SHELL AUSTRALIA E. & P. OIL AND GAS

SDA 938

JUDITH-1
WELL COMPLETION REPORT

VOLUME 2

~~INTERPRETATIVE DATA~~

SOUTHERN TEAM/PETROLEUM
ENGINEERING/DRILLING
OPERATIONS

JUNE 1990

Keywords : Exploration, reservoir, seal, source, stratigraphy, structure, hydrocarbons, petrophysics, palynology, palaeontology, geochemistry, synthetic seismogram

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1. INTRODUCTION

Gippsland Basin permit VIC/P11 is held jointly by Shell (29.16%, operator) and Gas and Fuel Corporation (70.84%). This follows Shell's purchase of Lasmo's interest in September 1989. At the time of drilling, VIC/P11 was in the final year (Year 5) of the second permit term, which expired on the 2nd May, 1990. Judith-1 fulfilled the Year 5 drilling obligation which completes the permit's work commitment.

Judith-1 is located at SP 600 on seismic line GL88-26 in 76m of water (Fig. 1). The well is located basinward of the Rosedale Fault and was optimally located to assess the prospectivity of that part of the permit, having two objectives. The primary objective was to test lower Golden Beach Group alluvial fan sandstones in a rotated fault block. Top and lateral sealing was expected to be provided by the lacustrine Kipper Shale. The secondary objective was to test the possibility of a northwesterly extension to the Kipper gas accumulation at top Golden Beach level (SDA 915). All depths are quoted in metres below derrick floor, unless otherwise stated.

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 Southern Australia's rift valley 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 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 condensed glauconitic sequence known as the Gurnard Formation which, where preserved, 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 latter 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 Judith-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): 97-955m (858m)

The Gippsland Limestone consists of interbedded argillaceous limestone, limestone and minor marl, ranging in age from Late Miocene (D1 zone) to Recent. The argillaceous limestone and limestone are light to medium grey and greenish grey, with trace amounts of pyrite, glauconite and carbonaceous material. These units contain common to abundant fossils, including forminifera, echinoderms, bryozoans and shell fragments. Marl increases in abundance toward the base of the Gippsland Limestone and is light to medium greenish grey slightly pyritic and micaceous, with occassional to common fossils.

The carbonate depositional environment has been interpreted from foraminiferal assemblages as middle to outer neritic (200-20m water depth) in the lower marl dominated sequence, with a shallowing to middle neritic (20-100m) for the overlying, dominantly limestone section. Deposition of predominantly argillaceous limestone in the upper Gippsland Limestone may suggest increasing water depths.

3.2 Lakes Entrance Formation (SELE) : 955-1451m (496m)

The Lakes Entrance Formation ranges in age from Early to Middle Miocene (H1-D1/D2 zones) and consists of dominantly calcareous claystone, grading from marl in the upper section and grading to calcareous siltstone near the base of the unit. Minor thin interbeds of argillaceous limestone occur throughout.

The calcareous claystone is light to medium greenish grey, silty in places, with traces of pyrite, glauconite, carbonaceous detritus and fossils. It is commonly soft and sticky with dispersive clay. The interbedded limestone is argillaceous, light greenish grey to medium grey and buff, amorphous to finely crystalline, occasionally arenaceous, slightly pyritic with trace to common fossils.

Foraminiferal assemblages indicate that the Lakes Entrance Formation was deposited in an outer neritic (100-200m water depths) environment in its lower reaches, shallowing upwards to middle to outer neritic water depths (200-20m).

3.3 Latrobe Group (LA) : 1451-1886m (435m)

The Latrobe Group is subdivided into three main units: Gurnard Formation, Flounder Formation and the informal "Coarse Clastics" sequence. The "Coarse Clastics" have been further subdivided on the basis of palynological zonations.

3.3.1 Gurnard Formation (LAGU) : 1451-1472m (21m)

The Gurnard Formation unconformably underlies the Lakes Entrance Formation and consists of dark olive green to greenish brown siltstone. The Gurnard siltstones are heavily glauconitic, commonly micaceous and sandy in places with yellow stained, medium to coarse grains. Significant limonitic alteration indicates oxidation and possible subaerial exposure.

The Gurnard Formation represents a condensed sequence of shallow marine deposits ranging in age from Middle to Late Eocene (Lower to Upper N. asperus).

3.3.2 Flounder Formation (LACH) : 1472-1509.5m (37.5m)

The Flounder Formation unconformably underlies the Gurnard Formation and consists of medium to dark brownish grey and greenish grey glauconitic siltstone and dark green grey to yellow brown glauconitic sandstone. Limonitic alteration is common in the upper Flounder Formation.

The unit represents the marine infilling stage of the Tuna-Flounder Channel complex during the Early to Middle Eocene (Middle M. diversus - P. asperopolus).

3.3.3 Latrobe Group "Coarse Clastics"

3.3.3.1 M. diversus Biozone (LAMD) : 1509.5-1550m (30.5m)

The Early Eocene M. diversus biozone unconformably underlies the Flounder Formation and can be divided into two distinct depositional units. The upper unit from 1509.5-1525m consists of medium to coarse grained, upward-fining sandstones, with minor interbedded reddish brown to dark brown, carbonaceous siltstone and coal. Depositional environment is interpreted as lower coastal plain. The lower unit from 1525 - 1550m comprises medium to coarse grained sandstone, grading with depth to light grey siltstone, and represents deposition in a coastal barrier to marine environment.

3.3.3.2 L. balmei Biozone (LALB) : 1550-1752m (202m)

The Paleocene L. balmei biozone can be subdivided into three major depositional units. The upper unit from 1550-1612m is a thinly interbedded sequence of upward-coarsening sandstones, argillaceous siltstone, mudstone and coal, deposited in a back barrier/ lagoonal setting. From 1612-1715m, medium to very coarse, moderately well sorted, upward-fining sandstones, interbedded with light brownish grey siltstone, dark brown mudstone and coal were deposited in a dominantly lower coastal plain setting. The lower unit from 1715-1752m represents deposition in a coastal barrier to marine setting and consists of medium to very coarse, moderately well sorted sandstone with minor glauconite, pyrite and silica cement. The sandstone grades with depth to medium to dark grey pyritic and glauconitic siltstone.

3.3.3.3 T. longus Biozone (LALO) : 1752-1886m (134m)

The Maastrichtian T. longus biozone consists of sandstones, siltstones and coals deposited in estuarine, lower to upper coastal plain and braided stream environments. Estuarine channel sands (1752-1802m) are light grey, fine to coarse grained, moderately sorted, subrounded and friable with good visual porosity and traces of silica cement, carbonaceous detritus and lithics. Minor interbedded siltstones and mudstones are medium to dark brown grey and carbonaceous.

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 to upper coastal plain facies (1802-1845m) consist of upward-fining, fluvial sandstones, interbedded with carbonaceous siltstones and thin coals. The sandstone is typically light grey, fine to very coarse grained, dominantly coarse, moderately well sorted, subangular to subrounded and friable to moderately well cemented with good visual porosity. Minor amounts of pyrite, lithics and siliceous cement are also present.

The sequence from 1845 to 1886m comprises an overall fining-upward unit of braided stream sandstones and arenaceous siltstones. The sandstone is light grey, fine to coarse grained, poor to moderately sorted, subangular to subrounded, moderately cemented with siliceous cement and has fair to good visual porosity. Volcanic lithics, mica and pyrite are also common.

Sediments of the T. longus biozone directly overlie the Intra-Campanian Unconformity.

3.4 Golden Beach Group (GB) : 1886-2958m (1072m)

The Golden Beach Group is subdivided on the basis of lithology and palynological zonation.

3.4.1 Kipper Volcanics : 1886-1971m (85m)

The Kipper Volcanics directly underlie the Intra-Campanian Unconformity which marks the top of the Golden Beach Group. The unit consists of a sequence of stacked, intermediate to occasionally acid, highly altered volcanic flows. Relatively unaltered volcanics are also present. The altered volcanics are pale to medium green, off white and red brown, abundant clay alteration, soft to firm, chloritised, relict feldspar laths and trachytic texture in places, common siliceous groundmass, lateritic in parts, commonly amygdaloidal with buff, amorphous, concentrically layered chalcedonic amygdales and occasional to common coarsely crystalline calcite vein/fracture fill. The less altered volcanics are black to dark green, acid to intermediate, amorphous to aphanitic texture, common glassy groundmass, hard to very hard, occasional chloritic and red brown alteration of mafics, occasional silica and calcite vein fill.

3.4.2 T. apoxyenxinus Biozone (GBTA) : 1971-1991m (20m)

The T. apoxyexinus biozone is Santonian in age and consists of thinly interbedded sandstone, siltstone and mudstone, deposited in a braided stream environment. The sandstone is typically light grey, medium to coarse grained, poor to moderately sorted, subangular to subrounded, friable to hard, siliceous cement, common pyrite and has fair to good visual porosity. The sequence is equivalent to the lower part of the S1 reservoir sands intersected in the Kipper wells.

3.4.3 P. mawsonii Biozone (GBPM) : 1991-2726m (735m)

The Turonian-Coniacian P. mawsonii biozone is subdivided into two distinct units: the lacustrine Kipper Shale and an underlying alluvial/lacustrine sequence.

The Kipper Shale (1991-2391m) as penetrated in Judith-1 is 400m thick. Its true stratigraphic thickness however, is likely to be greater due to intersection of the Judith Fault at 2158m, within the Kipper Shale. The Kipper Shale was deposited in a lacustrine setting and consists primarily of medium to dark grey, argillaceous to arenaceous siltstone with common carbonaceous detritus and laminae. Deltaic, fluvial and alluvial fan sandbodies, generally in the order of 10m thick (although up to 40m), also occur within the sequence. The sandstones are typically white to pale grey, fine to coarse grained, moderately to well sorted, angular to subrounded, friable to well cemented with siliceous cement, poor to good visual porosity and minor amounts of lithics and pyrite. From around 2300m the sandstones become more lithic and poorly sorted with argillaceous matrix and common carbonate cement.

The sequence from 2391-2726m consists of alluvial fan and minor braided stream sandstones with intervening lacustrine siltstone units up to 60m thick and minor shales. The sandstones are generally lithic, off white to light grey, fine to coarse grained, poor to moderately sorted, angular to subrounded, poor to moderately cemented with dolomitic cement, dispersive argillaceous matrix and poor visual porosity. Petrographical analysis of these sands indicates the lithic component to be between 20 and 35%. These lithics are predominantly soft and argillised, and as a consequence have been squeezed and deformed into the pore spaces to occlude porosity. Provenance for the lithics is likely to have been sediments of the Strzelecki Group, shed from nearby fault scarps. The lithic sandstones became easily disaggregated whilst drilling (due to the high clay content) resulting in the zones becoming severely washed out.

The siltstone units are typically medium to dark grey and brown grey, arenaceous to argillaceous, grading to very fine sandstone in places, firm to hard, blocky to subfissile and contain abundant carbonaceous detritus. The shales are medium to dark grey, silty, indurated, laminated, slightly micaceous and carbonaceous, and subfissile to fissile.

3.4.4 <u>A. distocarinatus Biozone</u> (GBAD) : 2726-2958m (232m)

A diminishing lacustrine influence is recognised in the Cenomanian <u>A. distocarinatus</u> biozone which is essentially a sequence of stacked alluvial fan sandstones. The sandstones are lithic, off white to light buff grey and have the same characteristics as described for the overlying <u>P. mawsonii</u> alluvial sands. Intervening lacustrine siltstone units are up to 20m thick, medium to dark grey, argillaceous to arenaceous, firm to hard, slightly dolomitic and micaceous, with common carbonaceous laminae and detritus.

4. SEISMIC MARKERS AND STRUCTURE

4.1 Seismic Markers (Figure 4)

A check-shot survey (WST) was included in the final logging suit at Judith-1 (Appendix 4, Volume 1). The synthetic seismogram provides a good match with seismic at the well location (Encl. 3). Comparison with pre-drill picks of the major seismic markers shows that in most cases the correct pick had been made. A summary of pre- and post-drill depths is given below in Table 1. The discrepancy in depths below the base Gippsland Limestone is mainly attributed to slightly higher than modelled velocities in the Lakes Entrance Formation, affecting the depth conversion.

TABLE 1 : Pre- and post-drill depths to markers (See Figure 5)

SEISMIC MARKER	PRE-DRILL DEPTH (mbsl)	ACTUAL DEPTH (mbsl)	DIFFERENCE (m)
Base Gippsland Limestone	951	934	+ 17
Top Latrobe Group	1483	1431	+ 53
Top Golden Beach Group	1941	1865	+ 76
Base Kipper Volcanics	2006	1950	+ 56
Top Kipper Shale	2251	1970	+ 281
Base Kipper Shale	2466	2370	+ 96

Base Gippsland Limestone

The base of the Gippsland Limestone was penetrated at 934 mbsl, 17m high to prediction and within the pre-drill error estimate. It marks the base of an interval of decreasing velocity with depth due to a facies transition from the limestones of the Gippsland Limestone to marls and calcareous claystones of the Lakes Entrance Formation.

Top Latrobe Group

The top of the Latrobe Group was penetrated at 1431 mbsl, 53m high to prediction. Although the event was correctly picked as a prominent trough, the modelled velocity for the Lakes Entrance Formation was somewhat less than the actual.

Top Golden Beach Group

The top of the Golden Beach Group was penetrated at 1865 mbsl, 76m high to prediction. Penetration at least 50m high to prediction was expected after the top Latrobe pick had indicated higher than modelled velocities in the Lakes

Entrance Formation. The extra 26m is due to the pre-drill pick being made half a loop low, in a trough chosen for convenient mapping. The event is actually marked by the overlying black loop, corresponding to the 'soft' seismic response of weathered volcanics.

Base Kipper Volcanics

Base Kipper Volcanics were penetrated at 1950 mbsl, 56m higher than predicted. The pre-drill pick was correctly made in a trough.

Top Kipper Shale

Top Kipper Shale was penetrated at 1970 mbsl, 281m high to prediction. Pre-drill, the Kipper shale was expected to be around the same thickness as penetrated in Tuna-1 and as modelled in Kipper-1. The Kipper Shale however, is much thicker than predicted in the downthrown Judith fault block and as such provides the lateral seal for the Top Golden Beach Kipper accumulation (Fig. 6).

Base Kipper Shale

The base of the Kipper Shale was penetrated at 2370 mbsl, 96m high to prediction, although confirming the pre-drill pick. Allowing for approximately +50m due the Lakes Entrance velocities, the depth is well within the pre-drill estimated error margins.

4.2 Structure

Judith-1 was primarily a test of a rotated fault block in the deep Golden Beach Group. Strong gas shows whilst drilling and low hydrocarbon saturations interpreted from logs are taken to indicate that Judith-1 tested a valid hydrocarbon bearing trap (with tight reservoirs) at this level. Dipmeter data confirms mapping at the well location with structural dips to the WSW in the downthrown block and to the SSE in the objective, upthrown block. The Judith Fault is interpreted to have been penetrated at 2137 mSS.

A secondary objective was to test the top of the Golden Beach Group for a possible northwesterly extension of the Kipper Field (SDA 915). The well results show that the Kipper Field is bounded by the Kipper Fault and laterally sealed by juxtaposition of the Kipper Shale (see Figure 6). The sands encountered at the top of the Golden Beach (S1 reservoir equivalent) are interpreted to be only locally distributed on the downthrown side of the Judith Fault.

5. <u>HYDROCARBON SHOWS</u>

No significant shows were recorded whilst drilling through the Latrobe Group. One sample of very fine grained sandstone from 1458 - 1461 m did, however, contain a trace of dull yellow fluorescence with very slow streaming cut. No gas above background was recorded over this interval and the show may merely represent the migration of hydrocarbons at this level. Background gas levels were generally in the order of 0.1 to 0.3% TG with peaks up to 3% associated with coal beds (95% C1, 4% C2, 1% C3 and tr C4). Average gas compositions show a trend of increasing wetness with depth. From 1500-1700 m, the main coal bearing interval, average gas composition recorded was 97% C1, 3% C2 and traces of C3. From 1700m to the top of the volcanics at 1886m the average gas composition was 85% C1, 10% C2, 4.5% C3 and 0.5% C4.

Background gas levels within the Golden Beach Group over the interval 1971 - 2391 m remained in the order of 0.1% TG although within the volcanics, gas levels decreased to around 0.02% (1886-1921m). No appreciable increase in gas levels were recorded in the upper objective, S1 equivalent sands (1971-1991m). Significant ditch gas levels did not begin until the lower objective, <u>A. distocarinatus</u> sands were reached at 2391m, beneath the base of the Kipper Shale. From 2391 m to TD, strong gas shows with peaks of up to 6% TG were recorded associated with these sands. Average gas composition of 97% C1, 2% C2, 1% C3 and traces of C4 indicates the gas to be essentially dry, although one sand from 2659 - 2662m appeared slightly wetter with a gas composition of 91.8% C1, 7% C2, 1% C3 and 0.2% C4. No hydrocarbon fluorescence was observed for the Golden Beach Group sequence.

P. mawsonii

6.0 RESERVOIRS, SEALS AND SOURCE ROCKS

6.1 Reservoirs (Figure 7, Appendices 3, 4 and 6)

Reservoir quality of the Latrobe Group fluvial, estuarine and coastal barrier sandstones (1509.5-1886m) is excellent, with log-derived porosity in the range 21-29% and average approximately 24%. The sandstones are quartzose, fine to coarse grained, with weak to moderate siliceous cement and fair to very good visual porosity.

Beneath the top Golden Beach Group volcanics, braided stream sandstones of the upper Golden Beach objective (1971-1991m) are quartzose, medium to coarse grained with moderate siliceous cement, traces of lithics and fair to good visual porosity. Log derived porosities for these sands are in the range 17-24% and average approximately 20%.

Within the Kipper Shale interval (1991-2391m) occasional deltaic, fluvial and alluvial fan sandstones occur. These sandstones vary from a clean, well sorted quartzose, medium to coarse grained deltaic sandbody (2037-2075m) with good visual porosity, to lithic, clayey, poorly sorted, fine to coarse grained alluvial fan sandstones (2331-2342m) with poor visual porosity. Log analysis indicates decreasing porosity with depth, reflecting the change in depositional processes from deltaic to alluvial fan as well as an increasing Strzelecki Group lithic provenance. Log derived porosities range from 11-25%, and average 22% for the interval 2037-2075m down to 12% from 2331-2342m. Drawdown permeabilities of 331 and 54 mD (2331.5 and 2341.6m respectively) were calculated from RFT pretests in the lower sand.

Beneath the Kipper Shale, the lower objective (2391-2958m) Golden Beach sandstones were found to be gas bearing, albeit with low saturations. These sandstones were deposited by dominantly alluvial fan processes and are lithic, clayey, poorly sorted, fine to coarse grained, commonly carbonate cemented and have poor visual porosity. Petrographic analysis of the sands indicates a lithic component of between 20 and 35%. The lithic component is typical of a Strzelecki Group provenance and comprise predominantly soft, argillaceous clasts which have contributed to porosity reduction by being squeezed between the detrital grains to fill intergranular pore space. Log analysis indicates these sands have porosities in the range 6-12% (average 9%). With the exception of one point at 2535.5m (26.0 mD), permeabilities of between 0.05 and 1.6 mD were calculated from RFT pretest drawdowns, confirming the tight nature of the reservoir. The interval has an overall sand/shale ratio of 51% and a net:gross of 19% (using 10% porosity cutoff).

6.2 Seals (Figure 6)

The top seal of weathered volcanics for the Kipper Extension objective, was penetrated as prognosed, albeit with greater vertical thickness (85m) than anticipated. Lateral sealing at the S1 sand level at Judith-1, however, is more difficult to prove. Based on a mapped throw of 60m at base Kipper Volcanics, it is likely that a thick lacustrine delta sandbody (2037-2075m) almost completely juxtaposes the S1 equivalent sands. It is probable therefore, that trapping at the upper Golden Beach level fails due to lack of a lateral seal.

The proposed top and lateral seal for the lower Golden Beach Judith Deep objective, the Kipper Shale, was penetrated from 1991 to 2391m. The unit is essentially an argillaceous siltstone, sandy in places and carbonaceous. Low gas saturations in poor quality reservoir sands from the base of the Kipper Shale to TD indicates that the siltstone unit provides an effective seal.

6.3 Source Rocks (Figure 8, Appendix 5)

Moderate to excellent source potential is recognised in lower coastal plain/back barrier carbonaceous siltstones and coals of the Latrobe Group. A plot of hydrogen index vs oxygen index indicates the dominant kerogen is Type 3, although a trend towards Type 1 with a more oil prone nature is also observed. Source potential within the lacustrine siltstones of the Golden Beach Group sediments is noticeably more lean, ranging between poor and marginal. A plot of hydrogen index vs oxygen index indicates dominantly gas prone Type 3 kerogen.

7. CONCLUSIONS AND CONTRIBUTIONS TO GEOLOGY

(a) The lithological and stratigraphical sequences encountered in Judith-1 were essentially as anticipated from the regional facies distribution mapping.

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

(c) The seismic markers below the base Gippsland Limestone were penetrated 50 m+ high, due mainly to a higher than modelled average velocity in the Lakes Entrance Formation.

(d) Judith-1 is interpreted to have tested a valid hydrocarbon bearing trap at the primary objective, lower Golden Beach Group level, with low effective porosities and very low permeabilities (<1mD). Strong gas shows were recorded whilst drilling and low (30-40%) hydrocarbon saturations were interpreted from logs.

(e) A secondary objective of the well was to test the top of the Golden Beach Group for a possible extension to the Kipper Field. The well results show that the Kipper Field is bounded to the north by the Kipper Fault.

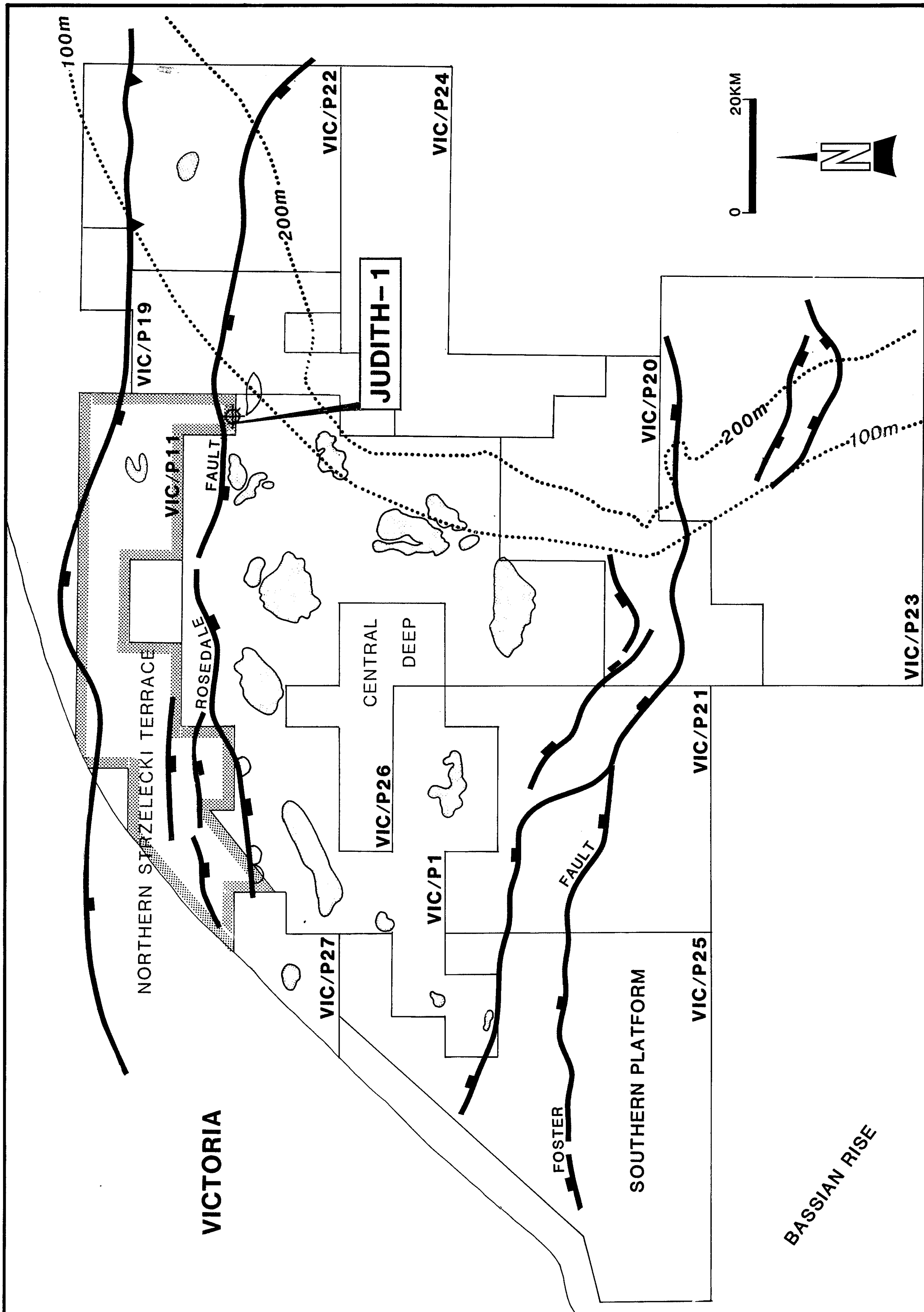
(f) Judith-1 confirmed the excellent top and lateral sealing potential of the lacustrine Kipper Shale.

(g) Reservoir quality of the lower Golden Beach Group alluvial fan sandstones is extremely poor, with log derived porosities in the range 6 to 12% and RFT drawdown permeabilities <1mD. The occlusion of porosity can be mainly attributed to the high proportion of lithic fragments which have given rise to authigenic clays.

(h) The implications of Judith-1 are that, while demonstrating the sealing potential of the Kipper Shale, it also severely downgrades the hydrocarbon potential of the lower Golden Beach Group along the Rosedale Fault margin due to the very poor reservoir quality of the sands.

8. REFERENCES

SDA 915 1989 Exploration Well Proposal Judith-A



SHELL-AUSTRALIA E.& P. OIL AND GAS	GIPPSLAND BASIN VIC/P11			Figure
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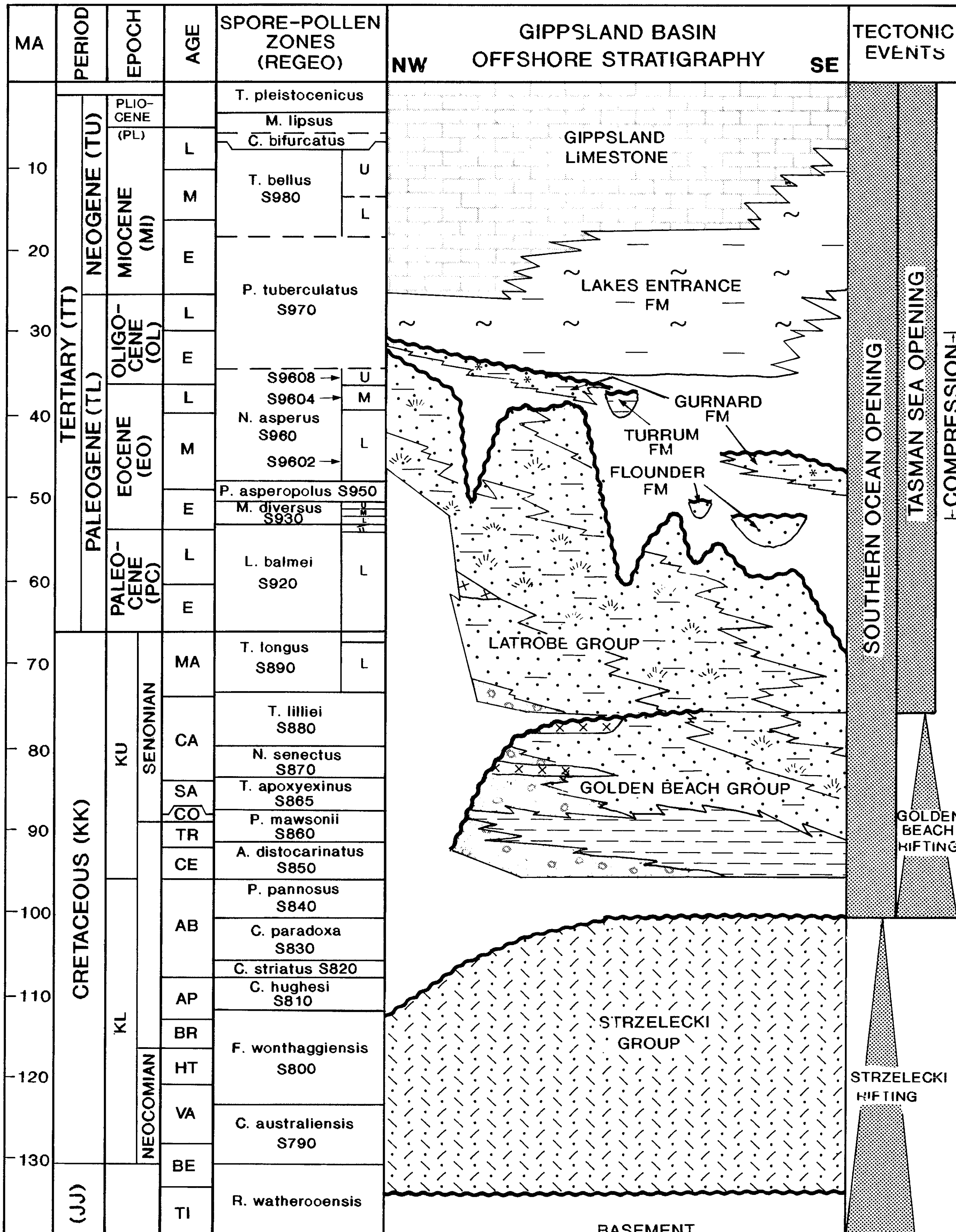
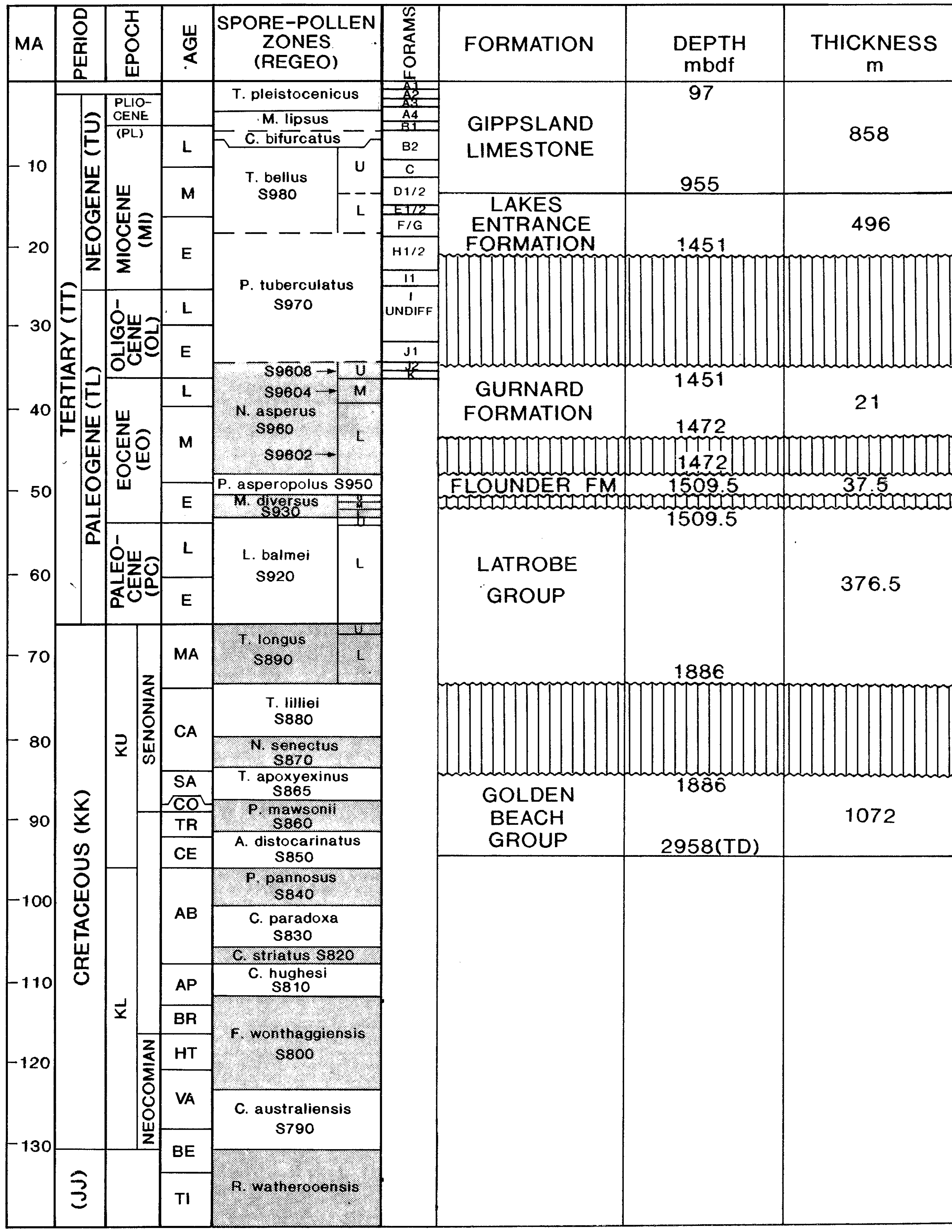
Author: EXO	Report No.: SDA 938	Date: SEPT. 1989	Drawing No.: 25613	



SHELL-AUSTRALIA E.& P. OIL AND GAS	GIPPSLAND BASIN			Figure
	OFFSHORE STRATIGRAPHY			2
	Author: EXO	Report No.: SDA 938	Date: JAN.1990	Drawing No.: 25630



SHELL-AUSTRALIA
E.& P. OIL AND GAS

JUDITH-1 STRATIGRAPHIC TABLE

Author: EXO | Report No..SDA 938 | Date: JUNE 1990 | Drawing No.: 26221

Figure 3

PE900041

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The enclosure PE900041 is enclosed within the container PE900021 at this location in this document.

The enclosure PE900041 has the following characteristics:

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PERMIT =	VIC/P11
TYPE =	SEISMIC
SUBTYPE =	SECTION
DESCRIPTION =	Judith 1 Interpreted Seismic Line GL88-26. Figure 4 from WCR volume 2.
REMARKS =	
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DATE_RECEIVED =	20/08/90
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CONTRACTOR =	
CLIENT_OP_CO =	Shell Australia

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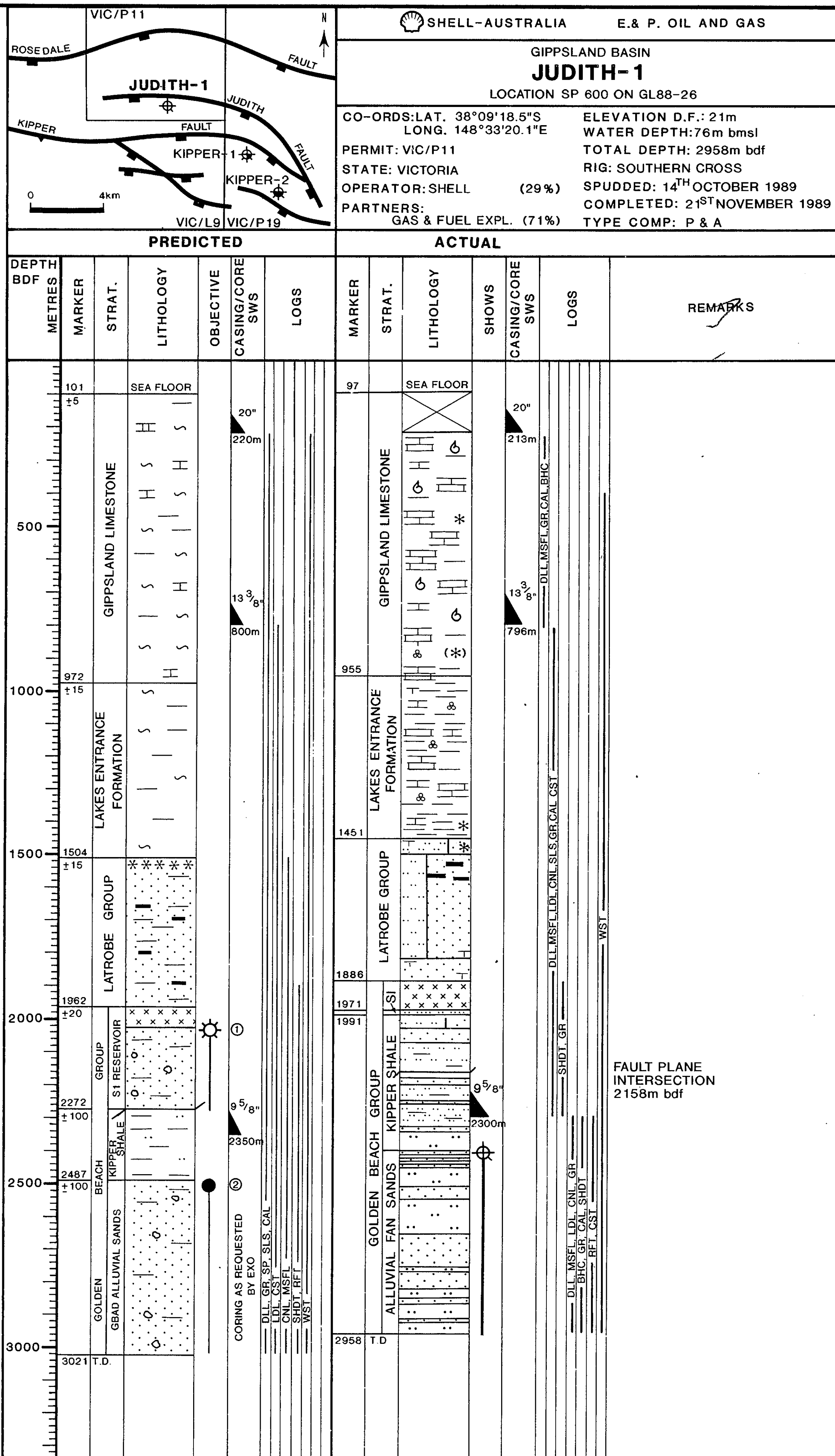


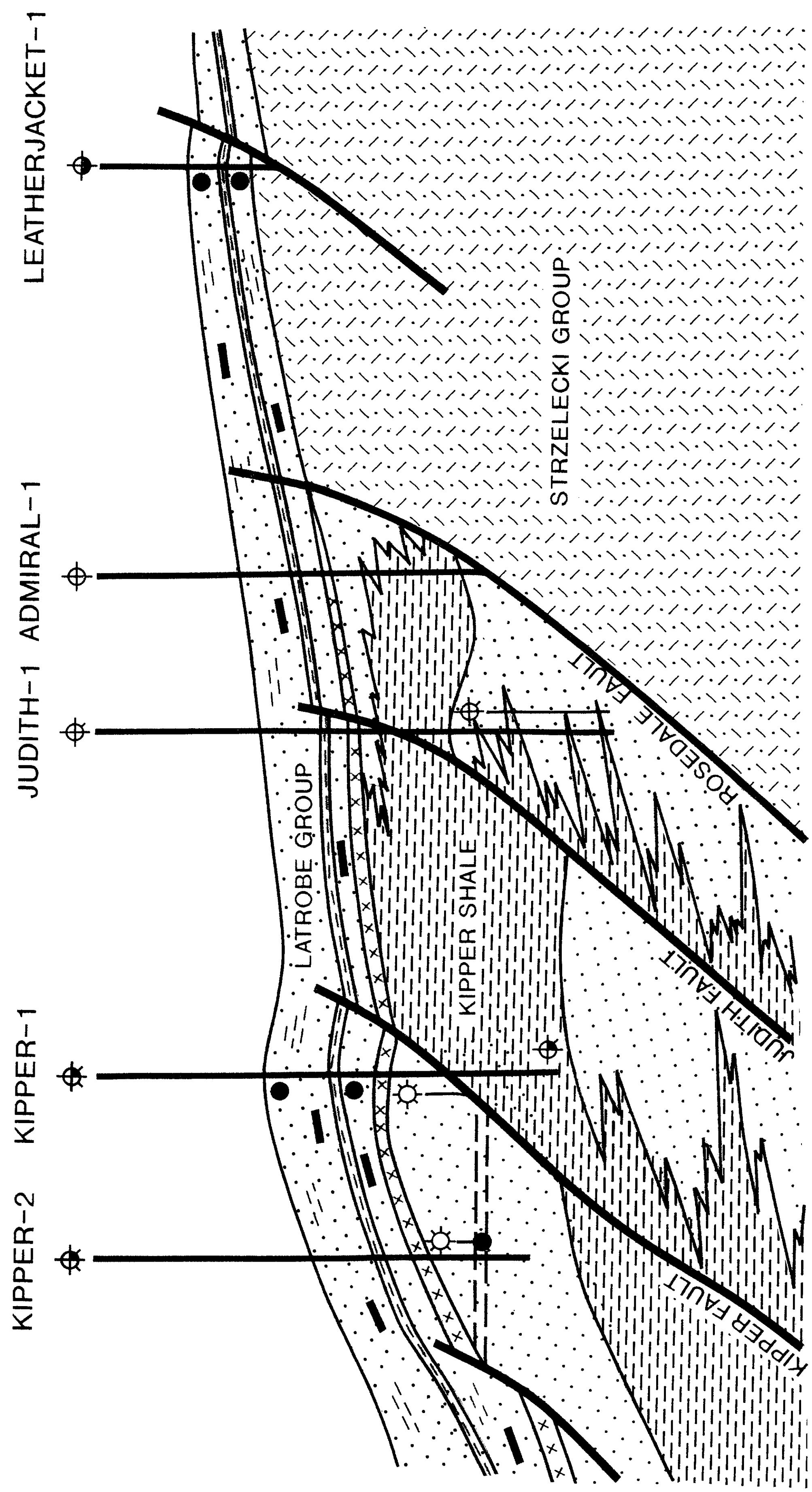
SHELL-AUSTRALIA
E.& P. OIL AND GAS

GIPPSLAND BASIN

JUDITH-1 PREDICTED VS ACTUAL STRATIGRAPHY

Author: EXO | Report No.: SDA 938 | Date: AUGUST 1990 | Drawing No.: 26296

Figure 5



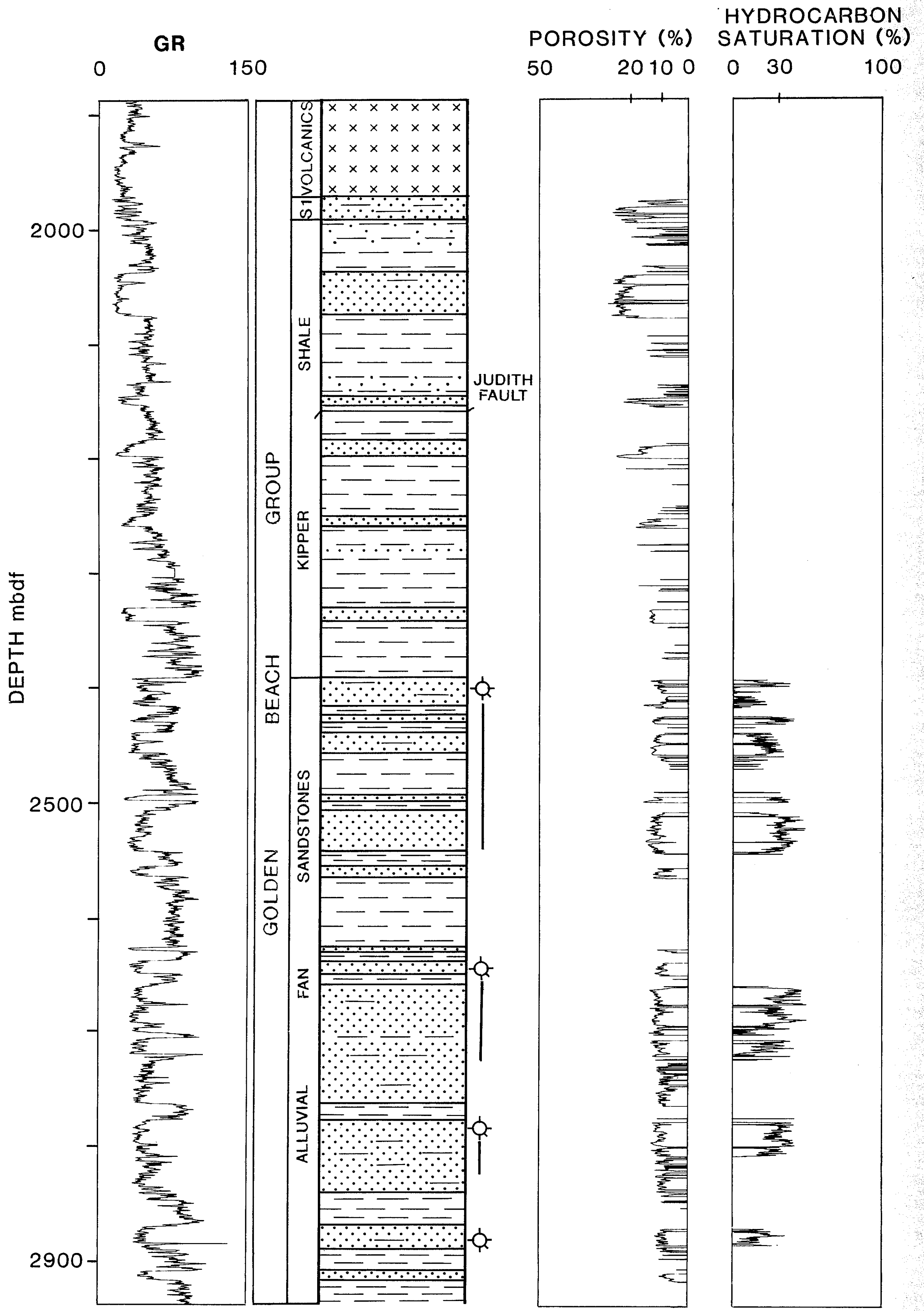
SHELL-AUSTRALIA
E.& P. OIL AND GAS

GIPPSLAND BASIN

CONCEPTUAL GEOLOGICAL CROSS-SECTION KIPPER-LEATHERJACKET

Author: EXO	Report No SDA 938	Date: JUNE 1990	Drawing No.: 25409

Figure 6



SHELL-AUSTRALIA E.& P. OIL AND GAS	GIPPSLAND BASIN VIC/P11 JUDITH-1 PETROPHYSICAL EVALUATION			Figure 7
	Author: EXC	Report: SDA 938	Date: DEC 1989	Drawing No.: 25817

PE905171

This is an enclosure indicator page.
The enclosure PE905171 is enclosed within the container PE900021 at this location in this document.

The enclosure PE905171 has the following characteristics:

ITEM_BARCODE = PE905171
CONTAINER_BARCODE = PE900021
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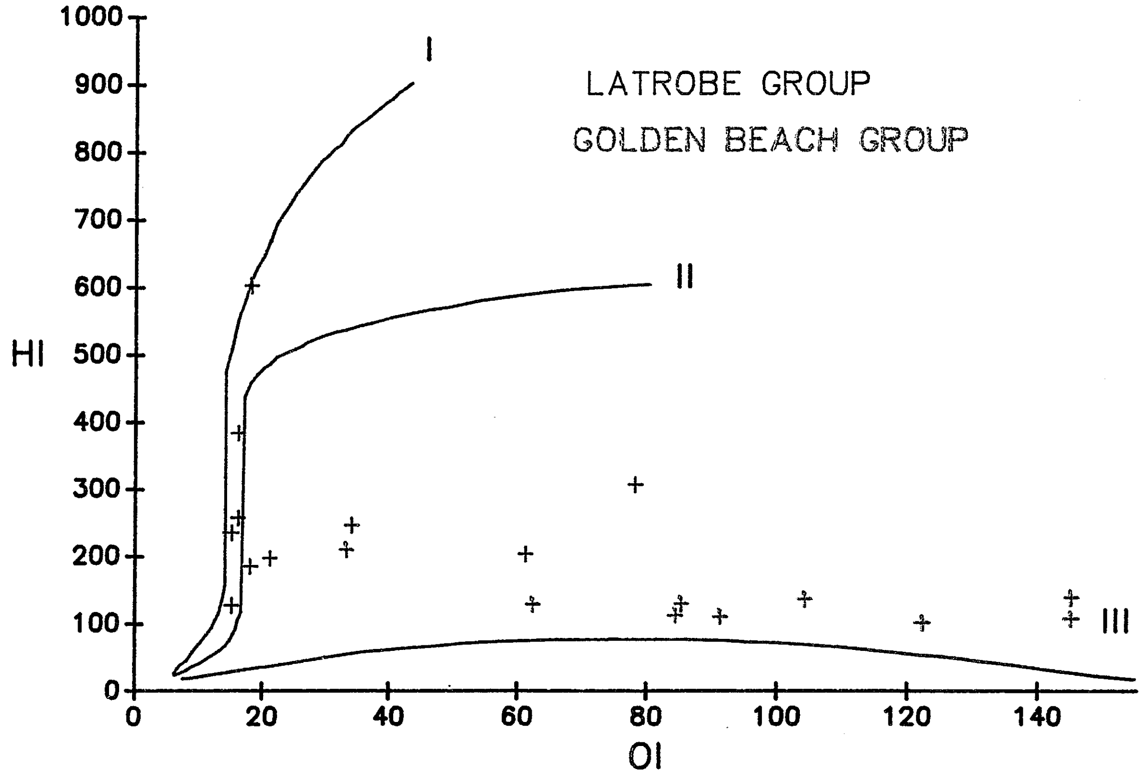
BASIN = GIPPSLAND
PERMIT = VIC/P11
TYPE = WELL
SUBTYPE = DIAGRAM
DESCRIPTION = Judith-1 Rock-Eval Organic Matter Type. Figure 8 from WCR volume 2.
REMARKS = This item contains colour.
DATE_CREATED = 30/06/1990
DATE_RECEIVED = 20/08/1990
W_NO = W1011
WELL_NAME = Judith-1
CONTRACTOR =
CLIENT_OP_CO = Shell Company of Australia Limited

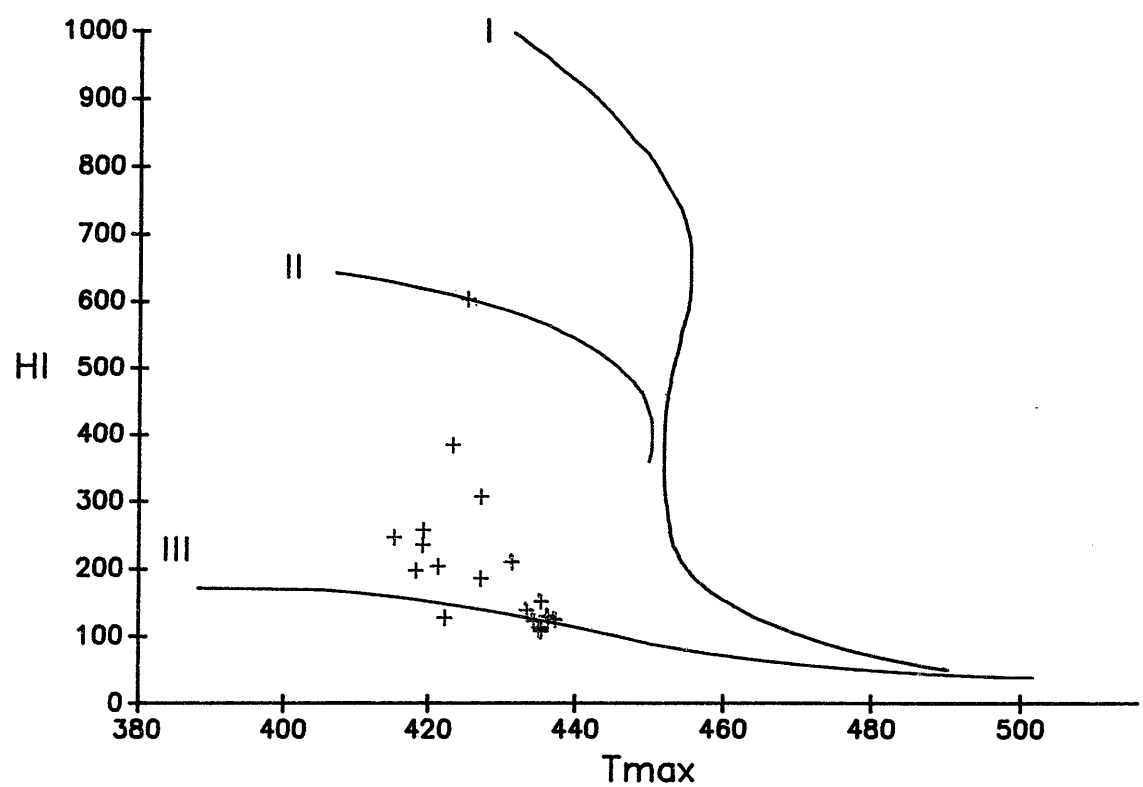
(Inserted by DNRE - Vic Govt Mines Dept)

JUDITH-1

HYDROGEN INDEX vs OXYGEN INDEX



HYDROGEN INDEX vs Tmax



SHELL-AUSTRALIA
E.& P. OIL AND GAS

GIPPSLAND BASIN

JUDITH-1 ROCK-EVAL ORGANIC MATTER TYPE

Author: EXO	Report No.: SDA 938	Date: JUNE 1990	Drawing No.: 26222

Figure 8

PE603206

This is an enclosure indicator page.
The enclosure PE603206 is enclosed within the container PE900021 at this location in this document.

The enclosure PE603206 has the following characteristics:

ITEM_BARCODE =	PE603206
CONTAINER_BARCODE =	PE900021
NAME =	Composite Log
BASIN =	GIPPSLAND
ON_OFF =	OFFSHORE
PERMIT =	VIC/P11
TYPE =	WELL
SUBTYPE =	LOG
DESCRIPTION =	Judith 1 Composite Log. Enclosure 1 of WCR volume 1.
REMARKS =	
DATE_CREATED =	30/06/90
DATE_RECEIVED =	20/08/90
W_NO =	W1011
WELL_NAME =	Judith 1
CONTRACTOR =	Schlumberger
CLIENT_OP_CO =	Shell Australia

(Inserted by DNRE - Vic Govt Mines Dept)

PE603207

This is an enclosure indicator page.
The enclosure PE603207 is enclosed within the container PE900021 at this location in this document.

The enclosure PE603207 has the following characteristics:

ITEM_BARCODE =	PE603207
CONTAINER_BARCODE =	PE900021
NAME =	Synthetic Seismogram
BASIN =	GIPPSLAND
ON_OFF =	OFFSHORE
PERMIT =	VIC/P11
TYPE =	WELL
SUBTYPE =	SYNTH_SEISMOGRAM
DESCRIPTION =	Judith 1 Synthetic Seismogram. Enclosure 2 of WCR volume 2.
REMARKS =	
DATE_CREATED =	30/06/90
DATE_RECEIVED =	20/08/90
W_NO =	W1011
WELL_NAME =	Judith 1
CONTRACTOR =	
CLIENT_OP_CO =	Shell Australia

(Inserted by DNRE - Vic Govt Mines Dept)

APPENDIX 1

PALYNOLOGY

APPENDIX 1

Palynology

PALYNOLOGICAL ANALYSIS, JUDITH-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 eight sidewall core samples and five cuttings samples, representing the interval 1449.0 to 2923.0m in Judith-1, were processed and examined for spore-pollen and dinoflagellates.

Yields and preservation were adequate to high but down-hole caving and low levels of mud-contamination has reduced the confidence of many age-determinations.

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
Late Oligocene - Miocene	LAKES ENTRANCE FORMATION	P. tuberculatus	1449.0	open marine
- - - - -	- - - - -	- Top of Latrobe	- - - - -	- - - - -
Early Oligocene	GURNARD facies?	Upper N. asperus	1451.0	open marine
Late Eocene	GURNARD facies	Middle N. asperus	1454.0	open marine
Middle Eocene	LATROBE GROUP coarse clastics	Lower N. asperus	1471.0	marginal marine
Early Eocene	"	P. asperopolus	1488.0-1503.5	marginal marine
- - - - -	- - - - -	- unconformity?	- - - - -	- - - - -
Early Eocene	"	Middle M. diversus	1509.5	channel fill
"	"	Lower M. diversus	1546.0	marginal marine
Paleocene	"	Upper L. balmei	1571.5-1622.0	marginal marine
"	"	Lower L. balmei	1667.5-1701.5	coastal plain
Maastrichtian	"	Upper T. longus	1764.0-1835.5	coastal plain
"	"	Lower T. longus	1858.0-1875.5	coastal plain
- - - - -	- - - - -	- unconformity	- - - - -	- - - - -
Lower Santonian - Turonian	GOLDEN BEACH FORMATION	P. mawsonii	1993.0-2721.0	rift-valley lake

GEOLOGICAL COMMENTS

1. Judith-1 contains an almost continuous sequence of palynological zones from the Cenomanian-Lower Turonian A. distocarinatus to the Oligo-Miocene P. tuberculatus Zone. Not recorded are the Upper M. diversus, T. lilliei, N. senectus and T. apoxyexinus Zones.

2. The SWC descriptions and palynological determinations indicate that Top of Latrobe occurs between 1449.0 and 1451.0m.

   Based on the abundance of glauconite, the SWC at 1454.0m was shot in the Gurnard facies and, despite the confident Middle N. asperus Zone date, the sample is likely to be part of a condensed sequence incorporating older sediments [see Biostratigraphy Section].

   The glauconitic siltstone sampled at 1451.0m may be part of the same facies or part of the informally named "Oligocene Wedge" - a glauconitic marl and claystone facies which separates Latrobe Group coarse clastics and limestones/marls of the Lakes Entrance Formation in a number of wells around the margin of the basin. The latter is considered the less likely due to the absence of carbonate but is possible due to the Early Oligocene date [see Biostratigraphy Section].

3. Sidewall core descriptions indicate a facies change, from glauconitic to argillaceous siltstones between 1503.5-1509.5m.

   If this lithologic change corresponds to the boundary between P. asperopolus and M. diversus Zone sediments, then I note that thicknesses of the latter [minimum 43m, possibly 68m] run counter to the general thinning trend of M. diversus Zone sediments as these onlap the northern margin of the Gippsland Basin.

4. The SWC at 1509.5m contains a Lower M. diversus Zone palynoflora that appears to have been reworked during Middle M. diversus Zone time. This scenario is typical of Early Eocene channel sediments. Erosion rather than non-deposition appears to be responsible for the absence or very thin nature of M. diversus Zone sediments in wells surrounding the Kipper Trend.

5. Paleocene sediments [minimum 155m] and Maastrichtian sediments [minimum 93m] in Judith-1 are thin relative to sections penetrated in wells closer to the central deep. Again, this may reflect thinning of the unit up onto the flanks of the basin, or erosion.

6. It is possible that the Lower T. longus Zone interval in Judith-1 will appear to correlate with T. lilliei Zone sediments in adjacent wells. This is due to the extreme rarity of the T. longus Zone index species in the early Maastrichtian and therefore some imprecision in the position of the T. longus/T. lilliei Zone boundary in individual wells.

7. On present indications, sediments of Campanian, T. lilliei and N. senectus Zone age are absent. This can only be confirmed by additional palynological analyses of sediments between 1858.0-1993.0m.

   The explanation favoured here is that Judith-1 has intersected the Lowry (1987) "intra-Campanian" unconformity. Given that igneous material was recovered at 1879m [Run 1 sidewall sample description sheet], volcanics may mark the position of an erosion surface.

8. Due to limited sampling and the difficulty of dating mud contaminated SWCs shot in the critical interval [1875.5-1993.0m: see Biostratigraphy Section], it is uncertain whether sediments of Santonian, T. apoxyexinus Zone age are present or not in Judith-1.

   Species which range no lower than the T. apoxyexinus Zone occur at 1984.0m and 1993.0m but the specimens appear to be caved. The former sample lacks "Kipper Shale" dinocysts and therefore represents a facies that is different from the underlying P. mawsonii Zone.

9. SWC and cuttings samples between 2017.0 and 2721.0m are confidently dated as Turonian-Lower Santonian, P. mawsonii Zone.

   The thickness of P. mawsonii Zone unit in Judith-1 [minimum 704m] is comparable to that penetrated in Kipper-1. The relatively shallow depth of the top of the zone is consistent with the location of the well on the upside of a major fault.

10. This unit is characterized by a unusual assemblage of freshwater dinocysts and other algae, previously

recorded only from Kipper-1, Sunfish-1 and grab samples from the Bass Canyon (Marshall, 1990).

These algae, informally known as the "Kipper Shale" dinocysts are abundant only in the upper part of the zone, above 2113.0m and may prove useful in correlating facies across the fault separating Judith-1 and the Kipper wells. Conversely an undescribed but distinctive dinocyst is confined to the lower part of the P. mawsonii Zone, suggesting that this section was not penetrated by Kipper-1.

11. Although it is uncertain if any of the above dinocysts are diagnostic of a particular facies or Zone in the Gippsland Basin, these algae **are** likely to indicate a particular intra-rift valley lacustrine environment.

12. Judith-1 is one of ca. five wells in the offshore Gippsland Basin which appear to have penetrated into Cenomanian-Lower Turonian, Appendicisporites distocarinatus Zone.

    As with the other wells [Golden Beach-1, Moray-1, Sole-1, Tuna-1] the A. distocarinatus dates are of low confidence due to poor preservation and low diversity of palynomorphs. A similar scenario prevails in the Otway Basin.

    It is recommended that future wells likely to intersect Turonian-Cenomanian sediments be sampled in detail at the appropriate depths in order to improve the palynological recognition of non-marine A. disto-carinatus Zone units and environments along the southern margin.

13. The well terminated within the early Late Cretaceous Golden Beach Formation. As is usually the case, recycled Early Cretaceous and Permo-Triassic spore-pollen are frequent in SWCs shot in this formation.

PALAEOENVIRONMENTS

1. Based on the first reliable occurrence of marine dinoflagellates, the Judith-1 wellsite was located in a coastal plain but away from any direct marine influence from Maastrichtian times until the Late Paleocene.

   The earliest definite marine influence recorded in Judith-1 is the Apectodinium homomorpha transgression at 1571.5m. Thereafter, in common with much of the Gippsland Basin, the site was affected by the progressive encroachment of the Tasman Sea. Significant developments include:

   (a) the establishment of a Nypa palm (mangrove) swamp close to but probably not at the wellsite during the earliest Eocene Apectodinium hyperacantha transgression [see Partridge, 1976].

   (b) the persistence of marginal marine/deltaic conditions through the Early Eocene.

   (c) the establishment of open marine conditions at the wellsite during the P. asperopolus Zone, based on (i) the deposition of glauconitic sandstones and siltstones between 1471.0-1503.5m and (ii) the marked increase in abundance and diversity of marine dinoflagellates at and above 1488.0m.

2. During the Turonian-Santonian the wellsite is likely to have been located within a rift valley, almost certainly within the circumference of a large freshwater lake. This lake appears to have fluctuated in area and possibly in depth during the P. mawsonii Zone.

   The evidence for this, as in Kipper-1 and Sunfish-1 consists of freshwater algae whose relative abundance appears to vary inversely with swamp gymnosperms, ferns and other cryptogams.

   Assuming this relationship reflects the distance of the wellsite from the paleoshoreline, then it is possible to speculate on environmental trends due to the unusually thick and well-sampled P. mawsonii Zone sediments in Judith-1:

(a) 2496-2721.0m.

This interval is characterized by very low numbers of a distinctive but undescribed Rimosicysta [R. robusta ms] which almost certainly was tolerant of nearshore/swamp conditions since the cyst occurs in coal floats at 2496-99m, 2571-74m and 2583-86m.

(b) 2143.0-2474.0m

This interval is characterized by sporadic occurrences of dinocysts, mainly Rimosicysta kipperii. Whilst the palaeoenvironmental significance of this is uncertain, the increase upsection in the relative abundance of shrub conifers and treeferns [Microcachrydites antarcticus, Podosporites microsaccatus, Cyatheacidites tectifera] suggests progradation of the shoreline.

(c) 1993.0-2113.0m

This interval is characterized by a marked increase in the abundance of peridinacean cysts and diversity of Rimosicysta spp. This trend is considered to reflect a major expansion/deepening of the lake.

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].

Dinocyst species encountered in the P. mawsonii Zone interval conform well with genera and species described by Marshall (1990).

Because of mud-contamination and the possibility of recycled spore-pollen within lacustrine sediments, it is not certain that the **last** appearance of Appendicisporites distocarinatus or **first** appearances of Phyllocladidites mawsonii are reliable indicators of age in this well.

Appendicisporites distocarinatus Zone 2895.0-2908.0m
Cenomanian-Lower Turonian

SWC samples at 2895.0m and 2908.0m are provisionally dated as A. distocarinatus Zone based on the presence of the nominate species **and** absence of definite specimens of Phyllocladidites mawsonii. The sample at 2908.0m contains an Ornamentifera sp. whose closest known analogue is a species, O. sp cf Ornamentifera sentosa, recovered by Norwick & Burger (1975) from Cenomanian sediments on Bathurst Is., Northern Territory. Otherwise species typical of non-marine Cenomanian sediments elsewhere in Australia were absent. Accordingly a P. mawsonii age remains a possibility for this interval given the rarity of the nominate species in the Turonian.

SWCs below 2908.0m were not recovered or [2923.0m] extensively mud-contaminated. Palynomorphs recovered include the acritarch Micrhystridium, derived from the Kipper Shale?

Phyllocladidites mawsonii Zone 1993.0-2721.0m Lower Santonian -Turonian

This interval is represented by twenty two SWC and five cuttings samples, most of which yielded poorly-preserved palynofloras dominated by gymnosperm pollen, Gleicheniidites and other long-ranging spores.

The nominate and index species of the zone, Phyllocladidites mawsonii, is present throughout the interval although on staining characteristics at least some specimens are caved.

Similarly, described/undescribed species of "Kipper Shale" dinocysts are ubiquitous but only become frequent-dominant in palynofloras near the top of the zone [1993.0-2017.0, 2113.0m].

The base of the P. mawsonii Zone is picked at 2721.0m, a mud-contaminated sample containing the distinctive spore Appendicisporites distocarinatus as well as Phyllocladidites mawsonii.

The first appearance of dinocysts, a species informally described as Rimosicysta robusta, is at 2705.0m. This species extends up section to 2202.0m. The first occurrence of a **described** "Kipper Shale" dinocyst species, R. kipperii, is at 2474.0m. Other records of biostratigraphic significance are:

1. Ornamentifera spp. cf O. sentosa and O. minima Norvick & Burger 1975 at 2653.0m, 2248.0m and 2282.0m [see above].

2. Interulobites intraverrucatus in the SWC sample at 2344.0 and cuttings at 2571-74.0m. These records are important evidence that the samples and hence the associated dinocysts are no younger than P. mawsonii Zone (cf Marshall, 1990). Appendicisporites distocarinatus occurs in the cuttings palynoflora.

3. Frequent to common Cyatheacidites tectifera at 2248.0m. Again this is good evidence that the sample is no younger than Lower Santonian since the species is abundant only in the P. mawsonii Zone in Southern Australia. Several spores have rugulate sculpture on the distal surface and may prove to be the first records in Australia of the related South American fossil spore C. archangelskyi.

Balmeisporites holodictyus and Rouseisporites reticulatus occur in association at 2282.0 and2325.0m.

The upper boundary is provisionally picked at 1993.0m, based on frequent Rimosicysta kipperii. This palynoflora includes a caved? specimen of Tricolpites confessus, a species which first appears in the T. apoxyexinus Zone.

The indeterminate SWC at 1984.0m is extensively contaminated by palynomorphs derived from drilling mud, including T.

confessus.

Lower Tricolpites longus Zone 1858.0-1875.5m Maastrichtian

This zone is weakly defined by the first appearance of Tetracolporites verrucosus in a mixed Nothofagidites-Gambierina palynoflora at 1875.5m. Tricolporites lilliei and Triporopollenites sectilis demonstrate that the sample is no older than 'upper' T. lilliei Zone.

The second of the two samples assigned to this zone contains Forcipites longus and therefore is no older than Lower T. longus Zone. The age determination is supported by the relative abundance of Nothofagidites [frequent] and Gambierina [common]. Stereisporites punctatus is absent.

Upper Tricolpites longus Zone 1764.0-1835.5m Maastrichtian

Palynofloras within this interval are characterized by common-abundant Gambierina.

The lower boundary is defined by the first appearance of Stereisporites punctatus at 1835.5m and the upper boundary at 1764.0m by the last appearance of species which range no higher than this zone, e.g. Forcipites longus, Proteacidites reticuloconcavus, Tricolporites lilliei and Triporopollenites sectilis.

Lower Lygistepollenites balmei Zone 1667.5-1701.5m Paleocene

This interval is distinguished from the above zone by the abundance of Proteacidites spp., in particular P. angulatus, and rarity of Gambierina rudata. The nominate species is frequent to common. Australopollis obscurus is abundant at 1667.5m, picked as the top of the zone.

Upper Lygistepollenites balmei Zone 1571.5-1622.0m Paleocene

The lower boundary is defined by the first appearance at 1622.0m of Proteacidites incurvatus and Malvacipollis subtilis in a palynoflora dominated by Lygistepollenites balmei, Nothofagidites kaitangata and Australopollis obscurus

The sample is mud-contaminated [Rimosicysta kipperii, Phimopollenites pannosus] making it uncertain whether specimens of the Paleocene dinoflagellate Apectodinium homomorphum are in situ or caved.

The upper boundary, at 1571.5m, is defined by Cyathidites gigantis, Banksieaeidites elongatus and Polycolpites langstonii in a palynoflora dominated by Lygistepollenites balmei, Gleicheniidites and Australopollis obscurus. Apectodinium homomorphum is frequent.

Based on staining characteristics, the interval 1571.5-1667.5m is the source of much of the caved spore-pollen encountered in Judith-1, in particular Australopollis obscurus and Phyllocladidites mawsonii.

Lower Malvacipollis diversus/A. hyperacantha Zone 1546.5m Early Eocene

The one palynoflora assigned to this zone contains an association of spore-pollen and dinoflagellates which first appears in, and possibly is unique to, the Lower M. diversus Zone: Spinizonocolpites prominatus, Crassiretitriletes vanraadshoovenii, Polypodiaceoisporites varus, Apectodinium hyperacantha and Fibrocysta bipolare. The nominate species Malvacipollis diversus is abundant.

Although all of the above species range above the Lower M. diversus, the sample is highly unlikely to be younger than this zone based on the relative abundance of S. prominatus and frequency of [reworked] Lygistepollenites balmei and other long-ranging Cretaceous-Paleocene species.

Middle Malvacipollis diversus Zone 1509.5m Early Eocene

The palynoflora at 1509.5m is essentially Lower M. diversus Zone [Cyathidites gigantis and frequent Proteacidites grandis and Malvacipollis spp.] but includes a population of the typically Middle M. diversus Zone dinoflagellate Apectodinium parvum and two specimens of Proteacidites ornatus, a species which first appears in the same zone.

Although species diagnostic of the Upper M. diversus-P. asperopolus Zone are absent, e.g. Myrtaceidites tenuis and Proteacidites pachypolus, the sample does appear to contain anomalously early records of Proteacidites crassus and Tricolporites leuros.

This mixture of species is characteristic of channel fill sediments which have undergone reworking, in the present case during the Middle M. diversus Zone and possibly during P. asperopolus Zone time.

The change in lithology from argillaceous to glauconitic between 1509.5 and 1503.5m may correspond to the biostratigraphic boundary between the P. asperopolus and M. diversus Zones.

Proteacidites asperopolus Zone 1488.0-1503.5m Early Eocene

The three SWC samples within this interval contain Myrtaceidites tenuis and Proteacidites pachypolus and therefore definitely are no older than Upper M. diversus Zone.

The lower boundary, at 1503.5m, is defined by the first appearance of Tricolpites incisus and Clavatipollenites glarius, species which very occasionally are found below this zone. Proteacidites ornatus and Intratriporopollenites notabilis demonstrate the sample is no younger than P. asperopolus Zone.

The sample contains a number of Early Eocene marine dinoflagellates, e.g. Cordosphaeridium inodes, Homotryblium tasmaniense and Apectodinium sp cf Apectodinium parvum, as well as reworked Paleocene spp. such as Australopollis obscurus and Lygistepollenites balmei.

The palynoflora recovered from the SWC at 1502.0m is similar except that dinoflagellates present include fragments of a Kisselovia sp., possibly K. coleothrypta. Specimens of the typically Middle N. asperus Zone species Tricolpites thomasii and Lower N. asperus Zone dinoflagellate Areosphaeridium diktyoplokus indicate minor mud-contamination of this SWC.

The upper boundary is confidently placed at 1488.0m, a sample containing the nominate species, Sapotaceoidaepollenites rotundus and frequent Conbacũlites apiculatus in addition to species which range no higher than the P. asperopolus Zone, e.g. Myrtaceidites tenuis, Proteacidites ornatus and P. tuberculiformis. Dinoflagellates include Cleistosphaeridium epacrum, Apectodinium sp. cf A. hyperacantha and [caved] Areosphaeridium diktyoplokus.

Lower Nothofagidites asperus Zone 1471.0m Middle Eocene

Palynofloras at and above 1471.0m are dominated by Nothofagidites emarcidus-heterus, a reliable indication of a N. asperus Zone age.

One sample is confidently assigned to the Lower N. asperus Zone, based on Proteacidites asperopolus, Tricolpites simatus, Verrucatosporites attinatus, Rugulatisporites trophus and the dinocyst Tritonites pandus. Areosphaeridium diktyoplokus is present, and a Deflandrea sp. closely resembling the Early Eocene species D. dartmooria frequent, in this sample.

Middle Nothofagidites asperus Zone 1454.0m Late Eocene

The sample at 1454.0m contains both pollen and dinoflagellate index species for the Middle N. asperus Zone: Triorites magnificus and Gippslandica extensa. Other dinoflagellates include Cleistosphaeridium epacrum and Schematophora speciosus.

The occurrence of an Early Eocene species Proteacidites tuberculiformis indicates incorporation of older sediments, probably through bioturbation.

Upper Nothofagidites asperus Zone 1451.0m Early Oligocene

The SWC at 1451.0m is dated as Upper N. asperus Zone with a low degree of confidence due to the **absence** of both Middle N. asperus and P. tuberculatus Zone indicators, in particular Cyatheacidites annulatus and the dinocyst Protoellipsodinium simplex. Dinoflagellates are abundant relative to spore-pollen.

Irrespective of the zonal uncertainty, an Early Oligocene age is probable based on the presence of multiple specimens of Pyxidinopsis pontus and the abundance of Nothofagidites spp., including N. falcatus.

Proteacidites tuberculatus Zone 1449.0m Oligo-Miocene

Cyatheacidites annulatus and Protoellipsodinium simplex confirm a P. tuberculatus Zone age for this, the highest sample available for palynological analysis in Judith-1.

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LEGEND

SPORE-POLLEN	DINOFLAGELLATE
P. tub. = P. tuberculatus Zone	P. com. = P. comatum Zone
U. N.a. = Upper N. asperus Zone	C. inc. = C. incompositum
M. N.a. = Middle N. asperus Zone	D. ext. = D. extensa Zone
L. N.a. = Lower N. asperus Zone	D. het. = D. heterophylcta
P. asp. = P. asperopolus Zone	T. pan. = T. pandus Zone
U. M.d. = Upper M. diversus Zone	A. aro. = A. australicum
M. M.d. = Middle M. diversus Zone	T. ast. = T. asteris Zone
L. M.d. = Lower M. diversus Zone	K. edw. = K. edwardsii
U. L.b. = Upper L. balmei Zone	K. tom. = K. thompsonae
L. L.b. = Lower L. balmei Zone	K. orn. = K. ornatum
U. T.l. = Upper T. longus Zone	K. wai. = K. waipawaensis
L. T.l. = Lower T. longus Zone	A. hyp. = A. hyperacantha
T. lil. = T. lilliei Zone	A. hom. = A. homomorphum
N. sen. = N. senectus Zone	E. crs. = E. crassitabulata
T. apx. = T. apoxyexinus Zone	T. evt. = T. evittii Zone
P. maw. = P. mawsonii Zone	M. drg. = M. druggii Zone
A. dst. = A. distocarinatus Zone	I. kor. = I. korojonense
P. pan. = P. pannosus Zone	X. aus. = X. australis
C. pdx. = C. paradoxa Zone	N. asc. = N. asceras
C. str. = C. striatus Zone	I. cre. = I. cretaceum
C. hug. = C. hughesii Zone	O. por. = O. porifera
F. wng. = F. wonthaggiensis Zone	C. str. = C. striatoconus
C. aus. = C. australiensis Zone	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 2: SUMMARY OF BASIC PALYNOLOGICAL DATA

SWC	DEPTH (m)	YIELD S-P	YIELD DINO	DIVERSITY S-P	DIVERSITY DINO	PRES.	LITH.*
Logging Run 1							
49	1449.0	med.	med.	low	high	good	ST.ls
48	1451.0	low	high	med.	med.	poor	ST.gc
47	1454.0	mod.	med.	high	high	mod.	GC
46	1471.0	high	high	med.	high	good	ST.gc
45	1488.0	med.	med.	high	med.	mod.	ST.gc
44	1502.0	low	low	med.	med.	poor	ST.gc
43	1503.5	med.	high	high	med.	good	SS.gc
42	1509.5	high	med.	med.	low	good	ST.cl
41	1546.5	high	high	med.	med.	mod.	ST.cl
39	1571.5	med.	low	med.	low	poor	ST.cl
38	1600.0	high	-	high	-	mod	ST.cl
36	1622.0	high	caved?	high	low	good	ST.cl
34	1667.5	med.	-	med.	-	mod.	ST.cl
33	1691.0	High	caved	med.	-	good	ST.sa
32	1701.5	high	-	med.	-	good	ST.cl
29	1764.0	med.	-	high	-	good	ST.cl
28	1777.5	high	caved	med.	-	mod.	MS/CO
27	1803.0	low	caved	med.	low	mod.	ST.sa
26	1821.5	low	-	high	-	mod.	ST.cl
25	1835.5	high	caved	high	low	mod.	ST.cl
24	1858.0	high	-	high	-	mod.	ST.cl
22	1875.5	med.	-	high	-	poor	ST.cl
19	1977.0	low	caved	med.	-	mod.	ST.cl
18	1984.0	low	-	med.	-	mod.	MS.st
17	1993.0	med.	med.	med.	med.	poor	ST.sa
16	2017.0	med.	med.	med.	high	poor	ST.cl
15	2023.0	high	low	high	med.	poor	ST.sa
ctg	2025-28	high	low	high	low	good	
12	2092.0	med.	low	med.	low	poor	SS.cl
ctg	2112-14	high	low	high	low	mod.	
11	2113.0	med.	high	med.	high	poor	ST.cl
10	2143.0	high	caved	med.	-	poor	SS.st
08	2176.0	med.	-	high	-	mod.	ST.sa
07	2202.0	low	low	med.	low	good	ST.sa
05	2224.0	med.	low	med.	low	mod.	ST.cl
04	2248.0	high	low	high	low	poor	SS.st
02	2282.0	high	low	high	low	mod.	ST.cl
01	2308.0	high	low	med.	low	mod.	SS.cl

TABLE 2: SUMMARY OF BASIC PALYNOLOGICAL DATA

SWC	DEPTH (m)	YIELD S-P	YIELD DINO	DIVERSITY S-P	DIVERSITY DINO	PRES.	LITH.
Logging Run 2							
30	2325.0	high	low	low	low	poor	ST
28	2344.0	med.	low	med.	low	poor	ST
27	2364.0	low	-	low	-	mod.	ST.sa
22	2435.0	med.	-	low	-	poor	SS.st
21	2474.0	low	low	low	low	poor	ST.sa
ctg	2496-99	high	low	med.	low	mod.	ST.co
ctg	2571-74	low	low	med.	low	poor	ST.co
ctg	2583-86	low	low	med.	low	poor	ST.co
14	2630.5	high	-	med.	-	poor	ST.cl
13	2653.0	low	low	low	low	mod.	SS.st
11	2705.0	high	low	med.	low	mod.	MS.st
10	2721.0	high	caved	med.	-	poor	MS
05	2895.0	low	-	med.	-	poor	ST.cl
04	2908.0	low	caved	med.	-	mod.	ST.cl
03	2923.0	low	caved	med.	-	mod.	SS.cl

* Lithological descriptions [main rock type.qualifer] taken from hand-written sidewall sample description sheet.

PART A: SAMPLES 1451.0-2023.0m

Well Name JUDITH-1 Basin GIPPSLAND Sheet No. 1 of 5

SAMPLE TYPE OR NO. *	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
FOSSIL NAMES / DEPTHS metres	1451.0	1454.0	1471.0	1488.0	1502.0	1503.5	1509.5	1546.5	1571.5	1600.0	1622.0	1667.5	1691.0	1701.5	1764.0	1777.5	1803.0	1821.5	1835.5	1858.0	1875.5	1977.0	1984.0	1993.0	2017.0	2023.0
SPORE-POLLEN																										
Alisporites grandis					R																					
A. similis													•													
Amosopollis cruciformis												•									•				•	•
Anacolosidites acutullus				•	•	•																				
A. rotundus ms			•		•	•																				
A. sectus																										
Araucariacites australis		•		•		•	•	•		•	•				•		•	•	•	•	•			•	•	
Arecipites spp.				•		•				•																
Australopollis obscurus					C				•	•	•	•	•			•		•		•		C	•		C	
Baculatisporites comaumensis								R										•								•
B. disconformis		•		•	•					•	•	•	•													
Balmeisporites holodictyus																									•	
Banksieaeidites arcuatus										•																
B. elongatus							•		•																	
B. lunatus ms																										
Basopollis mutabilis ms								•	•					•												
B. otwayensis ms									•	•	•	•		•	•		•	•			•					
Beaureadites eleganisformis		•	•			•																				
B. orbiculatus												•			•											
B. verrucatus		•					•																			
Bluffopollis scabratus			•																							
Camarozonosporites australiensis													•			•			•		•		•			
C. dumus ms							•													•	•					
C. heskermensis													•	•				•		•	•					
C. horrendus ms																				•	•					
Ceratosporites equalis																										•
Cicatricosisporites australiensis								R			R			R				•								•
C. ludbrookii												R														
C. pseudotripartitus													R													
C. spp. indet./undescribed	•												R									C		•		
Clavifera triplex			•					•	•	•							•	•	•							
Clavatipollenites glarius			•			•																				
Conbaculatisporites apiculatus ms				•						C																
Concavissimisporites penolaensis																									•	
Coptospora sp. nov.																									•	
Crassiretitriletes vanraadshooveni					•																					
Crybelosporites striatus																			R							
Cunoniaceae-type				•						•																
Cupanieidites or oteichus		•	•	•	•	•																				
C. reticularis				•																						
Cyathidites australis				R				R	R				R					R								
C. gigantis							•		•																	
C. minor	•	•		•		•		•	•		•	•	•					•					•		•	•
C. palaeospora	•		•																							
C. splendens			•	•	•	•	•	•	•	•	•		•	•	•		•	•	•	•		C				•
Cyclosporites hughesii														R												
Dacrycarpites australiensis				•				•					•		•	•										
Deltoidaspora			•	•																						
Densoisporites velatus																				•	•					
Dicotetradites clavatus		•		•		•	•			•		•					•		•	•		C	C			
Dictyophyllidites spp.						•							•													
Dictyotosporites speciosus																					R					
Dilwynites granulatus						•			•										•			C		•	•	•
D. tuberculatus					•	•																				
Dryptopollenites semilunatus			•																							

C=CORE S=SIDEWALL CORE

R = REWORKED SP.

Well Name JUDITH-1 Basin GIPPSLAND Sheet No. 2 of 5

SAMPLE TYPE OR NO. *	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
FOSSIL NAMES / DEPTHS metres	1451.0	1454.0	1471.0	1488.0	1502.0	1503.5	1509.5	1546.5	1571.5	1600.0	1622.0	1667.5	1691.0	1701.5	1764.0	1777.5	1803.0	1821.5	1835.5	1858.0	1875.5	1977.0	1984.0	1993.0	2017.0	2023.0
Elphredripites notensis				•		•		•																		
Ericipites scabratus	•					•				•							•			•	•	C				
Foraminisporis asymmetricus																								R		R
Forcipites longus															•					•	?					
Forcipites spp. indet./undescribed															•				•							
Foveosporites canalis													R												•	
Foveotriletes balteus					•																					
F. parviretus					R			R			R		R	R						R						
Gambierina rudata											•	•	•	•	•	•	•	•	•	•	•	C	C			C
Gleicheniidites spp.	•		•	•	•	•	•	•	•	•	•	•	•	•		•	•	•	•	•		C	•	•	•	•
Grapnelispora cf evansii																				•						
Haloragacidites harrisii	•	•	•	•	•	•	•	•	•	•	•						C					C				
Herkosporites elliotii				•					•	•			•	•		•		•		•					•	•
Ilexpollenites anguloclavatus		•	•				•	•			•		•									C				
Intratriporopollenites notabilis						•																				
Ischyosporites gremius	•	•	•	•	•	•																				C
I. irregularis ms					•	•		•								C										
I. punctatus																			R							
Klukisporites scaberis																			R							
Kraeuselisporites majus														•				•	•		•					•
Laevigatosporites spp.		•		•	•	•		•	•	•	•	•	•	•	•		•	•	•	•	•	C?	•	•		
Latrobosporites amplus									•		•	•	•	•			•	•	•	•		C				
L. crassus				•			•		•		•	•			•	•	•	•	•		•	C				
Leptosporites verrucatus					R									R												
Liliacidites ruppiaeformis ms															•			•	•							
L. spp. indet./undescribed				•											•					•	•					•
cf Lycopodiacites asperatus					R					R			R												•	
Lycopodiumsporites australoclavatidites																							•			
L. circolumenus														R												
L. nodosus																										
L. spp.			•								•	•		•	•	•			•	•				•		•
Lygistepollenites balmei						R		R	•	•	•	•	•	•		•	•	•	•	•	•	C	C		C	
L. florinii	•	•		•	•	•	•	•	•	•	•	•	•	•			•	•	•		•	C			C	
Malvacipollis diversus		•					•	•																		
M. duratus ms			•	•		•	•																			
M. robustus ms		•																								
M. subtilis			•	•	•	•	•				•															
Matonisporites ornamentalis	•	•				•			•	•	•															
Micrantheum spinyspora		•																								
Microcachrydites antarcticus	•		•								•				•	•	•		•	•	•	•	•	•	•	•
Milfordia homeopunctata					•	•																				
Monolites alveolatus			•																							
Myrtaceidites eugenioides				•																						
M. eucalyptoides	•	•			•	•																				
M. parvus-mesonesus		•	•	•	•	•	•																			
M. tenuis				•	•	•		C																		
Neoraistrickia truncata		R																						R		
Nothofagidites asperus	•	•									•															
N. brachyspinulosus		•	•		•				•																	
N. deminutus-vansteenii	•	•	•																							
N. emarcidus-heterus	•	•	•	•	•	•	•															C	C		C	C
N. flemingii		•	•	•	•	•	•		•		•												C			
N. falcatus	•	•																				C				
N. goniatus			•	•																						
N. kaitangata								C	•	•	•	•	•	•			•	•	•	•	•	C		C		
N. senectus s.l.										•	•	•		•				•	•	•	•					

* C=CORE S=SIDEWALL CORE

R = REWORKED SP.

Well Name JUDITH-1 Basin GIPPSLAND Sheet No. 3 of 5

FOSSIL NAMES / DEPTHS (metres)	1451.0	1454.0	1471.0	1488.0	1502.0	1503.5	1509.5	1546.5	1571.5	1600.0	1622.0	1667.5	1691.0	1701.5	1764.0	1777.5	1803.0	1821.5	1835.5	1858.0	1875.5	1977.0	1984.0	1993.0	2017.0	2023.0
SAMPLE TYPE OR NO. *	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
Osmundacites wellmanii																					•			•		
Parvisaccites catastus			•	•					•																	
Peninsulapollis askinae																							C			
P. gillii										•		•	•	•	•	•	•	•	•	•	•	C?:	C			
Periporopollenites demarcatus			•	•	•	•	•				•				•	•			•	•						
P. polyoratus		•					•				•	•			•	•				•		C				
P. vesicus				•																						
Peromonolites bacculatus ms												•														
P. densus										•	•		•				•	•		•						
Phimopollenites pannosus											C					C										•
Phyllocladidites mawsonii	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	C	C		•	•
P. verrucosus								C			•	•		•		•		•			•					
P. reticulosaccatus									•	•		•	•	•	•	•			•				C		•	
Phyllocladus palaeogenicus	•		•							•																
Podocarpidites spp.	•	•	•	•		•	•	•	•	•	•	•	•		•	•	•	•	•	•	•	•	•		•	•
Podosporites erugatus			•																							
P. microsaccatus				•		•	•	•			•	•			•	•	•		•	•	•	•	•		•	•
Polycingutriletes pocockii																										
Polypodiaceoisporites varus				•	•			•																		
Polypodiidites spp.	•		•															•	•			C				
Polycolpites langstonii									•		•															
Proteacidites adanthoides		•				•	•																			
P. ademonosus ms																•		•		•	•					
P. angulatus												•	•	•	•		•			•		C				
P. annularis				•	•	•	•		•													C				
P. asperopolus			•	•																						
P. callosus																										
P. cleinei ms															•	•	•	•	•		•					
P. cf confragosus															•											
P. crassus		•	•	•	•		•																			
P. differentipollis		•																								
P. dierama															•	•		•	•							
P. grandis	•			•	•	•	•																			
P. incurvatus							•				•															
P. kopiensis						•																				
P. latrobensis			•		•	•																				
P. leightonii			•	•	•	•																				
P. nasus		•		•																						
P. obscurus			•			•	•			•																
P. ornatus				•																						
P. otwayensis ms															•		•	•	•							
P. pachypolus		•	•	•	•	•																				
P. palisadus															•					•	•					
P. pseudomoides			•																							
P. rectus								•		•																
P. reticuloconcavus ms															•			•	•		•	C		C		
P. reticuloscabratus			•		•				•																	
P. retiformis													•		•			•	•							
P. tuberculiformis		R		•		•																				
P. xestoformis ms						•																				
P. spp. indet./undescribed	•		•	•	•	•		•	•	•	•	•	•	•	•	•	•	•	•	•	•		•			
Pseudowinterapollis cranwellae											•															
P. wahooensis																		•								
Quadraplanus brossus																•						C				
Rouseisporites reticulatus													•	•					•		•					
R. simplex																	•							•	•	•

* C=CORE S=SIDEWALL CORE

R = REWORKED SP.

Well Name JUDITH-1 Basin GIPPSLAND Sheet No. 4 of 5

SAMPLE TYPE OR NO. *	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
FOSSIL NAMES / DEPTHS metres	1451.0	1454.0	1471.0	1488.0	1502.0	1503.5	1509.5	1546.5	1571.5	1600.0	1622.0	1667.5	1691.0	1701.5	1764.0	1777.5	1803.0	1821.5	1835.5	1858.0	1875.5	1977.0	1984.0	1993.0	2017.0	2023.0
Rugalatisporites mallatus					●	●		●		●													●			
R. trophus			●																							
Santalumidites cainozoicus			●	●	●	●																				
Sapotaceoidaepollenites rotundus		●	●	●																						
cf Sestrosporites																										●
Spinizonocolpites prominatus								●																		
Stereisporites antiquisporites								●	●	●	●		●	●	●			●		●	●	●			●	●
S. australis f. crassa					●						●			●		●	●					C				
S. punctatus ms				●	●	●		●	●	●	●	●	●	●	●	●	●		●				C			
S. regium ms																●		●	●	●	●					
S. spp.		●				●	●	●	●	●	●	●	●	●		●		●	●	●	●		●	●		
Stoveripollis lunaris																●										
taeniate bisaccates [Permo-Triassic]																							R	R	R	R
Tetracolporites multistrixus ms						●	●		●					●												
T. textus ms									●													C				
T. verrucosus											●		●	●		●		●	●		●					
Tetradopollis securus																		●			●					
Tricolpites confessus													●		●	●		●	●		●		C	C?		
T. gigantis ms									●	●																
T. halis				●		●		●																		
T. incisus				●	●	●																				
T. phillipsii							●		●		●			●			●									
T. reticulatus										●																
T. paenestriatus				●		●																				
T. simatus		●	●																							
T. thomasii			●		C																					
T. waiparensis															●	●		●	●	●	●					
T. spp indet./undescribed			●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Tricolporites adelaidensis						●																				
T. balmei ms										●																
T. lilliei															●			●	●	●	●					
T. moultonii ms						●																				
T. patulus																										
T. scabratus		●				●																				
T. sphaerica						●	●																			
T. spp. indet./undescribed			●	●	●	●	●	●	●	●	●	●	●		●	●	●	●	●	●	●	●	●	●		●
indeterminate trilete spores	●		●		●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Triletes tuberculiformis		●																								
Triorites magnificus																										
Triporopollenites heleosus				●		●																				
T. sectilis															●	●		●	●	●	●					
Trisaccites																										●
Verrucatosporites attinatus ms			●																							
Verrucosisporites kopukuensis		●	●	●	●			●	●																	
Bysmapollis emaciatus					●																					
Myrtaceidites verrucosus						●																				
Corollinia spp.													R													
Proteacidites amolosexinus															●			●		●	●					
Appendicisporites distocarinatus																	R								●	●
Proteacidites wahooensis																			●							
Cyatheacidites tectifera																									●	

C=CORE S=SIDEWALL CORE

R = REWORKED SP.
C = CONTAMINANT

Well Name JUDITH-1 Basin GIPPSLAND Sheet No. 5 of 5

SAMPLE TYPE OR NO. *	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
FOSSIL NAMES / DEPTHS METRES	1451.0	1454.0	1471.0	1488.0	1502.0	1503.5	1509.5	1546.5	1571.5	1600.0	1622.0	1667.5	1691.0	1701.5	1764.0	1777.5	1803.0	1821.5	1835.5	1858.0	1875.5	1977.0	1984.0	1993.0	2017.0	2023.0
DINOFLAGELLATES & OTHER ALGAE																										
Achomosphaera crassipellis								•																		
Aireiana verrucosa			•																							
Apectodinium homomorphum								•	•		C						C		C			C		C		
A. hyperacanthum						•		•																		
Areosphaeridium arcuatum		•																								
A. capricornum	•																									
A. diktyoplokus			•	C	C																					
Baltisphaeridium nanum																										
Cleistosphaeridium epacrum ms		•	•	•																						
Cordosphaeridium inodes		•	•	•		•	•																			
Deflandrea dartmooria			•																							
D. spp. indet/undescribed				•					•																	
Fibrocysta bipolare								•																		
Homotryblium tasmaniense				•		•																				
Impagidinium spp.	•	•																								
Kenleyia spp.								•																		
Kisselovia sp. cf K. coleothrypta					•																					
Operculodinium centrocarpum	•				•	•											C					C				
Paralecaniella indentata		•		•	•	•		•																		
Pediastrum																									•	
peridinaceaen cysts cf Luxadinium																			C					•	•	•
Pyxidinopsis pontus ms	•																									
Rimosicysta cf cucullata																									•	
R. cf eversa																									•	
R. kipperii											C													•	•	
R. cf kipperii																								•	•	
R. robusta ms																										
R. spp. indet./undescribed																						C		•	•	
Schematophora speciosus		•																								
Spiniferites spp.	•	•			•		•										C					C				
Thalassiphora spp.			•																							
Wuroia corrugata																								•	•	
W. unciformis																								•	•	
INDET. DINOCYSTS	•	•	•	•	•	•		•	•				C											•	•	•
Apectodinium parvum							•																			
Micrhystridium																								•	•	
Veryhackium																										
Gippslandica extensa		•																								
Tritonites pandus			•																							
Hystrichosphaeridium rigaude				•																						
Rimosicysta cf aspera																								•	•	

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

TABLE NO. :

CHECK LIST OF SPORE-POLLEN & DINOCYSTS

PART B: SAMPLES 2025-2923.0m

Well Name JUDITH-1 Basin GIPPSLAND Sheet No. 1 of 3

SAMPLE TYPE OR NO. *	T	S	T	S	S	S	S	S	S	S	S	S	S	S	S	S	T	T	T	S	S	S	S	S	S	S
FOSSIL NAMES / DEPTHS metres	2025-28	2092.0	2112-14	2113.0	2143.0	2176.0	2202.0	2224.0	2248.0	2282.0	2308.0	2325.0	2344.0	2364.0	2435.0	2474.0	2496-99	2571-24	2583-86	2630.5	2653.0	2705.0	2721.0	2895.0	2908.0	2923.0
IN SITU & REWORKED [R] SPORE-POLLEN																										
Aequitriradites spinulosus R										•									•							
Alisporites grandis						•																	•	•		
A. similis	•																									
Amosopollis cruciformis		•		•	•			•	•	•	•		•	•	•		•	•	•		•	•	•	•	•	
Appendicisporites distocarinatus			•					•	•	•		•						•					•	•	•	
Appendicisporites spp.						•	•				•	•														
Araucariacites australis	•	•	•		•			•	•	•							•	•	•	•		•	•			
Arecipites spp.																										
Asteropollis asteroides	•		•																							
Australopollis obscurus	•	•	•																							
Baculatisporites comaumensis									•	•			•		•			•								
B. disconformis									•																	
Balmeisporites holodictyus									•	•		•					•									
B. tridictyus																	•									
Biretisporites spp. R												•											•	•		
Camarozonosporites australiensis	•	•						•																		
Ceratosporites equalis				•					•	•							•	•								
Cicatricosisporites australiensis					•	•	•	•	•	•	•	•		•	•		•		•				•	•	•	
C. cuneiformis																	•	•								
C. ludbrookii	•					•		•		•	•						•			•						
C. cf Hughesii										•																
C. spp. indet./undescribed					•		•				•	•			•						•		•		•	
Concavissimisporites penolaensis R?									•															•		
Contignisporites cooksoniae R					•																					
Coptospora sp. nov.					•					•																
Corollinia spp. R			•	•												•										
Crybelosporites striatus R					•																					
Cyathidites australis				•	•	•	•	•	•	•		•			•	•	•		•	•					•	
C. minor	•				•	•	•	•	•								•	•	•	•	•	•		•	•	
Cyclosporites hughesii R					•									•												
Cyatheacidites tectifera					•		•	•	•	•			•										•		•	
Dictyophyllidites crenatus R?																										
D. pectinaeformis R?										•												•				
Dictyotosporites speciosus R						•	•												•		•					
Didecitriletes R					•																					
Dilwynites granulatus	•	•								•							•	•		•		•				
D. tuberculatus					•				•											•						
Elphredripites cf notensis	•																•									
Erdtmanipollis sp.					•				•																	
Foraminisporis asymmetricus R	•			•	•					•							•									
F. wonthaggiensis R									•																	
Foveosporites canalis	•		•					•					•				•			•		•				
Foveotriletes parviretus R?	•					•				•				•								•				
Herkosporites elliotii	•								•											•			•			
Interulobites intraverrucatus													•					•								
Ischyosporites punctatus R?							•			•																
Laevigatosporites spp.	•		•		•	•	•	•	•	•		•	•		•		•	•				•		•	•	
Leptolepidites verrucatus				•	•	•		•	•	•		•	•								•			•		
cf Lycopodiacites asperatus				•	•	•		•	•	•		•	•	•	•	•			•	•		•			•	
Lycopodiumsporites australoclavatidites						•		•	•	•							•									
L. circolumenus								•																		
L. nodosus						•																				
L. spp.				•									•					•	•	•	•	•	•	•	•	
Microcachrydites antarcticus	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Neoraistrickia truncata	•								•	•								•	•						•	

TABLE NO. .

Well Name JUDITH-1 Basin GIPPSLAND Sheet No. 2 of 3

SAMPLE TYPE OR NO. *	T	S	T	S	S	S	S	S	S	S	S	S	S	S	S	S	T	T	T	S	S	S	S	S	S	S
FOSSIL NAMES / DEPTHS metres	2025-28	2092.0	2112-14	2113.0	2143.0	2176.0	2202.0	2224.0	2248.0	2282.0	2308.0	2325.0	2344.0	2364.0	2435.0	2474.0	2496-99	2571-74	2583-86	2630.5	2653.0	2705.0	2721.0	2895.0	2908.0	2923.0
Ornamentifera minima																					•					
O. sp. cf O. sentosa Norwick & Burger									•	•											•				•	
Osmundacites wellmanii	•								•																	
Phimopollenites pannosus										•								•								
P. spp.		•		•															•	•						
Phyllocladidites mawsonii	•		•	•	•	•		•	•				•		•	•	•	•	•	•	•	•	•			
P. reticulosaccatus													•				•									
Plicatipollenites spp. R					•				•						•											
Podocarpidites spp.	•	•	•	•	•	•	•	•	•	•		•	•	•	•	•	•	•	•	•	•	•	•	•	•	
Podosporites microsaccatus	•	•		•	•	•	•	•		•		•	•		•			•	•					•		
Polycingutriletes				•		•		•									•									
Proteacidites spp. undescribed	•	•	•					•																		
Pseudowinterapollis cranwellae	•																									
Reticulatisporites pudens																		•								
Rouseisporites reticulatus	•								•	•			•				•	•						•		
R. simplex	•								•	•		•					•	•					•			
Rugulatisporites mallatus [K-var.]	•								•								•				•	•				
cf R. mallatus													•											•		
Schizea digitatoides						•		•		•					•											
Schizocolpus sp.																										
cf Sestrosporites				•		•			•	•			•	•			•	•			•			•		•
Stereisporites antiquisporites		•		•	•	•	•	•		•					•	•	•	•		•	•	•	•		•	•
S. spp.			•	•		•				•					•	•			•	•						
Striatopollis sp.																						•				
taeniate bisaccates				•	•		•		•					•												
Tricolpites spp. indet./undescribed	•				•	•		•	•	•		•	•		•	•		•		•	•	•	•		•	
Tricolporites spp. indet./undescribed	•						•		•	•							•	•		•			•		•	
indeterminate trilete spores	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Triletes tuberculiformis		•											•									•				
Triporopollenites spp. indet./undescribed										•									•							
Tsugaepollenites spp.				•																						
Verrucosisporites spp.	•		•																•							
Densoisporites velatus							•																			
Gleicheniidites spp	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•			•	•	•	•	•	
Kraeuselisporites majus						•		•		•	•	•				•	•	•		•		•	•			
DINOCYSTS																										
Rimosicysta aspera			•																							
R. cucullata												•														
R. cf cucullata				•																						
R. kipperii		•		•					•	•			•			•										
R. cf kipperii			•	•						•		•	•			•					•					
R. robusta ms							•					•					•	•	•			•				
R. spp. indet./undescribed	•	•		•					•							•						•				
Micrhystridium																										•
peridinacean cysts cf Luxadinium				•						•		•	•													
Spheripollenites psilatus				•																						
amorphous algal cysts	•	•	•	•	•			•		•			•			•				•	•					

Well Name JUDITH-1 Basin GIPPSLAND Sheet No. 3 of 3

FOSSIL NAMES / METRES DEPTHS	2025-28	2092.0	2112-14	2113.0	2143.0	2176.0	2202.0	2224.0	2248.0	2282.0	2308.0	2325.0	2344.0	2364.0	2435.0	2474.0	2496-99	2571-74	2583-86	2630.5	2653.0	2705.0	2721.0	2895.0	2908.0	2923.0
SAMPLE TYPE OR NO. *	T		T						S	S	S	S	S	S	S	S	T	T	T	S	S	S	S	S	S	S
MUD CONTAMINANTS/CAVED SPECIES																										
Australopollis obscurus	•		•	•	•	•	•		•	•				•			•			•		•				•
Banksieaeidites lunatus	•																									
Bysmapollis emaciatus			•																							
Cupanieidites orthoteichus	•		•																							
Cyatheacidites annulatus	•		•								•															
Cyathidites gigantis			•																							
C. splendens	•		•			•		•									•									
Dicotetradites clavatus		•	•								•															
Ericipites scabratus							•																			
Foveotriletes lacunosus											•															
Gambierina rudata	•		•			•	•	•		•																
Gleicheniidites spp.	•										•															
Haloragacidites harrisii			•			•								•												
Laevigatosporites spp.	•						•							•												
Latrobosporites amplus									•																•	
Lygistepollenites balmei	•		•	•		•	•																			
L. florinii	•		•																							
Malvacipollis subtilis			•												•											
Nothofagidites emarcidus-heterus			•				•		•		•	•	•										•			
N. falcatus											•															
N. kaitangata	•					•																				
N. cf waipawaensis	•						•																			
Peninsulapollis askinae						•			•									•								
P. gillii	•		•			•		•																		
Peromonolites densus	•		•																							
Phyllocladidites mawsonii	•		•			•	•	•			•							•	•					•		
Proteacidites angulatus			•				•																			
P. amolosexinus																										
P. spp.	•		•	•		•	•	•		•		•												•		•
Stereisporites punctatus ms						•		•		•													•			
S. regium						•		•																		
Tetracolporites multistrixus ms	•																									
T. verrucosus			•																							
Tricolpites phillipsii			•														•									
T. spp.	•		•				•	•			•															
Tricolporites spp.	•		•								•															
Triporopollenites heleosus			•																							
T. sectilis			•				•	•																		
												•														
Apectodinium homomorphum											•															
Operculodinium centrocarpum											•	•														
Protoellipsodinium simplex ms											•															
Spiniferites spp.											•												•			

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

R = REWORKED SP.
C = CONTAMINANT

PALYNOLOGY DATA SHEET

BASIN: GIPPSLAND ELEVATION: KB: ______ GL: ______

WELL NAME: JUDITH-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*	1449.0	0				1449.0	0			
	Upper *N. asperus*	1451.0	2				1451.0	2			
	Mid *N. asperus*	1454.0	0				1454.0	0			
	Lower *N. asperus*	1471.0	1				1471.0	1			
	P. asperopolus	1488.0	0				1503.5	2	1488.0	0	
	Upper *M. diversus*										
	Mid *M. diversus*	1509.5	2				1509.5	2			
	Lower *M. diversus*	1546.0	1				1546.0	1			
	Upper *L. balmei*	1571.5	0				1622.0	1			
	Lower *L. balmei*	1667.5	2	1691.0	1		1701.5	1			
LATE CRETACEOUS	Upper *T. longus*	1764.0	0				1835.5	1			
	Lower *T. longus*	1858.0	1				1875.5	2	1858.0	1	
	T. lilliei										
	N. senectus										
	T. apoxyexinus										
	P. mawsonii	1993.0	2	2017.0	1		2721.0	1			
	A. distocarinatus	2895.0	2				2908.0	2			
EARLY CRET.	*C. paradoxus*										
	C. striatus										
	F. asymmetricus										
	F. wonthaggiensis										
	C. australiensis										
	PRE-CRETACEOUS										

COMMENTS:
1471,0m T. pandus Zone
1546.0m A. hyperacantha Zone
1571,5m A. homomorpha Zone
Maximum abundance of "Kipper Shale" dinocysts 1993.0-2113.0m

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: 3 February 1990

DATA REVISED BY: ______ DATE: ______

Appendix 2

Micropalaeontology

MICROPALAEONTOLOGICAL ANALYSIS

JUDITH-1, GIPPSLAND BASIN

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WESTERN AUSTRALIA

January, 1990.

C O N T E N T S

I. SUMMARY

Judith-1 was drilled in offshore petroleum permit Vic P/11, Gippsland Basin to a depth of 2958mKB. Sidewall cores from 838m to 1563.5m 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

839m-890m	:	Indeterminate	
922m-1097m	:	Zone D1	Middle Miocene
1172m-1244m	:	Zones D1/D2	Middle Miocene
1320m	:	Zone E1	basal Middle Miocene
1391m-1436m	:	Zone G	upper Early Miocene
1449m-1451m	:	Zone H1	lower Early Miocene
1454m-1503.5m	:	Indeterminate	

Calcareous Nannoplankton Subdivision

839m-1172m	:	Zone NN6	mid Middle Miocene
1244m-1320m	:	Zone NN5	lower Middle Miocene
1391m-1436m	:	Zone NN3	upper Early Miocene
1449m	:	Zones NN2/NN1	lower Early Miocene
1451m	:	Zone NP25	latest Late Oligocene
1454m-1503.5m	:	Indeterminate	

Environment of Deposition

839m	:	middle neritic
Samples 890m-1172m incl.	:	middle-outer neritic
Samples 1244m-1449m incl.	:	outer neritic
1451m	:	middle-outer neritic
Samples 1454m-1503.5m incl.	:	undifferentiated marine

II. INTRODUCTION

A total of 18 sidewall cores have been scrutinized for foraminifera and calcareous nannoplankton from the interval 839m to 1503.5m in Judith-1. Fossil assemblages identified in the well section, interpreted zonation and depositional environment subdivision 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/NP calcareous nannoplankton zonal scheme of Martini (1971) are used for biostratigraphic subdivision.

(A) Benthonic Foraminiferal Subdivision

1. 839m-890m : Indeterminate

   The impoverished planktonic foraminiferal faunas in the interval lack age-diagnostic taxa.

2. 922m-1097m : Zone D1 (Middle Miocene)

   The sidewall core samples in the interval are assigned to Zone D1 on the basis of the association of Globorotalia miozea miozea and Globorotalia miozea conoidea, and the lack of diverse Globigerinoides, together with Praeorbulina and Orbulina suturalis.

3. 1172m-1244m : Zones D1/D2 (Middle Miocene)

   The sidewall core samples at 1172m and 1244m contain moderate to high yielding planktonic foraminiferal faunas. The occurrence of Orbulina universa in both samples, together with Orbulina suturalis at 1172m and Globorotalia praemenardii at 1244m, indicates that the interval is possibly Zone D2 in age. The lack of Globorotalia miozea conoidea is also consistent with a Zone D2 assignment. However the lack of Praeorbulina and Globigerinoides sicanus, which normally are well represented in Zone D2, puts doubt on a definitive Zone D2 assignment. For that reason the interval is assigned to Zones D1 and D2 undifferentiated.

4. 1320m : Zone E1 (basal Middle Miocene)

   The sample at 1320m contains a rich planktonic foraminiferal assemblage including Praeorbulina glomerosa and Orbulina suturalis without Orbulina universa. These taxa indicate a Zone E1 assignment.

5. 1391m-1436m : Zone G (upper Early Miocene)

   The interval is assigned to Zone G on the basis of the occurrence of Globigerinoides trilobus and the lack of Globigerinoides sicanus. The occurrence of Globorotalia miozea miozea is consistent with an age no older than Zone G.

6. 1449m-1451m : Zone H1 (lower Early Miocene)

   The occurrence of Globigerina woodi connecta without Globigerinoides trilobus indicates that the sidewall core samples at 1449m and 1451m are Zone H1 in age.

7. 1454m-1503.5m : Indeterminate

   The samples in the interval are barren of planktonic foraminifera.

(B) Calcareous Nannoplankton Subdivision

1. 839m-1172m : Zone NN6 (mid Middle Miocene)

The interval is assigned to Zone NN6 on the basis of the occurrence of *Cyclicargolithus floridanus* without *Sphenolithus heteromorphous*.

2. 1244m-1320m : Zone NN5 (lower Middle Miocene)

The occurrence of *Sphenolithus heteromorphous* without *Helicosphaera ampliaperta* is consistent with a Zone NN5 assignment.

3. 1391m-1436m : Zone NN3 (upper Early Miocene)

The sidewall core samples at 1391m and 1436m include *Sphenolithus belemnos* and on this basis are assigned to Zone NN3.

4. 1449m : Zones NN2 & NN1 (lower Early Miocene)

The sample at 1449m is assigned to Zones NN2 and NN1 on the basis of the lack of *Sphenolithus belemnos* (base Zone NN3 index species) and *Zygrhablithus bijugatus* (top Zone NP25 index species).

5. 1451m : Zone NP25 (latest Late Oligocene)

The association of *Zygrhablithus bijugatus* and *Dictyococcites* aff. *bisectus*, and the lack of pre-Zone NP25 taxa, indicates that the sample at 1451m is assignable to Zone NP25.

6. 1454m-1503.5m : Indeterminate

The samples in the interval are barren of calcareous nannoplankton.

IV. ENVIRONMENT OF DEPOSITION

1. 839m : Middle neritic

   The sample at 839m contains a moderately diverse foraminiferal fauna with benthonics predominant. The diverse benthonic fauna includes Globocassidulina subglobosa (frequent), Sphaeroidina bulloides (few), Brizalina (frequent) and Cassidulina laevigata. Deposition in a middle neritic environment is envisaged.

2. Samples 890m-1172m inclusive : Middle-outer neritic

   The calcilutites in the interval are interpreted to have been deposited in a middle to outer neritic environment. The rich foraminiferal assemblages in the interval comprise the following diverse benthonic fauna: Brizalina (frequent-abundant), Globocassidulina subglobosa (rare-few), Euuvigerina miozea (rare-few), Trifarina bradyi (frequent-abundant from 890m to 1033m), Cassidulina laevigata (rare-abundant), Siphouvigerina proboscidea (rare-common) and Sphaeroidina bulloides (rare-common).

3. Samples 1244m-1449m inclusive : Outer neritic

   The samples in the interval contain high yielding foraminiferal faunas with planktonics representing a dominant element (planktonic percentage ranging from 70 to 95). The benthonic assemblages in the interval include the following bathymetrically significant taxa: Brizalina (rare-frequent), Cassidulina laevigata (rare-few), Globocassidulina subglobosa (few), Siphouvigerina proboscidea (rare-few), Trifarina bradyi (few-frequent) and Sphaeroidina bulloides (few-frequent). Deposition in an outer neritic environment is envisaged.

4. 1451m : Middle-outer neritic

   The glauconitic marl at 1451 is interpreted to have been deposited in a middle to outer neritic environment on the basis of containing a benthonic foraminiferal assemblage including Trifarina bradyi (frequent), Brizalina (few), Globocassidulina subglobosa (rare), Sphaeroidina bulloides (few) and Gyroidina subzelandica.

5. Samples 1454m-1503.5m inclusive : Undifferentiated marine

   The interval is barren of foraminifera with the exception of the sample at 1454m which contains rare Haplophragmoides. The occurrence of pelletal glauconite throughout the interval indicates that the siliciclastics were deposited 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, JUDITH-1

SAMPLE (mKB)	FORAM YIELD	FORAM PRESERV.	FORAM DIVERSITY	NANNO YIELD	NANNO PRESERV.	NANNO DIVERSITY
SWC60, 839	mod/low	v. poor	mod/high	high	poor	mod/low
SWC59, 890	mod/high	mod/poor	mod/high	high	poor	low
SWC58, 922	high	mod/good	high	high	moderate	mod/low
SWC57, 964	high	mod/good	mod/high	high	mod/good	mod/high
SWC56, 1033	high	mod/good	mod/high	high	mod/good	mod/high
SWC55, 1097	high	moderate	mod/high	high	mod/poor	mod/low
SWC54, 1172	high	moderate	mod/high	high	mod/poor	high
SWC53, 1244	high	good	moderate	high	mod/good	mod/high
SWC52, 1320	high	moderate	mod/high	high	mod/poor	mod/high
SWC51, 1391	mod/low	v. poor	low	low	v. poor	low
SWC50, 1436	high	mod/good	mod/high	high	moderate	moderate
SWC49, 1449	high	mod/good	moderate	high	moderate	mod/high
SWC48, 1451	high	moderate	mod/high	high	mod/poor	moderate
SWC47, 1454	v. low	poor	v. low	barren	-	-
SWC46, 1471	barren	-	-	barren	-	-
SWC45, 1488	barren	-	-	barren	-	-
SWC44, 1502	barren	-	-	barren	-	-
SWC43, 1503.5	barren	-	-	barren	-	-

PE900794

This is an enclosure indicator page.
The enclosure PE900794 is enclosed within the container PE900021 at this location in this document.

The enclosure PE900794 has the following characteristics:

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CONTAINER_BARCODE =	PE900021
NAME =	Micropalaeontological Chart
BASIN =	GIPPSLAND
PERMIT =	VIC/P11
TYPE =	WELL
SUBTYPE =	DIAGRAM
DESCRIPTION =	Micropalaeontological Distribution Chart for Judith-1
REMARKS =	
DATE_CREATED =	
DATE_RECEIVED =	
W_NO =	W1011
WELL_NAME =	JUDITH-1
CONTRACTOR =	
CLIENT_OP_CO =	SHELL AUSTRALIA

(Inserted by DNRE - Vic Govt Mines Dept)

APPENDIX 3

Petrophysics

APPENDIX 3
PETROPHYSICS

APPENDIX 3

PETROPHYISCAL ANALYSIS

1.0 WIRELINE LOGS (all depths are logging depth below derrick floor)

The following wireline logs were run:

Date	Hole Size	Run	Interval	Type
18/10/89	17 1/2"	1	807-213m	DLL/BCSL/GR/CAL
	20" csg.	1	213-80m	GR
26/10/89	12 1/4"	1	2167-798m	DLL/SLS/LDL/CNL/GR/MSFL/CAL/AMS (MSFL & CNL TO 1400M)
27/10/89	12 1/4"	2	2315-2100m	DLL/SLS/LDL/CNL/GR/MSFL/CAL/AMS
2/11/89	12 1/4"	3	2309-1900m	SHDT/GR
		4	2308-839m	CST/GR
14-15/11/89	8 1/2"	1	2956-2303m	DLL/BCSL/LDL/CNL/GR/MSFL/CAL/AMS
15/11/89	8 1/2"	2	2960-2303m	SHDT/GR
16/11/89	8 1/2"	3	2911-2332m	RFT/HP/GR
		4	2958-500m	WST
		5	2956-2325m	CST/GR

2.0 EVALUATION

2.1 General

Petrophysical evaluation indicates the objective Latrobe and Golden Beach Formations to be entirely water-bearing. Marginal hydrocarbon saturations (up to 45%) corresponding to above-background mud gas readings were calculated in the low porosity Lower Golden Beach section (2392m BRT - TD). "Quick-look" permeabilities calculated from RFT pressure data acquired in these argillaceous sandstones ranged from 0.5 to 1.5 mD.

2.2 Factors affecting log evaluation in the 8 1/2 inch hole section (Lower Golden Beach)

2.2.1 Deep Invasion

High mud weight (10.3 ppg) and low porosity/permeability sandstones resulted in relatively deep mud invasion (20-40 inches) between 2300m and T.D. Borehole-corrected resistivity curves were used to calculate an invasion-corrected true formation resistivity (RT).

2.2.2 Porosity Determination

A neutron/sonic combination was used instead of the density/ neutron curves for determination of porosity in zones below 2303m BRT where hole rugosity and resultant FDC correction were deemed excessive.

2.2.3 Determination of A, m, n and Qv

No core-derived values for the cementation exponent (m), saturation exponent (n), Archie constant (A) and cation exchange capacity (Qv) were available for calculation of hydrocarbon saturations in the Golden Beach Formation. Default values used in the calculations were:

m = 2.00
n = 2.00
A = 1.00

In the absence of Qv data, the shaly-sand Indonesia equation was used for calculation of hydrocarbon saturations.

2.2.4 Rw Determination

Resistivity of the formation water over the Lower Golden Beach section (2391m BDF - T.D.) was derived using the Rwa technique ($Rwa = \frac{RT * Por^m}{A}$) over low resistivity sands where no above-background mud gas was recorded. An Rw of 0.09 ohmm corresponding to an NaCl equivalent salinity of 25000 ppm was derived. A relatively featureless SP curve (recorded by Schlumberger and transmitted via computer link) supports this estimate (MF salinity 25000 ppm).

2.3 Evaluation Procedure

2.3.1 Menu Structure

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

2.3.1.1 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 " $V_{SH} \geq 51\%$
- Correct FDC for borehole effects (Chart POR-15a)
- Apply cutoff for coal definition:
  Coal: FDC ≤ 2.0 g/cc

2.3.1.2 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 R_{WA} from porosity and true resistivity.

2.3.1.3 Latrobe and Upper Golden Beach/Kipper Shale (1504-2304m BDF)

- 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.

2.3.1.4 Kipper Shale/Lower Golden Beach (2304-2938m BDF); Good Hole Section

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

2.3.1.5 Kipper Shale/Lower Golden Beach (2304-2938m BDF); Poor Hole Section

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

2.3.2 Petrophysical Parameters (see Table 1 below)

	1504-1700 (Latrobe)	1700-1886 (Latrobe)	1971-2155 (UGB/KSH)	2155-2304 (KIPPER SH)	2304-2938 mBRT (KSH/LGB)
Hole size (inches)	12 1/4	12 1/4	12 1/4	12 1/4	8 1/2
GR_{MA} (API)	12	12	14	14	25
GR_{SH}	84	84	76	82	110
R_M (OHMM)	0.21	0.21	0.17	0.156	0.115
R_{MC}	0.41	0.41	0.32	0.30	0.22
R_W	0.08	0.07	0.067	0.075	0.09
R_{SH}	4.7	4.7	5.0	7.5	9.0
A	1.0	1.0	1.0	1.0	1.0
M	2.098	2.098	2.00	2.00	2.00
N	1.84	1.84	2.00	2.00	2.00
RHO_{MA} (g/cc)	2.66	2.66	2.66	2.66	calculated curve
RHO_{MUD}	1.23	1.23	1.23	1.23	1.23
RHO_{MF}	1.0	1.0	1.0	1.0	1.0
RHO_{HC}					0.15
SAL_{MF} (ppm)					25,000

2.4 Evaluation Summary

No net hydrocarbon zones above the porosity and hydrocarbon saturation cutoffs (10% and 50% respectively) were identified from logs. Gas saturations up to 45% occur in the low porosity/low permeability Lower Golden Beach section between 2391 and 2938m BDF (enclosure 1).

Results of the analysis are summarised below:

	1504-1886 (Latrobe)	1971-2074 (Upper Golden Beach)	2074-2391 (Kipper Shale)	2391-2938 mBRT (Lower Golden Beach)
Gross Thickness (m)	382	103	317	547
Net Sst. (m)	166	64	58	281
Average Porosity (net sst)	24%	18%	12%	9%
Net sst/gross	43%	62%	18%	51%
Net Porous Sst. (≥10%)	164	55	42	102
Average porosity (net porous sst.)	24%	20%	15%	11%
Net porous sst/gross	43%	54%	13%	19%
SH Average	16%	17%	17%	25%

PE603208

This is an enclosure indicator page.
The enclosure PE603208 is enclosed within the container PE900021 at this location in this document.

The enclosure PE603208 has the following characteristics:

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PERMIT =	VIC/P11
TYPE =	WELL
SUBTYPE =	LOG
DESCRIPTION =	Judith 1 Petrophysical Evaluation Summary. From appendix 3 of WCR volume 2.
REMARKS =	
DATE_CREATED =	31/12/89
DATE_RECEIVED =	20/08/90
W_NO =	W1011
WELL_NAME =	Judith 1
CONTRACTOR =	
CLIENT_OP_CO =	Shell Australia

(Inserted by DNRE - Vic Govt Mines Dept)

APPENDIX

RFT Evaluation

APPENDIX 4
RFT EVALUATION

JUDITH #1 RFT EVALUATION

Introduction

A total of 35 pretests were taken in sands over the interval 2300-2900 m bdf. A list of pretest pressures is given in Table 1 and is plotted in Figure 1.

Discussion

The first two pretests were taken in a water bearing sand at 2331.5 m and 2341.6 m and lie on a water gradient.

Other sands evaluated on logs as water bearing (2560.5 m, 2762 m, 2884.5 m) however, do not fall on any water gradient which can be extrapolated from this water sand. A line drawn through the remaining water bearing sands would require an equivalent gradient of 0.67 psi/ft suggesting that the individual pretest pressures are supercharged and/or the sands are of limited extent and are overpressured within individual pressure regimes.

Remaining pretests show signs of tight formation (large pretest draw downs and long duration buildups) supercharging and/or overpressure with considerable scatter observed even within individual sands. Two possible gas columns have been included in Figure 1 from pretests between 2495.5 m to 2535.5 m and from 2670.8 m to 2691.5 m. The large degree of scatter observed, however, casts considerable doubt on the interpretation of these points as true gas columns.

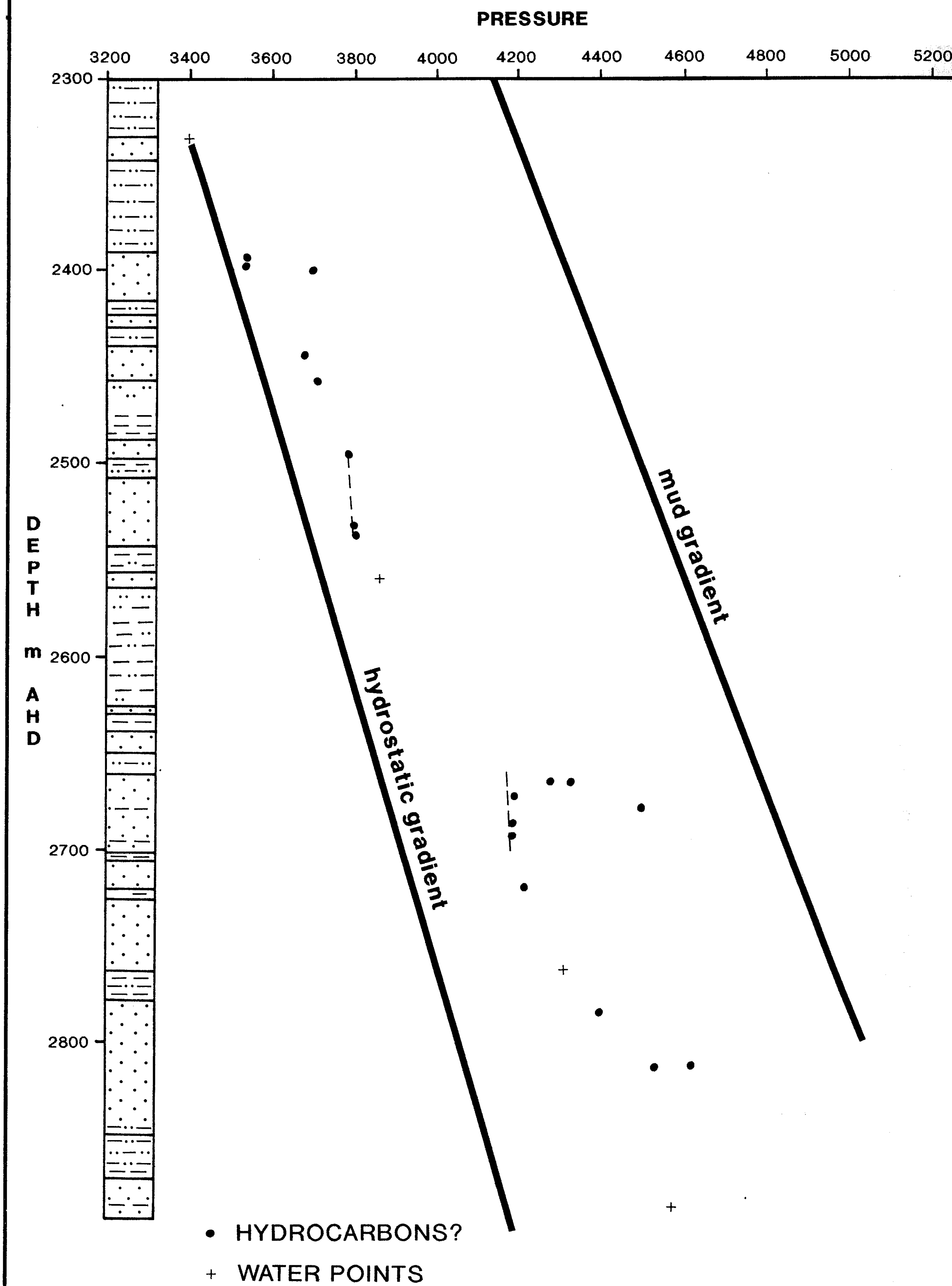
Permeability values calculated for the individual pretests are also listed Table 1. With the exception of the two shallowest pretests and one sand at 2535.5, permeabilities lie in the range 0.05 to 1.6 mD which is supporting evidence for the observed supercharging.

Conclusion

No hydrocarbon columns can be unambiguously deduced from the large scatter of pressures observed. With the exception of the initial water bearing sand at 2330 m, pretest buildups are indicative of low permeability formation.

Table 1

Depth (mbdf)	Build-up Pressure (psia)	Minimum Flowing Pressure (psia)	Drawdown Permeability (mD)
2331.5	3397.2	3391.0	331.0
2341.6	3411.2	3410.0	54.0
2391.3	3538.1	15.6	0.3
2396.1	3534.5	10.2	0.05
2398.2	3693.8	10.1	0.3
2398.7	3695.9	9.6	-
2413.2	8.7	5.2	-
2413.0	8.3	5.4	-
2439.3	9.1	3.8	-
2442.0	3677.3	11.5	0.3
2455.0	3705.0	15.1	0.5
2495.5	3783.9	32.9	0.5
2522.4	5.9	4.0	-
2531.5	3797.9	574.0	0.3
2535.5	3798.2	3712.6	26.0
2555.8	tight	-	-
2559.0	31.8	26.2	-
2560.5	3858.9	1072.4	-
2563.4	19.5	15.5	-
2641.6	seal failure	-	-
2665.5	4279.4	1274.3	0.5
2665.5	4330.4	1249.4	0.3 Repeat
2670.8	4187.2	629.6	0.4
2677.7	11.0	8.2	-
2678.5	4486.5	918.9	0.6
2684.5	4182.2	2527.8	1.2
2691.5	4183.8	-	1.6
2719.4	4216.2	1878.6	0.7
2762.0	4317.3	12.9	0.2
2785.0	4394.2	12.4	0.3
2811.6	4613.7	862.0	0.4
2813.0	4526.4	1634.4	0.4
2871.4	16.0	8.4	-
2884.5	4587.4	1120.0	0.3
2911.0	12.0	8.6	-



SHELL-AUSTRALIA E.& P. OIL AND GAS	GIPPSLAND BASIN				Figure 1
	JUDITH-1 RFT EVALUATION				
	Author: EEP/1	Report No.:SDA 938	Date: JULY 1990	Drawing No.: 26266	

APPENDIX 5

Geochemistry

APPENDIX 5
GEOCHEMISTRY

PETROLEUM GEOCHEMISTRY

JUDITH 1

DATA REPORT

Prepared for:

THE SHELL COMPANY OF AUSTRALIA

May 1990

ANALABS

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A Member of the Inchcape Group

TABLE 1

ROCK-EVAL PYROLYSIS DATA (one run)

WELLNAME = JUDITH 1 DATE OF JOB = NOVEMBER 1989

DEPTH(m)	TMAX	S1	S2	S3	S1+S2	S2/S3	PI	PC	TOC	HI	OI
1555.0	421	0.30	4.89	1.48	5.19	3.30	0.06	0.43	2.40	203	61
1571.5	418	0.51	6.18	0.66	6.69	9.36	0.08	0.56	3.13	197	21
1600.0	425	0.48	11.23	0.35	11.71	32.09	0.04	0.97	1.86	603	18
1610.0	419	0.48	7.40	0.46	7.88	16.09	0.06	0.65	2.87	257	16
1654.0	415	0.27	3.99	0.56	4.26	7.13	0.06	0.35	1.62	246	34
1710.5	419	0.31	5.19	0.35	5.50	14.83	0.06	0.46	2.20	235	15
1764.0	427	0.20	3.85	0.38	4.05	10.13	0.05	0.34	2.08	185	18
1777.5	423	1.02	25.44	1.12	26.46	22.71	0.04	2.20	6.62	384	16
1821.5	422	0.33	2.83	0.35	3.16	8.09	0.10	0.26	2.22	127	15
1835.5	426	0.17	1.98	1.01	2.15	1.96	0.08	0.18	1.42	139	71
1869.5	427	0.18	2.00	0.51	2.18	3.92	0.08	0.18	0.65	307	78
1993.5	431	0.15	2.20	0.35	2.35	6.29	0.06	0.20	1.05	209	33
2023.0	435	0.06	1.98	2.70	2.04	0.73	0.03	0.17	1.85	107	145
2081.0	434	0.14	3.11	3.73	3.25	0.83	0.04	0.27	3.05	101	122
2113.0	434	0.08	1.18	4.37	1.26	0.27	0.06	0.10	0.89	132	491
2163.0	435	0.10	1.89	2.29	1.99	0.83	0.05	0.17	1.25	151	183
2210.5	435	0.16	1.86	1.39	2.02	1.34	0.08	0.17	1.65	112	84
2248.0	436	0.09	1.36	0.90	1.45	1.51	0.06	0.12	1.05	129	85
2268.0	435	0.09	1.44	1.93	1.53	0.75	0.06	0.13	0.95	151	203
2308.0	nd	nd	nd	nd	nd	nd	nd	nd	0.49	nd	nd
2325.0	435	0.09	1.49	1.24	1.58	1.20	0.06	0.13	1.35	110	91
2344.0	433	0.24	2.35	2.47	2.59	0.95	0.09	0.21	1.70	138	145
2364.0	437	0.07	0.47	0.96	0.54	0.49	0.13	0.04	0.50	94	192
2474.0	436	0.16	1.89	1.44	2.05	1.31	0.08	0.17	1.38	136	104
2630.5	441	0.10	1.19	3.94	1.29	0.30	0.08	0.11	0.90	132	437
2721.0	437	0.14	2.24	2.85	2.38	0.79	0.06	0.20	1.05	213	271
2908.0	437	0.17	1.16	1.51	1.33	0.77	0.13	0.11	0.93	124	162
2923.0	436	0.52	3.74	1.80	4.26	2.08	0.12	0.35	2.90	128	62

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

K.K. No.	Depth (m)	$\bar{R}_v$ max	Range	N	Description Including Liptinite (Exinite) Fluorescence
v1855	1555.0 SWC 40	0.34	0.28-0.47	28	Common cutinite, yellow to dull orange, sparse sporinite, yellow to orange, rare to sparse resinite and liptodetrinite, yellow to orange. (Siltstone>sandstone. Dom abundant, I>V>L. Inertinite abundant, vitrinite and liptinite common. Pyrite abundant. Iron oxide sparse.)
v1856	1571.5 SWC 39	0.36	0.28-0.47	26	Sparse cutinite, yellow to dull orange, rare to sparse sporinite, yellow to orange, rare resinite, yellow to orange. (Siltstone>shaly coal>coal. Coal rare, vitrinite only. Vitrite. Shaly coal common, V>I>L. Vitrite. Dom abundant, V>I>L. Vitrinite abundant, inertinite common, liptinite sparse. Pyrite abundant. Iron oxide rare.)
v1857	1610.0 SWC 37	0.37	0.29-0.48	26	Sparse cutinite, sporinite and liptodetrinite, yellow to orange, rare to sparse resinite, yellow. (Siltstone>claystone. Dom abundant, I>V>L. All three maceral groups common. Rare bitumen, yellow. Pyrite abundant. Iron oxide sparse to common.)
v1858	1654.0 SWC 35	0.36	0.29-0.43	28	Common cutinite, yellow to dull orange, sparse sporinite, yellow to orange, rare to sparse resinite, yellow to orange. (Siltstone>sandstone>shaly coal. Shaly coal sparse, V>I>L. Vitrite>vitrinertite. Dom abundant, V>I>L. Vitrinite abundant, inertinite and liptinite common. Sparse oil drops, yellow. Pyrite abundant. Iron oxide common.)
v1859	1777.5 SWC 28	0.44	0.36-0.52	26	Common cutinite and sporinite, yellow to dull orange, sparse resinite and liptodetrinite, yellow to dull orange, sparse suberinite, non fluorescing. (Siltstone>shaly coal>coal. Coal abundant, V>>L>I. Vitrite. Shaly coal major, V>>L>I. Vitrite>>clarite. Dom abundant, V>L>I. Vitrinite and liptinite abundant, inertinite sparse. Sparse bitumen, yellow. Pyrite abundant. Iron oxide sparse.)
v1860	1821.5 SWC 26	0.42	0.33-0.54	26	Sparse cutinite and sporinite, yellow to dull orange, rare suberinite, yellow to orange, rare <u>Botryococcus</u> related telalginite, yellow to orange. (Sandstone>siltstone>shaly coal. Shaly coal rare, V>L. Vitrite. Dom abundant, I>V>L. Inertinite common to abundant, vitrinite common, liptinite sparse. Pyrite abundant. Iron oxide common.)

K.K. No.	Depth (m)	$\bar{R}_v max$	Range	N	Description Including Liptinite (Exinite) Fluorescence
v1861	1835.5 SWC 25	0.45	0.34-0.62	27	Sparse to common cutinite, yellow to dull orange, sparse sporinite, yellow to dull orange, sparse resinite, yellow to orange. (Siltstone>carbonate>sandstone>shaly coal. Shaly coal rare, V>L. Vitrite. Dom abundant, I>V>L. All three maceral groups common. Pyrite abundant. Iron oxide sparse.)
v1862	1869.5 SWC 23	0.41	0.30-0.56	27	Common cutinite, yellow to brown, sparse sporinite, yellow to dull orange, rare resinite, yellow to orange. (Sandstone>siltstone>carbonate>shaly coal. Shaly coal sparse, I>V>L. Inertite>vitrite. Dom abundant, V>I>L. All three maceral groups common. Pyrite sparse to common. Iron oxide sparse.)
v1863	2023.0 SWC 15	0.47	0.38-0.55	28	Sparse cutinite and sporinite, yellow to dull orange, rare resinite, orange. (Siltstone>>carbonate. Dom abundant, I>V>L. Inertinite and vitrinite common, liptinite sparse to common. Iron oxide sparse. Pyrite rare to sparse.)
v1864	2081.0 SWC 13	0.51	0.41-0.62	28	Sparse cutinite, yellow to brown, sparse sporinite, yellow to dull orange, rare resinite, yellow to orange. (Siltstone>>shaly coal. Shaly coal sparse, V>I>L. Vitrinertite>vitrite. Dom abundant, I>V>L. Inertinite abundant, vitrinite common to abundant, liptinite sparse. Pyrite common. Iron oxide sparse.)
v1865	2163.0 SWC 9	0.53	0.40-0.63	27	Sparse cutinite, orange to dull orange, sparse liptodetrinite, yellow to orange, rare sporinite, yellow to dull orange. (Siltstone>>carbonate. Dom common, I>L>or=V. Inertinite common, liptinite and vitrinite sparse. Pyrite and iron oxide sparse.)
v1866	2210.5 SWC 6	0.56	0.41-0.68	27	Sparse cutinite and resinite, orange to brown, rare to sparse sporinite, orange to brown. (Siltstone. Dom abundant, I>L>V. Inertinite abundant, liptinite and vitrinite sparse. Rare bitumen, orange. Iron oxide sparse. Pyrite rare.)
v1867	2325 SWC	0.54	0.44-0.64	27	Sparse cutinite, orange to brown, sparse sporinite, orange to dull orange, rare resinite, orange to dull orange. (Siltstone. Dom abundant, I>V>L. Inertinite common to abundant, vitrinite and liptinite sparse. Iron oxide sparse. Pyrite rare.)

K.K. No.	Depth (m)	$\bar{R}_v max$	Range	N	Description Including Liptinite (Exinite) Fluorescence
v1868	2344 SWC	0.57	0.43-0.67	26	Sparse cutinite, orange to brown, sparse sporinite, yellow to dull orange, rare resinite, orange to dull orange, rare liptodetrinite, yellow to dull orange. (Siltstone>carbonate. Dom abundant, I>V>L. Inertinite abundant, vitrinite common, liptinite sparse. Pyrite and iron oxide sparse.)
v1869	2364 SWC	0.58	0.50-0.66	7	Rare liptodetrinite and sporinite, orange to dull orange. (Sandstone>siltstone>carbonate>shaly coal. Shaly coal sparse, I only. Inertite. Dom common to abundant, I>>L=V. Inertinite common to abundant, liptinite and vitrinite rare.)
v1870	2474 SWC	0.59	0.44-0.72	27	Sparse cutinite and sporinite, orange to brown. (Siltstone>sandstone>shaly coal. Shaly coal sparse, V>I>L. Vitrite>vitrinertite(V). Dom abundant, I>V>L. Inertinite and vitrinite common, liptinite sparse. Pyrite and iron oxide sparse.)
v1871	2630.5 SWC	0.61	0.48-0.75	23	Rare cutinite and liptodetrinite, orange to dull orange. (Calcareous siltstone>carbonate>sandstone>?coal. ?Coal is rare and possibly occurs as intraclasts. Dom common, I>V>L. Inertinite common, vitrinite sparse, liptinite rare. Pyrite common. Iron oxide rare.)
v1872	2721 SWC	0.72	0.54-0.89	27	Sparse cutinite, orange to brown, sparse phytoplankton, yellow to dull orange, rare to sparse sporinite, yellow to dull orange. (Carbonate>calcareous siltstone. Dom abundant, V>I>L. All three maceral groups common. Pyrite common. Iron oxide rare.)
v1873	2923 SWC	0.78	0.65-0.92	27	Sparse cutinite, orange to brown, sparse resinite, orange to dull orange, rare to sparse liptodetrinite, yellow to dull orange, rare sporinite, orange to brown. (Carbonate>siltstone>sandstone>shaly coal>coal. Coal abundant, V>I>L. Vitrinertite>vitrite>clarodurite> clarite=inertite. Shaly coal abundant, V>I>L. Vitrite>vitrinertite>inertite>clarodurite. Dom abundant, V>I>L. Vitrinite abundant, inertinite common to abundant, liptinite sparse. Pyrite common. Iron oxide 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 = 1μ 1 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:

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

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

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 ααα (20R) sterioisomer is converted in sediment to a mixture of the ααα (20R) and ααα (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 17β,21β hopanes to the corresponding 17α,21β and 17β,21α 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 17α,21β 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

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

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.	C29 ααα steranes / (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.	C29 diasteranes / (C29 ααα steranes + C29 αββ steranes)	217
12.	C30 (hopanes + moretanes) / 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. 18 α (H)-hopane/17 α (H)-hopane (Ts/Tm)

Maturity indicator. The ratio of 18 α (H) trisnorhopane to 17 α (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 17 β, 21 β hopane to 17 β, 21 α 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 ααα /C29 20R ααα 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 20Sααα /C29 20R ααα + C29 20Sααα

<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 αββ/C29 ααα + C29 αββ steranes

<u>Maturity</u> indicator. The form is produced biologically, it converts gradually into a mixture of αα (normal steranes) and ββ (isosteranes) compounds upon maturation. Equilibrium is reached at about 65% ββ 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.

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APPENDIX 6

Petrography

AMDEL

CORE

SERVICES

AMDEL CORE SERVICES

14 December 1989

Shell Company of Australia
1 Spring Street
MELBOURNE VIC 3000

Attention: EXO

REPORT: 001/005

CLIENT REFERENCE:	ITC 03147/EXO
MATERIAL:	Sidewall Cores
LOCALITY:	Judith -1
WORK REQUIRED:	Petrography Services

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

Brian 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

Five sidewall cores from Judith -1 were received for petrography.

An impregnated thin section was prepared from each and these were examined by conventional means. 300 points were counted in each thin section. Photomicrographs were taken to illustrate significant features of the rocks.

In summary, the samples are sandstones which are characterised particularly by the abundance of "clay" rich lithic fragments. During compaction and lithification these have been squeezed so as to fill intergranular spaces and choke pore throats. This has been the most important process which has affected porosity modifications to the original sand.

The development of authigenic carbonate and kaolinite has been much less significant petrophysically.

2. PETROLOGY

Judith No 1 - Sidewall Core 12 - 2688 m

Rock Name: Compact Lithic Sandstone

Thin Section: The mineralogy of the sample as determined by point counting is as follows:

Component	%
Quartz and Quartzite	58
Soft argillaceous clasts	29
Rigid Siliceous clasts	2
Carbonate	7
Pores	2
Kaolinite	2
Opaques	Trace
Feldspar/Heavy Minerals	Trace

Fine-grained heterogeneous material is abundant in this rock and this is interpreted, with confidence,as being derived from original lithic fragments. In many instances the outlines of the original lithic grains can be seen and this applies particularly to siliceous, strong lithologies rather than to the softer, more argillaceous lithic fragments. Some of these give the appearance in places, of being matrix but their heterogeneity is taken as a clear indication that they are derived from sand-grade lithic fragments and not from a muddy matrix.

The lithic material consists, particularly from a petrophysical point of view, of two types of rocks: those which retain compact detrital outlines and therefore may be regarded as part of the framework of the rock; and deformed argillaceous lithic fragments which appear to have been squeezed between the detrital grains and now fill intergranular space where they occur. As the rock now appears, the inter-quartz material is simply a dense aggregate of varied fine-grained material and there is little or no porosity in most fields of view. The more abundant types of lithic grains are cherts, fine-grained siliceous silty rocks and phyllosilicate-rich shales which have been deformed. There are rare instances of what appear to be fine-grained siliceous volcanics, some large aggregates of fine-grained carbonate which maybe derived from limestone fragments and some examples of opaques which may have been original fragments of some kind.

Authigenic minerals are represented by carbonate and kaolinite. Carbonate, as well as forming as what are taken to be limestone fragments, occurs as widely distributed fine-grained material which has probably replaced some types of lithic fragments. It is thought unlikely that the carbonate is a significant void-filling phase. Authigenic kaolinite, by contrast, forms monomineralic aggregates generally not more than 0.2 mm in size. These are featureless fine-grained aggregates and are taken to be pore filling precipitates. The kaolinite is not abundant and probably contributed little to occlusion of the original porosity (compared to compaction and deformation of the lithic fragments).

Much of the apparent porosity in the thin section is thought to be derived from fracturing of the rock during collection of the sidewall core and it appears to the author unlikely that the in-situ rock contained very much porosity or permeability.

Quartz grains are well to moderately well-sorted and commonly range in size from approximately about 0.2 mm to the order of about 0.7 mm. The average grain size is a little difficult to determine but is probably at least 0.3 mm. Some of the grains have been fractured during collection of the side-wall core but, disregarding this, it appears likely that the detrital grains were mainly separated from each other by fine-grained material as a result of deformation of soft lithic fragments.

Judith No 1 - Sidewall Core 18 - 2532 m

Rock Name: Lithic Sandstone

Thin Section: The volume percentages of the minerals determined by point counting are as follows:

Component	%
Quartz and Quartzite	48
Soft argillaceous clasts	22
Rigid Siliceous clasts	8
Carbonate	8
Pores	9
Kaolinite	5
Feldspar/Heavy Minerals	Trace

This is a well sorted sandstone in which the average grain size of the majority of the grains is approximately 0.2 - 0.25 mm. Quartz grains are equant in shape and range from angular to sub-round in outline. A very small proportion of the quartz grains show narrow overgrowths. It appears that some of the angularity of the quartz is due to partial corrosion by cement (especially carbonate) and partly to the devlelopment of long and curved contacts. It is difficult to see in a sidewall core the overall significance of pressure solution effects but there are certainly areas of the thin section in which more than half of the grains show more than simply touching, tangential contacts. Minor detrital phases are a few grains of clear microcline and rare instances of non-twinned feldspar which is probably orthoclase. The latter generally shows a slight turbid alteration. Lithic fragments are somewhat more abundant and are quite varied. Probably the most abundant types are grains of chert and rather more indeterminate fine-grained quartz/clay/mica aggregates. The latter are probably best referred to as metasedimentary types. The thin section contains one or two instances of finely intergrown quartz/feldspar lithic grains and these appear to be related to high level igneous rocks such as granophyres.

The rock contains, apart from traces of quartz overgrowths alluded to above, two diagenetic cement minerals: kaolinite and a carbonate. The kaolinite is generally present as monomineralic aggregates of relatively well-crystallised but fine-grained material. This shows no internal textures (such as might be present in kaolinite which has replaced a pre-existing mineral) and it is concluded that the kaolinite is simply a precipitate which filled pore spaces. The carbonate cement has a somewhat patchier distribution and it commonly forms crystals which are equant and irregular in shape and up to 0.1 mm in size. Some of these are distributed as single crystals throughout the rock but elsewhere they form loose and irregular aggregates commonly up to about 0.3 mm in size. In places somewhat ragged crystals of carbonate occur within aggregates of kaolinite and, although this texture cannot be interpreted unambiguously, it probably indicates that the carbonate crystalized after the kaolinite.

Thin sections of sidewall cores are not an ideal medium for estimating the amount of porosity in the rock but an attempt has been made to count the pores. It should be noted, however, that there is likely to be significant overestimation of the in-situ porosity by this counting method. The pores which appear to be an integral part of the rock are commonly not more than 0.25 mm in size and are probably reasonably well-interconnected in three dimensions. It is difficult to estimate to what extent the pores are of secondary origin but it seems likely that at least one third of the pores are probably large enough to be included in this category.

Judith No 1 - Sidewall Core 23 - 2428.5 m

Rock Name: Compact Carbonate-Cemented Lithic Sandstone

Thin Section: The volume percentages of the minerals determined by point counting are as follows:

Component	%
Quartz and Quartzite	53
Soft argillaceous clasts	26
Rigid Siliceous clasts	9
Carbonate	8
Pores	3
Kaolinite	1
Feldspar/Heavy Minerals	Trace

This sample is richer in lithic fragments and correspondingly deficient in pores compared to sidewall core 18. There are numerous aggregates of fine-grained minerals in this rock which form patches of the order of 0.1 -0.3 mm in size which, because of their heterogeneity, are interpreted as being compressed and possibly partly re-crystallized remnants of lithic fragments. To a large extent it is the compaction and squeezing of these between the more rigid quartz grains which has resulted probably in a relatively early decrease in the porosity in the original sand. What porosity remained was probably occluded largely by the precipitation of kaolinite and, more particularly, carbonate. As a result of these processes the sample appears to be rather impervious and probably essentially impermeable.

The rock is well-sorted and quartz grains mostly range from 0.2 - 0.35 mm in size. Most are equant in shape and generally are angular. There is evidence of pressure solution effects on the quartz grains and the development of concavo-convex grain boundaries. More commonly however, the quartz grains are separated from each other by fine-grained aggregates of either lithic material or cements. Feldspar is present only in trace amounts in this rock but has the same characteristics as those described in sidewall core 18.

A large proportion of the volume of the rock is composed of fine-grained material which appears to be derived from original fine-grained lithic fragments which have been distorted during compaction of the rock. In addition, some may have been partly re-crystallized and some partly invaded by later carbonate cement so that the textures are obscure in many areas. It seems likely, from a mineralogical point of view, that the material consists of quartz with smaller amounts of phyllosilicates, including clays and mica. Chert is less abundant than in sidewall core 18 and there is much more material which can probably be thought of as fine-grained metasiltstones and metamorphosed shales.

Carbonate is essentially a cementing phase and much of it forms rather irregular and porous aggregates of equant anhedral crystals commonly less than 0.1 mm in size. Such material is widely distributed throughout the whole area of the rock and is associated in rather varied patchy aggregates with the fine-grained lithic material which it appears to have partly replaced. Elsewhere carbonate forms finer-grained aggregates which are much larger than this; they range in size up to about 0.5 mm. The origin of such large aggregates of carbonate is probably related to the deformation of original limestone fragments.

The rock contains only trace amounts of authigenic kaolinite and there are small amounts of stable heavy minerals of which tourmaline appears to be the most abundant.

Judith No 1 - Sidewall Core 25 - 2392.5 m

Rock Name: Coarse Lithic Sandstone

Thin Section: The volume percentages of the minerals determined by point counting are as follows:

Component	%
Quartz and Quartzite	72
Soft argillaceous clasts	16
Rigid Siliceous clasts	4
Carbonate	5
Pores	3
Feldspar	Trace

This is a relatively coarse-grained sandstone and the average grain size of quartz and quartz-rich lithic fragments is probably at least 0.4 mm. There is a fairly wide size range from approximately 0.2 - 0.8 mm and the sample appears somewhat less well sorted than the two finer-grained rocks described immediately above. The rock contains a high proportion of quartzite grains (this may be a function of the coarse-grained nature of the sandstone but, including these with the single crystals of quartz, the grains are generally equant in shape and angular in outline with a few instances of sub-round grains. None of the grains show overgrowths. There is considerable evidence of the development of long contacts between the grains even though this is inhibited, to some extent, by the abundance of fine-grained lithic material which has been squeezed between the grains. The extent of pressure solution is also difficult to determine because the sidewall core tends to fracture along grain margins and disrupts these parts of the thin section.

Feldspars are present in only trace amounts and only two grains were unambiguously identified in the thin section. These tend to be towards the finer end of the grain size distribution and one is a perthite and the other has a rather indeterminate banded twinning pattern and may well be some kind of orthoclase. Lithic material is relatively abundant and includes a large amount of fine-grained phyllosilicate-rich material as well as finer-grained quartz/mica/clay lithologies. The phyllosilicate-rich rocks are metamorphosed aluminous sediments, with well developed banded textures which have been, now distorted and curved as the lithic fragments have been distorted around the more rigid quartz grains during compaction. Many of these aggregates are as much as 1.0 mm in length and relatively narrow. Most consist of birefringent sericite or micaceous material and in some there is a considerable amount of fine-grained carbonate. It seems likely that this carbonate is introduced material, although there is no specific evidence for this. Elsewhere lithic fragments are more quartz-rich and can be considered as metamorphosed siltstones and they have a more equant outline and clearly were somewhat more rigid than the micaceous or argillaceous lithologies. As in the sample described immediately above, there are a few large aggregates of very fine-grained carbonate which were probably limestone lithic fragments.

Occlusion of the porosity of the original sandstone occurred in this rock to a moderate extent as a result of pressure solution effects on the quartz grains but, more significantly, by the deformation and squeezing of relatively soft lithic fragments between the quartz grains. Carbonate may be a cementing phase but it appears not to be void-filling but, rather, has replaced some of the lithic material. No authigenic kaolinite was identified.

The description above refers to the bulk of the thin section but it should be recorded that a significant proportion of the rock (as represented by the sidewall core) is a bed of a dark ferruginous and argillaceous silty shale.

Judith No 1 - Sidewall Core 29 - 2332 m

Rock Name: Compact Lithic Sandstone

Thin Section: The volume percentages of the minerals determined by point counting are as follows:

Component	%
Quartz and Quartzite	66
Soft argillaceous clasts	26
Rigid Siliceous clasts	2
Pores	4
Opaques	2
Feldspar/heavy minerals	Trace

This sample has been somewhat more damaged during collection of the sidwall core and is, correspondingly, somewhat more difficult to interpret. This applies particularly to rather fine-grained quartz aggregates between larger grains. These are taken to be derived from fragmentation of sand-grade grains and it is thought likely that the sample probably originally showed considerable pressure solution effects and the development of long and concavo-convex boundaries. Even so there is a considerable amount of fine-grained lithic material.

The quartz grains appear to have been well-sorted about an average size of approximately 0.3 mm. Some grains are mainly surrounded by lithic material and retain sub-angular to sub-round original detrital outlines but more have at least some evidence of the development of long contacts which developed as a result of pressure solution. It is likely that this was an early stage in the occlusion of the original porosity of the sandstone. Lithic fragments include both phyllosilicate-rich foliated metasedimentary rocks and fine-grained siliceous lithologies. The latter generally retain equant detrital outlines but the phyllosilicate-rich rocks are commonly extremely distorted in shape and tend to fill intergranular spaces where they occur and it is thought that this process has been probably the most significant in reducing the porosity of the rock. Both the fine-grained quartz lithologies (mainly chert) and the metamorphosed shales testify to the presence of sedimentary rocks in the provenance terrains.

The sample contains only traces of feldspar and small amounts of stable heavy minerals. In one area of the thin section there are large aggregates of an opaque mineral and these are in some instances as much as 1.0 mm in size. These aggregates tend to fill intergranular spaces and probably represent a late introduction of ferruginous material into the rock. Also present is an elongate raft of a dark ferruginous siltstone. This is several millimetres in length and generally about 0.5 - 1.0 mm in thickness. Carbonate is irregularly distributed throughout the rock (mainly as a fine-grained replacement of lithic material) and this, too, probably represents material introduced into the rock at a relatively late stage in the diagenetic history of the sample.

3. PHOTOMICROGRAPHS

3. PHOTOMICROGRAPHS

Photomicrographs have been taken to show features of the rocks.

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

PE904962

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The enclosure PE904962 has the following characteristics:

ITEM_BARCODE = PE904962
CONTAINER_BARCODE = PE900021
NAME = Photomicrograph
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ON_OFF = OFFSHORE
PERMIT = VIC/P11
TYPE = WELL
SUBTYPE = PHOTOMICROGRAPH
DESCRIPTION = Judith 1 Photomicrograph of Thin Sections (crossed polars). Figure 1 SWC 18, 2532 m, 2 mm, CL; Figure 2 SWC 18, 2532, 0.2 mm, CL. From appendix 6 of WCR volume 2.
REMARKS =
DATE_CREATED = 30/06/90
DATE_RECEIVED = 20/08/90
W_NO = W1011
WELL_NAME = Judith 1
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The enclosure PE904963 has the following characteristics:

ITEM_BARCODE =	PE904963
CONTAINER_BARCODE =	PE900021
NAME =	Photomicrograph
BASIN =	GIPPSLAND
ON_OFF =	OFFSHORE
PERMIT =	VIC/P11
TYPE =	WELL
SUBTYPE =	PHOTOMICROGRAPH
DESCRIPTION =	Judith 1 Photomicrograph of Thin Sections (crossed polars). Figure 3 SWC 23, 2428.5 m, 2 mm, PPL; Figure 4 SWC 25, 2392.5, 2 mm, PPL. From appendix 6 of WCR volume 2.
REMARKS =	
DATE_CREATED =	30/06/90
DATE_RECEIVED =	20/08/90
W_NO =	W1011
WELL_NAME =	Judith 1
CONTRACTOR =	
CLIENT_OP_CO =	Shell Company of Australia

(Inserted by DNRE - Vic Govt Mines Dept)

Figure 1: SWC 18, 2532m, 2mm, CL
The field includes deformed aluminous lithic clasts (L) and a patch of well-crystallised authigenic carbonate (C). Note several instances of long contacts.

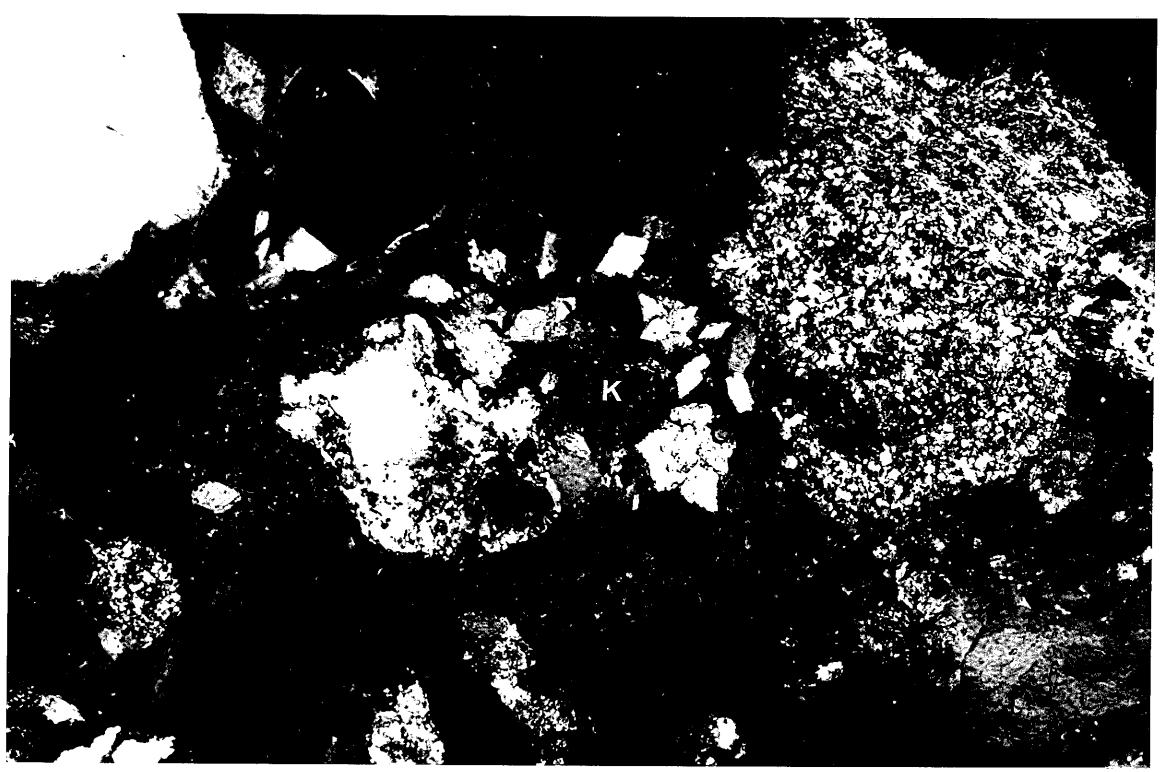

Figure 2: SWC 18, 2532m, 0.2mm, CL
Abundant authigenic kaolinite (K) with rhombs of carbonate. Lithic material occurs in the upper, right-hand corner.

Figure 3: SWC 23, 2428.5m, 2mm, PPL
Typical appearance in plane polarised light; pale buff material is deformed argillaceous clasts and dark material is secondary ferruginous oxides. Blue is porosity; interpretation of how much is a genuine part of the rock is difficult.

Figure 4: SWC 25, 2392.5m, 2mm, CL
This field shows moderately birefringent lithics squeezed so as to fill pore throats and three grains of quartzite.