



FORAMINIFERAL SEQUENCE

in

DISCOVERY BAY # 1.

for:- PHILLIPS AUSTRALIAN OIL COMPANY

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### SUMMARY.

The Phillips Australia Otway Basin Well, DISCOVERY BAY # 1 can be divided into four broad units on microfaunal and residue grain evidence.

UNIT 4 - 795m to 434m - MID EOCENE, OLIGOCENE and PLIOCENE marine sediments. The late Eocene/early Oligocene and the entire Miocene periods were not represented in the sedimentary sequence.

UNIT 3 - 1013.5m to 1594m - BARREN INTERVAL (No foraminifera found). Grain analysis suggests marginal marine, lagoon/deltaic complex shoreward of barrier/dune system.

UNIT 2 - 1618m to 2399.5m - LATE CRETACEOUS marginal marine; salt marsh/pro-delta environments.

UNIT 1 - 2458.5m to 2772m - BARREN INTERVAL (No foraminifera found). Marginal marine deltaic complex.

### Arrangement of Report.

Units 1 and 2 are discussed on pages 3 to 4, and pertinent results shown on Table 1 at back of report.

Unit 3 - briefly discussed on page 4 with grain analysis summarised on Table 2 (2 sheets) at back of report.

Unit 4 - Described with biostratigraphic correlations and environmental interpretations on pages 5 to 9, with summary on page 5. Planktonic foraminiferal distribution is given on Table 3, with significant benthonic foraminifera and other grains present tabulated on Table 4. Reliability of zonal determinations given on the Data Sheet - Table 5.

UNIT 1 - 2458.5 to 2772m - probably CRETACEOUS.

Represented in sidewall cores by carbonaceous and clayey, fine, angular quartz sandstone. No foraminifera were found in this sediment, although it was lithologically similar to the fossiliferous, late Cretaceous sediment at and above 2399.5m. This unit was probably deposited in a deltaic/marginal marine environment, in water less saline (<5‰) than those present in Unit 2, above 2400m.

UNIT 2 - 1618m to 2399.5 - LATE CRETACEOUS.

This unit can be divided on both lithological and faunal grounds into two formations:-

1618-1846.5m = CURDIES FORMATION

E-Log change at ?1851m?

1974-2399.5m = PAARATE FORMATION

The interval between 1974 and 2399.5m contains a heterogeneous admixture of sandstone types (refer Table 1) with carbonaceous material in some samples. The foraminifera are all arenaceous benthonic forms, typical of the late Cretaceous Paarate Formation (Taylor, 1964). On biofacies evidence, the interval is equated with that between 1590 and 2165m in Voluta # 1 (S.D.A., 1967). Absence of any calcareous foraminifera as well as the heterogeneity of sediment types precludes any correlation of this interval with the Belfast Mudstone.

The Paarate Formation was deposited in salt marsh and/or lagoonal environments, with salinities less than that of normal seawater (= 35‰), though in all the waters were polyhaline with seasonal fluctuations as in the modern Gippsland Lakes (Apthorpe, 1980). Note is made of presence of the thick shelled pelecypod (mollusca) *Inoceramus* at 2047.5m in Discovery Bay # 1. Sporadic occurrences of *Inoceramus* have been reported within the Paarate Formation in a number of drilled sequences. The existence of this molluscan type, plus the complete dominance of arenaceous foraminifera indicates that the sediment/water interface was deplete in oxygen; that is anaerobic.

The interval between 1618 and 1846.5m contains a suite of arenaceous foraminifera dominated by the arenaceous benthonic foraminifera *Haplophragmoides* spp. The morphometric nature of these forms would suggest that they were early Tertiary rather than late Cretaceous (refer Taylor, 1965). However, a similar

association was described from Voluta # 1 between 1412 and 1551m; an interval considered as being late Cretaceous on palynological evidence (S.D.A. 1967). The sedimentary sequence was fairly homogenous, being predominantly a quartz sandy siltstone. In most samples, very little residue (>.075mm) remained after processing. In the sample at 1687m, only 50 grains were in the residue and of these, 48 were arenaceous foraminifera.

The interval is regarded as representing the Curdies Formation, deposited in the margins of a deltaic fan. Water salinity and oxygenation were similar to these deduced for the Paarate Formation interval.

UNIT 3 - 1013.5m to 1594.5m.

An interval barren of fauna. Although the sedimentary sequence is heterogenous, a broad subdivision can be made of presence or absence of carbonaceous material and/or pitted and impact fractured quartz grains (refer Table 2).

1013.5m to 1400.5m - high percentages of pitted and impact fractured quartz grains.

1426.75 - oxidized pyritic/limonitic clayey, quartz sandstone with high percentage of pitted quartz.

1525 to 1594.5 - carbonaceous, silty fine quartz sandstone with varying percentages of pyrite.

No statement can be made regarding age or other correlations, because of absence of foraminifera. However, all samples contained pitted and/or impact fractured quartz grains, suggesting aeolian transport mechanisms, with the possibility that the depositional area was lagoonal; enclosed on the shoreward side of a barrier/dune system.

UNIT 4 - 434m to 795m - MID EOCENE to PLIOCENE SEQUENCE.

The tabulation below summarises the biostratigraphy and paleoenvironment from nineteen sidewall cores. The interval was divisible into three discrete biostratigraphic units with an unconformity bounding the top and bottom of the middle unit. Cutting samples were examined at 5 metre intervals between 650 and 680 metres.

Sidewall Cores depth (m)	Approx. E-Log Pick	AGE*	ZONE*	PALEOENVIRONMENT <sup>¶</sup>	LITHO-UNIT
434 to 660		LATE to MID PLIOCENE	A-3 to A-4	Canyon fill or outer shelf fan (<200m)	WHALERS BLUFF FORMATION equivalent
664					
675 to 758		LATE OLIGOCENE	I-1 to I-2	MID SHELF (<100m)	Chert horizon in cuttings between 665 & 675. GAMBIER LIMESTONE
765					
766 to 786		EARLY OLIGOCENE	J-1	INNER SHELF (<40m)	CLIFTON FORMATION
788					
790 to 795		MID EOCENE		INNER SHELF (<40m)	NIRANDA GROUP equivalent
795					

\*Biostratigraphy is based on Taylor (in prep.); see also comments on next page regarding correlations. Planktonic foraminiferal distribution for Discovery Bay # 1 is presented on Table 3 of this report with reliability of zonal determinations on the Data Sheet - Table 5.

¶Interpretation based on distribution of selected benthonic foraminiferal species and other sediment grains (<.075mm) as shown on Table 4 (Paleo-depth estimates are in parentheses).

MIDDLE EOCENE, Inner Shelf Carbonate; interval from 795m to 790m.

The planktonic foraminifera associations were typical of those representing the upper part of the Middle Eocene westward from Portland along the southern Australian Margin. Similar faunas were listed by McGowran (1973) from bores onshore, in the Gambier Embayment of the Otway Basin. This assemblage, here designated as Zone N, can be correlated on a worldwide basis with Blow Zone P14 (refer also McGowran, 1973).

The benthonic foraminiferal faunas are dominated by *Cibicides* spp. Group 1 (including *C. perforatus* and *C. brevoralis*) with *Elphidium* sp. and *Notorotalia* in a muddy bryozoal calcarenite, indicating medium energy conditions on an inner continental shelf sea floor with water depths in the vicinity of 40 metres. Sediments containing the same planktonic association in the Gambier Embayment were non calcareous, with carbonaceous material, suggesting a shallower, more shoreward position than in Discovery Bay # 1. For these reasons, the term Niranda Group is applied rather than the Gambier Embayment term Lacepede Formation (refer McGowran, 1973).

Both the Discovery Bay # 1 and Gambier Embayment mid Eocene sediments contain evidence of open marine influence with planktonic foraminifera being present, but east of the Gambier Embayment, no open marine mid Eocene has been reported (Taylor, 1971). This west to east trend from marine to marginal marine, was no doubt related to the opening of the Southern Ocean (Deighton et al, 1976).

A HIATUS from mid Eocene into the early Oligocene is apparent from the foraminiferal associations between 790m and 786m, with a period of some 5 to 7 million years not represented by sediment. Late Eocene, open marine carbonates were absent from the sequence, although they were present both to the west (McGowran, 1973) and in the east (Taylor, 1971). It is assumed that structural growth and/or regional uplift of the "Portland/Dartmoor High" prevented late Eocene deposition or removed it from the Discovery Bay # 1 sequence.

EARLY OLIGOCENE - inner shelf detritus; interval 786m to 766m.

The basal Oligocene, J-2 association with *Globigerina brevis* and *Globorotalia gemma* was not found in this sequence. The planktonic

association at 782m represented the Zone J-1 assemblage which was present up to 766m, which contains the highest appearance of *Globigerina angiporoides angiporoides*. This biostratigraphic event correlates with the Blow Zones P20/P21 of the pan tropical belt.

The lowest sample of this unit, at 786m was unfossiliferous, however the sedimentary grain characters are typical of the basal unit of the heterogeneous, detritus rich, Clifton Formation. As elsewhere in the Otway Basin, the Clifton Formation lithological and paleontological sequence in Discovery Bay represents the record of the Early Oligocene transgression onto an exposed shelf platform with water depth increasing from intertidal at 786m to around 40 metres at 766m.

LATE OLIGOCENE - mid shelf bryozoal calcarenite; interval 758m to 665m.

The litho and biofacies of this sedimentary interval is characteristic of the Gambier Limestone. Biostratigraphically, the top of the interval approximates the top of Blow Zone N3, at around 25 million years ago, although in the type area the Gambier Limestone deposition continued to the base of the Miocene at 22.5 million years (refer McGowran, 1973).

A HIATUS from late Oligocene to mid Pliocene is apparent from the dramatic change in planktonic foraminiferal associations between sidewall core at 675m (= Late Oligocene) and that at 660m (= Mid Pliocene). Examination of ditch cuttings revealed the existence of considerable chert in the interval between 665m and 680m; with the highest appearance of Oligocene planktonic foraminifera in the interval 665m to 670m. Abundance of chert is a feature of the upper part of the Gambier Limestone (McGowran, l.c., p.45). This chert horizon no doubt arrested post-Oligocene erosion of the Limestone unit, as well as providing a prominent seismic reflector.

The Oligocene/Pliocene unconformity is placed at 665m on microfossil and lithological changes in the ditch cutting sequence, which corresponds with an E-log character change at 664m. A time span of some 20 million years is estimated for the period *not represented* by sediment in Discovery Bay. Such a span includes the entire Miocene; yet most of the Miocene is represented by sediment onshore at Portland (Singleton et al, 1976) with at least the early Miocene (22.5 to 17.5 m.y.) being present in Voluta # 1 (S.D.A., 1967).

MID to LATE PLIOCENE - turbo-carbonate wedge; interval 434m to 665m.

This is a sedimentary interval of polymodal, biogenic carbonates with sporadic concentrations of quartz grains. The basal sidewall core at 660m contains remaini  grains; both chert from the underlying Gambier Limestone, as well as quartz from another source. Table 3 demonstrates the Oligocene to Pliocene abrupt faunal change, although recycled Oligo/Miocene planktonic species were present in the basal samples. The sidewall core at 650m contains a typical mid Pliocene Zone A-4 fauna which can be correlated with Blow Zone N19, as well as with planktonic foraminiferal species listed by Mallett (in Singleton et al, 1976) from Whalers Bluff, onshore at Portland. The highest sidewall core (at 434m) examined was no younger than late Pliocene, thus the Discovery Bay # 1 sampled interval of Pliocene corresponds with the 2 million year time span allotted to the onshore Whalers Bluff Formation by Singleton et al (l.c.) in their interpretation of radiometric dating and planktonic foraminiferal biostratigraphy. Base of the Pliocene in both sections approximates 4.5 m.y.

Comparison between the Whalers Bluff Pliocene and that in Discovery Bay # 1 illustrates thickening seaward, with an increase in accumulation rate by some 30 times.

	<u>Whalers Bluff</u>	<u>Discovery Bay # 1</u>
Paleowater Depth	<20m	100m to 200m
Sedimentary time span	$2 \times 10^6$	$2 \times 10^6$
Thickness (not compensated for compaction)	8m	+231m
Accumulation rate per 1000 years	4 millimetres	12 centimetres

The characteristics of this biogenic carbonate suggests transport was by gravity flow, at first along the compact surface of the chert enriched Gambier Limestone. The Pliocene sediments could be described as limestone *turbidites* or "*turbo-carbonates*". There are close

similarities between the Discovery Bay Pliocene turbo-carbonates and the mid Miocene canyon fill carbonates of the Gippsland Basin. Furthermore, seismic surveys showed a thick, late Tertiary canyon fill deposit offshore from Portland (Hopkins, 1966). However, recent seismic extrapolation suggests that this thick Pliocene sequence in Discovery Bay # 1 was part of a widespread fan shaped, wedge of sediment rather than fill restricted within a deeply incised canyon. A single vertical sample sequence does not permit any comment regarding the geometric form of the sediment packet; however, the high accumulation rate denotes amazingly high biological productivity. This conclusion, together with high plankton percentages and other grain characters indicates that nutrient enriched, deep oceanic waters, upwelled onto the continental shelf; a phenomena explained by Diester-Haas (1978). Submarine canyons act as pathways for such upwellings. Therefore, adjacent canyons may have generated this prolific organic growth, thus indirectly contributing to this rapid and massive accumulation of biogenic carbonates.

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AGE	Depth of lowest sample	ENVIRONMENT and LITHOLOGICAL CORRELATION	E-LOG CHARACTER CHANGE	RESIDUE LITHOLOGY		ARENACEOUS BENTHONIC FORAMINIFERA & MOLLUSCA	SIDEWALL CORE Depth in metres	
				MINOR COMPONENTS	MAJOR COMPONENTS			
				c-m ang-subrd qtz. c ang rock frags. limonite staining mica pyrite pyrite glauconite pellets	f = foraminifera f = f ang qtz silty sdst. Q = f-c ang subrd qtz. c.sdst. = carbonaceous clayey f. qtz. sandstone			
?	?	?	?					
LATE CRETACEOUS	1846.5	Delta fan CURDIES FORMATION	?1851?	A A A	QQQ qqqqqqqqqqqq		↑ 1618	
				A A	ffffffffff	° ° ° x	↑ 1687	
				A A	qqqqqqqqqqqqqqqq		↑ 1719	
				A A	qqqqq fffffff	° ° ° ?	↑ 1796.75	
				A A	qqqqq fffffff	° ° ° x	↑ 1846.5	
		Salt Marsh/ lagoonal PAARATE FORMATION		A	c.sdst c.sdst		N.F.F.	↑ 1974.5
				Q Q	c.sdst c.sdst	x °	° ° °	↑ 2047.5
				Q Q	c.sdst c.sdst		N.F.F.	↑ 2097
				A	pppppppppppppppppp		° °	↑ 2164
				A A A	pppppppppppppppppp		° °	↑ 2260
?	2399.5	?	?2400?	A A A	QQQQQQQQQQQQQQQQ		↑ 2268.5	
				A	c.sdst c.sdst		°	↑ 2293
				A	c.sdst c.sdst		x ° °	↑ 2357
				A	c.sdst c.sdst		° ° ° °	↑ 2381.5
				A	c.sdst c.sdst		° ° ° °	↑ 2399.5
				A	c.sdst c.sdst		↑ 2458.5	
				r	c.sdst c.sdst		N.F.F.	↑ 2633.5
				A A A	c.sdst c.sdst		↑ 2772	

A = abundant 1-5% total grains  
r = rare

KEY: ° = <20 specimens  
x = >20 specimens  
N.F.F. = no foraminifera found

TABLE 1: LATE CRETACEOUS FORAMINIFERA, MOLLUSCA & RESIDUE LITHOLOGY - DISCOVERY BAY # 1.  
David Taylor, November 9, 1982.



BIOSTRATIGRAPHY		D. OST. IGR. & PALEOENVIRONMENT with paleodepth estimates in metres		MINOR COMPONENTS					MAJOR COMPONENTS					MID & OUTER SHELF <200m		INNER + MID SHELF <100m		*SAMPLE DEPTH*				
AGE	Depth of lowest sample	ZONE	LITHOLOGICAL UNITS with major E-Log character changes	INNER SHELF <40m	MID SHELF <100m	OUTER SHELF WEDGE <200m	PLANK. FORAM %	FORAM COUNT	coarse subrd qtz PITTED glauconite pellets & moulds limonite - pellets coarse quartz fine quartz biogenic pyrite mollusca frags. echinoid frags. ostracods fish frags. bryozoal frags. sponge spicules	BM=biomicrite ▲=Chert BC=bryozoal calcarenite m=marl b=bryozoa f=foraminifera s=calc.siltstone q=fine quartz Q=med.coarse qtz. G=glaucanite L=pellet limonite	BC BC BC BC BC	BC BC BC BC BC	BC BC BC BC BC	BC BC BC BC BC								
Pliocene	570 to 665	A-3	Turbo-Carbonate. Distal equivalent of WHALERS BLUFF FORMATION	60	60	664	60	300										434				
				60	200															484		
				60	200		A														525	
				80	200		A A															560
				90	300		A	C														570
				60	2000			A														580
				70	1000		A	C														650
				80	100																	660
				665																		665-675
		Oligocene		675 to 758	I-1		GAMBIER LIMESTONE	?	?				r r A									675
	30		1000						r r A										725			
I-2	?		?																	750		
?	?																			758		
?	?																			766		
Oligocene	782 to 786	J-1	CLIFTON FORMATION	5	200				A	C A								774				
				10	50														778			
				20	750															782		
				10	500															786		
Eocene	795	N	NIRANDA GROUP	30	200				A	A A								790				
				30	300														795			

→ = sidewall core; \* = cutting samples

A = abundant 1-5% total grains  
 C = common <20 grains  
 r = rare

KEY: ° = <20 specimens  
 x = >20 specimens  
 D = >60% specimens  
 W = worn specimens

TABLE 4: TERTIARY BENTHONIC FORAMINIFERA & RESIDUE LITHOLOGY - DISCOVERY BAY # 1; 795 to 434 metres.  
 David Taylor, November 9, 1982.

TABLE 5.

MICROPALAEONTOLOGICAL DATA SHEET

BASIN: OTWAY ELEVATION: KB: 23.0m GL: -96.0m  
 WELL NAME: DISCOVERY BAY # 1 TOTAL DEPTH: 2777m

AGE	FORAM. ZONULES	HIGHEST DATA					LOWEST DATA					
		Preferred Depth	Rtg	Alternate Depth	Rtg	Two Way Time	Preferred Depth	Rtg	Alternate Depth	Rtg	Two Way Time	
PLEIS- TOCENE	A <sub>1</sub>											
	A <sub>2</sub>											
PLIO- CENE	A <sub>3</sub>	434	1				570	1				
	A <sub>4</sub>	580	0				665	3	650	0		
	B <sub>1</sub>											
MIOCENE	LATE	B <sub>2</sub>										
		C										
		D <sub>1</sub>										
	MIDDLE	D <sub>2</sub>										
		E <sub>1</sub>										
		E <sub>2</sub>										
		F										
	EARLY	G										
		H <sub>1</sub>										
		H <sub>2</sub>										
	OLIGOCENE	LATE	I <sub>1</sub>	665	3	675	1	775	1			
			I <sub>2</sub>	725	1			725	1			
EARLY		J <sub>1</sub>	766	2	778	0	782	2	778	0		
		J <sub>2</sub>										
EOC- ENE	K											
	Pre-K *	790*	0				795*	0				

COMMENTS: \*The Pre-K Unit was ZONULE N representing the top of the mid Eocene.

No foraminifera were found in 19 SWCs examined between 1013.5 & 1594.5m.

Late Cretaceous arenaceous benthonic foraminiferal assemblages in SWCs between 1618 and 2399.5m assigned lowest confidence rating re. age, but high confidence re local correlation to Voluta # 1.

- CONFIDENCE RATING:
- 0: SWC or Core - Complete assemblage (very high confidence).
  - 1: SWC or Core - Almost complete assemblage (high confidence).
  - 2: SWC or Core - Close to zonule change but able to interpret (low confidence).
  - 3: Cuttings - Complete assemblage (low confidence).
  - 4: Cuttings - Incomplete assemblage, next to uninterpretable or SWC with depth suspicion (very low confidence).

NOTE: If an entry is given a 3 or 4 confidence rating, an alternative depth with a better confidence rating should be entered, if possible. If a sample cannot be assigned to one particular zone, then no entry should be made, unless a range of zones is given where the highest possible limit will appear in one zone and the lowest possible limit in another.

DATA RECORDED BY: David Taylor

DATE: November 16, 1982.

DATA REVISED BY: \_\_\_\_\_

DATE: \_\_\_\_\_