W1013

WCR VOL 2

SHARK-1 W1013

SHELL AUSTRALIA E. & P. OIL AND GAS

SDA 937

SHARK-1 CONFIDENTIAL

WELL COMPLETION REPORT

GIPPSLAND BASIN 06 APR 1990

VIC/P22

PETROLEUM DIVISION

VOLUME 2

INTERPRETATIVE DATA

SOUTHERN TEAM/PETROLEUM
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1. INTRODUCTION

Gippsland Basin Permit VIC/P22 was awarded to a consortium of Shell (45%, operator), Ampol Exploration (30%) and Santos Limited (25%) on the 25 July, 1987, for a period of six years. Shark-1 fulfilled the Year 2 drilling commitment. Shark-1 was located at S.P. 450 on seismic line GS88B-100 in 319.6m of water. All depths are quoted in metres below derrick floor, unless otherwise stated.

Shark-1 is situated basinward of the Rosedale Fault (Fig. 1) in a similar mega-tectonic setting to the Kipper discovery in adjacent VIC/P19. The primary objective of Shark-1 was to test alluvial sandstones in a downthrown fault trap at top and intra-Golden Beach Group levels. Top seal was expected to be provided by weathered volcanic rocks. Secondary targets were anticipated in lower coastal plain sands in the lower Latrobe Group (SDA 903).

2. REGIONAL GEOLOGY

The stratigraphy of the offshore Gippsland Basin is summarised in Figure 2.

The Early Cretaceous Strzelecki Group represents the initial rift infill sequence, and its deposition can be correlated with the onset of the development of the Southern Australian rift system. The Group consists of non-marine greywackes, shales and minor coals, and is regarded as economic basement.

The Cenomanian to Late Campanian Golden Beach Group overlies Strzelecki Group sediments with an angular unconformity (marking the onset of opening of the Southern Ocean), and represents a second phase of rift infill, associated with the development of the Tasman Sea rift. Where penetrated, sediments comprise dominantly immature non-marine sandstones, siltstone, shales and minor coals deposited in alluvial fan, braided stream, lacustrine and upper coastal plain environments. Basaltic volcanics are both stratigraphically and areally widespread. Continued subsidence, though with much-reduced extension, resulted in growth on earlier faults during deposition of the Golden Beach Group. This was followed by a pronounced phase of tectonism and associated volcanism during the Campanian, which produced the major throws now seen on intra-Golden Beach Group faults. This "Intra-Campanian Unconformity" can be correlated with the onset of drift in the Tasman Sea (ca. 76 MA BP), and marks the cessation of Golden Beach Group deposition.

From Late Campanian to Late Eocene the Latrobe Group was deposited as a non-marine to coastal sequence of sandstones, siltstones, shales and extensive coals under the progressive influence of the opening Tasman Sea. As marine conditions encroached from southeast to northwest, a diachronous succession of laterally equivalent sedimentary facies was deposited comprising alluvial, upper coastal plain, lower coastal plain, estuarine, back barrier/lagoonal, coastal barrier, shoreface and offshore marine deposits. Slow subsidence characterised Latrobe Group deposition with continued movement on earlier faults. The major basin-bounding faults continued to exert a major influence of sedimentary patterns. Early to Late Eocene tectonic uplift of the northeastern part of the basin, in association with a series of sea level falls, led to submarine channelling of the Top Latrobe surface. Late Eocene deposition is recorded by a thin condensed glauconitic sandy siltstone sequence known as the Gurnard Formation, which marks the top of the Latrobe Group.

Convergent wrenching due to Southern Ocean spreading, and strike slip movement along Tasman Sea fracture zones occurred during the later part of Latrobe Group deposition. In the Late Eocene, this phase of activity terminated Latrobe Group deposition in the offshore basin and was responsible for strike slip and reverse reactivation of many earlier normal faults and the formation/enhancement of the major anticlinal features in the basin. Thermal subsidence from the Oligocene to Recent resulted in the deposition to calcareous siltstones and marls of the Lakes Entrance Formation overlain by a marine, eastwards prograding sequence of bryozoan limestones and marls of the Gippsland Limestone.

3. STRATIGRAPHY

The stratigraphic sequence in Shark-1 is summarised in Figure 3 and Enclosure 1. Formation tops and ages are based on lithological, palynological (Appendix 1) and palaeontological (Appendix 2) data from cuttings and sidewall samples, together with wireline log characteristics. All depths are quoted in metres below derrick floor.

3.1 Gippsland Limestone (SEGL): 347-1526m. (1179m)

The Gippsland Limestone consists of interbedded calcilutite, calcisiltite and marl. The calcilutite and calcisiltites are light grey and argillaceous, with traces of pyrite, glauconite and carbonaceous material. These lithological units contain locally abundant fossils, predominantly foraminifera, echinoderms, and rare mollusc fragments. Marl occurs as interbeds throughout the interval and increases in abundance with depth. The marl is light grey to greenish-grey, with traces of pyrite, glauconite, carbonaceous material, fossils (foraminifera and echinoderms), and is soft and sticky.

The carbonate depositional environment appears to have been upper continental slope to shelf edge, with continual shallowing of water depth from approximately 300-400m to 100-200m.

3.2 Lakes Entrance Formation (SELE): 1526-1816m (290m)

The Lakes Entrance formation can be divided into two lithologic units: an upper, dominantly marly sequence and a lower claystone sequence. The marl (1526-1723m) is light grey to white, with traces of glauconite, pyrite, carbonaceous detritus and fossil fragments. It is locally sticky/gummy to dispersive and interbedded with calcareous claystone and calcisiltite. From 1723-1816m the formation consists predominantly of calcareous claystone, which is light grey to light brown, with traces of pyrite, lithic fragments and fossils.

Foraminiferal assemblages indicate that the upper Lakes Entrance marly sequence was deposited in a middle to outer neritic environment (approximately 200 - 300m water depth) whilst the lower section was deposited in an outer neritic to upper bathyal environment (water depths of 200 - 400m).

3.3 Latrobe Group (LA): 1816-2310m (494m)

The Latrobe Group may be subdivided into three units: Gurnard Formation (transgressive greensand unit), Flounder Formation (marine channel fill) and a usually predominant "coarse clastic" sequence (Fig. 2). The Latrobe Group "coarse clastics" have been further subdivided on the basis of palynological biozones.

3.3.1 Gurnard Formation (LAGU): 1816-1854m (38m)

Sediments of the Gurnard Formation consist of grey to brownish green siltstones. The siltstones may be slightly sandy, but contain abundant glauconite and common pyrite. The presence of minor limonite indicates mild oxidation.

The Gurnard Formation is interpreted to have been deposited in a shallow marine environment, during the upper L.balmei biozone.

3.3.2 Flounder Formation (LACH): 1854-1915m (61m)

The Flounder Formation consists of a glauconitic sandstone, with minor pyrite, lithic fragments and calcite cement. The abundance of pelletal glauconite supports deposition in a marine environment during the lowermost L. balmei biozone.

3.3.3 T. longus Biozone (LALO): 1915-2230m (315m)

From 1915-2002m the T. longus biozone consists of sandstones, siltstones and shales deposited in an estuarine environment (1915-1939m) overlying a transgressive coastal barrier system (1939-2002m). The sandstones are white to light grey, dominantly medium grained, moderately sorted, subangular to subrounded, spherical, unconsolidated and with fair visual porosity. Traces of glauconite, pyrite and calcite cement were observed.

The first occurrence of coal marks the change in facies to a lower coastal plain depositional environment overlying upper coastal plain and braided stream sediments. The lower coastal plain facies (2002-2108m) and upper coastal plain facies (2108-2132m) consist of fining-upwards, fluvial sandstones, carbonaceous shales, siltstones, claystones and thin coals. The sandstones are typically white, fine to medium grained, moderately sorted, subangular to subrounded, subspherical, and contain minor amounts of pyrite, lithic fragments and calcite cement.

From 2132-2230m the section is dominated by braided stream sandstones and minor shales. The sandstones are white to clear, dominantly coarse grained, moderately sorted, subangular to rounded, spherical and unconsolidated with fair to moderate visual porosity.

3.3.4 T. lilliei Biozone (LALI): 2230-2310m (80m)

Sediments of the T. lilliei biozone have been deposited in upper coastal plain and braided stream environments, and consist of interbedded sandstones, shales and siltstones. The sandstones are generally white to light grey, fine to coarse grained, moderately sorted, subangular to angular, subspherical to subelongate, unconsolidated and with fair visual porosity.

3.4 <u>Golden Beach Group</u> (GB) 2310-3518m (1208m)

The Golden Beach Group has also been subdivided into biozones on the basis of palynological data.

3.4.1 <u>T. apoxyexinus Biozone</u> (GBTA) 2310-2459m (149m)

Based on petrographical analysis the section from 2310-2370m consists of interbedded crystal tuffs and argillaceous sandstones. The tuff contains large crystals of quartz and feldspar, rare aggregates of monomineralic phyllosilicate, and argillaceous sandstone. The textural relationships noted in thin section suggest a pyroclastic derived rock with a water-lain component (Appendix 5).

The interval from 2370-2459m is characterised by thinly interbedded claystones, siltstones, shales, sandstones and coals. The sandstones are generally white, fine grained, moderately sorted, subangular, subspherical, unconsolidated with minor calcite cement. The siltstones and shales are dark brown, firm and carbonaceous. This sequence was deposited in a lower coastal plain setting.

3.4.2 <u>P. mawsonii Biozone</u> (GBPM) 2459-3518m (1059m)

Lower coastal plain deposition also occurred in the upermost part of the GBPM biozone from 2459-2586m, as evidenced by interbedded shales, siltstones, coals and sandstones. The sands are commonly white to transparent, fine to medium grained, moderately sorted, subangular to angular, subspherical, unconsolidated but locally cemented with poor to moderate visual porosity. The siltstones and shales are brown, firm and carbonaceous, and the coals are black, vitreous and woody.

From 2596-2907m, the sequence consists of interbedded shales, siltstones, sandstones and minor coals. The shales and silts are dark brown, contain abundant carbonaceous material, and are firm. The sandstones are generally white to buff in colour, fine to medium grained, moderately well sorted, subangular, subelongate, unconsolidated but with local dolomite cement and moderate visual porosity. The section is interpreted to have been deposited in an upper coastal plain environment.

A distinctive, thick sequence of siltstones and minor sandstones was penetrated from 2907-3518m which represents the informally named Kipper Shale. Individual siltstone units may be up to 140m thick. Typically the siltstones are dark grey, clayey, contain carbonaceous fragments, are slightly micaceous, blocky and firm. The thin sandstone interbeds are white, clayey, fine to medium grained, poorly sorted, subrounded, subspherical and contain minor a lithic component.

The sands generally have poor visual porosity with trace to locally abundant dolomite cement. The sequence becomes slightly more sandy beneath 3338m. This section is interpreted to have been deposited in a stable, lacustrine environment. As also noted in Kipper-1 and Judith-1, this biozone is characterised by an unusual assemblage of freshwater algae, known informally as the Kipper Shale dynocysts (Appendix 1). These algae are however only abundant in the lower part of the biozone (below 3065m) in Shark-1.

4. SEISMIC MARKERS AND STRUCTURE

A well velocity survey was conducted at Shark-1 upon completion of drilling (Appendix 3, Volume 1). The synthetic seismogram (Encl. 3) for Shark-1 was used to relate the main seismic markers to the well results as shown below. A good match with seismic at the well location was achieved. Drill depths to marker horizons were in close agreement with the predicted depths (Fig. 4).

TABLE 1: ACTUAL DEPTH TO MARKERS

SEISMIC HORIZON	TWO-WAY TIME (secs)	DEPTH (m bdf)	DEPTH (m SS)
BASE GIPPSLAND LIMESTONE	1.323	1526	1498
TOP LATROBE GROUP	1.528	1816	1788
TOP GOLDEN BEACH GROUP	1.826	2310	2282
INTRA-GOLDEN BEACH GROUP (orange marker)	1.951	2530	2502

The Shark structure is a downthrown fault trap, mapped at Top Golden Beach and several intra-Golden Beach levels (Fig. 5). The dipmeter data confirms the depth mapping at Top Golden Beach and Intra-Golden Beach (orange marker) levels. Although fault plane sections cannot unequivocally demonstrate reservoir-seal juxtapositions, it is considered that Shark-1 tested a valid trap.

5. HYDROCARBON SHOWS

No significant hydrocarbon shows were encountered in Shark-1. Mud gas levels were low throughout the entire section with background levels in the order of 0-0.15% methane. Minor gas increases were recorded in association with coal and some carbonaceous shales, with the maximum formation gas reading (1.0% C_1) at 3440-3442m associated with a carbonaceous siltstone.

Petrophysical evaluation indicates the objective lower Latrobe and Golden Beach Groups to be entirely water bearing (see Appendix 3).

6. RESERVOIRS, SEALS AND SOURCE ROCKS

Reservoirs

Reservoir quality of the upper Latrobe estuarine and barrier sandstones (1915-2002m) is excellent, with log-derived porosity in the range 22-30% and average approximately 26%. The sandstones are medium grained, moderately well sorted and with fair to good visual porosity.

Sandstones in the lower Latrobe lower coastal plain and upper coastal plain sequences (2002-2310m) are dominatly quartoze, fine to coarse grained, with fair to moderate visual porosity. Log-derived porosities are in the range 17-25%, and average approximately 20%.

Beneath the top Golden Beach Group tuffs, sands of lower and upper coastal plain origin (2370-2907m) have poor to moderate reservoir quality. In general, these sands are slightly argillaceous, but locally carbonate cemented, and have poor to fair visual porosity. Log-derived porosities for such sands are in the order 8-15% (averaging 12%). This section has a sand/shale ratio of 39%, and a net:gross ratio of 28%.

Within the Kipper Shale interval (2907-3518m) minor sandstones were encountered. These sandstones are clayey, fine to medium grained, locally dolomite cemented and with low visual porosity. Log analyses indicate these sands have porosities in the range 5-12% (average 8%). This interval has an overall sand/shale ratio of 17% and a net: gross ratio of 5%.

The overall decrease in reservoir quality with depth (and age) appears to be a function of textural and compositional maturity. In addition, the Strzelecki Group appears to have been a major clastic source for the older Golden Beach Group fill.

Seals

Top seal for the primary objective Golden Beach Group alluvial sands was anticipated to be weathered basalts, however only a 60m tuffaceous interval was encountered. The tuff has no porosity in thin section and would likely act as an effective seal. Additional volcanic intervals were expected within the Golden Beach Group based on the reflective character of the seismic data. The high amplitude refelctors were however, a result of coals within the lower coastal plain section encountered above the Kipper Shale.

Within the Kipper Shale, individual siltstone units are up to 140m thick and should provide effective lateral and vertical seals to the thin intraformational, lacustrine delta sands.

Secondary targets in Shark-1 were lower coastal plain sands near the base of the Latrobe Group, however the well penetrated a sandy upper coastal plain sequence with a high net: gross. Favourable sand-shale juxtaposition at the bounding fault is therefore considered unlikely.

Source Rocks (Appendix 4)

Source rocks were encountered in carbonaceous shales and coals from the lower coastal plain sections in the Latrobe and Golden Beach Groups. No rich source intervals have been recognised within the thick lacustrine Kipper Shale sequence.

7. CONCLUSIONS AND CONTRIBUTIONS TO GEOLOGY

(a) The seismic markers mapped can be directly related to the well data.

(b) The drill depths to the seismic markers are in very close agreement with the predicted depths.

(c) The lithological and stratigraphical sequences encountered in Shark-1 were for the most part as anticipated from the regional facies distribution mapping. The lowermost Latrobe Group comprised more proximal facies (upper coastal plain) as opposed to the lower coastal plain facies which was expected. The Latrobe Group did however, consist of a typical transgressive sequence from upper coastal plain to estuarine. Rather than the weathered basalts encountered in wells to the west, the top Golden Beach Group in Shark-1 is marked by a tuffaceous pyroclastic sequence, interbedded with sandstones and claystones. The upper Golden Beach Group consists of a thick lower coastal plain sequence, not the alluvial and upper coastal plain deposits which were predicted. The well encountered a thick lacustrine interval, the Kipper Shale, as anticipated. Data from the well has refined facies distribution mapping in permit VIC/P22.

(d) Reservoir quality of the deep Golden Beach Group sandstones is extremely poor, with log derived porosities in the range 5-12%. The occlusion of porosity can be attributed to authigenic clays and carbonate cementation.

(e) No significant hydrocarbon shows were encountered. The well is considered to have tested a valid trap, and a lack of hydrocarbon charge is the regarded as the main cause of failure.

<u>REFERENCE</u>

SDA 903: Exploration Well Proposal Shark-A, Gippsland Basin Permit VIC/P22

FIGURES

PE905004

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SUBTYPE =	PROSPECT_MAP
DESCRIPTION =	Location and Geology Map showing Shark-1, Figure 1, copy of PE905001
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DATE_RECEIVED =	6/04/90
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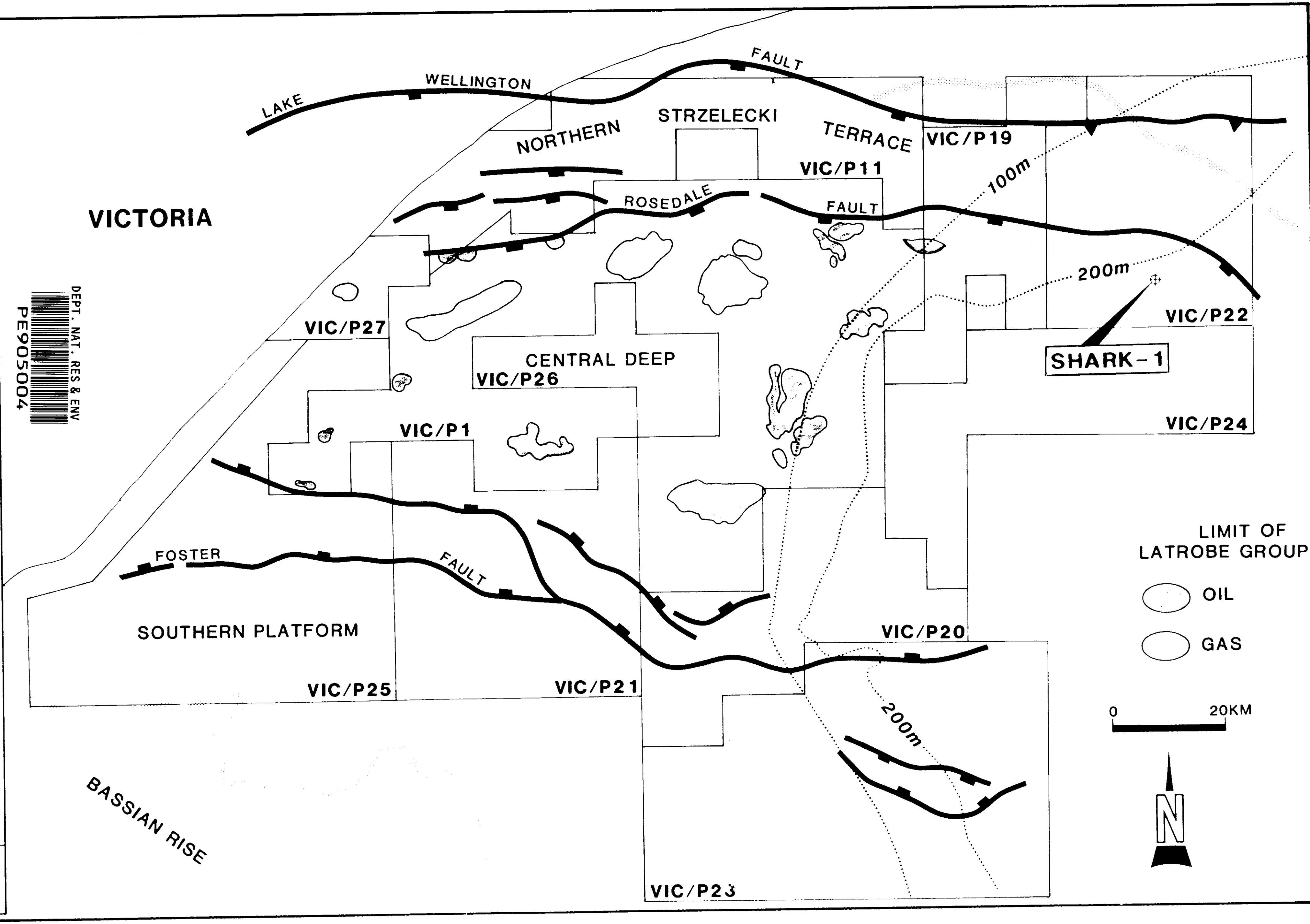
CLIENT_OP_CO =	SHELL AUSTRALIA

(Inserted by DNRE - Vic Govt Mines Dept)

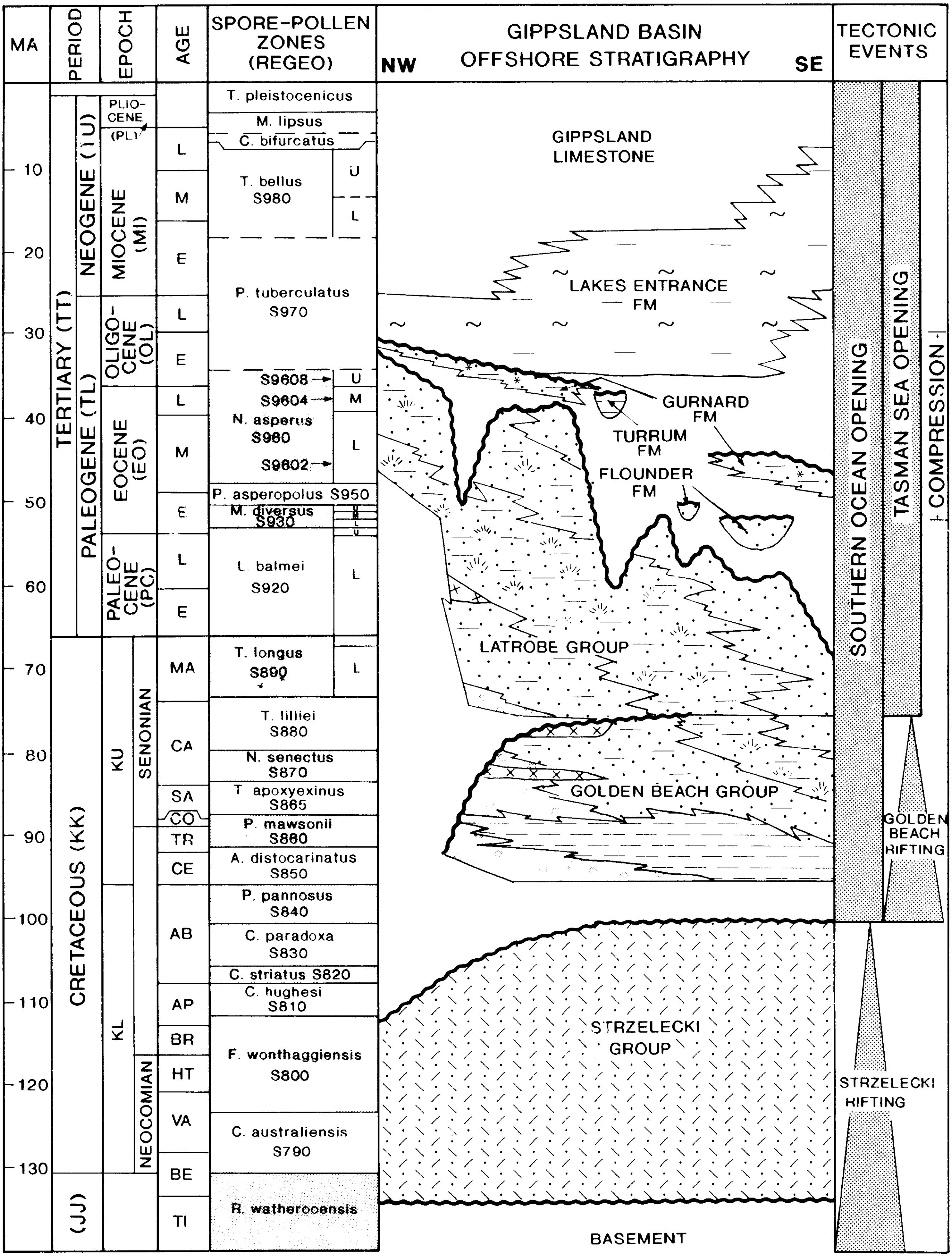


SHELL AUSTRALIA

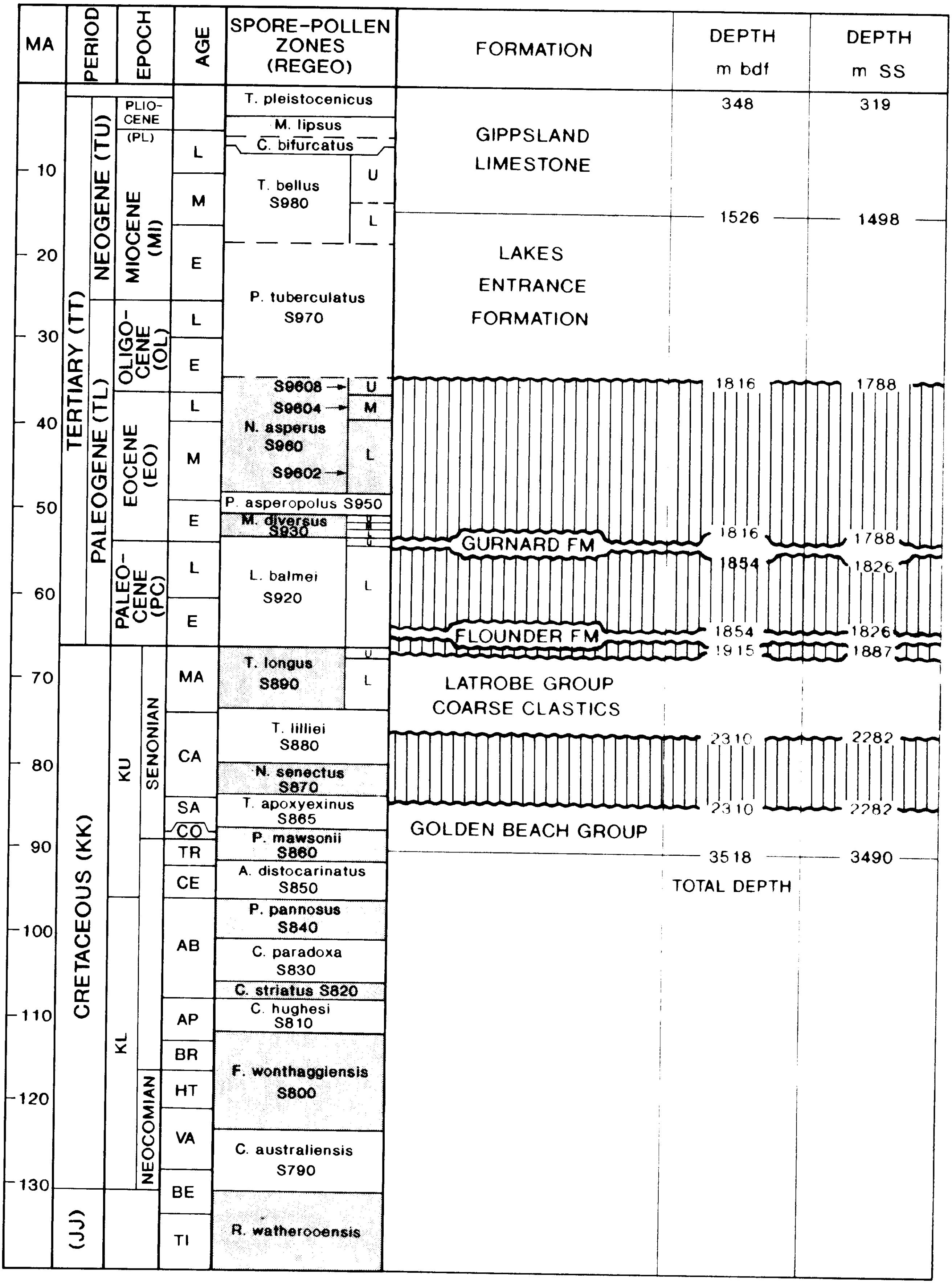
LOCATION MAP - SHARK-1

Figure 1

Author EXO | Report No. | Date | Drawing No.



SHELL-AUSTRALIA E & P. OIL AND GAS	GIPPSLAND BASIN **OFFSHORE STRATIGRAPHY**			Figure 2
	Author: EXO	Report No. SDA 937	Date: SEPT 1989	Drawing No.: 25630



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GIPPSLAND BASIN

SHARK-1 STRATIGRAPHIC TABLE

Figure 3

Author: EXO	Report No.: SDA 937	Date: MARCH 1990	Drawing No.: 26025

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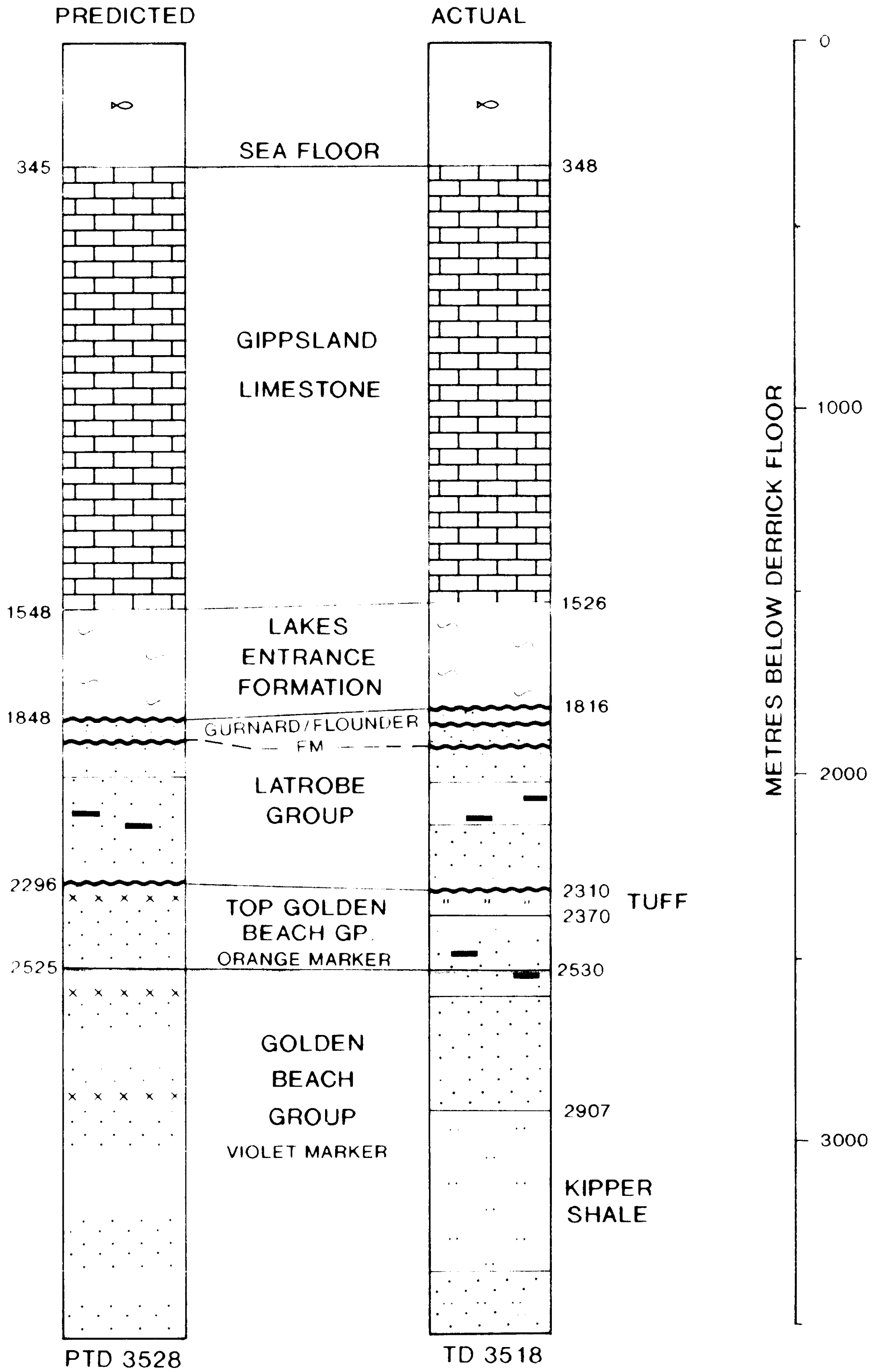
CLIENT_OP_CO =	SHELL AUSTRALIA

(Inserted by DNRE - Vic Govt Mines Dept)



SHELL-AUSTRALIA
E & P OIL AND GAS

GIPPSLAND BASIN

SHARK-1 PREDICTED VS ACTUAL STRATIGRAPHY

Figure 4

Author: EXO | Report No.: SDA 937 | Date: MARCH 1990 | Drawing No.: 26024

PE905006

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DATE_RECEIVED =	6/04/90
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WELL_NAME =	SHARK-1
CONTRACTOR =	
CLIENT_OP_CO =	SHELL AUSTRALIA

(Inserted by DNRE - Vic Govt Mines Dept)

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            PERMIT = VIC/P22
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           SUBTYPE = SYNTH_SEISMOGRAPH
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                     (Enclosure 2)
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              W_NO = W1013
         WELL_NAME = SHARK-1
        CONTRACTOR =
      CLIENT_OP_CO = SHELL AUSTRALIA
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APPENDIX I

PALYNOLOGY

APPENDIX I
PALYNOLOGY

PALYNOLOGICAL ANALYSIS, SHARK-1

GIPPSLAND BASIN

by

M.K. MACPHAIL

Palaeontological report prepared 7 February 1990 for
The Shell Company of Australia Ltd.

Consultant Palynologist, 20 Abbey St., Gladesville, NSW 2111

INTRODUCTION

SUMMARY OF RESULTS

GEOLOGICAL COMMENTS

PALAEOENVIRONMENTS

BIOSTRATIGRAPHY

INTERPRETATIVE DATA

BASIC DATA

SPECIES CHECK LIST

INTRODUCTION

Forty five sidewall core samples and eight cuttings samples, representing the interval 1850.0 to 3510.0m in Shark-1, were processed and examined for spore-pollen and dinoflagellates.

Yields and preservation were adequate to high, allowing most samples to be dated with a good degree of confidence.

Many of the T. longus Zone samples contained Late Tertiary dinoflagellates derived from caved Lakes Entrance Formation. but, in contrast to Judith-1 (Macphail, 1990), mud-contamination of the Late Cretaceous samples was minor.

Lithological units and palynological determinations are summarized below. Interpretative and basic data are given in Tables 1 and 2 respectively. Check lists of all species recorded are attached. Electric log data were unavailable.

SUMMARY

AGE	UNIT	ZONE	DEPTH RANGE (m)	ENVIRONMENT
Paleocene	GURNARD facies	Upper L. balmei	1850.0	open marine
"	"	Lower L. balmei	1880.0	open marine
Maastrichtian	LATROBE GROUP coarse clastics	Upper T. longus	1937.0-2030.0	coastal plain
"		Lower T. longus	2074.0-2197.0	coastal plain
Campanian	"	T. lilliei	2245.0	coastal plain
- - - - -	- - - - -	unconformity?	- - - - -	- - - - -
Santonian	GOLDEN BEACH FORMATION	T. apoxyexinus	2294.0-2456.0	rift-valley
Lower Santonian - Turonian	"	P. mawsonii	2490.0-3510.0	rift-valley lake

GEOLOGICAL COMMENTS

1. Shark-1 contains an almost continuous sequence of palynological zones from the Turonian--Lower Santonian P. mawsonii to the Paleocene, Upper L. balmei Zone. The N. senectus Zone was not recorded.

2. Based on the sidewall core description, the SWCs at 1850.0m and 1880.0m were shot in the Gurnard facies. The Paleocene date for this unit is consistent with other wells in the area and demonstrates the time-transgressive nature of the Gurnard facies due to the progressive encroachment of the Tasman Sea from the S.E.

   The SWC descriptions indicate that Top of Latrobe occurs between 1850.0 and 1810.0m.

3. Because of limited availability of sidewall material between 2377.0 and 2245.0m, it is unclear whether 'lower' T. lilliei and N. senectus Zone sediments are absent due to non-deposition or erosion, or were not sampled. If the former, then Shark-1 has intersected an unconformity, provisionally equated here with the "intra-Campanian" unconformity of Lowry (1977).

4. Some uncertainty exists concerning the position of the T. apoxyexinus and P. mawsonii Zone boundaries due to limited sampling and the difficulty of dating mud-contaminated SWCs shot in the critical interval [2245.0-2490.0m: see Biostratigraphy Section].

5. On present indications, P. mawsonii Zone sediments in Shark-1 are the thickest penetrated to date in the Gippsland Basin [minimum 1020m, cf approximately 700m in Judith-1 and Kipper-1] and are overlain by ca. 160-190m of T. apoxyexinus Zone sediments.

6. Like Judith-1 and Kipper-1, the P. mawsonii Zone is characterised by an unusual assemblage of freshwater algae, now informally known as the "Kipper Shale" dinocysts. However unlike Judith-1 and Kipper-1, these algae are abundant only in the **lower** part of the zone in Shark-1, below ca. 3065m. Possible explanations include:

   (a) Environmental conditions permitting "blooms" of the "Kipper Shale" dinocysts were time-transgressive and occurred earlier at the Shark-1 wellsite than sites on the Kipper Trend.

(b) The period of time represented by the upper section of _P. mawsonii_ Zone sediments in Shark-1 was a period of low/non-deposition or erosion at Judith-1 and Kipper-1.

7. Shark-1 terminated in the Late Cretaceous Golden Beach Formation.

PALAEOENVIRONMENTS

1. Despite the paucity of dinoflagellates at 1880.0m, glauconite in this sample indicates that open marine conditions were first established across the well site during the Lower Paleocene. Palynofloras at 1850.0 and 1880.0m were deposited during the A. homomorpha and T. evittii marine transgressions respectively.

2. Otherwise the only marine-influenced sediments in Shark-1 occur at 1983.0m. These appear to have been deposited during the M. druggii marine transgression.

   The episodic nature of this marine influence is demonstrated by the subsequent development of freshwater conditions at 1937.0m

3. The excellent preservation of Lower T. longus and T. lilliei palynofloras is consistent with an aquatic depositional environment, probably fluvio-lacustrine, given the virtual absence of algal cysts in the relevant facies.

4. During the Turonian-Santonian, T. apoxyexinus and 'upper' P. mawsonii Zone, the wellsite is likely to have been located within a large rift valley. Again, the low numbers of algal cysts imply that fluvial rather than lacustrine conditions prevailed at the wellsite.

5. This was not the case during 'lower' P. mawsonii Zone time [2748.0m-3510.0m] when the wellsite was almost certainly located within the circumference of a large freshwater lake.

   Based on the relative abundance of "Kipper Shale" dinocysts, this lake appears to have fluctuated in area/depth, with the shoreline being most distant near TD.

BIOSTRATIGRAPHY

Zone and age-determinations have been made using criteria proposed by Stover & Partridge (1973), Helby et al. (1987) and unpublished observations made on Gippsland Basin wells drilled by Esso Australia Ltd. The informal subdivision of the T. longus Zone proposed by Macphail (1983b: see Helby et al., ibid p.58) is followed here. Zone names have not been altered to conform with nomenclatural changes to nominate species such as Tricolpites longus [now Forcipites longus: see Dettman & Jarzen, 1988].

The majority of dinocyst species encountered in the P. mawsonii Zone interval conform well with genera and species described by Marshall (1990). A distinctive but undescribed trilobate dinocyst is referred to a new informal genus, Trifidicysta.

The well is of considerable biostratigraphic importance not only because it contains probably the thickest and most closely sampled unit of Turonian-Lower Santonian sediments drilled to date in the Gippsland Basin but also because it places in stratigraphic sequence a number of species which previously have been recovered only in grab samples from the Bass Canyon.

Phyllocladidites mawsonii Zone 2490.0-3510.0m Lower Santonian -Turonian

This interval is represented by twenty eight SWC and seven cuttings samples, all of which yielded low to moderate numbers of poorly-preserved and often pyrite scarred palynomorphs.

Virtually all palynofloras are dominated by gymnosperm pollen with Gleicheniidites, Amosopollis cruciformis and Cretaceous long-ranging spores being the next most frequent taxa. Most samples contained low numbers of recycled Early Cretaceous and Permo-Triassic spores.

The nominate and index species of the zone, Phyllocladidites mawsonii, is present throughout the interval. Virtually all specimens are likely to be in situ based on staining characteristics. Conversely, species which range no higher than the P. mawsonii Zone, notably Appendicisporites distocarinatus and Interulobites intraverrucatus, are very rare.

Palynofloras between 2490.0-2574m include a distinctive but undescribed pollen which morphologically is intermediate between Tricolpites [which ranges down into the P. pannosus Zone] and Forcipites sensu stricto which first appears in the Santonian, T. apoxyexinus Zone.

Whilst the biostratigraphic range of this pollen type ["cf Forcipites"] is unknown, it is noted that a similar pollen type occurs 2783.0 m, 2955.0m and 2990.0m, the last two **below** occurrecneces of Interulobites intraverrucatus and therefore in sediments no younger than P. mawsonii Zone.

Described/undescribed species of "Kipper Shale" dinocysts are frequent to dominant in palynofloras only close to the base of the P. mawsonii Zone [3430.0-3510.0m] and do not range above 2593.0m.

Angiosperm pollen, although rare, are widely distributed throughout the interval with undescribed species of Tricolpites, Proteacidites and Phimopollenites being the most frequently recorded taxa.

The base of the zone is picked at 3510.0m, the basal SWC sample, which contains a poor specimen of the nominate species as well as a diverse assembage of Rimosicysta spp. and related dinocysts - Rimosicysta eversa, R. cf eversa, Wuroia corrugata, Trididicysta and peridinacean cysts cf Luxadinium.

Proteacidites demonstrates that the sample is no older than P. mawsonii Zone.

Rimosicysta concava first appears at 3490.0m and, like Bassicysta keenei, becomes common at 3430.0m. This sample contains Phyllocladidites mawsonii as well as Proteacidites spp., Cyatheacidites tectifera and a probable specimen of Appendicisporites distocarinatus.

Other first appearances of biostratigraphic and/or palaeo-environmental significance within the P. mawsonii Zone are:

1. A possible specimen of Interulobites intraverrucatus occurs at 3290.0m and a definite specimen at 2867.5m. The latter record is evidence that the sample and hence the "Kipper Shale" dinocysts are restricted to the P. mawsonii Zone in Shark-1.

2. The freshwater alga Pediastrum in cuttings at 3018-21m.

3. *Appendicisporites distocarinatus* in cuttings at 2949-52m and 2571-74m.

4. *Balmeisporites holodictyus*-*Rouseisporites reticulatus* association at 2524.0m. The same sample yielded an early Late Cretaceous population of *Foveotriletes balteus*.

The upper boundary is provisionally placed at 2490.0m, a low-yield sample which contains *Phyllocladidites mawsonii* and *Proteacidites* spp. but not species which first appear in the *T. apoxyexinus* Zone. The sample contains a poor specimen of *Appendicisporites distocarinatus*.

A more confident pick for the top of the *P. mawsonii* Zone is 2573.0m.

Because of mud-contamination, the SWC at 2464.5m cannot be dated with any degree of confidence. "cf *Forcipites*" is present in this sample.

Tricolporites apoxyexinus Zone 2294.0-2456.0m Santonian

This zone is weakly defined by the first appearance at 2456.0m of an undescribed *Forcipites* sp. related to *F. stipulatus*.

Like the undated SWC at 2464.5m and many samples within the *P. mawsonii* Zone, the palynoflora is dominated by *Gleicheniidites* and gymnosperm pollen but is distinguished from these by (i) frequent *Clavifera triplex* and (ii) the diversity of Early Cretaceous spores. The latter include *Cyclosporites hughesii*, *Dictyotosporites complex*, *Foraminisporis asymmetricus*, *F. wonthaggiensis* and *Pilosisporites notensis*.

Forcipites stiplatus and *Tricolpites confessus* first appear at 2426.0m, associated with a recycled (?) specimen of *Appendicisporites distocarinatus*. The specimen of *Rimosicysta kipperii* at 2390.0m is attributed to mud-contamination.

The cuttings sample at 2376m yielded *Forcipites* spp. and *Tricolpites confessus*, possibly not *in situ* since caved specimens of *Nothofagidites kaitangata*, *Gambierina rudata* and *Tricolporites lilliei* also are present.

The upper boundary is provisionally placed at 2294m, based on specimens of *Phimopollenites pannosus* and *Tricolpites confessus*. Because of the very small amount of sediment available, it is uncertain whether these pollen are *in situ* or not. No sediment was available from the SWC shot at 2320.0m.

Tricolporites lilliei Zone 2245.0m Campanian

One sample is confidently assigned to this zone, based on Tricolporites lilliei, T. waiparensis, Triporopollenites sectilis and the abundance of Nothofagidites spp. relative to Gambierina rudata. The sample yielded a small population of a tricolporate species which closely resembles T. lilliei except that the sculpture is verucate not apiculate.

Lower Tricolpites longus Zone 2074.0-2197.0m Maastrichtian

The lower boundary is defined by the first appearance at 2197.0m of Forcipites longus. Gambierina rudata, Nothofagidites kaitangata, and Triporopollenites sectilis are frequent and Late Cretaceous Proteacidites spp. diverse. Like most of the samples in this interval, the palynoflora includes caved Late Eocene-Oligocene marine dinoflagellates.

Quadraplanus brossus occurs at 2180.0m and Beaupreadites orbiculatus at 2150.0m, the latter associated with frequent Proteacidites reticuloconcavus, Nothofagidites kaitangata and Tricolporites lilliei.

The upper boundary is placed at 2074.0m, a sample yielding approximately equal numbers of Gambierina rudata and Nothofagidites [73:58] as well as Forcipites longus and Quadraplanus brossus and [frequent] Tricolporites lilliei and Triporopollentites sectilis. Stereisporites punctatus was not recorded despite other Stereisporites spp. being abundant in the sample.

Upper Tricolpites longus Zone 1937.0-2030.0m Maastrichtian

The three SWC samples assigned to this zone contain common to abundant Gambierina rudata. Nothofagidites spp. are rare to infrequent.

The lower boundary is provisionally placed at 2030.0m, based on the relative abundance of Gambierina rudata.

Stereisporites punctatus is first recorded at 1983.0m, associated with Forcipites longus and the marine dinoflagellate Isabelidinium coronatum. The same sample contains Beaupreadites orbiculatus and the earliest record of Tetracolporites verrucosus in Shark-1.

The SWC at 1937.0m, picked as the upper boundary, yielded Forcipites longus, Quadraplanus brossus, multiple specimens of Stereisporites punctatus, Grapnelispora evansii, Tetracolporites verrucosus and [frequent] a probable freshwater algal cyst. Minor contamination or reworking is indicated by Phimopollenites pannosus.

Lower Lygistepollenites balmei Zone 1880.0m Paleocene

The palynoflora at 1880.0m is dominated by Lygistepollenites balmei and Proteacidites but lacks species first appearing in the Upper L. balmei Zone. The dinoflagellate Trithyrodinium evittii is almost certainly present but the identification cannot be confirmed due to unfavourable orientation of the cyst. The frequent occurrence of Gambierina rudata is consistent with a marine-influence [reworking of Maastrichtian sediments].

Upper Lygistepollenites balmei Zone 1850.0m Paleocene

The association of Camarozonosporites bullatus, Cyathidites gigantis and frequent Lygistepollenites balmei at 1850.0m, provides a confident Upper L. balmei Zone date for this SWC, the highest sample available for palynological analysis in Shark-1.

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LEGEND

SPORE-POLLEN

P. tub. = P. tuberculatus Zone
U. N.a. = Upper N. asperus Zone
M. N.a. = Middle N. asperus Zone
L. N.a. = Lower N. asperus Zone
P. asp. = P. asperopolus Zone
U. M.d. = Upper M. diversus Zone
M. M.d. = Middle M. diversus Zone
L. M.d. = Lower M. diversus Zone
U. L.b. = Upper L. balmei Zone
L. L.b. = Lower L. balmei Zone
U. T.l. = Upper T. longus Zone
L. T.l. = Lower T. longus Zone
T. lil. = T. lilliei Zone
N. sen. = N. senectus Zone
T. apx. = T. apoxyexinus Zone
P. maw. = P. mawsonii Zone
A. dst. = A. distocarinatus Zone
P. pan. = P. pannosus Zone
C. pdx. = C. paradoxa Zone
C. str. = C. striatus Zone
C. hug. = C. hughesii Zone
F. wng. = F. wonthaggiensis Zone
C. aus. = C. australiensis Zone

DINOFLAGELLATE

P. com. = P. comatum Zone
C. inc. = C. incompositum
D. ext. = D. extensa Zone
D. het. = D. heterophylcta
T. pan. = T. pandus Zone
A. aro. = A. australicum
T. ast. = T. asteris Zone
K. edw. = K. edwardsii
K. tom. = K. thompsonae
K. orn. = K. ornatum
K. wai. = K. waipawaensis
A. hyp. = A. hyperacantha
A. hom. = A. homomorphum
E. crs. = E. crassitabulata
T. evt. = T. evittii Zone
M. drg. = M. druggii Zone
I. kor. = I. korojonense
X. aus. = X. australis
N. asc. = N. asceras
I. cre. = I. cretaceum
O. por. = O. porifera
C. str. = C. striatoconus
P. inf. = P. infusorioides
D. mlt. = D. multispinum
X. asp. = X. asperatus
P. lud. = P. ludbrookiae
C. den. = C. denticulata
M. tet. = M. tetracantha
D. dav. = D. davidii
O. opr. = O. operculata

TABLE 1: SUMMARY OF INTERPRETATIVE PALYNOLOGICAL DATA

SWC	DEPTH (m)	ZONE S-P	ZONE DINO	CONF. RTG.	COMMENT
Run 1					
19	1850.0	U. B.l.	A. hom.	0	C. gigantis
18	1880.0	L. L.b.	T. evt.	1	
16	1937.0	U. T.l.	-	0	F. longus, S. punctatus
15	1983.0	U. T.l.	M. druggii?	0	I. coronatum
12	2023.0	U. T.l.	-	2	
09	2074.0	L. T.l.	-	1	F. longus
06	2124.0	No older than T. lilliei Zone			
04	2150.0	L. T.l.	-	1	F. longus
03	2168.5	No older than T. lilliei Zone			
02	2180.0	L. T.l.	-	1	Q. brossus
01	2197.0	L. T.l.	-	0	F. longus
Run 2					
59	2245.0	T. lil.	-	0	T. lilliei
58	2294.0	T. apx.	-	2	neglig. sample
ctg	2376	T. apx.	-	3	
55	2377.0	T. apx.	-	1	F. stipulatus
54	2390.0	T. apx.	-	1	"
53	2426.0	T. apx.	-	1	"
51	2456.0	T. apx.	-	2	Forcipites spp.
50	2464.5	Indeterminate		-	Mud-contaminated
49	2490.0	P. maw.	-	2	A. distocarinat.
48	2500.0	P. maw.	-	2	P. mawsonii
47	2524.0	P. maw.	-	2	"
ctg	2526	P. maw.	-	3	
45	2560.5	P. maw.	-	1	F. balteus
ctg	2571	P. maw.	-	3	
44	2573.0	P. maw.	-	1	
43	2593.0	P. maw.	-	1	
ctg	2628	P. maw.	-	3	
42	2630.0	P. maw.	-	1	A. distocarinat.
41	2640.0	P. maw.	-	1	
ctg	2664	P. maw.	-	3	
36	2707.0	P. maw.	-	1	
34	2748.0	P. maw.	-	1	
32	2783.0	P. maw.	-	1	
31	2794.0	P. maw.	-	1	
29	2835.0	P. maw.	-	1	
28	2867.5	P. maw.	-	0	I. intraverrucat
27	2886.0	P. maw.	-	1	

SWC	DEPTH	ZONE S-P	. DINO	CONF. RTG.	COMMENT (m)
23	2918.5	P. maw.	-	1	
ctg	2949-52	P. maw.	-	3	A. distocarinat.
21	2955.0	P. maw.	-	1	
ctg	2988-91	P. maw.	-	3	
20	2990.0	P. maw.	-	1	
ctg.	3018-21	P. maw.	-	3	
19	3065.0m	P. maw.	-	2	
13	3227.0	P. maw.	-	1	
11	3260.0	P. maw.	-	1	
10	3290.0	P. maw.	-	2	
09	3325.0	P. maw.	-	1	
05	3388.0	No older than A. distocarinatus Zone			
04	3430.0	P. maw.	-	0	
02	3490.0	P. maw.	-	1	
01	3510.0	P. maw.	-	1	

TABLE 2: SUMMARY OF BASIC PALYNOLOGICAL DATA

SWC	DEPTH (m)	YIELD S-P	YIELD DINO	DIVERSITY S-P	DIVERSITY DINO	PRES.	LITH.*
Run 1							
19	1850.0	low	med.	high	low	good	ST.gc
18	1880.0	med.	-	med.	-	good	ST.gc
16	1937.0	med.	-	high	-	mod.	SH.st
15	1983.0	med.	low	high	low	mod.	SH.st
12	2030.0	low	caved	med.	-	poor	ST.cl
09	2074.0	high	caved	high	-	mod.	SH.st
06	2124.0	low	caved	med.	-	mod.	SH.st
04	2150.0	med.	-	high	-	mod.	ST.cl
03	2168.5	low	caved	med.	-	good	SS.cl
02	2180.0	low	caved	low	-	mod.	SS.cl
01	2197.0	high	caved	high	-	good	SS.cl
Run 2							
59	2245.0	high	-	high	-	good	ST.
58	2294.0	low	-	low	-	mod.	SS.
ctg	2376	high	caved	high	-	mod.	
55	2377.0	med.	-	med.	-	mod.	Cly.
54	2390.0	med.	-	med.	-	good	Cly.
53	2426.0	low	-	med.	-	poor	ST.
51	2456.0	high	-	med.	-	good	Cly.st
50	2464.5	low	-	med.	-	good	SS.
49	2490.0	low	-	low	-	mod.	ST.
48	2500.0	low	-	med.	-	mod.	ST.
47	2524.0	high	-	med.	-	mod.	Cly.st
ctg	2526	high	-	med.	-	mod.	
45	2560.5	low	-	low	-	mod.	Cly.st
ctg	2571	high	-	med.	-	mod.	
44	2573.0	high	-	low	-	mod.	CO.cl
43	2593.0	mod.	low	low	low	poor	SH.
ctg	2628	high	-	med.	-	poor	
42	2630.0	med.	low	med.	low	good	SH.
41	2640.0	low	-	med.	-	mod.	SH.st
ctg	2664	high	-	med.	-	poor	
36	2707.0	high	-	med.	-	mod.	CO.cl
34	2748.0	med.	low	med.	low	mod.	SH.cl.
32	2783.0	med.	-	med.	-	poor	SH
31	2794.0	high	-	low	-	mod.	SH.co
29	2835.0	low	-	low	-	mod.	ST.ss
28	2867.5	high	low	med.	-	mod.	SH.co
27	2886.0	low	-	med.	-	mod.	ST.
23	2918.5	low	-	low	-	mod.	ST.

SWC	DEPTH (m)	YIELD S-P	YIELD DINO	DIVERSITY S-P	DIVERSITY DINO	PRES.	LITH.*
ctg	2949-52	high	-	med.	-	mod.	
21	2955.0	med.	low	med.	med.	poor	ST.
ctg	2988-91	med.	-	med.	-	mod.	
20	2990.0	low	low	low	low	poor	ST.
ctg	3018-21	high	low	med.	low	mod. 19	
	3065.0m	low	low	low	low	poor	SH. 13
	3227.0	med.	low	low	low	poor	ST.cl 11
	3260.0	med.	low	low	med.	poor	ST.cl 10
	3290.0	med.	low	low	low	poor	ST.cl 09
	3325.0	high	low	low	med.	poor	ST.cl 05
	3388.0	med.	low	low	low	poor	ST.cl 04
	3430.0	high	med.	med.	high	poor	SH.st 02
	3490.0	med.	low	low	high	poor	ST.cl 01
	3510.0	med.	med.	low	high	poor	ST.cl

* Lithological descriptions [main rock type.qualifier] taken from hand-written sidewall core sample description sheets

TABLE NO. :

CHECK LIST OF SPORE-POLLEN & DINOFLAGELLATES

Well Name SHARK-1 Basin GIPPSLAND Sheet No. 1 of 6

FOSSIL NAMES / DEPTHS (metres)	1937.0	1983.0	2023.0	2074.0	2124.0	2150.0	2180.0	2186.5	2197.0	2245.0	2376	2377.0	2390.0	2426.0	2456.0	2464.5	2490.0	2500.0	2524.0	2526	2560.5	2571	2573.0	2593.0	2628	2630.0
SAMPLE TYPE OR NO. *	S	S	S	S	S	S	S	S	S	S	T	S	S	S	S	S	S	S	S	T	S	T	S	S	T	S
Aequitriradites spinulosus									•			•	•													
Alisporites grandis																	•	•								
A. similis			•	•					•			•												•		
Amosopollis cruciformis	•					•							•		•	•		•	•	•		•		•	•	•
Appendicisporites distocarinatus														R			•					•				
A. spp. indet./undescribed															•											•
Araucariacites australis	•	•	•				•		•	•	•		•	•	•	•		•		•		•		•	•	•
Baculatisporites comaumensis				•						•			•			•	•		•	•				•		
B. disconformis					•							•		•	•											
Balmeisporites holodictyus																			•							
Basopollis otwayensis ms	•								•	•	•															
Beaupreadites orbiculatus		•				•																				
Camarozonosporites australiensis																						•				
C. dumus ms		•				•																				
C. heskermensis									•																	
Ceratosporites																				•						
Cicatricosisporites australiensis										•							•	•	•	•		•	•	•	•	•
C. sp. cf C. hughesii																			•							
C. ludbrookii																			•			•				
C. spp. indet./undescribed														•	•	•	•		•	•						
Clavifera triplex											•	•	•			•		•	•	•	•	•			•	•
Concavissimisporites penolaensis																•		•								
Corollinia spp.																		R								R
Crybelosporites striatus																							R			R
Cyatheacidites annulatus									C																	
C. tectifera																										
Cyathidites australis	•	•		•		•				•			•	•	•	•		•	•	•				•		•
C. minor			•	•	•	•	•	•		•	•	•	•		•	•		•	•	•				•		•
C. splendens	•	•		•					•																C	
C. subtilis									C																	
Cyclosporites hughesii															R		R									
Dacrycarpites australiensis										•																
Dicotetradites clavatus	•				•				•																	
Dictyophyllidites pectinaeformis																										
Dictyotosporites complex															R								R			
D. speciosus															R											
Dilwynites granulatus													•	•												•
D. tuberculatus													•													•
Elphredripites cf notensis																										
Ericipites crassiexinus	•					•			•																	
Foraminisporis asymmetricus																										
F. dailyii		R																								
F. wonthaggiensis															R											
Forcipites longus	•	•		•		•			•																	
F. sabulosus				•							•															
F. spp. indet./undescribed				•		•				•	•	•	•	•	•	C?										
cf Forcipites																•			•	•		•				
Foveosporites canalis													•					•			•					
Foveotriletes balteus																			•		•		•			
F. parviretus				•	•										•											
Gambierina rudata	•	•	•	•		•	•	•	•	•	•															
Gleicheniidites spp.	•			•	•	•		•	•	•		•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Grapnelispora evansii	•																									
Herkosporites elliotii	•			•		•	•				•		•		•	•		•			•					•
Ilexpollenites anguloclavatus		•				•																				
Interulobites intraverrucatus																										

Well Name SHARK-1 Basin GIPPSLAND Sheet No. 2 of 6

SAMPLE TYPE OR NO. *	S	S	S	S	S	S	S	S	S	S	T	S	S	S	S	S	S	S	S	T	S	T	S	S	T	S
FOSSIL NAMES / DEPTHS metres	1937.0	1983.0	2023.0	2074.0	2124.0	2150.0	2180.0	2186.5	2197.0	2245.0	2376	2377.0	2390.	2426.0	2456.0	2464.5	2490.0	2500.0	2524.0	2526	2560.5	2571	2573.0	2593.0	2628	2630.0
Ischyosporites punctatus			R										R													
Klukisporites scaberis			R	R											R											
Kraeuselisporites linearis																										
K. majus	•					•				•		•	•		•			•	•						•	•
Laevigatosporites spp.		•	•	•	•	•		•	•	•	•	•	•	•	•		•	•	•			•	•	•	•	•
Latrobosporites amplus		•		•	•	•	•	•				•		•				C								
L. crassus		•																								
Leptolepidites major				•								•														•
L. verrucatus															•			•								
Liliacidites ruppiaeformis ms									•																	
L. spp. indet./undescribed	•	•		•	•				•	•	•		•													•
cf Lycopodiacites asperatus				•	•									•	•		•				•					
Lycopodiumsporites australoclavatidites													•		•											
L. circolumenus						•																				
L. facetus															•											
L. nodosus	•																			•						
L. spp. indet./undescribed			•	•	•	•				•		•		•	•			•	•	•	•	•		•	•	•
Lygistepollenites balmei	•	•				•			•																	
L. florinii	•	•	•		•	•				•			•													
Microcachrydites antarcticus	•					•	•	•			•	•	•	•	•	•		•	•	•	•	•	•	•	•	•
Neoraistrickia truncata									•				•	•												•
Nothofagidites brachyspinulosus			•						•																	
N. emarcidus-heterus			C	C	C		C		C																	
N. kaitangata	•	•		•		•	•	•	•	•	•					C										
N. senectus s.l.	•			•		•	•		•	•																
Ornamentifera sentosa						•																				
O. sp. cf O. sentosa of Norvick & Burger																						•				
Osmundacites wellmanii	•			•														•								
Peninsulapollis gillii	•	•	•	•	•	•	•	•	•	•	•	•							C							
Periporopollenites demarcatus	•	•																								
P. polyoratus				•		•	•			•																
Phimopollenites pannosus	•												•					•								
P. spp. indet./undescribed												•		•					•		•			•		
Phyllocladidites mawsonii	•	•		•	•	•	•	•	•	•	•	•	•	•			•	•	•	•	•	•	•	•	•	•
P. reticulosaccatus	•																								•	
Pilosisporites notensis									R						R											
Plicatipollenites																	•									
Podocarpidites spp.	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Podosporites microsaccatus	•			•		•		•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Polycingutriletes pocockii		•													•											
Proteacidites ademonosus ms		•		•	•	•			•	•																
P. amolosexinus	•					•			•																	
P. angulatus									•																	
P. clinei ms	•	•		•		•			•																	
P. otwayensis ms		•							•																	
P. palisadus				•						•																
P. reticuloconcavus ms	•	•		•		•	•	•	•																	
P. retiformis		•		•																						
P. spp. indet./undescribed	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•		•	•		•	•			•	•	•
P. wahooensis ms	•	•		•																						
Pseudowinterapollis cranwellae	•			•																						
Quadraplanus brossus	•			•			•		•																	
Rouseisporites reticulatus	•		•							•			•	•			•	•	•			•	•			
Rugulatisporites mallatus					•										•					•					•	
R. cf mallatus											•	•			•	•		•							•	
Schizaea digitatoides													•		•											

* C=CORE S=SIDEWALL CORE
T=CUTTINGS J=JUNK BASKET

R = REWORKED SP.
C = CONTAMINANT

TABLE NO.:

Well Name SHARK-1 Basin GIPPSLAND Sheet No. 3 of 6

FOSSIL NAMES / DEPTHS (metres)	1937.0	1983.0	2023.0	2074.0	2124.0	2150.0	2180.0	2186.5	2197.0	2245.0	2376	2377.0	2390.0	2426.0	2456.0	2464.5	2490.0	2500.0	2524.0	2526	2560.5	2571	2573.0	2593.0	2628	2630.0
SAMPLE TYPE OR NO. *	S	S	S	S	S	S	S	S	S	S	T	S	S	S	S	S	S	S	S	T	S	T	S	S	T	S
Schizocolpus sp.																			•							
cf Sestrosporites													•											•		
Stereisporites australis f. crassa				•																						
S. antiquisporites	•	•		•		•		•	•	•	•			•	•			•	•	•		•			•	
S. punctatus ms	•	•																								
S. regium		•		•						•																
S. spp. indet./undescribed	•	•	•	•	•	•		•	•	•		•	•	•				•	•	•		•		•		
Striatopollis sp.									•																	
Stoveripollis lunaris															•			•								
taeniate bisaccates																•		•				•				
Tetracolporites verrucosus	•	•		•																						
Tetradopollis securus	•			•		•																				
Tricolpites confessus	•		•	•	•			•		•	•	•	•	•						C						
T. waiparensis	•	•		•		•		•	•	•																
T. spp. indet./undescribed	•	•		•	•	•	•	•	•	•	•	•	•	•	•			•	•	•	•	•	•	•	•	•
Tricolporites apoxyexinus																				C						
T. lilliei	•	•		•		•	•		•	•	C															
T. sp. cf T. lilliei [verrucate]						•		•		•																
T. marginatus ms										•			•			C										
T. spp. indet./undescribed	•	•		•	•	•			•	•		•	•	•						•		•			•	•
indeterminate trilete spores	•	•	•	•	•	•		•	•	•		•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Triletes tuberculiformis										•			•			•		•								
Triporopollenites sectilis		•	•	•	•	•	•		•	•																
T. spp. indet./undescribed		•		•		•				•		•		•												
Australopollis obscurus				•		•						•						•	•	•		•	•		•	•
Forcipites stiplatus												•	•	•												
Bassicysta keenei																										
Impagidinium spp.			C						C		C															
Isabelidium coronatum		•																								
Nematosphaeropsis balcombiana			C				C		C																	
Operculodinium centrocarpum		C	C					C																		
Pediastrum																										
peridinacean dinocysts																								•		
Protoellipsodinium simplex ms			C				C		C																	
Pyxidinopsis pontus ms							C		C																	
Rimosicysta cf aspera																								•		
R. concava																										
R. cf concava																										
R. cf cucullata																								•		
R. eversa																										
R. cf eversa																										
R. kipperii													R													
R. cf kipperii																										
R. spp. indet./undescribed																								•		•
Spiniferites spp.		C		C			C		C					C												
Trifidicysta spp. ms																										
Wuroia corrugata																								•		•
W. cf corrugata																										
W. cf unciformis																										
indeterminate algal cysts	•											•		•		•					•			•		•
Micrhystridium spp.																										
Spheripollenites psilatus																										
Veryhackium spp.																										

TABLE NO. :

CHECK LIST OF SPORE-POLLEN & DINOFLAGELLATES

Well Name SHARK-1 Basin GIPPSLAND Sheet No. 4 of 6

FOSSIL NAMES / DEPTHS (metres)	2640.0	2664	2707.0	2748.0	2783.0	2794.0	2835.0	2867.5	2886.0	2918.5	2949-52	2955.0	2988-91	2990.0	3018-21	3065.0	3227.0	3260.0	3290.0	3325.0	3388.0	3430.0	3490.0	3510.0		
SAMPLE TYPE OR NO. *	S	T	S	S	S	S	S	S	S	S	T	S	T	S	T	S	S	S	S	S	S	S	S	S		
Aequitriradites spinulosus																										
Alisporites grandis										•	•		•													
A. similis							•																			
Amosopollis cruciformis	•	•	•	•	•	•		•	•		•	•	•	•	•			•			•			•		
Appendicisporites distocarinatus											•															
A. spp. indet./undescribed				•	•											•						•				
Araucariacites australis	•	•	•	•	•			•		•	•	•	•	•	•	•	•		•	•	•	•	•	•		
Baculatisporites comaumensis												•	•		•				•							
B. disconformis		•																								
Balmeisporites holodictyus																										
Basopollis otwayensis ms				•																						
Beaupreadites orbiculatus																										
Camarozonosporites australiensis											•															
C. dumus ms																										
C. heskermensis																										
Ceratosporites equalis				•																						
Cicatricosisporites australiensis		•			•			•	•	•	•		•		•	•							•			
C. sp. cf C. hughesii	•																									
C. ludbrookii												•														
C. spp. indet./undescribed								•	•	•	•		•		•								•			
Clavifera triplex		•	•	•							•	•			•											
Concavissimisporites penolaensis											•															
Corollinia spp.						R•												R•								
Crybelosporites striatus															R•											
Cyatheacidites annulatus																										
C. tectifera					•														•			•	•			
Cyathidites australis		•		•	•			•				•			•	•		•				•				
C. minor							•				•	•	•		•											
C. splendens											C															
C. subtilis																										
Cyclosporites hughesii																										
Dacrycarpites australiensis																										
Dicotetradites clavatus																										
Dictyophyllidites pectinaeformis											•															
Dictyotosporites complex																										
D. speciosus									R		R															
Dilwynites granulatus					•	•		•					•	•												
D. tuberculatus		•																•								
Elphredripites cf notensis															•											
Ericipites crassiexinus																										
Foraminisporis asymmetricus									R																	
F. dailyii																										
F. wonthaggiensis																										
Forcipites longus																										
F. sabulosus																										
F. spp. indet./undescribed													C													
cf Forcipites					•							•		•												
Foveosporites canalis									•		•	•						•	•			•				
Foveotriletes balteus	•						•																			
F. parviretus													•	•												
Gambierina rudata													C													
Gleicheniidites spp.	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•			•		
Grapnelispora evansii																										
Herkosporites elliotii	•	•			•		•				•	•		•	•									•		
Ilexpollenites anguloclavatus																										
Interulobites intraverrucatus								•																		

TABLE NO.:

Well Name SHARK-1 Basin GIPPSLAND Sheet No. 5 of 6

SAMPLE TYPE OR NO. *	S	T	S	S	S	S	S	S	S	S	T	S	T	S	T	S	S	S	S	S	S	S	S	S
FOSSIL NAMES / DEPTHS metres	2640.0	2664	2707.0	2748.0	2783.0	2794.0	2835.0	2867.5	2886.0	2918.5	2949-52	2955.0	2988-91	2990.0	3018-21	3065.0	3227.0	3260.0	3290.0	3325.0	3388.0	3430.0	3490.0	3510.0
Ischyosporites punctatus																								
Klukisporites scaberis																								
Kraeuselisporites linearis											•													
K. majus	•				•					•		•							•	•			•	
Laevigatosporites spp.	•	•	•		•	•	•	•		•	•		•	•	•	•	•	•	•	•		•		
Latrobosporites amplus																								
L. crassus																								
Leptolepidites major														•				•						
L. verrucatus										•			•								•	•		
Liliacidites ruppiaeformis ms																								
L. spp. indet./undescribed				•											•									
cf Lycopodiacites asperatus		•		•	•							•	•								•	•		
Lycopodiumsporites australoclavatidites																								
L. circolumensu					•																			
L. facetus																								
L. nodosus										•														
L. spp. indet./undescribed		•		•		•		•	•	•	•	•									•			•
Lygistepollenites balmei																								
L. florinii																					C			
Microcachrydites antarcticus	•	•	•	•	•	•		•	•		•	•	•	•	•	•	•	•	•	•	•	•	•	•
Neoraistrickia truncata	•																							•
Nothofagidites brachyspinulosus																								
N. emarcidus-heterus																								
N. kaitangata																								
N. senectus s.l.																								
Ornamentifera sentosa																								
O. sp. cf O. sentosa of Norvick & Burger																								
Osmundacites wellmanii																		•						
Peninsulapollis gillii																					C			
Periporopollenites demarcatus																								
P. polyoratus																								
Phimopollenites pannosus		•							•			•			•		•							
P. spp. indet./undescribed	•	•		•		•	•	•							•						•			
Phyllocladidites mawsonii	•	•	•	•	•	•	•		•	•	•	•	•	•	•		•	•		•		•	•	•
P. reticulosaccatus									•				•											
Pilosisporites notensis																								
Plicatipollenites																								
Podocarpidites spp.	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Podosporites microsaccatus	•	•	•	•		•		•	•	•	•	•	•	•	•	•	•	•	•					•
Polycingutriletes pocockii								•																
Proteacidites ademonosus ms																								
P. amolosexinus																								
P. angulatus																C								
P. clinei ms																								
P. otwayensis ms																								
P. palisadus																								
P. reticuloconcavus ms																								
P. retiformis																								
P. spp. indet./undescribed	•	•		•	•				•	•	C	•	•	•			•					•	•	•
P. wahooensis ms																								
Pseudowinterapollis cranwellae																								
Quadraplanus brossus																								
Rouseisporites reticulatus	•									•										•	•			
Rugulatisporites mallatus					•	•					•											•		
R. cf mallatus	•		•	•				•	•						•									
Schizaea digitatoides																								

Well Name SHARK-1 Basin GIPPSLAND Sheet No. 6 of 6

SAMPLE TYPE OR NO. *	S	T	S	S	S	S	S	S	S	S	T	S	T	S	T	S	S	S	S	S	S	S	S	S
FOSSIL NAMES / DEPTHS metres	2640.0	2664	2707.0	2748.0	2783.0	2794.0	2835.0	2867.5	2886.0	2918.5	2949-52	2955.0	2988-91	2990.0	3018-21	3065.0	3227.0	3260.0	3290.0	3325.0	3388.0	3430.0	3490.0	3150.0
Schizocolpus sp.								•																
cf Sestrosporites		•																						
Stereisporites australis f. crassa																								
S. antiquisporites	•			•	•		•			•			•	•	•		•		•			•		•
S. punctatus ms																								
S. regium																								
S. spp. indet./undescribed		•		•	•			•	•		•	•	•				C					•		
Striatopollis sp.																								
Stoveripollis lunaris																								
taeniate bisaccates									•	•								•		•				
Tetracolporites verrucosus																								
Tetradopollis securus																								
Tricolpites confessus																	C							
T. waiparensis											C													
T. spp. indet./undescribed	•	•	•		•	•		•			•		•		•				•			•		•
Tricolporites apoxyexinus																								
T. lilliei																								
T. sp. cf T. lilliei [verrucate]																								
T. marginatus ms																								
T. spp. indet./undescribed	•	•	•																					
indeterminate trilete spores	•	•	•	•	•	•	•	•	•	•	•	•	•		•	•	•	•	•	•	•	•	•	•
Triletes tuberculiformis													•						•	•		•		
Triporopollenites sectilis																								
T. spp. indet./undescribed											•	•	•		•									
Australopollis obscurus		•	•	•	•	•	•	•	•	•	•				•									
Bassicysta keenei																						•	•	
Impagidinium spp.																								
Isabelidium coronatum																								
Nematosphaeropsis balcombiana																								
Operculodinium centrocarpum																								
Pediastrum															•									
peridinacean dinocysts					•			•		•			•			•				•		•	•	•
Protoellipsodinium simplex ms																								
Pyxidinopsis pontus ms																								
Rimosicysta cf aspera																			•				•	
R. concava																•				•		•	•	
R. cf concava																•						•	•	•
R. cf cucullata																•								
R. eversa													•							•			•	•
R. cf eversa																•				•				•
R. kipperii												•					•	•				•		
R. cf kipperii					•												•	•		•		•		
R. spp. indet./undescribed				•	•										•		•	•	•	•	•	•	•	•
Spiniferites spp.																								
Trifidicysta spp. ms																						•	•	•
Wuroia corrugata												•										•		
W. cf corrugata																				•			•	
W. cf unciformis																		•				•	•	•
indeterminate algal cysts				•			•			•	•	•	•		•		•	•		•				
Micrhystridium spp.				•																				
Spheripollenites psilatus			•								•													
Veryhackium spp.											•													

C=CORE S=SIDEWALL CORE * R = REWORKED SP.

TABLE NO.:

ADDITIONAL SWC SAMPLES: SHARK-1

Well Name ______ Basin ______ Sheet No. ______ of ______

SAMPLE TYPE OR NO. *	S	S	S
FOSSIL NAMES / DEPTHS (m)	1850.0	1880.0	2294.0
Amosopollis cruciformis	•		
Araucariacites australis		•	•
Australopollis obscurus	•		
Baculatisporites disconformis	•		
Banksieaeidites lunatus ms	•		
Basopollis spp. ms	•	•	
Camarozonosporites bullatus	•		
Clavifera triplex		•	
Cyathidites gigantis	•		
Cyathidites spp.	•	•	
Dilwynites granulatus		•	
Foveotriletes balteus	•		
Gambierina rudata	•	•	
Gleicheniidites spp.	•	•	
Haloragacidites harisii	•	•	
Jaxtacolpus pieratus ms		•	
Laevigatosporites spp.	•	•	
Lygistepollenites balmei	•	•	
L. florinii	•	•	
Microcachrydites antarcticus	•		
Myrtaceidites parvus-mesonesus	•		
Nothofagidites kaitangata	•	•	
N. flemingii	•		
Parvisaccites catastus	•		
Periporopollenites polyoratus	•	•	•
Peninsulapollis gillii	•	•	
Peromonolites densus	•	•	
Phyllocladidites mawsonii	•	•	
P. paleogenicus	•		
P. reticulosaccatus	•	•	
Podocarpidites spp.	•	•	•
Podosporites microsaccatus	•	•	•
Proteacidites annularis	•		
Proteacidites spp.	•	•	
Rugulatisporites mallatus	•		
Stereisporites punctatus	•	•	
Stereisporites spp.	•	•	
Tetracolporites multistrixus ms	•	•	
T. textus ms	•		
Tricolpites spp.	•	•	•
Tricolporites spp.	•	•	•
trilete spores	•	•	•
Verrucosisporites kopukuensis	•		
Apectodinium homomorphum	•		
Deflandrea metcalfii complex	•		
Trithryodinium evittii		•	
Paralecaniella indentata	•		
Phimopollenites pannosus			•
Proteacidites adenanthoides			•
Tricolpites confessus			•

PALYNOLOGY DATA SHEET

BASIN: GIPPSLAND ELEVATION: KB: ______ GL: ______

WELL NAME: SHARK-1 TOTAL DEPTH: ______

AGE	PALYNOLOGICAL ZONES	HIGHEST DATA Preferred Depth	Rtg	Alternate Depth	Rtg	Two Way Time	LOWEST DATA Preferred Depth	Rtg	Alternate Depth	Rtg	Two Way Time
NEOGENE	*T. pleistocenicus*										
	M. lipsis										
	C. bifurcatus										
	T. bellus										
PALEOGENE	*P. tuberculatus*										
	Upper *N. asperus*										
	Mid *N. asperus*										
	Lower *N. asperus*										
	P. asperopolus										
	Upper *M. diversus*										
	Mid *M. diversus*										
	Lower *M. diversus*										
	Upper *L. balmei*	1850.0	0				1850.0	0			
	Lower *L. balmei*	1880.0	1				1880.0	1			
LATE CRETACEOUS	Upper T. longus	1937.0	0				2030.0	2	1983.0	0	
	Lower T. longus	2074.0	1				2197.0	0			
	T. lilliei	2245.0	0				2245.0	0			
	N. senectus										
	T. apoxyexinus	2294.0	2	2377.0	1		2456.0	2	2426.0	1	
	P. mawsonii	2490.0	2	2560.5	1		3510.0	1			
	A. distocarinatus										
EARLY CRET.	*C. paradoxus*										
	C. striatus										
	F. asymmetricus										
	F. wonthaggiensis										
	C. australiensis										
	PRE-CRETACEOUS										

COMMENTS:
A. homomorpha Zone 1850.0m
T. evittii Zone 1880.0m
M. druggii Zone 1983.0m
Maximum abundance of "Kipper Shale" dinocysts 3325.0-3510.0m

CONFIDENCE RATING:
- O: SWC or Core, Excellent Confidence, assemblage with zone species of spores, pollen and microplankton.
- 1: SWC or Core, Good Confidence, assemblage with zone species of spores and pollen or microplankton.
- 2: SWC or Core, Poor Confidence, assemblage with non-diagnostic spores, pollen and/or microplankton.
- 3: Cuttings, Fair Confidence, assemblage with zone species of either spores and pollen or microplankton, or both.
- 4: Cuttings, No Confidence; assemblage with non-diagnostic spores, pollen and/or microplankton.

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

DATA RECORDED BY: M.K. Macphail DATE: 7 February 1990

DATA REVISED BY: ______ DATE: ______

APPENDIX 2

MICROPALAEONTOLOGY

APPENDIX 2
MICROPALAEONTOLOGY

MICROPALAEONTOLOGICAL ANALYSIS

SHARK-1, GIPPSLAND BASIN

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WESTERN AUSTRALIA

January, 1990.

C O N T E N T S

1. SUMMARY

Shark-1 was drilled in offshore petroleum permit Vic P/22, Gippsland Basin to a depth of 3518mKB. Sidewall cores from 1440m to 1880m have been examined for foraminifera and calcareous nannoplankton. A summary of the biostratigraphic breakdown of the respective microfossil groups and environmental sub-division is given below:-

Planktonic Foraminiferal Subdivision

1440m-1550m	:	Zone D1	Middle Miocene
1700m	:	Zone D2	Middle Miocene
1810m	:	Zone G	upper Early Miocene
1850m-1880m	:	Indeterminate	

Calcareous Nannoplankton Subdivision

1440m-1550m	:	Zone NN6	mid Middle Miocene
1700m	:	Zone NN5	lower Middle Miocene
1810m	:	Zone NN3	upper Early Miocene
1850m-1880m	:	Indeterminate	

Environment of Deposition

Samples 1440m-1510m incl.	:	middle-outer neritic
1540m & 1550m	:	outer neritic
1700m & 1810m	:	outer neritic-upper bathyal
1850m & 1880m	:	undifferentiated marine

II. INTRODUCTION

A total of 9 sidewall cores have been scrutinized for foraminifera and calcareous nannoplankton from the interval 1440m to 1880m in Shark-1. Fossil assemblages identified in the well section have been plotted on the distribution chart (Enclosure No. 1).

III. BIOSTRATIGRAPHIC ANALYSIS

The planktonic foraminiferal letter zonal scheme of Taylor (in prep.) and the NN calcareous nannoplankton zonal scheme of Martini (1971) are used for biostratigraphic subdivision.

(A) Planktonic Foraminiferal Subdivision

1. **1440m-1550m : Zone D1 (Middle Miocene)**

   The sidewall cores in the interval are assigned to Zone D1 on the basis of the association of Globorotalia miozea miozea and Globorotalia praescitula, and the lack of diverse Globigerinoides and Praeorbulina. The occurrence of Globorotalia miozea conoidea at and above 1540m is also consistent with a Zone D1 assignment.

2. **1700m : Zone D2 (Middle Miocene)**

   The association of Orbulina suturalis, Praeorbulina glomerosa and Globigerinoides cf. sicanus with Orbulina universa is consistent with a Zone D2 assignment.

3. **1810m : Zone G (upper Early Miocene)**

   Assignment to Zone G is based on the occurrence of Globigerinoides trilobus without Globigerinoides sicanus.

4. **1850m-1880m : Indeterminate**

   The samples at 1850m and 1880m are barren of foraminifera.

(B) Calcareous Nannoplankton Subdivision

1. **1440m-1550m : Zone NN6 (mid Middle Miocene)**

   The occurrence of Cyclicargolithus floridanus without Sphenolithus heteromorphous is consistent with a Zone NN6 assignment.

2. **1700m : Zone NN5 (lower Middle Miocene)**

   Assignment to Zone NN5 is based on the occurrence of Sphenolithus heteromorphous and the lack of Helicosphaera ampliaperta.

3. **1810m : Zone NN3 (upper Early Miocene)**

   The occurrence of Sphenolithus belemnos without Sphenolithus heteromorphous indicates that the sample at 1810m is Zone NN3 in age.

4. **1850m-1880m : Indeterminate**

   The samples at 1850m and 1880m are barren of calcareous nannoplankton.

IV. ENVIRONMENT OF DEPOSITION

1. Samples 1440m-1510m inclusive : Middle-outer neritic

The calcilutites in the interval are interpreted to have been deposited in a middle to outer neritic environment. The high yielding foraminiferal assemblages in the interval contain even numbers of benthonics and planktonics. The moderately diverse benthonic assemblages include Cassidulina laevigata (common), Brizalina (few-frequent), Globocassidulina subglobosa (few) and Trifarina bradyi (rare-few).

2. 1540m & 1550m : Outer neritic

The calcilutites at 1540m and 1550m contain high yielding foraminiferal faunas with the percentage of planktonics ranging from 85% at 1540m to 30-40% at 1550m. The diverse benthonic foraminiferal faunas include Cassidulinoides bradyi (few-common), Quadrimorphina (few), Gyroidina zelandica (few), Cassidulina laevigata (frequent), Brizalina (frequent-abundant), Globocassidulina subglobosa (frequent at 1550m), Trifarina bradyi (few-common), Sphaeroidina bulloides (few) and Pullenia bulloides/P. aff. bulloides (few). Deposition in an outer neritic environment is envisaged.

3. 1700m & 1810m : Outer neritic-upper bathyal

The calcilutite samples at 1700m and 1810m contain high yielding foraminiferal faunas with planktonics dominant (95%-98% of total foraminiferal fauna). The benthonic fauna includes Pleurostomella (rare-few), Gyroidina zelandica (rare-few), ? Laticarinata (rare at 1810m) and Cyclammina (few at 1810m). The calcilutites are interpreted to have been deposited in an outer neritic to upper bathyal environment.

4. 1850m & 1880m : Undifferentiated marine

Although the glauconitic siliciclastics at 1850m and 1880m are barren of foraminifera and nannoplankton, the abundance of pelletal glauconite indicates deposition in a marine environment.

V. REFERENCES

MARTINI, E., 1971. Standard Tertiary and Quaternary calcareous nannoplankton zonation. In: FARINACCI, A., (Ed). Proc. Second Planktonic Conf., Roma. : 739-785.

TAYLOR, D.J., (in prep.). Observed Gippsland biostratigraphic sequences of planktonic foraminiferal assemblages.

APPENDIX NO. 1: SUMMARY OF MICROPALAEONTOLOGICAL DATA, SHARK-1

SAMPLE (mKB)	FORAM YIELD	FORAM PRESERV.	FORAM DIVERSITY	NANNO YIELD	NANNO PRESERV.	NANNO DIVERSITY
SWC30, 1440	high	poor	moderate	high	poor	low
SWC28, 1490	high	poor	moderate	mod/high	poor	low
SWC27, 1510	high	poor	mod/high	moderate	poor	low
SWC25, 1540	high	poor	mod/high	high	mod/poor	moderate
SWC24, 1550	high	mod/good	high	high	moderate	moderate
SWC22, 1700	high	good	moderate	high	mod/good	mod/high
SWC21, 1810	high	good	moderate	high	mod/good	mod/high
SWC19, 1850	barren	-	-	barren	-	-
SWC18, 1880	barren	-	-	barren	-	-

PE905007

This is an enclosure indicator page.
The enclosure PE905007 is enclosed within the container PE905003 at this location in this document.

The enclosure PE905007 has the following characteristics:

ITEM_BARCODE = PE905007
CONTAINER_BARCODE = PE905003
NAME = Micropalaeontological Chart
BASIN = GIPPSLAND
PERMIT = VIC/P22
TYPE = WELL
SUBTYPE = DIAGRAM
DESCRIPTION = Micropalaeontological Distribution Chart for Shark-1
REMARKS =
DATE_CREATED = 28/02/90
DATE_RECEIVED = 6/04/90
W_NO = W1013
WELL_NAME = SHARK-1
CONTRACTOR =
CLIENT_OP_CO = SHELL AUSTRALIA

(Inserted by DNRE - Vic Govt Mines Dept)

APPENDIX 3

PETROPHYSICS

APPENDIX 3
PETROPHYSICS

APPENDIX 3

PETROPHYSICAL ANALYSIS

WIRELINE LOGS (all depths are logging depths in metres below derrick floor)

The following rieline logs were run:

Date	Hole Size	Run	Interval	Type
5/11/89	17-1/2"	1	1204-685m	DLL/SLS/GR/CAL
	20" csg	1	685-350m	GR
12/11/89	12-1/4"	1	2194-1200m	DLL/BCSL/LDL/CNL /GR/MSFL/CAL/AMS (CNL & MSFL to 1750M)
		2	2200/1750M	SHDT/GR
		3	2197-1750M	CST/GR
28/11/89	8-1/2"	1	3519-2230M	DLL/BCSL/LDL/CNL/ GR/MSFL/CAL/AMS
	9-5/8" csg	1	2230-2170m	CNL/GR
29/11/89	8-1/2"	2	3522-2230m	SHDT/GR
		3	3518-700m	WST
		4	3510-2241m	CST/GR

EVALUATION

GENERAL

Petrophysical evaluation indicates the objective Latrobe and Golden Beach Groups to be entirely water-bearing. No significant above-background mud gas readings were recorded.

FACTORS AFFECTING LOG EVALUATION

Hole washouts 2369-2525m:

A neutron/sonic combination was used instead of the density/neutron curves for determination of porosity between 2369 and 2525m where hole rugosity and resultant density correction were deemed excessive.

Determination of A, m, n, RHOMA and Qv.

Values of 2.098 for the cementation exponent m, 1.84 for the saturation exponent n and 2.66 g/cc for matrix density were used in the evaluation of the Latrobe sandstones. These parameters were derived from Basker-1 and Manta-1 Latrobe Group core analyses.

No core-derived values for the parameters A, m and n were available for the Golden Beach Group; the following default values were used:

m = 2.00
n = 2.00
A = 1.00

In the absence of Qv data both in the Latrobe and Golden Beach sections, the shaly sand Indonesia equation was used for calculation of hydrocarbon saturations.

Rw determination

Resistivity of the formation water was derived using the Rwa technique ($Rwa = \frac{Rt * Por^m}{A}$) over low resistivity sands where no above-background mud gas was recorded. Relatively constant Rw's of 0.04 to 0.06 ohmm corresponding to an NaCl equivalent salinity of 80000 to 65000 ppm were calculated for the Latrobe and Golden Beach sections.

Cased Hole Logging 2174-2231m:

The section between 2174 and 2231m was not logged in open hole. The CNL and GR surveys were run through 9-5/8" casing but did not allow a complete petrophysical evaluation.

EVALUATION PROCEDURE

Menu Structure

The following steps were used in the petrophysical evaluation of Shark-1:

Preliminary Lithology Calculation

- Correct GR for borehole effects (Chart POR-7m)
- Calculate fraction of shale (V_{SH} from GR)
- Apply cutoffs for sst/sh definition
  sst : $V_{SH} \leq 50\%$
  sh : $V_{SH} > 50\%$
- Correct FDC for borehole effects (Chart POR-15a)
- Apply cutoff for coal definition: coal : FDC $\leq$ 2.0 g/cc

Preliminary Rwa Calculation over Apparently Water-bearing Sandstones.

- Correct LLD, LLS and MSFL for borehole effects (Charts R_{cor}-2 and R_{xo}-2)
- Calculate diameter of invasion and true resistivity (R_T) from corrected MSFL, LLS and LLD
- Correct FDC for borehole effects (Chart POR-15a)

- Calculate porosity from density or neutron/sonic combination.
- Calculate Rwa from porosity and true resistivity

- Latrobe Group (1915-2174m and 2231-2269m):

- Correct GR for borehole effects (Chart POR-7m)
- Calculate V_{SH} from GR
- Correct LLD, LLS and MSFL for borehole effects (Charts R_{cor}-2 and R_{xo}-2)
- Calculate diameter of invasion and true resistivity from corrected MSFL, LLS and LLD.
- Correct FDC for borehole effects (Chart POR-15a)
- Calculate porosity from density log
- Calculate hydrocarbon saturation using the Indonesia equation for shaly sands.

Latrobe Group - Cased Hole (2174-2231m):

- Lithology evaluation
- No calculation of porosity and hydrocarbon saturation.

Golden Beach (2369-2525m); Poor Hole Section:

- Preliminary corrections/calculations as above.
- Iterative calculation of porosity, detailed lithology and apparent matrix travel time from neutron/sonic combination.
- Calculate hydrocarbon saturation using the Indonesia equation for shaly sands.

Golden Beach (2525-3503m); Good Hole Section:

- Preliminary corrections/calculations as above
- Iterative calculation of porosity, detailed Lithology and apparent matrix density from neutron/density combination.
- Calculate hydrocarbon saturation using the Indonesia equation for shaly sands.

Petrophysical Parameters

	Interval (m)			
	1915-2174 (Latrobe)	2174-2231 (Latrobe)	2231-2369 (Latrobe)	2369-3503 (Golden Beach)
Hole size (inches)	12 1/4	12 1/4	8 1/2	8 1/2
GR_{ma} (API)	28	28	42	22
GR_{sh}	135	135	135	107
R_m (ohmm)	0.123		0.15	0.125
R_{mc}	0.131		0.26	0.21
R_w	0.053		0.06	0.04
R_{sh}	5.0		6.0	7.0
A	1.00		1.00	1.00
m	2.098		2.098	2.000
n	1.84		1.84	2.000
RHO_{ma} (g/cc)	2.66		2.66	Calculated Curve
RHO_{mud}	1.10		1.15	1.15
RHO_{mf}	1.00		1.00	1.00

EVALUATION SUMMARY

No net hydrocarbon zones above the porosity and hydrocarbon saturation cutoffs (10% and 50% respectively) were identified from logs. Results of the analysis are tabulated below:

	Interval (mBRT)			
	1915-2369 (Latrobe)	2369-2917 (UGB)*	2917-3338 (Kipper Shale)	3338-3503 (LGB)*
Gross Thickness (m)	454	548	421	165
Net Sst (m)	275	213	42	41
Average Porosity (net sst)	20%*	11%	8%	8%
Net Sst/Gross	60%	39%	10%	25%
Net Porous sst($\geq$10%) (m)	218*	154	15	10
Average Porosity (net porous sst)	21%*	13%	12%	11%
Net Porous Sst/Gross	55%*	28%	3%	6%
S_H Average	16%	14%	18%	7%

* Does not include unevaluated sst behind 9 5/8" casing from 2174-2231m

* UGB - Upper Golden Beach Group.
* LGB - Lower Golden Beach Group.

PE603638

This is an enclosure indicator page.
The enclosure PE603638 is enclosed within the container PE905003 at this location in this document.

The enclosure PE603638 has the following characteristics:

ITEM_BARCODE = PE603638
CONTAINER_BARCODE = PE905003
NAME = Petrophysical Evaluation Log
BASIN = GIPPSLAND
PERMIT = VIC/P22
TYPE = WELL
SUBTYPE = WELL_LOG
DESCRIPTION = Petrophysical Evaluation Summary Log for Shark-1
REMARKS =
DATE_CREATED = 31/12/89
DATE_RECEIVED = 6/04/90
W_NO = W1013
WELL_NAME = SHARK-1
CONTRACTOR =
CLIENT_OP_CO = SHELL AUSTRALIA

(Inserted by DNRE - Vic Govt Mines Dept)

APPENDIX 4

GEOCHEMISTRY

APPENDIX 4
GEOCHEMISTRY

PETROLEUM GEOCHEMISTRY

SHARK 1

DATA REPORT

Prepared for :

THE SHELL COMPANY OF AUSTRALIA LTD.

March 1990

ANALABS

A Division of Inchcape Inspection and Testing Services Pty. Ltd.

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TABLE 1

ROCK-EVAL PYROLYSIS DATA (one run)

WELLNAME = SHARK 1 DATE OF JOB = NOVEMBER 1989

DEPTH(m)	TMAX	S1	S2	S3	S1+S2	S2/S3	PI	PC	TOC	HI	OI
1937.0	422	0.59	1.12	0.32	1.71	3.50	0.35	0.14	1.02	109	31
1983.0	475	0.08	1.18	0.52	1.26	2.27	0.06	0.10	0.55	214	94
2025.5	429	0.06	0.94	1.28	1.00	0.73	0.06	0.08	0.71	132	180
2064.5	416	1.23	25.91	0.60	27.14	43.18	0.05	2.25	8.60	301	6
2105.0	415	4.31	149.50	3.62	153.81	41.30	0.03	12.77	48.10	310	7
2150.0	425	0.23	5.55	0.41	5.78	13.54	0.04	0.48	1.65	336	24
2377.0	nd	nd	nd	nd	nd	nd	nd	nd	0.49	nd	nd
2390.0	431	0.13	1.63	5.14	1.76	0.32	0.07	0.15	0.98	166	524
2426.0	434	0.15	3.68	0.34	3.83	10.82	0.04	0.32	2.35	156	14
2456.0	432	0.08	0.58	0.89	0.66	0.65	0.12	0.05	0.61	95	145
2490.0	438	0.04	0.89	0.35	0.93	2.54	0.04	0.08	1.70	52	20
2524.0	435	0.08	0.83	1.84	0.91	0.45	0.09	0.08	0.96	86	191
2528.0	435	0.20	8.56	0.35	8.76	24.46	0.02	0.73	3.42	250	10
2560.5	438	0.08	1.05	0.31	1.13	3.39	0.07	0.09	1.65	63	18
2573.0	425	0.75	38.00	1.55	38.75	24.52	0.02	3.22	20.50	185	7
2593.0	431	0.21	12.83	0.67	13.04	19.15	0.02	1.08	4.33	296	15
2630.0	433	0.25	9.16	0.93	9.41	9.85	0.03	0.78	4.22	217	22
2640.0	433	0.17	3.68	2.87	3.85	1.28	0.04	0.32	3.58	102	80
2707.0	427	1.30	84.60	2.20	85.90	38.45	0.02	7.13	29.84	283	7
2748.0	434	0.13	2.67	2.31	2.80	1.16	0.05	0.23	2.52	105	91
2783.0	433	0.37	5.88	1.29	6.25	4.56	0.06	0.52	3.17	185	40
2794.0	434	0.26	10.42	0.46	10.68	22.65	0.02	0.89	4.88	213	9
2835.0	434	0.35	8.83	3.38	9.18	2.61	0.04	0.76	5.80	152	58
2867.5	431	0.46	75.81	0.53	76.27	143.04	0.01	6.33	7.35	1031	7
2886.0	437	0.26	3.95	2.02	4.21	1.96	0.06	0.35	3.50	112	57
2918.5	439	0.06	0.93	3.36	0.99	0.28	0.06	0.08	1.19	78	282
2955.0	437	0.06	0.93	5.90	0.99	0.16	0.06	0.08	1.15	80	513
2990.0	438	0.11	1.79	5.05	1.90	0.35	0.06	0.16	2.21	80	228
3065.0	435	0.09	1.39	2.55	1.48	0.55	0.06	0.12	1.55	89	164
3226.0	429	0.38	7.31	0.98	7.69	7.46	0.05	0.64	2.71	269	36
3227.0	440	0.19	1.54	1.55	1.73	0.99	0.11	0.14	1.58	97	98
3260.0	437	0.14	1.39	9.98	1.53	0.14	0.09	0.13	1.70	81	587
3290.0	439	0.11	1.62	1.99	1.73	0.81	0.06	0.14	1.70	95	117
3325.0	440	0.13	1.83	1.26	1.96	1.45	0.07	0.16	1.70	107	74
3388.0	438	0.15	1.37	1.12	1.52	1.22	0.10	0.13	1.24	110	90
3430.0	438	0.25	1.95	1.14	2.20	1.71	0.11	0.18	1.45	134	78
3490.0	442	0.17	2.04	0.68	2.21	3.00	0.08	0.18	2.17	94	31
3510.0	434	1.09	4.20	2.18	5.29	1.93	0.21	0.44	2.00	210	108

TMAX = Max. temperature S2
S1 = Volatile hydrocarbons (HC)
S2 = HC generating potential
S1+S2 = Potential yield
S3 = Organic carbon dioxide
PI = Production index
PC = Pyrolysable carbon
TOC = Total organic carbon
HI = Hydrogen index
OI = Oxygen Index
nd = no data

SHARK NO. 1

K.K. No.	Depth (m)	$\bar{R}_v$ max	Range	N	Description Including Liptinite (Exinite) Fluorescence
v1849	1937 SWC 16	0.42	0.29-0.61	28	Rare sporinite, yellow to orange, rare cutinite and resinite, yellow to dull orange, rare resinite. (Sandstone>siltstone>shaly coal. Shaly coal rare, vitrinite only. Vitrite. Dom common, I>V>L. Inertinite common, vitrinite sparse, liptinite rare. Pyrite abundant. Iron oxide sparse.)
v1850	1983 SWC 15	0.39	0.31-0.51	28	Common sporinite, yellow to orange, sparse cutinite, yellow to orange, sparse liptodetrinite, yellow to dull orange, rare resinite, yellow. (Sandstone> siltstone> shaly coal>coal. Coal rare to sparse, vitrinite only. Vitrite. Shaly coal common, V>L>I. Vitrite>>clarite. Dom abundant, V>L>I. Vitrinite and liptinite common, inertinite sparse to common. Pyrite abundant. Iron oxide sparse.)
v1851	2025.5 SWC 13	0.38	0.29-0.52	29	Sparse sporinite and cutinite, yellow to orange, rare liptodetrinite, yellow to orange. (Siltstone>carbonate> shaly coal. Shaly coal common, V>I>L. Vitrite>vitrinertite(I). Dom abundant, V>I>L. Vitrinite and inertinite common, liptinite sparse. Pyrite and iron oxide common.)
v1852	2064.5 SWC 10	0.42	0.33-0.49	27	Common cutinite, orange to dull orange, sparse sporinite and liptodetrinite, yellow to orange, rare resinite, yellow to dull orange, rare suberinite, non fluorescing. (Siltstone>shaly coal>coal. Coal sparse, V>L>I. Vitrite. Shaly coal abundant, V>I>L. Vitrite>>inertite. Dom abundant, V>L>I. Vitrinite abundant, liptinite and inertinite common. Pyrite abundant. Iron oxide sparse.)
v1853	2105 SWC 7	0.47	0.38-0.61	28	Abundant sporinite, yellow to dull orange, common to abundant cutinite, yellow to dull orange, sparse liptodetrinite, yellow to dull orange. sparse suberinite, dull orange to brown. (Coal>shaly coal>claystone. Coal dominant, V>I>L. Duroclarite>clarite>vitrite. Shaly coal common, V>I>L. Duroclarite>clarite>vitrite. Dom common, V>I>L. Vitrinite common, inertinite and liptinite sparse. Pyrite common. Iron oxide sparse.)
v1854	2150 SWC 4	0.44	0.31-0.56	27	Common cutinite, yellow to dull orange, sparse sporinite, yellow to dull orange. sparse resinite, yellow, rare liptodetrinite, yellow to orange. (Sandstone>siltstone>claystone. Dom abundant, I>V>L. Inertinite abundant, vitrinite common to abundant, liptinite common. Pyrite and iron oxide sparse.)

SHARK NO. 1

K.K. No.	Depth (m)	$\bar{R}_v$ max	Range	N	Description Including Liptinite (Exinite) Fluorescence
v2029	2456 SWC 51	0.63	0.50-0.73	27	Sparse liptodetrinite, yellow to dull orange, rare phytoplankton, yellow to orange, rare sporinite and cutinite, yellow to dull orange. (Siltstone>>carbonate>>coal. Coal sparse, V only. Vitrite. Dom common, I>L>V. Inertinite common, liptinite sparse and vitrinite rare. Abundant fossil tests. Mineral fluorescence abundant, dull orange. Pyrite and iron oxide common.)
v2030	2490 SWC 49	0.86	0.61-0.93	25	Rare liptodetrinite and resinite, yellow to orange, rare cutinite and sporinite, orange to dull orange, rare phytoplankton, orange. (Sandstone>siltstone. Dom abundant, I>V>>L. Inertinite common, vitrinite common, liptinite rare. Rare bitumen, yellow to orange. Common pyrite and iron oxide.)
v2031	2528 SWC 46	0.50	0.43-0.56	23	Common cutinite, orange to brown, sparse sporinite and liptodetrinite, yellow to brown, rare resinite, yellow, rare suberinite, brown to non fluorescing. (Claystone> siltstone. Dom abundant, V>I>L. Vitrinite common, inertinite common, liptinite common. Common iron oxide and pyrite.)
v2032	2573 SWC 44	0.58	0.48-0.78	27	Common sporinite, orange to brown, sparse cutinite and liptodetrinite, orange to brown, sparse suberinite, brown to non fluorescing. (Siltstone>>claystone>coal. Coal abundant, V>L=I. Vitrite. Dom abundant, V>L>I. Vitrinite abundant, liptinite and inertinite common. Common iron oxide and pyrite.)
v2033	2640 SWC 41	0.60	0.45-0.73	27	Sparse to common cutinite, yellow to brown, sparse liptodetrinite, yellow to dull orange, rare sporinite, yellow to dull orange. (Siltstone>>shaly coal>coal. Coal rare, V only. Vitrite. Shaly coal sparse, V>I>L. Vitrite. Dom abundant, I>V>L. Inertinite abundant, vitrinite and liptinite common. Pyrite sparse. Iron oxide rare.)
v2034	2707 SWC 36	0.61	0.54-0.68	26	Common sporinite, cutinite and liptodetrinite, orange-brown, sparse resinite, yellow to orange, rare suberinite, brown to non fluorescing. (Shaly coal>coal. Coal major, V>E>I. Clarite>vitrite>>trimacerite. Shaly coal dominant, V>E>I. Clarite>vitrite>trimacerite. Mineral fluorescence rare, yellow to orange. Pyrite rare.)

SHARK NO. 1

K.K. No.	Depth (m)	$\bar{R}_v$ max	Range	N	Description Including Liptinite (Exinite) Fluorescence
v2035	2757 SWC 33	0.64	0.54-0.72	26	Abundant sporinite, yellow to brown, sparse to common cutinite and resinite, orange to brown, sparse to common liptodetrinite, yellow to dull orange, sparse fluorinite/bitumen, greenish yellow. (Shaly coal>coal> or=siltstone. Coal major, V>L>I. Vitrite>clarite> duroclarite. Shaly coal dominant, V>I>L. Clarite> vitrite>duroclarite>vitrinertite>inertite. Dom abundant, V>L>I. Vitrinite abundant, liptinite and inertinite common. Sparse Sparse oil drops and oil haze yellow. Pyrite and iron oxide sparse.)
v2036	2794 SWC 31	0.64	0.55-0.83	28	Common cutinite orange to brown, sparse sporinite and liptodetrinite, orange to brown, sparse resinite, yellow to dull orange, sparse fluorinite/bitumen, greenish yellow. (Siltstone>coal>shaly coal. Coal abundant, V>L>I. Vitrite>>clarite. Shaly coal abundant, V>L>I. Vitrite>clarite. Dom abundant, V>I>L. Vitrite abundant, inertinite and liptinite common. Pyrite and iron oxide sparse.)
v2037	2867.5 SWC 28	0.60	0.51-0.68	26	Common cutinite and sporinite orange to dull orange, sparse liptodetrinite, orange to dull orange. (Claystone>siltstone>shaly coal. Shaly coal rare, V>I>L. Vitrite. Dom abundant, V>or=I>L. Vitrinite and inertinite abundant, liptinite common. Pyrite sparse to common. Iron oxide sparse.)
v2038	2900 SWC 25	0.53	0.39-0.65	27	Abundant sporinite, orange to brown, common <u>Botryococcus</u> related telalginite, yellow to orange, common resinite, yellow to brown, common cutinite, orange to brown. (Shaly coal>claystone>coal. Coal rare, V only. Vitrite. Shaly coal dominant, I>V>or=L. Duroclarite>durite. Coal is canneloid. This low reflectance matrix may be referable to bituminite but has been classified here as vitrinite as it is most closely related to detrovitrinite. Dom abundant, I>L>V. Inertinite common to abundant, liptinite and vitrinite common. Pyrite and iron oxide sparse.)
v2039	3065 SWC 19	0.61	0.47-0.67	19	Rare to sparse cutinite, orange to dull orange, rare sporinite, orange to dull orange. (Siltstone. Dom abundant, I>V>L. Inertinite abundant, vitrinite common, liptinite rare to sparse. Pyrite and iron oxide sparse.)

K.K. No.	Depth (m)	$\bar{R}_v$ max	Range	N	Description Including Liptinite (Exinite) Fluorescence
v2040	3226 SWC 14	0.56	0.43-0.73	28	Sparse cutinite, orange to brown, rare sporinite, orange to dull orange, rare resinite, yellow to dull orange. (Sandstone>shaly coal>siltstone>coal. Coal sparse, V>>L>I. Vitrite. Shaly coal abundant, V>I>L. Vitrite>vitrinertite>inertite. Dom abundant, V>I>L. Vitrinite abundant, inertinite common, liptinite rare to sparse.)
v2041	3290 SWC 10	0.65	0.46-0.84	17	Sparse cutinite, orange to brown, rare sporinite, orange to dull orange. (Siltstone>carbonate. Dom abundant, I>V>L. Inertinite abundant, vitrinite and liptinite sparse. Pyrite and iron oxide sparse.)
v2042	3355 SWC 7	0.79	0.69-0.90	26	Common cutinite and sporinite, orange to brown, common liptodetrinite, yellow to dull orange, sparse resinite, yellow to dull orange. (Shaly coal>claystone>coal. Coal major, V>I>L. Vitrite>>inertite. Shaly coal dominant, V>L>I. Clarite>vitrite. Dom abundant, V>I>L. Vitrinite abundant, inertinite and liptinite common. Sparse bitumen, greenish yellow. Sparse oil drops, yellow. Sparse pyrite. Rare iron oxide.)
v2043	3430 SWC 4	0.73	0.58-0.89	24	Sparse cutinite and liptodetrinite, orange to brown, rare sporinite, orange to dull orange. (Siltstone> claystone. Dom abundant, I>V>L. Inertinite common to abundant, vitrinite common, liptinite sparse. Pyrite and iron oxide sparse.)
v2044	3490 SWC 2	0.76	0.60-0.93	27	Sparse to common cutinite and sporinite, orange to dull orange, sparse to common liptodetrinite, yellow to dull orange, sparse resinite, dull orange. (Siltstone> carbonate. Dom abundant, I>V>L. Inertinite abundant, vitrinite common, liptinite sparse to common. Rare oil drops in siltstone. Rare glauconite. Iron oxide and pyrite rare.)
v2045	3510 SWC 1	0.76	0.62-0.95	26	Sparse cutinite and sporinite, orange to dull orange, sparse phytoplankton and liptodetrinite, yellow to orange, rare to sparse resinite, dull orange. (Siltstone>carbonate. Dom abundant, I>V>L. Inertinite abundant, vitrinite common, liptinite sparse. Rare bright yellow fluorescence from bitumen/oil drops. Rare glauconite. Iron oxide and pyrite rare to sparse.)

THEORY AND METHODS

This section details a series of geochemical methods which are commonly used in our laboratory, including those used to obtain the data presented in this report. Where applicable, the discussion is accompanied by a summary of the general theory used to interpret the data generated by each method.

1. SEDIMENTARY GAS ANALYSIS

a) Headspace Analysis

Headspace analysis is carried out using sealed containers (usually tinned cans) of wet cuttings. The containers are approximately three quarters filled with the cuttings and water to leave an appreciable headspace into which volatile hydrocarbons contained in the cuttings diffuse.

After covering about 1cm2 of the container lid with silicone and allowing the silicone to dry, the procedure involves placing a small hole in the lid through the silicone, then sampling an aliquot of the headspace gas with a gas injection syringe, and finally gas chromatographing this sample of gas under the following conditions: instrument = Shimadzu GC-8APF; column = 6' x 1/8" Chromosorb 102; column temperature = 110 Deg. C; carrier gas = nitrogen at 23mls/min; injector temperature = 120 Deg. C.; analysis cycle = C1-C4 components are flushed from the column in the forward direction and then the C5-C7 compounds are removed from the column by backflushing.

The integrated areas of peaks representing each of the C1-C7 components of the headspace gas are compared to the areas of corresponding components of a standard gas of known composition. The calculated amount of each component in the sample gas is adjusted for the total headspace volume and reported as ppm (parts of gas per million parts of sediment by volume).

Data from headspace analysis is commonly used to identify the zone of oil generation by plotting gas wetness (C2-C4/C1-C4) expressed as a % against sediment burial depth. Gas containing appreciable quantities of C2-C4 components, termed wet gas (Fuex, 1977), is generally considered to be gas associated with oil generation. In addition, the ratio of isomeric butanes can sometimes be used for assessment of sediment maturity (Alexander et. al., 1981). The amount of gas in sediments can be used to identify zones of significant gas generation and out-of-place gas (LeTran et. al., 1975).

b) Cuttings Gas Analysis

This analysis is the same as Headspace Analysis with the exception that instead of analysing the gas in the container headspace, a known volume of the wet cuttings are transferred to the blender bowl of a Kenwood electronic blender with the lid modified to incorporate a septum, water at 75 Deg. C is added to leave a headspace of 160ml, and the mixture is blended at maximum speed for 2 minutes. Following a 2 minute settling period 1ml of the blending bowl headspace gas is analysed as described in section 1a.

It is recommended that for the most meaningful gas data both headspace and cuttings gas analysis are carried out. In such cases we provide tabulations of the headspace, gas, and combined headspace/cuttings gas data. Normally, the combined data is used for plotting purposes.

2. SAMPLE PREPARATION

a) Cuttings

Cuttings samples are inspected by our qualified geological staff and then water washed according to the drilling mud content and lithology. In special cases (e.g. diesel contamination) it is necessary to lightly solvent wash samples. After washing, the samples are air dried, either sieved or picked free of cavings, and crushed to 0.1mm using a ring pulveriser.

b) Sidewall Cores

Sidewall samples are freed of mud cake and any other visible contaminants, and are also inspected for lithologic homogeneity. For homogeneous samples, the minimum amount of material required for the requested analyses is air dried and handcrushed to 0.1mm. For non-homogeneous samples, the whole sample is air dried and handcrushed to 0.1mm.

c) Conventional Core and Outcrop Samples

These sample types are firstly inspected for visible contaminants, and where applicable, are freed of these contaminants to the best of our ability. Commonly, the surface of conventional core and outcrop samples are lightly solvent washed. The samples are then crushed to approximately 1/8" chips using a jaw crusher, air dried, and finally further crushed to 0.1mm using a ring pulveriser.

d) Petroleum/Aqueous Mixtures

The most common sample type in this category are RFT tests containing oil, water and mud. The mixture is placed in a separation funnel and allowed to stand for several hours which enables the petroleum and water/mud fractions to separate. The neat petroleum is isolated by removal of the lower layer (water/mud) from the funnel. To remove the last traces of water and mud, the neat petroleum is centrifuged at moderate speed.

When the volume of petroleum accounts for only a very small part of the sample the method above is unsatisfactory and the petroleum is solvent extracted from the mixture with dichloromethane. The petroleum is recovered by careful evaporation of the solvent from the organic layer.

3. TOTAL ORGANIC CARBON DETERMINATION

The total organic carbon value (TOC) is determined on the unextracted sediment sample. The value is determined by treating a known weight of sediment with hot dilute HCl for 1 hour to remove carbonate minerals, and then heating the residue to 1700 Deg. C (Leco Induction Furnace CS-044) in an atmosphere of pure oxygen. The carbon dioxide produced is transferred to an infra-red detector which has been calibrated with a series of standards, and the microprocessor of the Leco unit then automatically calculates the % TOC in the sample. To ensure reliable data a standard is run after every 10 samples, regular sample repeats are carried out, and at least one blank determination is carried out for each batch of samples.

The following scales are normally used for source rock classification based on % TOC data:

Classification	Clastics	Carbonates
Poor	0.00 - 0.50	0.00 - 0.25
Fair	0.50 - 1.00	0.25 - 0.50
Good	1.00 - 2.00	0.50 - 1.00
Very Good	2.00 - 4.00	1.00 - 2.00
Excellent	> 4.00	> 2.00

4. ROCK-EVAL PYROLYSIS

Although a preliminary source rock classification is made using TOC data a more accurate assessment accounting for organic source type and maturity is made by pyrolysis analysis. Two types of Rock-Eval pyrolysis services are offered: "one run" which involves pyrolysis of the crushed but otherwise untreated sediment and "two run" which involves pyrolysis of both the crushed, untreated sediment and sediment which has been rendered free of carbonate minerals by treatment with hot dilute HCl. The two run service offers considerably more reliable S3 data.

The method involves accurately weighing approximately 100mg of the sample into a sintered steel crucible and subjecting it to the following pyrolysis cycle:

Stage (i) - Sample purged with helium for 3.5 minutes in unheated part of pyrolysis furnace;

Stage (ii) - Sample heated at 300 Deg. C for 3 minutes to liberate free petroleum (S1 peak);

Stage (iii) - Sample heated from 300 Deg. C to 550 Deg. C at 25 Deg. C/minute to produce petroleum from kerogen (S2 peak). The furnace is maintained at 550 Deg. C for one minute. Carbon dioxide produced during this pyrolysis up to 390 Deg. C in the case of "one run" and 550 Deg. C for "two run" is absorbed on a molecular sieve trap;

Stage (iv) - During the cool down period the carbon dioxide produced during pyrolysis is measured (S3 peak).

The units used for Rock-Eval data are as follows:

S1, S2, S3 = kg/tonne or mg/g of rock

Tmax = Deg. C

Hydrogen Index = $\frac{S2}{TOC} \times \frac{100}{1}$

Oxygen Index = $\frac{S3}{TOC} \times \frac{100}{1}$

Rock-Eval data is most commonly used in the following manner:

(i) S1 - indicates the level of oil and or/gas already generated by the sample according to the following scale:

S1 (mg/g or kg/tonne)	Classification
0.00 - 0.20	Poor
0.20 - 0.40	Fair
0.40 - 0.80	Good
0.80 - 1.60	Very Good
> 1.60	Excellent

(ii) S1+S2 - referred to as the genetic potential this parameter is used for source rock classification according to the following criteria:

S1+S2 (mg/g or kg/tonne)	Classification
0.00 - 1.00	Poor
1.00 - 2.00	Marginal
2.00 - 6.00	Moderate
6.00 - 10.00	Good
10.00 - 20.00	Very Good
> 20.00	Excellent

(iii) S1/(S1+S2)- this parameter is the production index (PI) which is a measure of the level of maturity of the sample. For oil prone sediments, values less than 0.1 are indicative of immaturity, the values increase from 0.1 to 0.4 over the oil window and values greater than 0.4 represent over maturity. For gas prone sediments, the PI data shows a relatively smaller change with increasing maturity.

(iv) Tmax - the temperature corresponding to the S2 maxima. This temperature increases with increasingly mature sediments. Values less than 430 Deg. C are indicative of immaturity while values from 430/435 to 460 Deg. C represent the maturity range of the oil window. Tmax values greater than 460 Deg. C are indicative of over maturity.

(v) HI, OI - the hydrogen ((S2 x 100)/TOC) and oxygen ((S3 x 100)/TOC) indices when plotted against one another provide information about the type of kerogen contained in the sample and the maturity of the sample. Both parameters decrease in value with increasing maturity. Samples with large HI and low OI are dominantly oil prone and conversely samples with low HI and large OI are at best gas prone.

5. EXTRACTION OF SEDIMENT SAMPLES

Crushed sediment (maximum of 250g) and 300mls of purified dichloromethane are placed in a 500ml conical flask and are then blended for ten minutes with a Janke and Kunkel Ultra-Turrax T45/2G high efficiency disperser. After a ten minute settling period the solvent is separated from the sediment using a large Buchner filtration system. The extract is recovered by careful evaporation of the solvent on a steam bath and weighed. The weight of extract is used to calculate % EOM and ppm EOM using the following formulae:

$$\%\ EOM = \frac{Wt\ EOM}{Wt\ Sediment\ Extracted\ (g)} \times \frac{100}{1}$$

$$ppm\ EOM = \frac{Wt\ EOM\ (mg)}{Wt\ Sediment\ Extracted\ (kg)}$$

The following scale is used to classify the source rock richness of samples based on C12+ extractables:

Classification	ppm Total Extract
Poor	0 - 500
Fair	500 - 1000
Good	1000 - 2000
Very Good	2000 - 4000
Excellent	> 4000

6. SEPARATION OF PETROLEUM INTO CONSTITUENT FRACTIONS

Sediment extracts and crude oil or condensate samples are separated into saturate, aromatic and NSO (asphaltenes plus resins) fractions by medium pressure liquid chromatography (MPLC). That part of the petroleum which is soluble in pentane is applied to the MPLC system via a sample loop and is then pumped using pentane to a partially activated silicic acid pre-column which prevents further movement of the non-hydrocarbon compounds. The hydrocarbon components are pumped further to a Merck Si60 column where the saturate fraction is obtained by forward flushing and the aromatic fraction is recovered by reverse flushing. This separation procedure is monitored using a refractive index detector. To complete the separation the pre-column is removed from the MPLC system and flushed with dichloromethane: methanol (1:10). This non-hydrocarbon fraction is combined with the pentane insoluble material which is not applied to the MPLC system, and is labelled as the NSO fraction. The neat fractions are recovered by careful removal of the solvent by distillation and are weighed.

The weight of each fraction is used to calculate the % of each fraction in the sediment according to the following formulas:

$$\%\ Fraction = \frac{Wt\ Fraction}{Wt\ all\ Fractions} \times \frac{100}{1}$$

$$ppm\ Fraction = \frac{Wt\ Fraction\ (mg)}{Wt\ Sediment\ Extracted\ (kg)}$$

The ppm hydrocarbon (saturates and aromatics) and ppm saturate values can be used to classify source rock richness and oil source potential respectively according to the following criteria:

Classification	ppm Hydrocarbon	ppm Saturates
Poor	0 - 300	0 - 200
Fair	300 - 600	200 - 400
Good	600 - 1200	400 - 800
Very Good	1200 - 2400	800 - 1600
Excellent	> 2400	> 1600

The composition of the extracts can also provide information about their levels of maturity and/or source type (LeTran et. al., 1974; Philippi, 1974). Generally, marine extracts have relatively low concentrations of saturated and NSO compounds at low levels of maturity, but these concentrations increase with increased maturation. Terrestrially derived organic matter often has a low level of saturates and large amount of aromatic and NSO compounds irrespective of the level of maturity.

N.B. If requested by a client the NSO fraction is separated into asphaltenes and resins by conventional methods.

7. EXTRACTABLE/TOTAL ORGANIC CARBON RATIOS

The ratios of EOM(mg)/TOC(g) and SAT(mg)/TOC(g) are determined from the appropriate data. The EOM(mg)/TOC(g) ratio can be used as a maturation indicator, especially if the parameter is plotted against depth for a given sedimentary sequence. In an absolute sense it is less reliable as a maturation indicator, although previous work (Tissot et. al., 1971; LeTran et. al., 1974) suggests that the following criteria can be used to determine maturity with this parameter.

< 50	Low maturity
50 - 100	Moderate maturity
> 100	High maturity

The ratios of EOM(mg)/TOC(g) and SAT(mg)/TOC(g) can be used collectively to provide information about source type. For example, if SOM(mg)/TOC(g) is > 100, suggesting a high level of maturity, but the SAT(mg)/TOC(g) < 20 it is very likely that the organic matter is gas prone. Conversely, the same EOM(mg)/TOC(g) value with a SAT(mg)/TOC(g) value > 40 suggests oil prone source type.

8. PYROLYSIS GAS CHROMATOGRAPHY

Pyrolysis-gas chromatography (PGC) incorporates a Chemical Data System Pyroprope 150 flash pyrolysis unit interfaced with a capillary gas chromatograph. A sample (5-10mg) of extracted sediment is placed in a quartz tube inside the element coil of the pyrolysis probe and is then heated to 610 Deg. C in a few milliseconds, and is maintained at this temperature for 20 seconds. Products generated from the pyrolysis are swept onto the bonded phase capillary column of the gas chromatograph and are chromatographed from -20 Deg. C (isothermal for two minutes) to 280 Deg. C at 4 Deg. C/minute. The product distribution is dominated by the nature of the kerogen from which it is derived.

9. C12+ GAS CHROMATOGRAPHY

C12+ gas chromatography is commonly carried out on the saturate fraction but in certain instances is carried out on neat oil, condensate or extract. The analysis is carried out under the following conditions: instrument = Shimadzu GC-9A; column = 50m x 0.2mm ID OV101 vitreous silica; column temperature = programmed from 60 Deg. C to 280 Deg. C at 4 Deg. C/min; injection system = Grob splitless using a 30 second dump time and split ratio of 25:1, carrier gas = hydrogen at 2mls/min; sample = 1μl of 0.5% soln in pentane.

The following information is commonly obtained from C12+ gas chromatographic analysis:

(a) n-Alkane Distribution - The C12-C31 n-alkane distribution is determined from the area under peaks representing each of these n-alkanes. This distribution can yield information about both the level of maturity and the source type (LeTran et. al., 1974).

(b) Carbon Preference Index - Two values are determined:

$$CPI(1) = \frac{(C23 + C25 + C27 + C29)\ Wt\% + (C25 + C27 + C29 + C31)\ Wt\%}{2 \times (C24 + C26 + C28 + C30)\ Wt\%}$$

$$CPI(2) = \frac{(C23 + C25 + C27)\ Wt\% + (C25 + C27 + C29)\ Wt\%}{2 \times (C24 + C26 + C28)\ Wt\%}$$

The CPI is believed to be a function of both the level of maturity (Cooper and Bray, 1963; Scalan and Smith, 1970) and the source type (Tissot and Welte, 1978). Marine extracts tend to have values close to 1.0 irrespective of maturity whereas values for terrestrial extracts decrease with maturity from values as high as 20 but do not usually reach a value of 1.0

(c) (C21+C22)/(C28+C29) - This parameter provides information about the source of the organic matter (Philippi, 1974). Generally, terrestrial source material gives values <1.2 whereas a aquatic source material results in values >1.5.

(d) Pristane/Phytane Ratio - This value was determined from the areas of peaks representing these compounds. The ratio renders information about the depositional environment according to the following scale (Powell and McKirdy, 1975):

< 3.0	Relatively reducing depositional environment
3.0-4.5	Reducing/oxidizing depositional environment
>4.5	Relatively oxidizing depositional environment

(e) Pristane/n-C17 Ratio - This ratio was determined from the areas of peaks representing these compounds. The value can provide information about both the depositional environment and the level of maturation (Lijmbach, 1975). Very immature crude oil has a pristane/n-C17 ratio >1.0, irrespective of the depositional environment. However, the following classification can be applied to mature crude oil:

<0.5	Open water depositional environment
0.5-1.0	Mixed depositional environment
>1.0	Peat-swamp depositional environment

In the case of sediment extracts these values are significantly higher and the following classification is used:

<1.0	Open water depositional environment
1.0-1.5	Mixed depositional environment
>1.5	Peat-swamp depositional environment

(f) Phytane/n-C18 Ratio - This ratio was determined from the areas of peaks representing these compounds. The value usually only provides information about the level of maturity of petroleum. The value decreases with increased maturation.

(g) Relative Amounts of n-Alkanes and Naphthenes - Since n-alkanes and naphthenes are the two dominant classes of compounds in the saturate fraction, a semi-quantitative estimate of the relative amounts of these compounds can be made from saturate GLC's. This information can be used to assess the degree of maturation and/or the source type of the petroleum (Philippi, 1974; Tissot and Welte, 1978). Very immature petroleum has only small proportions of n-alkanes, but as maturity increases the relative amount of n-alkanes increases. In addition, terrestrial petroleum has a greater proportion of high molecular weight naphthenes than petroleum comprising aquatic source material.

10. API/SPECIFIC GRAVITY

A specific gravity (SG) bottle was accurately weighed, then filled with crude oil at 60 Deg. F and finally reweighed. The weight difference was divided by the weight of an equal volume of water at 60 Deg. F to obtain the specific gravity. The following formula was then used to calcuate the API gravity:

$$\text{API Gravity} = \left[\frac{141.5}{\text{SG (60 Deg. F)}}\right] - 131.5$$

The reported gravity value is the average of duplicate determinations.

11. SULPHUR DETERMINATION

The % sulphur by weight is determined by dissolving 0.5g of the petroleum in 50mls kerosene and then analysing this mixture with an inductively coupled plasma (ICP) instrument which has been calibrated with a series of sulphur standards.

This parameter is influenced by the nature of the source material from which a crude is derived, the depositional environment of the source rocks, and reservoir alteration processed such as bacterial alteration.

12. C1-C31 WHOLE SAMPLE GAS CHROMATOGRAPHY

This method of analysis is normally only applied to oil or condensate samples. The technique provides a "picture" of the sample which shows good resolution of the low, medium and high molecular weight components. Whole sample GC data is considered to be more useful than C12+ saturate fraction GC data for oil or condensate samples.

The analysis is carried out under the same conditions as for the C12+ GC analysis with the following exceptions: column temperature = programmed from -20 Deg. C to 280 Deg. C at 4 Deg. C/min (uses cryogenic mode); injection is carried out in split mode; sample = 0.1 µl of neat petroleum.

C1-C31 analysis data can be used to obtain the same information as that obtained from C12+ GC but further provides detailed compositional data on the C1-C11 fraction and enables calculation of the distillation range of the sample.

13. MOLECULAR SIEVE EXTRACTION

This technique is used to isolate the branched/cyclic alkanes from the saturate fraction for gas chromatography/mass spectometry analysis. A mixture of saturates: 5A molecular sieves: purified benzene in the proportions 1:5:12 by weight is placed in a 100ml round bottom flask and refluxed for 24 hours. After cooling, the seives are filtered from the liquid phase and are washed with 4 x 10ml aliquots of benzene. The liquid phase plus washing are freed of benzene by distillation yielding the branched/cyclic compounds.

14. COMPUTERIZED GAS CHROMATOGRAPHY/MASS SPECTOMETRY (GC/MS)

Gas chromatography/mass spectrometry employs a capillary column gas chromatograph linked in series with a mass spectrometer and data system (GC/MS/DS). As molecules are eluted from the capillary column they are bled into the analyser tube of the mass spectrometer where they are bombarded with high energy electrons and consequently fragment to form several ions each with molecular weights less than that of the parent molecule. The fragmentation pattern is characteristic of the particular molecular type. The spectrum of these ions (referred to as a mass spectrum) is recorded approximately once every second and all of the mass spectra recorded during a GC/MS/DS analysis are memorised by the data system. Since any given class of molecules will breakdown in the analyser type to give one or more characteristic ion fragments of known molecular weight, after a GC/MS/DS analysis it is possible to examine the distribution of compounds within a given class by having the data system reproduce a mass fragmentogram (plot of ion concentration against gas chromatography retention time) representative of the particular class.

GC/MS/DS analyses can be carried out using one of the two following modes of operation:

(i) Acquire mode - in which all ions in each mass spectrum are memorised by the data system;

(ii) Selective ion monitoring (SIM) mode - in which only selected ions of interest are memorised by the data system.

At present the sterane/triterpane/bicyclane fraction of petroleum is considered most useful for GC/MS/DS analysis and therefore we commonly use the second of the above mentioned modes of operation and run the following twenty-two ions which are pertinent to the sterane/triterpane/bicuclane fraction.

Ion	Molecular Type
177	Demethylated triterpanes
191	Normal triterpanes
205	Methyl triterpanes
163	Specific dethylated triterpanes
356	Parent ion - C26 triterpanes
370	Parent ion - C27 triterpanes
384	Parent ion - C28 triterpanes
398	Parent ion - C29 triterpanes

412	Parent ion - C30 triterpanes
426	Parent ion - C31 triterpanes
183	Isoprenoids
217	Normal steranes
218	Normal steranes
231	4-methylsteranes
259	Diasteranes
358	Parent ion - C26 steranes
372	Parent ion - C27 steranes
386	Parent ion - C28 steranes
400	Parent ion - C29 steranes
414	Parent ion - C30 steranes

GC/MS/DS analysis of the sterane/triterpane/bicyclane fraction can often provide information about the maturity and source type of petroleum and whether it has been affected by micro-organisms. This technique is also often useful for oil:oil and oil:source rock correlation. The following sections indicate which parameters are used to obtain this information and summarize the theory behind their use.

Maturity

(i) Based on Steranes

(a) The biologically produced $\alpha\alpha\alpha$ (20R) sterioisomer is converted in sediment to a mixture of the $\alpha\alpha\alpha$ (20R) and $\alpha\alpha\alpha$ (20S) compounds. The ratio of

$$C29 \frac{\alpha\alpha\alpha\ (20S)}{\alpha\alpha\alpha\ (20R) + \alpha\alpha\alpha\ (20S)}$$

expressed as a percentage is about 25% at the onset of oil generation and increases almost linearily to a value of about 50% at the peak of oil generation.

(ii) Based on Triterpanes

(a) The C31, C32, C33, C34 and C35 hopanes have the biological R configuration at C22. On mild thermal maturation equilibration occurs to produce a 60/40 mixture of S/R. This equilibration occurs before the onset of oil generation.

(b) The conversion of the biological $17\beta,21\beta$ hopanes to the corresponding $17\alpha,21\beta$ and $17\beta,21\alpha$ compounds is also maturation dependant. For C30 triterpanes the ratio of $\frac{17\beta,21\alpha}{17\alpha,21\beta}$ decreases steadily from a value of about 0.4 at the onset of oil generation to a value of about 0.1 at peak oil generation.

(c) Two of the C27 triterpanes can also be used as maturity indicators. The ratio of 18 α(H) trisnorhopane to 17 α(H) trisnorhopane increases exponentially with increasing maturity from a value of approximately 0.2 at the onset of oil generation to approximately 1.0 at peak oil generation.

(d) It is our experience that the ratio of the C27 18α(H) + C27 17α (H) triterpanes to C30 $17\alpha,21\beta$ triterpane is maturity dependent. The ratio decreased from values around 1.0 at the onset of oil generation to a value of approximately 0.4 at peak oil generation. With increasing maturity at levels greater than that equivalent to peak oil generation the ratio increases steadily to values greater than 3.0.

Source Type

(i) Based on Steranes
Algal organic matter contains steranes in which the C27 compounds are more abundant than the C29 compounds. General aquatic organic matter has approximately equivalent amounts of the C27 and C29 compounds while organic matter rich in land-plants usually has a lot more of the C29 steranes.

(ii) Based on Triterpanes
The triterpane components in petroleum can be derived from both bacteria and higher plants. The common bacterial products are the C27-C35 hopanes and moretanes whereas the higher plant triterpanes are compounds other than hopanes or moretanes and are commonly C30 compounds.

(iii) Based on Diasteranes
The diasteranes are not produced biologically but are formed during early diagenesis from sterane precursors. The diasterane ratios

$$\frac{C27(20R)}{C29(20R)} \text{ and } \frac{C27(20R+20S)}{C29(20R+20S)}$$

should reflect the nature of the organic matter in the same manner as that outlined above for the steranes.

Biodegradation

It has been observed that in severely biodegraded petroleum the series of normal hopanes are converted to a series of A ring demethylated hopanes and the C29 (20R) sterane is selectively removed. For altered crudes which have not been degraded to this extent the severity of biodegradation can often be gauged by studying the isoprenoid and aromatic fractions. However, this type of investigation extends beyond a standard GC/MS/DS analysis.

Correlation

Our present approach to oil:oil or oil:source rock correlation problems is as follows:

(i) Compare the distribution of compounds in the 123, 177, 191, 205, 217, 218, 231 and 259 mass fragmentograms for an oil or sediment extract to the distribution of compounds in the respective fragmentograms for the other oil(s) or sediment extract(s). It is necessary in this type of comparison to make allowance for small variations due to possible maturity differences.

(ii) Examine the fragmentograms for peaks or sets of peaks which may represent compounds that are specific to the geological system under investigation. Normal steranes, diasteranes and bacterial hopanes cannot be used for this purpose because they are present in virtually all crude oils and sediment extracts. However, compounds like higher plant triterpanes, bisnorhopane and botryococcane can often prove very useful for this purpose.

15. CARBON ISOTOPE ANALYSIS

The measurement is carried out on one or more of the following mixtures; topped oil; saturate fraction; aromatic fraction; NSO fraction. The organic matter is combusted at 860 Deg. C in oxygen and the carbon dioxide formed is purified and transferred to an isotope mass spectrometer. The carbon isotope ratio is measured relative to a standard gas of known isotopic composition. In our case the standard gas is prepared from the NBS No. 22 oil. However, since the isotopic relationship between NBS No. 22 oil and the international reference PDB limestone are known, the values are adjusted to be relative to PDB limestone.

Although carbon isotope data has been commonly used for oil:oil and oil:source rock correlation its most significant application is the identification of the source of gas according to the following criteria (Fuex, 1977):

δ13C (PDB)	Gas Type
-85 to -58	Biogenic methane
-58 to -40	Wet gas/associated with oil
-40 to -25	Thermal methane

16. VITRINITE REFLECTANCE MEASUREMENT

Vitrinite is a coal maceral which responds to increasing levels of thermal maturity. This response can be measured by the percent of light reflected off a polished surface of a vitrinite particle immersed in oil. Reflectance measurements are made on a number (40 if possible) of vitrinite particles in each sample, in order to establish a range and mean for reflectance values. Immature rocks have low reflectance values (0.2% Ro to 0.6% Ro), with mature values ranging from 0.6% Ro to 1.2% Ro. Very mature values are between 1.2 % Ro and 1.8% Ro, while severely altered rocks have reflectances above 1.8% Ro.

Vitrinite reflectance results are best obtained from coals or rocks deposited in environments receiving large influxes of terrestrially-derived organic matter. Unfortunately, these environments are not conducive to the accumulation of large quantities of oil-prone organic mater. Also vitrinite reflectance cannot be performed on rocks older than Devonian Age, due to the absence of land plants in the older geological time periods.

17. VISUAL KEROGEN

Visual kerogen assessment is carried out by the coal petrologist and/or the palynologist. In the case of the petrologist the assessment is made in reflected light using the plug prepared for vitrinite reflectance measurement, and reports the relative amounts of alginite, exinite, vitrinite and inertinite particles.

Visual study of kerogen by the palynologist is carried out in transmitted light and can indicate the relative abundance, size and state of preservation of the various recognizable kerogen types and hence indicates the source character of a sedimentary rock. In addition, the colour of the kerogen is related to the thermal maturity of the sediments and is often used as a maturation indicator.

The preparation of slides for visual kerogen assessment by the palynologist firstly involves concentration of the organic matter by removal of the rock matrix using hydrochloric and hydrofluoric acid treatment and heavy liquid separation. The organic concentrate is then mounted on a glass slide using Petropoxy.

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APPENDIX 1

SIGNIFICANCE OF SELECTED PARAMETERS FROM GC/MS ANALYSIS

	Parameter	Ion(s)
1.	18α(H)-hopane/17α(H)-hopane (Ts/Tm)	191
2.	C30 hopane/C30 moretane	191
3.	C31 22S hopane/C31 22R hopane	191
4.	C32 22S hopane/C32 22R hopane	191
5.	C29 20S ααα sterane/C29 20R ααα steranes	217
6.	C29 20S ααα /C29 20R ααα + C29 20S ααα	217
7.	$\frac{\text{C29 ααα steranes}}{\text{C29 ααα steranes + C29 αββ steranes}}$	217
8.	C27/C29 diasteranes	259
9.	C27/C29 steranes	217
10.	18α (H)-oleanane/C30 hopane	191
11.	$\frac{\text{C29 diasteranes}}{\text{C29 ααα steranes + C29 αββ steranes}}$	217
12.	$\frac{\text{C30 (hopanes + moretanes)}}{\text{C29 (steranes + diasteranes)}}$	191/217
13.	C15 drimane/C16 homodrimane	123
14.	Rearranged drimanes/normal drimanes	123
15.	C15 alkylcyclohexane/C16 homodrimane	83/123

nd = not detectable

Significance of selected parameters from GC-MS analysis

1. 18α (H)-hopane/17α (H)-hopane (Ts/Tm)

   Maturity indicator. The ratio of 18α (H) trisnorhopane to 17α (H) trisnorhopane increases exponentially with increasing maturity from approximately 0.2 at the onset to approximately 1.0 at the peak of oil generation, i.e. Tm decreases with maturity. This parameter is not reliable in very immature samples.

2. C30 hopane/C30 moretane

   Maturity indicator. The conversion of C30 17β, 21β hopane to 17β, 21α moretane is maturity dependent. Values increase from approx. 2.5 at the onset of oil generation to approx. 10. Once the hopane/moretane ratio has reached 10, no further changes occur. A value of 10 is believed to represent a maturity stage just after the onset of oil generation, hopane/moretane ratios are therefore mainly useful as indicators of immaturity in a qualitative sense.

3.&4. C31 and C32 22S/22R hopanes

   Maturity indicator. An equilibrium between the biological R- and the geological S- configuration occurs on mild termal maturation. A ratio of S:R = 60:40, i.e. a value of 1.5 characterise this equilibrium which occurs before the onset of oil generation.

5. C29 20S $\alpha\alpha\alpha$ /C29 20R $\alpha\alpha\alpha$ steranes

   Maturity indicator. Upon maturation, the biologically produced 20R stereoisomer is converted into a mixture of 20R and 20S compounds. An equilibrium between the two forms is reached at approximately 55% 20R and 45% 20S compounds. VR equivalents are approximately 0.45% for a 20S/20R value of 0.2 and 0.8% for a 20S/20R value of 0.75. This parameter is most useful between maturity ranges equivalent to 0.4% to 1.0% VR.

6. C29 20S$\alpha\alpha\alpha$ /C29 20R $\alpha\alpha\alpha$ + C29 20S$\alpha\alpha\alpha$

<u>Maturity</u> indicator. Different way of expressing the conversion from the biological 20R to the geological 20S configuration (see parameter 5). Expressed as a percentage, a value of about 25% indicates the onset of oil generation and of about 50% the peak of oil generation.

7. C29 $\alpha\beta\beta$/C29 $\alpha\alpha\alpha$ + C29 $\alpha\beta\beta$ steranes

<u>Maturity</u> indicator. The form is produced biologically, it converts gradually into a mixture of $\alpha\alpha$ (normal steranes) and $\beta\beta$ (isosteranes) compounds upon maturation. Equilibrium is reached at about 65% $\beta\beta$ compounds, which is equivalent to approximately 0.9% VR.

8.&9.C27/C29 diasteranes and steranes

<u>Source</u> indicator. It has been suggested that marine phytoplankton is characterised by a dominance of C27 steranes and diasteranes whereas a preponderance of C29 compounds indicates strong terrestrial contributions. (C28 compounds are nearly always the lowest of the three sterane groups. High proportions of C28 compounds could indicate a contribution from of lacustrine algae). Values smaller than 0.85 for C27/C29 diasterane and sterane ratios are believed to be indicative for terrestrial organic matter, values between 0.85 to 1.43 for mixed organic material, and values greater than 1.43 for an input of predominantly marine organic matter.

As it has shown recently that apparently also pelagic marine sediments can contain a predominance of C29 steranes, the above rules have to be applied with caution. Any simplistic interpretation of C27/C29 steranes and diasteranes can be dangerous and the interpretation of these data should be consistent with other geological evidence.

10. 18 α (H) - oleanane/C30 hopane

<u>Source</u> indicator. Oleanane is a triterpenoid compound which has often been reported from deltaic sediments of late Cretaceous to Tertiary age. It is thought to be derived from certain angiosperms which developed in the late Cretaceous. If the 18 (H)-oleanane/C30 hopane ratio is below 10%, no significant proportions of oleanane are present. At higher values, it can be used as indicator for a reducing environment during deposition of land plant-derived organic matter.

11. C29 diasteranes/C29 ααα steranes + C29 αββ steranes

Source indicator. Parameter used to characterise the oxidity of depositional environments. High values (up to 10) indicate oxic conditions, low values (down to 0.1) indicate reducing environments.

12. C30 (hopanes + moretanes)/C29 (steranes + diasteranes)

Source indicator. Triterpanes are believed to be of prokariotic (bacterial) origin, whereas steranes are derived from eukariotic organisms. This ratio reflects the preservation of primary organic matter derived from eukariots relative to growth and preservation of bacteria in the sediment after deposition (prokariots).

13. C15 drimane/C16 homodrimane

Drimanes and homodrimanes are ubiquitous compounds most likely derived from microbial activity in sediments. The C15 drimane/C16 homodrimane ratio is a useful parameter for correlation purposes in the low molecular weight region, e.g. for condensates which lack most conventional biomarkers. Drimanes are also useful for an assessment of the level of biodegradation as the removal of C14 to C16 bicyclics characterises an extensive level of biodegration.

14. Rearranged/normal drimanes

Like parameter 13, for correlation purposes in samples without conventional biomarkers, and to assess level of biodegradation.

15. C15 alkylcyclohexane/C16 homodrimane

Like parameters 13 and 14, useful for correlation purposes. Mainly used for condensates and light oils.

APPENDIX 5

PETROGRAPHY

AMDEL

CORE

SERVICES

AMDEL CORE SERVICES

15 December 1989

Shell Company of Australia
1 Spring Street
MELBOURNE VIC 3000

Attention: EXO

REPORT: 001/006

CLIENT REFERENCE: ITC 03148/EXO

MATERIAL: Sidewall Cores

LOCALITY: Shark -1

WORK REQUIRED: Petrography Services

Please direct technical enquiries regarding this work to Brian G Steveson.

Dr Brian G Steveson
Manager Australasia
on behalf of Amdel Core Services Pty Ltd

Please reply to: PO Box 109 Eastwood SA 5063

Amdel Core Services Pty Limited
Incorporated in South Australia

1. INTRODUCTION

1. INTRODUCTION

Thirteen sidewall core samples from Shark -1 were received for petrographic work (ITC 03148/EXO). An impregnated thin section was prepared from each sample and this was used for microscopic description, point-counting 300 points, and photomicroscopy. One sample of sandstone was extremely damaged and one rock was a ?tuff; point-counting was not attempted on these two.

X-ray diffraction analysis was requested on two samples (SWC's 57 and 58); the results are included with the petrographic descriptions.

The rocks are mainly clay-rich sandstones; in some cases the clays are derived from lithic clasts (shales, siltstones, schists etc.) but in a few SWC's the clay is thought to be a genuine matrix. The types of clasts referred to above were plastically deformed during compaction, squeezed by the more rigid quartz grains and filled pore spaces and pore throats. In general, this was the most important process in reducing the original porosity. Minor kinds of lithics are cherts, siliceous sandstones/siltstones and acid volcanics.

Authigenic minerals are rarely abundant but carbonate is much more common in the geological section than either kaolinite or quartz, both of which occur in a few samples. SWC 3 (3471m) is somewhat different in that it is a mature quartz sandstone and contains abundant primary and secondary porosity.

2. PETROGRAPHY

Shark No 1 - Sidwall Core No 3 - 3471 m

Rock Name: Mature Quartz Sandstone

Thin Section: The mineralogy of this rock as a result of counting 300 points is as follows:

Components	%
Quartz and Quartzite	80
Soft Lithic Clasts	1
Siliceous Clasts	4
Pores	15

For the most part this rock consists of quartz grains and pores with only minor amounts of lithic fragments, feldspar and heavy minerals. Cementing phases are represented only by overgrowths on the quartz grains; these are widespread and in most fields of view there are several quartz grains showing some overgrowths but, even so,the development of these is unlikely to have been a significant factor in reducing the porosity of the rock to any great extent.

The quartz grains are well sorted and most range in size from 0.2 mm to about 0.5 mm. The grains are equant in shape and generally sub-round to sub-angular in outline. Probably about 30% of the grains show some evidence of overgrowths and in rare instances these tend to be relatively wide. Considering the rock overall, however, it is unlikely that the overgrowths comprise more than one or two percent of the volume of the rock and they will have reduced the porosity of the original sand to this extent only. Most of the porosity reduction occurred through pressure solution effects on the quartz grains and the development of long and curved contacts. There is evidence in places of two grains showing concavo-convex contacts and overgrowths have been developed later on the same grains. The photomicrographs of this rock show the extent of these diagenetic features.

Minor detrital grains consist of lithic fragments, feldspars and heavy minerals. The lithic grains are varied and include cherts, which show compact and generally sub-round outlines, and phyllosilicate-rich rocks which have been squeezed between the quartz grains and are now elongate and irregular and fill the intergranular spaces where they occur. Other types of lithic grains are rare instances of fine-grained igneous rocks and rather indeterminate quartz-rich lithologies possibly best referred to as meta-siltstones. For the most part the lithic grains form part of the framework and were essentially as strong and rigid as the quartz grains during compaction and lithification. Feldspars have generally been substantially altered and a small amount of secondary porosity in the rock can definitely be ascribed to the partial disillusion of feldspar. Typical minerals are either sub-round in outline or include a few tabular remnanats of potassium feldspar. There is evidence in the thin section of outlines of grains that have been completely dissolved away (therefore now forming secondary pores) but none of these show any specific evidence of having been original feldspar grains and it is possible that there was some kind of lithic fragment which was susceptible to disolution and this is now responsible for the development for a small proportion of secondary pores. The rock contains minor amounts of stable heavy minerals, particularly tourmaline.

The sample contains a relatively high porosity and most of the pores are several tenths of a millimetre in size and they are probably well interconnected in three dimensions. Most of the pores are bounded by quartz with small amounts of indeterminate clay films. As indicated above, there is a proportion of secondary pores but it is difficult to estimate the relative proportions of primary and secondary, apart from indicating that primary pores predominate.

Shark No 1 - Sidewall Core No 6 - 3378 m

Rock Name: Compact Argillaceous Sandstone

Thin Section:

This sample has been greatly damaged during collection of the sidewall core and no attempt has been made to provide a quantitative mineralogy by point counting. Approximately 50% of the rock consists of sand-grade quartz grains and the remainder is a melange of fine-grained quartz, clays and carbonate. Probably a large amount of the finer-grained quartz is derived from fragmentation of original quartz grains but it is difficult to determine, thereafter, what proportion of the fine-grained non-quartz material is derived from matrix, lithic fragments or broken grains. The carbonate is a fine-grained late replacement feature generally associated with the fine-grained parts of the rock. As the rock now stands, there is very little porosity in the thin section and much of this may well be as a result of breaking during collection of the sidewall core.

The quartz grains were probably well-sorted about an average grain size in the range of 0.2 - 0.3 mm. In some places there is considerable evidence of the grains showing long and concavo-convex boundaries and it appears that the rock was probably subjected to compaction forces which resulted in pressure solution effects on the quartz grains. In some parts of the thin section these pressure solution effects appear to be reasonably well developed and it is likely that the sample may have been rendered relatively impervious at an early stage in diagenesis. As well as quartz, the sample contains probably not more than about 2% of feldspar but in places this forms grains as much as 0.4 mm in size. One rather deformed (not exceptionally chemically altered) grain was noted in one place in the thin section. Elsewhere the feldspar appears to be mainly non-twinned material and some is distinctly turbid.

As suggested above, the rock contains abundant fine-grained material and some, at least, of this is probably derived from fine-grained lithic fragments whereas much of it may be broken quartz which is not an intregral part of the rock in-situ. Some of the lithic material is clearly cherty in character and there are patches of such material 0.15 to as much as 0.3 mm in size. Elsewhere there are aggregates of moderately birefringent phyllosilicate minerals (probably sericite or illite) which were probably derived from fine-grained metasedimentary lithic fragments which have clearly been compressed and deformed so that they now fill spaces between the quartz grains. Inevitably, much of the fine-grained material is rather indeterminate but it is thought likely that much of it is derived from lithic fragments probably of a largely metasedimentary origin.

Secondary carbonate obscures a considerable proportion of this fine-grained material and itself probably comprises of the order of 3-5% of the area of the thin section. Examination under a high magnification shows fine-grained carbonate widely distributed in virtually every field of view. This mineral is not void filling but, instead, has replaced fine-grained constituents. In places there are large monomineralic aggregates of carbonate (up to 0.4 mm in size) and it seems likely that these have been derived from original limestone clasts. The carbonate of which they are composed is certainly very distinctly finer-grained than even some of the authigenic carbonate which can be seen in this thin section.

Shark No 1 - Sidewall Core No 8 - 3340 m

Rock Name: Compact Lithic Sandstone

Thin Section: The mineralogy of this rock is a result of counting 300 points is as follows:

Components	%
Quartz and Quartzite	66
Soft Lithic Clasts	14
Siliceous Clasts	4
Carbonate	10
Pores	6

This sample is similar in many respects to sidewall number 6 but an attempt has been made to provide a point count analysis; indeterminate fine-grained material was assigned to argillaceous lithic fragments and broken fine-grained quartz was assumed to be derived from original sand-grade quartz grains. The rock is a compact lithic sandstone which has been affected by the introduction of carbonate during diagenesis. Occlusion of the original porosity and permeability probably occurred by processes of pressure solution on quartz grains and distortion and squeezing of softer lithic fragments so that they filled intergranular pore spaces. It is likely that the introduction of carbonate probably contributed little to reducing the original porosity.

Some quartz grains are as much as 0.7 mm in size and the average grains size is probably 0.3 to 0.4 mm. The quartz grains are equant and compact in shape and some show significant evidence of rounding although this is by no means common. The angularity of the grains, however, is proabably largely a result of pressure solution effects and these are such that in some cases there is clear evidence of suturing of some boundaries between quartz grains and the development of small microstylolitic textures. The quantitative extent of these pressure solution effects is a little difficult to determine in this rather fragmented rock but where the sample is better preserved it seems likely that more than 60% of the quartz grains show a significant proportion of long and curved contacts (as opposed to simply a tangential, touching contacts).

Very little feldspar was specifically identified in the rock and the second most abundant detrital phase is definitely lithic fragments. Some of these are equant, sub-round and well-defined and these tend to be stronger lithic fragments such as cherts and quartzites. It seems likely, however, that these were less abundant than fine-grained quartz-clay-mica aggregates which were plastically deformed during compaction of the rock. These are now represented by fine-grained mosaics between the quartz grains and it is the heterogeneity of this material which suggests that it is derived from lithic fragments rather than from some kind of muddy matrix. This fine-grained material now essentially fills all the intergranular spaces. There are instances of fine-grained sandstones, quartz-feldspar volcanic rocks but few examples of aluminous rocks consisting wholly of phyllosilicate minerals (such as have been identified in sidewall core 6).

Carbonate is widely dispersed as fine-grained material throughout the rock and forms anhedral crystals rarely more than 0.1 mm in size. The carbonate appears to have replaced some of the fine-grained constituents rather than being simply a void filling mineral. It seems likely that carbonate was introduced into the rock at a relatively late stage in its diagenetic history and it probably contributed little to occlusion of the porosity and reduction of the permeability.

Shark No 1 - Sidewall Core No 12 - 3230 m

Rock Name: Lithic Sandstone

Thin Section: The mineralogy of this rock as a result of counting 300 points is as follows:

Components	%
Quartz and Quartzite	74
Soft Lithic Clasts	8
Siliceous Clasts	7
Carbonate	8
Pores	3

As in the case of sidewall core 8, the sample was point counted on the assumption that fine-grained angular quartz fragments are broken remnants of quartz grains and fine-grained rather indeterminate material was assigned to soft lithic fragments.

In places (probably the more quartz-rich areas of the rock) this sample is fairly well preserved and quartz grains commonly range in size from 0.4 to 0.7 mm and most show significant development of convaco-convex grain margins. In these areas of the rocks there is some primary porosity which appears to be an integral part of the original rock. A small proportion of the quartz grains also show small overgrowths. In the bulk of the thin section, however, the sample shows many of the features described in sidewall core 8 in that there is a considerable amount of fine-grained material between the quartz grains which is very likely to be derived from original lithic clasts. It is necessary to distinguish this material from fine-grained quartz which is interpreted as being derived from brecciation of during collection of the sidewall core.

About half the lithic fragments are fine-grained quartz-rich lithologies which appear to have been essentially rigid during lithification and compaction of the rock. Such grains now form areas in the thin section 0.2 - 0.5 mm in size commonly and some even show evidence of original sub-angular to sub-round detrital outlines. Some of these grains are definitely chert but many are difficult to describe with certainty and appear to be fine-grained siliceous metasediments. There are rare instances of acid fine-grained volcanic rocks and some show the presence of tabular feldspar microphenocrysts. Other lithic material is more indeterminate, more argillaceous and generally forms smaller and more irregular aggregates. Such material, by virtue of its heterogeneity from place to place in the thin section is ascribed to lithic fragments rather than muddy matrix and is probably derived from fine grained aluminous sediments such as shales and mudstones which may well have been somewhat metamorphosed. There are only rare instances of well-defined grains of this type which show a deformed a schistose texture between the adjacent quartz grains.

Apart from small amounts of quartz overgrowths, referred to above, the sample contains only one diagenetic mineral and this is a carbonate. Most fields of view contain several aggregates and many crystals of this mineral but, nevertheless, it has a rather patchy distribution. Typically, the carbonate forms rather open and irregular patches 0.3 to 0.6 mm in size where the carbonate may have preferentially replaced ?argillaceous lithic fragments. Elsewhere the carbonate is more widely disseminated as single crystals and some of these are up to 0.05 mm in size. The carbonate is interpreted as being more in the nature of a replacing mineral rather than filling voids in the sandstone. There are, even so, one or two places in the thin section where the carbonate forms rhombs and may well be associated with pore spaces which are an integral part of the rock. Although this is fairly distinctive where it occurs such relationships have negligible quantitative importance and it is stressed that it seems most likely that occlusion of the porosity of this rock occurred at a time when the sample was compacted, pressure solution occurred where the quartz grains were in contact and soft lithic fragments were squashed to such an extent that they filled the intergranular spaces. Most of these events may well have occurred relatively early in the diagenetic history of this sandstone.

Shark No 1 - Sidewall Core No 16 - 3170.5 m

Rock Name: Compact Lithic Sandstone

Thin Section: The mineralogy of this rock as a result of counting 300 points is as follows:

Components	%
Quartz and Quartzite	52
Soft Lithic Clasts	36
Siliceous Clasts	5
Carbonate	3
Pores	2
Kaolinite	1
Feldspar	1

This is a compact rock in which virtually all of the original porosity has been occluded during diagenesis. This has been achieved largely by pressure solution effects on the quartz grains and by squeezing and compaction of plastically deformable lithic fragments. There is a little authigenic carbonate and kaolinite but these are quantitatively less significant.

This is a fine-grained sandstone and the average grain size is approximately 0.1 mm; quartz grains are well sorted and most are compact and equant in shape but generally sub-angular or angular in outline. Despite the abundance of fine-grained lithic material, many of the grains are in contact with one another and there is considerable evidence of the development of at least long contacts and in some places concavo-convex contacts between the grains. These have developed by pressure solution effects probably at a relatively early stage in the lithification of the sand. The quartz is of the common or plutonic variety.

Feldspar is only a minor constituent of the rock but both plagioclase and potassium feldspar could be identified in the thin section. Both types of minerals are sufficiently fresh to retain some evidence of twinning but the degree of alteration does vary considerably from grain to grain and this is some evidence that the alteration is inherited from the provenance area. Some of the feldspar appears to be a non-twinned, somewhat altered type probably an orthoclase.

Apart from the quartz, the most abundant detrital material is lithic fragments. These now form what is, in effect, a contiguous aggregate of fine-grained material between the quartz grains. The material is notably heterogeneous and it is this which suggests that it is of lithic origin and not a muddy matrix, for example. The lithic fragments typically range from those which appear to consist almost entirely of moderately birefringent phyllosilicates (illite, sericite or mica) to fine-grained quartz-rich lithologies which can probably be referred to as fine-grained sandstone or siltstones. These grains represent a spectrum of sedimentary and metasedimentary types and these were probably predominant in the provenance area. There are rare instances of what appear to be acid fine-grained volcanic rocks and some fine-grained siliceous rocks which are interpreted as being cherts. Most of these detrital lithic fragments have been somewhat deformed during compaction of the rock and now have irregular though generally equant, shapes and they fill the spaces left between the quartz grains.

The rock contains small amounts of authigenic carbonate and kaolinite. The carbonate mostly forms rather porous and irregular aggregates where it appears to have replaced some of the lithic fragments. The kaolinite, by contrast, forms monomineralic aggregates which are interpreted as being precipitates from percolating pore waters. These aggregates generally contain no internal textures of any kind and there is no specific evidence that the kaolinite is derived by alteration of any pre-existing phase. In one or two places the carbonate forms notably fine-grained monomineralic aggregates and these are tentatively interpreted as being derived from limestone clasts.

Shark No 1 - Sidewall Core No 22 - 2945 m

Rock Name: Compact Lithic Sandstone

Thin Section: The mineralogy of this rock as a result of counting 300 points is as follows:

Components	%
Quartz and Quartzite	40
Soft Lithic Clasts	30
Siliceous Clasts	4
Carbonate	6
Pores	4
Kaolinite	1
Opaques	15

This sample is similar to sidewall core 16 and a detailed description of the quartz, feldspar lithic fragments is not, therefore, warranted. The sample is a little coarser grained and the average grain size is estimated to be approximately 0.2 mm. Argillaceous lithic fragments appear to be somewhat more abundant than in the case of sidewall core 16 and there are more foliated phyllosilicate-rich aggregates which may be considered to be shales or their metamorphosed equivalents which have been compressed and distorted during compaction of the rock. Associated with these are some rare flakes of mucovite.
One feature which does distinguish this sample from that described immediately above is the presence of elongate opaque aggregates. These can readily be seen when the thin section is examined macroscopically and in thin section they tend to be rather irregular but distinctly elongate features. The largest of these extends across the length of the core and varies in thickness from about 0.3 to 0.5 mm. Other opaque aggregates are smaller but equally elongate and typically range in overall length from 0.2 to about 1.00 mm. Under intense illumination all of these aggregates appear to be completely opaque and this suggests that they may represent plant debris rather than, for example, ferruginous minerals. In at least one clear case in the thin section one of the opaques appears to have a punctate texture and this, too, is possibly indicative of a plant origin. Presumably the direction of foliation of these dark aggregates corresponds to the bedding in the rock and this appears to be completely laminar. It is noticeable that in the case of this sample and many others described from this well, that if it were not for the presence of these plant remains, the sample would appear to be completely homogeneous and massive.

In the case of both this sample and sidwall core 16, very little porosity is visible in the thin section and pores are rarely more than 0.1 mm in size. The pores are clearly not interconnected in three dimensions and presumably the samples have extremely limited permeability. In general this can be attributed to the abundance of plastically deformable lithic fragments.

Shark No 1 - Sidewall Core No 24 - 2908 m

Rock Name: Lithic (Argillaceous) Sandstone

Thin Section: The mineralogy of this rock as a result of counting 300 points is as follows:

Components	%
Quartz and Quartzite	74
Matrix	18
Siliceous Clasts	3
Carbonate	4
Pores	-
Kaolinite	1

The two characteristics which serve to distinguish this sidewall core from the few described immediately above are the relatively large average grain size and the presence of fine-grained intergranular material which appears to be homogeneous and is therefore probably derived from an original argillaceous matrix. Certainly the intergranular space tends to be choked with fine-grained material and the thin section shows only limited porosity (and it is likely that at least some of this is not characteristic of the rock as it was in-situ). The pores tend to be concentrated in broken areas whereas in better preserved parts of the thin section pores are less abundant, not more than 0.3 mm in size and probably not well interconnected in three dimensions.

The rock is only moderately well-sorted and the grains commonly range in size from 0.3 mm to as much as 1.5 mm and the average grain size is of the order of 0.5 mm. Most of the grains are separated from each other by fine-grained material but where the rock is more quartz-rich there are moderately well-developed long and curved contacts. It seems likely, however, that pressure solution was probably only locally intense and for the most part was inhibited by the presence of fine-grained intergranular material which prevented much circulation of pore waters. The quartz grains tend to be equant in shape and angular in outline with only a few showing sub-rounded vertices.

There is a small amount of feldspar in the rock but few of the grains are more than about 0.6 mm in size and most show some turbid alteration. The feldspar is generally an untwinned variety probably of potassic composition.

Immediately identifiable lithic fragments can be seen in the rock and are commonly at least as large as adjacent quartz grains. The most distinctive types are either fine-grained quartz-rich rocks (some of these are definitely chert) and a range of metamorphic rocks with schistose and related textures. Some of the latter are as much as 2.00 mm in length. Elsewhere lithic fragments are relatively small and less easily distinguished from the matrix material but, even so, there is a range of sedimentary and metasedimentary types which are generally more or less equant in shape and range in size up to about 0.5 mm.

The rock contains a moderate amount of fine-grained material which is characterised by the presence of quartz grains which are of about silt grade and secondary (authigenic) carbonate which speckles this material. The quartz and carbonate crystals occur in a finer-grained indeterminate matrix which is probably largely argillaceous. This material forms small aggregates and intergranular seams throughout the whole of the thin section and, because it is notably homogeneous, this can be attributed to a fine-grained matrix which was deposited at approximately the same time as were the sand-grade quartz, feldspar and lithic fragments. Since the sample is a sidewall core which has been damaged during collection there is an element of uncertainty in this interpretation and it is possible that this fine-grained material is lithic material which has been intensely broken during collection of the sidewall core. This is not the preferred interpretation, however.

The carbonate mineral in the rock is distinctly an authigenic phase and it occurs both as widely distributed small crystals in the matrix and as larger polycrystalline aggregates. Some of the latter are essentially monomineralic and are commonly several tenths of a millimetre in size. These do not appear to have been derived from original limestone fragments but simply represent areas of the rock where replacement by carbonate has been most extensive. Both within these aggregates and the isolated crystals there are some rhombic crystals and the carbonate generally forms more or less equant crystals up to 0.02 mm in size.

Shark No 1 - Sidewall Core No 26 - 2892 m

Rock Name: Argillaceous Lithic Sandstone

Thin Section: The mineralogy of this rock is a result of counting 300 points is as follows:

Components	%
Quartz and Quartzite	56
Soft Lithic Clasts & Matrix	31
Siliceous Clasts	5
Carbonate	7
Pores	1
Feldspar/Heavy Minerals	Trace

This sample is similar to sidewall core no 24 in that it is generally coarse-grained and only moderately well sorted. As well as readily identifiable (commonly large) lithic fragments the rock contains a relatively large amount of fine-grained intergranular material much of which is probably ascribable to a matrix phase which was deposited with the larger grains. The apparently impervious and impermeable nature of the sample derives from the effect of compaction on the soft lithic fragments and also from the abundance of the muddy matrix material.

Quartz grains are equant in shape and have a wide size range commonly from approximately 0.25 mm to the order of 1.00 mm. The grains are generally angular in outline and are commonly separated from each other by fine-grained material. Many of the grains have the appearance of being somewhat broken and this could well be an integral feature of the original sandstone (not due to collection of the sidewall core).

Minor detrital components are feldspars and small amounts of stable heavy minerals (particularly tourmaline). Feldspar is almost invariably non-twinned which shows considerable dusty alteration.

Lithic fragments are typically represented by large grains of sedimentary and metasedimentary rocks which range from extremely siliceous cherts to shales and their metamorphosed equivalents which consist very largely of moderatley birefringent phyllosilicate minerals. Many of the latter type of lithic fragments have a foliation and are distinctly elongate. They probably consist of sericite, muscovite and possibly illite.

As in the case of the sample described immediately above, there is a considerable amount of fine-grained material which is rather dark between crossed Nicols and pale brown in plane polarised light. It tends to contain small amounts of widely dispersed authigenic carbonate but probably originally consisted of a mixture of fine-grained quartz and argillaceous minerals.

Carbonate is invariably of authigenic origin and is patchily distributed throughout thin section. The bulk of the carbonate forms rather pourous and irregular aggregates 0.3 - 0.6 mm in size and the widely dispersed carbonate represents probably only a relatively minor proportion of this mineral in the rock.

Shark No 1 - Sidewall Core No 30 - 2807.5 m

Rock Name: Argillaceous Siltstone with Calcareous/Carbonaceous Bands

Thin Section: The mineralogy of this rock as a result of counting 300 points is as follows:

Components	%
Quartz and Quartzite	29
Soft Lithic Clasts & Matrix	24
Siliceous Clasts	3
Carbonate	30
Opaques	14

Most of the rock consists of a homogeneous, massive siltstone which contains abundant fine-grained material completely filling spaces between the quartz grains. It is likely that this material includes both lithic fragments deposited with the quartz and proabably also the remnants of some kind of argillaceous matrix. There are beds within this silstone which contain relatively large aggregates of plant remains and monomineralic carbonate.

The siltstone is a moderatley well-sorted rock in which few grains are as much as 0.1 mm in size but the average grain size is about 0.05 mm. Most of the grains of quartz are equant in shape but rather angular. They tend to be separated from each other by fine-grained material and there is little evidence of pressure solution effects. The second most abundant detrial material which can be seen in this part of the rock is lithic fragments; where these were relatively strong and siliceous they still retain their equant detrital outlines and can be seen as patches similar in size to adjacent quartz grains. Some of these lithics are clearly chert but others are less readily defined and were probably relatively quartz-rich fine-grained metasediments. The remainder of the fine-grained intergranular material contains abundant phyllosilicate minerals including, proabably illite, sericite and mica and although there is no doubt a lithic component in this part of the rock it also seems likely to the author that there is probably a considerable remnant of an original muddy matrix. Such material now completely fills the spaces between the quartz grains and during compaction and lithification all of this phyllosilicate-rich material has acted as though it were a matrix and has completely occluded any original porosity and permeability.

Trace components of this part of the rock are rare grains of fairly fresh feldspar, flakes of detrital muscovite and rare grains of heavy minerals.

The most characteristic feature of this rock is the presence of abundant carbonate and opaques. Both minerals tend to be concentrated in specific beds although the carbonate, particularly, is also somewhat more widely dispersed throughout the siltstone. Typical occurrences of the carbonate are as monomineralic aggregates which range in size from 0.1 mm commonly to as much as 0.4 mm. The carbonate aggregates are equant in shape but vary somewhat in detailed outline from some which appear to be sub-round to others which have an almost tabular shape. The opaques are concentrated in the same bands as is the carbonate and the opaques form an almost contiguous network of rather ragged elongate fragments which are probably plant remains of some kind. Typical occurrences of the carbonate and carbonaceous material are shown in the photomicrograph.

Shark No 1 - Sidewall Core No 40 - 2650 m

Rock Name: Lithic Sandstone

Thin Section: The mineralogy of this rock as a result of counting 300 points is as follows:

Components	%
Quartz and Quartzite	53
Soft Lithic Clasts	28
Siliceous Clasts	5
Carbonate	7
Opaques	7

This sample represents a return to a relatively coarse-grained lithic sandstones in which the fine-grained material between the quartz grains can be ascribed with some certainty to an abundant population of lithic fragments. The rock shows evidence of the crystallisation of carbonate in the diagenetic environment but the formation of this mineral will have had a minor effect on reducing the porosity of the rock; this occurred principally by squeezing of the softer lithic fragments into pore spaces and pore throats during compaction.

The rock is moderately well-sorted and most quartz grains are 0.2 - 0.5 mm in size. Many of the quartz grains are distinctly angular in shape and this is an integral feature of the detritus since there is only a little evidence of pressure solution effects. In some areas of the thin section there is some evidence of a bimodal grain size distribution since there are several grains 1-1.5 mm in size amongst other grains, few of which exceed 0.4 mm in size. Elsewhere these large grains are much less abundnat and the sample simply appears to be only moderately sorted. Feldspar is present only in trace amounts and most of the grains which could be identified show significant alteration. Some of this appears to be physical damage caused by collection of the sidewall core but some is probably an integral part of the rock and may be a cause of a small amount of a secondary porosity.

A relatively large proportion of the rock consists of fine-grained material which now essentially fills much of the space between the quartz and feldspar grains. This material is extremely varied and it is on this basis that it can be assigned to lithic clasts which were deposited with the quartz and feldspar grains. Some of these clasts can readily be identified where they are quartz-rich and therefore tend to retain their original detrital outlines. Some of these grains are cherts but there is a small population of somewhat banded metamorphic quartzites. Most of the lithic fragments, however, were fine-grained argillaceous rocks ranging from argillaceous sandstones to foliated shales and metamorphosed shales which appear to consist of moderately birefringent phyllosilicate minerals. Some of these latter rocks show extreme examples of squeezing and distortion. Inevitably, a moderate proportion of the intergranular material is simply an ill-defined fine-grained melange of phyllosilicates, quartz and dusty powdery material. Some of this will be a result of a collection of sidewall core but elsewhere it probably represents broken smaller lithic fragments.

Authigenic carbonate is fairly widely distributed throughout the rock and occurs both as a fine-grained replacement of some of the lithic fragments and also as small, rather porous patches distributed throughout the thin section. One or two of the almost monomineralic patches of carbonate could be derived from original limestone clasts but it appears to the author more likely that these are simply areas of particular concentration of the carbonate, possibly where a particular type of lithic fragment was almost completely replaced.

As in many of these lithic sandstones, the thin section shows a small amount of porosity but it is difficult to determine how much of this is an intregral part of the rock in-situ. In this sidewall core many of the pores are of the order of 0.1 to 0.3 mm in size and those that appear to be original are probably mainly of primary origin and are unlikely to be interconnected in three dimensions.

Shark No 1 - Sidewall Core No 57 - 2320 m

Rock Name: ?Crystal Tuff

Thin Section:

This rock consists of an abundant fine-grained "matrix" in which there are large crystals of quartz and feldspar, rare aggregates of monomineralic phyllosilicate and one or two patches of a fine-grained argillaceous sandstone. The shape of the quartz and feldspar crystals clearly indicates that they are of volcanic origin but the presence of aggregates of sandstone and rather varied textures within the matrix suggest to the author that the sample has a sedimentary component. It seems most likely therefore that the rock is some kind of pyroplastic-derived rock with a water-lain component. The almost euhedral appearance of many of the quartz and feldspar crystals suggest that these have not been transported very far but were probably derived from an immediate igneous source and incorporated in a fine-grained sediment which, in the volcanic environment was probably rapidly transported and deposited. Possibly the rock is some kind of lahoric deposit(?)

The quartz and feldspar crystals comprise approximately 25% of the volume of the rock and typically are 0.5 - 1.5 mm in size. The quartz crystals show slightly rounded verticies but many have evidence of crystal faces and they also show rather typical embayments. Feldspar crystals are either not twinned or show simple Carlsbad Law twinning and, these too, show subhedral outlines. Some of the feldspar crystals are tabular and they are as much as 1.2 mm in length and about 0.4 mm in width.

Other identifiable fragments in the rock consist of argillaceous compact siltstones and others are simply monomineralic mosaics of a moderately birefringent phyllosilicate mineral. Some of these show moderately preferred orientation but others apparently have a random orientation of the small flakes. In one instance, at least, it is possible that the phyllosilicate is entirely secondary after some primary igneous fragment which has been completely replaced. Unfortunately, the outline of this aggregate of phyllosilicate is not characteristic of any group of minerals and there is no internal texture to suggest the extent of the cleavage in the original mineral, for example.

All of these relatively large fragments rest in a fine-grained matrix which is pale brown in plane polarised light and dark and speckled under crossed Nicols. It is likely that this material consists of an admixture of clays and quartz with small amounts of minerals such as sericite. When the groundmass/matrix is examined under high magnification it can be seen that there are structures present on a scale of less than 0.1 mm. The extent and nature of these varies very considerably from place to place but there are few areas where the groundmass/matrix could be described as featureless. In some place there are very small patches of what appears to be concentrations of phyllosilicates and these sometimes have elongate or tabular habits possibly suggesting that they are pseudomorphs after small crystals of feldspar. In other places there are what appear to be partly absorbed and altered fine-grained siltstones or very fine-grained sandstones which can be just discerned amongst the fine-grained material which makes up the bulk of the ground mass/matrix of this rock.

X-ray Diffraction Analysis

The bulk mineralogy and that of the -2μm fraction (13% of the weight of the sample) are as follows:

(values in % approximate)

Bulk Mineralogy		-2μm fraction	
Quartz	62	Kaolinite	46
K-feldspar	18	Mica/Illite	44
Mica/Illite	8	Quartz	10
Kaolinite	8		
Dolomite	4		

Shark No 1 - Sidewall Core No 58 - 2294 m

Rock Name: Compact Argillaceous Very Fine-Grained Sandstone

Thin Section: The mineralogy of this rock as a result of counting 300 points is as follows:

Components	%
Quartz and Quartzite	50
Soft Lithic Clasts	50

The fragments of sidewall core consist mainly of a homogeneous very fine-grained sandstone which contains abundant argillaceous material but also present are smaller areas of a coarser-grained lithic sandstone similar to many others in this collection and in one of the fragments there is a relatively large and very coarse-grained vein of secondary quartz. The last will be described below (see final paragraph).

The very fine-grained sandstone has an average grain size of about 0.1 mm and is moderately well sorted. The quartz grains are generally equant but are rather irregular in shape partly as a result of embayments of the fine-grained matrix material. There are places where there has been some development of long and curved contacts but this is not a notable feature of the texture of the rock. More significant (from a petrophysical point of view) is the abundance of fine-grained material between the quartz grains; most of this is moderately birefringent and it probably contains a significant proportion of illite and possibly fine-grained mica. Some less birefringent material may well be kaolinite. In some places it can clearly be seen that this material is derived from lithic fragments. This occurs particularly where there are small foliated aggregates of the phyllosilicate minerals squeezed between the quartz grains. For the most part, however, the fine-grained material is simply a heterogeneous matrix which forms a contiguous network between the quartz grains. As a result of the abundance of this material the sample shows no porosity in the thin section which can be attributed to the rock in-situ.

Minor constituents of the rock are rare instances of detrital muscovite and grains of heavy minerals (particularly zircon) and a few rather turbid non-twinned grains which are interpreted as being potassium feldspar. None of these constituents contributes more than a fraction of 1% of the volume of the rock.

In contrast to many sedimentary rocks from this collection, carbonate appears to be virtually absent and this may indicate that there was little circulation of pore waters even from the very early stages of compaction and diagenesis of this rock. This is probably a function of the abundance of matrix material.

In one of the fragments of the sidewall core there is part of a vein of secondary quartz which is approximately 1.00 cm in width. This vien shows a sharp and apparently essentially planar contact against the very fine-grained sandstone. The vein contains, in places, granular aggregates of quartz crystals which are more than 1.00 mm in size but these abut against aggregates of fine-grained granular quartz in which the average crystal size is not more than about 0.05 mm. These variations in quartz crystal size approximately parallel the apparent length of the vein and also are related to what appear to be thin shear zones which are also sub-parallel to the length of the vein. It is not clear what the origin of this feature is but the quartz is clearly re-crystallised and it seems to be related to some deformation rather than being simply quartz in a vein-filling habit.

X-ray Diffraction Analysis

The bulk mineralogy and that of the -2μm fraction (6% of the weight of the sample) are as follows:

(values in % approximate)

Bulk Mineralogy		-2μm fraction	
Quartz	73	Kaolinite	39
K-feldspar	8	Mica/Illite	40
Mica/Illite	8	Quartz	13
Kaolinite	8	Chlorite	8
Chlorite	3		

Shark No 1 - Sidewall Core No 60 - 2241 m

Rock Name: Lithic Sandstone

Thin Section: The mineralogy of this rock as a result of counting 300 points is as follows:

Components	%
Quartz and Quartzite	67
Soft Lithic Clasts	21
Siliceous Clasts	1
Carbonate	0
Pores	7
Matrix	4

This sandstone shows good to moderate sorting of the detrital quartz grains and most of the grains are in the size range 0.2 to 0.6 mm. The grains are equant but angular in outline and there is litlle evidence of any pressure solution effects. The grains tend to be embedded in fine-grained material which consists entirely of deformed lithic fragments. Feldspar is present in very small amounts only and the grains show considerable evidence of having been fractured (probably during collection of the sidewall core); most of the grains are rather grey and turbid but it is likely that the feldspar forms part of the framework of the rock rather than having been substantially altered during diagenesis. The feldspar appears to be a potassic variety and there are one or two instances of what may be a perthitic intergrowths.

A substantial proportion of the volume of the rock is composed of fine-grained material which now forms a contiguous network between the grains of quartz and feldspar. This material varies on a scale of 0.2 - 0.4 mm and, as far as can be determined petrographically, it is consistent with almost all of this material having been derived from lithic clasts. Most of these clasts were likely to have been sedimentary or metasedimentary rocks and they range from cherts and fine-grained quartzites to foliated rocks which appear to consist almost entirely of phyllosilicate minerals. Some of the latter show extreme deformation and distortion between the quartz grains. There are lithic fragments which have intermediate compositions and these are probably best regarded as weakly metamorphosed argillaceous siltstones and shales. In general the lithic fragments appear to have been soft and were plastically deformed during compaction of the rock and few of them can be regarded as being part of the quartz-feldspar framework.

The interpretation of the porosity visible in the thin section is difficult in this instance. No doubt a considerable proportion of the porosity is a result of the fracturing of the rock during collection of the sidewall core but it still seems likely of the order of 5% of the rock may have been porosity in-situ. Many of the pores are in effect cavities within fine-grained aggregates and they tend to be bounded as much by fine-grained argillaceous debris as by clean surfaces of quartz grains. It is likely that a small amount of secondary porosity is associated with partly corroded and fractured feldspar grains and also with patchy dissolution of some of the lithic fragments.

3. PHOTOMICROGRAPHS

The caption for each photomicrograph shows the SWC number, depth, length of long axis and either PPL (plane polarised light) or CL (crossed Nicols).

PE905008

This is an enclosure indicator page.
The enclosure PE905008 is enclosed within the container PE905003 at this location in this document.

The enclosure PE905008 has the following characteristics:

ITEM_BARCODE =	PE905008
CONTAINER_BARCODE =	PE905003
NAME =	Microphotographs
BASIN =	GIPPSLAND
PERMIT =	VIC/P22
TYPE =	WELL
SUBTYPE =	PHOTOMICROGRAPH
DESCRIPTION =	Microphotographs from Shark-1, Figures 1 and 2, Appendix 5
REMARKS =	
DATE_CREATED =	15/12/89
DATE_RECEIVED =	6/04/90
W_NO =	W1013
WELL_NAME =	SHARK-1
CONTRACTOR =	AMDEL
CLIENT_OP_CO =	SHELL AUSTRALIA

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PE905009

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The enclosure PE905009 has the following characteristics:

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CONTAINER_BARCODE =	PE905003
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BASIN =	GIPPSLAND
PERMIT =	VIC/P22
TYPE =	WELL
SUBTYPE =	PHOTOMICROGRAPH
DESCRIPTION =	Microphotographs from Shark-1, Figures 3 and 4, Appendix 5
REMARKS =	
DATE_CREATED =	15/12/89
DATE_RECEIVED =	6/04/90
W_NO =	W1013
WELL_NAME =	SHARK-1
CONTRACTOR =	AMDEL
CLIENT_OP_CO =	SHELL AUSTRALIA

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PE905010

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The enclosure PE905010 has the following characteristics:

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CONTAINER_BARCODE =	PE905003
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PERMIT =	VIC/P22
TYPE =	WELL
SUBTYPE =	PHOTOMICROGRAPH
DESCRIPTION =	Microphotographs from Shark-1, Figures 5 and 6, Appendix 5
REMARKS =	
DATE_CREATED =	15/12/89
DATE_RECEIVED =	6/04/90
W_NO =	W1013
WELL_NAME =	SHARK-1
CONTRACTOR =	AMDEL
CLIENT_OP_CO =	SHELL AUSTRALIA

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PE905011

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The enclosure PE905011 has the following characteristics:

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CONTAINER_BARCODE = PE905003
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BASIN = GIPPSLAND
PERMIT = VIC/P22
TYPE = WELL
SUBTYPE = PHOTOMICROGRAPH
DESCRIPTION = Microphotographs from Shark-1, Figures 7 and 8, Appendix 5
REMARKS =
DATE_CREATED = 15/12/89
DATE_RECEIVED = 6/04/90
W_NO = W1013
WELL_NAME = SHARK-1
CONTRACTOR = AMDEL
CLIENT_OP_CO = SHELL AUSTRALIA

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PE905012

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The enclosure PE905012 is enclosed within the container PE905003 at this location in this document.

The enclosure PE905012 has the following characteristics:

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CONTAINER_BARCODE =	PE905003
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BASIN =	GIPPSLAND
PERMIT =	VIC/P22
TYPE =	WELL
SUBTYPE =	PHOTOMICROGRAPH
DESCRIPTION =	Microphotographs from Shark-1, Figures 9 and 10, Appendix 5
REMARKS =	
DATE_CREATED =	15/12/89
DATE_RECEIVED =	6/04/90
W_NO =	W1013
WELL_NAME =	SHARK-1
CONTRACTOR =	AMDEL
CLIENT_OP_CO =	SHELL AUSTRALIA

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PE905013

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The enclosure PE905013 is enclosed within the container PE905003 at this location in this document.

The enclosure PE905013 has the following characteristics:

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CONTAINER_BARCODE =	PE905003
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BASIN =	GIPPSLAND
PERMIT =	VIC/P22
TYPE =	WELL
SUBTYPE =	PHOTOMICROGRAPH
DESCRIPTION =	Microphotographs from Shark-1, Figures 11 and 12, Appendix 5
REMARKS =	
DATE_CREATED =	15/12/89
DATE_RECEIVED =	6/04/90
W_NO =	W1013
WELL_NAME =	SHARK-1
CONTRACTOR =	AMDEL
CLIENT_OP_CO =	SHELL AUSTRALIA

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PE905014

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The enclosure PE905014 is enclosed within the container PE905003 at this location in this document.

The enclosure PE905014 has the following characteristics:

ITEM_BARCODE = PE905014
CONTAINER_BARCODE = PE905003
NAME = Microphotographs
BASIN = GIPPSLAND
PERMIT = VIC/P22
TYPE = WELL
SUBTYPE = PHOTOMICROGRAPH
DESCRIPTION = Microphotographs from Shark-1, Figures 13 and 14, Appendix 5
REMARKS =
DATE_CREATED = 15/12/89
DATE_RECEIVED = 6/04/90
W_NO = W1013
WELL_NAME = SHARK-1
CONTRACTOR = AMDEL
CLIENT_OP_CO = SHELL AUSTRALIA

PE905015

This is an enclosure indicator page.
The enclosure PE905015 is enclosed within the container PE905003 at this location in this document.

The enclosure PE905015 has the following characteristics:

ITEM_BARCODE =	PE905015
CONTAINER_BARCODE =	PE905003
NAME =	Microphotographs
BASIN =	GIPPSLAND
PERMIT =	VIC/P22
TYPE =	WELL
SUBTYPE =	PHOTOMICROGRAPH
DESCRIPTION =	Microphotograph from Shark-1, Figure 15, Appendix 5
REMARKS =	
DATE_CREATED =	15/12/89
DATE_RECEIVED =	6/04/90
W_NO =	W1013
WELL_NAME =	SHARK-1
CONTRACTOR =	AMDEL
CLIENT_OP_CO =	SHELL AUSTRALIA

(Inserted by DNRE - Vic Govt Mines Dept)