

ROBERTSON RESEARCH (SINGAPORE) PRIVATE LIMITED

Report No. 1176

THE BIOSTRATIGRAPHY OF THE
AMOCO AUSTRALIA PETROLEUM CO.
CAPE SORELL-1 WELL,
OFFSHORE WEST TASMANIA, AUSTRALIA

by

G. W. HUGHES
W. P. SEYMOUR
O. VAROL
Y. C. CHOW

Project No. S/I/823/41
January 1983

Prepared for:

Amoco Australia Petroleum Company,
Amoco Building,
201-209 Pacific Highway,
North Sydney,
N.S.W. 2060,
Australia.

OR-0358C

CONTENTS

	<u>Page No.</u>
SUMMARY	
I INTRODUCTION	1
II GENERAL LITHOLOGY, BIOSTRATIGRAPHY AND ENVIRONMENTS OF DEPOSITION	4
EARLY MIOCENE, Interval 690'-990'	4
LATE OLIGOCENE, Interval 990'-1230'	10
EARLY OLIGOCENE, Interval 1230'-1350'	14
MIDDLE-EARLY EOCENE, Interval 1350'-2550'	16
EARLY EOCENE, Interval 2550'-5770'	23
PALAEOCENE, Interval 5770'-11576' T.D.	30
III CONCLUSIONS	37
IV SELECTED REFERENCES	40
APPENDIX I : South East Australia Floral Zonation Scheme (Stover and Partridge, 1973; Stover and Evans, 1973)	
APPENDIX II : Robertson Research (Singapore) Classification of benthonic marine environments (1981), modification of Hedgpeth (1957), Murray (1973), Berggren (1978) and Ingle (1980)	

Tables

1. Biostratigraphic Summary
2. Depositional Environment Summary

Figures:

1. Locality of Cape Sorell-1 Well

Enclosures:

1. Micropalaeontological Analysis Chart
2. Palynological Analysis Chart
3. Calcareous Nannofossil Analysis Chart
4. Biostratigraphic Data Summary Log

SUMMARY

Analysis of the section 690'-11576' T.D. of the Cape Sorell-1 well provide the following lithological, biostratigraphic and palaeoenvironmental information:

1. The well section studied consists of a limestone succession between 720' and 1110', which is underlain by a thick sequence of calcareous sandstones between 1110' and 4150' approximately. Silty and shaley sandstones form a variable succession between 4150' and 6450' approximately, where they are replaced by a predominantly shale sequence, with interbedded silty sandstones, between 6450' and 9300'. The basal section consists predominantly of sandy breccid conglomerates and extends from 9300' to 11576' T.D., interrupted by a unit of silty sandstones with shales between 10300' and 10950'.
2. The sediments recovered are dated to range from the Early Miocene to Palaeocene; caved Middle Miocene to ?Pleistocene foraminiferal species are also present. A summary of the biostratigraphic results is presented in Table 1.
3. The environments of deposition for the sediments penetrated are interpreted to range from outer sublittoral to supra-littoral. A summary of the depositional environments is presented in Table II.

TABLE I

BIOSTRATIGRAPHIC SUMMARY

<u>Interval</u> (Feet)	<u>Floral Zone</u>	<u>Calcareous</u> <u>Nannofossil</u> <u>Zone</u>	<u>Age</u>
690	)	<u>H. ampliaperta</u>)
690- 720	)	<u>S. belemnos</u>)
720- 990	) <u>Proteacidites</u>	<u>T. carinatus</u>)
	) <u>tuberculatus</u>)
990- 1230	) and	<u>S. ciperensis</u>)
	) ?younger	-)
	)	<u>S. predistentus</u>)
1230- 1350	)	<u>H. reticulata</u>)
	)	----- ? UNCONFORMITY -----)
1350- 1410)))
	)	<u>D. sublodoensis</u>)
1410- 2550	) Lower))
	) <u>Nothofagidites</u>))
	) <u>asperus</u>))
2550- 2580)))
)))
2580-?4050	) <u>Proteacidites</u>))
	) <u>asperopolus</u>))
)))
	)	<u>D. lodoensis</u>)
?4050- 5770	) <u>Malvacipollis</u>	-)
	) <u>diversus</u>	<u>D. mohleri</u>)
)))
5770- 7170	) <u>Lygistepollenites</u>))
	) <u>balmei</u>))
)))
)))
7170- 7590	) <u>Lygistepollenites</u>))
	) <u>balmei</u>))
)))
7590-10270	) <u>Tricolpites longus</u>))
	)	<u>?D. mohleri</u>)
	)	and older)
10270-11576TD	) <u>Tricolpites longus</u>))

TABLE II

DEPOSITIONAL ENVIRONMENT SUMMARY

<u>Depth (Feet)</u>	<u>Microfaunal Assemblage Subzones</u>	<u>Microfaunal Assemblage Zones</u>	<u>Local Pollen Assemblage Zones</u>	<u>Depositional Environment</u>
690- 720	<u>Sphaeroidina</u>))))
	)	)	)	) Outer
	)	)	)	) sublittoral
720- 1110	<u>Guttulina/</u>))))
	<u>Clavulina/</u> )	)	CS-1-I)
	<u>Bryozoa</u>))))
))))
1110- 1140	) <u>Globocassidulina/</u>))))
	) <u>"Planktonic"</u>))))
	) <u>Triloculina</u> )	)	)	) Deep middle
	)	)	)	) sublittoral
1140- 1350	)	)	CS-1-II)
))))
1350-1410	) <u>Pullenia</u> )	)	)	) Shallow
	)	)	)	) outer
	)	)	)	) sublittoral
1410- 1470))))
))))
1470- 1950	)	<u>Lenticulina/</u> )	)	) Middle
	)	<u>Eponides</u> )	)	) sublittoral
	)	)	CS-1-III)
))))
1950- 2460	)	<u>Eponides/</u> )	)	) Deep middle
	)	<u>"Planktonic"</u> )	)	) sublittoral
))))
2460- 2490	) <u>Lenticulina/</u> )	)	)	) ?Middle
	) <u>Ammodiscus</u> )	)	)	) sublittoral
2490- 2970))))
	)	<u>Cyclammina/</u>)))
	)	<u>Ceratobulimina</u>)))
2970- 3510	<u>"Poor Fauna"/</u> )	)	)	) ?Inner
	<u>Cyclammina</u> )	)	)	) sublittoral
	)	)	CS-1-IV)
))))
3510- 4020	<u>Lenticulina/</u> )	)	)	) ?Middle
	<u>Amphicoryna</u> )	)	)	) sublittoral

TABLE II (cont'd.)

<u>Depth (Feet)</u>	<u>Microfaunal Assemblage Subzones</u>	<u>Microfaunal Assemblage Zones</u>	<u>Local Pollen Assemblage Zones</u>	<u>Depositional Environment</u>
4020- 4050))))
	)	"Barren" I	)	?Brackish
4050- 4200	)	)	)	littoral
)))	-
	)	)	)	?Inner
4200- 5040	)	"Arenaceous"/ <u>Cyclammina</u>	)	sublittoral
))))
	)	)	CS-1-V)
5040- 5310	)	"Barren" II	)	?Supra-
	)	)	)	littoral
5310- 5770))))
	)	<u>Cyclammina</u>/	)	Brackish
	)	<u>Ammodiscus</u>	)	littoral-
5770- 6450	)	)	)	Shallow
	)	)	)	inner
	)	)	)	sublittoral
6450- 6950	"Arenaceous"))))
	)	"Poor Fauna"	CS-1-VI	Brackish
	)	)	)	littoral
6950- 7430	<u>Cyclammina</u>))))
7430- 7610))))
	)	"Barren" III	)	?Supra-
	)	)	)	littoral
7610- 7910	)	)	CS-1-VII)
7910- 9250))))
	)	"Poor Fauna"/	)	Brackish
	)	"Arenaceous"	)	littoral
9250- 9320))))
9320-10230	)	"Barren" IV	CS-1-VIII	?Supra-
	)	)	)	littoral
10230-10270))))
	)	<u>Trochammina</u>	)	Brackish
	)	)	)	littoral-
	)	)	)	?Shallow
10270-11170	)	)	)	inner
	)	)	)	sublittoral
11170-11576 TD	)	)	CS-1-IX)
	)	"Barren"/	)	Supra-
	)	"Poor Fauna"	)	littoral

Note

Environmental determinations of the Palaeogene section of the succession are based mostly on the arenaceous foraminiferal assemblage. The apparent inconsistency of placing Cyclammina species in the shallow inner sublittoral, when extant forms of this genus are recorded as occupying the bathyal regime, is based on Robinson (1970) and Ludbrook (1977). These authors examine the distribution of fossil Cyclamminids, and conclude a sublittoral environment for Palaeogene forms.

INTRODUCTION

This report presents the results of biostratigraphic analysis of ditch cutting samples over the section 690'-11576' T.D. and of sidewall core samples over the section 9586'-11380', from the Amoco Australia Petroleum Company, Cape Sorell-1 well, drilled offshore West Tasmania, Australia (Figure 1) ($40^{\circ} 08' 09.54''$ S; $145^{\circ} 01' 47.06''$ E), at 309' water depth.

Lithological descriptions are based upon an examination of washed ditch cutting residues, supplemented by a summary lithological log supplied by the client.

A total of 425 ditch cuttings at intervals of 30', spanning the entire well section, together with eight sidewall cores between 9586' and 11380', were examined for their foraminiferal content. The scarcity of stratigraphically useful species precludes detailed age determination. The presence of foraminifera throughout most of the well, however, enables conclusions regarding the environment of deposition to be obtained.

A palynological investigation was performed on 121 ditch cutting samples over the entire well section, together with 8 sidewall cores between 9586' and 11380'. Palynomorph recovery was extremely variable, with assemblages ranging from rich and diverse

- 1a -

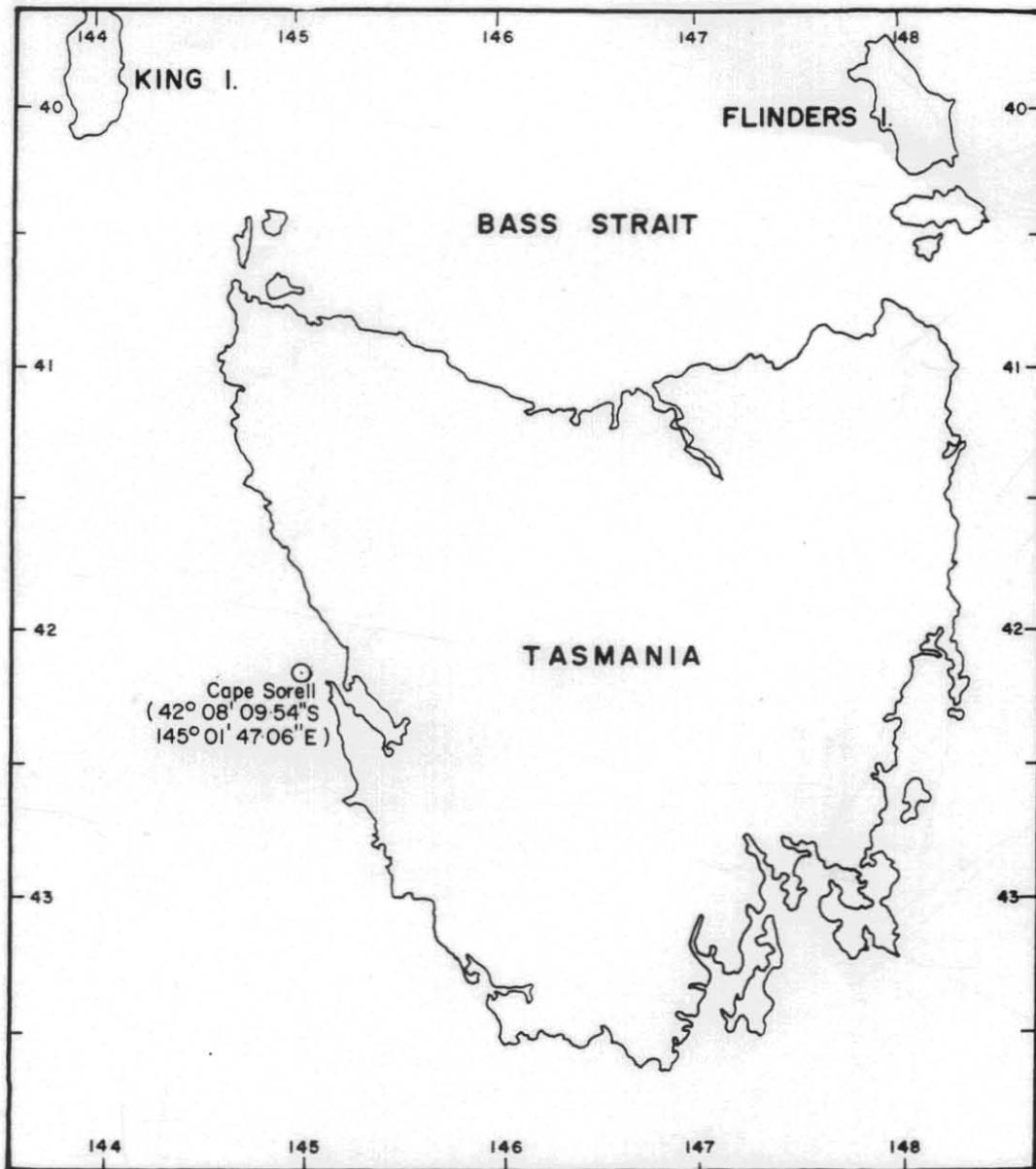


FIGURE 1 : LOCALITY OF AMOCO INTERNATIONAL
AUSTRALIA CAPE SORELL-1 WELL,
OFFSHORE W. TASMANIA

5 cm

to extremely poor or barren. Taxonomic nomenclature and identification of forms is based mainly on Stover and Partridge (1973) and Stover and Evans (1973), with the assistance of Harris (1965), Cookson (1950, 1953, 1959) and Martin (1973, 1974, 1978).

Nine local pollen assemblage zones have been determined. These zones have been given the suffix CS-1 to indicate that they relate only to this well section. However, through examination of ranges of marker taxa and comparison with zones described in other studies in S.E. Australia (Stover and Partridge, 1973; Stover and Evans, 1973) a scheme of age diagnostic floral zones has been identified (Appendix I). Supportive evidence for the ages presented comes from quantitative fluctuations of the pollen data, described by Martin (1978).

A total of 186 ditch cutting samples, spanning the section 690'-11576' were examined for their calcareous nannofossil content, using the smear slide technique. Calcareous nannofossil recovery is moderate to good between 690' and 2610', whereas between 2610' and 11576' T.D. samples are either barren or recovery is poor. The zonal scheme of Bukry (1973) is followed for age determination.

Preparation of samples followed standard micropalaeontological and palynological techniques.

All foraminifera and other microfauna identified in this investigation are plotted on the Micropalaeontological Analysis Chart. Pollen, spores and other palynomorphs are plotted on the

Palynological Analysis Chart, graphically on a percentage basis when the pollen sum is greater than 30, and on a presence/absence basis when the pollen sum is less than 30. Calcareous nannofossils identified are plotted on the Calcareous Nannofossils Analysis Chart. Inferred biostratigraphic and palaeoenvironmental conclusions are plotted on the Biostratigraphic Data Summary Log.

Environmental nomenclature is based upon a Robertson Research (Singapore) (1981) modification of Hedgpeth (1957), Murray (1973), Berggren (1978) and Ingle (1980), a summary of which is included as Appendix II.

II

GENERAL LITHOLOGY, BIOSTRATIGRAPHY AND
ENVIRONMENTS OF DEPOSITION

EARLY MIOCENE, Interval 690'-990'

General Lithology

The highest sample, at 690', consists of a microconglomerate with coarse sands and with common shell fragments and foraminifera. Samples collected below the casing point, at 693', are comprised of grey calcareous silty claystone, so rich in bryozoan fragments that an impure biocalcarenite limestone is produced, and persists throughout the section 693'-990'.

Biostratigraphy

Foraminifera

Foraminifera are common within this interval, and display a high diversity. Calcareous benthonic species predominate, with less well represented planktonic species. Arenaceous forms are rare, but present throughout most of the interval. Miliolids are rare and confined to the top of the section (690'-720'). The abundance and presence of species of mixed stratigraphic range suggests the presence of caved Plio-Pleistocene sediments above and immediately below the casing point, at 693'. One microfaunal assemblage zone and two subzones have been erected.

The Globocassidulina/"Planktonic" microfaunal assemblage zone (part) (690'-990') is characterized by the consistent and common

presence of a variety of calcareous benthonic species, especially Globocassidulina subglobosa, and planktonic species with rare arenaceous forms.

The Sphaeroidina assemblage subzone (690'-720') contains features which are common to the host assemblage zone but, in addition, contains a higher abundance and diversity of species, with rare arenaceous and miliolid specimens. A number of calcareous benthonic species are either particularly common or confined to this subzone, including Sphaeroidina bulloides, Pullenia bulloides, Eponides sp. cf. suturicrassus, Siphonina pulchra, Uvigerina senticosa and Trifarina bradyi. Planktonic species display their greatest diversity within this subzone, with Globigerina bulloides/praebulloides and G. nepenthes being the predominant, but probably caved, species. Three rare arenaceous species and two rare miliolid forms are also present.

The Guttulina/Clavulina/Bryozoa microfaunal assemblage subzone (part)(720'-990') is characterized by good recovery of foraminifera, especially of calcareous benthonic forms. Planktonic species are less well represented, and rare arenaceous forms are also present. The calcareous benthonic assemblage is dominated by Globocassidulina subglobosa, Cibicides spp., Guttulina elegantissima, Cassidulina delicata, Parellina vericulatus, Nonion sp. cf. maoricum, Guttulina pacifica, Heterolepa mediocris and Sphaeroidina bulloides. The planktonic assemblage is dominated by Globigerina bulloides/praebulloides and Globigerinoides triloba.

Clavulina pacifica is the most consistent arenaceous species, and is accompanied by less well represented Textularia sp., T. sp. cf. abbreviata and Bigenerina cylindrica.

Other Microfauna

Echinoid spines and bryozoa are common throughout this interval. Rare microfauna include an echinoid plate, lamellibranch and brachiopod.

Calcareous Nannofossils

Species recovery is variable within this interval, being moderately common and diverse at the top, but becoming poorer towards the base; recovery is probably affected by the casing point at 693'.

Species recovered include Cyclicargolithus gammation, Helicosphaera euphratis, Sphenolithus belemnos, Sphenolithus heteromorphus, Sphenolithus moriformis, Helicosphaera carteri, Cyclicargolithus abisectus and Coccolithus pelagicus. The presence of Helicosphaera recta at 750' is possibly due to reworking.

Palynomorphs

Recovery from the interval is extremely poor, with only rare pollen and spores recorded, including Proteacidites spp., Myrtaeidites spp., Acacia sp., Psilatricolporites spp., Podocarpidites spp., Phyllocladidites spp. (bisaccate), Gleicheniidites spp. and Verrucosisporites spp. Dinocysts were commonly identified in the

sample at 780'. The spectrum has been assigned as part of local pollen assemblage zone CS-1-I.

Age

The presence of the calcareous nannofossil species Sphenolithus heteromorphus and Sphenolithus belemnos at sample 690' indicates the presence of the Helicosphaera ampliaperta zone.

The presence of Sphenolithus belemnos, in the absence of the younger taxon Sphenolithus heteromorphus, indicates the presence of the Sphenolithus belemnos zone for sample 690'-720'.

The section between 720'-990' is assigned to the Triquetrorhabdulus carinatus zone, in the absence of younger taxon Sphenolithus belemnos and the older taxa Zygrhablithus bijugatus and Helicosphaera recta. Further subdivision is difficult due to the presence of caved species.

All the above mentioned zones are of Early Miocene age.

No definite age diagnostic palynomorphs were recovered from the interval. However, the presence of Acacia sp. is suggestive of a Miocene and/or younger age.

The planktonic foraminifera indicative of a Pliocene-Pleistocene age at the top of this interval, including Sphaeroidinella dehiscens immatura and Globorotalia pseudopima, are

considered to be caved. The presence of Pararotalia sp. cf. mecatepecensis, at 930' suggests proximity to the Oligocene-Miocene boundary.

Environments of Deposition

The depositional environment for the Globocassidulina/
"Planktonic" assemblage zone (part) (690'-990') ranges from the middle to outer sublittoral regime.

An outer sublittoral environment is suggested for the Sphaeroidina assemblage subzone (690'-720') by the presence of various deep water species, such as Sphaeroidina bulloides, Pullenia bulloides, Uvigerina senticosa. Further supportive evidence is provided by the relatively high planktonic component of the total population in which keeled species, Sphaeroidinella and Sphaeroidinellopsis, usually characteristic of upper bathyal and deeper conditions, are present, though rare. Most of the species present in this subzone are considered to be caved, as they are either absent or less well represented below the casing point.

An outer sublittoral depositional environment is also concluded for the Guttulina/Clavulina/Bryozoa assemblage subzone (part) (720'-990') based upon the rich calcareous benthonic component, in which upper bathyal species are less well represented. The assemblage includes poorly represented Pullenia bulloides and Sphaeroidina bulloides, but common to abundant Globocassidulina subglobosa and typical sublittoral forms such as species of

Guttulina. The presence of common bryozoa support an outer sublittoral environment, as there have been found in southern Australia between depths of 120m to 240m (Wass et. al., 1970).

Poor pollen recovery, together with the recovery of dinocysts, supports a marine environment of deposition.

LATE OLIGOCENE, Interval 990'-1230'General Lithology

This interval is comprised of an upper unit (990'-1110') of a grey impure biocalcarenite limestone, rich in bryozoa, and a lower unit (1110'-1230') of white, calcareous quartz sandstones which are slightly silty.

BiostratigraphyForaminifera

Foraminifera are common throughout most of this interval, but their relative abundance is gradually reduced towards the base. Calcareous benthonic species predominate, with subsidiary planktonic forms, rare arenaceous and miliolid forms. One microfaunal assemblage zone (part) and two assemblage subzones (part) have been erected.

The Globocassidulina/"Planktonic" microfaunal assemblage zone (990'-1230') consists of a foraminiferal association which has been described in the previous interval.

The Guttulina/Clavulina/Bryozoa assemblage subzone (part) (990'-1110') has been described in detail in the previous interval.

The Triloculina assemblage subzone (part) (1110'-1230') is characterized by the consistent presence of rare to common miliolid forms, including species of Triloculina and Quinqueloculina. Arenaceous species, though rare, are especially concentrated at the

upper part of this subzone, but Textularia spp. maintain a presence throughout. A rich calcareous benthonic assemblage is maintained throughout the subzone, in which the most consistently occurring species include Pullenia bulloides, Globocassidulina subglobosa, Sphaeroidina bulloides, Eponides spp. and Anomalinoides sp. cf. cavus. Planktonic species diversity is very low, but Globigerina bulloides/praebulloides and G. sp. cf. apertura are well represented in high numbers of individuals.

Other Microfauna

Bryozoa are relatively common throughout most of this interval, and are accompanied by echinoid spines in the lower part. Ostracoda are also present.

Calcareous Nannofossils

Cyclicargolithus gammation and Cyclicargolithus abisectus are the most common species in this interval together with Zygrhablithus bijugatus and Sphenolithus moriformis. Also, rare occurrences of Coccolithus pelagicus, Braarudosphaera bigelowi, Helicosphaera recta, and Reticulofenestra bisecta were recorded.

Palynomorphs

Two local pollen assemblage zones, CS-1-I and CS-1-II were, in part, identified within the interval.

Zone CS-1-I (990'-1140', in part), as in the previous interval, is characterized by poor recovery. Within the Late

Oligocene, forms recorded include Nothofagidites spp. (brassii group), Proteacidites spp., Myrtacidites spp., Sapotaceoidaepollenites sp., Tricolporopollenites endobalteus, Psilatricolporites spp. and Podocarpidites spp.

Within zone CS-1-II (1140'-1230', in part), in contrast to the above, recovery was moderate with fairly diverse assemblages. Relatively high percentages of Nothofagidites spp. (brassii group) (33-47%) are the dominant feature of the zone, together with Nothofagidites spp. (fusca group) (0-5%), Proteacidites spp. (0-5%), Tripoporopollenites spp. (0-6%), cf. Casuarina (2-5%), Myrtacidites spp. (15-18%), Malvacipollis subtilis (0-1%), Liliacidites spp. (2-5%), Podocarpidites spp. (2-6%) and Dacrydiumites spp. (0-2%). Several other forms were sporadically represented and dinocysts and chitinous foraminiferal tests were consistently recorded.

Age

The presence of the calcareous nannofossil species Helicosphaera recta and Zygrhablithus bijugatus, in the absence of older taxon Reticulofenestra umbilica, indicates the Sphenolithus ciperensis zone to Sphenolithus predistentus zone which is of Late Oligocene age. Further subdivision is impossible due to scarcity or absence of other marker species and caving.

No age diagnostic palynomorphs were recovered from the interval. However, the high frequencies recorded for Nothofagidites spp. provides supportive evidence for the age determined by calcareous nannofossils (Martin, 1978).

No age diagnostic foraminifera were recovered; most forms present, including the Miocene to Pleistocene species Globigerinoides triloba, are considered to be caved.

Environments of Deposition

An outer sublittoral depositional environment is concluded for the Guttulina/Clavulina/Bryozoa assemblage subzone (part) (990'-1110') based upon evidence discussed for this subzone in the previous interval.

The presence of the miliolid genera Quinqueloculina, Triloculina, Cornuspira and Pyrgo in the Triloculina assemblage subzone (part) (1110'-1230') suggests a slightly shallower depositional environment, and a deep middle sublittoral regime is concluded. This determination is supported by the consistent presence of common Eponides spp., Anomalinoides sp. cf. cavus, Oolina hexagona, Trifarina bradyi, Guttulina pacifica, Globocassidulina subglobosa, Pullenia bulloides and Sphaeroidina bulloides.

Between 1140' and 1230' the palynomorph assemblage suggests a slightly shallower environment, although the increased recovery may be a reflection of pollen preservation in less hostile conditions. The recovery of dinocysts and foraminiferal tests continue to support a marine influence.

EARLY OLIGOCENE, Interval 1230'-1350'General Lithology

This interval is comprised of calcareous quartz sandstones, which become increasingly silty towards the base.

BiostratigraphyForaminifera

Foraminiferal recovery is poor within this interval, with calcareous benthonic species predominating and planktonic forms being less well represented. Miliolid and arenaceous forms are rare. This assemblage is assigned to the Triloculina microfaunal assemblage subzone (part) (1230'-1350') of the Globocassidulina/
"Planktonic" assemblage zone (part) (1230'-1350').

Calcareous benthonic species which are present throughout much the subzone in this interval include Globocassidulina subglobosa, Sphaeroidina bulloides, Discorbis spp., Nonion sp., Vaginula sp. cf. margaritifera and Lenticulina sp. Planktonic species are restricted to well represented Globigerina praebulloides with a few rare species. Triloculina and Quinqueloculina species are rare, and arenaceous forms are restricted to a single occurrence of Textularia sp.

Other Microfauna

Other microfauna are rare, and confined to echinoid spines, ostracoda and bryozoa.

Calcareous Nannofossils

Calcareous nannofossil recovery is moderately good. Species recovered include Zygrhablithus bijugatus, Reticulofenestra umbilica, Cyclicargolithus gammatum, Sphenolithus moriformis, Cyclicargolithus abisectus, Cyclococcolithus formosus and Reticulofenestra bisecta.

Palynomorphs

The interval falls entirely within local pollen assemblage zone CS-1-II described above.

Age

The presence of Reticulofenestra umbilica in the absence of any older marker taxon indicates the Helicosphaera reticulata zone which is of Early Oligocene age.

No stratigraphically useful palynomorphs nor foraminifera were recovered from this interval.

Environments of Deposition

The combined presence of Globocassidulina subglobosa, Eponides spp., Lenticulina sp. in the localized rare occurrence of Pullenia bulloides and Sphaeroidina bulloides within this interval, suggests a deep middle sublittoral environment.

MIDDLE-EARLY EOCENE, Interval 1350'-2550'General Lithology

This interval is comprised of poorly calcareous quartz sandstones with localized development of calcareous claystones (1420'-1530'), silty claystones (1600'-1720') and shales (2380'-2550').

BiostratigraphyForaminifera

Foraminiferal recovery is poor within this interval, but no samples are barren of foraminifera. Calcareous benthonic species predominate, while planktonic foraminiferal abundance decreases sharply below 1470'; most samples below 1470' do not contain planktonic species. Arenaceous forms appear at 2460' and increase rapidly in relative abundance below this datum. Miliolids are rare, and present only at the top of the interval, and in three isolated samples within the interval.

Four microfaunal assemblage zones are recognized, together with one assemblage subzone each from the uppermost and lowest zones.

The Globocassidulina/"Planktonic" microfaunal assemblage zone (part) (1350'-1470') is represented by the Pullenia assemblage subzone (1350'-1470'). This subzone is characterized by the localized reappearance of Pullenia bulloides, the continued presence of Globocassidulina subglobosa and Eponides spp. Planktonic forms are well represented only by Globigerina praebulloides; miliolids are

rare. The base of this zone is marked by the distinct final presence of G. subglobosa and planktonic species.

The Lenticulina/Eponides assemblage zone (1470'-1950') is characterized by a reduced number of calcareous benthonic species, when compared with the younger assemblage zone. Certain calcareous benthonic species are consistently present throughout the zone, and include Eponides sp. cf. subhaidingeri, E. spp., Lenticulina spp. and Anomalinoidea spp.. Baggina sp., Astacolus sp., Guttulina sp. and Globocassidulina subglobosa maintain a scattered, rare to common presence throughout the zone. Other foraminifera are rare, but a slight concentration of rare arenaceous genera is present at 1740', where Textularia sp., Alveophragmium, Trochammina and ?Clavulina species are present.

The Eponides/"Planktonic" assemblage zone (1950'-2450') is characterized by a poor foraminiferal recovery in which Eponides spp. is the only calcareous benthonic species which is consistently present. The planktonic species Globigerina praebulloides is rare, but present throughout most of the zone. Rare Quinqueloculina spp. are also present towards the base of the zone.

Only the upper part of the Cyclammina/Ceratobulimina assemblage zone (part) (2460'-2550') is present within this interval, the general characteristics will therefore be discussed in detail in the following interval. The Lenticulina/Ammodiscus assemblage subzone (part) (2460'-2550') is recognized by the slight increase

in foraminiferal recovery, with the first appearance of Ceratobulimina pacifica and the reappearance of Lenticulina spp., Amphicoryna hirsuta, Nodosaria albatrossi and increased occurrence of Astacolus sp. A marked increase in arenaceous forms is manifest by the initial and continued common presence of Ammodiscus incertus, Cyclammina incisa and C. rotundata. Rare, possibly caved planktonic species are present.

Other Microfauna

Other microfauna, though rare, are restricted to the upper (1350'-1830') and lower (2790'-2550') parts of the interval. In the upper part, echinoid spines, bryozoa, lamellibranchs, gastropods, pteropods, calcareous alga and solitary corals are present. In the lower part, this assemblage is reduced to include rare echinoid spines, bryozoa, lamellibranchs, calcareous alga, ostracoda and, below 2430', common and consistent solitary corals.

Calcareous Nannofossils

Species recovered include Discoaster lodoensis, Zygrhablithus bijugatus, Coccolithus pelagicus, Cyclicargolithus gammation, Sphenolithus moriformis, Helicosphaera seminulum, Cyclicargolithus reticulatus, Transversopontis spp. and Rhabdosphaera spp.

Palynomorphs

No samples between 1350' and 1410' were examined for palynomorphs. That part of the section, therefore has been assigned to zone CS-1-II. Within the remainder of the interval two pollen assemblage zones were identified, CS-1-III (1410'-2490') and

CS-1-IV (2490'-2550', in part). Zone CS-1-III is characterized by reduced frequencies for Nothofagidites spp. (brassii group) (7-17%) and, conversely, increased percentages for Proteacidites spp. (7-15%), Tripoporollenites spp. (6-13%) and Myrtacidites spp. (25-33%). Proteacidites latrobensis and Tricolpites simatus make their first downhole appearance at 1410' and Proteacidites leightonii, P. asperopolus and P. kopiensis first occur slightly below that level. Other forms which define the top of the assemblage zone include Ephedripites spp., Dicolpopollis spp., Polycolpites esobalteus, Tricolporites prolata/Tricolpites prolata, Psilatricolpites operculatus, Peripoporollenites demarcatus, Podocarpidites australiensis, Dacrydiumites spp. (type 1) and Baculatisporites disconformis. The last downhole occurrence of Tricolpites simatus was identified at 2340'.

Zones CS-1-IV will be described within the underlying interval.

Age

The presence of the calcareous nannofossil Discoaster lodoensis in the absence of older taxon Marthastrites tribranchiatus indicates the Discoaster sublodensis zone which is of Middle to Early Eocene age.

The zones between Helicosphaera reticulata to Discoaster sublodensis are not recorded and therefore suggest the possible presence of an unconformity at 1350'.

The recovery of the palynomorphs Proteacidites latrobensis and Tricolpites simatus at 1410' indicates penetration of the lower Nothofagidites asperus zone of Early-Middle Eocene age. This conclusion is supported by the identification of Proteacidites leightonii and P. asperopolus, at slightly lower levels. These forms become extinct at the top of and during the lower N. asperus zone respectively. Furthermore, as Tricolpites simatus is restricted to within the Lower N. asperus zone, its recovery at 2340' again supports an Early-Middle Eocene age at that depth, as determined by calcareous nannofossils.

Additional evidence for the age suggested is provided by quantitative analysis of the pollen data. Reduced frequencies for Nothofagidites spp. and, conversely, increased percentages for Proteacidites spp., have been noted elsewhere (Martin, 1978), within the Early-Middle Eocene.

From the composite evidence supplied by age diagnostic microfossils, therefore, a major unconformity appears present at 1350'. Material from possibly Early-Middle Eocene to Early Oligocene appears to be missing from the section. Such an unconformity has been recognised in all ocean basins (Moore et al. 1978).

No age diagnostic foraminifera were recovered from this interval. A single specimen of the Early to Middle Miocene planktonic species Praeorbulina glomerosa at 2100' is considered to be caved.

Environments of Deposition

A shallow outer sublittoral depositional environment is concluded for the Pullenia assemblage subzone (1350'-1470') of the Globocassidulina/"Planktonic" assemblage zone (part) (1350'-1470'), based upon the consistent localized presence of Pullenia bulloides and the planktonic species Globigerina praebulloides. The relatively sparse assemblage is considered to be related to the presence of sandstones slightly higher in the assemblage (1350'-1420') which were possibly deposited during a relatively high energy submarine environment.

The Lenticulina/Eponides assemblage zone (1470'-1950') is considered to have been deposited in a middle sublittoral environment, based upon the common, consistent presence of the two nominate genera, together with Astacolus sp. This conclusion is supported by the absence of outer sublittoral forms such as Pullenia bulloides, Sphaeroidina bulloides, and rare Globocassidulina subglobosa, together with rare planktonic species.

The Eponides/"Planktonic" assemblage zone (1950'-2460') was probably deposited in a deep middle sublittoral environment, based upon the combined presence of scattered Globocassidulina subglobosa and planktonic species.

A middle sublittoral depositional environment is tentatively concluded for the Lenticulina/Ammodiscus assemblage subzone (part) (2460'-2550') of the Cyclammia/Ceratobulimina assemblage zone

(part) (2460'-2550'), based upon the relatively high proportion of arenaceous forms within the assemblage. The arenaceous assemblage has a low diversity, but a relatively high number of individuals, of Ammodiscus incertus, Cyclammia incisa and C. rotundata. Lenticulina and Eponides species are consistently well represented, and suggest a sublittoral environment. There is evidence (Robinson, 1970; Lubdook, 1977) to suggest that the genus Cyclammia was able to survive in the sublittoral environment during the Palaeogene, unlike its present day confinement to the bathyal regime. The significance of the localized concentration of simple corals is not known.

The recovery of dinocysts from the interval supports a marine environment of deposition. On the basis of the diverse and rich nature of the palynomorph assemblage, however, nearshore environment should be considered, with the possibility of a slighter deeper environment in the zone of poor recovery between 1680' and 2310'.

EARLY EOCENE, Interval 2550'-5770'

General Lithology

This interval is comprised of an upper unit of slightly calcareous quartz sandstones with scattered, thin shale beds (2550'-4180') and a lower unit (4180'-5770') of mixed quartz sandstones, silty sandstones, siltstones with shales, and shales. Shales are especially well developed at 4180'-4480' and 5530'-5680'; the former group are pyritic.

Biostratigraphy

Foraminifera

Foraminiferal recovery is very poor throughout this zone, with barren samples present at 4020'-4140' and 5040'-5310'. Calcareous benthonic forms and arenaceous forms occupy approximately equal proportions of the assemblage, with rare, sporadic and possibly caved planktonic forms also present.

Three microfaunal assemblage zones and two barren zone are recognized, one zone is comprised of three subzones.

The Cyclammina/Ceratobulimina assemblage zone (part) (2550'-4020') is characterized by the common and consistent presence of Cyclammina species, together with the rare and scattered occurrence of Ceratobulimina pacifica. Both the arenaceous and calcareous benthonic assemblages display a low species diversity, but the latter does contain a comparatively greater variety of species. These include Lenticulina spp., Amphicoryna spp., Guttulina sp.

cf. yabei, Eponides spp., Astacolus sp., Nodosaria albatrossi and Nodosaria radricula glanduliniformis. Planktonic forms are rare and considered to have been caved.

The Lenticulina/Ammodiscus assemblage subzone (part) (2550'-2970') is characterized by the consistent and common presence of Lenticulina spp., Nodosaria albatrossi, together with the arenaceous form Ammodiscus incertus, Cyclammina incisa and C. rotundata.

The "Poor Fauna"/Cyclammina assemblage subzone (2970'-3510') is characterized by the predominance of Cyclammina incisa and C. rotundata in the presence of rare, scattered calcareous benthonic species. Lenticulina spp. persist throughout the upper part of this subzone (2970'-3270'), but are absent in the lower part.

The Lenticulina/Amphicoryna assemblage subzone (3510'-4020') is characterized by the consistent presence of Lenticulina spp. and Amphicoryna sp., together with the scattered presence of Eponides spp., Ceratobulimina pacifica and Nodosaria radricula glanduliniformis. Cyclammina species maintain a common and consistent presence throughout the subzone, together with rare ?Psammionopelta sp. The absence of foraminifera between 4020'-4200' enables designation of the "Barren" I zone.

The "Arenaceous"/Cyclammina assemblage zone (4200'-5040') is characterized by an entirely arenaceous, low diversity, foraminiferal assemblage in which Cyclammina incisa and C. rotundata predominate, with scattered ?Trochammina spp.

The absence of foraminifera between 5040'-5310' enables designation of the "Barren" II zone.

The Ammodiscus/Cyclammina assemblage zone (part) (5310'-5770') is characterized by an entirely arenaceous, low diversity, foraminiferal assemblage in which Cyclammina incisa, C. rotundata and Ammodiscus incertus predominate.

Other Microfauna

Other microfauna are rare, and confined to the upper part (2550'-4020') of this interval. These include relatively consistent presence of solitary corals, calcareous algae and gastropods, with a less common, scattered presence of lamellibranchs, bryozoa, echinoid spines and ostracoda.

Calcareous Nannofossils

Calcareous nannofossil recovery is very poor in this interval. The section from 2550' to 2610' and 4110' to 4170' contains rare calcareous nannofossils while the remainder of interval is barren. Species recovered include Transversopontis pulcher, Zygrhablithus bijugatus, Marthastrites tribranchiatus and Coccolithus pelagicus.

Palynomorphs

Two local pollen assemblage zones were identified within the interval. These are CS-1-IV (2550'-4050', in part) and CS-1-V (4050'-5770').

Zone CS-1-IV is marked by higher recorded frequencies for Triporopollenites spp. (16-45%) and, conversely, lower levels for Myrtaceidites spp. (0-19%). Percentages for Nothofagidites spp. (brassii group) (0-32%) are low at the top of the zone, peaking towards the base. Proteacidites spp. (10-26%) were commonly recovered, together with Retitricolpites spp. (2-12%), Retitricolporites spp. (0-10%), Cyathidites spp. (0-8%), Podocarpidites spp. (0-5%) and dinocysts (4-14%). At 2580' Proteacidites grandis makes its first downhole occurrence, with Spinizonocolpites prominatus present below 2760'. Periporopollenites demarcatus and Tricolporopollenites endobalteus both make their last downhole appearance within the zone and further significant contributors to the pollen sum include Proteacidites annularis, P. reticulatus, P. adenanthoides, P. pachypolus and Malvacipollis diversus. P. pachypolus is only found within this assemblage zone.

Zone CS-1-V is characterized by generally poorer recovery. The upper boundary is located at the basal occurrence of Proteacidites pachypolus, P. asperopolus and P. leightonii. Within the zone, Proteacidites spp. were consistently identified and were the most common forms recorded. Triporopollenites spp. and Myrtaceidites spp. were also recovered throughout CS-1-V, together with Cyathidites spp., Gleicheniidites sp. and, more rarely dinocysts. Other important features of the zone include the recovery of Intratriporopollenites notabilis at 4050' and the basal occurrences of Proteacidites grandis, P. latrobensis and Spinizonocolpites prominatus within its boundaries. Proteacidites reticulatus was recorded in the sample at 5770'.

Age

The presence of the calcareous nannofossil Marthastrites tribranchiatus at 2550' indicates the penetration of Discoaster lodoensis zone which is of Early Eocene age.

The first downhole occurrence of the palynomorph Proteacidites grandis at 2580' indicates penetration of the Proteacidites asperopolus zone of Early Eocene age. This conclusion is supported by the recovery of Spinizonocolpites prominatus below 2760' and the presence of Periporopollenites demarcatus and Tricolporopollenites endobalteus above 3300'. The lower boundary of the P. asperopolus zone is tentatively placed at 4050', based on the record for Proteacidites pachyopolus above that depth. Although it is known to extend into the underlying Malvacipollis diversus zone, Stover and Partridge (1973) and Stover and Evans (1973) note that increased frequencies of P. pachyopolus are characteristic of the P. asperopolus zone. Supportive evidence is provided by the recovery of Nothofagidites spp. (menziesii group) at 4110'. This form makes its first evolutionary appearance around the M. diversus-P. asperopolus boundary.

Between 4050' and 5770' the section has been ascribed to the Malvacipollis diversus zone, also of Early Eocene age. The recovery of Proteacidites grandis, P. latrobensis, P. reticulatus and Spinizonocolpites prominatus, which all make evolutionary appearances during the zone, is not thought to be a result of caving, due to the presence of a casing point at 4144'. The base

of the zone, marking the Palaeocene-Eocene boundary, has been placed to coincide with the bottom occurrence of Proteacidites reticulatus, which is at the same level as the uppermost occurrence of the older markers Gambierina edwardsii and Tricolpites waiparaensis.

Environments of Deposition

A middle sublittoral depositional environment is tentatively concluded for the Lenticulina/Ammodiscus assemblage subzone (part) (2550'-2970') based upon the consistent and common presence of species which are common to that regime, and include Lenticulina spp., Nodosaria albatrossi, with rare planktonic forms and a common, though low diversity, arenaceous component comprised of Ammodiscus incertus and Cyclammina species. It is the presence of the latter species, together with the comparatively poor fauna, which enables a middle sublittoral depositional environment to be concluded, as Ludbrook (1977) states "They (Cyclammina) are all assumed to have been deposited in shallow water".

A possibly inner sublittoral depositional environment is tentatively concluded for the "Poor Fauna"/Cyclammina assemblage subzone (2970'-3510'), based upon the reduced faunal recovery and also upon the dominance of Cyclammina.

A possibly middle sublittoral depositional environment is concluded for the Lenticulina/Amphicoryna assemblage subzone (3510'-4020') based upon the faunal similarity, though less rich, between this zone and that at 2550'-2970'.

A brackish littoral to inner sublittoral environment is tentatively concluded for the "Barren" I zone (4020'-4200') and "Arenaceous"/Cyclammia assemblage zone (4200'-5040'), based upon the sparse foraminiferal population in which Cyclammia species are consistently present. The barren zone is considered to be lithologically controlled as it coincides approximately with the presence of clean quartz sands.

A supralittoral environment is tentatively concluded for the "Barren" II zone (5040'-5310'), although the absence of foraminifera may be lithologically controlled.

A brackish littoral to shallow inner sublittoral depositional environment is concluded for the Cyclammia/Ammodiscus assemblage zone (part) (5310'-5770') based upon the entirely arenaceous assemblage. This assemblage has a present day equivalent in the lower bathyal regime, but a similar environment of stress is considered to have existed in the marginal marine regime of the Palaeogene.

The decrease in relative abundance of dinoflagellate cysts of marine origin in the section 4050'-5770' supports the shallower marginal marine conditions suggested in the above discussion.

PALAEOCENE, Interval 5770'-11576' T.D.

General Lithology

A varied sedimentary succession is present within this interval, which may be grouped into an upper sandy shale unit (5770'-9600') and a lower breccio-conglomerate/sandy shale unit (9600'-11576' T.D.).

The upper unit consists of silty shales (5770'-6100') which grade downhole into haematite-stained shales with silty sandstones (6100'-6750'). Interbedded shales with quartz silty sandstones form a thick, monotonous succession (6750'-9300'), with haematite-stained basal beds. These overlie a unit of clean, quartz sandstones (9300'-9600').

A polymictic breccio-conglomerate underlies the sandstone and continues to the base of the well (9600'-11576' T.D.), enclosing a unit of sandstones with shales at 10300'-10950'.

Biostratigraphy

Foraminifera

Foraminiferal recovery is very poor within this interval, and many samples are barren of foraminifera. Five arenaceous microfaunal assemblage zones have been erected, together with two barren zones.

The Cyclammina/Ammodiscus assemblage zone (part) (5770'-6450') is characterized by the entirely arenaceous assemblage, with low diversity, in which Cyclammina incisa, C. complanata and Ammo-

discus incertus are predominant.

The "Poor Fauna" assemblage zone (6450'-7430') consists of two assemblage subzones, both of which are predominantly arenaceous, but in which rare calcareous benthonic forms are found in the lower subzone (6950'-7430'). The "Arenaceous" assemblage subzone (6450'-6950') contains many barren samples, and a sparse, low diversity arenaceous assemblage in which Cyclammina and ?Trochammina species are marginally more consistently present than other forms. The Cyclammina assemblage subzone (6950'-7430') is characterized by a low diversity arenaceous assemblage in which Cyclammina species predominate, despite their rare presence, together with rare, scattered calcareous benthonic forms, which may possibly be caved, and include Eponides sp.

The absence of foraminifera between 7430'-7910' enables designation of the "Barren" III zone.

The "Poor Fauna"/"Arenaceous" assemblage zone (7910'-9320') is characterized by the reappearance of scattered arenaceous forms, interspersed with barren samples. Cyclammina species are scattered throughout the upper part of this zone.

The absence of foraminifera between 9320'-10230' enables designation of the "Barren" IV zone.

The Trochammina assemblage zone (10230'-11170') is characterized by the reappearance of a comparatively rich arenaceous

assemblage in which Trochammina sp. cf. squamata is consistently present, and accompanied by indeterminate forms, with ?Ammobaculites spp. and Trochammina spp.

The rare, scattered presence of arenaceous foraminifera in an otherwise barren section enables designation of the "Barren"/"Poor Fauna" assemblage zone (11170'-11576' T.D.).

Other Microfauna

Other microfauna are rare within this interval, and confined to the rare, scattered occurrence of Ostracoda.

Calcareous Nannofossils

In this interval only samples 6320', 7110' and between 7590' and 7620' contained very poor calcareous nannofossils; the remainder of interval is barren. Species recovered include Cruciplacolithus tenuis, Chiasmolithus danicus and Coccolithus pelagicus.

Palynomorphs

Four local pollen assemblage zones were identified from the interval.

Zone CS-1-VI (5770'-7610') is characterized by increased recovery, when compared with the overlying zone. Higher percentages for Proteacidites spp. (9-39%), Retitricolpites spp. (0-24%), Nothofagidites spp. (brassii group) (0-15%) and dinocysts are evident. The dominant feature of the zone, however, is the record

for gymnosperms, both in terms of frequency and diversity. Forms identified include Podocarpidites spp., Dacrydimites spp. (type 1), Dacrydimites spp. (type 2), Phyllocladidites spp. (bisaccate), Phyllocladidites mawsonii, Phyllocladidites reticulosaccatus, Phyllocladidites spp. (trisaccate) and trisaccate undifferentiated grains. Also recorded regularly within the zone were Proteacidites annularis, Triporopollenites spp., Gambierina edwardsii, G. rudata, Myrtaceidites spp., Tricolpites confessus, T. gillii, Retitricolpites spp., Cyathidites spp., and Gleicheniidites spp. Tricolpites waiparaensis and Proteacidites adenanthoides were recorded at the top of the zone and T. phillipsii at 7170'.

Zone CS-1-VII (7610'-9250') is marked by reduced levels of palynomorph recovery. Nevertheless, Nothofagidites spp. (brassii group), Nothofagidites spp. (fusca group), Proteacidites spp., Triporopollenites spp., Retitricolpites spp., Podocarpidites spp., Cyathidites spp. and dinocysts are well represented within its boundaries, together with sporadic occurrences of Tricolpites gillii. Gymnosperm pollen occurs more commonly in the top of the zone.

Zone CS-1-VIII (9250'-10270') is a zone of particularly poor recovery with only rare grains recorded.

In contrast, zone CS-1-IX (10270'-11576' T.D.) is characterized by slightly increased recovery, although the assemblages recovered are not very diverse. Nothofagidites spp. (brassii

type), Nothofagidites spp. (fusca type), Proteacidites spp., Tripoporollenites spp., Tripoporollenites sectilis, Gambierina rudata, Retitricolpites spp., Tricolporites lilliei, Retitricolporites spp., Podocarpidites spp., Phyllocladidites spp. (bisaccate), Cyathidites spp. and several other pteridophyte taxa were recorded from the zone.

Age

The presence of the calcareous nannofossil Cruciplacolithus tenuis at 7590' indicates the penetration of the ?Discoaster mohleri zone and older which is of Palaeocene age.

The occurrence of the palynomorph Gambierina edwardsii below 5770' indicates penetration of Palaeocene sediments. This is confirmed by the recovery of Phyllocladidites reticulosaccatus, and Gambierina rudata at a slightly lower level. The identification of Tricolpites phillipsii at 7170' and Proteacidites annularis down to 7070' more specifically suggests the Lygistepollenites balmei zone of Middle to Late Palaeocene age.

Between 7170' and 10270' there is no evidence of age from marker taxa.

Below 10270', however, the presence of Tripoporollenites sectilis is indicative of the Tricolpites longus floral zone, Early to Middle Palaeocene. This is supported by the recovery of Quadraphanus brossus and Tricolporites lilliei at 10470' and below 10960'

respectively. The continuous record for Nothofagidites spp. (fusca group) to the base of the section, if in situ, indicates that Cretaceous sediments have not been penetrated. The entire interval has therefore been assigned to the Palaeocene.

Reworked Vitreisporites pallidus and Striatopodacarpidites sp. were recorded around 6050'-6150'.

Environments of Deposition

A brackish littoral to shallow inner sublittoral depositional environment is concluded for the Cyclammina/Ammodiscus assemblage zone (part) (5770'-6450') based upon evidence presented in the previous interval.

A brackish littoral, possibly estuarine, environment is concluded for the "Poor Fauna" assemblage zone (6450'-7430') based upon the poor recovery of foraminifera. The scattered calcareous benthonic species present in the lower subzone of the zone (6950'-7430') are possibly either washed in from the marine environment, or caved.

A supralittoral, possibly fluvial, depositional environment is tentatively concluded for the "Barren" III zone (7430'-7910'), as there is no obvious lithological change which would possibly indicate a higher energy environment.

A brackish littoral environment is concluded for the "Poor Fauna"/"Arenaceous" assemblage zone (7910'-9320'), based upon the reappearance of an arenaceous foraminiferal assemblage.

Supralittoral conditions are tentatively concluded for the "Barren" IV zone (9320'-10230'). The absence of foraminifera is easily explained by the presence of clean, quartz sands and breccio-conglomerates which indicate high energy, probably fluvial flood depositional conditions.

A brackish littoral to possibly shallow inner sublittoral depositional environment is concluded for the Trochammina assemblage zone (10230'-11170'), based upon the arenaceous foraminifera in which Trochammina sp. cf. squamata is well represented.

A supralittoral, probably fluvial environment is concluded for the deposition of the "Barren"/"Poor Fauna" assemblage zone (11170'-11576'T.D.). This zone lies within a breccio-conglomerate lithology, which probably represents an immature, flood transported, environment.

III

CONCLUSIONS

The Palaeocene to Early Miocene history of the Cape Sorell-1 well is traced in this report.

During the Palaeocene (11576'T.D.-5770') deposition of breccio-conglomerates took place in a supralittoral environment (11576'T.D.-9600') which temporarily became affected by a brackish to marine influence to allow the deposition of sandstones and claystones (10950'-10300'). Deposition of interbedded sandstones and shales continued in environments which fluctuated between brackish littoral and supralittoral, probably fluviatile (9600'-6100'). Haematite-staining of the uppermost part of this shale sequence suggests oxygenated conditions which support the marginal environment envisaged at this time. The siltstones with thin shale beds (6100'-5770') were deposited in a possibly deeper environment which spanned the brackish littoral to shallow inner sublittoral regimes.

During the Early Eocene (5770'-2550'), deposition of a predominantly sandstone sequence took place in a variety of environments which initially spanned the brackish littoral to shallow inner sublittoral regime (5770'-5310') but gradually the site of deposition deepened to a possibly middle sublittoral regime during the upper part of the Early Eocene (2970'-2550').

Deposition of calcareous sandstones took place during the Early to Middle Eocene (2550'-1350') in an environment which fluctuated between the shallow outer sublittoral (2460'-1950'; 1470'-1350') and middle sublittoral (2550'-2460'; 1950'-1470').

Calcareous sandstones continued to be deposited, despite the possible presence of an unconformity at 1350', during the Early Oligocene (1350'-1230') in a deep middle sublittoral regime. The presence of such an unconformity is in agreement with the global unconformity at this datum, which is detected in deep marine sequences. Submarine erosion, rather than uplift and subaerial erosion, is cited as the erosive mechanism, hence the apparent lack of change in the detectable depositional environment.

Calcareous sandstones were deposited during the Late Oligocene (1230'-990'), in a deep middle to outer sublittoral environment.

Further deepening of the site of deposition to an outer sublittoral regime is concluded for the deposition of the pelagic bryozoan rich limestones of Early Miocene age (990'-690').

The site of deposition was, therefore, subject to the marginal effects of a nearby sea during the Palaeocene and Early Eocene. During the Early Eocene, a relative marine transgression took place and continued with minor regressions during the Early to Middle Eocene. A single major marine transgressive phase took

place during the Early Oligocene to Early Miocene. During this time, the well section studied provides evidence for basement subsidence (at T.D.) of at least 10886'.

IV

SELECTED REFERENCES

- BALME, B.E. 1957 Spores and pollen grains from the Mesozoic of Western Australia. C.S.I.R.O. Aust., Coal Res. Sect. T.C., 25:1-48.
- BARKER, R.W. 1960 Taxonomic notes on the species figured by H.B. Brady in his report on the Foraminifera dredged by H.M.S. Challenger during the years 1873-1876. Amer. Assoc. Petrol. Geol., Spec. Publ., 9:238.
- BELFORD, D.J. 1966 Miocene and Pliocene smaller Foraminifera from Papua New Guinea. Bull. Bur. Miner. Resour. Geol. Geophys. Aust., 79:1-306.
- BERGGREN, W.A. 1978 Marine micropalaeontology, an introduction:1-77. In Introduction to Marine Micropalaeontology, Eds. Haq, B.U. and Boersma, A.:376pp.
- BOEUF, M.F. & DOUST, H. 1975 Structure and development of the southern margin of Australia. J. Aust. Petrol. Explor. Ass., 15: 33-43.
- BLOW, W.H. 1969 Late middle Eocene to Recent planktonic foraminiferal biostratigraphy:199-422. In Proceedings of First International Conference on Planktonic Microfossils, Geneva, 1967, Eds. Brönniman, P. & Renz, H.H.:422pp.

- BRENNER, G.J. 1963 The spores and pollen of the Potomac group of Maryland. Maryland Bd. Nat. Res. Bull. 27: 1-215.
- COOKSON, I.C. 1950 Fossil pollen grains of proteaceous type from Tertiary deposits in Australia. Aust. J. Res., ser. B, 3:166-176.
- COOKSON, I.C. 1959 Fossil pollen grains of Nothofagus from Australia. Proc. R. Soc., Vict., 71:25-30.
- COOKSON, I.C. & DETTMANN, M.E. 1958 Some trilete spores from Upper Mesozoic deposits in the eastern Australian region. Proc. R. Soc. Vict., 70:95-128.
- COOKSON, I.C. & PIKE, K.M. 1954 The fossil occurrence of Phyllocladus and two other podocarpaceous types in Australia. Aust. J. Bot., 2:60-68.
- COUPER, R.A. 1953 Upper Mesozoic and Cainozoic spores and pollen grains from New Zealand. N.Z. Geol. Surv. Pal. Bull., 22:1-77.
- COUPER, R.A. 1960 New Zealand Mesozoic and Cainozoic plant microfossils. N.Z. Geol. Surv. Pal. Bull., 32:1-87.
- DETTMANN, M.E. 1963 Upper Mesozoic microfloras from southeastern Australia. Proc. R. Soc. Vic., 77:1-148.
- DETTMANN, M.E. & PLAYFORD, G. 1968 Taxonomy of some Cretaceous spores and pollen grains from eastern Australia. Proc. R. Soc. Vict., 81:69-94.

- EDWARD, A.R. & PERCH-NIELSEN, K. 1975 Calcareous nannofossils from the Southern Southwest Pacific, D.S.D.P., Leg. 29. Init. Rep. Deep Sea Drilling Proj., 29:469-539.
- EVANS, P.R. 1969 Mesozoic stratigraphic palynology of the Otway Basin. Bur. Min. Res. Geol. Geophys. Aust. Records, 1966/1969, 45pp., Canberra, mimeographed.
- GLOVER, J.E. & PLAYFORD, G. Eds. 1973 Mesozoic and Cainozoic palynology: essays in honour of Isabel Cookson. Geol. Soc. Aust. Spec. Publ., 4, 211pp.
- HAQ, B.U. 1973 Evolutionary trends in the Cenozoic coccolithophore genus Helicopontosphaera. Micropaleontology., 19:32-52.
- HARRIS, W.K. 1965 Basal Tertiary microfloras from the Princetown area, Victoria, Australia. Palaeontographica B, 115:76-106.
- HEDGPETH, J.W. 1957 Classification of marine environments. In Treatise on marine ecology and palaeoecology. Geol. Soc. Amer. Mem., 67(1):17-28.
- INGLE, J.C. Jr. 1980 Cenozoic palaeobathymetry and depositional history of selected sequences within the southern California continental borderland. Cush. Found. Spec. Publ., 19:163-195.
- JENKINS, D.G. 1975 Cenozoic planktonic foraminiferal biostratigraphy of the southwestern Pacific and Tasman Sea - DSDP Leg. 29. Repr. from Kennet, J.P., Houtz, R.E. et al., 1975. Initial Reports of the Deep Sea Drilling Project, XXIX, 449-467, Washington.

- LUDBROOK, N.H. 1977 Early Tertiary Cyclamina and Haplophragmoides (Foraminifera: Lituolidae) in southern Australia. Trans. R. Soc. S. Aust., 101(7):165-197.
- MARTIN, H.A. 1973 Upper Tertiary palynology in southern New South Wales. Geol. Soc. Aust. Spec. Publ., 4:35-54.
- MARTIN, H.A. 1974 The identification of some Tertiary pollen belonging to the family Euphorbiaceae. Aust. J. Bot., 22:271-2=91.
- MARTIN, H.A. 1978 Evolution of the Australian flora and vegetation through the Tertiary: evidence from pollen. Alcheringa, 2:181-202.
- MARTINI, E. 1971 Standard Tertiary and Quaternary calcareous nannoplankton zonation. Proc. 2nd. Conf. Planktonic Microfossils. 2:-739-9
- MOORE, T.C.,
VAN ANDEL, T.H.,
SANCETTA, C. &
PISIAS, N. 1978 Cenozoic hiatuses in pelagic sediments. Micropalaeontology, 24(2):113-138.
- MURRAY, J.W. 1973 Distribution and ecology of living benthonic foraminiferids :274pp.
- PFLUM, C.E. &
FRERICHS, W.E. 1976 Gulf of Mexico deep-water foraminifers. Cush. Found. Spec. Publ., 14:125pp.
- RADE, J. 1977 Tertiary biostratigraphic zonation based on calcareous nannoplankton in eastern Australian nearshore basins. Micropalaeont., 23: 270-296.

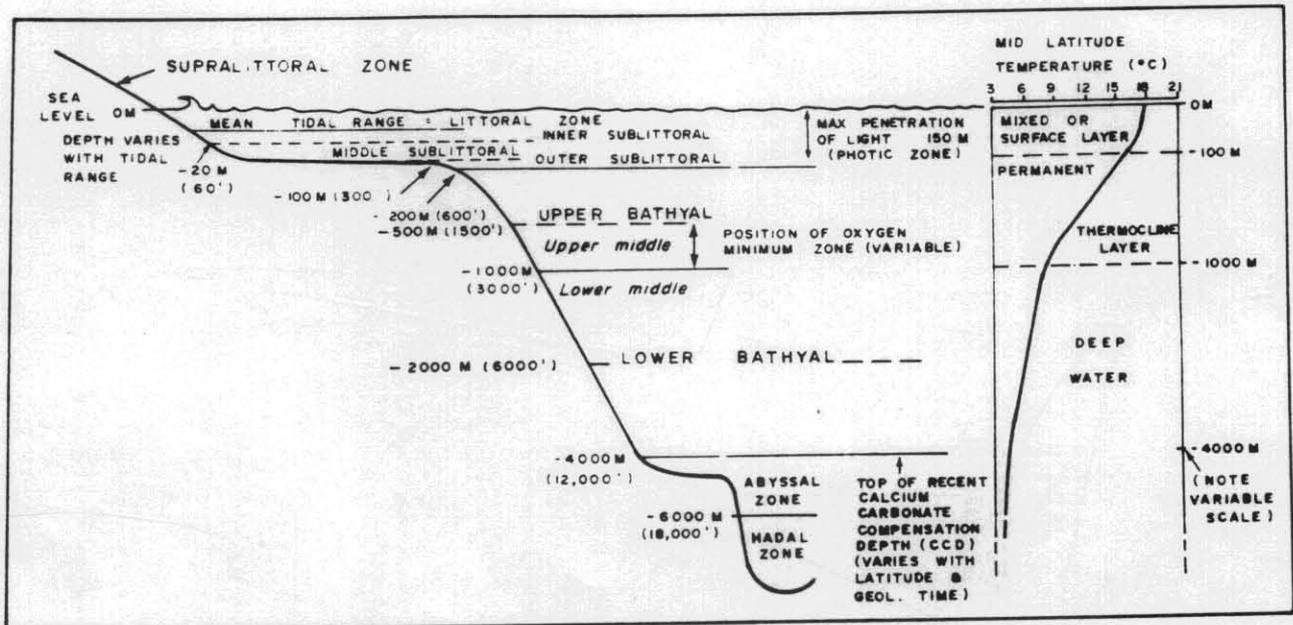
- ROBINSON, G.S. 1970 Change of the bathymetric distribution of the Genus Cyclamina. Trans. Gulf-Cst. Ass. Geol. Soc., 20:201-209.
- STAINFORTH, R.M.,
LAMB, J.L.,
LUTERBACHER, H.,
BEARD, J.H. &
JEFFORDS, R.M. 1975 Cenozoic planktonic foraminiferal zonation and characteristics of index forms. Univ. Kansas Paleo. Contrib., Art. 62:425pp.
- STOVER, L.E. &
EVANS, R.R. 1973 Upper Cretaceous-Eocene spore-pollen zonation, offshore Gippsland Basin, Australia. Geol. Soc. Aust. Spec. Publ., 4:55-72.
- STOVER, L.E. &
PARTRIDGE, A.D. 1973 Tertiary and Late Cretaceous spores and pollen from the Gippsland Basin, southeastern Australia. Proc. R. Soc. Vict., 85:237-86.
- WASS, R.E.,
CONOLLY, J.R. &
MACINTYRE, R.J. 1970 Bryozoan carbonate sand continuous along southern Australia. Mar. Geol., 9:63-73.

APPENDIX I

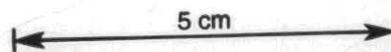
SOUTH EAST AUSTRALIAN FLORAL ZONATION SCHEME	
AGE	FLORAL ZONE
MIDDLE - EARLY MIOCENE	<i>Triporopollenites bellus</i>
	<i>Proteacidites tuberculatus</i>
OLIGOCENE	Upper <i>Nothofagidites asperus</i>
	Lower <i>Nothofogeidites asperus</i>
EOCENE	<i>Proteacidites asperopolus</i>
	<i>Malvacipollis diversus</i>
PALAEOCENE	LATE - MIDDLE <i>Lygistepollentes balmei</i>
	MIDDLE - EARLY <i>Tricolpites longus</i>
LATE CRETACEOUS	<i>Tricolporites lilliei</i>

AFTER STOVER AND EVANS (1973) ,
STOVER AND PARTRIDGE (1973)

APPENDIX II



Note: Sublittoral is equated with "shelf" of other authors, and is the benthonic equivalent of the neritic water mass.



CLASSIFICATION OF BENTHONIC MARINE ENVIRONMENTS ADAPTED FROM HEDGPETH (1957), MURRAY (1973), BERGGREN (1978) AND INGLE (1980)

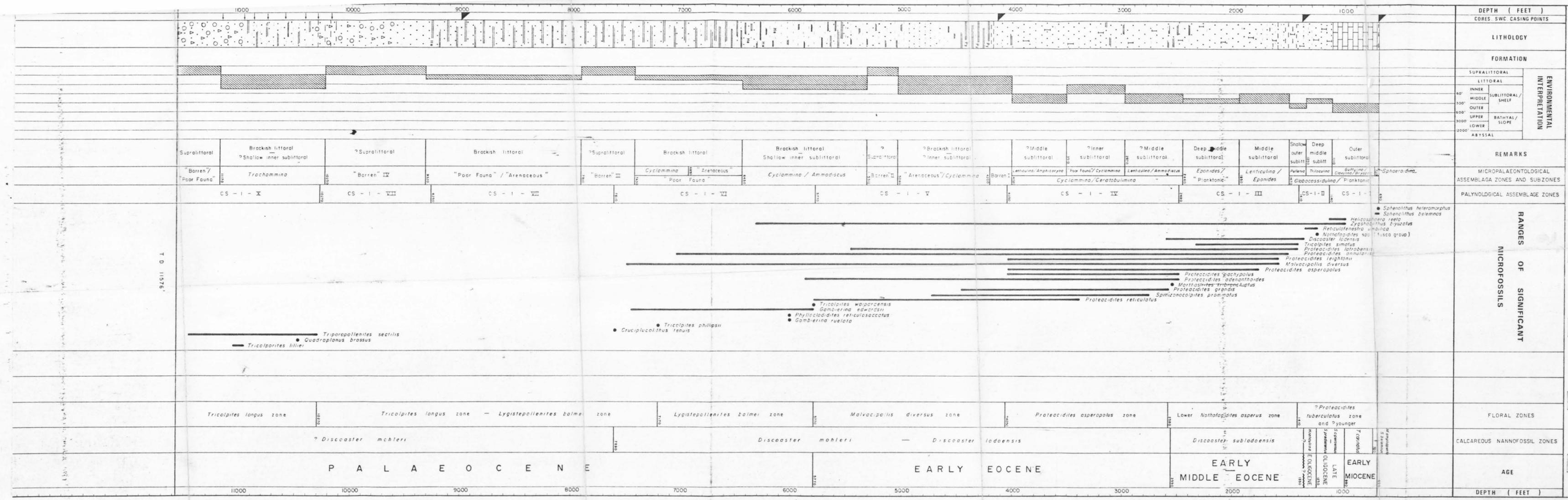


BIOSTRATIGRAPHIC DATA

LOG

LIMITED

ENCLOSURE 4
 RL 04-38C
 462059
 ROBERTSON RESEARCH (SIN)
 CAPE SORELL No. 1
 Date: JAN, 1983 Scale 1:5000
 Report No. 117



5cm