, 1905—Additions to the Cambrian fauna of South Australia. *Trans. Proc. Roy. Soc. S. Aust.,* 29, 246-51, pl. XXV.

ETHERIDGE, R., JNR, 1906—Cambrian limestone on the Daly River, Northern Territory. *S. Aust. parl. Pap.,* 55, 42, pl. 1.

*ETHERIDGE, R., JNR., 1919—The Cambrian trilobites of Australia and Tasmania. *Trans. Proc. Roy. Soc. S. Aust.,* 43, 373-93, pls XXXIX-XL.

FAIRBRIDGE, R. W., 1953—AUSTRALIAN STRATIGRAPHY, 2nd edn, Part II, Cambrian, 1-26. *Univ. W. Aust.*

FERGUSON, W. H., 1899—Report on an area of Cambrian rocks at Heathcote. *Geol. Surv. Vic. Monthly progr. Rep.,* 2, 23-5, pl. 1.

FLETCHER, A. W., 1890—Exhibited Cambrian fossils from Curramulka and Ardrossan. *Trans. Proc. Roy. Soc. S. Aust.,* 13, 249.

†FLETCHER, H. O., 1935—Trilobite hunting in the north. *Mag. Aust. Mus.,* 5(9), 305-12.

FLETCHER, H. O., 1964—New linguloid shells from Lower Ordovician and middle Palaeozoic rocks of New South Wales. *Rec. Aust. Mus.*, 26(10), 283-294, pls 31-32.

*FOORD, A. H., 1890—Notes on the palaeontology of Western Australia. *Geol. Mag.* (n.s.) dec. III, 3, 97-106, pls 4-5.

GATEHOUSE, C. G., 1964—Early Upper Cambrian fossils from the Comet Slate at Dundas, Tasmania. *Dep. Min. Tas. Tech. Rep.* 8(1963), 50-51.

*GATEHOUSE, C. G., 1968—Early Middle Cambrian trilobites of the Litchfield area, N.T. *Bur. Miner. Resour. Aust. Bull.* 80, 45-64, pls 5-7.

GEE, C. E., JAGO, J. B., and QUILTY, P. G., 1970—The age of the Mt Read Volcanics in the Que River Area, western Tasmania. *J. geol. Soc. Aust.*, 16(2), 761-3.

GLAESSNER, M. F., 1955—*in* SPRIGG, R. C., The Point Marsden Cambrian Beds, Kangaroo Island, South Australia. *Trans. Roy. Soc. S. Aust.*, 78, 165-8.

GLAESSNER, M. F., 1958—Oldest fossil faunas in South Australia. *Geol. Rdsch.*, 47(2), 522-31.

GLAESSNER, M. F., and PARKIN, L. (eds), 1957—Geology of South Australia. *J. geol. Soc. Aust.*, 5(2).

GLAUERT, L., 1910—A list of Western Australian fossils (systematically arranged). *Geol. Surv. W. Aust. Bull.* 36, 71-106.

GLAUERT, L., 1912—Determination of the exact localities where Cambrian fossils were collected by E. T. Hardman in 1884. *Rec. W. Aust. Mus. Art Gallery,* 1(2), 66-74.

GLAUERT, L., 1926—A list of Western Australian fossils. Supplement No. 1. *Geol. Surv. W. Aust. Bull.* 88, 36-72.

GREEN, D. H., 1959—Geology of the Beaconsfield district, including the Anderson's Creek Ultrabasic complex. *Rec. Queen Vic. Mus., Launceston* (n.s.), 10, 1-25.

*GREGORY, J. W., 1903—The Heathcotian—a pre-Ordovician Series—and its distribution. *Proc. Roy. Soc. Vic.*, 15, 148-75, pls XXIII-XXVI.

GREGORY, J. W., 1907—STANFORD'S COMPENDIUM OF GEOGRAPHY AND TRAVEL (new issue). AUSTRALASIA. VOL. 1. AUSTRALIA AND NEW ZEALAND (2nd edn). *London, Edward Stanford.*

HARRIS, W. J., and THOMAS, D. E., 1954—Notes on the geology of the Wellington-Macalister area. *Min. geol. J., Dep. Min. Vic.*, 5(3), 34-49.

HENDERSON, R. A., and SHERGOLD, J. H. (in press)—*Cyclocystoides* from early Middle Cambrian rocks of northwestern Queensland, Australia. *Palaeontology,* 14(4), 704-10.

HILL, D., and DENMEAD, A. K. (eds), 1960—The geology of Queensland. *J. geol. Soc. Aust.*, 7.

HORWITZ, R., and DAILY, B., 1957—Yorke Peninsula; *in* GLAESSNER, M. F., and PARKIN, L. (eds). Geology of South Australia. *J. geol. Soc. Aust.*, 5(2), 46-60.

HOWCHIN, W., 1904—The geology of the Mt Lofty Ranges, Pt I. The coastal district. *Trans. Roy. Soc. S. Aust.*, 28, 253-80, pls 37-44.

HOWCHIN, W., 1907—A general description of the Cambrian Series of South Australia. *Rep. Aust. Assoc. Adv. Sci., Adelaide,* 11, 414-22.

†HOWCHIN, W., 1918—THE GEOLOGY OF SOUTH AUSTRALIA. *Adelaide, Education Department.*

HOWCHIN, W., 1920—Note on the generic position of certain Australian Cambrian trilobites. *Trans. Roy. Soc. S. Aust.*, 44, 382.

†HOWCHIN, W., 1929—THE GEOLOGY OF SOUTH AUSTRALIA, WITH NOTES ON THE CHIEF GEOLOGICAL SYSTEMS AND OCCURRENCES IN THE OTHER AUSTRALIAN STATES. 2nd edn. *Adelaide, Walter Howchin.*

HOWITT, A. M., 1923—The Mansfield phosphate deposits. *Geol. Surv. Vic. Bull.* 46, 1-46, pls I-XIV.

†HUPE, P., 1952—Contribution à l'étude du Cambrien inférieur et du Précambrien III de l'Anti-Atlas carocain. *Serv. geol. Maroc. Mém.* 103, 5-402, pls 1-24.

IVANAC, J. F., 1954—The geology and mineral deposits of the Tennant Creek goldfield, Northern Territory. *Bur. Miner. Resour. Aust. Bull.* 22, 8-164.

JAGO, J. B., and BUCKLEY, J. H., 1971—An abrupt upper Middle Cambrian faunal change, Christmas Hills, Tasmania, Australia. *Pap. Proc. Roy. Soc. Tas.*, 105, 83-5.

JELL, P. A., 1970—*Pagetia ocellata,* a new Cambrian trilobite from northwestern Queensland. *Mem. Qld Mus.,* 15(4), 303-13, pls 23-24.

JENSEN, H. I., 1915—Report on the geology of the country between Pine Creek and Tanami. *Bull. N. Terr. Aust.,* 14, 5-19.

JOKLIK, G. F., 1955—The geology of the mica fields of the Harts Range, central Australia. *Bur. Miner. Resour. Aust. Bull.* 26, 13-226.

JONES, P. J., SHERGOLD, J. H., and DRUCE, E. C., 1971—Late Cambrian and early Ordovician stages in western Queensland. *J. geol. Soc. Aust.,* 18(1), 1-32.

KAULBACK, J. A., and VEEVERS, J. J., 1969—Cambrian and Ordovician geology of the southern part of the Bonaparte Gulf Basin, Western Australia. *Bur. Miner. Resour. Aust. Rep.* 109, 1-80.

KING, W. B. R., 1941—The Cambrian fauna of the Salt Range of India. *Rec. geol. Surv. India,* 75, *prof. Pap.* 9 (for 1940), 1-15, pls 1-5.

KOBAYASHI, T., 1934—Middle Cambrian fossils from Kashmir. *Amer. J. Sci.,* 28, 295-304.

*KOBAYASHI, T., 1935—Cambro-Ordovician formations and faunas of South Chosen. Palaeontology, Pt 3—Cambrian faunas of South Chosen. *J. Fac. Sci. imp. Univ. Tokyo,* 2, 4(2), 49-344.

KOBAYASHI, T., 1939a—On the Agnostids, part 1. *J. Fac. Sci. imp. Univ. Tokyo* 2, 5(5), 69-198.

KOBAYASHI, T., 1939b—Supplementary notes on the Agnostida. *J. geol. Soc. Japan,* 46, 97-100.

KOBAYASHI, T., 1942a—On the Dolichometopinae. *J. Fac. Sci. imp. Univ. Tokyo,* 2, 6(10), 141-206.

KOBAYASHI, T., 1942b—Cambrian faunas in South Australia with a brief note on the history of the Nullagine Basin. *Proc. imp. Acad. Tokyo,* 18(8), 484-91.

KOBAYASHI, T., 1942c—Two Cambrian trilobites from the Parara Limestone in Yorke's Peninsula, South Australia. *Proc. imp. Acad. Tokyo,* 18(8), 492-8.

KOBAYASHI, T., 1943a—Brief notes on the Eodiscids. I, their classification with a description of a new species and a new variety. *Proc. imp. Acad. Tokyo,* 19, 37-42, figs 1-5.

KOBAYASHI, T., 1943b—Brief notes on the Eodiscids. II, phylogeny of the Dawsonidea. *Proc. imp. Acad. Tokyo,* 19, 43-7, figs 1-17.

KOBAYASHI, T., 1944a—Miscellaneous notes on the Cambro-Ordovician geology and palaeontology. No. 15, The Cambrian formation in the middle Yangtze Valley and some of the trilobites contained therein. *Jap. J. Geol. Geogr.,* 19, 89-105, pl. VIII.

*KOBAYASHI, T., 1944b—Miscellaneous notes on the Cambro-Ordovician geology and palaeontology. No. 16, On the Cambrian formations in Yunnan and Haut-Tonkin and the trilobites contained. *Jap. J. Geol. Geogr.,* 19, 107-38, pls IX-X.

*KOBAYASHI, T., 1944c—On the Eodiscids. *J. Fac. Sci. imp. Univ. Tokyo,* 2, 7(1), 1-74.

*KOBAYASHI, T, 1949—The *Glyptagnostus* hemera, the oldest world-instant. *Jap. J. Geol.* Geogr., 2(1), 1-6, pl. 1.

KOBAYASHI, T., 1951—Discovery of *Proceratopyge* in the *Chuangia* Zone in Manchuria, with a note on the Ceratopygidae. *Trans. Proc. paleont. Soc. Japan* (n.s.), 19, 65-72, pl. II.

KOBAYASHI, T., 1957—Upper Cambrian fossils from Peninsular Thailand. *J. Fac. Sci. Univ. Tokyo,* 2, 10(30), 367-82, pls IV-V.

KOBAYASHI, T., 1962—The Cambro-Ordovician formations and faunas of South Korea, Part IX. Palaeontology VIII. The Machari fauna. *J. Fac. Sci. Univ. Tokyo,* 2, 14(1), 1-152, pls I-XII.

KOBAYASHI, T., 1967—The Cambrian of eastern Asia and other parts of the continent. The Cambro-Ordovician formations and faunas of South Korea, part X, section C. *J. Fac. Sci. Univ. Tokyo,* 2, 16(3), 381-534.

LASERON, C., 1969—ANCIENT AUSTRALIA: THE STORY OF ITS PAST GEOGRAPHY AND LIFE (revised by BRUNNSCHWEILER, R. O.). Revised edn. *Sydney, Angus & Robertson.*

LAZARENKO, N. P., 1962—New Lower Cambrian trilobites from the Soviet Arctic. *Sborn. Stat. Paleont. Biostrat.,* 29, 29-78, pls 1-8. *Nauchno-issled. Inst. Geol. Arktik.*

LORMONTOVA, E. V., 1951—Lower Cambrian trilobites and brachiopods from Eastern Siberia. *Vsesoiuz. Nauchno-issled. geol. Inst. (VSEGEI)*, 1-218, pls 1-21.

LUDBROOK, N. H., and JOHNS, R. K., 1970—Geology of South Australia. *In* South Australian Yearbook, 1970. *Dep. Min. S. Aust.*

MCWHAE, J. R. H., PLAYFORD, P. E., LINDNER, A. W., GLENISTER, B. F., and BALME, B. E., 1958—The stratigraphy of Western Australia. *J. geol. Soc. Aust.*, 4(2), 1-161.

MADIGAN, C. T., 1932—The geology of the eastern MacDonnell Ranges. *Trans. Roy. Soc. S. Aust.*, 56, 71-117, pls 3-5.

MAITLAND, A. G., 1907a—Recent advances in the knowledge of the geology of Western Australia. *Presidential Address, Aust. Assoc. Adv. Sci.*, 11, 131-57.

MAITLAND, A. G., 1907b—Recent advances in the knowledge of the geology of Western Australia. *Geol. Surv. W. Aust. Bull.* 26, 37-66.

MAITLAND, A. G., 1915—Geology of Western Australia. *Geol. Surv. W. Aust. Bull.* 64(8), 79-91.

MAITLAND, A. G., 1919—A summary of the geology of Western Australia. *Geol. Surv. W. Aust. Mem.* 1, 1-55.

MAITLAND, A. G., and MONTGOMERY, A., 1912—The geology and mineral industry of Western Australia. *Geol. Surv. W. Aust. Bull.* 50, 3-68.

MAITLAND, A. G., and MONTGOMERY, A., 1924—The geology and mineral resources of Western Australia. *Geol. Surv. W. Aust. Bull.* 89, 1-119.

MALONE, E. J., 1962—Pine Creek, N.T.—1:250 000 geological series sheet D/52-8. *Bur. Miner. Resour. Aust. explan. Notes.*

MATHESON, R. S., and TEICHERT, C., 1948—Geological reconnaissance in the eastern portion of the Kimberley Division, Western Australia, between latitudes 15°30'S and 18°S, and longitudes 128°15' and 129°E. *Dep. Min. W. Aust. Rep.* (1945), 73-87, pls IX-XII.

MAWSON, D., 1939—The Cambrian sequence in the Wirrealpa Basin. *Trans. Roy. Soc. S. Aust.*, 63(2), 331-47.

*MITCHELL, J., 1922—Descriptions of two new trilobites, and notes on *Griffithides convexicaudatus* Mitchell. *Proc. Linn. Soc. N.S.W.*, 47(4), 535-40.

NOAKES, L. C., 1951—Urandangi—4-mile geological series sheet F/54-5. *Bur. Miner. Resour. Aust. explan. Notes* 1.

NOAKES, L. C., CARTER, E. K., and ÖPIK, A. A., 1959—Urandangi—4-mile geological series sheet F/54-5. 2nd edn. *Bur. Miner. Resour. Aust. explan. Notes* 1.

*ÖPIK, A. A., 1949—A Middle Cambrian trilobite from Victoria—*Centropleura neglecta* n. sp. *Min. geol. J. Dep. Min. Vic.*, 3(5), 55-8, pl. 1.

ÖPIK, A. A., 1952—The hypostoma of *Pagetia*. *J. Paleont.*, 26(2), 272-4.

ÖPIK, A. A., 1954—see IVANAC, J. F.

ÖPIK, A. A., 1956a—Cambrian geology of Queensland. *In* Cambrian Symposium, 2, 1-24. *20th Sess. int. geol. Congr., Mexico.*

ÖPIK, A. A., 1956b—Cambrian geology on the Northern Territory. *In* Cambrian Symposium, 2, 25-54. *20th Sess. int. geol. Congr., Mexico.*

ÖPIK, A. A., 1956c—Cambrian palaeogeography of Australia. *In* Cambrian Symposium, 2, 239-84. *20th Sess. int. geol. Congr., Mexico.*

ÖPIK, A. A., 1957a,b,c—Papers as above *reprinted in* Cambrian geology of Australia. *Bur. Miner. Resour. Aust. Bull.* 49, 1-24, 25-54, 239-84.

†ÖPIK, A. A., 1958a—The Middle Cambrian trilobite *Centropleura* in Queensland. *Nature* 182, 204, fig. 1. July 19th.

*ÖPIK, A. A., 1958b—The Cambrian trilobite *Redlichia*: organization and generic concept. *Bur. Miner. Resour. Aust. Bull.* 42, 5-38.

ÖPIK, A. A., 1960—Cambrian and Ordovician geology. *In* HILL, D., and DENMEAD, A. K. (eds), The geology of Queensland. *J. geol. Soc. Aust.*, 7, 89-109.

*ÖPIK, A. A., 1961a—Alimentary caeca of Agnostids and other trilobites. *Palaeontology*, 3(4), 410-438, pls 68-70.

*Öpik, A. A., 1961b—The geology and palaeontology of the headwaters of the Burke River, Queensland. *Bur. Miner. Resour. Aust. Bull.* 53, 5-249, pls 1-24.

*Öpik, A. A., 1963a—*Nepea* and the Nepeids (Trilobites, Middle Cambrian, Australia). *J. geol. Soc. Aust.*, 10(2), 313-6.

*Öpik, A. A., 1963b—Early Upper Cambrian fossils from Queensland. *Bur. Miner. Resour. Aust. Bull.* 64, 5-133, pls 1-9.

Öpik, A. A., 1966—The early Upper Cambrian crisis and its correlation. Clarke Memorial Lecture for 1965. *J. Proc. Roy. Soc. N.S.W.*, 100, 9-14.

*Öpik, A. A., 1967a—The Mindyallan fauna of northwestern Queensland. *Bur. Miner. Resour. Aust. Bull.* 74, vols 1-2.

*Öpik, A. A., 1967b—The Ordian Stage of the Cambrian and its Australian Metadoxididae. *Bur. Miner. Resour. Aust. Bull.* 92, 133-170, pls 19-20.

Öpik, A. A., 1968—Ordian (Cambrian) Crustacea Bradoriida of Australia. *Bur. Miner. Resour. Aust. Bull.* 103, 1-44, pls 1-4.

Öpik, A. A., 1969—Appendix 3, The Cambrian and Ordovician sequence, Cambridge Gulf; *in* Kaulback, J. A., and Veevers, J. J., Cambrian and Ordovician geology of the southern part of the Bonaparte Gulf Basin, Western Australia. *Bur. Miner. Resour. Aust. Rep.* 109, 74-77.

*Opik, A. A., 1970—Nepeid trilobites of the Middle Cambrian of northern Australia. *Bur. Miner. Resour. Aust. Bull.* 113, 1-48, 17 pls.

*Öpik, A. A., 1971—*Redlichia* of the Ordian (Cambrian) of northern Australia and New South Wales. *Bur. Miner. Resour. Aust. Bull.* 114, 1-39, 14 pls.

Öpik, A. A., Carter, E. K., and Noakes, L. C., 1961—Mount Isa—4-mile geological series sheet F/54-1. *Bur. Miner. Resour. Aust. explan. Notes* 20.

Palmer, A. R., 1962—*Glyptagnostus* and associated trilobites in the United States. *U.S. geol. Surv. prof. Pap.* 374F, 1-49, pls 1-6.

Palmer, A. R., 1968—Cambrian trilobites from east-central Alaska. *U.S. geol. Surv. prof. Pap.* 559B, 1-115, pls 1-15.

Pocock, K. J., 1964—*Estaingia,* a new trilobite genus from the Lower Cambrian of South Australia. *Palaeontology,* 7(3), 458-71, pls 75-76.

*Pocock, K. J., 1970—The Emuellidae, a new family of trilobites from the Lower Cambrian of South Australia. *Palaeontology,* 13(4), 522-62, pls 106-110.

Pokrovskaya, N. V., 1959—Trilobite faunas and stratigraphy of Cambrian deposits of Tuva. *Tr. Inst. Geol. Nauk, Akad. Nauk SSSR,* 27, 1-200, pls 1-11.

Pokrovskaya, N. V., 1961—Regarding the stage divisions of the Cambrian. *In* Cambrian Symposium, 3, 256-74. *20th int. geol. Congr., Mexico* (available only in USSR).

Poletaeva, O. K., and Romanenko, E. V., 1970—Some trilobites from the Middle and Late Cambrian of the Altay. *Paleont. Zh.*, 1970(2), 72-83, pls 10-11.

Poulsen, V., 1964—Contributions to the Lower and Middle Cambrian palaeontology and stratigraphy of northwest Greenland. *Medd. Grønld,* 164(6), 1-105, pls 1-3.

Pritchard, G. B., 1892—On the Cambrian rocks at Curramulka. *Trans. Proc. Roy. Soc. S. Aust.* (1891-92), 15, 179-82.

Randal, M. A., 1962—Fergusson River, N.T.—1:250 000 geological series sheet D/52-12. *Bur. Miner. Resour. Aust. explan. Notes.*

Randal, M. A., 1963—Katherine, N.T.—1:250 000 geological series sheet SD/53-9. *Bur. Miner. Resour. Aust. explan. Notes.*

Randal, M. A., 1966a—Avon Downs, N.T.—1:250 000 geological series sheet SE/53-4. *Bur. Miner. Resour. Aust. explan. Notes.*

Randal, M. A., 1966b—Ranken, N.T.—1:250 000 geological series sheet SE/53-16. *Bur. Miner. Resour. Aust. explan. Notes.*

Rasetti, F., 1948—Cephalic sutures in *Loganopeltoides* and the origin of the 'hypoparian' trilobites. *J. Paleont.*, 22(1), 25-9, pl. 7.

Reed, F. R. C., 1949—THE GEOLOGY OF THE BRITISH EMPIRE. 2nd edn. *London, Arnold.*

REPINA, L. N., 1966—Lower Cambrian trilobites from southern Siberia (superfamily Redlichioidea). Part 1. *Akad Nauk SSSR, Sib. otdel., Tr. Inst. Geol. Geofyz.*, 1-204, pls 1-27.

REPINA, L. N., 1969—Lower and Middle Cambrian trilobites from southern Siberia (superfamily Redlichioidea). Part 2. *Akad. Nauk SSSR, Sib. otdel., Tr. Inst. Geol. Geofyz.*, 67, 1-108, pls 1-4.

REYNOLDS, M. A., 1965—Glenormiston, Qld—1:250 000 geological series sheet SF/54-9. *Bur. Miner. Resour. Aust. explan. Notes.*

ROZANOV, A. Yu., 1967—The Cambrian lower boundary problem. *Geol. Mag.*, 104(5), 415-34.

ROZANOV, A. Yu., and MISSARZHEVSKII, V. V., 1966—Biostratigraphy and fauna of Lower Cambrian horizons. *Akad. Nauk SSSR, geol. Inst.*, 148, 1-126, pls 1-12.

SAINT-SMITH, E. C., 1924—Note on the occurrence of Cambrian strata near Mt Isa, north west Queensland. *Qld Govt Min. J.*, 25, 411.

SCHINDEWOLF, O. H., 1955—Über Hypostom und Gesichtnaht bei *Redlichia* (Trilob.). *Neues Jb. Geol.*, 3, 130-6.

SCHINDEWOLF, O. H., and SEILACHER, A., 1955—Beiträge zur Kenntnis des Kambriums in der Salt Range (Pakistan). *Akad. Wiss. Lit. Abh. math.-naturwiss. Kl.*, 1955(10), 261-446, pls I-XXXIII.

*SHERGOLD, J. H., 1969—Oryctocephalidae (Trilobita: Middle Cambrian) of Australia. *Bur. Miner. Resour. Aust. Bull.* 104.

SHERGOLD, J. H., 1971—Résumé of data on the base of the Ordovician in northern and central Australia. Colloque ordovicien-silurien, Brest, September 1971. *Mém Bur. Recherches géol. min.*, 73, 391-402.

*SHERGOLD, J. H., 1972—Late Cambrian trilobites from the Gola Beds, western Queensland. *Bur. Miner. Resour. Aust. Bull.* 112.

*SHERGOLD, J. H., 1973—A new conocoryphid trilobite from the Middle Cambrian of western Queensland. *Bur. Miner. Resour. Aust. Bull.* 126.

SKEATS, E. W., 1908—On the evidence of the origin, age, and alteration of the rocks near Heathcote, Victoria. *Proc. Roy. Soc. Vic.*, 21, 302-48, pls 14-18.

SMITH, K. G., 1963—Huckitta, N.T.—1:250 000 geological series sheet SF/53-11. *Bur. Miner. Resour. Aust. explan. Notes.*

SMITH, K. G., 1964a—Progress report on the geology of the Huckitta 1:250 000 sheet, Northern Territory. *Bur. Miner. Resour. Aust. Rep.* 67, 1-76, pls 1-4.

SMITH, K. G., 1964b—Frew River, N.T.—1:250 000 geological series sheet, SF/53-3. *Bur. Miner. Resour. Aust. explan. Notes.*

SMITH, K. G., 1967—Stratigraphic drilling in the Georgina Basin, Northern Territory. *Bur. Miner. Resour. Aust. Rep.* 124, 1-64.

SMITH, K. G., 1972—Geology of the Georgina Basin. *Bur. Miner. Resour. Aust. Bull.* 111.

SMITH, K. G., and ROBERTS, H. G., 1963—Mt Drummond, N.T.—1:250 000 geological series sheet E/53-12. *Bur. Miner. Resour. Aust. explan. Notes.*

SPRIGG, R. C., 1955—The Point Marsden Cambrian beds, Kangaroo Island, S.A. *Trans. Roy. Soc. S. Aust.*, 78, 165-8.

SPRY, A., and BANKS, M. R., 1962—The geology of Tasmania. *J. geol. Soc. Aust.*, 9(2), 1-362.

STUBBLEFIELD, C. J., 1942—Specimens of the trilobite *Redlichia* from the Cambrian of Western Australia. *Proc. Geol. Assoc.*, 53, 107.

SUSSMILCH, C. A., 1911—AN INTRODUCTION TO THE GEOLOGY OF NEW SOUTH WALES. *Sydney, Govt Printer.*

SUVOROVA, N., 1964—Corynexochid trilobites and their historical development. *Tr. Paleont. Inst. Akad. Nauk SSSR*, 103, 3-319, pls 1-31.

*TATE, R., 1892—The Cambrian fossils of South Australia. *Trans. Proc. Roy. Soc. S. Aust.*, 15, 183-9, pl. II.

TCHERNYSHEVA, N. E., 1961—Cambrian stratigraphy of the Aldan anticline and palaeontological reasoning for the establishment of the Amgan Stage. *Tr. Vsesoiu. Nauchno-issled. Geol. Inst.*, 49, 1-347, pls I-XXX.

TEALE, E. O., 1920—A contribution to the Palaeozoic geology of Victoria, with special reference to the districts of Mount Wellington and Nowa Nowa respectively. *Proc. Roy. Soc. Vic.*, 32(2), 67-146, pls VIII-IX.

TEICHERT, C., 1946—Stratigraphy of Western Australia. *J. Proc. Roy. Soc. N.S.W.*, 80(3), 81-142, pls 4-7.

TEICHERT, C., 1947—Stratigraphy of Western Australia. *Bull. Amer. Assoc. Petrol. Geol.*, 31(1), 1-70.

TEICHERT, C., 1950—Some recent additions to the stratigraphy of Western Australia. *Bull. Amer. Assoc. Petrol. Geol.*, 34(9), 1787-1794.

†TERMIER, H., and TERMIER, G., 1964—LES TEMPS FOSSILIFERES. 1. PALEOZOIQUE INFERIEUR. *Paris, Masson.*

THOMAS, D. E., 1935—Cambrian *in* SKEATS, E. W. (ed.), Handbook for Victoria. *Aust. N.Z. Assoc. Adv. Sci.*, 91-95.

THOMAS, D. E., and SINGLETON, O. P., 1956—The Cambrian stratigraphy of Victoria. *In* Cambrian Symposium, 2, 149-63. *20th Sess. int. geol. Congr., Mexico.*

THOMAS, D. E., and SINGLETON, O. P., 1957—As above *reprinted in* Cambrian geology of Australia. *Bur. Miner. Resour. Aust. Bull.* 49, 149-63.

†TILLYARD, R. J., 1936—Tracing the dawn of life further backwards. Cawthron Lecture (1935). *Cawthron Inst., N.Z.*

TRAVES, D. M., 1955—The geology of the Ord-Victoria region, northern Australia. *Bur. Miner. Resour. Aust. Bull.* 27, 1-133.

TRAVES, D. M., 1956—Upper Proterozoic and Cambrian geology in northwestern Australia. *In* Cambrian Symposium, 2, 75-90. *20th Sess. int. geol. Congr., Mexico.*

TRAVES, D. M., 1957—As above, *reprinted in* The Cambrian geology of Australia. *Bur. Miner. Resour. Aust. Bull.* 49, 75-90.

WALCOTT, C. D., 1905—Cambrian faunas of China. *Proc. U.S. nat. Mus.*, 29, 1-106.

WALCOTT, C. D., 1913—The Cambrian faunas of China. *Carnegie Inst. Washington Publ.* 54, 1-276.

WALCOTT, C. D., 1914—Cambrian geology and palaeontology III. No. 1—Cambrian faunas of eastern Asia. *Smithsonian misc. Coll.*, 64(1), 1-75, pls 1-3.

WALCOTT, C. D., 1916—Cambrian geology and palaeontology III. No. 5—Cambrian trilobites. *Smithsonian misc. Coll.*, 64(5), 303-456, pls 45-67.

WALPOLE, B. P., 1958—The Maranboy tin-field, Northern Territory. *Bur. Miner. Resour. Aust. Bull.* 37, 1-40.

WALPOLE, B. P., CROHN, P. W., DUNN, P. R., and RANDAL, M. A., 1968—Geology of the Katherine-Darwin region, Northern Territory. *Bur. Miner. Resour. Aust. Bull.* 82, vols 1-2.

WALTER, M. R., 1967—Archaeocyatha and the biostratigraphy of the Lower Cambrian Hawker Group, South Australia. *J. geol. Soc. Aust.*, 14(1), 139-152, pls 7-8.

WARNER, R. A., and HARRISON, J., 1961—Discovery of Middle Cambrian fossils in New South Wales. *Aust. J. Sci.*, 23(8), 268.

WELLS, A. T., RANFORD, L. C., STEWART, A. J., COOK, P. J., and SHAW, R. D., 1967—Geology of the northeastern part of the Amadeus Basin, Northern Territory. *Bur. Miner. Resour. Aust. Rep.* 113, 1-93.

WESTERGAARD, A. H., 1946—Agnostidae of the Middle Cambrian of Sweden. *Sver. geol. Unders. Avh.*, ser. C, 477, 1-140, pls 1-16.

WESTERGAARD, A. H., 1947—Supplementary notes on the Upper Cambrian trilobites of Sweden. *Sver. geol. Unders. Avh., ser. C*, 489, 3-34, pls 1-3.

WHITEHOUSE, F. W., 1928—Notes accompanying an exhibit of fossils. *Proc. Roy. Soc. Qld* (1927), 39, vii-viii.

WHITEHOUSE, F. W., 1930—The geology of Queensland. *In* Handbook for Queensland. *Aust. Assoc. Adv. Sci., Brisbane,* 23-9.

WHITEHOUSE, F. W., 1931—Report of the Palaeontologist. *Ann. Rep. Dep. Min. Qld* (1930), 1-142.

*WHITEHOUSE, F. W., 1936—The Cambrian faunas of northeastern Australia. Part 1—Stratigraphical outline. Part 2—Trilobita (Miomera). *Mem. Qld Mus.*, 11(1), 59-112, pls VIII-X.

*WHITEHOUSE, F. W., 1939—The Cambrian faunas of northeastern Australia. Part 3—The Polymerid trilobites (with supplement no. 1). *Mem. Qld Mus.*, 21(3), 179-282, pls 19-25.

WHITEHOUSE, F. W., 1940—Studies in the late geological history of Queensland. 2. Late Tertiary Limestones in Queensland and their significance. *Pap. Univ. Qld Dep. Geol.*, 1, 23-40.

WHITEHOUSE, F. W., 1941—The Cambrian faunas of northeastern Australia. Part 4—Early Cambrian echinoderms similar to the larval forms of Recent forms. *Mem. Qld Mus.*, 12(1), 1-28, pls 1-4.

*WHITEHOUSE, F. W., 1945—The Cambrian faunas of northeastern Australia. Part 5—The trilobite genus *Dorypyge*. *Mem. Qld Mus.*, 12, 117-23, pl. XI.

*WOODWARD, H., 1884—Notes on the remains of trilobites from South Australia. *Geol. Mag.*, dec. 3, 1, 342-344, pl. XI.

WOPFNER, H., 1970—Early Cambrian palaeogeography, Frome embayment, South Australia. *Bull. Amer. Assoc. Petrol. Geol.*, 54(12), 2395-409.

LIST OF NAMED TRILOBITE SPECIES ALPHABETICALLY ARRANGED WITH THEIR MOST RECENT GENERIC ASSIGNMENT

abundans Öpik, 1967, *Cermataspis*
accuminatus Whitehouse, 1936, *Solenagnostus* (=*Ptychagnostus cassis* Öpik 1961 *in pars*)
acrolebes Shergold, 1972, *Geragnostus* (*Micragnostus*)
aculeatus (Angelin, 1851) *Ptychagnostus*
acutangulus Angelin, 1851, *Acontheus*
adjusta Öpik, 1967, *Onaraspis*
adnatum Öpik, 1967, *Placosema*
advena Öpik, 1967, *Mindycrusta*
advialis Öpik, 1971, *Redlichia*
agra Öpik, 1961, *Proampyx*
agrestis Öpik, 1967, *Idolagnostus*
alexandriensis Shergold, 1969, *Oryctocephalus*
alienum Öpik, 1963, *Erixanium*
alroiensis (Etheridge Jnr, 1919), *Lyriaspis*
amadeana Öpik, 1971, *Redlichia*
amplinatis Öpik, 1963, *Agnostardis*

cf. *amplinatis* Öpik, 1963, *Agnostardis*
ampullatus Öpik, 1967, *Pseudagnostus*
amydium Öpik, 1967, *Teinistion*?
angusta (Whitehouse, 1939), *Mapania*
anitys Öpik, 1967, *Ascionepea*

aff. *anitys* Öpik, 1967, *Ascionepea*
anoxys Öpik, 1970, *Nepea*
apicula Öpik, 1967, *Oxyagnostus*
arenata Öpik, 1967, *Quitacetra*
arepo Öpik, 1961, *Holteria*
armata (Linnarsson, 1869), *Leiopyge laevigata* (Dalman, 1828)
arta Öpik, 1961, *Amphoton*?
artilimbatus Öpik, 1967, *Agnostus*
asper Öpik, 1967, *Lophoholcus*
aspis Öpik, 1967, *Paracoosia*
atavus (Tullberg, 1880), *Ptychagnostus*
auriculata Öpik, 1967, *Meropalla*
aurita Öpik, 1967, *Auritama*
australiensis (Chapman, 1911), *Acmarhachis*?
australis Shergold, 1971, *Kaolishania*
australis (Woodward, 1884), *Yorkella*

avara Öpik, 1970, *Nepea*
avius Shergold, 1972, *Rudagnostus*
baccata Öpik, 1967, *Idamea*
bacculata Shergold, 1972, *Palacorona*
bassa Öpik, 1967, *Agnostoglossa*
bensoni Öpik, 1961, *Amphoton*
biaverta Öpik, 1967, *Biaverta*
bidens Öpik, 1967, *Meteoraspis*
aff. *bidens* Öpik, 1967, *Meteoraspis*
bigeneris Öpik, 1967, *Triadaspis*
cf. *biloba* Kobayashi, 1942, *Blackwelderia*
bilobata Pocock, 1964, *Estaingia*
bisectus Öpik, 1967, *Clavagnostus*
brevifrons (Angelin, 1851), *Hypagnostus*
browni (Etheridge Jnr, 1896), *Xystridura*
aff. *browni* (Etheridge Jnr, 1896), *Xystridura*
cf. *buda* Resser & Endo, 1937, *Pagodia*
bulgosus Öpik, 1967, *Pseudagnostus*
burkeanus Öpik, 1961, *Acontheus*
caelatum Öpik, 1967, *Placosema*
caseyi Öpik, 1967, *Leichneyella*
cassis Öpik, 1961, *Ptychagnostus*
cf. *ceres* (Walcott, 1905), *Tsinania*
cherria Gatehouse, 1968, *Piaziella*
chinensis Dameš, 1883, *Agnostus sensu* Chapman, 1929 (=*Peronopsis normata* (Whitehouse, 1936), *fide* Whitehouse, 1936; Kobayashi, 1939)
chinensis Walcott, 1905, *Redlichia*
aff. *chuhsiensis* Lu, 1956, *Proceratopyge*
clara Shergold, 1972, *Duplora*
clavus Shergold, 1972, *Pseudagnostus*
clipeus Whitehouse, 1939, *Hypagnostus*
compacta Öpik, 1967, *Mindycrusta*
confertum Whitehouse, 1939, *Anomocare*
cf. *confertum* Whitehouse, 1939, *Anomocare*
conspicabilis Chapman, 1929, *Marjumia*
(= *Xystridura saintsmithi* (Chapman), *fide* Whitehouse, 1939)
convexa Gatehouse, 1968, *Gunnia*
correctus Öpik, 1967, *Hypagnostus*
corusca Whitehouse, 1945, *Dorypyge*
cos Öpik, 1967, *Leiopyge*
crassus Öpik, 1967, *Diplagnostus*
creta Öpik, 1971, *Redlichia*
cyclopyge (Tullberg, 1880), *Pseudagnostus*
cylindrica Shergold, 1972, *Eoshumardia*
dailyi Pocock, 1970, *Balcoracania*
dalgarnoi Pocock, 1970, *Emuella*
declivis Öpik, 1967, *Aedotes*
decoris Whitehouse, 1945, *Dorypyge*
delicatus Öpik, 1963, *Olenus*
dicella Öpik, 1961, *Mapania*
aff. *difformis* Angelin, 1851, *Agraulos*
dilemna Öpik, 1961, *Delagnostus*
diloma Öpik, 1963, *Stigmatoa*
dimota Gatehouse, 1968, *Elliota*
dipentas Öpik, 1967, *Dipentaspis*
aff. *dipentas* Öpik, 1967, *Dipentaspis*
discretus Öpik, 1967, *Pleurinodus*
cf. *discretus* Öpik, 1967, *Pleurinodus*
discus Whitehouse, 1939, *Oryctocephalus*

(united with *Paradoxides peregrinus* Whitehouse, 1939 to become *Chienaspis peregrina* (Whitehouse), *fide* Shergold, 1969).
dissidens Öpik, 1967, *Palaeodotes*
aff. *dissidens* Öpik, 1967, *Palaeodotes*
dryas Öpik, 1967, *Idolagnostus*
dubitalis Öpik, 1967, *Norwoodella*?
dubium (Whitehouse, 1936), *Pseudophalacroma*
dunstani Chapman, 1929, *Dikelocephalus*
(= *Xystridura saintsmithi* (Chapman), *fide* Whitehouse, 1939).
durus Öpik, 1967, *Hypagnostus*
elaticeps Öpik, 1970, *Penarosa*
elegans Chapman, 1929, *Marjumia*
(= *Xystridura saintsmithi* (Chapman), *fide* Whitehouse, 1939).
elegans Whitehouse, 1939, *Protemnites*
elkedraensis (Etheridge Jnr, 1902), *Peronopsis*
cf. *elkedraensis* (Etheridge Jnr, 1902), *Peronopsis*
enodis Öpik, 1967, *Alomataspis*
eretes Öpik, 1967, *Erediaspis*
ergodes Shergold, 1972, *Distagnostus*
erista Öpik, 1967, *Solenopleura?*
erugata Whitehouse, 1939, *Charchaqia*
etheridgei (Chapman, 1911), *Tricrepicephalus*
euryaxis Öpik, 1967, *Ammagnostus*
evexus Öpik, 1967, *Grandagnostus*
exilis Whitehouse, 1936, *Leiopyge*
(= *Leiopyge laevigata* (Dalman) or *L.l. armata* Linnarsson), *fide* Öpik, 1961b)
expansa Öpik, 1967, *Auritama*
expansa Shergold, 1969, *Barklyella*
exserta Öpik, 1970, *Nepea*
cf. *exserta* Öpik, 1970, *Nepea*
extricans Öpik, 1967, *Idamea*
faceta Öpik, 1961, *Mapania*
cf. *faceta* Öpik, 1961, *Mapania*
fallax (Linnarsson, 1869), *Peronopsis*
aff. *fallax* (Linnarsson, 1869), *Peronopsis*
fastosa Öpik, 1967, *Acrodirotes*
fergusoni (Gregory, 1903), *Kootenia*
flexuosa Öpik, 1967, *Polycertaspis*
flindersi Pocock, 1970, *Balcoracania*
forresti (Etheridge Jnr, 1890), *Redlichia*
fortis Gatehouse, 1968, *Probowmannia*?
fumicola Öpik, 1961, *Ptychagnostus* (*Goniagnostus*)
futiliformis Shergold, 1972, *Mansuyites*
aff. *geikiei* (Walcott, 1908), *Oryctocare*
gelasinus Shergold, 1969, *Oryctocephalites*
cf. *gelasinus* Shergold, 1969, *Oryctocephalites*
georginae Öpik, 1967, *Blountia*
gibberina Öpik, 1967, *Blackwelderia*
gibbus (Linnarsson, 1869), *Ptychagnostus*
cf. *gibbus* (Linnarsson, 1869), *Ptychagnostus*
globiceps Öpik, 1967, *Anopocodia*
granulatus Lermontova, 1940, *Dinesus* (*Erbia*), cf.
gravis Öpik, 1967, *Agnostascus*
aff. *gravis* Öpik, 1967, *Agnostascus*
griphus Öpik, 1967, *Griphasaphus*
cf. *hamulus* (Owen, 1863), *Saratogia*
aff. *helena* (Walcott, 1889), *Calodiscus*
hippalus Öpik, 1961, *Hypagnostus*
hispida Öpik, 1967, *Ferenepea*

cf. *holopyga* (Hall, 1859), *Bathynotus*
howchini Etheridge Jnr, 1898, *Ptychoparia*
(= *Yorkella australis* (Woodward), *fide* Kobayashi 1935, 1942b)
humilis (Whitehouse, 1936), *Diplagnostus*
hunanicus Lu, 1957, *Hypagnostus*
ida Etheridge Jnr, 1896, *Dinesus*

cf. *ida* Etheridge Jnr, 1896, *Dinesus*
idalis Öpik, 1967, *Pseudagnostus*

cf. *idalis* Öpik, 1967, *Pseudagnostus*
idonea Whitehouse, 1939, *Redlichia*

cf. *idonea* Whitehouse, 1939, *Redlichia*
illimbatum Öpik, 1967, *Aulocodigma*
imitans Öpik, 1961, *Grandagnostus*
immodulata Öpik, 1967, *Modocia*
incertus (Brögger, 1878), *Doryagnostus*

cf. *incerta* (Rusconi) Leanza, 1947, *Kootenia*
incognitus Öpik, 1967, *Agnostogonus*
inconstans Öpik, 1963, *Agnostogonus*
inexpectans (Kobayashi, 1938), *Innitagnostus*
iniotoma Öpik, 1967, *Iniotoma*
innitens Öpik, 1967, *Innitagnostus*

aff. *innitens* Öpik, 1967, *Innitagnostus*
? *innitens* Öpik, 1967, *Innitagnostus*
inquilinus Öpik, 1967, *Aspidagnostus*
instans Öpik, 1967, *Aedotes*
integra Öpik, 1967, *Henadoparia*
integriceps Öpik, 1967, *Ammagnostus*
intricata Öpik, 1967, *Cyrtoprora*
italops Öpik, 1967, *Palaeadotes*
janitrix Öpik, 1967, *Ascionepea*
junior Shergold, 1972, *Connagnostus*
kainelliformis Shergold, 1972, *Richardsonella?*

aff. *kjerulfi* (Brögger, 1878), *Linguagnostus*
krausei Monke, 1903, *Liostracina*

aff. *kushanensis* (Walcott, 1905), *Cotalagnostus*
laciniatus Öpik, 1961, *Blystagnostus*
laciniosa Shergold, 1972, *Richardsonella*
laevigata (Dalman, 1828), *Leiopyge*
laevis Shergold, 1972, *Dellea?*
lancastrioides Shergold, 1969, *Oryctocephalina*
lanceola Whitehouse, 1939, *Papyriaspis*

aff. *lanceola* Whitehouse, 1939, *Papyriaspis*
las Öpik, 1967, *Hadragnostus*
lata Whitehouse, 1939, *Proceratopyge*
laticeps Öpik, 1967, *Agelagma*
legirupa Öpik, 1967, *Xestagnostus*

aff. *legirupa* Öpik, 1967, *Xestagnostus*
lenis Öpik, 1969, *Glyptagnostus* (*Lispagnostus*)
lepta Öpik, 1971, *Redlichia*
levior Whitehouse, 1939, *Asthenopsis*
limbatus Whitehouse, 1936, *Phoidagnostus*
(= *Pseudophalacroma dubium* (Whitehouse) or *Hypagnostus hippalus* Öpik, *fide* Öpik, 1961b)

cf. *lisani* (Walcott, 1911), *Koptura*
lobata Shergold, 1969, *Sandoveria*
longilira Shergold, 1972, *Sigmakainella*
longula Whitehouse, 1939, *Rhodonaspis*

aff. *loveni* (Angelin, 1851), *Centropleura*
loxophrys Öpik, 1970, *Loxonepea*
lutea Gatehouse, 1968, *Gunnia*
macrops Shergold, 1972, *Lorrettina*
magister Whitehouse, 1939, *Ceratagnostus*
mayalis Öpik, 1971, *Redlichia*
melota Öpik, 1970, *Penarosa*
meniscops Öpik, 1970, *Penarosa*
meringaspis Öpik, 1967, *Meringaspis*
merrotskii Mitchell, 1922, *Ptychoparia*
(= *Lyriaspis alroiensis* (Etheridge), *fide* Whitehouse, 1939)
mestus Öpik, 1967, *Pseudagnostus*
micrograpta Öpik, 1971, *Redlichia*
milesi Chapman, 1929, *Marjumia*
(= *Xystridura saintsmithi* (Chapman), *fide* Whitehouse, 1939)
mindycrusta Öpik, 1967, *Mindycrusta*
minima (Chapman, 1911), *Thielaspis*
mitis Öpik, 1967, *Ammagnostus*
mitis Öpik, 1967, *Plectrifer*
modica (Whitehouse, 1939), *Kootenia*
momedahensis Shergold, 1972, *Golasaphus*
mutans Öpik, 1967, *Aedotes*
nans Öpik, 1970, *Folliceps*
nanus Öpik, 1963, *Asilluchus*
narinosa Whitehouse, 1939, *Nepea*

aff. *narinosa* Whitehouse, 1939, *Nepea*
nathorsti (Brögger, 1878), *Ptychagnostus* (*Goniagnostus*)

aff. *nathorsti* (Brögger, 1878), *Ptychagnostus* (*Goniagnostus*)
nectans Whitehouse, 1939, *Proceratopyge*
neglecta Öpik, 1949, *Centropleura*
neglectus Westergaard, 1946, *Agnostus*
neuter Öpik, 1967, *Rhyssometopus*
nitens Öpik, 1967, *Lampropeltis*
nitidus Chapman, 1929, *Bathyuriscus*
(= *Xystridura saintsmithi* (Chapman) *fide* Whitehouse, 1939)
noakesi Öpik, 1967, *Lynaspis*
nobilis Öpik, 1967, *Peratagnostus*

aff. *nobilis* Walcott, 1905, *Redlichia*
nodibundus Öpik, 1967, *Ptychagnostus*
nolens Öpik, 1967, *Liostracina*
normata (Whitehouse, 1936), *Peronopsis*

cf. *normata* (Whitehouse, 1936), *Peronopsis*
notostena Öpik, 1967, *Mindycrusta*
notulata Öpik, 1963, *Talbotinella*
novella Öpik, 1967, *Dipyrgotes*

aff. *novella* Öpik, 1967, *Dipyrgotes*

cf. *nudum* (Beyrich, 1845), *Phalacroma*
nuperus Whitehouse, 1936, *Pseudagnostus*

cf. *obesus* (Belt, 1884), *Homagnostus*
ocellata Jell, 1971, *Pagetia*
ocellatus Shergold, 1972, *Crucicephalus*
oculosa Öpik, 1967, *Histiomona*
offula Öpik, 1967, *Onchonotellus*
ogilviei Öpik, 1963, *Olenus*
olenelloides Chapman, 1929, *Bathyuriscus*
(= *Xystridura saintsmithi* (Chapman), *fide* Whitehouse, 1939)
opiki Shergold, 1969, *Oryctocephalus*
opimus Whitehouse, 1936, *Euagnostus*

cf. *orientalis* Resser & Endo, 1937, *Saukia*?
ornata Öpik, 1967, *Doremataspis*
papilio Shergold, 1972, *Pseudagnostus*
parmatus Whitehouse, 1936, *Aspidagnostus*
pelta Öpik, 1967, *Peichiashania*?
peregrina (Whitehouse, 1939), *Chienaspis*?
(comment under *Oryctocephalus discus* Whitehouse)
personatus Öpik, 1967, *Oidalagnostus*
petalifera Öpik, 1970, *Penarosa*
petasatus Shergold, 1972, *Atopasaphus*
petita Öpik, 1971, *Redlichia*
phoenix Öpik, 1961, *Centropleura*
pilaris Öpik, 1967, *Ferenepea*

aff. *pisiformis* Linnaeus, 1758, *Agnostus*

cf. *planicauda* (Angelin, 1851), *Diplagnostus*
plebcia Whitehouse, 1939, *Elrathiella*
plectrifer Öpik, 1967, *Plectrifer*
plumula Whitehouse, 1939, *Corynexochus*
polita Whitehouse, 1939, *Proceratopyge*
polymera Pocock, 1970, *Emuella*
princeps Öpik, 1967, *Rhyssometopus*
priscilla Öpik, 1967, *Saukia*?
pristinus Öpik, 1967, *Nomadinis*
pritchardi Tate, 1892, *Olenellus*?
(= *Pararaia tatei* (Woodward), *fide* Kobayashi, 1942b)
propinquum Whitehouse, 1939, *Eugonocare*
prosecta Whitehouse, 1939, *Rhodonaspis*
psammium Öpik, 1967, *Ammagnostus*
punctuosus (Angelin, 1851), *Ptychagnostus*
purus Whitehouse, 1939, *Ptychagnostus* (*Goniagnostus*)

aff. *puteata* Endo *in* Resser & Endo, 1937, *Paramansuyella*
pyriceps Öpik, 1967, *Lobocephalina*
quadrans Öpik, 1967, *Meropalla*
quadratum Öpik, 1967, *Agelagma*
quasispinale Öpik, 1967, *Aulocodigma*

cf. *quasispinale* Öpik, 1967, *Aulocodigma*
quasivespa Öpik, 1967, *Cyclagnostus*

aff. *quasivespa* Öpik, 1967, *Cyclagnostus*
rasilis Öpik, 1967, *Xestagnostus*

cf. *rasilis* Öpik, 1967, *Xestagnostus*
ratis Öpik, 1967, *Dipentaspis*
reineri Öpik, 1967, *Biaverta*
repanda Öpik, 1967, *Blackwelderia*

cf. *repanda* Öpik, 1967, *Blackwelderia*
reticulatus (Angelin, 1851), *Glyptagnostus*
retifera Öpik, 1970, *Penarosa*
reynoldsi Reed, 1889, *Oryctocephalus*

cf. *reynoldsi* Reed, 1889, *Oryctocephalus*
rhinodelpha Öpik, 1970, *Penarosa*
rhyssometopus Öpik, 1967, *Rhyssometopus*
richthofeni Monke, 1903, *Stephanocare*
rostrifinis Öpik, 1967, *Rhyssometopus* (*Rostrifinis*)

aff. *rostrifinis* Öpik, 1967, *Rhyssometopus* (*Rostrifinis*)
rudis Öpik, 1963, *Hercantyx*
rugiceps Öpik, 1967, *Rhyssometopus*
rugifera Westergaard, 1946, *Leiopyge laevigata* (Dalman 1828)

cf. *rugulata* Chapman, 1917, *Saratogia*
runcinatus Shergold, 1969, *Oryctocephalites*
rutellum Whitehouse, 1939, *Proceratopyge*
sabulosa Öpik, 1967, *Blackwelderia*
saintsmithi (Chapman, 1929), *Xystridura*
scaphoa Öpik, 1961, *Peronopsis*
scarabaeus Whitehouse, 1939, *Ptychagnostus* (*Goniagnostus*)

cf. *scutalis* (Salter *in* Hicks, 1872), *Peronopsis*
seminula Whitehouse, 1939, *Agnostus*
sentum Öpik, 1963, *Erixanium*
serena Öpik, 1967, *Interalia*
sericatus Öpik, 1967, *Pseudagnostus*
serotinum Whitehouse, 1939, *Amphoton*
serus Öpik, 1967, *Ptychagnostus*?
sidonia Öpik, 1963, *Stigmatoa*
sigillum Whitehouse, 1939, *Lyriaspis*
sigmata Öpik, 1967, *Nilegna*
significans (Etheridge Jnr, 1902), *Pagetia*
aff. *significans* (Etheridge Jnr, 1902), *Pagetia*

cf. *significans* (Etheridge Jnr, 1902), *Pagetia*
silex Öpik, 1963, *Stigmatoa*
solus Öpik, 1967, *Adelogonus*
somniura Öpik, 1967, *Onaraspis*
sonax Öpik, 1961, *Centropleura*
sors Öpik, 1961, *Tosotychia*

aff. *speciosus* (Ford, 1873), *Serrodiscus*
spectator Öpik, 1963, *Discagnostus*
spiniger (Westergaard, 1931, *Ptychagnostus* (*Goniagnostus*)
spinigerum Whitehouse, 1939, *Amphoton*
splendens Endo *in* Resser & Endo, 1937, *Malladioidella*
stictus Öpik, 1967, *Aspidagnostus*

aff. *stictus* Öpik, 1967, *Aspidagnostus*
stolidotus Öpik, 1961, *Glyptagnostus*
strabum Öpik, 1963, *Erixanium*
striata Resser & Endo, 1937, *Mapania*
subsagittatus Tate, 1892, *Microdiscus*
(= *Pararaia tatei* (Woodward), fide Kobayashi 1942b)
subsulcatus Westergaard, 1946, *Agnostus pisiformis* Linnaeus 1758
succincta Shergold, 1969, *Cheiruroides*
sulcatus Shergold, 1969, *Oryctocephalites*
superstes Whitehouse, 1939, *Pagodia* (*Idamea*)
synophrys Öpik, 1961, *Mapania*
tatei (Woodward, 1884), *Pararaia*
templetonensis (Chapman, 1929), *Xystridura*
tenella Whitehouse, 1945, *Dorypyge*

aff. *teres* Resser & Endo, 1937, *'Quadraticephalus'*
tesselatum Whitehouse, 1939, *Eugonocare*
thielei (Chapman, 1911), *Thielaspis*
tiro Öpik, 1967, *Rhyssometopus* (*Rostrifinis*)
tonsillata Öpik, 1970, *Nepea*
toreuma Whitehouse, 1936, *Glyptagnostus*
(= *Glyptagnostus reticulatus* (Angelin), *fide* Westergaard, 1947, Kobayashi, 1949, Öpik, 1961a, 1963b, Palmer, 1962)
torosa Öpik, 1967, *Damesella*
torquata Shergold, 1972, *Lophosaukia*
townleyi Öpik, 1967, *Townleyella*
tranans Öpik, 1967, *Olenoides*
translira Shergold, 1972, *Sigmakainella*

aff. *transversus* Linnarsson *in museo,* Westergaard, 1922, *Olenus*
travesi Öpik, 1967, *Metopotropis*
tridens Öpik, 1967, *Oedorhachis*?
trigona Whitehouse, 1939, *Eurostina*
trilunata Öpik, 1967, *Auritama*

cf. *typicalis* Resser, 1939, *Oryctocephalites*
tropica Öpik, 1963, *Irvingella*

cf. *typicalis* Resser, 1939, *Oryctocephalites*
(= *Oryctocephalites runcinatus* Shergold or *O. gelasinus* Shergold, *fide* Shergold, 1969)
tysoni Öpik, 1963, *Stigmatoa*
uncata Öpik, 1967, *Quitalia*

cf. *uncata* Öpik, 1967, *Quitalia*
varicosus Öpik, 1961, *Hypagnostus*
vastulus Whitehouse, 1936, *Pseudagnostus*

cf. *vastulus* Whitehouse, 1936, *Pseudagnostus*
velaevis Öpik, 1961, *Grandagnostus*
venerabilis Öpik, 1967, *Connagnostus*
venulosa (Whitehouse, 1939), *Redlichia*
venusta Whitehouse, 1939, *Pagodia* (*Idamea*)
versabunda Öpik, 1971, *Redlichia*
vertumnia Öpik, 1971, *Redlichia*
vestgothicus (Wallerius, 1895), *Diplagnostus planicauda* (Angelin, 1851)

cf. *vestgothicus* (Wallerius, 1895), *Diplagnostus planicauda* (Angelin, 1851)
vetusta Öpik, 1967, *Saratogia*?
viatrix Shergold, 1973, *Meneviella*
vicaria Öpik, 1967, *Pseudagnostina*

aff. *vicaria* Öpik, 1967, *Pseudagnostina*
vicenalis Whitehouse, 1939, *Chancia*
vittata Öpik, 1970, *Penarosa*
volens Öpik, 1967, *Liostracina*
vortex Whitehouse, 1936, *Hypagnostus*
warramunga Öpik *in* Ivanac, 1954 (*nom. nud.*), *Xystridura*
willsi Öpik, 1961, *Hypagnostus*
zeabunda Öpik, 1970, *Penarosa*
zonatus Öpik, 1967, *Connagnostus*?

Designated Species Remaining Under Open Nomenclature

sp. *a* Öpik, 1958, *Redlichia*
sp. *b* Öpik, 1958, *Redlichia*
sp. *c* Öpik, 1958, *Redlichia*
sp. *d* Öpik, 1958, *Redlichia*
    (= *Redlichia advialis* Öpik, 1971)
sp. *A* Öpik, 1963, *Olenus* ? (aff. *Parabolina ? quadrisulcata* Henningsmoen, 1951)
sp. *B* Öpik, 1963, *Aphelaspis*?
sp. *D* Öpik, 1961, *Proampyx*
sp. *e* Öpik, 1961, *Agnostus* (*Agnostus* cf. *neglectus* Westergaard 1946)
sp. *F* Opik, 1961, *Hypagnostus*
sp. *g* Öpik, 1961, *Peronopsis*
sp. *H* Öpik, 1961, *Crepicephalus*?
sp. *i* Öpik, 1961, *Diplagnostus*?
sp. *K* Öpik, 1961, *Pseudophalacroma*
sp. *L* Öpik, 1961, *Pseudophalacroma*
sp. *O* Öpik, 1961, *Ptychagnostus*
sp. *I* Shergold, 1972, *Pseudagnostus*
sp. *II* Shergold, 1972, *Pseudagnostus*
sp. *III* Shergold, 1972, *Pseudagnostus*
sp. nov. *A* Öpik, 1967, *Blackwelderia*?
sp. nov. *A* Öpik, 1967, *Dipyrgotes*?
sp. nov. *A* Öpik, 1967, *Leichneyella*?
sp. nov. *A* Öpik, 1967, *Meringaspis*
sp. nov. *B* Öpik, 1967, *Blackwelderia*?
sp. nov. *B*. Öpik, 1967, *Leichneyella*
sp. nov. *B* Öpik, 1967, *Meringaspis*
sp. nov. *NC* Öpik, 1970, *Nepea*?
sp. nov. *NC* Öpik, 1970, *Loxonepea*
sp *NA* (indet.) Öpik, 1970, *Nepea*
sp. *NB* (indet.) Öpik, 1970, *Nepea*
sp. *PA*, aff. *retifera* Öpik, 1970, *Penarosa*
sp. *PB*, aff. *vittata* Öpik, 1970, *Penarosa*
sp. nov. *PC* Öpik, 1970, *Penarosa*
sp. nov. *PD* aff. *vittata*, Öpik, 1970, *Penarosa*
sp. nov. *PE* Öpik, 1970, *Penarosa*

CRETACEOUS STRATIGRAPHY OF PART OF THE WISO BASIN, NORTHERN TERRITORY

by S. K. SKWARKO

SUMMARY

Of the Cretaceous sediments of the Wiso Basin, only the plateau sediments are discussed here. They are a direct continuation of the Mullaman Beds that occur throughout the northern part of the Northern Territory. They are mostly covered by a thin veneer of Quaternary sand and soil and their total thickness is about 90 m, depending on the relief in the pre-Cretaceous land surface.

The lowest unit (A) in the sequence is a plant-bearing, non-marine, saccharoidal sandstone with local conglomerate. It is 14 m thick and is a local equivalent of Unit A (?Neocomian, Aptian) described previously from areas to the north and east of the Wiso Basin.

Unit A is overlain by up to 43 m of marine claystone and siltstone which is correlated with Unit 6 (Aptian) of the Coastal Belt Suite. It extends in an irregular diagonal belt along the southern and western margin of the Gulf of Carpentaria.

Unit 6a, up to 16 m of siltstone and sandstone, overlies Unit 6 with probable conformity. It is characterized by a rich assemblage of worm borings and was previously observed in the Coastal Belt Suite at localities TT 47-48. It is now distinguished as a separate unit of Aptian age.

At the top of the Cretaceous sequence there is about 30 m of marine claystone of Albian age, a local equivalent of Unit C of the Coastal Belt Suite.

The lithobiological content of the westernmost exposures of Unit A (coarse, poorly sorted conglomerate associated with fossil logs and branches) suggests that the lakes in which it was laid down did not extend farther to the west. No evidence regarding the proximity of margins of the shallow seas is forthcoming from the other units.

INTRODUCTION

In an earlier Bulletin (Skwarko, 1966), I described all the Cretaceous strata and their fossils which had been mapped in the Northern Territory up to that date. This paper contains descriptions of Cretaceous strata and fossils recently mapped in the northwest of the Northern Territory; particularly those mapped by a BMR field party in 1966—the Daly Waters and Larrimah 1:250 000 Sheets and the eastern portions of the Victoria River Downs and Delamere Sheets (Fig. 1).

The western portion of the Victoria River Downs and Delamere Sheets and the Port Keats and Cape Scott Sheets were mapped in 1967-9 by another BMR party. This area will be discussed elsewhere as it contains a markedly different suite of Cretaceous sediments and the relationships of the two sedimentary suites have not been conclusively worked out.

The area covered by the Wave Hill, Newcastle Waters, Beetaloo, Helen Springs, South Lake Woods, and Tennant Creek Sheets was mapped in 1968.

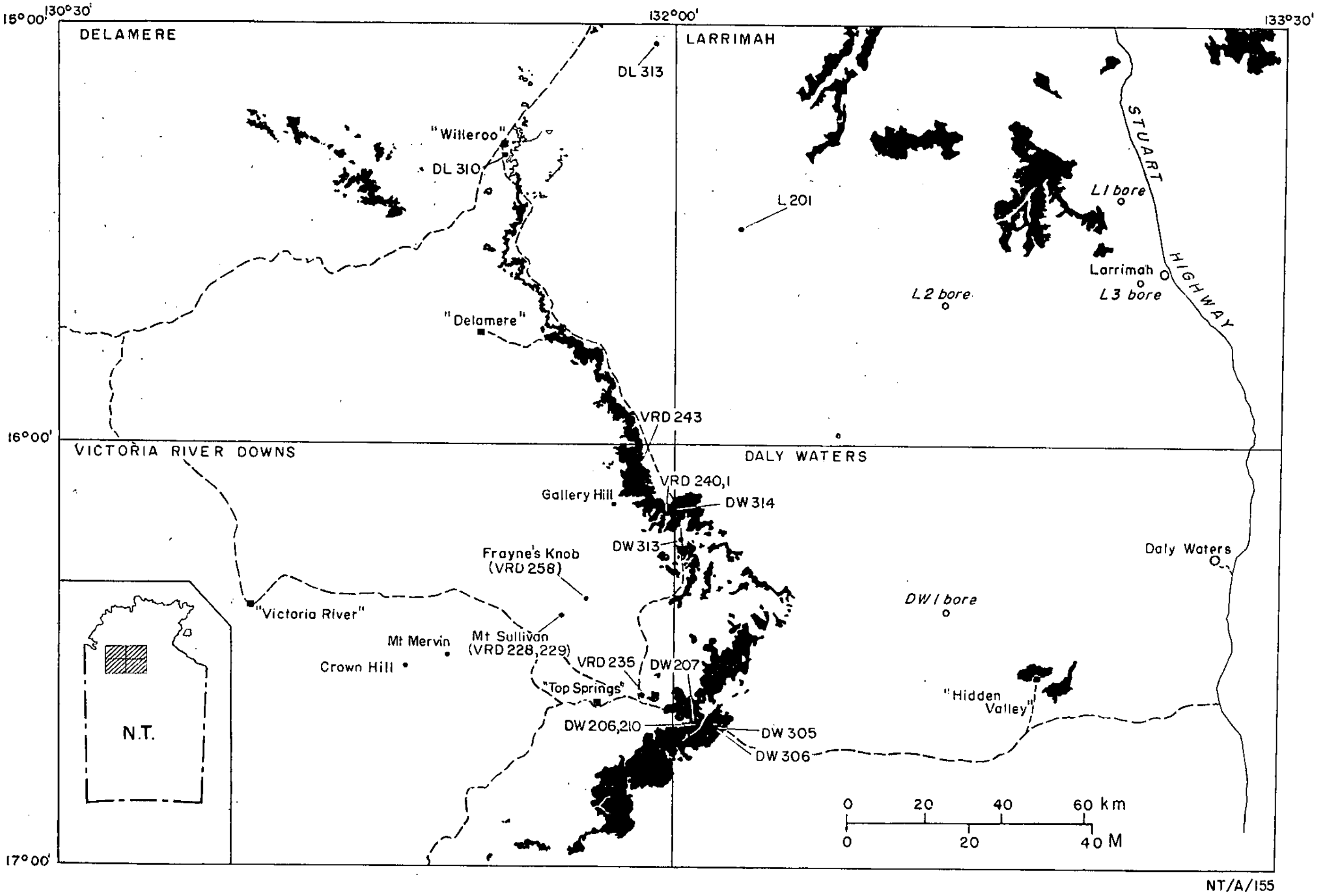


Fig. 1. Map showing the distribution of Cretaceous outcrops and fossil-bearing localities in the southwestern portion of the northern Region.

Examination of the few arid scattered remnants of the once continuous Cretaceous cover added more to the knowledge of their extent than to that of their nature. For their description the reader is referred to the explanatory notes on the relevant 1:250 000 Geological Sheets.

STRATIGRAPHY

The Cretaceous strata discussed here form a plateau which stretches over most of the Daly Waters and Larrimah Sheet areas and the eastern portions of the Victoria River Downs and Delamere Sheet areas (Fig. 1). The beds are a continuation of the *Mullaman Beds* to the north, east, and southeast (Fig. 2), which were discussed earlier (Skwarko, 1966). On the west the plateau terminates at a scarp formed by the headward erosion of streams flowing to the west and northwest into the Joseph Bonaparte Gulf. This easterly retreating scarp is low but strongly dissected, and extends in an almost continuous, though frilled and sinuous, line from the southeast corner of the Victoria River Downs Sheet area to the northeast corner of the Delamere Sheet area (Fig. 1). On the plateau, outcrops are few and reveal little because of shallow dissection by streams and an extensive, though shallow, blanket of Quaternary soils and sands.

Because of erosion over a long period it is not possible to establish the original thickness of the Mullaman Beds. As in the other parts of the Northern Territory it was probably not great, and was locally dependent on relief in the pre-Cretaceous land surface. The thickest section measured in the west of the plateau was only 51 m, but stratigraphic drilling in the eastern part showed a thickness of 87 m.

The plateau strata are heterogeneous in composition and are of different ages. They are readily divisible into four units, three of which can be correlated with units already established in other areas where Mullaman sediments crop out. The fourth, also represented in the east, has not been separated as a distinct unit before. The numbering system used here is the same as that used previously (Skwarko, 1966), and the four units represented in this part of the Wiso Basin are, in ascending order, Unit A, Unit 6, Unit 6a, and Unit C.

Unit A (?Neocomian, Aptian)

Unit A is the basal unit of the *Inland Belt Suite* of the Mullaman Beds, distributed extensively in the Northern Region. It is non-marine, almost certainly a lacustrine, saccharoidal sandstone, locally varying in grainsize and silt content and containing plant remains to the exclusion of other fossils. It was correlated with the *Lees Sandstone* of northwestern Queensland (Skwarko, 1966).

In the Wiso Basin Unit A also occupies a basal position in the plateau sequence. In its westernmost outcrop its lithology coarsens significantly. At locality VRD 235 (Fig. 1) small and low remnant outcrops of ferruginized grit and subangular cobble and pebble conglomerate with fossil impressions of twigs, branches, and logs overlie the old land surface in the Cambrian *Montejinni Limestone.* This outcrop implies a near-shore environment: the western margin of the lake was probably not far away.

The nearest known exposure of Unit A from locality VRD 235 is about 58 km due north in the low plateau escarpment (Daly Waters run 1, photo 5105, point VRD 305). Here coarse-grained sandstone and a basal conglomerate of angular quartz pebbles set in a claystone matrix crop out at the base of the exposed Cretaceous section. Only 60 cm of the conglomerate is visible here, but its base

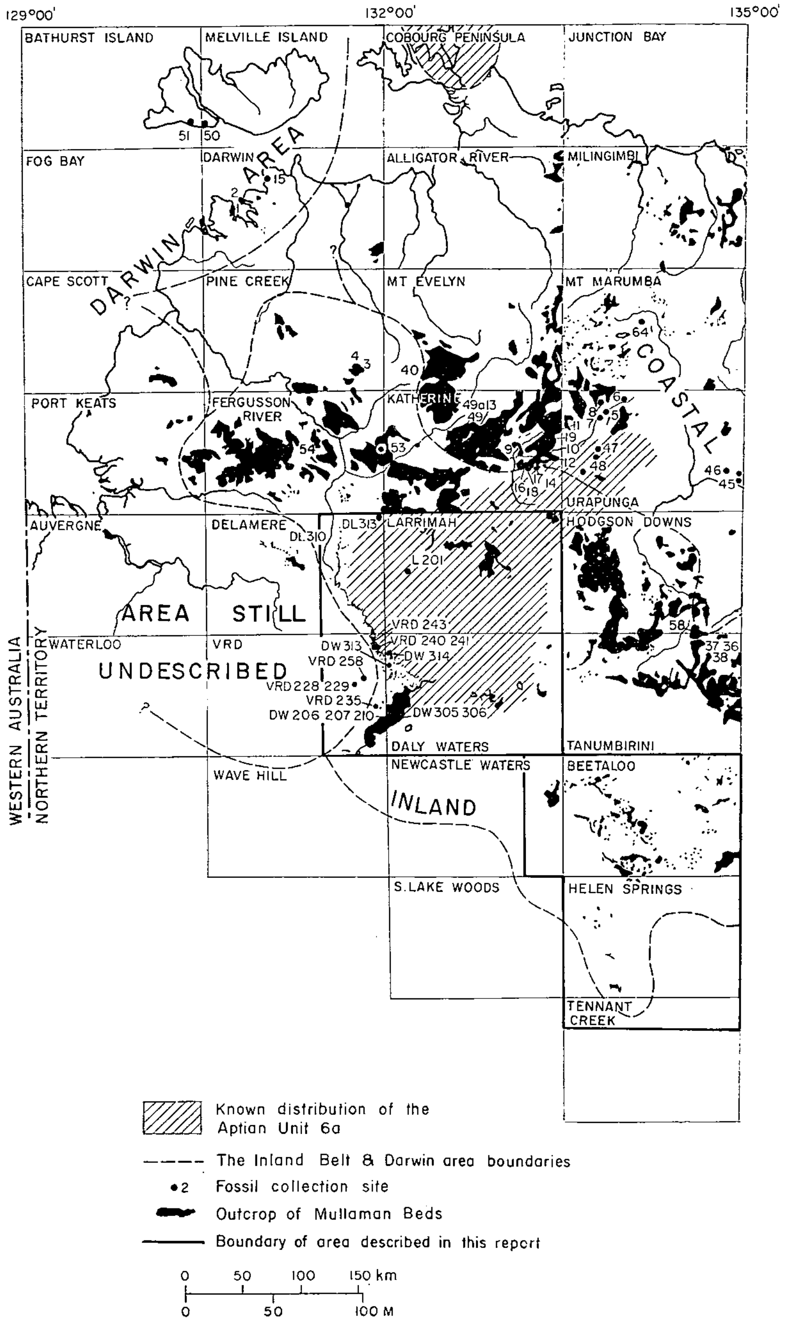
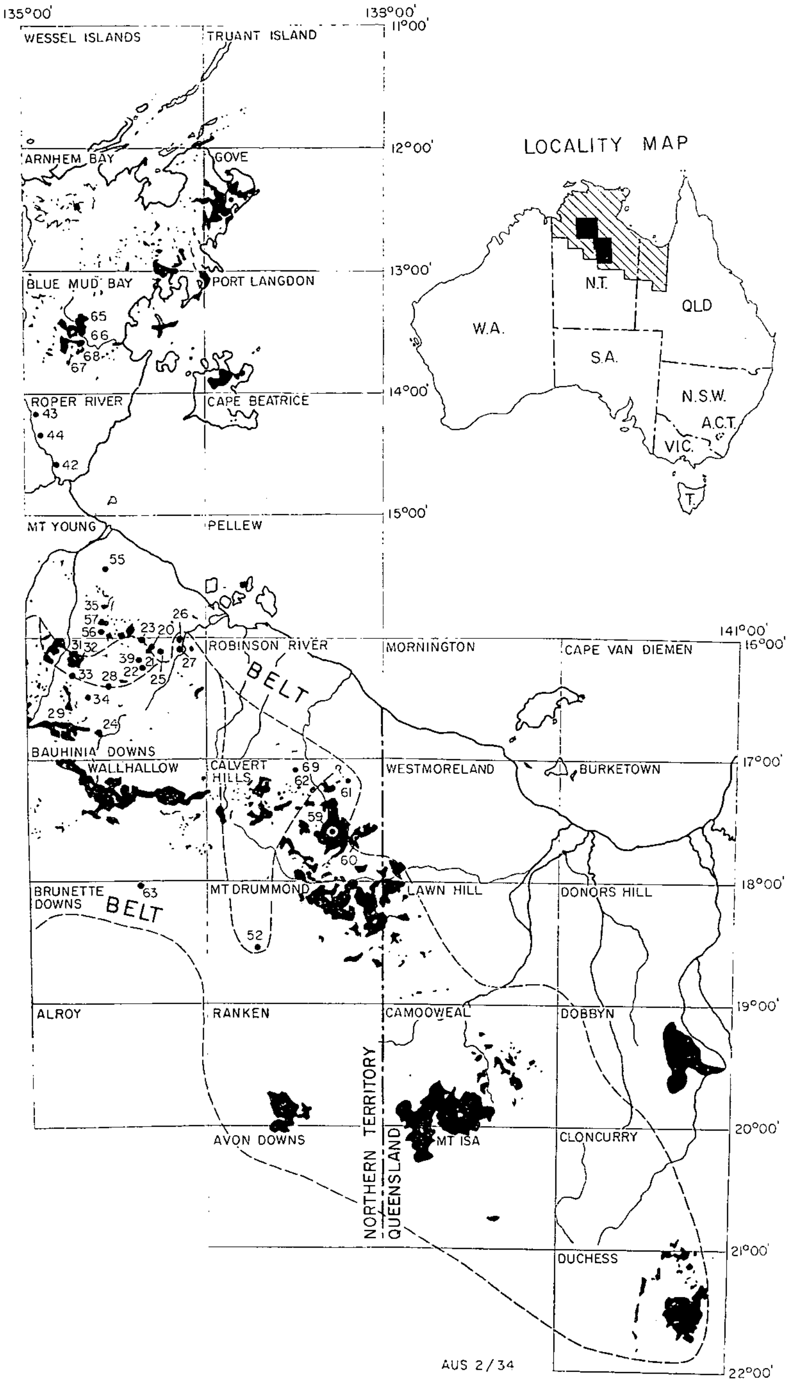


Fig. 2. Map showing the distribution of Cretaceous sedimentation in the northern



region and the relation of the recently mapped area to the areas mapped previously.

may be seen 16 km to the north in the southeast of the Delamere Sheet area (Run 15, photo 5169, point DL 301). Here 3 m of conglomerate and grit with a fine kaolinitic matrix crop out in a creek bed, overlying Palaeozoic siltstone. Six kilometres southeast from the Delamere homestead turn-off and also west of the Willeroo/Top Springs road (Run 12, photo 5224, point DL 303) the conglomerate and grit are replaced by large weathered boulders of clean saccharoidal sandstone with plant remains. Both these exposures are typical of numerous outcrops of Unit A in many parts of the Inland Belt of non-marine sedimentation (Skwarko, 1966).

Near Willeroo, however, at locality DL 310 (Fig. 1), very poorly sorted cobble and pebble conglomerate with sandstone occur once again. At DL 313 (northeast corner of the Delamere Sheet area), Unit A consists of 5 m of sandstone which is medium-grained, friable, and stained yellow and pastel brown; identifiable plant impressions give further evidence of its identity. A stratigraphic bore in the Larrimah Sheet area shows an easterly thickening of Unit A, which here measures at least 14 m.

It is concluded on the basis of the lithological variations in Unit A that the western and northwestern margin of the lacustrine sedimentary environment of the Northern Region was roughly parallel to and west of the present-day scarp which borders in the west the Cretaceous plateau sediments of the Wiso Basin.

Fossils and age. The fossils collected in Unit A, both in the areas under discussion and in the rest of the Northern Region, are plant impressions. M. E. White (pers. comm.) identified the following genera and species and dated them as Lower Cretaceous:

locality DL 310

Ptilophyllum sp.

locality DL 313

Neorhacopteris minuta White
Microphyllopteris gleichenioides Oldham & Morris
Otozamites bengalensis Oldham & Morris
locality VRD 235
indeterminate wood fragments

N. minuta was hitherto known only from the *Callawa Formation* (Upper Jurassic or Lower Cretaceous) of the Canning Basin (Veevers & Wells, 1961, p. 297). The remaining plants are known from Unit A of the Northern Region (Skwarko, 1966, p. 32). It was concluded elsewhere that Unit A was deposited during the early part of the Aptian, but deposition may have commenced in late Neocomian times (Skwarko, 1966).

Unit 6 and Unit 6a (Aptian)

Unit A is overlain disconformably by a marine claystone and siltstone layer with Mollusca, about 9 m thick in outcrop and possibly 40 m thick in the DW 1 bore. This layer is overlain apparently conformably by a marine, fossiliferous, medium-grained sandstone. The claystone-siltstone layer is correlated with Unit 6 of the *Coastal Belt Suite* of sediments and a new unit, Unit 6a, is established to include the sandstone layer.

Unit 6 (Aptian)

Originally Unit 6 was established in the Coastal Belt Suite to accommodate a claystone-siltstone layer with the Great Artesian Basin type of Mollusca of Aptian age. Outcrops at three localities, TT 20-22 and TT 33, all of small thickness and with eroded bases and tops, were included in this unit. Two additional outcrops tentatively placed in Unit 6, i.e. TT 47-48, and now placed in Unit 6a (Fig. 2).

Unit 6 overlies Unit A disconformably and crops out in many places in the area under discussion, the most revealing and fossiliferous sites being in the west of the Daly Waters and the east of the Victoria River Downs Sheet areas. The unit consists of a leached creamy claystone and siltstone with numerous consolidational slip features, and irregular, closely spaced, and iron-stained joint planes. It contains marine fossils which are generally not abundant and are absent from some outcrops. Locally the lower part of the unit contains quartz grains. The unit is at least 9 m thick in outcrop and 40 m thick in the scout bore DW 1 (Fig. 1), where its contact with the overlying Unit 6a is transitional.

In the Wiso Basin, Unit 6 was traced through outcrop over a distance of about 190 km and a surface area of about 26 000 km^2, which is more than twice the hitherto known area of distribution in the Northern Region. This indicates that the shallow waters of the Great Artesian Basin extended right across the top part of the Northern Territory in Aptian times.

Fossils and age. In Unit 6 macrofossils were found at six localities in the Daly Waters Sheet area and at three localities in the Victoria River Downs Sheet area. The individual occurrences of the fossils in each collection will be found in Figure 3. The complete fossil list for the unit is:

Grammatodon (I.) robusta (Etheridge Snr, 1872)
'Pseudavicula anomala' (Moore, 1870)
Phaenodesmia cf. *elongata* (Etheridge Snr, 1872)
Trigonia sp. juv. indet.
Bivalvia indet.
Belemnites indet.
Glyphea cf. *aborinsularis*
Ammonites indet.

Some idea of the microfossil content of Unit 6 is afforded from the scout bore DW 1, core No. 3 and DW 1B, core No. 1 (= core 4 in Fig. 4), which contain the following (Terpstra, 1967):

Haplophragmoides cf. *gigas* Cushman, 1927*
Haplophragmoides sp.
Ammobaculites subcretaceus Cushman & Alexander, 1930
Ammobaculites sp.
Verneuilina howchini Crespin, 1953
Trochammina sp.
Textularia cf. *anacooraensis* Crespin, 1953
Miliammina sproulei Nauss var. *gigantea* Mellon & Wall, 1956**
Dorothia sp.

---

* *H. gigas* Crespin (*non* Cushman) = *H. audax* Ludbrook, 1967.
** *M. sproulei* var. *gigantea* Crespin (*non* M. & W., 1956) = *M. inferior* Ludbrook, 1967.

	UNIT A			UNIT 6								UNIT 6a		
	VRD 235	DL 310	DL 313	L 201	DW 206	DW 207	DW 310	DW 313	VRD 240	VRD 241	VRD 243	DW 305	DW 306	DW 314
Phaenodesmia cf. *elongata*					?			X	X	X	X			
Grammatodon (I) robusta							X	X	X	X	X			
Eyrena ? sp. indet.											X			
'*Pseudavicula anomala*'								X			X			
'*Trigonia*' juv. indet.					X									
Unio ? sp.							X							
Panopea cf. *maccoyi*							X							
Bivalvia indet.				X	X		X	X	X	X	X			
Neritokrikus tuberosus												X	X	X
Labeceras aff. *taylori*								X						
Belemnites not identified					X	X	X	X		X	X	X		X
Rhizocorallium sp.												X	X	X
Worm borings indet.												X	X	X
Glyphaea ? cf. *aborinsularis*							X							
Plant remains	X	X	X											

Fig. 3. The distribution of Cretaceous macrofossils in the Wiso Basin stratigraphic units.

The known stratigraphic ranges of these fossils are plotted in Figure 4 and suggest an Aptian age, which, in the case of Unit 6, is supported by both its macrofossil content and also its stratigraphic relationships. At the present stage of our knowledge, however, arenaceous Foraminifera can hardly be regarded as a reliable dating tool within the Lower Cretaceous of Australia.

Unit 6a (Aptian)

In the Wiso Basin, the marine, fossiliferous, medium-grained sandstone layer is a well defined and persistent unit whose stratigraphic position is established with certainty. It is therefore separated from the underlying Unit 6 as Unit 6a.

Unit 6a overlies Unit 6 apparently conformably and is overlain with probable disconformity by the thick and widespread Unit C. It does not crop out on the surface of the plateau except at one or two places in the road cuttings along the Stuart Highway. In the western escarpment Unit 6a consists of about 5 m of indurated quartz sandstone, which is medium-grained, micaceous, and richly fossiliferous, and in places contains a large percentage of glauconite. Its secondary colours are yellow, brown, or rarely red. The best known outcrops are at localities DW 305-306 in the southwest corner of the Daly Waters Sheet area (Fig. 1). The unit was traced to locality DW 314, about 60 km due north of DW 306, which is still along the western escarpment of the plateau. It is 16 m thick in the scout bore DW 1 in the middle of the Daly Waters Sheet area (Fig. 1).

Localities TT 47-48 of the Coastal Belt Suite of sediments (Fig. 2), which were tentatively correlated with the claystone-siltstone layers at localities TT 20-22 and TT 33 on the basis of the presence of a gastropod, *Neritokrikus tuberosus* Skwarko, 1966, are now placed in Unit 6a with confidence, as they have similar lithology and fossil content. The two outcrops are located about 320 km east from locality DW 305 (Fig. 2).

Fossils and age. Unit 6a is richly fossiliferous, but its fauna consists mostly of hitherto undescribed worm borings. *Rhizocorallium* is well represented both in the Wiso Basin localities and in the Urapunga Sheet area, where it is accompanied by another boring organism, *Diplocraterion. Neritokrikus tuberosus* is limited in occurrence to Unit 6a in the Wiso Basin, but it occurs in both Unit 6 and Unit 6a in the Coastal Belt Suite of sediments. This fossil suggests Aptian age for Unit 6a as it is directly associated with Aptian bivalves of the Great Artesian Basin type at localities TT 20-21. Furthermore, it is the only evidence of age available, as the only associated forms in this unit, such as the internal cast of the *Nototrigonia* and an unidentified belemnite, are undatable.

Unit C (Albian)

Unit C is the youngest known lithological unit of Cretaceous age in the Northern Territory. Its outcrops are so widely distributed over the Northern Region that it is likely that the sea in which it was deposited, also an extension of the Great Artesian Basin, covered the whole of the north of the Northern Territory. Unit C has been correlated with the Albian *Polland Shale* of northwestern Queensland (Skwarko, 1966).

Unit C occurs extensively in the Wiso Basin, where it is up to 30 m thick and overlies Unit 6a, probably disconformably. It is predominantly a micaceous siltstone and claystone whose secondary alteration products, stratigraphic position, and fossil content are constant in its outcrop throughout the Northern Region and northwest Queensland. In the southern portion of the Victoria River Downs Sheet area the unit grades up into 1 m of grit and pebble conglomerate which may or may not mark the original top of the unit. In most outcrops, however, the claystone persists to the erosional surface, where protracted weathering gave the uppermost few metres the appearance of a breccia (Skwarko, 1966).

Fossils and age. As in the other parts of the Northern Region the fossil content of Unit C, apart from *Inoceramus* prisms, is limited to microfossils, which in the Wiso Basin consist of the following Foraminifera (Terpstra, 1967):

Haplophragmoides cf. *gigas* Cushman, 1927
Haplophragmoides sp.
Ammobaculites erectus Crespin, 1963
Verneuilina sp.
Verneuilinoides kansasensis Loeblich & Tappan, 1950
Trochammina depressa Lozo, 1944
Trochammina sp.
Trochammina raggatti Crespin, 1944
Inoceramus prisms

The known stratigraphic ranges of these fossils are plotted in Figure 4 and are based on the data from Crespin (1963) and Ludbrook (1967). Although this rather unreliable criterion tends to suggest Aptian rather than Albian age, it is very unlikely that Unit C is older in the Wiso Basin than it is in the other parts of the Northern Region and in Queensland.

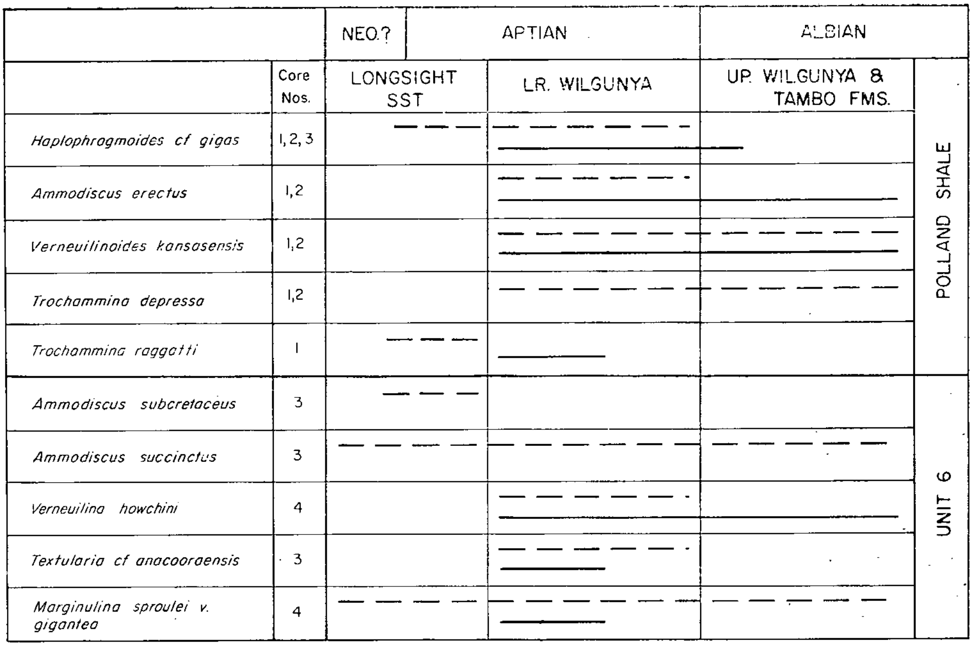


Fig. 4. Table showing Foraminifera identified from scout holes DW 1 and DW 1B and their known stratigraphic ranges according to Crespin (1963, broken line) and Ludbrook (1971, solid line). Identifications of genera only are not included.

SUBSURFACE DATA

Four stratigraphic scout holes were drilled in the Cretaceous plateau (DW 1 and L 1-3, shown in Fig. 1). One of these (DW 1) penetrated a large thickness of Cretaceous sediments in the Daly Waters Sheet area; the other bores in the Larrimah Sheet area found only a small thickness of Cretaceous strata.

In DW 1 the top 29 m of claystone (Fig. 5) probably represents Unit C because of lithologic similarity and foraminiferal content. The underlying 14 m of sandstone is correlated with Unit 6a because of its stratigraphic position and glauconite content. Beneath this unit is 43 m of claystone, siltstone, and fine-grained sandstone with Foraminifera which is inferred to be Unit 6 from its stratigraphic position between the proposed Unit 6a and the underlying sandstone, a coarse-grained friable rock of unknown thickness.

A preliminary correlation of the more important Cretaceous sections in the Wiso Basin is outlined in Figure 5. The correlation of the strata in scout hole DW 1 with the strata outcropping in the western escarpment presents no major problems, although it is rather difficult to decide the exact position of lower limit of Unit 6a.

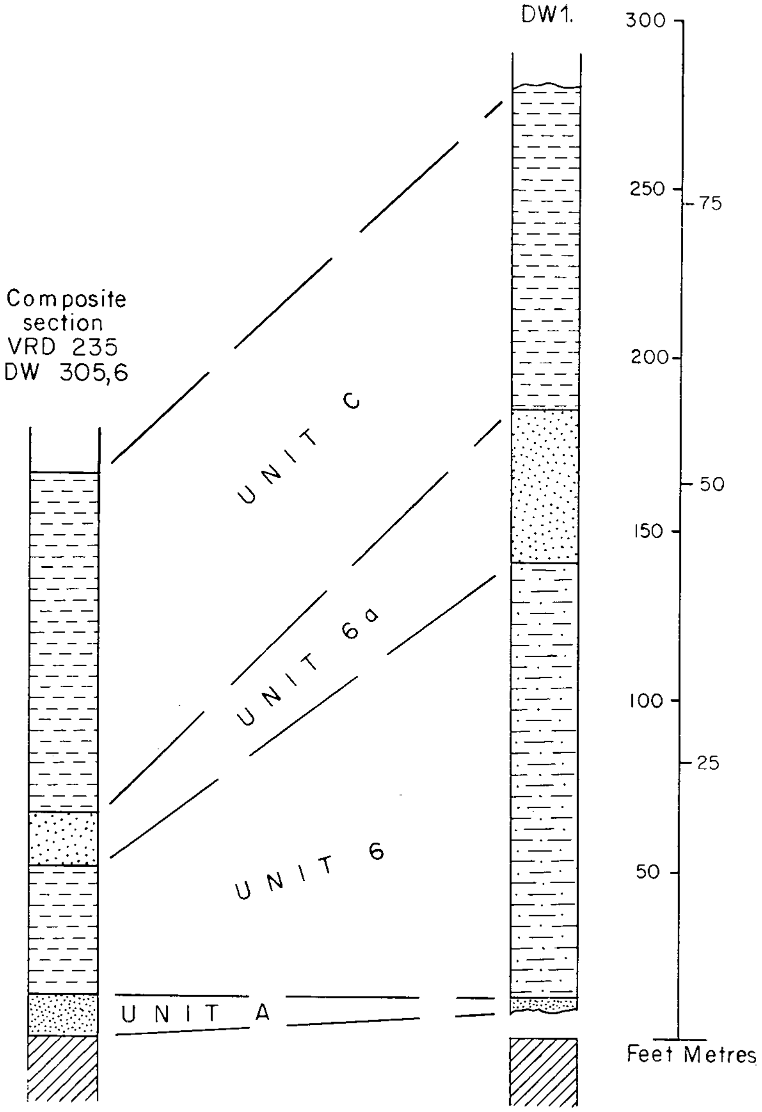


Fig. 5. Preliminary correlation of two of the more important Cretaceous sections in the Wiso Basin, N.T.

PALAEONTOLOGY

BIVALVIA

Family MALLETIIDAE Adams & Adams, 1858

Genus PHAENODESMIA Bittner, 1894

Type species: *Phaenodesmia klipsteiniana,* SD Diener, 1923.

PHAENODESMIA cf. ELONGATA (Etheridge Snr, 1872)

(Pl. 21, figs 2, 3, 6)

Material. Numerous though mostly incomplete and crushed external and internal impressions of both valves from localities DW 313, DW 240, VRD 241, VRD 243, and possibly DW 206.

Description. The shell is equivalve, strongly produced to the rear, moderately inflated with orthogyrous depressed umbo situated in the anterior third of the shell.

The anterodorsal shell margin is slightly concave. The anterior margin is strongly convex. The ventral margin is not uniformly convex but swings upwards at the rear, becoming almost straight before meeting the cardinal margin.

The escutcheon is narrow and concave and striated with growth-lines. The carina separating it from the rest of the shell is well marked. The external lineation consists of concentric growth-lines which are neither very uniformly spaced nor uniformly prominent, and which may be entirely absent from some specimens.

The dentition consists of two narrow rows of very small teeth, one of which is in front of and one behind the umbo. Details of musculature and pallial line are not preserved.

Discussion. In his revision of Cretaceous Palaeotaxodontida of the Maryborough Formation of eastern Queensland, Fleming (1966) reversed Etheridge's opinion regarding the synonymy of *Leda elongata* Etheridge Snr, 1872, and *Nucula randsi* Etheridge Jnr, 1892, retaining them as separate species of *Phaenodesmia* Bittner. It would seem from the list of differences between the two species (Fleming, 1966, p. 11) that little difficulty is encountered in separating the two in the Maryborough Formation. This is not the case with the specimens present in the fauna of the Wiso Basin sediments, but these are insufficiently well preserved to enable all morphological characters to be considered. Our specimens combine a lack of concentric ribbing, which is regarded by Fleming as typical of *randsi,* with an uneven ventral margin resulting in the uplifted appearance of its rear portion, which Fleming regards as typical of *elongata.* No specimens in our collection show complete dentition, but enough is visible for comparison with the uniformly thinner hinge plate of *elongata* rather than with the more spindle-shaped form, particularly of its front part, of *randsi.*

Family PARALLELODONTIDAE Dall, 1898

Genus GRAMMATODON Meek & Hayden, 1861

Type species: *Arca* (*Cucullaea*) *inornata* Meek & Hayden, 1859; OD

Subgenus INDOGRAMMATODON Cox, 1937

Type species: *Cucullaea virgata* J. de C. Sowerby, 1840; OD

GRAMMATODON (INDOGRAMMATODON) ROBUSTA (Etheridge Snr, 1872)

(Pl. 21, figs 1, 5, 8, 11, 14, 17)

1872 *Cucullaea robusta* Etheridge Snr, *Quart. J. geol. Soc. Lond.,* 28, 340, pl. 20, fig. 1.
1872 *Cucullaea costata* Etheridge Snr, *Quart. J. geol. Soc. Lond.,* 28, 340, pl. 20, fig. 2.
1892 *Cucullaea robusta* Etheridge Snr; Etheridge Jnr, *Geol. Surv. Qld Publ.* 92, 565, pl. 26, figs 1, 4.
1902 *Idonearca? robusta* (Etheridge Snr); Etheridge Jnr, *Mem. Roy. Soc. S. Aust.,* 2(1), 27.
1966 *Grammatodon* (*Indogrammatodon*) *robusta* (Etheridge Snr); Fleming, *Geol. Surv. Qld Publ.* 333, *palaeont. Pap.* 7. 14-16, pl. 5, figs 1-5; pl. 6, figs 1-4.

Material. Two almost complete external impressions of a set of mature valves, incomplete external impression of an immature valve, and a complete internal impression of a right valve, all from locality DW 310; external impression of a small portion of a valve from locality DW 313; external impression of both valves (incomplete) of immature specimens from locality VRD 243; some fragments from localities VRD 240-241.

Description. The bivalve is strongly inflated, asymmetrical, produced to the front more strongly than to the rear. The largest valve is 60 mm long, and its height and depth, which are altered by compression of the sediments, are 35 mm and 18 mm respectively.

The umbo is conspicuous, prosogyrous, incurved, bounded on the rear by an obtuse and ill defined post-umbonal carina. The dorsal cardinal margin is straight; the ligamental margin is sharp. The ligamental area is triangular, lined with 25 chevron-shaped, parallel, and evenly spaced striae, which cover its entire surface area.

The exterior ornament of the shell consists of prominent concentric growth-lines and rugae which parallel the lines of growth, and of two orders of radial ribs. There are 16 primary radial linear ribs, which originate at the tip of the umbo and proceed distally, diverging from each other and increasing in breadth only very slightly. Their spacing is regular. There are six secondary ribs between each pair of primary ribs. These are of lesser relief and occupy the broad and flat interspaces separating the primaries.

Family MYTILIDAE Rafinesque, 1815

Genus EYRENA Ludbrook, 1966

Type species: *Modiola linguloides* Hudleston, 1884

EYRENA? sp. indet.

(Pl. 21, fig. 4)

The material consists of a single proximal fragment of an internal cast from locality VRD 243 and is probably referable to *Eyrena,* but because of unsatisfactory preservation no definite determination is possible. Hitherto three Australian bivalves have been referred to *Eyrena*: *linguloides* (Hudleston, 1884) from the Aptian of Queensland and South Australia, *tatei* (Etheridge Jnr, 1902) from the Aptian of South Australia, and *primulafontensis* (Etheridge Jnr, 1902) from the Albian of South Australia.

Family LUCINIDAE Fleming, 1828

?Subfamily MILTHINAE Chavan, 1969

?Genus GIBBOLUCINA Cossman, 1904

Type species: *Venus callosa Lamarck,* 1806; OD

?Subgenus EOMILTHA Cossman, 1910

Type species: *Lucina contorta* Defrance, 1823; OD

?EOMILTHA sp.

(Pl. 21, fig. 15)

A single external impression of a left valve from locality VRD 228 is somewhat crushed and its overall shape somewhat distorted. It is ornamented with about 30 fairly regularly distributed concentric costae which are very narrow, sharp-ridged, and much narrower that flat-bottomed interspaces which separate them. It has some obvious similarities with *Eomiltha,* though lack of preserved dentition renders any generic determination speculative.

Family OXYTOMIDAE Ichikawa, 1958

Genus PSEUDAVICULA Hudleston, 1890

Type species: *Lucina anomala* Moore, 1870

'PSEUDAVICULA ANOMALA' (Moore, 1870)

(Pl. 21, fig. 10)

1870 *Lucina anomala* Moore, *Quart. J. geol. Soc. Lond.*, 26, 251, pl. 14, fig. 4.
1966 *Pseudavicula anomala* (Moore); Lubrook, *Bull. geol. Surv. S. Aust.*, 40 (for synonymy).

Material. One internal and one external impression of left valve, from localities DW 313 and VRD 243.

Discussion. The specimens of *Pseudavicula* are identical with forms described as *'Pseudavicula anomala'* (Moore, 1870) from the Gibson Desert collections (Skwarko, 1967) and indeed with the specimens of *P. anomala* from the type locality in eastern Australia. In the Gibson Desert *P. anomala* occurs as solitary specimens; our specimens occur in pairs but do not form matte surfaces characterizing occurrences of *Pseudavicula* in the Rumbalara area as well as in eastern Australia. *P. anomala* is one of the key fossils in sediments of Aptian age in Australia.

Family HIATELLIDAE Gray, 1824

Genus PANOPEA Menard, 1807

Type species: *Panopea faujasi* Menard, 1807

PANOPEA cf. MACCOYI (Moore, 1870)

(Pl. 21, fig. 7)

An incomplete impression of the exterior of a right valve of a *Panopea* from locality DW 310 is probably referable to *P. maccoyi* (Moore, 1870), originally described from the Aptian strata of the Roma area, eastern Queensland. Its size differentiates it from a similarly ribbed but smaller Albian species *P. aramacensis* (Etheridge Jnr, 1892).

Bivalve gen. et sp. indet.

(Pl. 21, fig. 18)

A single, small, right(?) valve from locality VRD 240 has well developed and complex radial ornament which will easily identify it should more specimens be collected.

It is much inflated and broadly sickle-shaped; it has a concave posterodorsal margin and is convex elsewhere, with greatest convexity in the posterior margin. The whole surface is ornamented with radial ribs of two orders and concentric growth striae. The primary ribs number about 11 and are evenly convex in cross section. They are thin proximally, but increase in breadth evenly and fairly rapidly distally so that close to the periphery they are quite robust. They are separated from each other by concave interspaces which equal them in breadth in the distal portion of the shell, but are wider on the umbo. There is a single linear riblet in each interspace, and three on each primary rib.

There is no record of this species having been reported in the Australian literature.

CEPHALOPODA

Order AMMONITIDA

Superfamily ANCYLOCERATIDA Meek, 1876

Family LABECERATIDAE Spath, 1925

Genus LABECERAS Spath, 1925

Type species: *Labeceras bryani* Whitehouse, 1926

LABECERAS aff. TAYLORI (Etheridge Jnr, 1892)
(Pl. 21, fig. 12)

A single, poorly preserved lateral impression of the exterior wall of a specimen from locality DW 313 may be that of *Labeceras taylori,* originally described from Aptian sediments from the Walsh River area in northern Queensland. Preservation is insufficient for a definite identification.

GASTROPODA

Family NERITOPSIDAE Grey, 1847

Genus NERITOKRIKUS Skwarko, 1966

Type species: *Neritokrikus tuberosus* Skwarko, 1966

NERITOKRIKUS TUBEROSUS Skwarko, 1966
(Pl. 21, figs 13, 16)

Material. Three almost complete specimens, one from locality DW 314 and two from locality DW 305.

Discussion. N. tuberosus occurs sparingly in the Mullaman Beds. In the Wiso Basin area it seems to be limited in occurrence to sediments included in Unit 6a, while in the Coastal Belt Suite it was identified from both Unit 6 and Unit 6a. *N. tuberosus* is an Aptian fossil, but the horizon in which it occurs (Unit 6 and Unit 6a) is probably stratigraphically lower than the widespread Roma Formation faunal horizon of the Great Artesian Basin.

DESCRIPTION OF FOSSIL-BEARING LOCALITIES AND THEIR CONTENT

Larrimah 1:250 000 Sheet Area

L 201 10 km south along track from No. 5 bore, Dry River Stock Route, on west side of track, near level of creek bed. Run 4, photo 5159, point L 201. Collected by M. C. Brown, October 1966.
Bivalves indet.

Daly Waters 1:250 000 Sheet Area

DW 206 Low, lancewood-covered hill, 91 m north of Top Springs/Dunmarra road, about 45 m NNW from DW 207, and 2 km east from No. 14 bore (Murranji Stock Route). Fossil band is about 2 m below top of hill. Run 6, photo 5140, point DW 206. Collected by M. C. Brown, M. A. Randal, and D. J. Guppy, August 1966.
?Phaenodesmia cf. *elongata* (Etheridge Snr, 1872)
'Trigonia' sp. indet. juv.
Fragments of large bivalves indet.
Belemnites fragments indet.

DW 207 Low knoll of white rocks covered by lancewood, on north side of Top Springs/Dunmarra road, about 2 km east of No. 14 bore (Murranji Stock Route). Fossils occur about 46 cm below the top of the knoll. Run 6, photo 5140, point DW 207. Collected by M. C. Brown, July 1966.
Belemnites indet.

DW 305 In creek crossing Top Springs/Dunmarra road, almost 8 km WNW from turn-off to No. 13 bore (Murranji Stock Route). Run 6, photo 5140, point DW 305. Collected by S. K. Skwarko, 21/8/1966.
Belemnites not identified.
Rhizocorallium sp.
Worm borings
Neritokrikus tuberosus Skwarko, 1966

DW 306 Near junction of two creeks about 2 km south of Top Springs/Dunmarra road, about 8 km from turn-off to No. 13 bore (Murranji Stock Route). Run 6, photo 5140, point DW 306. Collected by S. K. Skwarko, 21/8/1966.
Rhizocorallium sp.
Worm borings indet.
Neritokrikus tuberosus Skwarko, 1966

DW 310 Just north of Top Springs/Dunmarra road, about 24 km east from Top Springs. Run 6, photo 5140, point DW 310. Collected by S. K. Skwarko, 22/8/1966.

Grammatodon (I.) robusta (Etheridge Snr, 1872)
Panopea cf. *maccoyi* (Moore, 1870)
Unio? sp.
Bivalves indet., 3 spp.
Belemnites indet.
Glyphea cf. *arborinsularis* Etheridge Jnr, 1917

DW 313 0.5 km north of creek situated 10 km north of Nelly waterhole, along Dry River Stock Route. Run 2, photo 5164, point DW 313. Collected by S. K. Skwarko, 23/8/1966.

Grammatodon (I.) robusta (Etheridge Snr, 1872)
'Pseudavicula anomala' (Moore, 1870)
Phaenodesmia cf. *elongata* (Etheridge Snr, 1872)
Small bivalves and gastropods indet.
Labeceras aff. *taylori* (Etheridge Jnr, 1892)
Belemnites not identified

DW 314 Creek crossing on Dry River Stock Route, about 18 km north of Nelly waterhole. Run 2, photo 5164, point DW 314. Collected by S. K. Skwarko, 23/8/1966.

Neritokrikus tuberosus Skwarko, 1966
Rhizocorallium sp.
Worm borings
Belemnites indet.

Victoria River Downs 1:250 000 Sheet Area

VRD 235 About 12 km east from Top Springs (old town site), 1 km SSE from old Katherine/Top Springs road at a point 3 km along road from intersection with new Dunmarra/Timber Creek road. Run 10, photo 5161, point VRD 235. Collected by M. C. Brown, July 1966.

Indeterminate stems and wood fragments

VRD 240 27 km NNE from Killarney homestead on the east side of new Willeroo/Top Springs road and 0.4 km south of creek crossing. Run 3, photo 5077, point VRD 240. Collected by M. C. Brown, July 1966.

Grammatodon (I.) robusta (Etheridge Snr, 1872)
Phaenodesmia cf. *elongata* (Etheridge Snr, 1872)
Bivalve gen. et sp. indet.

VRD 241 27 km NNE from Killarney homestead on west side of new Willeroo/Top Springs road and 0.4 km south of creek crossing. Run 3, photo 5077, point VRD 241. Collected by M. C. Brown, July 1966.

Grammatodon (I.) robusta (Etheridge Snr, 1872)
Phaenodesmia cf. *elongata* (Etheridge Snr, 1872)
Eyrena? sp. indet.
Bivalve fragments indet.
Belemnites indet.

VRD 243 About 30 km NNE from Killarney, on east side of track, 4.6 km in from Katherine/Top Springs road, and about 180 m north of bend to west. Run 2, photo 5007, point VRD 243. Collected by M. C. Brown, July 1966.

Grammatodon (I.) robusta (Etheridge Snr, 1872)
'Pseudavicula anomala' (Moore, 1870)
Phaenodesmia cf. *elongata* (Etheridge Snr, 1872)
Eyrena? sp. indet.
Bivalves indet.
Ammonite fragments indet.
Belemnites indet.

Delamere 1:250 000 Sheet Area

DL 313 In escarpment, on both sides of track along fence running east-west in the extreme northeastern corner of sheet area. Run (Larrimah) 1, photo 5103, point DL 313. Collected by S. K. Skwarko, 31/8/1966.

Neorhacopteris minuta White
Microphyllopteris gleichenioides Oldham & Morris
Otozamites bengalensis Oldham & Morris

DL 310 First Cretaceous mesa along road southeast of Augusta Crown. Run 5, photo 5163, point DL 310. Collected by S. K. Skwarko, 26/8/1966.

Ptilophyllum sp.

REFERENCES

CRESPIN, I., 1963—Lower Cretaceous arenaceous Foraminifera of Australia. *Bur. Miner. Resour. Aust. Bull.* 66.

FLEMING, P. J. G., 1966—Cretaceous Palaeotaxodontida of the Maryborough Formation, south-east Queensland. *Geol. Surv. Qld Publ.* 333, *palaeont. Pap.* 6, 5-11.

LUDBROOK, N. H., 1967—Cretaceous biostratigraphy of the Great Artesian Basin in South Australia. *Geol. Surv. S. Aust. Bull.* 40.

SKWARKO, S. K., 1966—Cretaceous stratigraphy and palaeontology of the Northern Territory. *Bur. Miner. Resour. Aust. Bull.* 73.

SKWARKO, S. K., 1967—Lower Cretaceous Mollusca of the Great Artesian Basin type in the Gibson Desert central Western Australia. *Bur. Miner. Resour. Aust. Bull.* 75

SKWARKO, S. K., 1968—Lower Cretaceous Trigoniidae from Stanwell, eastern Queensland. *Bur. Miner. Resour. Aust. Bull.* 80, 10.

TERPSTRA, G. R. J., 1967—Report on the micropalaeontological examination of samples of scout bores D.W. 1 and D.W. 1B (Wiso Basin). *Bur. Miner. Resour. Aust. Rec.* 1967/45 (unpubl.).

VEEVERS, J. J., and WELLS, A. T., 1961—The geology of the Canning Basin, Western Australia. *Bur. Miner. Resour. Aust. Bull.* 60.

APPENDIX

THE AGE OF UNIT 2, MULLAMAN BEDS

The suggested Neocomian age of Unit 2 of the Mullaman Suite of sediments (Skwarko, 1966) has recently been questioned (Speden, 1969; Day, 1968). Unit 2 does not occur in the Wiso Basin (Skwarko, this vol.) but, as its fauna is more prolific than that from any other unit of the Mullaman Beds and as the age of other units in the Mullaman Beds, including those at the base of the sequence in the Wiso Basin, is partly based on relationships with Unit 2, it seems appropriate to discuss its age here.

Speden (1969, p. 148) preferred an Aptian age to a Neocomian one for the unit for the following reasons:

1. 'The presence in Skwarko's Units 2 and 4 of species either identical with or very similar to species characteristic of the Aptian-Albian of the Great Artesian Basin, e.g. *Fissilunula clarkei* (Moore), *Thracia primula* Hudleston, *Maccoyella* cf. *corbiensis, Nototrigonia* cf. *cinctuta* (Etheridge), *Panopea* cf. *sulcata* Etheridge, and *Tatella* cf. *aptiana* Whitehouse.'
2. Uncertainty of the taxonomic position of the Maccoyellas in Unit 2 (and Unit 4).
3. The presence of many new species, coupled with a lack of concrete evidence of their range.

Speden is under a misapprehension, as, with the exception of *Maccoyella* cf. *corbiensis,* all the species listed by him from Unit 2 occur instead in younger beds (Unit 4 or younger) or, in the case of *Tatella?* aff. *aptiana* (not *Tatella* cf. *aptiana*), occur in Units 2 and 6.

It is not practicable to discuss the taxonomic position of the Maccoyellas here. It is significant, however, that the lower limit of most of the Aptian Great Artesian Basin bivalves, including the Maccoyellas, is poorly known and some at least range up from the Neocomian-Aptian transition beds in the Northern Territory (Skwarko, 1966).

The difficulty of relating the different units of the Mullaman Beds has already been stressed (Skwarko, 1966, pp. 63-67) and the study in the Wiso Basin is particularly rewarding in adding further lithological and palaeontological evidence on the lateral persistence of Units A, C, and 6a. This study along with that recorded in Skwarko (1967) adds further evidence on the lateral persistence of the Aptian and Albian (Roma and Tambo) assemblages irrespective of the rock type in which they occur. This gives some assurance that the different suite of species found in a stratigraphically lower position in Unit 2 is of Neocomian age.

Day (1968) in his unpublished thesis has correlated Unit 2 with the Aptian Minmi Member on the basis of the close relationship of *Pseudavicula dickinsi* with *Meleagrinella woodsi* and the occurrence of *Australiceras jacki* (Etheridge Jnr) in Unit 2. He also considered that the trigoniid species of Unit 2 are distinct from the Neocomian trigoniids described from Stanwell, Queensland (Whitehouse, 1946; Skwarko, 1963).

P. dickinsi, however, has surface ornament substantially different from that of *M. woodsi* and is rather similar to a new species of *Meleagrinella* described by Day (1967) from the Nullawurt Member of the Blythesdale Formation, which Day regards as Neocomian.

The supposed occurrence of *Australiceras jacki* in Unit 2 is based on a misunderstanding as the ammonite was identified as a new species of *Australiceras* with similarities to *A. jacki,* i.e. *A.* sp. nov. aff. *A. jacki* (Skwarko, 1966, p. 123).

The trigoniid species in Unit 2 are certainly different specifically from those in the Stanwell Beds and also from those in the Neocomian assemblage of the Nanutarra Formation (Skwarko, 1966, pp. 67-68). This is in keeping with my original suggestion. In Aptian-Albian times a large portion of the Australian continent was inundated beneath the shallow sea of the Great Artesian Basin and bivalve faunas found conditions particularly favourable to long-distance migrations. In Neocomian times, however, the continent was only locally inundated along its peripheries. The faunas which evolved in the individual Neocomian embayments therefore found it difficult to intermingle. Hence the lack of similarities at specific level. I have also, however, pointed out the striking similarity of the Neocomian assemblages at generic level (Skwarko, 1966, pp. 67-88; 1968, pp. 171-172).

Although the arguments against a Neocomian age for Unit 2 do not seem very convincing it is too early to regard the matter as finally settled. Of the considerable volume of recent work done on the Cretaceous faunas of the Great Artesian Basin, some of it shows their extraordinary lateral persistence (Skwarko, 1967), while other, such as the unpublished work in the Cape York Peninsula, brings to light local development of diverse faunas. These very recent studies, the results of which it is too early to evaluate, show great need for a thorough, systematic, and detailed observation and collecting combined with a purely palaeontological systematic study. It is doubtful whether an accurate overall picture of the palaeogeography of the Cretaceous of eastern Australia will be forthcoming without such a study.

REFERENCES

DAY, R. W., 1967—Marine Lower Cretaceous fossils from the Minmi Member, Blythesdale Formation, Roma-Wallumbilla area. *Geol. Surv. Qld Publ.* 335. *Palaeont. Pap.* 9, 1-30.

DAY, R. W., 1968—Biostratigraphy and taxonomy of Lower Cretaceous molluscan faunas from the Queensland portion of the Great Artesian Basin. *Aust. Nat. Univ. Dep. Geol. Ph. D. Thesis, Canberra, A.C.T.* (unpubl.).

SKWARKO, S. K., 1963—Australian Mesozoic trigoniids. *Bur. Miner. Resour. Aust. Bull.* 67.

SKWARKO, S. K., 1966—Cretaceous stratigraphy and palaeontology of the Northern Territory. *Bur. Miner. Resour. Aust. Bull.* 73.

SKWARKO, S. K., 1967—Lower Cretaceous Mollusca of the Great Artesian Basin type in the Gibson Desert, central Western Australia. *Bur. Miner. Resour. Aust. Bull.* 75.

SKWARKO, S. K., 1968—Lower Cretaceous Trigoniidae from Stanwell, eastern Queensland. *Bur. Miner. Resour. Aust. Bull.* 80.

SKWARKO, S. K. (this vol.)—Cretaceous stratigraphy of part of the Wiso Basin, Northern Territory.

SPEDEN, I. G., 1969—Lower Cretaceous marine fossils, including *Maccoyella* sp., from the Whatarangi Formation, east side of Palliser Bay, New Zealand. *Trans. Roy. Soc. N.Z. Geol.,* 6(12), 143-153.

WHITEHOUSE, F. W., 1946—A marine early Cretaceous fauna from Stanwell (Rockhampton district). *Proc. Roy. Soc. Qld,* 57, 7-20, pl. 1.

PLATE 21

Figure

Grammatodon (*Indogrammatodon*) *robusta* (Etheridge Snr, 1872)

?1 Latex cast of impression of interior of juvenile right valve, xl.7, CPC 11499, locality DW 313.

5 Latex cast of impression of ?right valve dentition, xl. CPC 11500, locality DW 310.

8 Latex cast of impression of part of exterior proximal portion of both valves apparently in position, xl. CPC 11501, locality VRD 243.

11 Latex cast of impression of proximal external part of left valve, xl. CPC 11502, locality DW 310.

14 Latex cast of impression of exterior of right valve, xl. CPC 11503, locality DW 310.

17 Internal impression of right valve, xl. CPC 11504, locality DW 310.

Phaenodesmia cf. *elongata* (Etheridge Snr, 1872).

2 Internal impression of immature right valve, xl. CPC 11505, locality VRD 243.

3 Internal cast of left and right valves, xl. CPC 11506, locality VRD 241.

6 Internal cast of mature left valve, xl. CPC 11507, locality ?VRD 241.

Eyrena? sp. indet.

4 Internal cast of proximal portion of left valve, xl. CPC 11508, locality VRD 243.

Panopea cf. *maccoyi* (Moore; 1870)

7 Latex cast of incomplete external impression of right valve, xl. CPC 11509, locality DW 310.

Unio? sp.

9 Latex cast of external impression of right valve, xl. CPC 11510, locality DW 310.

'Pseudavicula anomala' (Moore, 1870)

10 Two impressions, xl. CPC 11511, locality VRD 243.

Labeceras aff. *taylori* (Etheridge Jnr, 1892)

12 Incomplete lateral impression of shell, xl. CPC 11512, locality DW 313.

Neritokrikus tuberosus Skwarko, 1966

13 Latex cast of impression of somewhat abraded rear portion of shell, xl. CPC 11513, locality DW 314.

16 Latex cast of impression of front portion of shell, xl. CPC 11514, locality DW 314.

Eomiltha? sp.

15 Latex cast of external impression of left valve, xl. CPC 11515, locality VRD 228.

Bivalve gen. et sp. indet.

18 Latex cast of external impression of right valve, x3. CPC 11516, locality VRD 240.

1

2

3

4

5

6

7

8

9

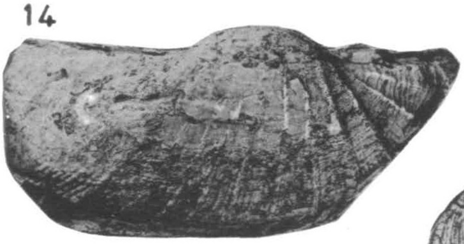
10

11

12

13

14

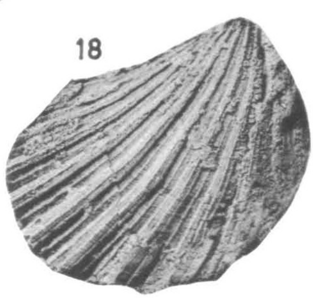


15

16

17

18



FIRST REPORT OF DOMERIAN (LOWER JURASSIC) MARINE MOLLUSCA FROM NEW GUINEA

by S. K. SKWARKO

SUMMARY

A small and rather poorly preserved collection of fossils from the South Sepik region is evidence of marine sedimentation in the Domerian (upper Pliensbachian) times in eastern New Guinea. It contains *Arieticeras* Seguenza, an ammonite known from the Domerian strata in the Euro-African region.

Although Jurassic seas covered most of the mainland of New Guinea, and large marine fossils of Upper Jurassic and Middle Jurassic age are widespread in that area, in the Lower Jurassic the seas might have been present much more locally.

ACKNOWLEDGEMENTS

I wish to thank Professor D. T. Donovan, University College, London, for his verification of the identity of the ammonite fragments.

INTRODUCTION

The fossils from New Guinea which are the basis of the present paper were recently collected by R. J. Ryburn of the Bureau of Mineral Resources in the course of regional mapping in the mountains to the south of the Sepik River.

The collection is small and rather poorly preserved, but owes its importance to the fact that it is the first and hitherto only evidence of marine conditions of sedimentation in mainland New Guinea in Domerian (upper Pliensbachian) times.

The fossils were collected on a foot-track near Yuat River, which is the site of the recent discovery of marine Middle and Upper Triassic sediments (Skwarko, 1973), and Ryburn's description of the locality is as follows: 'Locality No. 11NG 2652. Loose rubble on track to the north of Yalifa II in Kingerum River, a western tributary of the Yuat River, in the northeastern corner of Wabag 1:250 000 Sheet area. Photo reference: Avieme 5, Ph. 5005, Pt 2652. Long. 143°53′00″, Lat. 5°3′00″. Collected 5 October 1967'.

The sediments containing the fauna discussed were mapped as the Kana Formation (Fig. 1), but, as the age of this formation is Upper Triassic, it would seem that they should rather be referred to the Lower Jurassic Balimbu Greywacke, which in part is similar to the Kana Formation (Dow, Smit, Bain, & Ryburn, 1972).

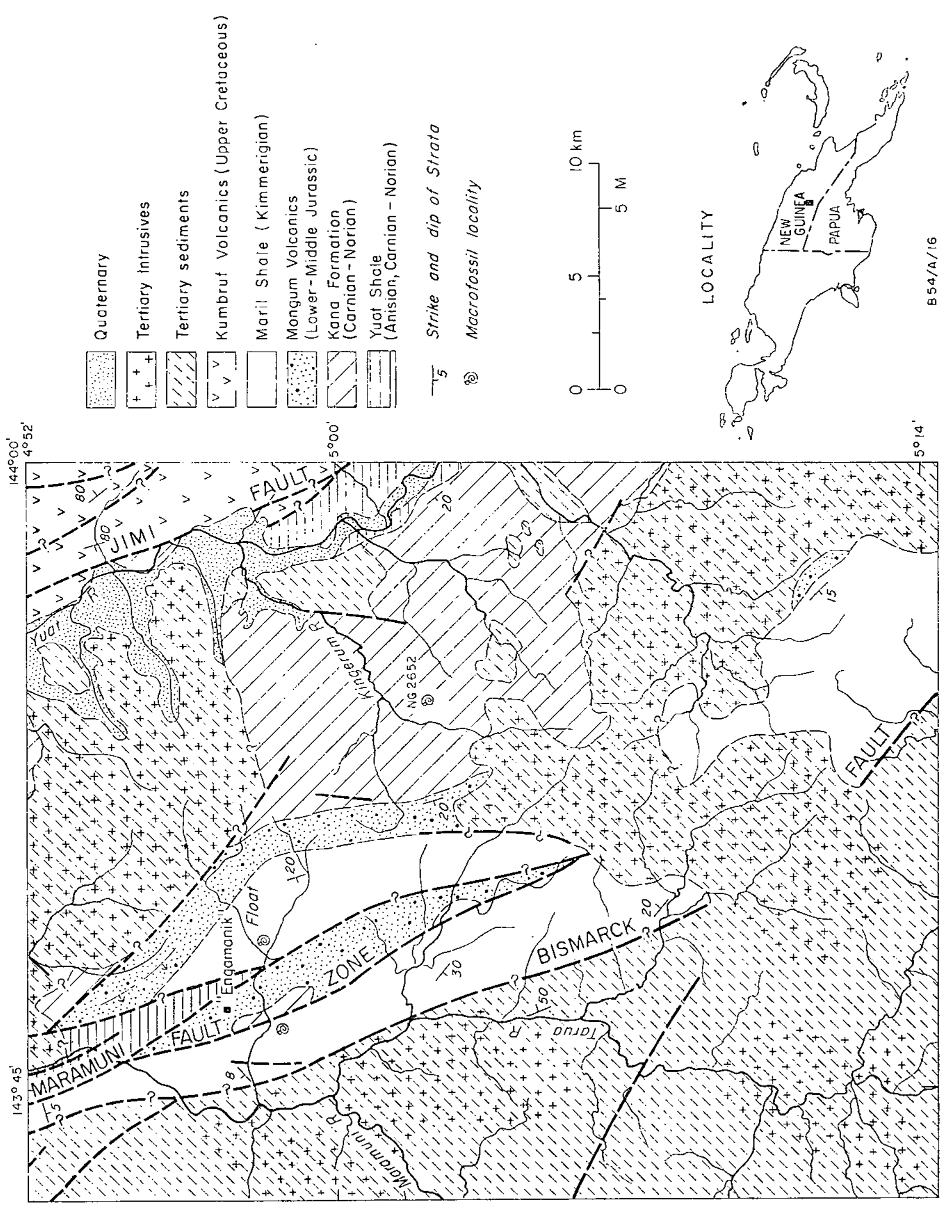


Fig. 1. Locality map of the collection site and its relationship to the Yuat middle and upper Triassic sites.

MARINE JURASSIC STRATA AND FOSSILS IN NEW GUINEA

It is difficult to speak authoritatively of the Jurassic strata and faunas in New Guinea, as much of the detailed information gathered over years of exploration by private oil companies remains unpublished, and many identifications of fossils seem to have been of a preliminary nature only.

The recent description of several ammonites from West Irian by Gerth (1965) and the very recent revision of the Middle Jurassic ammonites from the whole of

New Guinea by Westermann & Getty (1970) are exceptions to this. The latter work also contains an exhaustive bibliography of all the early palaeontological work on this subject. In stratigraphy two major sources of information have been prepared recently, one by the Australasian Petroleum Company Pty Ltd (1961) which summarizes the data gathered from the Territory of Papua, and another by Visser & Hermes (1962) which is concerned with West Irian. Drawing heavily on these, as well as on the work carried out in recent years by the geologists of the Bureau of Mineral Resources, some of which is published, Thompson (1967) and Harrison (1969) compiled concise reviews of the geological and sedimentary history of New Guinea.

Four generalizations on the development of the Jurassic in New Guinea can be made from the available data:

1. The molluscs, almost to the complete exclusion of other marine groups of fossils, have been used in New Guinea for the identification of Jurassic sediments and in establishing their depositional environment.
2. The outcrops of Jurassic marine sediments are limited to the axial ranges: these are mainly deeper-water sediments.
3. South of the axial ranges there are subsurface occurrences of Jurassic strata tonguing to the south and becoming shallower and finally non-marine in that direction.
4. Although the Jurassic seas were generally widespread over New Guinea so far there is little evidence for more than limited marine conditions in Lower Jurassic times.

Lower Jurassic Faunas

Until very recently the only sediments of possible Lower Jurassic age in New Guinea were from the Strickland Gorge where . . . 'the ammonite shales at the base of the section contained harpoceratid ammonites provisionally identified as Lower Jurassic, or lowermost Middle Jurassic' (APC, 1961, p. 19-20).

Sediments of probable Sinemurian-Pliensbachian age were recently reported from the Jimi River area in the Central Highlands (Skwarko, 1967), their dating was based on the identification of *Paltechioceras?* sp. (upper Sinemurian) and *Tropidoceras?* sp. (lower Pliensbachian) from the Balimbu Greywacke. It would seem that the specimen identified as *Tropidoceras?* sp. could equally or more probably be *Asteroceras* (D. T. Donovan, pers. comm.). As the genus *Asteroceras* is confined to Sinemurian strata, the age of the Balimbu Greywacke would seem to be upper Sinemurian, at least in part, on that evidence alone.

The discovery of the small and poorly preserved fauna of upper Pliensbachian age in the Yuat River area thus fills another gap in the known Jurassic stratigraphic column in eastern New Guinea.

The small collection of fossils contains:

Arieticeras sp. indet.
Pseudolimea cf. *duplicata* J. de C. Sowerby, 1827
Plagiostoma? sp.
Pectinacea gen. et spp.
Gastropod frag. indet.
Echinoid spine

Only one of these (the ammonite) is suitable for close dating of the assemblage. It probably belongs to the genus *Arieticeras* Seguenza, but it could be *Arnioceras* Hyatt (D. T. Donovan, pers. comm.). Both genera are useful for dating; *Arieticeras* is confined to the Domerian (upper Pliensbachian) strata of Europe, North Africa, and Caucasus, while *Arnioceras* is limited to rocks of Sinemurian age in Europe, North Africa, the American continent, and also in Indonesia and New Caledonia.

The worldwide distribution of *Arnioceras* would suggest that it, rather than *Arieticeras,* is the genus more likely to be present in New Guinea Jurassic sediments, although recent collecting of fossils on the island and the consequent study has considerably increased our knowledge of ammonite distribution in Mesozoic times. The ribbing on our specimens however is sigmoidal; as ribbing of this type is absent from *Arnioceras* but present on *Arieticeras* I follow Donovan's suggestion regarding their identity. This extends the time range of the Balimu Greywacke once again to Sinemurian-Pliensbachian. Obviously, however, additional material would be welcome.

MIDDLE JURASSIC FAUNAS

Westermann & Getty (1970) revised all the known Middle Jurassic ammonites of New Guinea.

The lower Bajocian is now known to contain:
Docidoceras (*Docidoceras*) *longalvum* cf. *limatum* (Pompeckj)
Fontannesia aff. *clarkei* Crick (subsp. *kiliani* (Kruizinga))
Pseudotoites (*Latotoites*) cf. *woodwardi* (Crick)
Pseudotoites sp.

The middle Bajocian contains:
Chondroceras (*Defonticeras*?) *boehmi* Westermann
'Itinsaites' cf. *intisae* McLearn
'Itinsaites' aff. *mackenzii* McLearn
Stephanoceras (*Stephanoceras*) aff. *humphriesianum* (Sowerby)
Stephanoceras (*Stephanoceras*) sp.
Stephanoceras (*Stemmatoceras*) *etheridgei* (Gerth)
Stephanoceras (*Stemmatoceras*) cf. *frechi* (Rentz)
Stephanoceras (*Stemmatoceras*) cf. *palliseri* (McLearn)
Stephanoceras (*Teloceras*) cf. *itinsae* (McLearn)
Stephanoceras s.l.

Only one species, *Chondroceras* (*Praetulites*) *kruizingai* Westermann, has been referred to the upper Bajocian, though *Cadomites?* ex. gr. *C. rectelobatus* (Hauer) is regarded as a Bajocian/Bathonian boundary form.

Possible Bathonian is represented by:
Bullatimorphites (?) (*Treptoceras?*) *costidensus* Westermann & Getty
Bullatimorphites (?) (*Treptoceras?*) aff. *microstoma* (d'Orbigny)
Bullatimorphites (*Treptoceras*) aff. *uhligi* (Popovici-Hatzeg)
Bullatimorphites (*Treptoceras?*) n. sp. A Westermann & Getty
Bullatimorphites? n. sp.
?Tulites godohensis (Boehm)
Cobbanites (?) aff. *engleri* (Frebold)

Bullatimorphites also probably represents in part the lower Callovian, in addition to the following:

Holcophylloceras mamapiricum (Boehm)
Irianites moermanni (Kruizinga)
Macrocephalites (*'Dolikephalites'*) *flexuosus* Spath
Macrocephalites (*'Dolikephalites'*) *keeuwensis* Boehm
Macrocephalites (*'Dolikephalites*) *cf. keeuwensis* Boehm
Macrocephalites (*'Kamptocephalites'*) *etheridgei* Spath
?Macrocephalites (*'Kamptocephalites'*) sp.
Macrocephalites (*'Pleurocephalites'?*) sp.

The middle Callovian contains five forms:
(*?*) *Eucycloceras intermedium* Spath
Idiocycloceras cf. *bifurcatum* (Boehm)
Idiocycloceras?
Subkossmatia obscura boehmi Westermann & Getty
Subkossmatia sp.?

Belemnites and rare bivalves are associated with the numerous specimens of ammonites and these await detailed examination. The Wok Feneng section in the headwaters of the Fly River yielded the presumably Callovian bivalve *Grammatodon* (*Indogrammatodon*) (APC, 1961, p. 18), although this subgenus is now known to range up into at least Aptian strata in Australia.

UPPER JURASSIC FAUNAS

In Papua New Guinea the Upper Jurassic sediments are more widespread than Lower and Middle Jurassic. Faunistically the association of *'Buchia' malayomaorica* and *Inoceramus* spp. is very common in the extensively outcropping Maril Shale in New Guinea. In Papua, Upper Jurassic strata and macrofossils have been encountered both in outcrop and subsurface. In Aramia No. 1 Bore the following were found:

Belemnopsis cf. *tanganensis* (Futterer)
Inoceramus
Grammatodon
Entolium cf. *orbiculare* (J. Sowerby) (APC, 1961, pp. 11, 15)

The association of *Belemnopsis gerardi* and *'Buchia' malayomaorica* at the top of the Wok Feneng section indicates Oxfordian age (APC, 1961, p. 18). The upper part of the Telefomin section is also Upper Jurassic in age (APC, 1961, p. 20).

Iehi No. 1 Bore contains *Inoceramus haasti* (APC, 1961, p. 23) and Omati No. 1 Bore contains *Buchia subpallasi* Krumbeck, *Belemnopsis* cf. *alfuricus* Boehm, and *Nucula* sp., indicating Oxfordian age (APC, 1961, p. 25).

In West Irian the Oxfordian faunas include:
Belemnites gerardi Oppel
Inoceramus galoi Boehm
?Pseudomonotis sp.
Posidonomya sp.
?Avicula sp.
?Gryphaea sp.
Peltoceras sp.
Grammatodon (*Indogrammatodon*) *virgatus* (Sowerby)
(Visser & Hermes, 1962, p. 54-55).

On the island of Misool the Upper Jurassic (Oxfordian, Kimmeridgian, Tithonian) is well represented by abundant fossils, of which the cephalopods and bivalves are the most important (Visser & Hermes, 1962, p. 55).

Recently Gerth (1965) described the following ammonites from the north slopes of the Snow Mountains in West Irian:

Berriasian	*Blanfordiceras novaguinense* Gerth *Blanfordiceras* sp. *Berriasella* sp.
Tithonian	*Pseudoparaboliceras aramarii* Gerth *Perisphinctes* (*Pachyplanulites*) *novaguinense* Gerth
Oxfordian	*Mayaites* cf. *maya* (Sowerby) *Inoceramus galoi* Boehm

DESCRIPTION OF FOSSILS

CEPHALOPODA

Family HILDOCERATIDAE Hyatt, 1867

Subfamily ARIETICERATINAE Howarth, 1955

Genus Arieticeras Seguenza, 1885

Type species: *Ammonites algovianus* Oppel, 1862

Arieticeras sp. indet.

(Pl. 22, figs 8, 9, 11, 12; Text-fig. 2)

Material. One almost complete but distorted specimen (CPC 11496); an impression of a fragment of a keel; fragment of a specimen.

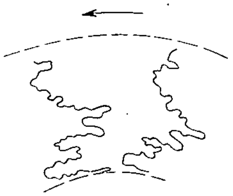


Fig. 2. ***Arieticeras*** **sp. indet. Suture pattern, x3.3. CPC 11492.**

Description. The specimen is evolute, about 2 cm high, originally probably well inflated, and strongly ribbed with moderately sigmoidally shaped ribs which do not extend onto the venter. The venter is unicarinate and sharp. The whorls are pseudoquadrate in cross section. The observed suture pattern is illustrated in Figure 2.

Discussion. In the above description no attempt is made to give detailed measurements of the specimens collected. As they are distorted and fragmentary, any specific determination would be in danger of error. For discussion on the generic affinity of the specimens, the reader is referred to pages 107-8.

BIVALVIA

Family LIMIDAE Rafinesque, 1815

Genus PSEUDOLIMEA Arkell *in* Douglas & Arkell, 1932

Type species: *Plagiostoma duplicata* J. de C. Sowerby, 1827

PSEUDOLIMEA cf. DUPLICATA (J. de C. Sowerby, 1827)

(Pl. 22, figs 3, 6)

Material. Seven mostly incomplete and distorted external and internal impressions of right and left valves.

Description. The bivalve is small, less than 12 mm long. It is distinctly ribbed with about 22 strong and rigid radial ribs which radiate out from the umbonal region, diverging distally with regular and fairly rapid increase in breadth. The interspaces are similarly angular and about the same width as the ribs. Each interspace carries a thread-like riblet along its entire length, at least on the left valve. A few widely separated growth rugae slightly offset the surface of each valve.

Discussion. The small size, distinct angular ribbing, and presence of the secondary riblets in the interspaces all label the relatively numerous specimens as *Pseudolimea.* The dentition is not known. The distortion does not allow reconstruction of the original shape and hence specific identification, but the large number of primary ribs on the main portion of the shell is a feature shared also by *P. duplicata.*

Genus PLAGIOSTOMA J. Sowerby, 1814

Type species: *Plagiostoma giganteum* J. Sowerby, 1814

PLAGIOSTOMA? sp.

(Pl. 22, figs 4-5)

Material. One specimen consisting of an external and an internal impression of a right valve. The specimen is slightly crushed in the umbonal region.

Description. The shell is 16 mm high and 20 mm long, moderately strongly inflated, with a well defined rather sharp beak and very evenly rounded anterior and ventral shell margins. Exterior sculpture consists of two prominent, impressed, constricting growth rugae and very weak, very closely spaced radial lineations.

Discussion. The overall shape of the shell is that common to the Limidae, and the virtual lack of any kind of ornament would suggest *Plagiostoma.* The two concentric growth-rings are uncommonly strong, however, constricting the shell surface in their vicinity to a degree not usually encountered in this genus.

GASTROPODA

Gastropod sp. indet.

(Pl. 22, fig. 10)

A fragment of a gastropod representing a large portion of the base of a shell probably belongs to a broad, low-spired pleurotomariid, but being incomplete it is unidentifiable. It is illustrated here, as its detailed structure should allow it to be identified if more complete specimens are found.

The shell is striated with even, low, concentric ribs of equal and uniform width separated from each other by a narrow and shallow interspace. Each rib is divided into secondary riblets by a linear shallow groove extending along its middle. Fine diagonal lines of growth impart a minute though regular striation pattern to the ribs.

REFERENCES

APC [AUSTRALIAN PETROLEUM COMPANY PTY LTD], 1961—Geological results of petroleum exploration in western Papua. *J. geol. Soc. Aust.*, 8(1), 1-133.

DOW, D. B., SMIT, J. A. J., BAIN, J. H. C., and RYBURN, R. J., 1972—The geology of the South Sepik Region. *Bur. Miner. Resour. Aust. Bull.* 133.

GERTH, H., 1965—Ammoniten des Mittleren und Oberen Jura und der ältesten Kreide vom Nordabhang des Schneegebirges in New Guinea. *Neues Jb. Geol., Abh.* 121(8), 209-18.

HARRISON, J., 1969—Review of the sedimentary history of the island of New Guinea. *APEA J.*, 41-8.

SKWARKO, S. K., 1967—Mesozoic fossils from eastern New Guinea. a. First Upper Triassic and ?Lower Jurassic marine Mollusca from New Guinea; *in* Mesozoic Mollusca from Australia and New Guinea. *Bur. Miner. Resour. Aust. Bull.* 75, 37-83.

SKWARKO, S. K., 1973—Middle and Upper Triassic Mollusca from Yuat River, eastern New Guinea; *in* Palaeontological Papers, 1969. *Bur. Miner. Resour. Aust. Bull.* 126.

THOMPSON, J. E., 1967—A geological history of eastern New Guinea. *APEA J.*, 83-93.

VISSER, W. A., and HERMES, J. J., 1962—Geological results of the exploration for oil in Netherlands New Guinea. *Staarsdruk. Uitgeveribedriff.*

WESTERMANN, G. E. C., and GETTY, T. A., 1970—New Middle Jurassic Ammonitina from New Guinea. *Bull. Amer. Paleont.*, 57, 256, 231-318.

PLATE 22

All specimens are at 1.7 magnification, and all are photographed in lateral view unless otherwise stated. The locality is 11NG 2652 and the age is Domerian (Lower Jurassic).

Figure 1	Pectinid indet. Latex casts of external impression of valves. CPC 11489.
Figure 2	Echinoid spine indet. CPC 11490.
Figure 3	*Pseudolimea* cf. *duplicata* J. de C. Sowerby Latex cast of distorted external impression of left valve. CPC 11493.
Figure 6	Latex cast of probably distorted external impression of right valve. CPC 11494.
Figures 4, 5	*Plagiostoma?* sp. Internal cast and latex cast of external impression of right valve. CPC 11495.
Figure 7	*Entolium* sp. indet. External impression. CPC 11491.
Figs 8, 11, 12	*Arieticeras* sp. indet. Latex casts of external impression of incomplete distorted specimen, and its internal cast. CPC 11496. (Figure 12 is at 3.3 magnification.)
Figure 9	Internal cast of fragment of a specimen, possibly undistorted. CPC 11492.
Figure 10	Gastropod sp. indet. Partial impression of base of conch. CPC 11498.

1

2

3

4

5

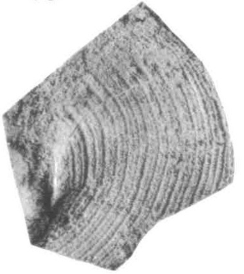
6

7

8

9

10



11

12