SHELL DEVELOPMENT

(AUSTRALIA)

PTY. LTD.

509

VOLUTA NO. 1, OFFSHORE VICTORIA

WELL COMPLETION REPORT

by

Shell Development (Australia) Pty. Ltd.

Melbourne,
April, 1968.

CONTENTS

APPENDICES

I. SUMMARY

1. Drilling -

Voluta-1 has been drilled with the SEDCO 135E semi-submersible rig in floating position for the operator, Shell Development (Australia) Proprietary Limited.

Although an elaborate sea bottom investigation suggested the presence of less favourable anchoring ground, no difficulties were encountered in positioning the unit over the location.

The well was spudded in on the 25th August, and abandoned as a dry hole on 15th December, 1967.

The time needed to complete the well was considerably longer than anticipated, mainly due to the following:-

(1) When drilling at a depth of 1762' a complete loss of circulation was experienced. After several attempts to restore circulation with plugging material and cement failed, drilling without returns was resumed using seawater down to the 13-3/8" casing setting depth.

(2) After cementing the 13-3/8" casing two days were needed to pull the marine riser due to failure of the H4 connector which could not be unlatched. While landing the 13-5/8 BOP stack the guide posts and 13-3/8" housing were damaged; this made it necessary to retrieve the stack to make a thorough investigation of the damage.

(3) At a depth of 3,335 ft again considerable mudlosses were experienced, but were quickly traced to a leak in the underwater equipment. The 13-5/8 BOP stack had to be retrieved once more to repair the flex joint.

(4) After cementing the 9-5/8" casing the pressure test failed before reaching the required test pressure of 5,000 psi. Subsequent investigation showed that both the interior of the collar and shoe had sheared off, allowing mud behind the shoe joint which consequently had to be recemented.

(5) On the 11th October, after a few days with severe weather conditions, the marine riser parted at a BT connection 140 ft above the BOP stack and had to be retrieved for repair.

(6) A considerable increase in the Upper Cretaceous section overlying the primary objective led to deepening of the well in an attempt to reach the Otway group.

Whilst drilling the 8½" hole to final depth at 13,037 ft bdf, the hole condition had deteriorated so badly that reaming tight spots after every roundtrip was common practice. The attempt to run Schlumberger logs to TD failed due to the survey tools holding up at 11,072 ft and 12,415 ft respectively after an additional check trip had to be made to ream several tight spots in the logging interval. When pulling out the Schlumberger Sonic/Gamma Ray/Caliper tool the caliper was found to have been lost in the hole. The attempt to retrieve the fish with a Globe junk basket failed when the assembly parted at a break in the sub between the basket and the upper part of the assembly. Further efforts to recover the fish, which was suggested to lie over on its side, were unsuccessful. This led to the decision to abandon the well.

2. Geological -

Voluta-1 was the third offshore exploration well (after Pecten-1A and Nerita-1) to be drilled in the Otway Basin. It was located on the culmination of a seismically defined anticlinal structure with a closed area of approximately 20 square miles and a vertical closure of up to 1,000 feet.

The sequence penetrated consisted of Lower Miocene - Lower Oligocene carbonates and Uppermost Eocene ferruginous sands of the Heytesbury group to 2754 feet. Sands, silts and clays of the Paleocene Wangerrip group were drilled to 4385 feet and sands and clayey siltstones of the Upper Cretaceous Sherbrook group to total depth at 13,037 feet.

Good quality reservoir rocks were present in the Tertiary and Upper Cretaceous sequence but only slight shows of hydrocarbons were encountered.

The stratigraphical knowledge of this part of the Otway Basin was considerably improved by the drilling of Voluta-1. In particular, the lower part of the Sherbrook group was found to be much thicker than in onshore wells.

II. INTRODUCTION

Voluta No. 1 is the third offshore exploration well situated in the Otway Basin in southwestern Victoria. It was drilled to test the hydrocarbon bearing potential of a seismically defined structure with approximately 20 square miles of closure area and up to 1,000 feet of vertical closure, situated 5 miles offshore in the Gambier Sub-basin.

The Gambier Sub-basin constitutes the western part of the Otway Basin (see locality map, Encl. 1), which trends approximately E-W across south-western Victoria into South Australia, extending offshore onto the continental shelf.

During the Lower Cretaceous (and possibly the Upper Jurassic), a thick sequence of first-cycle fluviatile sandstones, siltstones and shales of the Otway group were deposited in the E-W trending trough. At the end of the Lower Cretaceous, extensive fault movements accompanied by minor folding started to take place in the Otway Basin and the original E-W trough became divided into several embayments and sub-basins, one of which is the Gambier Sub-basin. Upper Cretaceous and Tertiary sediments were deposited in these sub-basins during several transgressive - regressive cycles above the eroded surface of the Otway group. Sedimentation was strongly influenced during this time by structure; most of the anticlinal features appear to be broad gentle folds draping basement highs.

The Upper Cretaceous Sherbrook group, the Paleocene Wangerrip group and the Eocene Nirranda group contain mature sandstones and sands with interbedded siltstones and clays. The uppermost strata in the sequence are Uppermost Eocene - Miocene carbonates deposited during a widespread transgression over the whole basin. Each of those major rock units recognized in the Otway Basin is limited by an unconformity.

Prior to drilling the well, the sands of the Wangerrip and Sherbrook groups were regarded as potential reservoirs, the main target being the lower part of the Sherbrook group in which reservoir rocks were known from onshore wells.

The section penetrated was generally as predicted for the Heytesbury and the Wangerrip group. The Sherbrook group was also encountered as expected, but its lower part was found to be greatly expanded in thickness.

The well was abandoned at 13,037 feet for mechanical reasons before the Otway group was reached.

III. WELL HISTORY

1. General Data

(a)	Well name and number:	VOLUTA NO. 1
(b)	Name and address of Operator:	Shell Development (Australia) Pty. Ltd., 155 William Street, Melbourne, Victoria, 3000, Australia.
(c)	Name and address of Tenement Holder:	Frome-Broken Hill Co. Pty. Ltd., 31 Queen Street, Melbourne, Vic., 3000, Australia.
(d)	Petroleum tenement:	Authority to prospect PEP 22 Otway Basin, offshore Victoria. Shell Development is acting as operator on behalf of itself and Frome-Broken Hill Co. Pty.Ltd. The operating agreement dated 29th June, 1965, between Frome-Broken Hill Co. Pty.Ltd., was approved by the Minister for Mines, Victoria, on 13th July, 1965.
(e)	District:	Otway Basin, offshore Victoria.
(f)	Location:	I. Geographical Co-ordinates: Long. 141° 18' 47.53" E Lat. 38° 25' 46.66" S II. Mercator ATM (Zone 6) 429910 yards E 262416 yards N
(g)	Elevation: Reference for depth: Derrick floor elevation:	Seabed 301 feet below MSL. Derrick floor. 112 feet above MSL.
(h)	Total Depth:	13,037 feet bdf.
(j)	Date total depth reached:	8th December, 1967.
(k)	Date well abandoned:	15th December, 1967.
(l)	Date rig was released:	21st December, 1967.
(m)	Drilling time to total depth:	105 days.
(n)	Status of well:	Abandoned as dry hole with following plugs:- Cement Plug No.1 (first stage): 7,500-6,700 ft bdf with 335 sacks Class "E" cement. Cement Plug No.1 (second stage): 6,700-5,800 bdf with 380 sacks Class "E" cement. Baker Model "N" Bridge Plug: At 5310 ft bdf in 9-⅝" casing. Baker Model "K" converted to bridge plug at 710 ft bdf. Cement Plug No.2:680-413 ft bdf with 100 sacks Class "E" cement. Cemented Annulus 20" - 13-⅜" casing with 350 sacks Class "E" cement. VETCO type temporary and permanent guide base left on sea bed.

(c) Total Cost: A$2,473,343

2. Drilling Data:

(a) Name and address of Drilling Contractor:

Southeastern Drilling, Inc.,
4400 First National Bank Building,
Dallas, Texas, 75202,
U.S.A.

In Australia:

143 Percy Street,
Portland, Vic., 3305, Australia.

(b) Drilling Plant:

Plant owned by Southeastern Drilling, Inc., of U.S.A.

Drawworks: Make: Oilwell
Type: E-3000 (electric driven (drawworks.

Power Units (Engine & Generators):

No.	Make	Model
3 (on skids)	Electro-Motive Division	SR-16" W

The skid mounted units comprised the following:-

I. Engines:

No.	Make	Model	H.P.
3	GM	16-645	2200 each at 857 RPM.

II. Generators:

Power Unit No. I:
One 1500 KW DC generator.
Two D-79 DC generators 553 KW each.

Power Unit No. II and III:
One 1500 KW DC generator.
One D-79 DC generator 553 KW.
One 750 KW AC alternator.

Auxiliary Units:
One Cat. D-353 engine driven.
250 KW AC alternator.

Horse Power:
Available to Drawworks - 1600 H.P.

Drill Pipe:

Size (in)	5 Range 2
Tool Joint (in)	6-$\frac{3}{8}$ - OD
Connection type	5" XH
Weight lb/ft	19.5
Grade	E
Length (ft)	15,000

Drill Collars:

Size O.D. (in)	9$\frac{1}{2}$	8	6$\frac{1}{2}$
I.D. (in)	2-13/16	2-13/16	2-13/16
Connection (type)	7$\frac{5}{8}$ API Reg.	6$\frac{5}{8}$ API Reg.	API No.46 IF (4"IF)
Weight lbs/ft	220	150	92
Number	6	30	40

Core Barrel:

1°.	2°.
Make : Christensen	Make: Christensen
Model : 250-P	Model: 250-P
Length : 6$\frac{3}{4}$ x 4 x 30'	Length: 5$\frac{3}{4}$x3$\frac{1}{2}$x30'
Number : One	Number: One

(c) Mast:

Make	:	Lee C. Moore
Type	:	Cantilever offshore mast-welded type.
Gross Capacity	:	1,333,000 lbs.
Static hook Capacity	:	1,000,000 lbs.

(d) Slush Pumps:

No.	Make	Type	Size
2	Oilwell	1700-P	7" x 18"
2	Mission	Centrifugal	5 x 6R

All electrically driven (see Power Units above).

(e) Blowout Preventer Stacks:

1. 20" (Nom.) BOP's - comprising the following From Top to Bottom -

(i) One inverted VETCO H-4 - 20¾" hydraulic connector.
(ii) One VETCO 24" breach lock flex joint for a maximum of 9 degrees deflection.
(iii) One hydril MSP 2000 psi.
(iv) One Cameron 20" nominal drilling spool with one studded 3-1/16" 10,000 lbs test outlet.
(v) One VETCO H-4 - 20¾" hydraulic connector.

2. 13" (Nom) BOP's comprising the following from Top to Bottom -

(i) One inverted VETCO H-4 13⅝" hydraulic connector.
(ii) One VETCO 16" breach lock flex joint, (allowing a maximum deflection of 9º).
(iii) One Hydril GK-5,000 psi W.P.
(iv) Two double Cameron U-type preventors with ram locks, each with 2 studded outlets 10,000 psi. test, 3-1/16" I.D.
(v) One VETCO H-4, 13⅝" hydraulic connector.

(f) Hole size and depth (bdf):
36 inch to 525 feet
26 inch to 976 feet
17½ inch to 2650 feet
12¼ inch to 6335 feet
8½ inch to 13037 feet.

(g) Casing and Cementing Details:

Size (in)	30	20	13-⅜	9⅝
Weight (lbs/ft)	310	94	72	47
Grade	-	J55	N80	P110
Range	3	3	2	2
Setting Depth (ft/bdf)	516	966	2,625	6,314
Shoe - Collar	Float/-	Float	Float/Diff Fillup	Diff Fillup Shoe & Collar
Plugs	-	-	Top & Bott.	Top & Bott.
Centralisers	-	-	3	10
Cement (sacks)	1,200	2,000	1,220	1,700
TOC annulus (ft/bdf)	Seabed	Seabed	1,824(CBL)	2,620(CBL)
Method used	Displacement	Displacement	Plugs	Plugs

(h) Drilling Fluid:

Seawater was used as a drilling fluid to the 20" casing setting depth. Before running 30" and 20" casing 66 lbs/cuft Bentonite mud was spotted in the hole; Spersene and XP-20 inhibited mud was used after drilling out the 20" casing shoe. At 1,757' total mudlosses were experienced and drilling was continued with the use of seawater to 2650' at which depth the 13-⅜" casing was run. After drilling out the 13-⅜" casing shoe again Spersene and XP-20 inhibited mud was used. From 11,000 ft CMC had to be used to keep the fluid loss at a desirable level.

Tabled below are the average weekly mud properties:

Week	Weight lbs/cuft	Viscosity MF-Sec	API Fluid Loss cc/30 min	Sand %	Silt %	P_H	Chlorine PPM
1	Seawater	-	-	-	-	-	-
2	69	61	6.3	-	-	-	-
3	Seawater						
4	Seawater						
5	66	38	5.0	0.3	0.8	10	2,000
6	67	37	5.1	1.3	0.5	9.8	2,200
7	69	45	6.8	1.3	3.0	9.7	1,710
8	71	43	5.2	0.6	2.5	9.6	1,400
9	72	45	5.4	0.9	3.0	9.6	1,650
10	72	45	4.1	0.3	2.4	9.7	1,420
11	73	42	4.2	0.5	3.7	9.5	1,420
12	73	43	4.6	0.4	3.5	9.5	1,300
13	73	46	4.2	0.4	3.0	9.7	1,065
14	75	52	4.0	0.4	4.0	9.3	1,400
15	78	57	4.1	0.5	8.0	9.6	1,400
16	79	57	4.2	0.5	8.0	9.6	1,400

(i) Water Supply:

Fresh water for industrial purposes was transported from Portland's main water supply system to the drilling barge on the two work boats. Both boats have a fresh water storage capacity of approximately 250 tons each. The drinking water is distilled on board.

(j) Perforation and Shooting Record:

Not applicable.

(k) Plugging Back and Squeeze Cementation Jobs:

Abandonment plugs as agreed by the Victorian Mines were as follows:-

	Bridge Plug No. 1	Bridge Plug No. 2
Type of Plug:	Baker Model "N"	Baker Model "K" converted to BP
Size :	6 A A	6 A A
Depth :	5,310 ft	710 ft
Method Used :	Set on wire line	Set on wire line
Plug Tested :	No	No

	Cement Plug No. 1 (First Stage)	Cement Plug No. 1 (Second Stage)
Length :	800 ft	900 ft
Type of Plug:	Class "E" Cement	Class "E" Cement
Number of Sacks Used :	335	380
Depth interval Plugged(bdf):	7500'-6700'	6700'-5800'
Method Used :	900 ft open ended 2-$\frac{7}{8}$"	TBG on 5" DP
Squeeze Pressure	None	None
Amount Squeezed	Nil	Nil
Plug Tested :	No	No

	Cement Plug No. 2
Length	: 297 ft
Type of Plug	: Class "E" Cement
Number of Sacks Used	: 100
Depth Interval Plugged (bdf)	: 710' - 413'
Method Used	: 720' open ended 2-$\frac{7}{8}$" Tbg on 5" DP
Squeeze Pressure	: None
Amount Squeezed	: Nil
Plug Tested	: No

(l) Fishing Operations:

The caliper of the Schlumberger Sonic/Gamma Ray/Caliper tool parted the assembly and remained in the hole. The attempt to retrieve the fish with a Globe type junk Basket failed when the assembly parted at a break in the sub between the basket and the Upper Assembly. The top of the fish was located at 9,966 ft bdf. All efforts to recover the fish, which was suggested to lie over its side, were unsuccessful.

(m) Side-tracked hole:

None.

3. Logging and Testing:

(a) Ditch Cuttings:

Samples were collected in Voluta-1 from 966' on, at ten feet intervals during drilling, with the exception of the interval 1757'-2650' because of the lack of mud returns. All samples were taken from the shale shaker. Time lag checks were made at frequent intervals. The ditch cutting samples were washed, dried, and split into portions which were placed in separate marked envelopes. Complete sets of these samples are stored in the Core Laboratories of the Victorian Mines Department, the Core and Cutting Laboratory BMR, and in the Geological Laboratory, Shell Development (Australia) Pty. Ltd., Melbourne.

(b) Coring:

The following cores were taken or attempted:

No.	Interval	Recovery %	No.	Interval	Recovery %
1	2660 - 2673	85	12	7597 - 7612	100
2	2970 - 3000	85	13	8069 - 8099	100
3	3335 - 3362	0	14	8617 - 8627	0.85
4	3612 - 3639	0	15	8767 - 8777	90
5	4630 - 4649	57	16	9954 - 9975	82
6	4950 - 4976	35	(in 2 stages: 9954-9964, 9964-9975)		
7	5480 - 5500	23	17	10472 -10482	82.5
8	5880 - 5905	79	18	10903 -10913	65
9	6277 - 6302	100	19	11378 -11388	0
10	6680 - 6697	73	20	11511 -11523	100
11	7089 - 7114	68	21	11988 -11999	73

(c) Side Wall Cores:

Prior to running and cementing the 9$\frac{5}{8}$" casing and after reaching total depth, Schlumberger shot a total of 189 side wall cores of which 133 were accepted by the wellsite geologist.

Interval	Shots	Misfires	Lost	Empty	Not Accepted	Accepted
1946-1763	30	1	1	8	3	17
2640- 989	84	32	1	3	1	47
6247-2684	57	-	1	1	-	55
8901-6482	18	-	4	-	-	14

4. Logging and Surveys

(a) Electric and Other Logging Summary:

The several types and runs of Schlumberger logs recorded in Voluta-1 are listed in Appendix I and presented graphically in Enclosure I; the calculations carried out at the level of interest are presented in Appendix II.

(b) Penetration Rate Log:

A penetration Rate Log (drilling time log) is included in the Composite Well Log (Encl. 3) and in the Drilling Data Log (Encl. 4).

(c) Deviation Surveys:

A total of 41 drift surveys were carried out in this hole (Encl. 3). The Totco Double Recorder for measuring drift up to 8° was used. Deviation below 10,330' rapidly increased from 3° to 9¼° at 12,060'.

(d) Temperature Surveys:

The following temperature surveys were taken to locate the zone of lost circulation:-

Run No.	Interval
1	256-2002, 2002-1500
2	990-2034, 2034-1400, 2034-1500
3	430-2648, 2648-966

(e) Gas Log:

A continuous mud gas recorder and a gas chromatograph were used to record and analyse gas shows from the mud. The Mud Gas Log is included in the Composite Well Log (Encl. 3).

5. Formation Testing:

(a) FIT/FTT : None

(b) DST : None

(c) Production Testing : None.

IV. GEOLOGY

1. History of Exploration

The search for petroleum has been carried out in the Otway Basin for many years and several companies hold exploration permits granted by the Victorian and South Australian Governments. The work of these companies, supported by the B.M.R. and State Mines Departments has contributed greatly to an understanding of the basin and its petroleum prospects. A number of hydrocarbon indications have been reported but as yet no commercial accumulation has been found.

In addition to surface and subsurface geological work, aeromagnetic and gravity surveys have been carried out in various parts of the basin and an extensive seismic coverage exists both onshore and offshore. Up to December 1967 a total of 31 petroleum exploration wells had been drilled in the Otway Basin, 10 of which were by Frome-Broken Hill, mainly in the Port Campbell area.

In the Gambier Sub-basin (see Enclosure 1) gas shows were encountered in several wells and Caroline-1 produced large quantities of carbon dioxide.

Following a Farm-in Agreement dated 13th July, 1965, Shell Development (Australia) Pty. Ltd. became the operator in Petroleum Exploration Permits 5, 6 and 22 with the right to earn a 50% interest for a total expenditure of $A4,000,000 including seismic and drilling obligations. During 1966 land seismic surveys were completed in the Yambuk, Portland and Nelson areas and two marine seismic surveys were carried out in P.E.P. 22 during January - February 1966 and September - November 1966. One structure located offshore in the Port Campbell Embayment was tested by the first offshore well in the Otway Basin, S.D.A.'s Pecten-1A well, during March - June 1967, and another offshore in the Torquay Sub-basin by Nerita-1 well during July 1967. Both proved to be dry. A structurally high trend was also delineated in the Gambier Sub-basin (Ref.Nos.9 and 10). A closure on this structural trend was tested by Voluta-1 well, the third offshore well in the Otway Basin.

2. Summary of Regional Geology

(a) Stratigraphy

The Otway Basin has been the depositional area for a sequence of (?) Jurassic - Tertiary sediments, trending east - west across south-western Victoria, almost at right angles to the predominant N-S trend of the underlying Paleozoic rocks of the Tasman Geosyncline.

During the (?) Jurassic - Lower Cretaceous the basin was a single large trough (probably connected to the Gippsland Basin), in which a monotonous sequence of continental fluviatile sandstones, siltstones and shales (Otway group) was deposited. The Otway group rocks are first-cycle type, immature sediments containing a high proportion of altered volcanic and feldspathic debris. These sediments are considered to be derived from both northern and southern sources. Occasional basal conglomerates and some clean quartz sands have also been found in the Otway group, mainly towards the northern margin of the basin.

After deposition of the Otway group, differential uplift accompanied by some warping resulted in the division of the Otway Basin into several sub-basins and embayments (see Enclosure 1); from west to east, the Gambier Sub-basin, the Tyrendarra and Port Campbell Embayments and the Torquay and Port Phillip Sub-basins. The latter two appear to have remained separate from the rest of the Otway Basin during the Upper Cretaceous and Paleocene. In the remainder of the basin several transgressive - regressive cycles are recorded in the post-Otway sequence.

During Upper Cretaceous times, the Otway group was unconformably overlain by the sediments of the Sherbrook group, a transgressive - regressive sequence known only from the subsurface.

The partly marine basal sands of the Waarre formation are very variable in thickness and locally contain a high clay content. Isopach maps of the unit, suggest it was deposited on an irregular topographic surface. The sediments vary from coarse sand through fine grained sandstone to clay with minor siltstone and carbonaceous layers. In the Gambier Sub-basin, they appear to derive mainly from reworked Otway group.

The overlying Flaxmans formation consists of glauconitic siltstones with dense to slightly porous, quartzitic to lithic sands. The Belfast Mudstone which lies above is the most marine of the Upper Cretaceous units. It is a thick sequence of glauconitic siltstone and shale with lenticular glauconitic sands. The thickness of the formation varies considerably and over structural highs it is thinner and consists of silt and sandstone, with only minor shale. An interfingering of the shale, silt and sandstone facies of the Belfast Mudstone and Flaxmans formations occurs in the Gambier Sub-basin, at least in the onshore part, rather than a clear superposition : this combination has been called the "Mount Salt formation" (Ref. Nos.6 and 7).

These formations are overlain by the Paaratte formation which consists of fine grained glauconitic quartz sandstone with interbeds of glauconitic shale, clay, siltstone and minor dolomite. This formation which marks the last marine episode of the Upper Cretaceous is transitional between the Belfast Mudstone and the predominantly fluviatile Curdies formation. It also varies in thickness and probably thins over structurally high areas.

The Curdies formation consists of carbonaceous shale, siltstones and sandstones representing the final regressive phase of the Upper Cretaceous depositional cycle. Deposition as in the underlying units appears to be structurally controlled, and the environment of deposition appears to have been mostly paralic. In the Gambier Sub-basin and the Tyrendarra Embayment seismic data show that folding continued to the end of the deposition of the Sherbrook group and was followed by erosion before deposition of the Wangerrip group.

The Paleocene Wangerrip group unconformably overlies the Upper Cretaceous. This group is a paralic deposit with shallow marine incursions and is comprised of siltstones and clayey sands ("Dilwyn formation") overlying a conglomeratic basal sand unit of variable thickness ("Pebble Point formation").

The Wangerrip group is surmounted with major disconformity by the Upper Eocene Nirranda group, composed of a basal glauconitic sandy littoral unit("Mepunga formation") and an upper marly to limy marine complex("Narrawaturk Marl") only present in the Port Campbell Embayment. The Nirranda group is generally thinner in the Gambier Sub-basin and is locally absent, suggesting that the Gambier Sub-basin was a relatively higher area than the Port Campbell Embayment during the Upper Eocene transgression.

In the Oligocene - Miocene the Otway Basin was invaded by a widespread transgression, and the "Heytesbury group" carbonates were deposited with a minor disconformity over the preceding sediments. The group is locally marked by a thin basal layer of glauconitic to limonitic marly sand ("Clifton" or "Nelson formation"), followed by predominant limestones, marls and in the Gambier Sub-basin important dolomites. The Heytesbury transgression appears to have started earlier in the Gambier Sub-basin than in the Port Campbell Embayment.

(b) Structural Geology

The Otway Basin developed as part of an east-west trending subsiding zone across the southern end of the Paleozoic Tasman Geosyncline. A thick sequence (locally more than 20,000 feet) of fluviatile Lower Cretaceous sediments was deposited in the trough.

Intensive faulting accompanied by local large scale gentle warping of sediments over structural highs commenced at the end of the Lower Cretaceous. The Otway Basin became divided into sub-basins and embayments separated by structurally high blocks transverse to the trend of the basin. The trends of the resulting major structures are NE - SW in the eastern part of the basin and NW - SE in the western part. The Otway group sediments were folded and eroded during these movements.

Phases of uneven downwarping followed in the region during the deposition of the complex transgressive - regressive Upper Cretaceous and Tertiary sedimentary cycles, producing mild folding, minor faults and warping effects in the respective strata. Frequent thinning of the contoured seismic intervals over old structural highs suggests that these structures remained positive features during the Upper Cretaceous and Lower Tertiary.

Offshore in the Gambier Sub-basin, there is a prominent structurally high trend often bordered by normal faults oriented WNW - ESE. The largest closure on this trend to be delineated by marine seismic was tested by drilling Voluta-1. The seismic results showed the structures appeared to be free of the volcanic intrusions occurring nearby at Cape Bridgewater and that faulting was restricted to the flank without affecting the closure area.

3. Stratigraphic Table : Voluta-1

Age	Rock Unit	Top (Ft.below R.T.)	Thickness (Ft.)
Lower Miocene - Uppermost Eocene	Heytesbury group	966 (=20" Casing Shoe)	1,788
Lower Miocene - Lower Oligocene	Mount Gambier formation	966 * (=20" Casing Shoe)	1,713
	Upper Limestone unit	966 (=20" Casing Shoe)	682
	Dolomite/Limestone unit	1,648	657
	Marl/Limestone unit	2,305	374
Uppermost Eocene	Nelson formation	2,679	75
Unconformity			
Paleocene	Wangerrip group	2,754	1,631
	Dilwyn formation	2,754	1,521
	Unit 5 (Sand)	2,754	76
	Unit 4 (Silt/Sand/Shale)	2,830	212
	Unit 3 (Sand)	3,042	768
	Unit 2 (Shale/Sand)	3,810	170
	Unit 1 (Sand/Shale/Silt)	3,980	295
	with Rivernook member	4,185	90
	Pebble Point formation	4,275	110
Unconformity (?)			
Upper Cretaceous	Sherbrook group	4,385	8,652 **
	Curdies formation	4,385	695
	Paaratte formation	5,080	2,020
	Belfast Mudstone equivalent	7,100	5,937 **
	Upper Sandstone/Siltstone/ Shale Unit	7,100	542
	Siltstone Unit	7,642	4,648
	Lower Sandstone/Siltstone/ Shale Unit	12,290	747 **
		T.D. 13,037	

* Several small cores taken on the bottom of the sea showed the sea floor mainly consisted of Middle Miocene limestone with patches of Uppermost Miocene soft clay and Pleistocene dune limestones. The clay is interpreted as infilling of holes or topographical depressions.

** Down to total depth.

4. Stratigraphy in Voluta-1

(a) General

The major rock units bounded by unconformities in the Tertiary - Mesozoic sediments of the Port Campbell Embayment (Ref. Nos.6 and 13) are easily recognisable in the Gambier Sub-basin (see Encl. 5). For simplicity the nomenclature used for the Port Campbell Embayment is kept here, although synonyms (Glenelg group for Heytesbury group, Knight group for Wangerrip group and Merino group for Otway group) are sometimes used in the western part of the Otway basin.

(i) Heytesbury group

Apart from discontinuous, thin surface beds of Uppermost Miocene clay and limestone layers of dune limestone of probable Pleistocene age, the sequence drilled down to 2,754 feet consisted of carbonates and sand belonging to the Heytesbury group. The group comprises two formations. The Lower Miocene to Lower Oligocene limestone, dolomite and marl, of the Mount Gambier formation (B.M.R. unit Bb - Ref. No. 6 -) was drilled to 2,679 feet. It can be subdivided into 3 lithological units, correlatable with equivalents in onshore wells in the Gambier Sub-basin (Encl. 5). It overlies the Uppermost Eocene Nelson formation (corresponding to the B.M.R. sub-unit Bc 1) consisting of transgressive sands with limonite and glauconite.

There is neither a palaeontological gap nor lithological evidence of regression between the two formations.

The "Nelson formation" is taken here as defined by Boutakoff and Sprigg, who state (Ref. No. 3) - : "overlying unconformably the Knight group is the Glenelg group which consists of the Nelson sandstone formation at the base and the Mount Gambier limestone formation at the top" (in the publication they more commonly use the terms "Nelson formation" and "Mount Gambier formation"). Although the term "Nelson formation" was often used in error as an equivalent to the "Mepunga formation" of the Nirranda group in later publications, it is considered here that the above original definition should be adhered to, because it has priority.

In Voluta-1 the Nelson formation is of Uppermost Eocene age, which means that the transgression of the Heytesbury group started earlier in the Voluta-1 area than anywhere else in the basin, because the Heytesbury transgression probably moved from west to east in the Otway Basin.

Since the Nirranda group is clearly missing, a time gap is inferred between 2,684 and 2,790 feet (see Appendix V). The probable unconformity is considered to occur at 2,754 feet where petrophysical changes in the rocks coincide with a downward disappearance of glauconite (see Encl. 3).

The Heytesbury directly overlies the Wangerrip group. The absence of the Eocene Nirranda group which occurs between these units elsewhere may be due to non-deposition.

(ii) Wangerrip group

The sequence between 2,754 and 4,385 feet is assigned to the Wangerrip group and is of Paleocene age. It is composed of the Dilwyn formation (B.M.R. unit Db) and the Pebble Point formation (B.M.R. unit Dd).

The Dilwyn formation consists of interbedded pebbly sand, silt and claystone. As was prognosticated (Ref. No. 11) the Dilwyn formation can be subdivided into 5 informal lithological units mainly differentiated by their petrophysical properties; these units can also be recognised in the onshore wells of the sub-basin (see Encl. 5). A silty to shaly glauconitic sequence occurs in the interval 4,185 - 4,275 feet and is correlated with the "Rivernook member" described by Baker (Ref. No. 2) and is clearly distinguishable both on lithology and wireline logs (see Encl. 3).

The Pebble Point formation consists of ferruginous and glauconitic coarse sand and minor shale. The top of this formation lies at 4,275 feet.

(iii) Sherbrook group

The top of the Upper Cretaceous Sherbrook group at 4,385 feet is marked by a lithological change to finer sand, less ferruginous, without glauconite and a marked change in log character, particularly in the resistivity logs (see Encl. 3). On palynological evidence (Appendix VI) the interval 4,566 - 4,587 feet represents a transitional zone between Tertiary and Upper Cretaceous, indicating that the unconformity detected on seismic sections at about this level (horizon B, see Ref. No. 9) represents only a relatively short depositional gap.

The Sherbrook group is considerably thicker in Voluta-1 than in onshore wells (see Encl. 5) and in fact the top of the Otway group was not reached. The thickening occurs in the Belfast Mudstone suggesting that the Voluta location was actively subsiding during Lower Sherbrook time.

The Curdies formation (B.M.R. unit Gb) consists of fluviatile (?) massive quartz sand, limonitic in the upper part, with minor shale interbeds and a few coal seams. It has approximately the same thickness in Voluta-1 as in Caroline-1 well.

The Paaratte formation (B.M.R. unit Gd) comprises quartz sandstone, occasionally glauconitic, interbedded with clayey siltstone or silty shale. The top of the formation is taken at 5,080 feet at the top of this alternating sequence which is reflected in wireline logs. By comparison with Caroline-1 the Paaratte formation in Voluta-1 is thinner and contains less sand. The upper massive sand member called "Macdonnel member" in Caroline-1 (Ref. No. 12) could not be recognised in Voluta-1.

The Belfast Mudstone equivalent (B.M.R. unit Gg) is separated from the Paaratte formation at 7,100 feet by a minor fault contact shown in core No. 11. The top of the formation is characterised by a shale layer (interval 7,100 - 7,235 feet) which coincides with a log marker easily recognised in most wells in the Gambier Sub-basin. Where the Belfast Mudstone is interbedded with the sandy facies of Flaxmans formation as in Mount Salt -1 and in some other onshore wells in the sub-basin (see Encl. 5), the formation has been called "Mount Salt formation" (Ref. Nos.6 and 7). For simplicity and as the interval consists mainly of siltstone in Voluta-1 it is called the "Belfast Mudstone equivalent".

Apart from interbeds of quartz sandstone down to 7,642 feet and of quartz to sub-feldspathic and sub-lithic sandstone from 12,290 feet down to the total depth of 13,037 feet, this thick formation is mainly composed of a homogeneous and monotonous sequence of marine clayey siltstones with a few thin dolomitic streaks. The unusual thickness of the unit suggests an active subsidence and deposition in the area during the main Upper Cretaceous transgression (see Appendix V - Interpretation).

(b) Lithological description

In Voluta-1 the first samples were obtained from below the 20 inch casing shoe at 966'. No cuttings were available in interval 1,742 - 2,650 feet because of circulation losses and therefore lithological description in this interval is based on sidewall samples.

All the depths are given below derrick floor.

(i) Heytesbury group (Lower Miocene - Uppermost Eocene).

966'-2679' : Mount Gambier formation (Lower Miocene - Lower Oligocene).

966'-1648' : upper Limestone unit.

966'-1458' : bioclastic lime Grainstone, in loose fragments, white-beige, unconsolidated, consisting mainly of Bryozoa debris and in part Echinoids and Foraminifera, locally marly, occasionally grading into lime Packstone; trace of Chert, dark grey, very hard; traces of Limonite and Pyrite.
At 1230' and 1300', layers of lime Mudstone, white, silty.

1458'-1648' : Marl interbedded with bioclastic lime Grainstone.
Marl, beige - light grey, soft, plastic with abundant limestone and bioclastic fragments.
Bioclastic lime Grainstone, as above, in intervals 1530'-1560' and 1625'-1648'.

1648'-2305' : Dolomite Limestone unit.

1648'-1680' : Dolomite, porous, light grey to translucent, medium to fine grained, granular texture, crystalline, friable to moderately hard.

1680'-1864' : Dolomite interbedded with Limestone.
Dolomite, dense to slightly porous, white, calcitic, soft, with calcareous mud matrix, crystalline and fine grained in lower 100 feet, grading into dolomitic Limestone, bioclastic.
Lime Grainstone, porous (up to 40% vugular porosity), white, soft, bioclastic, very dolomitic; abundant Bryozoa, Foraminifera, some Gastropods.
In lower 100 feet, grades into lime Wackestone, with low vugular porosity, white, soft, bioclastic.

1864'-2305' : calcareous Dolomite with a few intercalations of dolomitic Limestone.
Calcareous Dolomite, dense to porous (15 to 20%), white, crystalline, sucrosic texture, medium to coarse grained, bioclastic with calcareous fragments, soft to firm, with calcareous mud matrix, sometimes marly; becoming harder in lower 150 feet.
Dolomitic lime Wackestone, slight vugular porosity, whitish, hard, bioclastic; abundant Bryozoa.
And dolomitic lime Mudstone, white, soft; but hard and crystalline in lower 150 feet.

2305'-2679' : Marl/Limestone unit.

2305'-2383' : dolomitic lime Mudstone (grading locally into Packstone), firm, white, marly; in lower part, white to green, crystalline, pyritic.

2383'-2480'(?) : Marl to lime Mudstone, crystalline, white, dolomitic, locally silty, laminated.

2480'(?)-2542' : Clay, medium grey, silty, calcareous; locally grades into Marl, fossiliferous, locally with silty streaks.

2542'-2645' : Siltstone, medium grey, clayey, locally calcareous, fossiliferous, laminated.

2645'-2679' : lime Wackestone (locally Packstone), dense, grey, very fine to fine structure, consolidated, clayey, locally dolomitic, pyritic, vaguely laminated, occasional burrows, a few streaks of Dolomite, dark grey, hard, microcrystalline.

2679'-2754' : Nelson formation (Uppermost Eocene).
Quartz Sand, porous, clear to light brown, medium to fine grained, occasionally coarse, moderately sorted, subrounded to rounded, moderate sphericity, smooth; locally semi-consolidated, small limonitic pellets and ferruginous staining, occasional grains of Glauconite, carbonaceous specks, traces of clay.

(ii) Wangerrip group (Paleocene).

2754'-4275' : Dilwyn formation.

2754'-2830' : Sand unit (informal unit 5).
Quartz Sand, slightly porous, clear, coarse to very coarse grained, locally granular, moderately sorted, subrounded, moderate sphericity, smooth, friable; at top, some grains of Limonite and traces of brown limonitic cement; a few streaks of Siltstone, dark grey, friable, carbonaceous, laminated.

2830'-3042' : Silt/Sand/Shale unit (informal unit 4).

2830'-2960' : Sand and silty Claystone.
Quartz Sand, as above, but locally consolidated, and with also medium to fine fraction.
Mainly in upper 50 feet, important intercalations of silty Claystone, dark grey, laminated and with Silt lenses.
Rare streaks of Coal, black, soft.

2960'-3042' : Siltstone, very clayey, dark grey to dark brownish, friable, micaceous, locally carbonaceous, irregular laminations, burrowed and churned.

3042'-3810' : Sand unit (informal unit 3).
Quartz Sand, as interval 2830'-2960'; and clear to whitish, locally dark grey, fine to pebbly grained, poorly sorted, rounded to subangular, moderate sphericity; unconsolidated, clayey matrix, locally limonitic, glauconitic and pyritic.
Some seams (an important one at 3675 feet) of Coal, black, soft.

3810'-3980' : Shale/Sand unit (informal unit 2).
Claystone, dark brown, dark grey, soft, silty, sandy, locally carbonaceous and ferruginous, with silty lenses.
Intercalated in interval 3905'-3945' with quartz Sand, as interval 3042'-3810', but rounded to angular, constantly limonitic and glauconitic.

3980'-4275' : Sand/Shale/Silt unit (informal unit 1).

3980'-4185' : quartz Sand, clear to whitish, very coarse to medium grained, locally granular, moderately sorted, rounded, low sphericity; unconsolidated; clayey matrix, carbonaceous, glauconitic, abundant Pyrite; with silty lenses and coaly streaks.

4185'-4275' : ("Rivernook Member") : silty Claystone interbedded with minor Siltstone and Sand.
Claystone, light brown, very silty, sandy, carbonaceous, locally pyritic;
with rare streaks of dolomitic Wackestone, beige to light brown, medium to fine grained, consolidated, silty, slightly sandy, grains of Limonite and Glauconite, rare coaly specks.
Siltstone (mainly interval 4215'-4230'), dark brown, clayey, slightly carbonaceous, friable, with Glauconite, pyritic.
Quartz Sand (mainly interval 4230'-4250'), clear to white, coarse to medium grained, pyritic, as interval 3980'-4185'.

4275'-4385' : Pebble Point formation.
Quartz coarse ferruginous Sand interbedded with minor silty Shale.
Quartz Sand, disintegrated in loose grains, clear, white, yellowish or reddish (ferruginous stain), very coarse to locally medium grained, well sorted, subangular to subrounded, moderate sphericity, unconsolidated, very abundant limonitic matrix/cement and grain coating and staining, locally pyritic.
Silty Claystone, brown, friable and unconsolidated, limonitic, locally glauconitic.

(iii) Sherbrook group (Upper Cretaceous).

4385'-5080' : Curdies formation.

4385'-4640' : quartz Sand interbedded with silty Claystone.
Quartz Sand, clear, very coarse, locally granular, and medium to fine and silty at about 4500', well sorted, subangular to subrounded, low to moderate sphericity, unconsolidated, very limonitic above 4500', rare lithic grains, pyritic, local traces of Coal and occasional calcitic streaks.
Silty Claystone, grey, partly hard, pyritic.

4640'-5080' : quartz Sand with thin streaks of silty Claystone and rare Coal.
Quartz Sand, porous, clear - white, very coarse to fine grained, moderately sorted, subangular, moderate to low sphericity, disintegrated in loose grains, constantly silty, pyritic, limonitic in upper 50 feet, clayey matrix, occasional rare calcitic cement.
Silty Claystone-Shale, as interval 4385'-4685', usually soft, locally pyritic and hard, partly sandy with fine to medium Quartz grains; grading into clayey Siltstone.
Coal, black, soft.

5080'-7100' : Paaratte formation.

5080'-5635' : quartz Sandstone interbedded with silty Shale and Siltstone.
Quartz Sandstone, dense to slightly porous, white, fine grained locally very coarse, moderately sorted, angular to subrounded, moderate to high sphericity; hard, white clayey cement with carbonaceous flecks, slightly glauconitic in upper part;
with a few very thin streaks of Dolomite, beige, crystalline, sandy, glauconitic.
Silty Shale, medium to dark grey, firm to soft, sandy, carbonaceous, occasionally glauconitic.
Siltstone, dark grey, firm, clayey and sandy, pyritic; with some dolomitic streaks, carbonaceous and locally glauconitic.

5635'-7100' : quartz Sandstone interbedded with clayey Siltstone.
Quartz Sandstone, dense to porous, white to light grey, fine to medium grained (and coarse in the upper 100 feet, locally coarse in lower 300 feet), moderately to poorly sorted, angular to subrounded, high sphericity; friable to firm, locally hard, white clayey cement, locally silty and carbonaceous and pyritic, more glauconitic below 6900'; grading

locally into quartz Sandstone, very dolomitic with abundant dolomitic cement.
Rare thin streaks of Dolomite, beige, crystalline, hard, sandy, glauconitic.
Siltstone, dark grey, clayey to very clayey, firm, pyritic, carbonaceous, locally glauconitic and micaceous, occasional dolomitic cement.

7100'-13,037' (=T.D.) : Belfast Mudstone equivalent.

The contact between Paaratte formation and Belfast Mudstone equivalent at 7100' is a minor fault marked by a 1" thick tectonic breccia (Appendix IV, core No. 11).

7100'-7642' : upper Sandstone/Siltstone/Shale unit.

7100'-7235' : Siltstone, dark grey, very sandy, clayey to very clayey, pyritic and carbonaceous.

7235'-7642' : quartz Sandstone with Siltstone.
Quartz Sandstone, porous to locally dense, clear to whitish, fine grained, very coarse in places, poorly sorted, rounded to angular, moderate sphericity; local clayey or dolomitic cement, Glauconite, occasional Pyrite, rare Mica.
A few thin streaks of Dolomite, beige to light brownish, crystalline and hard, sandy, silty, locally very glauconitic, with Coal specks and Mica flakes.
Siltstone, tight, grey to dark grey, friable to consolidated, very clayey, very sandy, very carbonaceous; grading into small laminated nests of quartz Sandstone, as above.

7642'-12,290': Siltstone unit.
Clayey Siltstone, dense, dark grey, clayey to pelitic cement, very consolidated, very sandy to locally extremely sandy with fine to very fine Quartz and some pinkish Feldspar grains, very glauconitic in places, Glauconite becomes very rare below 11,400', carbonaceous specks; occasional Foraminifera, a few debris of Gastropods and Lamellibranchs; grading into very thin and small lenses of quartz Sandstone, as above, becoming very rare and sub-feldspathic below 8700' and with some light greenish lithics below 9000'.
Rare streaks of Shale, grey, silty, sandy, carbonaceous; and very clayey intervals at 10,575'-10,595', 10,650'-10,660', 10,850'-10,860'.
Common small nodules and thin streaks of Dolomite, as interval 7325'-7642', locally ankeritic or calcitic.
The lithology of the Siltstone is very homogeneous and shows the following average composition:

40% silty grains,
10% sandy grains,
30% clayey cement,
10% carbonaceous material,
10% miscellaneous (Dolomite, Calcite, Ankerite, Pyrite crystals, Glauconite grains, Mica flakes, ...).

12,290'-13,037' (=T.D.) : lower Sandstone/Siltstone/Shale unit.

Clayey Siltstone, as above, interbedded with layers of Sandstone.
Quartz to locally sub-feldspathic Sandstone, dense, light grey, fine to very fine grained, locally medium, partly clayey, partly calcitic cement.
A few layers of quartz to sub-lithic Sandstone, dense, white to light-grey, medium to fine grained, moderately sorted, locally coarse to pebbly and poorly sorted, angular to sub-angular with grey, light-green or orange lithic grains.

Below approximately 12,450', layers of sub-lithic Sandstone (locally quartz Sandstone, locally lithic Sandstone), dense light grey to light brown, occasionally light greenish, medium to fine grained, moderately sorted, sub-angular, low sphericity; abundant lithic grains, carbonaceous material, Mica.
Below approximately 12,550', occasional interbeds of Shale, grey to dark grey, partly light grey, carbonaceous, pyritic.

5. Structure

The structure tested by drilling Voluta-1 is a broad gentle closed anticline trending NE-SW in the offshore part of the Gambier Sub-basin, with a culmination approximately 8 miles WSW of Cape Bridgewater.

The well was crestally located on the structure at the level of seismic horizon "G" in the Sherbrook group. At this level seismic data indicated (Ref. No. 9) a closed area of about 20 square miles and a vertical closure of circa 1,000 feet. Closure is also present at the base Wangerrip group (horizon "B") but with area and vertical closure decreased respectively to 10 square miles and 250 feet. In the base of the Heytesbury group (horizon "A1") closure is displaced north eastwards and considerably reduced.

The limited stratigraphic control in the Gambier Sub-basin made it impossible to tie the seismic interpretation into wells where the position of the top of the Otway group was known. Indeed this unit was not reached in Voluta-1 in spite of the considerable depth to which the hole penetrated. This indicates that the Sherbrook group was deposited in a deep subsiding trough at the location of Voluta-1. This fact combined with the existence of a synclinal area oriented NNW-SSE east of Portland and the ~~general~~ structural fault features of the area suggests the coastal part of the Gambier Sub-basin may be crossed by a "horst" - like structural high situated along the present Discovery Bay, and probably extending towards Point Danger (see Encl. 1).

Seismic results show a strong unconformity between the eroded surface of the Sherbrook group and the overlying Wangerrip group with a thinning and dipping of this unit from onshore towards the structure, whereas it thickens further to the south. The Heytesbury group is almost horizontal and thickens gradually towards the south.

The results of Voluta-1 have confirmed the structural picture interpreted from seismic data and there can be little doubt that the well was drilled on a closed anticlinal feature. Furthermore, low values in dipmeter readings indicate that Voluta-1 was effectively drilled on the top of the structure although a slight North dip was noticed in the Sherbrook group (see dipmeter in Enclosure 3).

6. Relevance to Occurrence of Petroleum

No hydrocarbon indications were noted from cuttings, cores or sidewall samples, but minor shows of methane were recorded from the mud returns by gas detector in the Belfast Mudstone equivalent. Traces of ethane and propane were also recorded below 10,850 feet.

Petrophysical evaluation (Appendix II) of the section drilled in Voluta-1 shows for all sands down to 7,600 feet a water saturation of at least 90%. A strong rise in the salinity of the formation water from approximately 1,300 to 37,000 ppm NaCl occurs between 3,000 and 3,800 feet; below 3,800 feet the salinity gradually increases to approximately 60,000 ppm NaCl at 7,600 feet.

Voluta-1 was drilled on a location which offered possibilities for the accumulation of hydrocarbons both from a lithological and structural point of view, but the sands of reasonable reservoir properties which were encountered in the Wangerrip group and in the upper part of the Sherbrook group contained no hydrocarbons and therefore did not warrant testing. One of the main objectives, a sand body encountered in Caroline-1 (from 8,179 to 8,565 feet), is not developed in the Voluta area. The basal sands of the Sherbrook group which were the principal target were not reached as the well had to be abandoned for mechanical reasons. A sandy section in the Lower Sherbrook group was encountered, below 12,290 feet, but cuttings and gas detectors did not reveal any substantial shows of hydrocarbons.

7. Porosity and Permeability of Sediments penetrated.

Calculated porosities from the Formation Density log (see Appendix II and Schlumberger Sidewall Neutron Porosity log) gave values of ± 30% in the sands of the Wangerrip group and about 27% in the Curdies formation. In the sands of the Paaratte formation values range from 24% to 30%, and from 20% to 26% in the sands of the upper part of the Belfast Mudstone equivalent. Due to mechanical difficulties, the lowest part of the well could neither be logged nor sampled with sidewall cores. However, cuttings of sandstones from this interval showed no visible porosity.

In general these results are similar to those from respective formations in Caroline-1 well.

Porosities described in cuttings, cores and sidewall samples (see Appendix IV) suggest generally lower values than the FDC log; as regards the sidewall samples this is partly due to "impact compaction", but mainly to the presence of much clayey matrix in the unconsolidated sands.

8. Contribution to Geological Concepts Resulting from Drilling

The results of Voluta-1 contribute significantly to the knowledge of the Gambier Sub-basin as well as supplying important geological control in the offshore area.

The most important points are summarized as follows :-

(a) Before drilling Voluta-1 there was some doubt as to the existence of Upper Cretaceous deposits in the structure. This problem was clearly resolved as 8,652 feet of proved Upper Cretaceous sediments were penetrated.

(b) As 5,937 feet of Belfast Mudstone were encountered, the offshore area of the sub-basin is now considered to have been a subsiding zone during the Upper Cretaceous time with more active sedimentation than in the rest of the sub-basin; it was probably an embayment with restricted marine conditions, separated from the open marine conditions prevailing at that time in the offshore Port Campbell Embayment. The significant greater percentage of sand in the Belfast Mudstone equivalent of Caroline-1 and Mount Salt-1 suggest a depositional environment nearer to the shore in these areas and more marine influence for the corresponding sediments of Voluta-1.

The well drilled into the oldest marine Upper Cretaceous sediments yet found in the basin, and a good biostratigraphic section, with slight breaks, was recorded from Cenomanian to at least Campanian. This long depositional history permitted the foraminiferal dating scheme of D.J. Taylor to be expanded and clarified (see Appendix V).

(c) The Paaratte formation is thinner than in onshore wells and the upper member (a massive sand of possible barrier bar origin) called the "Macdonnel member" in Caroline-1 (Ref. No. 12) is probably missing in Voluta-1.

(d) The slight angular unconformity at the top of the Sherbrook group confirmed the development of the structure before the deposition of the Paleocene Wangerrip group.

(e) The absence of the Eocene Nirranda group in the Voluta area suggests that the Nirranda transgression has been of minor importance in this part of the sub-basin. Possibly this area was left emergent or received a thin sedimentary deposit which was removed before the Uppermost Eocene - Lower Oligocene transgression.

(f) The Heytesbury transgression reached the Voluta area earlier than the central and eastern parts of the Otway Basin, since the basal transgressive sand of the group is of Uppermost Eocene age at Voluta-1 and of Oligocene age in the Port Campbell area and the Torquay Sub-basin.

In conclusion, it appears that, apart from these local and temporary environmental differences, the Gambier Sub-basin is essentially comparable with the Port Campbell and Tyrendarra Embayments in its geological development.

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APPENDIX I

LIST OF SCHLUMBERGER LOGS RUN IN VOLUTA-I

LOG	RUN NO.	DATE	INTERVAL LOGGED	SCALE (ins/100 ft)
IES/SP	1	16/10/67	6296 - 2624	1-5
	2	9/11/67	9636 - 6315	1-5
	3	8/12/67	12416 - 9500	1-5
LL7	1	17/9/67	2645 - 965	1-5
BSGRC	1	9/9/67	1978 - 965	1-5
	2	17/9/67	2640 - 2070	1-5
	3	16/10/67	6284 - 2624	1-5
	4	9/11/67	9625 - 6315	1-5
	5	8/12/67	12360 - 9500	1-5
FDC	1	16/10/67	6296 - 2624	1-5
	2	9/11/67	9636 - 6315	1-5
SNP	1	16/10/67	6296 - 2624	1-5
MLC	1	11/9/67	2038 - 966	1-5
	2	17/9/67	2648 - 965	1-5
CDM	1	16/10/67	6292 - 2624	1-5
	2	12/12/67	8706 - 6315	1-5
CBL	1	16/10/67	2624 - 940	1-5
	2	19/10/67	6325 - 2000	1-5
	3	20/10/67	6330 - 6100	1-5
	4	20/10/67	6340 - 6100	1-5

DEPTH IN FEET

LEGEND For Appendix-1A (next page)

I.E.S. Induction – Electrical log.

B.S.G.R.C. B.H.C. Sonic / Caliper / Gamma Ray logging.

F.D.C. Formation Density log. (composition)

S.N.P. Sidewall Neutron Porosity.

M.L.C. Microlog – Caliper

L. Laterologging

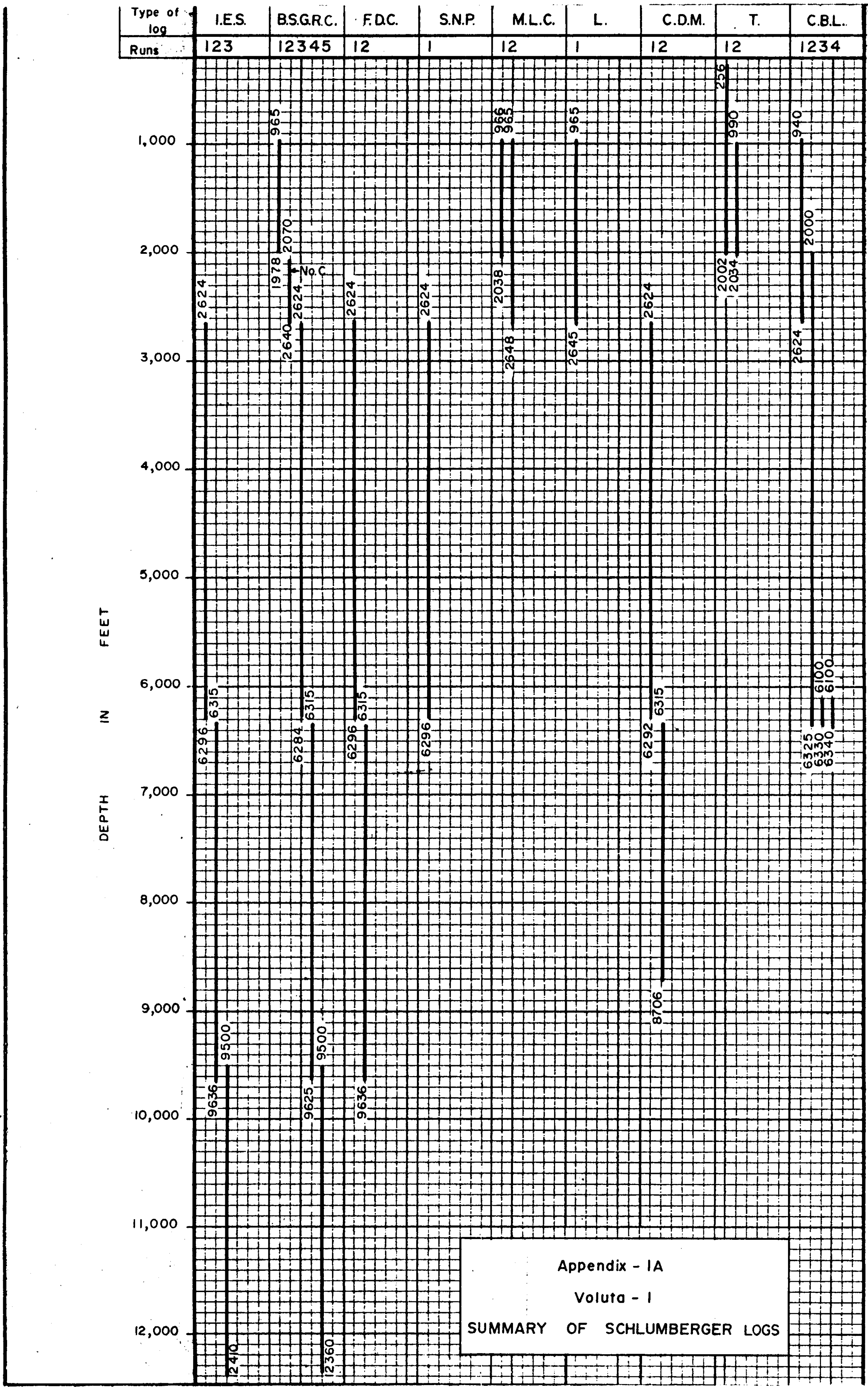
C.D.M. Continuous Dipmeter

T Temperature Logging.

C.B.L. Cement Bond logging.

Note : All logs have been run on two scales 1. 1" = 100' (1/1200)
2. 5" = 100' (1/240)

Drawing No. 2222



Appendix - IA

Voluta - 1

SUMMARY OF SCHLUMBERGER LOGS

PETROPHYSICAL EVALUATION IN VOLUTA-I

Rw AND Sw ESTIMATE

Depth (ft bdf)	SP (mV)	Ec (mV) @ 77°F	Rw (Ω m) @ 77°F/@ BHT	Ø (%) On FDC	"m"	F	Ro (Ω m) @ BHT	R_{IL} (Ω m) @ BHT	I	"n"	SW (%)
3750	48	36	0.38/0.23	39	1.8	5.6	1.3	0.9	< 1	1.6	100
4090	50	38	0.35/0.22	30	1.8	8.8	1.9	1.0	< 1	1.6	100
4500	56	42	0.31/0.18	27	1.8	10.7	1.9	0.8	< 1	1.6	100
4925	56	42	0.31/0.18	27	1.8	10.7	1.9	1.7	< 1	1.6	100
5480	57	41	0.32/0.19	24	1.8	13.5	2.6	0.7	< 1	1.6	100
5740	65	48	0.25/0.16	30	1.8	8.8	1.4	0.6	< 1	1.6	100
6600	65	41	0.23/0.095	26.5	2.0	14.5	1.38	1.3	< 1	1.6	100
6740	66	41	0.23/0.095	30	2.0	11.0	1.05	1.1	1.05	1.6	95
6980	60	39	0.26/0.11	26.5	2.0	14.5	1.59	2.0	1.26	1.6	90
7430	56	35	0.29/0.13	20	2.0	25.0	3.25	1.5	< 1	1.6	100

APPENDIX III

DEVIATION SURVEYS AT VOLUTA-I

Depth (ft.)	Deviation	Depth (ft.)	Deviation
525	1½	8381	2¾
930	½	8830	1¼
1300	2	9035	2
2660	2½	9390	2
2940	4½	9590	2½
3463	4½	9920	2¼
3565	5	10330	3
3660	5	10560	6
3762	7	10746	6
3849	5½	10903	6
4620	4	10905	6½
4950	3½	11148	7
5200	4¾	11282	7¾
5480	1¾	11316	7¾
5870	1¾	11480	8
6267	1	11620	8¼
6635	3½	11840	8
7045	3	11968	8¼
7585	2¾	12060	9¼
7879	2½	12190	9
8039	2¾		

CORE AND SIDEWALL CORE DESCRIPTIONS

VOLUTA-I

1. DESCRIPTION OF CORES (depths below derrick floor)

Core No. 1 : 2660 to 2673 feet, cored 13' recovered 11' (85%).

2660'-2663' : clayey lime Packstone, dense, light grey - medium grey, fine to very fine, welded to consolidated; rare minute specks of Glauconite, few small patches or Pyrite; Foraminifera common; irregularly laminated in dark thin beds (1mm to 4mm).

2663'-2664'6" : as above, with lighter colour, more clayey; laminated, occasional burrowing.

2664'6"-2665'6" : clayey Dolomite, dark grey, hard, microcrystalline.

2665'6"-2667'6" : as interval 2663'-2664'6", grading progressively downwards into lower interval.

2664'6"-2671' : as interval 2660'-2663'.

Core No. 2 : 2970 to 3000 feet, cored 30', recovered 25'6" (85%).
Clayey Silt to Siltstone, compact, dark grey - dark brownish to blackish, earthy, friable to slightly consolidated, crumbly in upper 14 feet, but more tight in lower 11 feet; abundant clayey matrix, very sandy with fine grains, slightly micaceous, locally carbonaceous, strongly churned and burrowed, many whitish platy traces (Algae ?), irregularly laminated and a few thin carbonaceous undulating laminae (1 - 2mm).

Core No. 3 : 3335 to 3362 feet, cored 27', no recovery.

Core No. 4 : 3612 to 3639 feet, cored 27', no recovery.

Core No. 5 : 4630 to 4649 feet, cored 19', recovered 10' 7" (57%).
From top to bottom,

0 - 2' : quartz Sand silty, very clayey, dense grey, very fine grained, sorted, subangular, low to moderate sphericity; irregular laminae, some burrows.

2'-3' : quartz Sand, as above, gradually changing into Clay to Claystone, as below.

3'-10' : Clay to Claystone, grey, silty to sandy with very fine grains, soft, carbonaceous, micaceous, much Pyrite finely divided and in bodies up to 2cm, very rare Glauconite, occasional Quartz grains, coarse to very coarse; vaguely laminated, some burrows.

10'-10'7" : Clay to Claystone, as above, with laminae of quartz Sand, coarse to very coarse, occasionally glauconitic; grains bound by Clay or locally Pyrite.

Missing part of core is probably the lower part.

Core No. 6 : 4950 to 4976 feet, cored 26', recovered 9' (35%).

4950'-4954' : quartz Sandstone, very clayey, dense, grey, very fine to fine grained, locally medium to pebbly, generally sorted, angular to subangular, low sphericity; consolidated to hard, calcitic to dolomitic to cement; carbonaceous, some Pyrite and Mica, rare Glauconite (?). Between 4950'9" and 4951'5" the calcitic-dolomitic cement is lacking and the rock is soft.

4594'-4959' : quartz Sand, very clayey, fine to coarse grained, occasionally granular, sorted to poorly sorted, subangular, low to moderate sphericity; soft and friable; carbonaceous, some Mica.

1670.3M

Core No. 7 : 5480 to 5500 feet, cored 20', recovered 4'8" (23%).

Quartz Sandstone, dense (locally slightly porous, up to 10%), light grey, fine to medium grained, angular to subrounded, moderate to high sphericity; soft, white clayey cement, slightly micaceous, contains light green Chert grains, dark grey siliceous Claystone grains, carbonaceous flecks.

Pebbles, 6" from top of core (one is 6 cm long, 4cm wide, 1.5cm thick), of white Quartz and weathered buff Claystone, very hard.

Laminae of Coal, black, soft, brittle, pyritic.

In lowest 8" of core, laminae of Siltstone, up to 1.5cm thick, medium grey, soft, micaceous, clayey, carbonaceous. In lowest 8" of core also occurs a half layer of Dolomite, pink, beige, crystalline, hard, glauconitic.

Sandstone is ripple - marked, contains small scale cross-bedding, micro-cross-laminae, current ripple laminae, some burrows in silty parts.

Deposit of lagoonal or estuarine paralic origin.

Core No. 8 : 5880 to 5905 feet, core 25', recovered 19'9" (79%).

1792

Quartz Sandstone, dense to slightly porous, light grey, fine to coarse grained, sorted to poorly sorted, moderate sphericity angular to subangular; moderately hard, clayey with clayey cement, glauconitic, slightly micaceous, some Tourmaline, pyritic; occuring as nests, lenses or streaks in major lithology: Siltstone, dark grey, very sandy, grading into very fine quartz Sandstone, very glauconitic, locally white, clean, mostly clayey, carbonaceous, slightly micaceous;

with very fine streaks of Dolomite, pink, and some pigments of resin;

some thin Claystone laminae, and some quartz Sandstone, very fine, well sorted.

Sediment extensively burrowed and primary sedimentary structures destroyed.

1913.22

Core No. 9 : 6277 to 6302 feet, cored 25', recovered 25' (100%).

6277'-6285' : quartz Sandstone, slight to moderate porosity (10-25%), light grey, medium grained, well sorted, angular - subrounded, high sphericity; some clayey cement, firm, carbonaceous with carbonaceous specks.

Below 6285', becoming very silty and micaceous, changing gradually through silty Sandstone to sandy Siltstone at 6289'.

Sandstone is extensively burrowed.

6290'-6296' : Siltstone, dark grey, clayey, carbonaceous with quartz Sandstone lenses, grading down into Claystone, black, hard, very silty, glauconitic, pyritic, with scattered Quartz grains.

6296'-6302' : Siltstone, as above; plus Claystone, silty, very glauconitic, with concretions and layers of Ankerite (dolomitic ?), glauconitic; inter-laminated quartz Sandstone, clean, white, very fine, sorted, carbonaceous, pyritic and laminated. Laminae 0.5mm. to 2.5cm thick. Ankerite consists of crystalline Ankerite. Plus at 6294' and 6299', two layers of finely laminated quartz Sandstone, very fine, well sorted, with abundant ankeritic cement and abundant carbonaceous laminae; totalling 10" in thickness.

2036M

Core No. 10 : 6680 to 6697 feet, cored 17', recovered 12'5" (73%).

Siltstone, dark grey to dark brown, very sandy, locally grading into small patches of silty Sandstone, very carbonaceous, with abundant small flecks of Coal, very clayey, micaceous. Sand grains consist of Quartz, Glauconite and pink Dolomite (?) and pink Feldspar, and small patches of resin.

Contains thin lenses of silty carbonaceous Claystone; plus thin lenses of quartz Sandstone, very fine and very silty, plus abundant small patches of pink Dolomite.

Evidence of burrowing throughout core.

2160.7M

Core No. 11 : 7089 to 7114 feet, cored 25', recovered 17' (68%).

7089'-7100'5" : mainly quartz Sandstone with abundant thin lenses and laminae of Siltstone, as below. Quartz Sandstone, dense (locally very clayey or porous), white, very fine, locally fine, well sorted, subangular - rounded, high sphericity; slightly micaceous, glauconitic, carbonaceous with Coal streaks, pyritic with Pyrite nodules.

7100'5"-7106' : Siltstone, dark grey, very sandy, clayey, sand grains of Feldspar, Quartz, dark lithics, Mica, pyritic and carbonaceous; with thin lenses and minute patches of quartz Sandstone, clean, white, very fine, silty. Contains dark brown dolomitic Siltstone layers. Sandstone contains microcrossbedding, current ripple laminae and several burrows.

Sandstone in part of core is extensively disrupted by microfaulting and contact between Sandstone and Siltstone is 1" thick fault breccia. Bottom 6" of Sandstone is reformed into Cataclasite.

2315.56M

Core No. 12 : 7597 to 7612 feet, cored 15', recovered 15' (100%).

Siltstone, dense, grey to dark grey, consolidated, crumbling in hard chips, clayey cement, very sandy with fine grains, carbonaceous with Coal microbeds, micaceous, slightly pyritic, sandy grains of Quartz, Feldspar and dark lithics; constant irregularly bedded laminae, locally burrowed.

Finely interbedded throughout core with irregular thin lenticular streaks (1mm to 2cm) or small patches of quartz Sandstone, slightly porous, whitish, fine to very fine sometimes medium grained, fairly sorted, subrounded - subangular, moderate sphericity, hard, little white clayey cement, occasional light brown dolomitic cement or very rare very thin lenses with white calcitic cement; silty, alined carbonaceous specks, accessory flakes of Mica, rare fine grains of Glauconite. Sandstone contains microcrossbedding, current ripple laminae, a few contorted microbedding and a few small scale load marks.

It occasionally grades into a few thin streaks (1cm maximum thickness) or small nodules of Dolomite, tight, light brown, crystalline, hard, very sandy, with carbonaceous specks, probably ankeritic; locally laminated.

2459.4M

Core No. 13 : 8069 to 8099 feet, cored 30', recovered 30' (100%).

Siltstone, very dense, dark grey to black, abundant clayey and pelitic cement, consolidated but brittle, fairly sandy with very fine Quartz and minor pinkish Feldspar grains, very carbonaceous, micaceous, few specks of Pyrite; some small Gastropods; particles in constant horizontal lineation and vague irregular laminations, locally burrowed, very poor bedding; minor micro-joints.

Grading into rare micro-interbeds of small lenticular patches or thin streaks (less than 5mm) of quartz Sandstone, dense grey, very fine, well sorted, clayey cement, very silty, slightly glauconitic, some grains of Feldspar and a few greenish volcanic lithics.

Occasional nodules (2 to 8 cm large) of Dolomite, light brown, crystalline, ankeritic, very hard, sandy, carbonaceous specks, a few minute veins of white Calcite or small patches of light brown Calcite.

Core is very homogeneous in general, although lower 10 feet are more broken.

2626.46

Core No. 14 : 8617 to 8627 feet, cored 10', recovered 1" (0.85%).

Siltstone, dense, dark grey to blackish, abundant clayey to pelitic cement, consolidated, abundant Quartz grains, very fine occasionally fine; very fine whitish Feldspar grains, abundant carbonaceous specks, slightly micaceous and glauconitic; a few irregular laminations, rare burrows.

Grading locally into rare thin (1 to 2 mm) streaks of quartz Sandstone, dense, whitish, very fine, well sorted, angular, a little clayey cement, consolidated, a few pinkish very fine Feldspar grains, somewhat glauconitic.

Micro-joints present; very poor bedding.

2672.1M

Core No. 15 : 8767 to 8777 feet, cored 10', recovered 9' (90%).

Siltstone, dense, grey dark to blackish, abundant clayey to pelitic cement, rare calcitic - dolomitic cement, consolidated but brittle; very sandy with very fine grains of whitish, pinkish, orange Feldspars, abundant carbonaceous alined specks, micaceous (mainly Muscovite), slightly glauconitic, some small patches of Pyrite, some light greenish lithics; at 8768'1" one light brownish calcitic tube 5mm diameter (horizontal burrow calcitised ?); vague and irregular laminations, rare burrows, constant lineation of particles.

Grading into occasional nodules (one is up to 10cm diameter) and streaks (one is up to 7cm thick) of Dolomite, very dense, light brownish, crystalline, very hard, sandy, silty, carbonaceous specks, rare grains of Glauconite, ankeritic; with some thin white or black brownish Calcite veins, locally silicified (?). These nodules appear to be the result of the dolomitisation of the original silty sediment.

Siltstone also grades into sparse thin (1 to 2mm) streaks and small patches throughout core of quartz locally sub-feldspathic Sandstone, dense, whitish, very fine, well sorted, angular - subangular, moderate sphericity, clayey cement and rare white calcitic cement, consolidated, very silty, glauconitic, carbonaceous specks, slightly micaceous, Feldspar grains as in Siltstone.

Micro-joints frequent. Aspect of core is very homogeneous.

3033.9m

Core No. 16 : 9954 to 9975 feet, cored 21', recovered 17'2" (82%).

Siltstone, dark grey, very sandy with Quartz, lithics and Feldspar grains, glauconitic, carbonaceous, clayey, with clayey thin streaks, massive.
Grading into Claystone, silty, very sandy and Sandstone, very fine, silty.
Locally slickensides, local Calcite filled minor fault planes. Burrowing evident. Fossiliferous. With 2 sideritic concretions at top of core.
Missing part is on top of core.

3191.8M

Core No. 17 : 10472 to 10482 feet, cored 10', recovered 8'3" (82.5%).

Siltstone, dark grey, abundant clayey cement, very consolidated but brittle, very fine grains of Quartz, Feldspar and lithics, very carbonaceous, micaceous, locally glauconitic, a little Pyrite.
With thin (2 to 4mm) clayey irregular streaks.
Grading locally into thin (1 to 2mm) lenticular rare streaks or small patches of quartz to locally sub-feldspathic Sandstone, dense, light grey, very fine, well sorted, angular to sub-angular, moderate sphericity, clayey to occasionally dolomitic cement, very silty, carbonaceous specks, light greenish lithics, local grains of Glauconite, a little Mica.
Rare nodules (1 to 2 cm diameter) of light brown Dolomite to Siderite, crystalline, very hard, sandy, silty, locally slightly glauconitic.
Very rare and very thin (± 1mm) veins of white to light brownish Calcite.
Few burrows, rare contorted microbeds; frequent micro-joints. Aspect of core is massive and homogeneous.

3323.2M

Core No. 18 : 10903 to 10913 feet, cored 10', recovered 6'6" (65%).

Siltstone, very dense, dark grey, abundant clayey cement, consolidated but brittle, very fine grains of Quartz, Feldspar and lithics, very carbonaceous, slightly micaceous, locally slightly glauconitic, patches of Pyrite.
With thin (1 to 2mm) clayey irregular streaks.
Grading locally in few places into quartz to locally sub-feldspathic Sandstone, light grey, very fine, very silty, specks of Coal.
At the top of the core, one nodule (± 9cm diameter) of Dolomite, light brown, sideritic, crystalline, very hard, carbonaceous specks, with an inside ovoid nucleus (1 x 5 cm) of beige to light brown Dolomite surrounded by very thin annular and radial brownish Calcite veins.
Frequent micro-joints. Particles alined. Stratification not clear. Massive and homogeneous core.

Core No. 19 : 11378 to 11388 feet, cored 10', no recovery.

3508.5M

Core No. 20 : 11511 to 11523 feet, cored 12', recovered 12' (100%).

Siltstone, very dense, dark grey, abundant clayey cement, consolidated but brittle, very fine grains of Quartz, Feldspar, a few reddish and light greenish lithics, very carbonaceous, patches of Pyrite, rare Mica.
With small lenticular clayey patches.
Grading into few small patches of quartz to locally sub-feldspathic Sandstone, light grey, very fine silty.
Rare nodules (3 to 10 cm diameter) of sideritic to calcitic Dolomite, light brown, crystalline, very hard, silty to sandy, carbonaceous specks, with evident light-coloured ovoid nucleus surrounded by narrow annular zone rich in brownish Calcite and crossed by thin veins of dark brownish Calcite.

Rare burrows. Particles alined. Frequent micro-joints, mainly parallel to lineation. Massive and homogeneous core.

Core No. 21 : 11988 to 11999 feet, cored 11', recovered 8' (73%).

Siltstone, dark grey, very clayey, sub-feldspathic, carbonaceous, pyritic, rare Glauconite, homogeneous; not very hard, breaks easily (along lamination planes ?); vaguely laminated.

6" below top, streak of carbonate rock, light grey to brown (Calcite + Dolomite).

Missing part is lower part of core.

2. DESCRIPTION OF SIDEWALL CORES (depths below derrick floor).

989'	Marl, light grey, soft, dolomitic, carbonaceous.
1,025'	Limestone, marly, slightly dolomitic, with Chert bands.
1,030'	Lime Mudstone, marly, light grey, soft.
1,040'	Marl, light grey, soft.
1,767'	Lime Packstone, vugular porosity (5 - 10%), light grey, bioclastic, soft; contains abundant calcareous mud matrix, scattered Dolomite crystals, grades into lime Wackestone; abundant Bryozoa, Foraminifera.
1,775'	Lime Grainstone, vugular porosity up to 40%, white, soft, bioclastic, abundant Bryozoa; plus lime Wackestone, dense (local vugular porosity lower than 5%), white.
1,778'	Lime Grainstone, porous (vugular and intergranular porosity up to 30%), white, soft, bioclastic, dolomitic (40% replaced by Dolomite crystals); abundant Bryozoa, rare Foraminifera.
1,782'	Dolomite, porous (15 - 20%), white, calcareous, crystalline, sucrosic, contains calcareous bioclastic fragments of abundant Bryozoa and of white lime mud.
1,787'	Dolomite, dense, white, calcareous, crystalline, soft, plastic, with calcareous mud matrix.
1,798'	Dolomite, as in 1,787'.
1,816'	Dolomite, slightly porous, white, fine grained, crystalline, sucrosic.
1,821'	Lime Wackestone, low vugular porosity, white, soft, bioclastic, white calcareous mud matrix; Bryozoa, Foraminifera, Gastropods.
1,825'	Lime Packstone, as in 1,821', with some Dolomite crystals.
1,838'	Dolomite, as in 1,787'.
1,842'	Dolomite, as in 1,787', ± 50% Dolomite crystals, soft, plastic, calcareous mud matrix.
1,846'	Lime Wackestone, dense, white, very fine grained, crystalline lime matrix, hard, with abundant Dolomite crystals (10%); bioclastic, abundant Bryozoa.
1,850'	Calcareous Dolomite, crystalline, grading with dolomitic lime Mudstone, white, hard, slightly bioclastic.

1,861'	Calcareous Dolomite, crystalline, as in 1,850', firm to soft, abundant white lime Mudstone matrix (± 50%), slightly bioclastic.
1,872'	Dolomite, slightly porous, light grey, crystalline, sucrosic, with abundant thin veins of white calcareous material.
1,887'	Lime Wackestone, dolomitic, with slight vugular porosity, hard, fractured; bioclastic, abundant Bryozoa.
1,903'	Dolomite, as in 1,872'.
1,915'	Dolomite, as in 1,872'.
1,928'	Dolomitic lime Mudstone, white, soft.
1,932'	Calcareous Dolomite, crystalline, as in 1,850'.
1,963'	Dolomite, crystalline, slightly porous, white, medium to coarse grained.
1,977'	Dolomite, very dense, crystalline, grey, hard.
2,060'	Limestone, white, medium grained crystals, friable, marly matrix, dolomitic.
2,080'	Dolomite, whitish, microcrystalline, semi-consolidated to friable, calcareous, locally marly,
2,090'	Lime Mudstone, slightly porous, whitish to cream, microcrystalline, chalky texture, friable.
2,160'	Dolomite, crystalline, very dense, white, calcareous, very hard.
2,170'	Dolomite, as in 2,160'.
2,180'	Dolomite, crystalline, very dense, white to light grey, hard, marly slightly calcareous.
2,196'	Dolomite, as in 2,180', less hard, less marly.
2,211'	Limestone, dolomitic, marly, dense, white to light grey, hard.
2,220'	Dolomite, clean, 20% porosity, whitish, crystalline, medium grained, sucrosic.
2,232'	Dolomite, dense, whitish calcareous, friable to hard, fractured, a few fossiliferous debris.
2,244'	Dolomite, as in 2,232'.
2,250'	Dolomite, crystalline, white, calcareous.
2,260'	Limestone, very dolomitic, dense, white, crystalline, hard.
2,272'	Limestone, slightly dolomitic, dense, white, crystalline, hard.
2,282'	Dolomite, crystalline, white, calcareous mud matrix, soft.
2,288'	Limestone, slightly dolomitic, crystalline, white, hard.

2,293'	Dolomite, white, crystalline, calcareous, firm.
2,300'	Dolomite, whitish, crystalline, calcareous, soft.
2,310'	Lime Mudstone, whitish, dolomitic, somewhat marly, firm.
2,328'	Lime Packstone, whitish, dolomitic, soft, with cream marly pellets.
2,360'	Lime Mudstone, whitish, dolomitic, chalky, friable, with a few bioclastic debris.
2,370'	Lime Mudstone, whitish to slightly greenish, microcrystalline, friable, marly (?), slightly pyritic.
2,390'	Marl, beige to white, firm, fine bioclastic debris.
2,400'	Marl, whitish to light grey, clayey; medium crystalline bioclastic debris, slightly vugular.
2,410'	Marl, light grey, many alined bioclastic debris.
2,420'	Lime Mudstone, whitish to very light grey, very fine dolomitic crystals, firm.
2,430'	Lime Mudstone, white, firm, slightly fossiliferous.
2,440'	Limestone, light grey, dolomitic, marly, firm.
2,450'	Marl, light grey, silty, vague calcareous laminations, whitish bioclastic debris.
2,460'	Marl, medium grey, silty, laminated, with Foraminifera.
2,470'	Marl, as 2,460'.
2,480'	Clay, medium grey, marly, silty, fossiliferous, with Foraminifera (?).
2,490'	Clay, medium grey, marly, silty, fossiliferous.
2,515'	Clay, medium grey, marly, silty, fossiliferous, grading into Marl.
2,530'	Marl, light grey, clayey, silty, friable.
2,540'	Siltstone, medium grey, clayey, calcitic, Foraminifera (?).
2,550'	Siltstone, medium grey, very clayey, compact and fractured.
2,569'	Siltstone, medium grey, clayey, calcareous.
2,580'	Siltstone, buff medium grey, clayey, friable.
2,600'	Siltstone, medium grey, clayey, slightly calcareous.
2,618'	Siltstone, medium grey, clayey, calcareous, vague laminations, organic debris.
2,630'	Siltstone, medium grey, clayey, slightly consolidated.

2,684' Siltstone to fine quartz Sand(stone), mauvish grey, grey, greenish-reddish brown, dense, very clayey, sorted grains, very glauconitic, limonitic pellets and ferruginous matrix, many dark lithics, with ferruginous clayey altered "pebbles".

2,710' Quartz Sand(stone), slightly porous, light brownish, medium to very coarse grained, moderately sorted, subrounded to rounded, high sphericity, semi-consolidated, clayey matrix, smooth grains with silky sheen and ferruginous staining, small limonitic pellets.

2,721' Siltstone to quartz Sand, slightly porous, fine to locally medium grained, well sorted, local clayey matrix, friable, carbonaceous grains, ferruginous staining.

2,790' Siltstone, grey, locally grading into very fine quartz Sand, friable, carbonaceous, poorly laminated.

2,803' Siltstone, dark grey with white laminations (1 to 5mm thick), locally grading into very fine quartz Sand, friable, very carbonaceous, locally clayey.

2,820' Quartz Sand, porous, cream to light grey and very light brownish, fine grained, well sorted, clean, friable.

2,837' Claystone, dark grey, very silty with Silt lenses and carbonaceous laminations.

2,876' Claystone, dark grey with white irregular laminations (1 to 2 mm thick), firm, very silty and carbonaceous.

2,942' Siltstone, slightly porous, whitish beige, quartzitic, locally very fine quartz Sand, moderately sorted, friable, one dark grey clayey carbonaceous streak.

3,038' Quartz Sand(stone) grading into Siltstone, no visible porosity, whitish, very fine grained, well sorted, firm, a few clayey-carbonaceous patches, rare very fine dark lithics.

3,100' Quartz Sand, porous, clear, medium grained, well sorted, subrounded, high sphericity, clean, friable.

3,275' Quartz Sand and Siltstone, slightly porous, as 2,942', with dark grey clayey-carbonaceous laminations.

3,316' Quartz Sand, moderately porous, clear to beige, medium to fine grained, moderately sorted, clean, friable.

3,402' Quartz Sand, no visible porosity, clear to white, fine to very coarse grained, very poorly sorted, rounded, low sphericity, friable, clean, coarse Quartz grains are smooth and with silky sheen.

3,459' Quartz Sand, as 3,402'.

3,541' Quartz Sand, as 3,402', but clayey cement, firm, pyritic.

3,610' Quartz Sand, as 3,541', with pyritic dark brown patches and a dark brown clayey and silty streak.

3,712' Quartz Sand, clear to very light brownish, as 3,402'.

3,770' Quartz Sand, traces of porosity, clear to very light brownish, medium to fine grained, poorly sorted, clean, friable, as 3,402'.

3,817'	Siltstone, dark grey, poorly sorted, firm, slightly sandy, clayey, slightly pyritic.
3,885'	Claystone, dark grey to black, firm, slightly sandy, very silty, carbonaceous, finely laminated.
3,965'	Claystone, dark grey, firm, very silty, carbonaceous, micaceous, vaguely laminated.
4,038'	Quartz Sand, slightly porous, clear to very light brownish, fine grained, well sorted, friable, traces of lithics and carbonaceous grains.
4,151'	Siltstone, medium and dark grey, clayey, firm,with irregular patches carbonaceous Clay, whitish lithic grains.
4,207'	Claystone, dark grey to black, silty, semi-consolidated, very carbonaceous, silty, pyritic, rare grains of Glauconite.
4,267'	Quartz Sand(stone), no visible porosity, brownish, fine to coarse grained, poorly sorted, subrounded, high sphericity, semi-consolidated, very silty, little grey clayey cement, ferruginous cement, limonitic grain coating.
4,332'	Quartz Sand, low porosity, grey slightly greenish, fine to coarse grained, poorly sorted, subangular to subrounded, moderate sphericity, firm to friable, white clayey and pyritic cement, carbonaceous patches.
4,370'	Siltstone, light grey, quartzitic, moderately sorted, firm, traces of sand and carbonaceous material, irregularly laminated.
4,441'	Quartz Sand, some porosity, whitish, fine grained, well sorted, angular, clean, friable, silty, some carbonaceous material.
4,531'	Siltstone, whitish and grey, unsorted, firm, clayey cement, with some coarse grains of Quartz, a few carbonaceous laminations.
4,566'	Siltstone, very light grey, a little clayey, firm to friable, carbonaceous in bands, regular very thin laminations, occasional micro-crossbedding.
4,587'	Siltstone, light grey, very clayey, firm, slightly carbonaceous, vaguely laminated.
4,620'	Siltstone, medium grey, dirty, grading into very fine quartz Sand with coarse Quartz grains, firm, very clayey.
4,690'	Quartz Sand, porous (± 15%), clear to yellowish, medium to coarse grained, well sorted, subrounded, moderate sphericity, clean, almost disintegrated in loose grains, rare Chert grains, some Pyrite pigmentation, ferruginous staining.
4,714'	Siltstone, very light grey, quartzitic, well sorted, locally fine grained, slightly clayey; half the core interbedded with laminations of Claystone, dark grey, carbonaceous and pyritic.
4,782'	Siltstone, light grey, as 4,531'.

4,806'	Siltstone, grey, moderately sorted, clayey, firm, carbonaceous, micaceous, dark grey, slightly yellowish-greenish (Pyrite), carbonaceous laminations.
4,878'	Shale, dark grey to black, very silty, carbonaceous, firm with streaks of quartz Sandstone, grey, fine grained, well sorted, abundant clayey cement, carbonaceous, pyritic, somewhat ferruginous; vague laminations.
4,912'	Quartz Sand, porous, very light grey, medium grained, well sorted, angular, friable to firm, grey clayey patches, traces of lithics, traces of Glauconite (?).
5,086'	Siltstone, dark grey, very clayey, consolidated, abundant grains of Quartz and Coal, pyritic, thin irregular laminations.
5,214'	Shale, dark grey - dark brownish, very silty, very carbonaceous, consolidated.
5,307'	Shale, dark grey with lighter patches, very silty, pyritic, carbonaceous, vague laminations.
5,332'	Quartz Sand(stone), no visible porosity, light greyish to whitish, fine to coarse grained, poorly sorted, sub-angular, moderate sphericity, abundant whitish clayey matrix, semi-consolidated, somewhat pyritic and glauconitic.
5,530'	Siltstone, dark grey with grey laminations, very clayey, carbonaceous, micaceous, consolidated, vague irregular thin laminations.
5,545'	Quartz Sand, porous, clear to light creamish, medium grained, well sorted, angular, friable, with dark lithics.
5,567'	Siltstone, dark grey with green spots, very clayey consolidated, very abundant grains of Glauconite, carbonaceous, very fine whitish lithics.
5,630'	Shale, dark grey-dark brownish, silty and very fine grains, carbonaceous flecks.
5,736'	Quartz Sand, traces of Clay, as 5,545'.
5,773'	Siltstone, dark grey, very clayey, carbonaceous, sandy, micaceous, consolidated, vague laminations.
5,812'	Quartz Sand, as 5,545', but slightly less sorted.
5,971'	Siltstone, medium grey, clayey, well cemented, abundant minute specks of Coal, some whitish very fine lithics, a few orange small patches (?).
6,003'	Quartz Sand, very little visible porosity, clear grains, medium grained, moderately sorted, subangular, dirty with some clayey matrix, unconsolidated, with Siltstone, dark grey, clayey, carbonaceous.
6,054'	Siltstone, whitish with dark grey and brownish laminations, quartzitic, some clayey cement, consolidated, brownish ferruginous spots, slightly glauconitic, with carbonaceous and clayey laminations.
6,131'	Siltstone, as 6,054', more dirty, micaceous, with irregular laminations.

1281,9m

6,194'	Quartz Sand, as 5,812', estimated 10% porosity or more.
6,482'	Shale, dark grey, very silty, with very fine grains, carbonaceous, micaceous, consolidated.
6,562'	Banded Siltstone, whitish as 6,054', with Shale, as 6,482'.
6,793'	Siltstone, medium grey with whitish patches, clayey cement, consolidated, abundant very fine Quartz grains, carbonaceous, slightly micaceous, vaguely laminated.
6,917'	Siltstone, as 6,793', with more regular dark grey clayey laminations.
7,320'	Siltstone, as 6,793'.
7,598'	Banded Siltstone and Shale, as 6,562'.
7,755'	Siltstone, dark grey, as 6,793'.
7,971'	Siltstone, very dark grey, clayey cement, consolidated, very carbonaceous, micaceous, a few whitish very fine lithics.
8,224'	Siltstone, as 7,971', hard, glauconitic.
8,387'	Shale, very dark grey with whitish patches, very silty, hard, carbonaceous, slightly micaceous.
8,438'	Siltstone, as 7,755'.
8,623'	Siltstone, as 8,224', very glauconitic with an important nest of Glauconite grains.
8,779'	Shale, medium grey, very silty, consolidated, carbonaceous, micaceous,
8,901'	Shale, dark to medium grey, very silty, as 8,779'.
12,634 (?)	(piece of rock collected in junk basket) Quartz Sandstone, no visible porosity, whitish to light grey, medium grained, well sorted, angular, moderate sphericity, well cemented, hard; with light greenish lithics (chloritic ?), black lithics, rare carbonaceous specks, slightly micaceous, irregular very thin dark laminae; one streak formed of quartz pebbles with quartzitic cement; one small pebble of greenish sub-lithic Sandstone (reworked rock from the Otway group).

PALAEONTOLOGICAL REPORT,

VOLUTA-1 WELL,

by

Geological Laboratory
Shell Development (Australia) Pty. Ltd.

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INTRODUCTION

Voluta-1 was drilled five miles offshore from Cape Bridgewater, in the western part of the Otway Basin.

SAMPLE DETAIL

Ditch cutting samples were received from first returns at 966' to T.D. at 13037', with some gaps due to lost circulation. Conventional cores were taken at approximately 500' intervals down to 11996' and sidewall cores down to 8901' were available. Cutting samples were examined at 100' intervals, which were reduced to 50' or 20' where necessary. Several samples from each core, and all sidewall cores of suitable lithology, were examined. Depths given are from B.D.F. (below derrick floor), and are as marked on samples.

As most of the investigation entailed a detailed examination of the Upper Cretaceous sequence, the following comments are relevant.

Upper Cretaceous faunas have a sparse distribution per unit volume of sediment analysed. Large core samples frequently provided only a small yield of foraminifera. Adjacent cuttings usually provided a much richer fauna, particularly below 9000'. This was largely due to taking a part of each ditch cutting sample from the mud flow at the de-sander mechanism, which produced a concentration of sand-size foraminifera. The remainder of the sample was taken from the shale shaker in the usual way, and the two samples combined in one bag.

Caving from fossiliferous horizons has evidently masked many barren intervals in the Upper Cretaceous. Thus only large-scale facies changes are evident in the cuttings. In some cases cores and sidewall samples have clarified depositional environments, but below 9000' sidewall cores were not taken, and interpretation was difficult.

ZONATION

The biostratigraphic zonation used is that of Taylor for the Gippsland, Bass and Otway Basins. (Ref. 1 and 2). Taylor's zonation of the Upper Cretaceous has been extended and subdivided.

BIOSTRATIGRAPHIC SEQUENCE

The sequence in Voluta-1 extends from Miocene to Cenomanian. Much of the Tertiary section is unsuitable for analysis (dolomitic) or unfossiliferous.

The greater part of the well is composed of 8500' of Upper Cretaceous sediments, largely fossiliferous, and extending in age from Cenomanian to Campanian (and probably to Uppermost Cretaceous). The great interest of the section lies in its thickness, its relatively continuous history of deposition, and the discovery of new faunas at the base, and probably also at the top of the sequence. The well contains the oldest Upper Cretaceous foraminiferal faunas yet found in the basin.

The sequence is detailed below.

Miocene to Oligocene - Zonules G to J - (1030' - 2660')

At 1030' a sidewall core contains a Zonule G (Lower Miocene) fauna including :

Globigerinoides triloba, Globigerina woodi, Globorotalia scitula and G. siakensis.

A cutting sample at 1120'-30' contains a Zonula H (Lowest Miocene) fauna, which includes Globigerina apertura, G. woodi and Globigerinoides triloba immatura.

The Oligocene- Miocene boundary occurs at approximately 1220'-30', where Globigerina euapertura, the Oligocene Zonule I index species, occurs with Miocene forms G. woodi, G. apertura, Globigerinoides triloba and Globorotalia siakensis. The presence of the latter species is probably due to contamination rather than to a position on the boundary between Zonules H and I-1.

At 1320'-30' the fauna is a sparse Upper Oligocene (Zonule I-1) one, with :

Globigerina euapertura.

Recrystallization and dolomitization of faunas obscure much of the Heytesbury section below this depth.

A sidewall core at 2618' contains Bolivina pontis, Angulogerina ototara and Chiloguembelina cubensis. These species, in the absence of Upper Eocene Globigerina linaperta, indicate a Lower Oligocene (Zonule J) age. Core 1 (2660'-2671') contains a very poorly preserved fauna of the same age.

Eocene - Zonule K - (2684')

Glauconitic ferruginous sandstone was recovered in a sidewall core at 2684', 13 feet below the clayey limestone of core 1. The sand contains abundant glauconitic internal molds of foraminifera, about 85% of them planktonic species. Globigerina linaperta and Globigerina ampliapertura indicate a Zonule K (Uppermost Eocene) age. No calcareous test material remains.

Sidewall cores at 2710' and 2721', still within the ferruginous sand, were barren of foraminifera. For reasons discussed later, the sand is believed to be the Nelson formation, the initial detrital deposit of the Heytesbury group.

Paleocene (?2754' - 4385')

Over an interval of 1500' (2710' - 4207') sidewall cores are barren of foraminifera, and only obvious downhole contaminants are present in ditch cutting samples. As there is only poor palynological data on the upper part of this interval, its age is problematical. A short communication from B.I.P.M. laboratories in The Hague suggested a Paleocene age.

A cutting sample at 4150-60' contains a solitary specimen of Haplophragmoides complanata. At 4207' a sidewall core contains H. complanata, many poorly preserved specimens of Haplophragmoides spp., and one Hyperammina sp. The poor fauna of this glauconitic core is supplemented by a moderately abundant H. complanata fauna from a cutting at 4210-20'. A Paleocene age can be assigned confidently.

This is the sum total of fauna found in the Wangerrip group. The assignment of this thin interval of paralic foraminifera to the Rivernook member is based partly on Dr. Dettmann's palynological examination. (see Appendix VI).

Lowermost Tertiary to Upper Cretaceous - Zonule ?Y - (4631' to 5086')

Poor arenaceous faunas occur in core 5 at 4631', and at 4878' and 5086' in sidewall cores. They are of transitional character between Paleocene and Upper Cretaceous, but have stronger affinities with the former, falling within the Haplophragmoides complanata and H. rotundata lineages of Taylor (Ref. No.3). The thinner, more lobate forms of the genus with acute compressed periphery, such as H. sp. A and H. paupera, do not occur.

Zonule Y, predicted by Taylor but not yet recognized in the Otway Basin, may be represented by these faunas. On palynological evidence these beds are Uppermost Cretaceous in age.

Upper Cretaceous - ?Campanian to Santonian - Zonule Z - (5214' - 7099')

Haplophragmoides sp. A is first seen in a sidewall core at 5214'; this is taken as the top of Zonule Z. Other components of the fauna are H. sp. B and H. sp. C, both common throughout the Upper Cretaceous sequence. Between 5400' and 5700' rare specimens of Trochammina sp., Textularia cf. semicomplanata, Ammobaculites subcretacea, A. goodlandensis and Trochammina cf. subinflata make their first appearance.

The faunas in sidewall cores, on which this Zonule is mainly based, become poorer in individuals and species, and all but Haplophragmoides spp. again disappear at 5773'. Sidewall and core samples at 5880', 5899', 5971' and 6054' are barren.

By 6210' a poor arenaceous fauna containing the same species as those listed above is again present. Dominated by Haplophragmoides sp. A, with some H. sp. B and very rare appearances of other species, this Zonule Z fauna continues down to 7099' with virtually no change. The lower boundary of this sparsely fossiliferous zonule, which is in part a facies variant rather than a sharply defined time zone, occurs at the fault which forms the boundary between the Paaratte formation and the underlying Belfast Mudstone.

Upper Cretaceous - Santonian - Zonule XA-1 - (7100'-8950')

The fauna which occurs below the fault in core 11, at 7104', is not greatly different from Zonule Z, still being dominated by H. sp. A, with H. sp. B and H. sp. C. But numbers of specimens show a tenfold increase; and several arenaceous species, including Textularia semicomplanata and Hyperammina elongata reappear. This paralic fauna marks the final regressive phase of the Belfast Mudstone. Because the facies changes seen here between final Belfast and initial Paaratte deposition are relatively slight, it is believed that relatively little section has been faulted out.

At 7200' the changes just perceptible with the crossing of the fault boundary are clearly marked. Calcareous and planktonic species make their appearance for the first time in the Upper Cretaceous, although in very small numbers. Except for the uppermost part, described above, it is a fairly homogeneous fauna, with a gradual increase in the abundance and diversity of species, down to about 8600'. At 7200' the fauna includes Haplophragmoides sp. A, H. sp. B, H. sp. C, Dorothia filiformis, Trochammina minuta, T. subinflata, Lenticulina sp. -4, Allomorphina pyriformis, Alabamina australis and Globigerina sp. At 7400' Textularia semicomplanata, T. anceps, Ammobaculites cf. subcretacea and Pallaimorphina heliciformis appear, and at 7500' Gyrodinoides nitida. The planktonic species group Hedbergella trochoidea occurs as rare specimens, but never exceeds three in any sample.

Typical Zonule XA faunas of Taylor's assemblage 2 from the Port Campbell Embayment, occur between 7760' and 8200'. They are also present in miniature forms, and much smaller numbers, between 8600' and 8800' (see section on interpretation). Calcareous forms include Cibicides excavatus, Gyrodinoides nitida, Valvulineria erugata, Lenticulina (Marginulinopsis) curvisepta, L. (Robulus) navarroensis-group, L. (Marginulinopsis) jarvisi, Quinqueloculina sp., Alabamina australis, Pallaimorphina heliciformis, Marginulina inaequalis, Buliminella cf. parvula and Hedbergella trochoidea group. Conspicuous by their absence are Ceratobulimina spp. and Hoeglundina supracretacea, both found in the Port Campbell Embayment. Hanzawaia californica appears just above the base of the zonule, at 8850'.

Arenaceous forms include Haplophragmoides sp. A, H. sp. B, H. sp. C., Dorothia filiformis, Marssonella oxycona, Textularia semicomplanata, T. anceps, Trochammina minuta, T. sp., Ammobaculites subcretacea, A. goodlandensis, A. cf. fragmentaria, Hyperammina elongata, and Dorothia conulus. The arenaceous species generally exceed 70% of the total fauna. The only significant difference from the composition of Taylor's faunas is the increased importance of Trochammina spp., reflecting the difference in facies.

Upper Cretaceous - ? Coniacian - Zonule XA-2 - (8950'-9180')

In this interval the same faunas are present, with the addition of Gavelinopsis cenomenica. This is one of the index fossils of Taylor's Upper Turonian Zonule XB, together with Colomia austrotrochus and Textularia trilobita. However, the highest appearance of G. cenomenica was never delineated by Taylor, because a facies change to paralic conditions near the base of his Zonule XA eliminated all calcareous species for some hundreds of feet. When they next appeared down section, a fully developed Turonian XB fauna was present. In Voluta-1, little regression occurs at the XA - XB boundary, and hence calcareous species remain in the fauna. The appearance of G. cenomenica 230' above Textularia trilobita (which marks true Zonule XB) necessitates splitting Zonule XA into two subzonules. The lower subzonule XA-2, is defined as extending from the highest appearance of Gavelinopsis cenomenica to the appearance of Textularia trilobita or other species indicative of XB, and is probably synchronous with Taylor's Assemblage 3 in the Port Campbell Embayment.

By inference, Zonule XA-2 is Coniacian in age, occurring above Upper Turonian and below Santonian zonules. Colomia austrotrochus, also an XB index fossil, appears within the zonule at 9010'.

Because of downhole contamination and lack of sidewall cores, it is not certain how many species of Zonule XA-1 actually extend down into XA-2.

Upper Cretaceous - Upper Turonian - Zonule XB - (9180'-11700')

The entry of Textularia trilobita at 9180' indicates the top of this zonule, which can be recognized in the absence of calcareous faunas.

Foraminifera from Zonule XA-2 are found for the first 500' of Zonule XB; they are then replaced by a slightly different fauna. This persistence of the younger fauna is probably partly due to caving.

Haplophragmoides sp. B becomes the most abundant arenaceous form, with some H. sp. C and H. sp. A. Marssonella oxycona, Dorothia filiformis, Trochammina spp., Ammobaculites goodlandensis, A. cf. subcretacea and A. cf. fragmentaria continue downwards. Textularia trilobita, the index species, is common to abundant in nearly all samples in the zone. Dorothia glabrella is rather sparsely, but persistently, distributed between 9630' and 11521' (core 20). Stensoina spp. occur throughout the zonule.

Faunas from cores are very sparse, due to the low frequency of specimens per ounce of core prepared, and the difficulty of extracting them intact from hard siltstone. Sampling of Zonule XB faunas from the mud flow at the de-sander mechanism, although somewhat misleading due to sample mixing and blurring, and some caving, produced a much richer fauna than from cores because of the natural grinding action of the drilling bit. Although foraminifera are abundant, many specimens at these depths are deformed and altered beyond recognition

Zonule XB faunas established from cores 16, 17, 18 and 20 include the following species: arenaceous Haplophragmoides sp. B, H. cf. sp. B, and H. sp. C (dominant), Dorothia filiformis, D. glabrella, Ammobaculites goodlandensis, Textularia trilobita, Marssonella oxycona and Hyperammina sp. Among the sparse calcareous forms are Gavelinopsis cenomenica, Hanzawaia californica, Nodosaria sp., several species of Lenticulina (Robulus), and Saracenaria cf. triangularis. Some other species can be added - Gyrodinoides nitida (abundant in cuttings, and present in core 21), and Pleurostomella spp., Stensoina cf. truncata, Stensoina sp., Lagena cf. apiculata and Colomia austrotochus - from new appearances in cutting samples. From their abundance in cuttings it is believed that Alabamina australis and Hedbergella trochoidea also continue into XB. Whether species such as Allomorphina pyriformis, Guembelina reussi, and certain Marginulina spp. also occur in situ in XB is uncertain.

At 9630' a large robust Textularia (designated sp.-6) is first found, and below 9880' a smaller T. sp.-7 is present, Both continue down into Zonule XC to at least core 21 (11988').

Upper Cretaceous - Cenomanian - Zonule XC - (11700' - ?12300')

A new zonule, designated XC, is marked by the entry of Textularia washitensis and T. "prototrilobita" (informal name only) at 11700'. The morphology of this species suggests that it is the ancestor of Textularia trilobita. The latter occurs in cuttings with decreasing frequency down to 12500', but its presence is probably due to caving. In core 21 at 11988' T. trilobita is absent and T. "prototrilobita" is the dominant textularid. As T. trilobita was a new species described by Taylor, it is believed that T. "prototrilobita" is also an undescribed form.

Due to caving in cuttings, a Zonule XB fauna masks the XC fauna for most of the zonule. However, core 21 at 11988' contains the following fauna:
Textularia washitensis, T. "prototrilobita", T. sp.-6, Haplophragmoides sp. C, Dorothia filiformis, Trochammina cf. umiatensis, Gyrodinoides nitida, Pyrulina cf. cylindroides, ?Hyperammina sp. and Dentalina spp., and shell fragments of Inoceramus sp. Thus the zonule can be fairly safely assigned to the Cenomanian.

Due to poor samples it is not possible to say whether the sequence between Zonules XB and XC as represented in Voluta-1 is continuous, or whether a faunal break is present.

? Upper Cretaceous - ?? Zonule XD - (?12300' - ?13037')

Between 12300' and 12950' the fauna decreases greatly in numbers and preservation becomes very poor. Cuttings down to 12950' contain sparse calcareous faunas from Zonule XC, which are probably due to caving. Indeterminable arenaceous genera make up over half the faunas. A distinctive species, Spiroplectammina goodlandana, which is possibly the ancestor of Textularia washitensis, is first found at 12940'-50'. It is possible that another zonule, "XD", is present below 12300', but the uselessness of most of the fauna prevents any conclusions being drawn at this stage.

DEPOSITIONAL ENVIRONMENT AND GENERAL DISCUSSION

Following deposition of the Otway group and downfaulting of the Voluta area, Upper Cretaceous deposition commenced in a paralic or brackish lagoonal environment. The oldest known foraminiferal strata in the basin contain very poor faunas below 12300', and are possibly of early Cenomanian age.

In the interval 12300' - 11700' Cenomanian faunas became established in a restricted marine environment. The evidence strongly suggests Voluta-1 to have been within a long narrow embayment, aligned NW - SE, with a silled entrance to the SE, producing ponded conditions even in the times of maximum marine transgression.

Arenaceous species tolerant of unfavourable conditions are dominant: mainly Haplophragmoides spp. and Textularia spp. Due to the lack of other diagnostic species, zonation in the Upper Cretaceous of the Otway Basin has been based mainly on species of Textularia.

Whether the sequence between Cenomanian Zonule XC and Upper Turonian Zonule XB remains marine, becomes regressive, or is broken by an unconformity, is uncertain. At the top of XC an unusual element of the fauna is the quantity of sea urchin fragments at 11700'. Faunas at 11620'-30' are poor but not markedly "regressive" in aspect. Core 20 at 11521' has a fauna dominated by Haplophragmoides spp., without Textularia spp., tending to suggest shallow water conditions. However, insufficient evidence is available for anything more than conjecture.

Essentially uniform restricted marine conditions seem to have prevailed throughout Upper Turonian (Zonule XB) times. (It is possible that the lower part of this zonule extends into the Middle Turonian.) Marine influence seems to have reached a maximum at this time, with ocean currents carrying a few planktonic specimens across the postulated circulation barrier at the entrance to the embayment.

Upper Turonian faunas apparently pass into Coniacian (XA-2) faunas at 9180' without a perceptible change in environment. Similarly, no change in facies is apparent between XA-2 and XA-1 (Santonian) at 8950'. In contrast to the Port Campbell Embayment, this part of the sequence appears to be without faunal breaks.

The interval assigned to the Coniacian may be too brief, and might eventually be extended.

Restricted marine conditions initiate Santonian Zonule XA-1 at 8950', but at 8800' the environment appears to change. Between this depth and 8600' the calcareous specimens become few in number and of miniature size. They are well sorted to a fine silt size. It is possible that the Voluta area was partially emergent at this time, and that small calcareous specimens were transported by wind, possibly over a beach barrier, to a lagoonal environment. A restricted arenaceous fauna of the normal size dominates this interval, and suggests regressive or lagoonal conditions.

A return to restricted marine conditions is evident at about 8600', and this environment persists almost to the top of Zonule XA-1.

Core 11 at 7104' has an abundant but almost entirely arenaceous fauna indicating shallowing and an approach to paralic conditions. Immediately above this is the bounding fault between Belfast Mudstone and Paaratte formation, and between Zonules XA-1 and Z. From the facies change to paralic at the top of the Belfast Mudstone, it would seem that relatively little of the section is missing through faulting.

The Zonule XA-1 - Zonule Z boundary is generally a reflection of facies changes rather than a time plane. The zonule is characterized by the continuation of paralic arenaceous species from Zonule XA-1, and the absence of calcareous species. However the zonule also has time significance, in that part of it extends into the Campanian. It is much more readily zoned by palynology (see Appendix VI).

The impossibility of defining Zonule Z as a time zone in Voluta-1 illustrates the severe difficulties imposed on time stratigraphy by the numerous facies variations in the Otway Basin. Only a well section in an open marine facies, possibly beyond the confines of the basin and situated on the upper continental slope, could resolve all these problems.

Zonule Z extends from 7100' to 5214' and comprises the Paaratte formation and part of the Curdies formation. It is a paralic sequence with a sparse and erratic distribution of microfauna. A minor regression is indicated between about 6100' and 5800', where cores are barren of fauna and dolomite and carbonaceous material appear in samples.

In the upper part of the Curdies formation, marine influence becomes still more remote. The environment varies from paralic to non-marine in Zonule ?Y. The existence of this zonule is suggested, not proven, by a series of poor faunas transitional in character between Upper Cretaceous and Paleocene.

The position of the Tertiary - Cretaceous boundary is impossible to determine in Voluta-1 in the present state of our knowledge. Its precise position does not seem to be of much practical importance, as deposition appears to have been continuous from Upper Cretaceous to Tertiary. The uppermost parts of the Curdies formation appear to extend into the basal Tertiary. (see Dettmann, Appendix VI). Paralic foraminifera with transitional characteristics, but generally with Paleocene affinities, occur between Core 5 (4631') and 5086'. The highest recognizable Cretaceous fauna occurs at 5214' (top of Zonule Z). However the top of the Cretaceous is placed at the top of the Nothofagidites spore-pollen zone.

No fauna was found in the basal sand of the Wangerrip group, the Pebble Point formation, and it is believed to be non-marine. The Rivernook member, directly above, contained an abundant arenaceous fauna at 4210', indicating a definite if brief return to paralic conditions. This contrasts with the open marine character of the Rivernook member further east in the Port Campbell Embayment. In keeping with this observation, the remainder of the Wangerrip group in Voluta-1 is entirely barren of microfauna, and appears to be non-marine.

The Nirranda group appears to be absent in Voluta-1. Ferruginous sands at 2754' mark the beginning of the Heytesbury group transgression, with the deposition of the Nelson formation. A sand at 2684' contains the glauconitic molds of an abundant planktonic fauna of Uppermost Eocene age (Zonule K). It indicates a rapid deepening and influx of ocean currents, which is quickly followed by carbonate sedimentation. At 2618' a sidewall core in the overlying marl contains a diagnostic Zonule J (Lower Oligocene) fauna. No perceptible faunal break is present. It is characteristic of the Nirranda group that where found it is separated from the overlying Heytesbury group by an unconformity that is recognizable as a faunal break. No such break is evident here, and the change from glauconitic sands to clays, marls and limestones seems to reflect a normal transgressive sequence. The Uppermost Eocene age of the Nelson formation confirms indications that the Heytesbury transgression moved from westward to eastward across the Otway Basin.

Post-Eocene Heytesbury sedimentation followed its customary pattern of moderately deep water shelf carbonates, with much secondary dolomitization obscuring the age of the limestone sequence. Open marine Lower Miocene limestone occurs in a sidewall core at 1030'.

The highest occurrence of the Heytesbury group is at the sea floor, where ?Miocene limestones are overlain in places by Pleistocene dune limestone. Upper Miocene clays of problematical relationship to the Heytesbury group also outcrop on the sea floor.

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PALYNOLOGICAL REPORT
ON VOLUTA-1 WELL,
4,151 FEET - 13,020 FEET,

by

Dr. M.E. Dettmann,
University of Queensland.

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PALYNOLOGICAL REPORT ON VOLUTA-1 WELL,

4151 FEET - 13,020 FEET,

by

Dr. M.E. Dettmann

The present account incorporates the documentation and evaluation of the microfloral succession observed in sediments between 4151 feet and 13,020 feet in Shell Voluta-1 well. From within this interval, a total of 63 samples including conventional cores, sidewall cores, junk basket samples, and cuttings have been studied. All samples were found to contain carbonaceous matter including usually abundant wood and cuticular fragments intermixed with sparse to abundant spores and pollen grains. Microplankton, although rarely common, are of fairly consistent occurrence in the sections between 4151 feet - 5086 feet and 5885 feet - 11,989 feet; however, they were not observed in sediments between 5214 feet and 5773 feet.

The method by which the plant microfossils were extracted from the enclosing sediments comprises initial treatment in cold hydrofluoric acid followed by mineral separation with zinc bromide. The resultant residues were then examined and the quality of preservation of the contained microfossils was ascertained (Encl. 7). Residues obtained from sediments between 4151 feet and 8901 feet were subjected to additional treatment with Schulze solution for five to fifteen minutes, followed by dilute (< ½%) ammonium hydroxide before the microfloras were specifically analysed. This maceration treatment, however, was found to be unsatisfactory for the poorly preserved palynological floras preserved in sediments at and below 9962½ feet, because the walls of the spore-pollen-microplankton forms became disorganised and their morphological characters were partially or completely destroyed. Thus, the microfloras enclosed in sediments between 9962½ feet and 13,020 feet were specifically analysed after the initial hydrofluoric acid - zinc bromide treatment.

The spore-pollen-microplankton suites identified in the sample are tabulated below with reference to their qualitative and quantitative content; the quantitative estimates are expressed in the following terms: Ab (abundant) - numerical representation of a particular species totals at least 5% of microflora, C (common) - numerical representation of a species forms 1-5% of total microflora, and R (rare) - numerical representation forms less than 1% of total microflora.

As outlined below Voluta-1 well contains several distinct microflora suites that conform with plant microfossil assemblages delineated by Harris (1965), Evans (1966), and Dettmann and Playford (1968) in Upper Cretaceous and Lower Tertiary sequences of the Otway Basin. On this basis the section between 4151 feet and 11,989½ feet in Voluta-1 well is shown to range in age from Paleocene to Turonian. Sediments at and below 12,634 feet contain only extremely poorly preserved palynological floras that provide insufficient evidence for firm age determinations.

DISCUSSION AND AGE OF MICROFLORAL ASSEMBLAGES

A. 4151 feet

The sidewall core from 4151 feet provided an excellently preserved microfloral assemblage consisting of good concentrations of spores and pollen grains together with extremely rare microplankton. Species identified include:

Spores:	Cyathidites minor Couper	C
	Gleicheniidites circinidites (Cookson)	C
	Laevigatosporites major (Cookson)	R
	Lycopodiumsporites sp.	R
Pollen:	Araucariacites australis Cookson	C
	Dacrydiumites florinii Cookson & Pike	R

	Duplopollis orthoteichus (Cookson & Pike)	R
	Malvacipollis diversus Harris	C
	Myrtaceidites parvus Cookson & Pike	R
	Microcachryidites antarcticus Cookson	R
	Nothofagidites emarcidus (Cookson)	C
	Phyllocladidites mawsonii Cookson	C
	Podocarpidites ellipticus Cookson	C
	P. marwickii Couper	R
	Podosporites microsaccatus (Couper)	R
	Polyporina fragilis Harris	C
	Proteacidites crassus Cookson	C
	P. dilwynensis Harris	R
	P. cf. rectomarginus Cookson	R
	P. reticuloscabratus Harris	R
	P. subscabratus Couper	Ab
	P. spp.	R
	Tricolpites cf. fissilis Couper	R
	Triorites harrisii Couper	Ab
	Tricolporites prolata Cookson	R
Microplankton:	Baltisphaeridium sp.	R
Remanié:	Nuskoisporites sp. - Permian	

The microflora contains Duplopollis orthoteichus together with Proteacidites dilwynensis and is accordingly assigned to Harris's (1965) Duplopollis orthoteichus Assemblage of Upper Paleocene age. The D. orthoteichus Assemblage was recorded from Nerita-1 well at 2570 feet(Dettmann 1967a).

B. 4267 feet - 4370 feet

4267 feet (sidewall core)

A small residue containing a few representatives of the following forms of spores, pollen, and microplankton was extracted from the sample:

Spores:	Baculatisporites comaumensis (Cookson)
	Cyathidites australis Couper
	Gleicheniidites circinidites (Cookson)
	Stereisporites antiquasporites (Wilson & Webster)
Pollen:	Microcachryidites antarcticus Cookson
	Proteacidites subscabratus Couper
	Triorites edwardsii Cookson & Pike
Microplankton:	Baltisphaeridium liniferum Cookson & Eisenack
	Cordosphaeridium bipolare Cookson & Eisenack
	Deflandrea dartmooria Cookson & Eisenack
	D. cf. dartmooria
	D. cf. dilwynensis Cookson & Eisenack
	Wetzelliella hyperacantha Cookson & Eisenack

4370 feet (sidewall core)

The following well preserved spore, pollen, and microplankton occur in the sample:

Spores:	Camarozonosporites amplus (Stanley)	C
	Cyathidites australia Couper	C
	C. minor Couper	Ab
	C. splendens Harris	C
	Kraeuselisporites papillatus Harris	R
	Laevigatosporites major (Cookson)	R
	L. ovatus Wilson & Webster	C
	Lycopodiumsporites cf. austroclavatidites (Cookson)	R
	Stereisporites antiquasporites (Wilson & Webster)	C

Pollen:	Araucariacites australis Cookson	C
	Dacrydiumites balmei Cookson	C
	D. ellipticus Harris	R
	Microcachryidites antarcticus Cookson	C
	Nothofagidites emarcidus (Cookson)	R
	Phyllocladidites mawsonii Cookson	Ab
	Polyporina fragilis Harris	R
	Proteacidites crassus Cookson	C
	P. subscabratus Couper	Ab
	aff. Triorites edwardsii Cookson & Pike	R
	Triorites harrisii Couper	R
Microplankton:	Deflandrea bakeri Deflandre & Cookson	R
Remanié:	Aequitriradites spinulosus (Cookson & Dettmann) - Lower Cretaceous	
	Nuskoisporites sp. - Permian	

The sample from 4370 feet contains aff. Triorites edwardsii, Dacrydiumites balmei and Deflandrea bakeri which collectively suggest a Middle Paleocene age and assignment of the horizon to Harris's (1965) Triorites edwardsii Assemblage Zone. The sediment at 4267 feet is also referred to this zone on the basis of T. edwardsii, although the microplankton suite shows certain features in common with the Middle-Upper Paleocene assemblage described by Cookson and Eisenack (1967) from the Rivernook Member. Cookson and Eisenack's sample came from below Harris's Triorites edwardsii - Duplopollis orthoteichus Concurrent Range Zone and apparently lacked both T. edwardsii and D. orthoteichus (p.255). They do not document the total spore-pollen content of the sample, but note (p.254) the presence of Proteacidites pachypolus Cookson & Pike, a form which is considered by Harris to make its first appearance in the Upper Paleocene D. orthoteichus Assemblage Zone.

C. 4566 feet - 4587 feet

4566 feet (sidewall core)

A well preserved assemblage of the following species of spores, pollen grains, and microplankton was extracted from the sample:

Spores:	Camarozonosporites amplus (Stanley)	C
	Cyathidites australis Couper	C
	C. splendens Harris	R
	Laevigatosporites major (Cookson)	R
	L. ovatus Wilson & Webster	C
	Lycopodiumsporites austroclavatidites (Cookson)	C
	Stereisporites antiquasporites (Wilson & Webster)	C
Pollen:	Araucariacites australis Cookson	C
	Dacrydiumites balmei Cookson	R
	D. florinii Cookson & Pike	R
	Microcachryidites antarcticus Cookson	C
	Nothofagidites emarcidus (Cookson)	C
	Phyllocladidites mawsonii Cookson	Ab
	Podocarpidites ellipticus Cookson	C
	Proteacidites amolosexinus Dettmann & Playford	R
	P. reticuloscabratus Harris	R
	P. parvus Cookson	R
	P. subscabratus Couper	Ab
	Triorites edwardsii Cookson & Pike	R
	aff. T. edwardsii	C
	Triorites harrisii Couper	R
	Tricolpites gillii Cookson	R
	T. lillei Couper	R
Remanié:	Nuskoisporites sp. - Permian	

4587 feet (sidewall core)

The following forms of well preserved spores and pollen grains were identified:

Spores:	Baculatisporites comaumensis (Cookson)	R
	Camarozonosporites amplus (Stanley)	C
	C. bullatus Harris	R
	C. sp.	R
	Cyathidites australis Couper	C
	C. splendens Harris	R
	Densoisporites velatus Weyland & Krieger	R
	Kraeuselisporites papillatus Harris	R
	Laevigatosporites major (Cookson)	R
	Lycopodiumsporites austroclavatidites (Cookson)	R
	Stereisporites antiquasporites (Wilson & Webster)	Ab
Pollen:	Dacrydiumites ellipticus Harris	R
	D. florinii Cookson & Pike	R
	Nothofagidites emarcidus (Cookson)	C
	Phyllocladidites mawsonii Cookson	Ab
	Podocarpidites ellipticus Cookson	C
	Proteacidites amolosexinus Dettmann & Playford	R
	P. annularis Cookson	R
	P. subscabratus Couper	Ab
	P. scaboratus Couper	C
	Tricolpites gillii Cookson	R
	Triorites edwardsii Cookson & Pike	R
	aff. T. edwardsii	R
Remanié:	Nuskoisporites sp. - Permian	

The sample from 4566 feet contains the earliest observed occurrences of Dacrydiumites balmei and the last appearances of both Tricolpites lillei and Proteacidites amolosexinus. These features suggest an uppermost Cretaceous or lowermost Tertiary age and characterise the microflora present in Pecten 1-A well at 3735 feet (Dettmann 1967c). The microflora extracted from Voluta-1 well at 4587 feet also appears to be of late Cretaceous or early Tertiary aspect.

D. 4620 feet - 7099 feet

4620 feet (sidewall core)

The well preserved assemblage extracted from the sample includes the following species of spores, pollen, and microplankton:

Spores:	Camarozonosporites amplus (Stanley)	R
	Clavifera triplex (Bolkhovitina)	R
	Cyathidites australis Couper	C
	Gleicheniidites circinidites (Cookson)	R
	Kraeuselisporites papillatus Harris	R
	Laevigatosporites major (Cookson)	R
	Lycopodiumsporites austroclavatidites (Cookson)	R
Pollen:	Cycadopites sp.	R
	Dacrydiumites ellipticus Harris	R
	D. florinii Cookson & Pike	R
	Microcachryidites antarcticus Cookson	C
	Nothofagidites emarcidus (Cookson)	R
	N. senectus Dettmann & Playford	R
	Phyllocladidites mawsonii Cookson	Ab
	Podocarpidites ellipticus Cookson	C
	Proteacidites parvus Cookson	R
	P. scaboratus Couper	C
	P. subscabratus Couper	Ab
	Stephanoporopollenites obscurus Harris	R
	Triorites edwardsii Cookson & Pike	R
	aff. T. edwardsii	C
	Tricolpites pachyexinus Couper	R
Microplankton:	Deflandrea pellucida Cookson & Eisenack	R

4631 feet (core 5)

The well preserved spores and pollen grains identified in the sample include:

Spores:	Camarozonosporites bullatus Harris	R
	Ceratosporites sp.	R
	Cyathidites australis Couper	C
	C. splendens Harris	R
	Densoisporites velatus Weyland & Krieger	R
	Gleicheniidites circinidites (Cookson)	C
	Kraeuselisporites papillatus Harris	R
	Lycopodiumsporites cf. circolumenus Cookson & Dettmann	R
	Stereisporites antiquasporites (Wilson & Webster)	Ab
Pollen:	Araucariacites australis Cookson	R
	Cycadopites sp.	R
	Dacrydiumites florinii Cookson & Pike	R
	Microcachryidites antarcticus Cookson	Ab
	Nothofagidites emarcidus (Cookson)	R
	N. senectus Dettmann & Playford	C
	Phyllocladidites mawsonii Cookson	C
	Podosporites microsaccatus (Couper)	R
	Proteacidites amolosexinus Dettmann & Playford	C
	P. scaboratus Couper	C
	P. subscabratus Couper	Ab
	Tricolpites gillii Cookson	R
	T. lillei Couper	R
	T. pachyexinus Couper	R
	aff. Triorites edwardsii Cookson & Pike	R
Remanié:	Nuskoisporites sp. - Permian	

4648 feet (core 5)

Abundant spores and pollen grains and rare microplankton were extracted from the sample. Species observed include:

Spores:	Camarozonosporites amplus (Stanley)	C
	Cyathidites australis Couper	C
	C. splendens Harris	C
	Gleicheniidites circinidites (Cookson)	C
	Kraeuselisporites papillatus Harris	R
	Laevigatosporites major (Cookson)	C
	L. ovatus Wilson & Webster	Ab
	Stereisporites antiquasporites (Wilson & Webster)	Ab
Pollen:	Araucariacites australis Cookson	R
	Microcachryidites antarcticus Cookson	C
	Nothofagidites emarcidus (Cookson)	C
	Phyllocladidites mawsonii Cookson	Ab
	Podosporites microsaccatus (Couper)	R
	Podocarpidites ellipticus Cookson	C
	Polyporina fragilis Harris	R
	Proteacidites amolosexinus Dettmann & Playford	C
	P. scaboratus Couper	R
	P. subscabratus Couper	C
	Tricolpites gillii Cookson	R
	T. lillei Couper	R
	T. pachyexinus Couper	R
	Triorites edwardsii Cookson & Pike	R
	aff. T. edwardsii	C
Microplankton:	?Trichodinium sp.	R
Remanié:	Nuskoisporites sp. - Permian	

4782 feet (sidewall core)

The sample yielded the following well, preserved assemblage of spores, pollen, and microplankton:

Spores:	Camarozonosporites amplus (Stanley)	C
	C. sp.	R
	Cyathidites minor Couper	Ab
	C. splendens Harris	R
	Densoisporites velatus Weyland & Krieger	R
	Stereisporites antiquasporites (Wilson & Webster)	Ab
Pollen:	Amosospollis cf. cruciformis Cookson & Balme	R
	Microcachryidites antarcticus Cookson	Ab
	Phyllocladidites mawsonii Cookson	Ab
	Polyporina fragilis Harris	R
	Proteacidites scaboratus Couper	R
	P. subscabratus Couper	Ab
	Tricolpites lillei Couper	R
	Triorites edwardsii Cookson & Pike	R
Microplankton:	Deflandrea pellucida Cookson & Eisenack	R
	D. spp.	R
	Epicephalopyxsis indentata Deflandre & Cookson	R
Remanié:	Nuskoisporites sp. - Permian	

4806 feet (sidewall core)

Fair concentrations of the following species of spores, pollen, and microplankton were extracted from the sample:

Spores:	Camarozonosporites amplus (Stanley)	C
	C. sp.	R
	Cyathidites australis Couper	C
	C. splendens Harris	R
	Gleicheniidites circinidites (Cookson)	Ab
	Laevigatosporites ovatus Wilson & Webster	C
	Stereisporites antiquasporites (Wilson & Webster)	C
	S. viriosus Dettmann & Playford	R
Pollen:	Araucariacites australis Cookson	R
	Dacrydiumites florinii Cookson & Pike	R
	Microcachryidites antarcticus Cookson	C
	Nothofagidites senectus Dettmann & Playford	C
	Phyllocladidites mawsonii Cookson	C
	Podocarpidites ellipticus Cookson	C
	Proteacidites amolosexinus Dettmann & Playford	R
	P. scaboratus Couper	C
	P. subscabratus Couper	Ab
	Triorites edwardsii Cookson & Pike	R
	aff. T. edwardsii	R
Microplankton:	Deflandrea pellucida Cookson & Eisenack	R
	Epicephalopyxsis indentata Deflandre & Cookson	R
	? Trichodinium sp.	R
Remanié:	Nuskoisporites sp. - Permian	

4878 feet (sidewall core)

Only spores and pollen grains were observed in the residue which contains the following well preserved forms:

Spores:	Camarozonosporites amplus (Stanley)	R
	C. bullatus Harris	R
	Ceratosporites sp.	R
	Cyathidites australis Couper	C
	C. minor Couper	C
	Gleicheniidites circinidites (Cookson)	C
	Stereisporites antiquasporites (Wilson & Webster)	Ab
Pollen:	Araucariacites australis Cookson	R
	Dacrydiumites florinii Cookson & Pike	R
	Microcachryidites antarcticus Cookson	C
	Nothofagidites senectus Dettmann & Playford	C
	Phyllocladidites mawsonii Cookson	Ab
	Proteacidites amolosexinus Dettmann & Playford	C
	P. subscabratus Couper	Ab
	Tricolpites pachyexinus Couper	R
	Triorites edwardsii Cookson & Pike	R
Remanié:	Nuskoisporites sp. - Permian	

4912 feet (Sidewall core)

The sample yielded a minute residue in which only the microplankton species, Epicephalopyxsis indentata Deflandre & Cookson was observed.

4952 feet (core 6)

The following well preserved forms of spores, pollen, and microplankton were extracted from the sample:

Spores:	Camarozonosporites amplus (Stanley)	R
	Cyathidites minor Couper	C
	Gleicheniidites circinidites (Cookson)	Ab
	Stereisporites antiquasporites (Wilson & Webster)	C
Pollen:	Dacrydiumites florinii Cookson & Pike	R
	Phyllocladidites mawsonii Cookson	C
	Podosporites microsaccatus (Couper)	R
	Podocarpidites ellipticus Cookson	C
	Proteacidites amolosexinus Dettmann & Playford	R
	P. scaboratus Couper	C
	P. subscabratus Couper	C
	Tricolpites pachyexinus Couper	R
	Triorites edwardsii Cookson & Pike	R
Microplankton:	Epicephalopyxsis indentata Deflandre & Cookson	C
	?Trichodinium sp.	R

4958 feet (core 6)

The following species of well preserved spores, pollen and microplankton were observed in the residue:

Spores:	Cyathidites australis Couper	C
	Gleicheniidites circinidites (Cookson)	Ab
	Laevigatosporites ovatus Wilson & Webster	R
	Lycopodiumsporites austroclavatidites (Cookson)	R
	Stereisporites antiquasporites (Wilson & Webster)	C
Pollen:	Cycadopites cf. nitidus (Balme)	R
	Microcachryidites antarcticus Cookson	C
	Proteacidites amolosexinus Dettmann & Playford	R
	P. scaboratus Couper	C
	P. subscabratus Couper	Ab
	Tricolpites gillii Cookson	R
	T. lillei Couper	R
	T. pachyexinus Couper	R
Microplankton:	Epicephalopyxsis indentata Deflandre & Cookson	R

5085 feet (sidewall core)

The sample provided a well preserved assemblage of the following forms of spores, pollen, and microplankton:

Spores:	Camarozonosporites amplus (Stanley)	R
	C. bullatus Harris	R
	Cyathidites australis Couper	C
	C. minor Couper	C
	C. splendens Harris	R
	Densoisporites velatus Weyland & Krieger	R
	Gleicheniidites circinidites (Cookson)	Ab
	Laevigatosporites major (Cookson)	R
	L. ovatus Wilson & Webster	C
	Lycopodiumsporites austroclavatidites (Cookson)	R
Pollen:	Araucariacites australis Cookson	R
	Dacrydiumites florinii Cookson & Pike	R
	Microcachryidites antarcticus Cookson	Ab
	Nothofagidites senectus Dettmann & Playford	R
	Phyllocladidites mawsonii Cookson	Ab
	Proteacidites amolosexinus Dettmann & Playford	R
	P. scaboratus Couper	C
	P. subscabratus Couper	R
	Tricolpites pachyexinus Couper	C
	T. sabulosus Dettmann & Playford	R
Microplankton:	Baltisphaeridium sp.	R
	Deflandrea sp.	R
	?Trichodinium sp.	R

5214 feet (sidewall core)

The well preserved spores and pollen grains observed include:

Spores:	Camarozonosporites amplus (Stanley)	R
	Cyathidites australis Couper	C
	C. splendens Harris	R
	Densoisporites velatus Weyland & Krieger	R
	Lycopodiumsporites austroclavatidites (Cookson)	R
	Ornamentifera sentosa Dettmann & Playford	R
	Stereisporites antiquasporites (Wilson & Webster)	Ab
Pollen:	Classopollis cf. classoides Pflug	R
	Microcachryidites antarcticus Cookson	R
	Nothofagidites senectus Dettmann & Playford	C
	Phyllocladidites mawsonii Cookson	C
	Podocarpidites ellipticus Cookson	C
	Podosporites microsaccatus (Couper)	R
	Proteacidites amolosexinus Dettmann & Playford	R
	P. subscabratus Couper	Ab
	Tricolpites pachyexinus Couper	C
	aff. Triorites edwardsii Cookson & Pike	R

5307 feet (sidewall core)

Spores and pollen grains extracted from the sediment constitute the following assemblage:

Spores:	Camarozonosporites amplus (Stanley)	C
	C. bullatus Harris	R
	Cyathidites minor Couper	C
	C. splendens Harris	R
	Ceratosporites sp.	R
	Densoisporites velatus Weyland & Krieger	R
	Lycopodiumsporites austroclavatidites (Cookson)	R

	Stereisporites antiquasporites (Wilson & Webster)	Ab
Pollen:	Dacrydiumites florinii Cookson & Pike	R
	Microcachryidites antarcticus Cookson	Ab
	Nothofagidites senectus Dettmann & Playford	C
	Podocarpidites ellipticus Cookson	C
	Proteacidites amolosexinus Dettmann & Playford	R
	P. subscabratus Couper	Ab
	Tricolpites gillii Cookson	R
	T. pachyexinus Couper	C
	T. sabulosus Dettmann & Playford	C
	aff. Triorites edwardsii Cookson & Pike	C
Remanié:	Nuskoisporites sp. - Permian	

5332 feet (sidewall core)

Low concentrations of the following species of spores and pollen grains occur in the sample:

Spores:	Camarozonosporites amplus (Stanley)	C
	Cyathidites minor Couper	C
	Gleicheniidites circinidites (Cookson)	C
	Laevigatosporites ovatus Wilson & Webster	C
	Lycopodiumsporites austroclavatidites (Cookson)	R
	Stereisporites antiquasporites (Wilson & Webster)	Ab
Pollen:	Araucariacites australis Cookson	R
	Cycadopites nitidus (Balme)	R
	Microcachryidites antarcticus Cookson	Ab
	Nothofagidites senectus Dettmann & Playford	C
	Podocarpidites ellipticus Cookson	C
	Proteacidites amolosexinus Dettmann & Playford	R
	P. scaboratus Couper	C
	P. subscabratus Couper	Ab
	Tricolpites gillii Cookson	R
	T. pachyexinus Couper	C
	T. sabulosus Dettmann & Playford	C
	Triorites edwardsii Cookson & Pike	R

5481 feet (core 7)

The following species of spores and pollen grains were observed in the sample:

Spores:	Camarozonosporites amplus (Stanley)	R
	Cyathidites australis Couper	C
	C. splendens Harris	R
	Baculatisporites comaumensis (Cookson)	R
	Gleicheniidites circinidites (Cookson)	C
	Stereisporites antiquasporites (Wilson & Webster)	Ab
Pollen:	Araucariacites australis Cookson	R
	Cycadopites nitidus (Balme)	R
	Microcachryidites antarcticus Cookson	Ab
	Nothofagidites senectus Dettmann & Playford	C
	Podocarpidites ellipticus Cookson	C
	Proteacidites amolosexinus Dettmann & Playford	R
	P. scaboratus Couper	C
	P. subscabratus Couper	Ab
	Tricolpites gillii Cookson	R
	T. pachyexinus Couper	C
	T. sabulosus Dettmann & Playford	C
	Triorites edwardsii Cookson & Pike	R

5481 feet (core 7)

The following species of spores and pollen grains were observed in the sample:

Spores:	Camarozonosporites amplus (Stanley)	R
	Cyathidites australis Couper	C
	C. splendens Harris	R
	Baculatisporites comaumensis (Cookson)	R
	Gleicheniidites circinidites (Cookson)	C
	Stereisporites antiquasporites (Wilson & Webster)	Ab
Pollen:	Araucariacites australis Cookson	R
	Cycadopites nitidus (Balme)	R
	Microcachryidites antarcticus Cookson	Ab
	Nothofagidites senectus Dettmann & Playford	C
	Phyllocladidites mawsonii Cookson	C
	Podocarpidites ellipticus Cookson	C
	Proteacidites amolosexinus Dettmann & Playford	R
	P. scaboratus Couper	C
	P. subscabratus Couper	Ab
	Tricolpites pachyexinus Couper	R
	T. sabulosus Dettmann & Playford	C
	Triorites edwardsii Cookson & Pike	R
Remanié:	Nuskoisporites sp. - Permian	

5498 feet (core 7)

The spore-pollen suite identified in the sample includes the following species:

Spores:	Camarozonosporites amplus (Stanley)	R
	C. sp.	R
	Cyathidites australis Couper	R
	Densoisporites velatus Weyland & Krieger	R
	Gleicheniidites circinidites (Cookson)	Ab
	Laevigatosporites ovatus Wilson & Webster	C
	Lycopodiumsporites austroclavatidites (Cookson)	R
	Kraeuselisporites papillatus Harris	R
	Stereisporites antiquasporites (Wilson & Webster)	Ab
Pollen:	Dacrydiumites florinii Cookson & Pike	R
	Microcachryidites antarcticus Cookson	C
	Nothofagidites senectus Dettmann & Playford	C
	Phyllocladidites mawsonii Cookson	C
	Podosporites microsaccatus (Couper)	R
	Podocarpidites ellipticus Cookson	C
	Proteacidites amolosexinus Dettmann & Playford	R
	P. scaboratus Couper	C
	P. subscabratus Couper	Ab
	Tricolpites gillii Cookson	R
	T. pachyexinus Couper	C
	T. sabulosus Dettmann & Playford	R
Remanié:	Nuskoisporites sp. - Permian	

5530 feet (sidewall core)

Poor concentrations of the following species of well preserved spores and pollen grains occur in the sample:

Spores:	Camarozonosporites amplus (Stanley)	R
	Ceratosporites sp.	R
	Cyathidites minor Couper	C
	C. splendens Harris	R
	Baculatisporites comaumensis (Cookson)	R
	Gleicheniidites circinidites (Cookson)	C
	Laevigatosporites ovatus Wilson & Webster	C
	Stereisporites antiquasporites (Wilson & Webster)	Ab
Pollen:	Phyllocladidites mawsonii Cookson	C
	Nothofagidites senectus Dettmann & Playford	C
	Proteacidites amolosexinus Dettmann & Playford	R
	P. scaboratus Couper	C
	P. subscabratus Couper	Ab
	Tricolpites pachyexinus Couper	R

	T. sabulosus Dettmann & Playford	C

5567 feet (sidewall core)

The reasonably well preserved spores and pollen grains identified in the residue include:

Spores:	Camarozonosporites amplus (Stanley)	R
	C. bullatus Harris	R
	Cyathidites australis Couper	C
	C. minor Couper	C
	Gleicheniidites circinidites (Cookson)	C
	Lycopodiumsporites austroclavatidites (Cookson)	R
	Stereisporites antiquasporites (Wilson & Webster)	Ab
Pollen:	Araucariacites australis Cookson	R
	Microcachryidites antarcticus Cookson	Ab
	Nothofagidites senectus Dettmann & Playford	R
	Phyllocladidites mawsonii Cookson	C
	Podocarpidites ellipticus Cookson	C
	Podosporites microsaccatus (Couper)	R
	Proteacidites amolosexinus Dettmann & Playford	R
	P. scaboratus Couper	C
	P. subscabratus Couper	Ab
	Tricolpites pachyexinus Couper	C
	T. sabulosus Dettmann & Playford	C

5630 feet (sidewall core)

As assemblage composed of the following reasonably well preserved spores and pollen grains was extracted from the sample:

Spores:	Baculatisporites comaumensis (Cookson)	R
	Camarozonosporites amplus (Stanley)	R
	C. bullatus Harris	R
	Cyathidites australis Couper	C
	C. minor Couper	C
	Gleicheniidites circinidites (Cookson)	C
	Lycopodiumsporites austroclavatidites (Cookson)	R
	Stereisporites antiquasporites (Wilson & Webster)	C
Pollen:	Nothofagidites senectus Dettmann & Playford	C
	Phyllocladidites mawsonii Cookson	C
	Podocarpidites ellipticus Cookson	Ab
	Proteacidites amolosexinus Dettmann & Playford	R
	P. scaboratus Couper	C
	P. subscabratus Couper	C
	Stephanoporopollenites obscurus Harris	R
	Tricolpites gillii Cookson	R
	T. pachyexinus Couper	C
	T. sabulosus Dettmann & Playford	C
Remanié:	Contignisporites sp. - Lower Cretaceous or Jurassic	
	Nuskoisporites sp. - Permian	

5773 feet (sidewall core)

A restricted microflora containing the following forms of spores and pollen grains was identified:

Spores:	Camarozonosporites amplus (Stanley)	R
	C. ohaiensis (Couper)	R
	Cyathidites australis Couper	C
	Densoisporites velatus Weyland & Krieger	R
	Laevigatosporites ovatus Wilson & Webster	Ab
	Lycopodiumsporites austroclavatidites (Cookson)	R
	Stereisporites antiquasporites (Wilson & Webster)	C

Pollen:	Microcachryidites antarcticus Cookson	Ab
	Nothofagidites senectus Dettmann & Playford	C
	Phyllocladidites mawsonii Cookson	C
	Podocarpidites ellipticus Cookson	C
	Proteacidites amolosexinus Dettmann & Playford	R
	P. scaboratus Couper	C
	P. subscabratus Couper	Ab
	Tricolpites pachyexinus Couper	C
	T. sabulosus Dettmann & Playford	C
Remanié:	Nuskoisporites sp. - Permian	

5885 feet (core 8)

The following fairly well preserved assemblage of spores, pollen, and microplankton was extracted from the sample:

Spores:	Camarozonosporites amplus (Stanley)	R
	Cyathidites australis Couper	C
	C. splendens Harris	R
	Gleicheniidites circinidites (Cookson)	C
	Stereisporites antiquasporites (Wilson & Webster)	C
Pollen:	Araucariacites australis Cookson	R
	Cycadopites nitidus (Balme)	R
	Microcachryidites antarcticus Cookson	Ab
	Nothofagidites senectus Dettmann & Playford	R
	Phyllocladidites mawsonii Cookson	C
	Podosporites microsaccatus (Couper)	R
	Proteacidites amolosexinus Dettmann & Playford	R
	P. subscabratus Couper	Ab
	Tricolpites gillii Cookson	R
	T. pachyexinus Couper	R
	T. spp.	C
	T. sabulosus Dettmann & Playford	C
Microplankton:	Nelsoniella aceras Cookson & Eisenack	R
	Xenikoon australis Cookson & Eisenack	R

5898 feet (core 8)

An abundant microflora containing the following species of spores, pollen grains, and microplankton was extracted from the sample:

Spores:	Camarozonosporites amplus (Stanley)	R
	C. bullatus Harris	R
	Ceratosporites sp.	R
	Clavifera triplex (Bolkhovitina)	R
	Cyathidites australis Couper	C
	C. minor Couper	C
	C. splendens Harris	R
	Lycopodiumsporites austroclavatidites (Cookson)	R
	Gleicheniidites circinidites (Cookson)	C
	Stereisporites antiquasporites (Wilson & Webster)	C
Pollen:	Araucariacites australis Cookson	R
	Dacrydiumites florinii Cookson & Pike	R
	Microcachryidites antarcticus Cookson	Ab
	Nothofagidites senectus Dettmann & Playford	R
	Phyllocladidites mawsonii Cookson	C
	Podosporites microsaccatus (Couper)	R
	Podocarpidites ellipticus Cookson	C
	Proteacidites amolosexinus Dettmann & Playford	R
	P. scaboratus Couper	C
	P. subscabratus Couper	Ab
	Stephanoporopollenites obscurus Harris	R
	Tricolpites pachyexinus Couper	C
	T. sabulosus Dettmann & Playford	R
	Triorites edwardsii Cookson & Pike	R
Microplankton:	Xenikoon australis Cookson & Eisenack	R

5971 feet (sidewall core)

The reasonably well preserved microflora contains rare microplankton together with common spores and pollen grains. Species identified include:

Spores:	*Baculatisporites comaumensis* (Cookson)	R
	Camarozonosporites amplus (Stanley)	R
	C. sp.	R
	Cyathidites australis Couper	C
	C. splendens Harris	R
	Gleicheniidites circinidites (Cookson)	C
	Lycopodiumsporites austroclavatidites (Cookson)	R
	Stereisporites antiquasporites (Wilson & Webster)	Ab
Pollen:	*Araucariacites australis* Cookson	R
	Microcachryidites antarcticus Cookson	C
	Nothofagidites senectus Dettmann & Playford	C
	Phyllocladidites mawsonii Cookson	C
	Proteacidites scaboratus Couper	C
	P. subscabratus Couper	Ab
	Tricolpites pachyexinus Couper	C
	T. sabulosus Dettmann & Playford	C
	T. sp.	R
Microplankton:	*Xenikoon australis* Cookson & Eisenack	R
Remanié:	*Aequitriradites spinulosus* (Cookson & Dettmann) - Lower Cretaceous	
	Nuskoisporites sp. - Permian	

6054 feet (sidewall core)

A sparse microflora containing the following species of spores and pollen grains was extracted from the sample:

Spores:	*Camarozonosporites amplus* (Stanley)	R
	C. sp.	R
	Cyathidites australis Couper	C
	C. minor Couper	C
	Gleicheniidites circinidites (Cookson)	C
	Laevigatosporites ovatus Wilson & Webster	Ab
	Stereisporites antiquasporites (Wilson & Webster)	C
Pollen:	*Araucariacites australis* Cookson	R
	Nothofagidites senectus Dettmann & Playford	R
	Phyllocladidites mawsonii Cookson	C
	Podocarpidites ellipticus Cookson	C
	Proteacidites scaboratus Couper	R
	P. subscabratus Couper	Ab
	Tricolpites pachyexinus Couper	R
	T. sabulosus Dettmann & Playford	R
	T. sp.	R

6131 feet (sidewall core)

The following species of spores, pollen grains, and microplankton were observed:

Spores:	*Cyathidites minor* Couper	C
	Camarozonosporites amplus (Stanley)	R
	Densoisporites velatus Weyland & Krieger	R
	Gleicheniidites circinidites (Cookson)	C
	Laevigatosporites ovatus Wilson & Webster	Ab
	Lycopodiumsporites austroclavatidites (Cookson)	R
	Stereisporites antiquasporites (Wilson & Webster)	Ab

Pollen:	Nothofagidites senectus Dettmann & Playford	R
	Phyllocladidites mawsonii Cookson	C
	Podocarpidites ellipticus Cookson	C
	Proteacidites scaboratus Couper	C
	P. subscabratus Couper	Ab
	Tricolpites gillii Cookson	R
	T. sabulosus Dettmann & Playford	R
	Triorites minor Couper	R
Microplankton:	Nelsoniella aceras Cookson & Eisenack	R
	Xenikoon australis Cookson & Eisenack	R

6277 feet (core 9)

The following species of spores, pollen, and microplankton were extracted from the sample:

Spores:	Baculatisporites comaumensis (Cookson)	R
	Cyathidites australis Couper	C
	C. minor Couper	R
	Stereisporites antiquasporites (Wilson & Webster)	Ab
Pollen:	Microcachryidites antarcticus Cookson	C
	Phyllocladidites mawsonii Cookson	C
	Podocarpidites ellipticus Cookson	R
	Proteacidites scaboratus Couper	C
	P. subscabratus Couper	C
	Tricolpites sabulosus Dettmann & Playford	C
Microplankton:	Xenikoon australis Cookson & Eisenack	R

6302 feet (core 9)

The reasonably well preserved microflora includes common spores and pollen grains and rare microplankton. Species identified include:

Spores:	Baculatisporites comaumensis (Cookson)	C
	Ceratosporites sp.	R
	Camarozonosporites amplus (Stanley)	R
	Cyathidites australis Couper	C
	Kraeuselisporites papillatus Harris	R
	Stereisporites antiquasporites (Wilson & Webster)	Ab
Pollen:	Microcachryidites antarcticus Cookson	Ab
	Phyllocladidites mawsonii Cookson	C
	Podosporites microsaccatus (Couper)	R
	Podocarpidites ellipticus Cookson	C
	Proteacidites amolosexinus Dettmann & Playford	R
	P. scaboratus Couper	C
	P. subscabratus Couper	C
	Tricolpites gillii Cookson	R
	T. pachyexinus Couper	C
	T. sabulosus Dettmann & Playford	R
Microplankton:	Xenikoon australis Cookson & Eisenack	R
Remanié:	Nuskoisporites sp. - Permian	

6482 feet (sidewall core)

The residue contains reasonably well preserved spores and pollen grains intermixed with a considerable amount of plant tissue. Microplankton are of rare occurrence. The following species were observed:

Spores:	Baculatisporites comaumensis (Cookson)	R
	Camarozonosporites amplus (Stanley)	R
	Ceratosporites sp.	R
	Cyathidites australis Couper	C
	C. minor Couper	Ab

	Gleicheniidites circinidites (Cookson)	C
	Laevigatosporites major (Cookson)	R
	L. ovatus Wilson & Webster	C
	Stereisporites antiquasporites (Wilson & Webster)	C
	S. viriosus Dettmann & Playford	R
Pollen:	Araucariacites australis Cookson	C
	Microcachryidites antarcticus Cookson	C
	Phyllocladidites mawsonii Cookson	R
	Podocarpidites ellipticus Cookson	Ab
	Proteacidites amolosexinus Dettmann & Playford	R
	P. scaboratus Couper	C
	P. subscabratus Couper	C
	Tricolpites pachyexinus Couper	R
	T. sabulosus Dettmann & Playford	C
	Stephanoporopollenites obscurus Harris	C
Microplankton:	Hystrichosphaeridium heteracanthum Deflandre & Cookson	R
	Nelsoniella aceras Cookson & Eisenack	R
	Xenikoon australis Cookson & Eisenack	R

6562 feet (sidewall core)

Abundant spores and pollen grains and rare microplankton were observed in the residue. Species identified include:

Spores:	Baculatisporites comaumensis (Cookson)	R
	Camarozonosporites amplus (Stanley)	R
	C. ohaiensis (Couper)	R
	Clavifera triplex (Bolkhovitina)	R
	Cyathidites australis Couper	C
	C. minor Couper	C
	Gleicheniidites circinidites (Cookson)	Ab
	Kraeuselisporites papillatus Harris	R
	Laevigatosporites major (Cookson)	R
	L. ovatus Wilson & Webster	C
	Lycopodiumsporites sp.	R
	Stereisporites antiquasporites (Wilson & Webster)	C
	S. viriosus Dettmann & Playford	R
Pollen:	Araucariacites australis Cookson	R
	Cycadopites nitidus (Balme)	R
	Microcachryidites antarcticus Cookson	Ab
	Nothofagidites senectus Dettmann & Playford	R
	Phyllocladidites mawsonii Cookson	C
	Podosporites microsaccatus (Couper)	R
	Podocarpidites ellipticus Cookson	Ab
	Proteacidites scaboratus Couper	C
	P. subscabratus Couper	C
	Stephanoporopollenites obscurus Harris	R
	Tricolpites gillii Cookson	R
	T. pachyexinus Couper	R
	T. sabulosus Dettmann & Playford	R
	T. spp.	R
Microplankton:	Nelsoniella aceras Cookson & Eisenack	R
	Odontochitina porifera Cookson	R
	Xenikoon australis Cookson & Eisenack	R
Remanié:	Dulhuntyispora sp. - Permian	

6680 feet (core 10)

The sample contains fairly common spores and pollen grains and rare microplankton. Forms present include:

Spores:	Baculatisporites comaumensis (Cookson)	R
	Cyathidites australis Couper	R
	C. minor Couper	C
	Stereisporites antiquasporites (Wilson & Webster)	Ab
Pollen:	Araucariacites australis Cookson	R
	Microcachryidites antarcticus Cookson	C
	Nothofagidites senectus Dettmann & Playford	R
	Proteacidites amolosexinus Dettmann & Playford	R
	P. scaboratus Couper	C
	P. subscabratus Couper	Ab
	Tricolpites pachyexinus Couper	C
	T. spp.	C
Microplankton:	Nelsoniella aceras Cookson & Eisenack	R
	Xenikoon australis Cookson & Eisenack	R

6684¾ feet (core 10)

Reasonable concentrations of spores, pollen grains, and microplankton were extracted from the sample. Species identified include:

Spores:	Baculatisporites comaumensis (Cookson)	R
	Camarozonosporites amplus (Stanley)	R
	Cyathidites australis Couper	R
	C. minor Couper	C
	Gleicheniidites circinidites (Cookson)	C
	Laevigatosporites ovatus Wilson & Webster	Ab
Pollen:	Araucariacites australis Cookson	R
	Nothofagidites senectus Dettmann & Playford	R
	Phyllocladidites mawsonii Cookson	C
	Podocarpidites ellipticus Cookson	C
	Proteacidites scaboratus Couper	R
	P. subscabratus Couper	C
	Tricolpites gillii Cookson	R
	T. pachyexinus Couper	C
	T. sabulosus Dettmann & Playford	R
Microplankton:	Hystrichosphaeridium heteracanthum Deflandre & Cookson	R
	Palambages Form A Manum & Cookson	R
	Xenikoon australis Cookson & Eisenack	C

6793 feet (sidewall core)

The reasonably well preserved microflora includes fairly common spores and pollen grains associated with rare microplankton. The following forms were observed:

Spores:	Ceratosporites sp.	R
	Cyathidites australis Couper	Ab
	C. minor Couper	C
	Kraeuselisporites papillatus Harris	R
	Laevigatosporites ovatus Wilson & Webster	C
	Stereisporites antiquasporites (Wilson & Webster)	C
	S. viriosus Dettmann & Playford	R
Pollen:	Araucariacites australis Cookson	C
	Microcachryidites antarcticus Cookson	Ab
	Nothofagidites senectus Dettmann & Playford	R
	Phyllocladidites mawsonii Cookson	C
	Podocarpidites ellipticus Cookson	Ab
	Proteacidites amolosexinus Dettmann & Playford	R

	P. scaboratus Couper	R
	P. subscabratus Couper	C
	Stephanoporopollenites obscurus Harris	C
	T. spp.	R
Microplankton:	Xenikoon australis Cookson & Eisenack	R

6917 feet (sidewall core)

Reasonably well preserved spores, pollen grains, and microplankton were extracted from the sample. Species identified include:

Spores:	Cyathidites australis Couper	Ab
	C. minor Couper	C
	Gleicheniidites circindites (Cookson)	Ab
	Stereisporites antiquasporites (Wilson & Webster)	C
Pollen:	Araucariacites australis Cookson	Ab
	Microcachryidites antarcticus Cookson	C
	Phyllocladidites mawsonii Cookson	C
	Podocarpidites ellipticus Cookson	Ab
	Proteacidites scaboratus Couper	R
	P. subscabratus Couper	C
	Stephanoporopollenites obscurus Harris	R
	Tricolpites pachyexinus Couper	C
	T. sabulosus Dettmann & Playford	R
	T. spp.	C
Microplankton:	Hystrichosphaeridium heteracanthum Deflandre & Cookson	R
	Nelsoniella aceras Cookson & Eisenack	R
	Xenikoon australis Cookson & Eisenack	R
Remanié:	Nuskoisporites sp. - Permian	

7099 feet (core 11)

The microflora extracted from the sample includes commonly occurring spores and pollen grains that exhibit fair to poor preservation, together with rare microplankton. The following types were observed:

Spores:	Camarozonosporites amplus (Stanley)	C
	Ceratosporites sp.	R
	Clavifera triplex (Bolkhovitina)	R
	Cyathidites australis Couper	C
	Gleicheniidites circinidites (Cookson)	Ab
	Laevigatosporites major (Cookson)	R
	L. ovatus Wilson & Webster	R
	Lycopodiumsporites sp.	R
	Stereisporites antiquasporites (Wilson & Webster)	C
Pollen:	Araucariacites australis Cookson	R
	Microcachryidites antarcticus Cookson	Ab
	Phyllocladidites mawsonii Cookson	C
	Podocarpidites ellipticus Cookson	C
	Proteacidites scaboratus Couper	R
	P. subscabratus Couper	C
	P.?amolosexinus Dettmann & Playford	R
	Stephanoporopollenites obscurus Harris	C
	Tricolpites pachyexinus Couper	R
	T.? sabulosus Dettmann & Playford	R
Microplankton:	Hystrichosphaeridium heteracanthum Deflandre & Cookson	R
Remanié:	Nuskoisporites sp. - Permian	

Microfloras present in samples between 4620 feet and 6917 feet are assigned to the uppermost Cretaceous (Santonian and later) Nothofagidites Microflora on the basis of their content of Nothofagidites senectus together with Tricolpites pachyexinus, T. lillei, T. sabulosus, Proteacidites amolosexinus, Ornamentifera sentosa, and Stereisporites viriosus. The microflora from 7099 feet is not certainly referred to the Nothofagidites Microflora since only doubtful specimens of the two diagnostic species, T. sabulosus and P. amolosexinus, were observed.

The Nothofagidites Microflora has been recorded from Pecten-1 well between 3908 feet and 5078 feet and from Nerita-1 well between 4245 feet and 4782 feet (Dettmann 1967a,c,d). In both these sequences and in Voluta-1 well, Triorites edwardsii and aff. T. edwardsii is restricted to the upper horizons (Pecten-1, down to 4493 feet; Nerita-1 well down to 4660 feet; and Voluta-1 well down to 5898 feet). Future subdivision of the Nothofagidites Microflora could be based upon the distribution of T. edwardsii and aff. T. edwardsii. Moreover; in all three well sequences record has been made of the earlier inception of Tricolpites sabulosus than Nothofagidites senectus; sediments containing T. sabulosus prior to the first appearance of N. senectus include Pecten-1 at 5078 feet, Nerita-1 at 4782 feet, and Voluta-1 at 6917 feet and (?) 7099 feet. The incoming of T. sabulosus prior to that of N. senectus may facilitate the distinction of a further biostratigraphic unit between the Tricolpites pachyexinus Zone and sediments containing the Nothofagidites Microflora.

Microplankton are associated with the Nothofagidites Microflora in Voluta-1 well between 4620 feet and 5086 feet and between 5885 feet and 7099 feet, but have not been observed in horizons between 5214 feet and 5773 feet. In the upper interval Deflandrea pellucida, Epicephalopyxsis indentata, and ?Trichodinium sp. are represented; D. pellucida occurs between 4620 feet and 4806 feet and the sediments are accordingly assigned to Evan's (1966) "Deflandrea pellucida" Zone. Horizons between 5885 feet and 6917 feet yielded the index of the Xenikoon australis Zone of Evans.

E. 7101 feet - 8901 feet

7101 feet (core 11)

Reasonably well preserved spores, pollen grains, and microplankton were recognized in the sample as follows:

Spores:	Camarozonosporites amplus (Stanley)	R
	Cyathidites australis Couper	C
	Gleicheniidites circinidites (Cookson)	C
	Kraeuselisporites papillatus Harris	R
	Laevigatosporites ovatus Wilson & Webster	Ab
	Lycopodiumsporites austroclavatidites (Cookson)	R
	Stereisporites antiquasporites (Wilson & Webster	C
	S. viriosus Dettmann & Playford	R
Pollen:	Microcachryidites antarcticus Cookson	C
	Phyllocladidites mawsonii Cookson	R
	Podocarpidites ellipticus Cookson	R
	Proteacidites scaboratus Couper	C
	P. subscabratus Couper	C
	Tricolpites pachyexinus Couper	C
	T. spp.	C
Microplankton:	Nelsoniella aceras Cookson & Eisenack	R
	Odontochitina porifera Cookson	R

7103 feet (core 11)

The reasonably well preserved microflora contains spores, pollen grains and rare microplankton.

Spores:	Cyathidites australis Couper	C
	C. minor Couper	C
	Gleicheniidites circinidites (Cookson)	C
	Kraeuselisporites papillatus Harris	R
	Laevigatosporites ovatus Wilson & Webster	C

	Lycopodiumsporites austroclavatidites (Cookson)	R
	Stereisporites antiquasporites (Wilson & Webster)	Ab
	S. viriosus Dettmann & Playford	R
Pollen:	Cycadopites nitidus (Balme)	R
	Microcachryidites antarcticus Cookson	Ab
	Phyllocladidites mawsonii Cookson	C
	Podocarpidites ellipticus Cookson	C
	Podosporites microsaccatus (Couper)	R
	Proteacidites scaboratus Couper	C
	P. subscabratus Couper	Ab
	Tricolpites pachyexinus Couper	C
Microplankton:	Hystrichosphaeridium heteracanthum Deflandre & Cookson	R
	Nelsoniella aceras Cookson & Eisenack	R
Remanié:	Nuskoisporites sp. - Permian	

7320 feet (sidewall core)

A sparse microflora containing the following spore, pollen, and microplankton species was extracted from the sample:

Spores:	Camarozonosporites amplus (Stanley)	R
	Ceratosporites sp.	R
	Cyathidites australis Couper	C
	C. minor Couper	Ab
	Gleicheniidites circinidites (Cookson)	C
	Stereisporites antiquasporites (Wilson & Webster)	C
Pollen:	Alisporites sp.	R
	Araucariacites australis Cookson	C
	Microcachryidites antarcticus Cookson	C
	Podocarpidites ellipticus Cookson	Ab
	Proteacidites subscabratus Couper	C
	Tricolpites pachyexinus Couper	R
Microplankton:	Hystrichosphaeridium heteracanthum Deflandre & Cookson	R
	Deflandrea cretacea Cookson	R

7598 feet (sidewall core)

The following forms of fairly preserved spores, pollen, and microplankton were observed:

Spores:	Cyathidites australis Couper	C
	C. minor Couper	Ab
	Laevigatosporites major (Cookson)	R
	L. ovatus Wilson & Webster	Ab
	Stereisporites antiquasporites (Wilson & Webster)	C
Pollen:	Araucariacites australis Cookson	C
	Microcachryidites antarcticus Cookson	Ab
	Phyllocladidites mawsonii Cookson	R
	Proteacidites scaboratus Couper	C
	P. subscabratus Couper	C
	Tricolpites pachyexinus Couper	C
	Triorites minor Couper	R
Microplankton:	Hystrichosphaeridium heteracanthum Deflandre & Cookson	C

7598 feet (core 12)

Spores, pollen, and microplankton identified include:

Spores:	Camarozonosporites amplus (Stanley)	R
	Cyathidites australis Couper	C
	C. minor Couper	C
	Gleicheniidites circinidites (Cookson)	C
	Laevigatosporites ovatus Wilson & Webster	C
	Stereisporites antiquasporites (Wilson & Webster)	C

Pollen:	Araucariacites australis Cookson	R
	Microcachryidites antarcticus Cookson	Ab
	Phyllocladidites mawsonii Cookson	R
	Podocarpidites ellipticus Cookson	C
	Podosporites microsaccatus (Couper)	C
	Proteacidites scaboratus Couper	R
	P. subscabratus Couper	Ab
	Stephanoporopollenites obscurus Harris	R
	Tricolpites pachyexinus Couper	C
Microplankton:	Deflandrea cretacea Cookson	C
	Hystrichosphaeridium heteracanthum Deflandre & Cookson	C

7612 feet (core 12)

The sparse microflora includes the following forms of spores, pollen, and microplankton:

Spores:	Camarozonosporites amplus (Stanley)	R
	Cyathidites minor Couper	C
	Gleicheniidites circinidites (Cookson)	C
	Laevigatosporites major (Cookson)	R
	L. ovatus Wilson & Webster	Ab
	Stereisporites antiquasporites (Wilson & Webster)	Ab
Pollen:	Araucariacites australis Cookson	R
	Microcachryidites antarcticus Cookson	C
	Proteacidites scaboratus Couper	R
	Tricolpites pachyexinus Couper	R
Microplankton:	Hystrichosphaeridium heteracanthum Deflandre & Cookson	R
Remanié:	Nuskoisporites sp. - Permian	

7755 feet (sidewall core)

Reasonably preserved spores, pollen grains and microplankton were extracted from the sample. Forms identified include:

Spores:	Balmeisporites glenelgensis Cookson & Dettmann	R
	Camarozonosporites amplus (Stanley)	R
	Ceratosporites sp.	R
	Cyathidites australis Couper	C
	C. minor Couper	C
	Gleicheniidites circinidites (Cookson)	Ab
	Laevigatosporites ovatus Wilson & Webster	C
	Cicatricosisporites sp.	R
	Stereisporites antiquasporites (Wilson & Webster)	C
Pollen:	Araucariacites australis Cookson	C
	Microcachryidites antarcticus Cookson	Ab
	Podocarpidites ellipticus Cookson	C
	Podosporites microsaccatus (Couper)	R
	Phyllocladidites mawsonii Cookson	R
	Proteacidites subscabratus Couper	C
	Stephanoporopollenites obscurus Harris	R
	Tricolpites sp.	R
Microplankton:	Gymnodinium nelsonense Cookson	R
	Hexagonifera vermiculata Cookson & Eisenack	R
	Hystrichosphaeridium heteracanthum Deflandre & Cookson	R

7971 feet (sidewall core)

The sediment yielded the following species of reasonably preserved spores, pollen, and microplankton:

Spores:	Baculatisporites comaumensis (Cookson)	R
	Cyathidites australis Couper	C
	C. minor Couper	C
	Gleicheniidites circinidites (Cookson)	Ab

	Stereisporites antiquasporites (Wilson & Webster)	C
Pollen:	Araucariacites australis Cookson	C
	Microcachryidites antarcticus Cookson	Ab
	Podocarpidites ellipticus Cookson	C
	Podosporites microsaccatus (Couper)	R
	Phyllocladidites mawsonii Cookson	C
	Proteacidites scaboratus Couper	R
	P. subscabratus Couper	C
	Stephanoporopollenites obscurus Harris	C
	Tricolpites pachyexinus Couper	R
	T. spp.	R
Microplankton:	Hexagonifera vermiculata Cookson & Eisenack	C
	H. glabra Cookson & Eisenack	C
	Hystrichosphaeridium heteracanthum Deflandre & Cookson	C
	Odontochitina striatoperforata Cookson & Eisenack	R

8085 feet (core 13)

Reasonably preserved plant microfossils include the following species of spores, pollen grains, and microplankton:

Spores:	Baculatisporites comaumensis (Cookson)	C
	Camarozonosporites amplus (Stanley)	C
	Clavifera triplex (Bolkhovitina)	R
	Cicatricosisporites sp.	R
	Cyathidites australis Couper	C
	C. minor Couper	C
	Gleicheniidites circinidites (Cookson)	C
	Laevigatosporites major (Cookson)	R
	L. ovatus Wilson & Webster	C
	Stereisporites antiquasporites (Wilson & Webster)	C
Pollen:	Araucariacites australis Cookson	R
	Microcachryidites antarcticus Cookson	Ab
	Phyllocladidites mawsonii Cookson	C
	Podocarpidites ellipticus Cookson	C
	Proteacidites scaboratus Couper	R
	P. subscabratus Couper	Ab
	Triorites minor Couper	R
Microplankton:	Deflandrea cretacea Cookson	R
	Hystrichosphaeridium heteracanthum Deflandre & Cookson	C
	Odontochitina porifera Cookson & Eisenack	R
	O. sp.	R

8224 feet (sidewall core)

The assemblage preserved in the sample contains the following spore, pollen, and microplankton types:

Spores:	Clavifera triplex (Bolkhovitina)	R
	Cyathidites minor Couper	C
	Gleicheniidites circinidites (Cookson)	Ab
	Laevigatosporites major (Cookson)	R
	Lycopodiumsporites sp.	R
	Stereisporites antiquasporites (Wilson & Webster)	C
Pollen:	Araucariacites australis Cookson	C
	Microcachryidites antarcticus Cookson	Ab
	Phyllocladidites mawsonii Cookson	R
	Podocarpidites ellipticus Cookson	C
	Proteacidites scaboratus Couper	R
	P. subscabratus Couper	C
	Stephanoporopollenites obscurus Harris	C
	Tricolpites pachyexinus Couper	R
	T. spp.	C
Microplankton:	Deflandrea cretacea Cookson	R
	Hystrichosphaeridium heteracanthum Deflandre & Cookson	R
	Odontochitina sp.	R

8387 feet (sidewall core)

The following species of fairly preserved spores, pollen, and microplankton were identified:

Spores:	Cyathidites australis Couper	R
	C. minor Couper	C
	C. cf. splendens Harris	R
	Cicatricosisporites sp.	R
	Gleicheniidites circinidites (Cookson)	C
	Lycopodiumsporites sp.	R
	Stereisporites antiquasporites (Wilson & Webster)	Ab
Pollen:	Microcachryidites antarcticus Cookson	Ab
	Phyllocladidites mawsonii Cookson	R
	Podocarpidites ellipticus Cookson	C
	Proteacidites subscabratus Couper	C
	P. scaboratus Couper	R
	Tricolpites pachyexinus Couper	R
	T. spp.	R
Microplankton:	Hystrichosphaeridium heteracanthum Deflandre & Cookson	R
	Odontochitina sp.	R
Remanié:	Nuskoisporites sp. - Permian	

8438 feet (sidewall core)

Fairly preserved spores, pollen, and microplankton are preserved in the sample. The following forms were identified:

Spores:	Camarozonosporites sp.	R
	Cyathidites australis Couper	R
	C. minor Couper	C
	Baculatisporites comaumensis (Cookson)	R
	Gleicheniidites circinidites (Cookson)	C
	Stereisporites antiquasporites (Wilson & Webster)	Ab
Pollen:	Araucariacites australis Cookson	C
	Microcachryidites antarcticus Cookson	Ab
	Phyllocladidites mawsonii Cookson	R
	Podocarpidites ellipticus Cookson	C
	Proteacidites scaboratus Couper	R
	P. subscabratus Couper	R
	Tricolpites sp.	R
Microplankton:	Hexagonifera vermiculata Cookson & Eisenack	C
	Hystrichosphaeridium heteracanthum Deflandre & Cookson	C
	Odontochitina porifera Cookson	R

8617 feet (core 14)

Fairly preserved spores, pollen grains and microplankton constitute the following diverse assemblage:

Spores:	Baculatisporites comaumensis (Cookson)	R
	Cicatricosisporites sp.	R
	Cyathidites australis Couper	C
	C. minor Couper	C
	Gleicheniidites circinidites (Cookson)	Ab
	Lycopodiumsporites sp.	R
	Stereisporites antiquasporites (Wilson & Webster)	C
Pollen:	Araucariacites australis Cookson	C
	Phyllocladidites mawsonii Cookson	C
	Podocarpidites ellipticus Cookson	Ab
	Proteacidites scaboratus Couper	R
	P. subscabratus Couper	C
	Stephanoporopollenites obscurus Harris	R
	Tricolpites pachyexinus Couper	R
	T. spp.	R
	Triorites minor Couper	R
Microplankton:	Hexagonifera ?vermiculata Cookson & Eisenack	R
	H. glabra Cookson & Eisenack	R
	Hystrichosphaeridium heteracanthum Deflandre & Cookson	C
	Odontochitina porifera Cookson	R

8623 feet (sidewall core)

The sample yielded a restricted microflora containing the following forms of fair to poorly preserved spores, pollen, and microplankton:

Spores:	Clavifera triplex (Bolkhovitina)	R
	Cyathidites minor Couper	C
	Gleicheniidites circinidites (Cookson)	Ab
	Stereisporites antiquasporites (Wilson & Webster)	C
Pollen:	Microcachryidites antarcticus Cookson	Ab
	Phyllocladidites mawsonii Cookson	R
	Podocarpidites ellipticus Cookson	Ab
	Podosporites microsaccatus (Couper)	R
	Proteacidites subscabratus Couper	C
	Tricolpites pachyexinus Couper	R
	T. spp.	C
Microplankton:	Hystrichosphaeridium heteracanthum Deflandre & Cookson	R

8768 feet (core 15)

Poor concentrations of generally poorly preserved spores, pollen grains and microplankton were observed in the residue:

Spores:	Baculatisporites comaumensis (Cookson)	R
	Camarozonosporites amplus (Stanley)	R
	Cyathidites australis Couper	Ab
	C. minor Couper	C
	Gleicheniidites circinidites (Cookson)	C
	Kraeuselisporites papillatus Harris	R
	Laevigatosporites ovatus Wilson & Webster	C
	Stereisporites antiquasporites (Wilson & Webster)	C
Pollen:	Araucariacites australis Cookson	C
	Microcachryidites antarcticus Cookson	Ab
	Phyllocladidites mawsonii Cookson	C
	Podocarpidites ellipticus Cookson	C
	Podosporites microsaccatus (Couper)	R
	Proteacidites subscabratus Couper	C
	Tricolpites cf. pannosus Dettmann & Playford	R
Microplankton:	Deflandrea victoriensis Cookson & Manum	R
	Hystrichosphaeridium heteracanthum Deflandre & Cookson	C

8779 feet (sidewall core)

The following species of fair to poorly preserved spores, pollen and microplankton were observed in the residue:

Spores:	Camarozonosporites sp.	R
	Clavifera triplex (Bolkhovitina)	C
	Cyathidites australis Couper	C
	C. minor Couper	Ab
	Baculatisporites comaumensis (Cookson)	R
	Gleicheniidites circinidites (Cookson)	C
	Stereisporites antiquasporites (Wilson & Webster)	C
Pollen:	Araucariacites australis Cookson	C
	Microcachryidites antarcticus Cookson	Ab
	Phyllocladidites mawsonii Cookson	R
	Podocarpidites ellipticus Cookson	R
	Podosporites microsaccatus (Couper)	R
	Proteacidites scaboratus Couper	R
	P. subscabratus Couper	C
	Tricolpites pachyexinus Couper	R
	T. spp.	R
Microplankton:	Hystrichosphaeridium heteracanthum Deflandre & Cookson	R

8901 feet (sidewall core)

Fair to poorly preserved spores, pollen grains, and microplankton were recovered from the sample. Species identified include:

Spores:	Cyathidites australis Couper	Ab
	C. minor Couper	C
	Gleicheniidites circinidites (Cookson)	C
	Laevigatosporites ovatus Wilson & Webster	C
	Stereisporites antiquasporites (Wilson & Webster)	C
Pollen:	Araucariacites australis Cookson	C
	Microcachryidites antarcticus Cookson	Ab
	Podocarpidites ellipticus Cookson	C
	Proteacidites scaboratus Couper	R
	Stephanoporopollenites obscurus Harris	R
	Tricolpites pachyexinus Couper	R
	T. spp.	R
	Triorites minor Couper	R
Microplankton:	Hystrichosphaeridium heteracanthum Deflandre & Cookson	R

The spore-pollen suites obtained from sediments between 7101 feet and 8901 feet contain Tricolpites pachyexinus with Proteacidites scaboratus and Camarozonosporites amplus and lack species diagnostic of the Nothofagidites Microflora. The sediments are accordingly assigned to the Santonian Tricolpites pachyexinus Zone. This zone is represented in Pecten-1 well between 5182 feet and 5650 feet (Dettmann 1967d).

Microplankton occur throughout the T. pachyexinus Zone in Voluta-1 well. In the lower horizons (8779 - 8901 feet) Hystrichosphaeridium heteracanthum, a long ranging species within the Upper Cretaceous, was observed. Deflandrea cretacea occurs at and above 8224 feet and Nelsoniella aceras at 7101 - 03 feet; The presence of these species indicates the representation of both the D. cretacea and N. aceras Zones in Voluta-1 well. However, the precise limits of these zones in the Voluta sequence is difficult to determine. Using Evan's (1966) criteria the D. cretacea Zone would embrace sediments between the first appearances of D. cretacea and N. aceras, i.e. between 7320 feet and 8224 feet. However, a downward extension of the zone to 8617 feet is testified by the presence of Hexagonifera glabra at this level.

Nelsoniella aceras first occurs at 7103 feet, thus implying that the horizon represents the base of the N. aceras Zone; however a possible extension of the zone to 7755 feet is suggested by the last appearances at this horizon of Hexagonifera vermiculata. This species is considered by Evans (1966) to range throughout the D. cretacea Zone into the base of the N. aceras Zone. On the basis of this evidence, the N. aceras Zone is tentatively suggested to occur between 7101 feet and 7755 feet, and the D. cretacea Zone between 7971 feet and 8617 feet.

F. 9962½ feet - 11,989 5/6 feet

9962½ feet (core 16)

Poorly preserved spores, pollen grains, and microplankton were extracted from the sample in low concentrations. The following forms were identified:

Spores:	Baculatisporites comaumensis (Cookson)	R
	Clavifera triplex (Bolkhovitina)	R
	Cyathidites australis Couper	Ab
	C. minor Couper	Ab
	Gleicheniidites circinidites (Cookson)	C
	Laevigatosporites ovatus Wilson & Webster	R
	Stereisporites antiquasporites (Wilson & Webster)	C

Pollen:	*Amosopollis cruciformis* Cookson & Balme	R
	Araucariacites australis Cookson	C
	Phyllocladidites mawsonii Cookson	R
	Podocarpidites ellipticus Cookson	C
	Proteacidites subscabratus Couper	C
	Tricolpites spp.	C
Microplankton:	*Hystrichosphaeridium heteracanthum* Deflandre & Cookson	R

10,472 5/6 feet (core 17)

The following poorly preserved forms of spores, pollen, and microplankton were observed in the residue:

Spores:	*Baculatisporites comaumensis* (Cookson)	R
	Clavifera triplex (Bolkhovitina)	C
	Cyathidites minor Couper	Ab
	Gleicheniidites circinidites (Cookson)	C
	Kraeuselisporites ?jubatus Dettmann & Playford	R
	Rouseisporites sp.	R
	Stereisporites antiquasporites (Wilson & Webster)	C
Pollen:	*Amosopollis cruciformis* Cookson & Balme	R
	Araucariacites australis Cookson	C
	Microcachryidites antarcticus Cookson	Ab
	?Phyllocladidites mawsonii Cookson	R
	Proteacidites subscabratus Couper	C
	Stephanoporopollenites obscurus Harris	R
Microplankton:	*Hystrichosphaeridium* cf. *complex* (White)	R
	H. heteracanthum Deflandre & Cookson	R

10,904¾ feet (core 18)

The poorly preserved and fragmented forms of spores, pollen grains, and microplankton preserved in the sediment include:

Spores:	*Cicatricosisporites* sp. indet.
	Cyathidites australis Couper
	C. minor Couper
	Gleicheniidites circinidites (Cookson)
	Stereisporites antiquasporites (Wilson & Webster)
Pollen:	*Alisporites* sp. indet.
	Araucariacites australis Cookson
	Microcachryidites antarcticus Cookson
	Phyllocladidites mawsonii Cookson
	Tricolpites spp. indet.
Microplankton:	*Hystrichosphaeridium* cf. *complex* (White)
	H. heteracanthum Deflandre & Cookson

11,512½ feet (core 20)

The sample yielded abundant fragmented plant microfossils. The following types were identified:

Spores:	*Cyathidites australis* Couper
	C. minor Couper
	Gleicheniidites circinidites (Cookson)
	Rouseisporites sp. indet
	Stereisporites antiquasporites (Wilson & Webster)
Pollen:	*Amosopollis cruciformis* Cookson & Balme
	Araucariacites australis Cookson
	Podocarpidites sp. indet
	Tricolpites sp. indet.
Microplankton:	*Hystrichosphaeridium* cf. complex (White)
	H. heteracanthum Deflandre & Cookson

11,989 5/6 feet (core 21)

A high yield of fragmented spores, pollen grains, and microplankton was obtained from the sample. Types represented include:

Spores:	Baculatisporites comaumensis (Cookson)
	Balmeisporites ?glenelgensis Cookson & Dettmann
	Clavifera triplex (Bolkhovitina)
	Cicatricosisporites sp. indet
	Gleicheniidites circinidites (Cookson)
	Klukisporites ?scaberis Cookson & Dettmann
Pollen:	Alisporites sp. indet
	Araucariacites australis Cookson
	Cycadopites sp.
	Microcachryidites antarcticus Cookson
	Tricolpites spp. indet
Microplankton:	Baltisphaeridium sp.
	Odontochitina ?operculata (Wetzel)

Plant microfossils extracted from sediments between 9962½ feet and 11,989 5/6 feet are poorly preserved and fragmented, especially in the lower portion of the section. Because the majority of fossils present in samples at and below 10,904¾ feet are unidentifiable at generic or specific level, quantative estimates have not been given in the microfloral lists. Species identified in the sediments include Clavifera triplex, Stephanoporopollenites obscurus, Phyllocladidites mawsonii, and Amosopollis cruciformis. The presence of these forms and the apparent absence of diagnostic species of the Tricolpites pachyexinus Zone suggest that the sediments may be referred to the Turonian - ?Coniacian Clavifera triplex Zone. This zone is represented in Pecten-1 well at 5735 feet (Detmmann 1967d).

Microplankton were observed in all samples and the presence at 11,989 5/6 feet of possible representatives of Odontochitina operculata is of some significance. This species is, in its last occurrences, an associate of the nominate species of Evans's (1966) Ascodinium parvum Zone. As outlined by Dettmann and Playford (1968), the uppermost horizons of the A. parvum Zone correspond to the basal part of the C. triplex Zone.

G. 12,634 feet - 13,020 feet

12,634 feet (junk basket sample)

The sample yielded much carbonaceous material including extremely badly preserved and fragmented spore-pollen exines, most of which are unidentifiable at generic level. Generic groups represented include Cyathidites, Cicatricosisporites, and Stereisporites. In addition some well preserved examples of Xenikoon australis, Nothofagidites senectus, and Tricolpites sabulosus were observed; these species are obviously contaminants from higher horizons.

12,767 feet (junk basket sample)

The sample also yielded very badly preserved spore-pollen forms. Taxa identified include Cyathidites, Appendicisporites, and Cicatricosisporites.

13,010-20 feet (cuttings)

Carbonaceous matter was extracted from the sample and spore-pollen fragments observed. However, none was sufficiently well preserved for identification.

CONCLUSIONS

Sediments between 4151 feet and 11,989 5/6 feet in Voluta-1 well range in age from Upper Paleocene to Turonian on the basis of their spore-pollen content. The Paleocene sequence extends from 4151 feet to 4370 feet, and includes the Upper Paleocene Duplopollis orthoteichus Assemblage Zone (4151 feet) and the Middle Paleocene Triorites edwardsii Assemblage Zone (4267 - 4370 feet). Spore-pollen suites suggestive of an early Tertiary - late Cretaceous age occur between 4566 feet and 4587 feet. The Upper Cretaceous (Santonian and later) Nothofagidites Microflora occurs in sediments between 4620 feet and 6917 feet and is probably represented in the horizon at 7099 feet. Underlying horizons between 7101 feet and 8901 feet are referred to the Santonian Tricolpites pachyexinus Zone, and those between 9962½ feet and 11,989 5/6 feet are probably representatives of the Clavifera triplex Zone (Turonian - ?Coniacian). The lowest horizons investigated (between 12,634 feet and 13,020 feet) yielded extremely badly preserved microfloras that provide insufficient basis for age determination.

Microplankton occur throughout much of the sequence and support the age determinations based upon spore-pollen taxa. Species associated with the Triorites edwardsii Assemblage Zone in Voluta-1 well occur within or immediately above the zone at its "type" locality (Pebble Point Formation and Rivernook Member). Several microplankton suites were recognized within the Upper Cretaceous section of Voluta-1 well. The youngest suite contains forms diagnostic of Evan's (1966) "Deflandrea pellucida" Zone and is associated with the youngest occurrences (between 4620 and 4806 feet) of the Nothofagidites Microflora. No diagnostic species were observed between 4878 feet and 5086 feet and the section between 5214 feet and 5773 feet lacked microplankton. Sediments within the interval 5885 - 6917 feet yielded forms indicative of the Xenikoon australis Zone of Evans (1966) together with the initial appearances of the Nothofagidites Microflora. Two microplankton zones were recognized within the Tircolpites pachyexinus Zone. The Nelsoniella aceras Zone of Evans (1966) is represented at 7101-03 feet and probably extends to 7755 feet; Evans's Deflandrea cretacea Zone seems to occupy most of the remaining (lower) portion of the T. pachyexinus Zone. The section referred to the Clavifera triplex Zone contains Upper Cretaceous microplankton assemblages; the one identified at 11,989 5/6 feet includes a form known from Evans's Ascodinium parvum Zone.

Recycled plant microfossils of Permian age occur in minor proportions throughout the Voluta sequence. In addition Lower Cretaceous spores were encountered in horizons at 4370 feet, 5630 feet, and 5971 feet.

The plant material extracted from the Paleocene sequence shows exceptional preservation and that enclosed in Upper Cretaceous sediments containing the Nothofagidites Microflora is generally well preserved. The horizon at 7099 feet yielded only fair or poorly preserved plant microfossils, but the underlying section between 7103 feet and 7971 feet contained reasonably well preserved plant material. The preservation quality of plant microfossils in in sediments between 8085 feet and 13,020 feet ranged from fair in the upper horizons to extremely bad and fragmented in the lowest intervals.

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18th March, 1968.

Mary E. Dettmann,
Department of Geology,
University of Queensland,
St. Lucia, Queensland.

VOLUTA-1 WELL VELOCITY SURVEY

by

Geophysical Department

Shell Development (Australia) Pty. Ltd.

CONTENTS

ATTACHMENTS

ENCLOSURES (numbers refer to Enclosures of the Voluta-1 well completion report).

1. INTRODUCTION

On the 16th October, 1967 a velocity survey was carried out by Western Geophysical Company between 1,500 ft. and 6,280 ft. in the Voluta No. 1 well. The velocity survey was carried out over this interval prior to casing as it is the one in which the most seismic horizons are observed. Furthermore the explosive restrictions imposed by SEDCO may have prevented reliable observations being made deeper in the hole. Extrapolation of these results using the sonic log will be fully adequate for seismic stacking and other purposes. The restrictions on the amount of explosives that could be used at specific distances from the pontoon footings were, as in the Nerita-1 well: a maximum of 2 lbs. at 1000 ft., 10 lbs. at 1500 ft. and 40 lbs. at 2000 ft.

These restrictions did not prevent the recording of good breaks by the well and reference geophones.

2. OPERATIONS

Although the sea was quite calm a T bar, resting on the top of the marine riser, was used for anchoring the well geophone and thus reducing noise from rig movement. Position of the reference buoys was determined by using 5 lbs. charges and measuring the time between the shotbreak and the break at the reference geophone at the well location. The positions of the individual shots were similarly determined.

The shooting position with respect to the rig is indicated in Enclosure 8.

Readings were taken for well geophone depths at 1500 ft., 2700 ft., 3500 ft., 4300 ft., 5350 ft., 6280 ft. below derrick floor. Moving back up the hole repeat shots were made at the 5350 ft., 4300 ft., and 3500 ft. levels.

3. RESULTS OF SURVEY

Good results were obtained from all nine shots. The shotbreak at Shot No. 5 was not clear but could be traced back from breaks at the reference and well geophone.

The resultant time-depth and velocity-depth graphs are shown in Enclosure 19 together with the plot of the sonic data. The sonic log was tied to the well shoot at 4300 ft.

The times from the geophone at 2700 ft. and 3500 ft. are somewhat smaller than the corresponding times from the integrated sonic log. This might be due to the fact that part of the travelpath from shot to well geophone was along the casing, which was set to a depth of 2625 ft. So the sonic plot is considered to be more reliable at this level. From 1600 ft. to 2300 ft. below sea level a high interval velocity of 13,350 ft./sec. is indicated. This high velocity layer corresponds with the limestone-dolomite section, which was encountered in the well over this interval. The high interval velocity at this depth was not observed in the refraction-profile, which was shot previously in the area. From 4,000 ft. downwards the Cape Bridgewater refraction probe corresponds very well with the results of the sonic log and the well shoot.

Unfortunately the tool of the sonic log stuck in the well at 12,250 ft. B.S.L. and no results are available below this depth. Thus the change in velocity, shown by the refraction probe at 12,750 ft. B.S.L. could not be checked by the sonic log. At the depth of the last reading the interval velocity is 12,500 ft./sec.

4. CONCLUSIONS

In spite of the restrictions on the amount of explosives good results were obtained in this well velocity survey and satisfactory calibration points for the sonic logs were provided.

Velocity profile 5, which was used in the seismic interpretation, shows too high velocities below 4,700 ft. The predicted depths of the different seismic horizons at the location of Voluta-1 (S.P.292 of line OD - 66 - 8) using velocity profile 5 compare to the actual depths as follows:

Horizon		V.P. 5	Based on results of Velocity Surveys
A1	620ms	2220 ft.	2460 ft.
B	1035ms (base Wangerrip group)	4320 ft.	4200 ft.
G	1230ms	5540 ft.	5160 ft.

ATTACHMENT A

PERSONNEL AND STATISTICS

Shell Geophysicists	J.R. Ley
	J.M. Oosterbaan
Western operator	B. Potter
Western shooter	D. Sutcliffe
Interval surveyed	1500 ft. - 6280 ft. B.D.F.
No. of horizons surveyed	6
No. of shots	13
Time of first shot	09.25
Time of last shot	13.50
Total explosives used	356 lbs.
Minimum charge size	1 lb.
Maximum charge size	40 lbs.
Depth of shot below sea level	5 ft.

ATTACHMENT B

INSTRUMENT SPECIFICATIONS

One GCE - 101 Pressure Sensitive Well Geophone

One S.I.E. P - 11 Amplifier (12 channels) with input switching unit.
Test Oscillator and Power Supply.

Two Battery Type 300 volt Blasters.

Three Kaar TR 327 Radios (C.B. Type)

Two RC - 5 Remote Control Units for Shooters Radio.

Two RA -12 Amplifier Units for Radio Time Break Recording.

Two PS - 2 Pressure Sensitive Hydrophones (Reference)

Portable Camera (12 trace)

Portable Developing System.