SDA 1085

WILD DOG-1
WELL COMPLETION REPORT
TORQUAY SUB-BASIN
VIC/P28

SHELL AUSTRALIA

UPSTREAM OIL AND NATURAL GAS

SDA 1085

WILD DOG-1
WELL COMPLETION REPORT
TORQUAY SUB-BASIN
VIC/P28

VOLUME 2
INTERPRETATIVE DATA

M. TRUPP, R. CRABTREE and C. LANKI

SEPTEMBER 1993

THE SHELL COMPANY OF AUSTRALIA LIMITED

1 SPRING STREET, MELBOURNE, 3000

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

LIST OF ENCLOSURES

1. INTRODUCTION

The Wild Dog-1 exploration well was spudded on 24 December 1992 in the exploration permit VIC/P28, Torquay Sub-basin, offshore Victoria (fig. 1). The well, drilled at shot point 1670 on seismic line OS90A-13, fulfilled the Year 5 work commitment. Woodside Oil Limited funded 100% cost of the well to earn 50% equity in the permit.

The primary objective of the well was to test Upper Eocene sands of the Boonah Formation sealed by silty shales of the Anglesea Siltstone Member of the Demons Bluff Group. The structure consists of an asymmetric faulted anticline which developed during the Oligocene in response to localised movement and inversion of a major basin forming fault. A secondary objective of Paleocene and Upper Cretaceous Eastern View Group interbedded sandstones, shales and coals was also penetrated. Pre-drill, hydrocarbon charge was proposed to be sourced from Lower Cretaceous Eumeralla Formation coals in the main Basin Deep and from postulated algal shales in the latest Jurassic to earliest Cretaceous Casterton Beds in the Snail Terrace half graben. It was thought that trap formation pre-dated the Miocene compressional event which tilted the basin and that the Oligocene palaeodrainage was significantly larger than the present day drainage area.

Wild Dog-1 was drilled to total depth of 1222 mBDF and was plugged and abandoned as a dry hole on 8 January 1993 after failing to encounter any hydrocarbon shows. The well was drilled on schedule and budget with no recorded safety incidents.

2. REGIONAL GEOLOGY

The Torquay Sub-basin is bounded to the west by the Otway Ranges uplift and by the King Island - Mornington Peninsula High to the southeast and east (fig. 1). The stratigraphic sequence has affinities with the Lower Cretaceous of the Otway Basin and the Upper Cretaceous-Recent of the Bass Basin (fig. 2). The sediments of the Torquay Sub-basin are assumed to be underlain by Palaeozoic metamorphic and igneous rocks of the Tasman Fold Belt. The oldest section penetrated in the Torquay Sub-basin is the lower Eumeralla Formation at Anglesea-1, hence the likely nature of the Lower Cretaceous Otway Group is largely derived by analogy with the onshore Otway Basin westward of VIC/P28 and from outcrop to the north and east of the permit. Two major tectonic elements have been identified in the Torquay Sub-basin, a Basin Deep area with a thick Otway Group section and a terrace/half graben area called the Snail Terrace (fig. 1).

The Torquay Sub-basin formed as one of a series of failed rifts on the southern margin of Australia, which developed in response to rifting and, ultimately, separation of Antarctica from Australia. Episodic extension began in the Jurassic with particularly strong pulses during the Late Jurassic and Barremian, resulting in the development of several unconformities in the Otway sequence. Otway Group deposition began with the uppermost Jurassic to lowermost Cretaceous Casterton Beds which consists of a carbonaceous basal unit of lacustrine sandstones, siltstones and shales overlain by basalts and tuffs. This unit is overlain by the Neocomian Crayfish Formation, a sand rich fluvial deposit which is the reservoir for several gas fields in the western Otway Basin. The Crayfish Formation is unconformably overlain by the Barremian to Albian Eumeralla Formation, an interbedded sequence of sandstone, siltstone and shale with a carbonaceous basal unit. The Eumeralla Formation contains abundant weathered volcanics and lithic detritus which has altered to zeolite facies.

Breakup between Australia and Antarctica during the mid-Cretaceous created an angular unconformity at the top of the Otway Group in parts of the Torquay Sub-basin. Uplift of the Otway Ranges during this time isolated the Torquay Sub-basin from the rest of the Otway Basin producing a hiatus which continued until the Campanian when deposition recommenced.

The Eastern View Group was deposited between the Campanian and Middle Eocene and consists of interbedded sandstones, siltstones, shales and coals deposited in a lower coastal plain environment. Some minor marine influence is also seen for the first time. The Eastern View Group is thickest in the north-west of the permit and is absent over much of the Snail Terrace.

In the mid-Eocene, an increased rate of sea floor spreading between Australia and Antarctica produced greater subsidence and the first true marine deposition. The Late Eocene to Early Oligocene Demons Bluff Group unconformably overlies the Eastern View and Otway groups. The Demons Bluff Group consists of a dominantly transgressive sandy unit, the Boonah Formation which was deposited evenly over most of the sub-basin. The Boonah Formation is overlain by the regionally extensive Anglesea Siltstone, a homogenous shallow marine unit which grades from fine sand to clay. The uppermost unit of the Demons Bluff Group, the Angahook Formation is lithologically varied with sand, clay, gravel, and basalts, tuffs and agglomerates.

The Demons Bluff Group is conformably overlain by the Torquay Group which consists of interbedded marls, limestones and claystones. Deposition in the Torquay Sub-basin ended with uplift during the Miocene. This uplift appears to be associated with the collision along the northern margin of the Australian Plate which produced compression in the southern margin region. In the vicinity of the Torquay Sub-basin, the major axis of inversion is the Otway Ranges with the degree of inversion diminishing eastward and westward of the Ranges.

Several periods of igneous activity occurred through the history of the Torquay Sub-basin. The first phase of volcanism was during the Late Jurassic in association with the onset of rifting. Two later pulses of volcanism occurred during the Early Cretaceous, at 126 and 103 Ma. (Gleadow & Duddy, 1980), along the edge of the developing rift system. The final phase of igneous activity occurred during the Oligocene, with widespread extrusives in the south and east of the sub-basin and localised intrusions along fault planes and sub-parallel to bedding in the centre of the sub-basin.

3. STRATIGRAPHY

The stratigraphic sequence penetrated by Wild Dog-1 is summarised in figures 3 and 4. Formation tops are based on lithological and palynological data (appendix A) together with wireline log character. The stratigraphy drilled by the well was essentially in agreement with that predicted.

3.1 Torquay Group (Sea floor - 760 mBRT)

No samples were taken from the Torquay Group for biostratigraphic dating, however, it is assumed that the Torquay Group ranges in age from the Miocene (Puebla Formation) to the Oligocene (Jan Juc Formation) as occurs at nearby outcrops. The Puebla Formation (sea floor? - 688 mBRT) consists of marl and claystone with some calcarenite. The Jan Juc Formation (688 - 760 mBRT) consists of argillaceous siltstone overlying a sand and limestone unit. The Torquay Group section is largely unconsolidated with abundant fossiliferous material.

3.2 Demons Bluff Group

3.2.1 Angahook Formation (760 m - 788 mBRT)

Biostratigraphic dating of a sample at the base of the Angahook Formation indicates it is Late Eocene in age (appendix B). The Angahook Formation is comprised of unconsolidated fine to very coarse grained sand with minor interbedded silty claystone. No volcanic influence was seen.

3.2.2 Anglesea Siltstone (788 m - 927 mBRT)

The Anglesea Siltstone penetrated in Wild Dog-1 was a silty, soft, dark brown claystone. The middle of the unit contained a 17 m thick sand rich section. Both the claystone and the sand contain minor pyrite and glauconite. The age of the Anglesea Siltstone is Late Eocene (appendix B).

3.2.3 Boonah Formation (927 m - 1007 mBRT)

The Boonah Formation was dated by palynology (appendix A) as Late Eocene (*N. asperus* biozone). It consists of a shallow marine sand which was described as medium to very coarse grained, moderately well sorted, subangular to round with minor silica cement, pyrite and glauconite. The lower part of the Boonah Formation becomes more argillaceous. Petrophysical evaluation of the Boonah Formation (appendix C) indicates the presence of intercalations of volcanoclastics in the top section; these were not described during the drilling.

3.3 Eastern View Group (1007 m - 1160 mBRT)

Prior to drilling, the age and lithology of a sedimentary wedge recognised on seismic beneath the Boonah Formation was unknown. This wedge was found to be Eastern View Group. Palynological dating of the Eastern View Group indicates the oldest section, from 1110-1152 m, is Campanian (*N. senectus* biozone) and the youngest, 1008-1054.5 m, is Late Paleocene (upper *L. balmei* biozone). The age of the sediments between these two intervals is unknown. Deposition in this location was probably controlled by periodic movement on the Snail Terrace Fault, hence it is unlikely that a complete condensed sequence is present. The two units are lithologically different with interbedded coals, silty claystone and carbonaceous claystone being dominant in the section between 1007 m and 1032 m. Beneath 1032 m the Eastern View Group consists of interbedded siltstone, sandstone and minor carbonaceous claystone grading to coal. The siltstone was described as light to medium brown grey, grading to very fine sandstone. The interbedded sandstones are medium to very coarse grained, subround to round and moderately well sorted.

3.4 Otway Group (1160 m - 1222 mBRT (T.D.))

The top of the Eumeralla Formation of the Otway Group was penetrated at 1160 mBRT. Palynology indicates the Eumeralla Formation at Wild Dog-1 is Early Albian in age (*C. striatus* biozone). It was described as light grey greywacke, consisting predominantly of chert with minor quartz in a silty matrix. The well reached its total depth of 1222 mBRT in the Eumeralla Formation.

4. SEISMIC MARKERS AND STRUCTURE

A well velocity survey was run upon completion of Wild Dog-1 with checkshots at all of the major formation boundaries. A synthetic seismogram (encl. 2) was used to calibrate the seismic picks at SP 1670 on line OS90A-13 with the well results. The synthetic seismogram matches the seismic fairly well except between 720 - 770 ms where the density and sonic logs are severely affected by the 9 $^{5}/_{8}$" casing shoe, and at 850 ms where a strong peak on the seismic is interpreted to be a multiple. All of the formation boundaries were correctly correlated from the Nerita-1 and Snail-1 wells into the Wild Dog-1 area and the stratigraphy penetrated was close to prognosis (table 1). An apparent 15 ms mistie between the seismic and the synthetic is the result of incorrect zero-phasing which has applied a 15 ms bulk shift to the seismic.

The Wild Dog-1 well was drilled to test a simple, faulted asymmetric anticline that formed in the Oligocene in response to localised wrench induced inversion of a major basin forming fault. Despite the Top Boonah Formation pick being one loop lower, the integrity of the structural interpretation remains intact.

Dipmeter data from Wild Dog-1 indicates that the structural dip at the well is the same as that mapped (fig. 6). The dipmeter log response in the Boonah Formation is not outstanding, however, the predominant dip from the rose plots appears to be to the north-west as expected from the mapping (fig. 6). The first clear 'green' pattern in the Eastern View Group occurs between 1055 and 1060 m where the dip is 2° to the south. This concurs with the dip into the major fault meausured from the seismic data. The rose plots throughout the Eastern View Group indicate an overall dip trend to the south/south-east. Another 'green' pattern at 1153 m shows the structural dip to be 3° to the south-south-east. The apparent dips seen on the seismic (figs 5 &6) are around 3.5°. There is no evidence to suggest the structure is significantly different from the pre-drill mapping.

Table 1. Seismic picks

SEISMIC MARKERS pre/post drill	TWT (secs) pre	post	DEPTH (mss) pre	post
Top Anglesea Siltstone	0.75	0.77	755	766
Top Boonah Formation	0.89	0.895	915	905
Top Eastern View Group	0.97	0.96	1020	985
Top Otway Group	1.09	1.08	1190	1138

5. HYDROCARBON SHOWS

The Wild Dog-1 well failed to encounter any significant hydrocarbon shows. The only cuttings gas measured was a total gas peak of 0.15% with trace C_1 in the basal Jan Juc Formation and very minor gas associated with the Eastern View Group coals. No fluorescence was seen in any samples. Petrophysical evaluation (appendix C) indicates the well is 100% water wet, which is supported by RFT pressure measurements in the Boonah Formation which all fall on the water gradient.

6. RESERVOIRS, SEALS AND SOURCE ROCKS

6.1 Reservoirs

The main objective of Wild Dog-1 was the Boonah Formation, a shallow marine basal transgressive sand deposit. It has excellent reservoir properties, with a net/gross of 99.6% and an average log porosity of 32.1% (appendix C). The volcanoclastics identified in the petrophysical evaluation have high porosities and are included as net reservoir. The cuttings were described as unconsolidated quartz sandstone. The grains are medium to very coarse grained, subangular to well rounded and moderately well sorted. The sand also contains minor glauconite, indicative of marine deposition.

The sandier section of the Eastern View Group is below the closure of the Wild Dog-1 structure. The Eastern View Group has a net/gross of 29.8% with the sands having an average log porosity of 31.1% (appendix C).

6.2 Seals

The sealing capacity of the Anglesea Siltstone was considered one of the main risks associated with the prospect prior to drilling. Sidewall samples from the Anglesea Siltstone found a plastic shale which has good membrane sealing capacity. A mercury injection capillary pressure measurement indicates the shale could retain a 120 m oil column (+/- 20%) (appendix D). The Wild Dog structure is a faulted anticline so may be susceptible to leakage via fracturing associated with the fault. The plastic nature of the shale sampled would, however, indicate that the seal is more likely to be ductile than brittle and hence would flow rather than fracture. A sandier section was seen in the middle of the Anglesea Siltstone which may allow leakage across the fault.

6.3 Source Rocks

The Eastern View Group coals are immature in the Torquay Sub-basin so were not sampled for their source rock potential. The well did not intersect any source rocks in the limited Eumeralla Formation section penetrated.

7. CONCLUSIONS AND CONTRIBUTIONS TO GEOLOGY

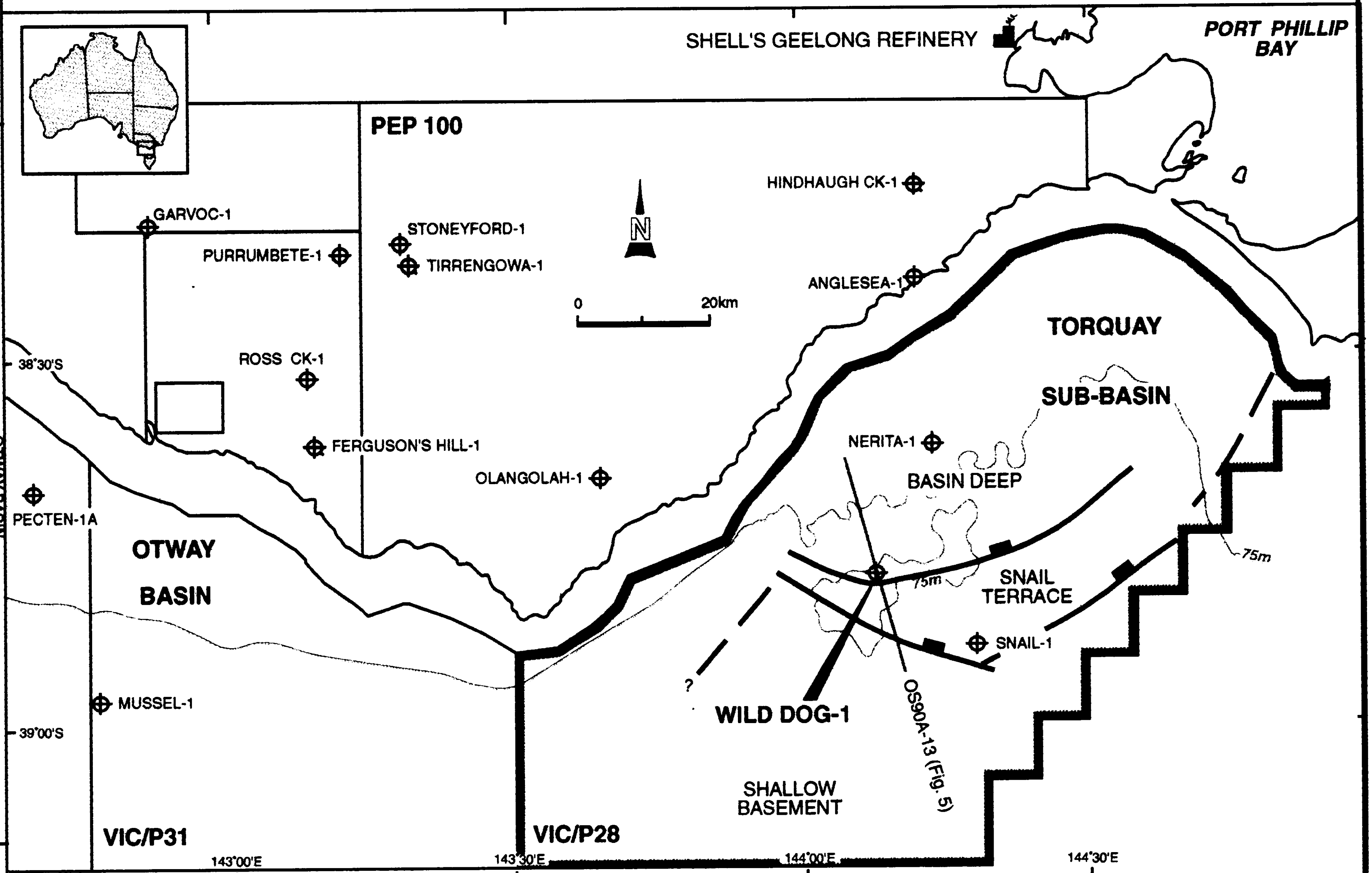
The lithological and stratigraphic section encountered by the Wild Dog-1 well was close to prognosis. The results of the well do not alter the structure that was mapped.

The failure of Wild Dog-1 to encounter any hydrocarbons severely downgrades the prospectivity of the offshore Torquay Sub-basin. The well intersected excellent quality reservoir sands in the Boonah Formation beneath a good seal, yet no shows were seen. The well is considered to have tested a valid trap hence the lack of shows must be attributed to lack of charge for which there are several possible explanations.

Basal Eumeralla Formation source rocks were proposed in the Basin Deep area of VIC/P28 based on penetrations elsewhere in the Otway Basin, however, no mature source rocks have been penetrated in the Torquay Sub-basin. The presence of these source rocks is therefore still uncertain. Maturity modelling was based on a notional depth for these source rocks, however if they are deeper in the section, charge generation may have preceded trap formation in the Oligocene. One other possible problem is secondary migration. If low vertical permeabilities in the Eumeralla Formation inhibit vertical migration, then the dip of the Eumeralla Formation would result in lateral migration to the northwest, away from the prospect (see fig. 5), and possibly outside of the pre-Miocene inversion palaeodrainage. Lack of permeable carrier beds in the lower Eumeralla Formation may also have prevented significant volumes from being expelled from the source rocks, or if expelled, the lithic sands of the Eumeralla Formation with low relative oil permeability may have behaved as a sponge, absorbing all of the expelled hydrocarbons.

8. REFERENCES

GLEADOW, A.J.W. & DUDDY, I.R., 1980 - Early Cretaceous volcanism and the early breakup history of southeastern Australia: Evidence from fission track dating of volcaniclastic sediments. *Proc. Fifth Int. Gondwana Symp., Wellington, New Zealand*, 295-300.



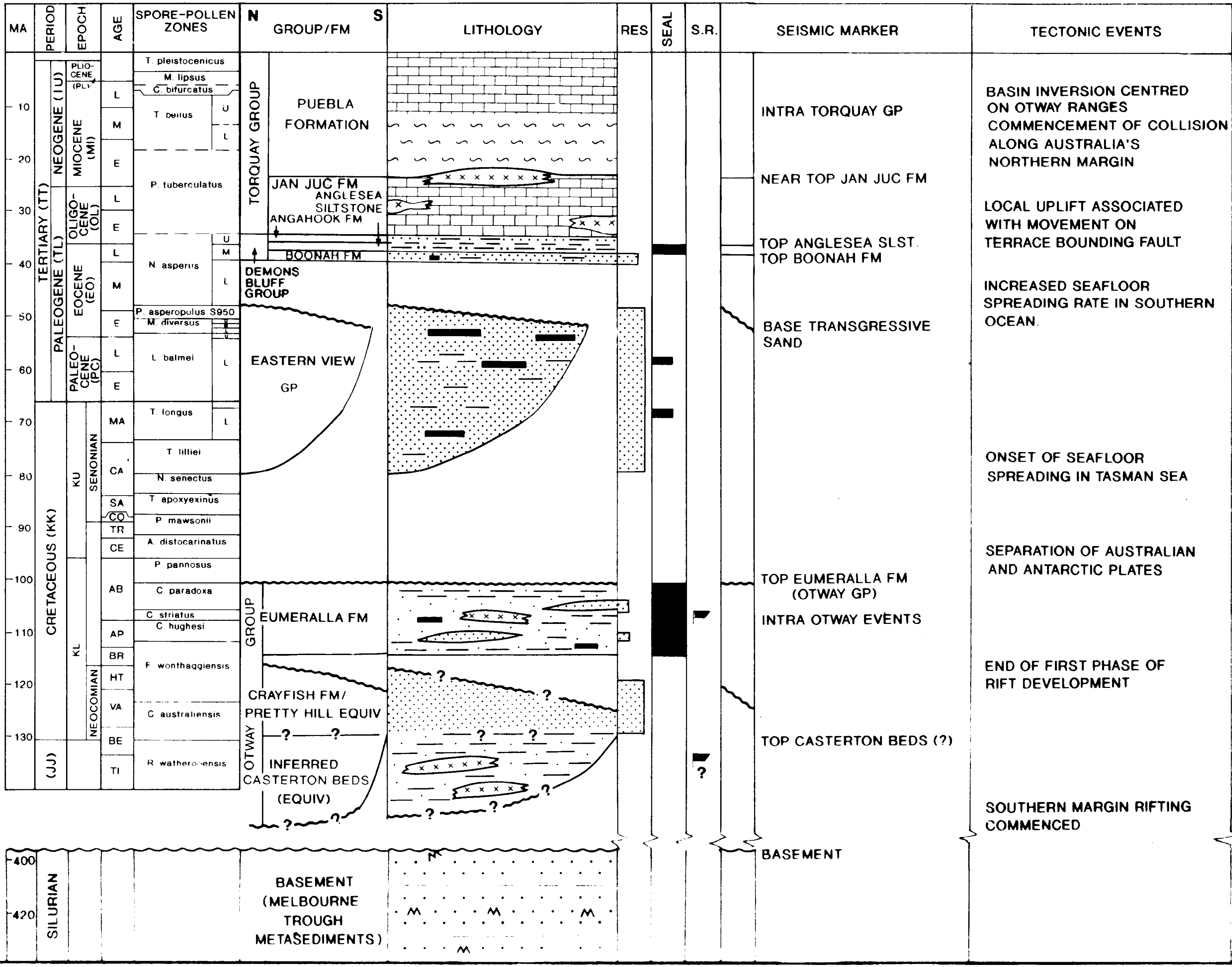
SHELL-AUSTRALIA
E.& P. OIL & GAS

OTWAY BASIN

LOCATION MAP

Author: EXO | Report No.: SDA 1065 | Date: JULY 1993 | Drawing No.: 27439

Figure 1



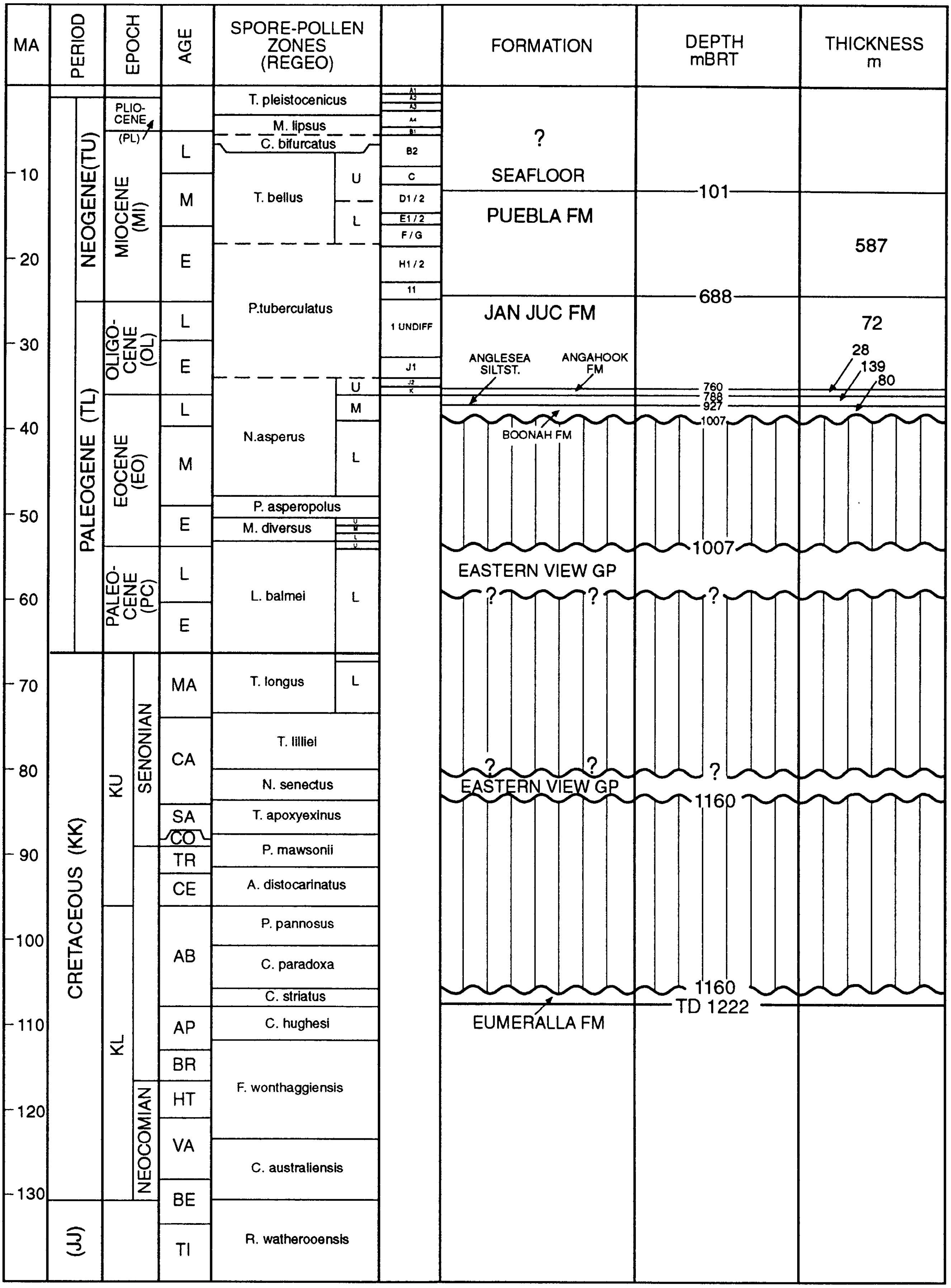
SHELL AUSTRALIA UPSTREAM OIL & NATURAL GAS

TORQUAY SUB-BASIN

GENERALISED STRATIGRAPHIC TABLE

Author: EXO | Report No.: SDA 1085 | Date: SEPT 1991 | Drawing No.: 25680

Figure 2



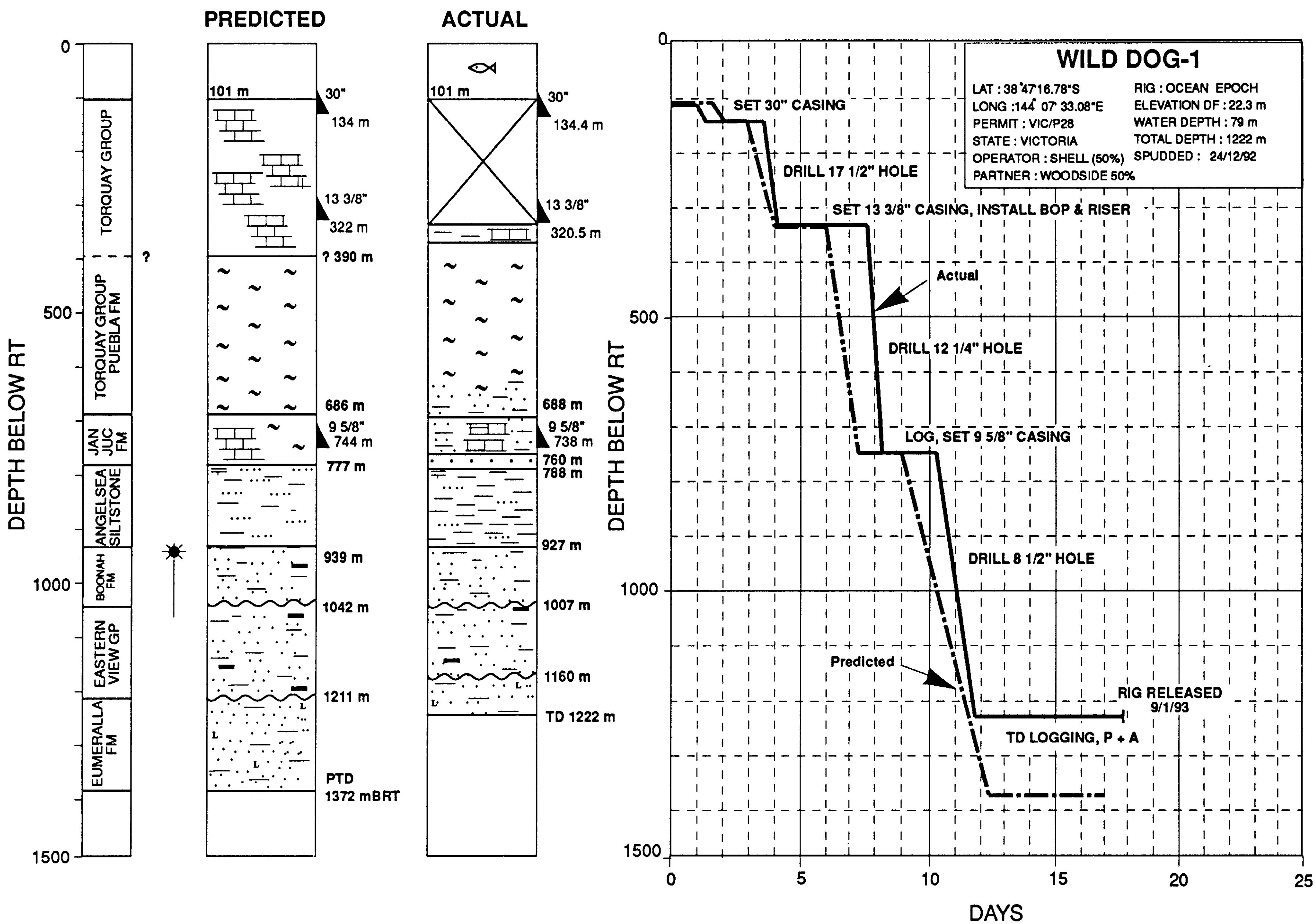
SHELL AUSTRALIA UPSTREAM OIL & NATURAL GAS

TORQUAY SUB - BASIN

WILD DOG - 1 STRATIGRAPHIC TABLE

Figure 3

Author: EXO	Report No.: SDA 1085	Date: AUGUST 1993	Drawing No.: 28562 C



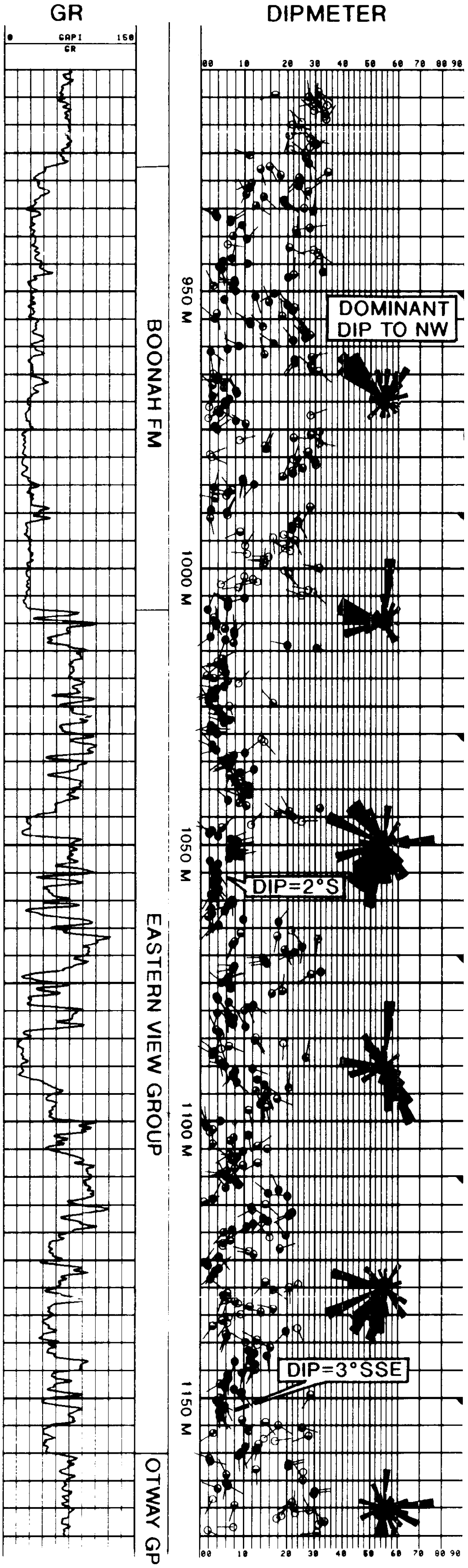
SHELL AUSTRALIA UPSTREAM OIL & NATURAL GAS

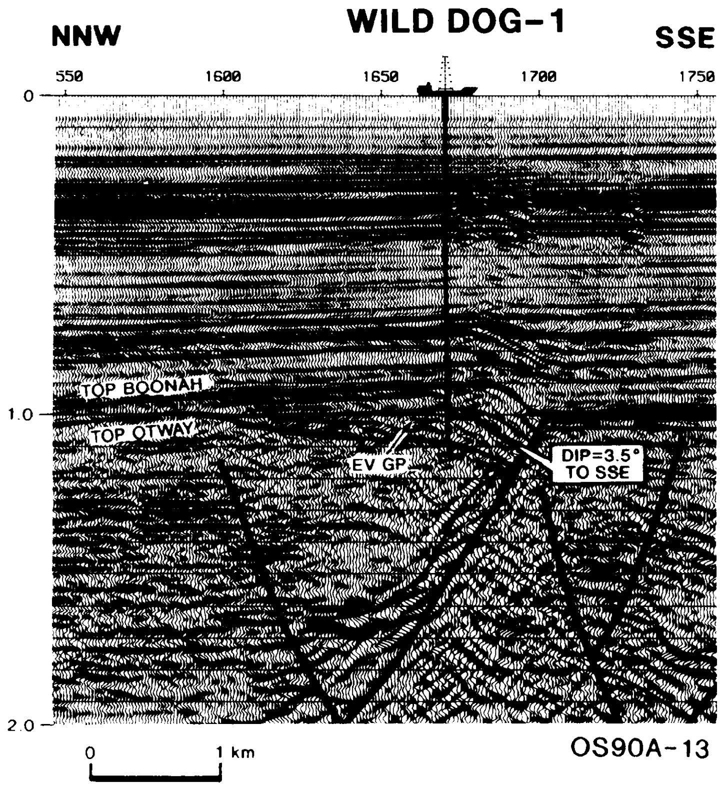
TORQUAY SUB-BASIN

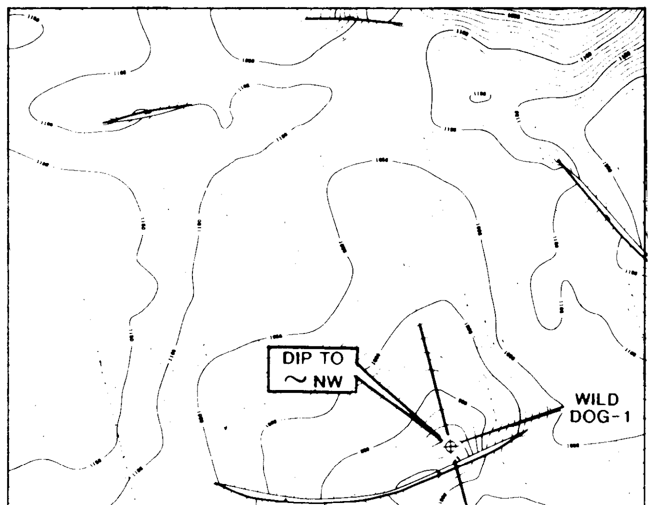
WILD DOG-1 DRILLING CURVE

Author: EXO | Report No.: SDA 1085 | Date: AUGUST 1993 | Drawing No.: 28539 C

Figure 4







0 2 km

C.I. = 10m

TOP BOONAH FM
DEPTH STRUCTURE MAP

SHELL AUSTRALIA UPSTREAM OIL & NATURAL GAS	TORQUAY SUB-BASIN			Figure 6
	WILD DOG-1 DIPMETER ANALYSIS			
	Author: EXO	Report No.: SDA 1085	Date: OCTOBER 1993	Drawing No.: 28722

APPENDIX A

PALYNOLOGY

PALYNOLOGICAL ANALYSIS, WILD DOG-1,

VIC-P-28, TORQUAY SUB-BASIN, VICTORIA

by

M.K. MACPHAIL

Palaeontological report prepared 1 March 1993 for
The Shell Company of Australia Ltd.

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

INTRODUCTION

SUMMARY OF RESULTS

GEOLOGICAL COMMENTS

KEROGEN YIELDS

PALAEOENVIRONMENTS

BIOSTRATIGRAPHY

INTERPRETATIVE DATA

BASIC DATA

RANGE CHART

INTRODUCTION

Eleven sidewall core and three cuttings samples, representing the interval 928 to 1220m in Wild Dog-1, were processed and examined for spore-pollen and dinoflagellates.

Yields and preservation were highly variable but overall were adequate for dating the major lithological units intersected within the above interval.

Lithological units and palynological determinations are summarized below. Kerogen yields (ccs of organic matter per gm sediment) are given on p.3.

Interpretative and basic data are given in Tables 1 and 2 respectively. The stratigraphic distribution of all species recorded is given in the attached range chart. Partial electric log data were made available for discussion.

SUMMARY

Age	Unit	Zone	Depth (m)	Environment
Late Eocene	**Boonah Fm.**	Middle *N. asperus*	928-990	Deltaic (marginal marine)
unconformity				
Late Paleocene	**Eastern View Gp.**	Upper *L. balmei*	1008-1054.5	Coastal plain (fluvio-lacust.)
unconformity				
Early Campanian	**Eastern View Gp.**	*N. senectus*	1110-1152	Rift valley (fluvio-lacust.)
unconformity				
Early Albian	**Eumeralla Fm.**	*C. striatus*	1161-1220	Rift valley (fluvio-lacust.)

TD 1223m

GEOLOGICAL COMMENTS

1. Wild Dog-1 intersects a stacked sequence of Late Eocene (Middle *N. asperus* Zone), Late Paleocene, (Upper *L. balmei* Zone) and Early Campanian (*N. senectus* Zone) units unconformably overlying the Eumeralla Formation. The top of this formation almost certainly is Early Albian, *C. striatus* Zone.

   The zone boundaries defined by the palynology are in excellent agreement with the lithologic formations established from electric log data.

2. Low yields and mostly poor preservation of spore-pollen dinoflagellates from the interval identified as Boonah Formation (922-1006m) are consistent with the sandy nature of this marginal marine unit. Caliper log data are against the palynomorphs being caved from the overlying clay/siltstone (ca. 890-1006m) at the base of the Demons Bluff Formation.

3. The presence of a non-marine Paleocene unit unconformably overlying Late Cretaceous sediments within the Eastern View Group corresponds well with the lithostratigraphic sequence recorded in Nerita-1A (Macphail, 1989) although the thickness of the unit is much less (46.5m vs 126m).

   The location of the SWCs close to the formation boundaries makes it certain that correlatives of the Lower *M. diversus* Zone and Lower *L. balmei* Zone facies in Nerita-1A are absent rather than not sampled. Maastrichtian *T. longus* and Late Campanian *T. lilliei* Zone facies may occur in the unsampled interval between 1054.5-1110m.

4. Based on confident *N. senectus* Zone dates for the interval between 1110-1152m, Wild Dog-1 includes a late Early Campanian unit that is missing or not sampled in the interval between 4460-4944ft. in Nerita-1A.

5. The absence of *in situ* Late Cretaceous angiosperm pollen in the SWC at 1161m confirms the log pick of 1160m for the unconformity separating the Eastern View and Otway Groups.

6. TAI values within the Early Cretaceous interval are immature to sub-mature.

KEROGEN YIELDS

Kerogen yields were highly variable with concentrations being highest in the Upper *L. balmei* Zone interval of the Eastern View Group and lowest at the top of the Boonah Formation (928m) and the Eumeralla Formation respectively.

Values for the individual SWC samples, determined by Konrad Weiss, Loala Pty Ltd., are:

SWC	DEPTH (m)	ORGANIC YIELD (cc/gm)
15	928	0.077
12	966	0.121
11	989	0.101
10	1008	0.530
09	1014.5	0.408
08	1054.5	0.425
07	1110	0.086
05	1152	0.075
04	1161	no data
02	1191	0.007
01	1220	0.006

Trends in the Organic yield will parallel variation in Total Organic Content (TOC) but, without additional data, the individual values cannot be directly correlated to TOC values.

PALAEOENVIRONMENTS

The variable (poor to excellent) preservation of Early Cretaceous palynofloras at 1220m and Early Campanian palynofloras at 1100m and 1152m are consistent with accumulation in fluvio-lacustrine depositional environments. Numbers of fresh-brackish water algal cysts are extremely low. There is no evidence of a marine-influence within the Paleocene interval within the Eastern View Group.

The sandy lithology and relative abundance of marine dinoflagellates to spore-pollen imply that the Boonah Formation is upper shore-face. This is consistent with evidence from other Torquay wells for a progressive encroachment of the Southern Ocean into the sub-basin during the Eocene.

BIOSTRATIGRAPHY

Zone and age-determinations have been made using criteria proposed by Stover & Partridge (1973), Helby *et al.* (1987) and unpublished modifications by A.D. Partridge and M.K. Macphail based on Gippsland and Otway Basin wells.

Crybelosporites striatus Zone 1161-1220m Early Albian

The age determination for the interval is based on the palynofloras at 1220m. This includes multiple specimens of *Crybelosporites striatus* but lacks indicator species of the *C. paradoxa* Zone. *Pilosisporites notensis* indicates the sample is no younger than earliest *C. paradoxa* Zone. The sample yielded rare specimens of the fresh-brackish water actritarch *Micrhystridium*.

Samples at 1161m and 1191m yielded very low numbers of long-ranging Cretaceous spores and/or gymnosperm pollen, consistent with an Early Cretaceous age. All angiosperm pollen appears to be caved.

Nothofagidites senectus Zone 1110-1152m Early Campanian

The two samples bracketing this interval yielded essentially the same assemblage of pollen and spores, dominated by *Nothofagidites senectus*, and related *Nothofagidites* spp. including *N. endurus*. The lowermost sample yielded a single specimen of *Micrhystridium*.

These "ancestral" *Nothofagus* pollen types and the consistent presence of *Forcipites sabulosus* and *Tricolporites apoxyexinus* show that the interval is no older than upper *N. senectus* Zone. That the interval is no younger than this zone is confirmed by multiple occurrences of *Forcipites stipulatus* and *Phimopollenites pannosus* and absence of *Gambierina* spp. and *Tricolporites lilliei.*

Both palynofloras are exceptionally well-preserved for their age. An anomalously young specimen of *Foraminisporis asymmetricus* occurs at 1110m: unusually early records of *Proteacidites amolosexinus* and *Dicotetradites meridianus* occur at 1152m and 1110m respectively.

Upper *Lygistepollenites balmei* Zone 1008-1054.5m Paleocene

Palynofloras within this interval are dominated by one or more of *Proteacidites*, *Nothofagus endurus* and gymnosperms of which *Araucariacites australis* and *Phyllocladidites mawsonii* are the most abundant. The nominate species, *Lygistepollenites balmei* is rare to infrequent throughout. A feature of the interval is presence of several *Proteacidites* spp. that are typical of the Otway Basin but which are rare to absent in the adjacent Bass and Gippsland Basins: *P.* sp. cf *P. fromensis*, *P. tripartitus* and *P wilkatenaensis*. Caved dinoflagellates occurs in very low numbers.

The lower boundary is placed at 1054.5m based on the association of *Cupanieidites orthoteichus*, *Malvacipollis diversus*, *M. subtilis*, *Proteacidites annularis* and *P obscurus* with frequent to common *Australopollis obscurus*, *Gambierina* spp. and *Proteacidites angulatus*. The last three taxa and *Camarozonosporites bullatus* show that the sample is no younger than Upper *L. balmei* Zone. Rare taxa restricted to Paleocene or older sediments include *Amosopollis cruciformis*, *Gambierina tenuis*, *G. edwardsii* and *Triporopollenites cirrus* ms. *Haloragacidites harrisii* provides a maximum lower age limit of Lower *L. balmei* Zone.

The palynofloras at 1014.5m includes *C. bullatus*, *G. rudata* *L. balmei*, *P. annularis* and *P.* sp. cf *P. incurvatus*.

The upper boundary is picked at 1008m, the highest sample to yield *in situ* *Lygistepollenites balmei* associated with *Malvacipollis diversus* and *M. subtilis*. *Australopollis obscurus*, *Nothofagidites endurus* and *Gleicheniidites* spp. are frequent to common. Rare species include *Tetracolporites multistrixus* ms and *Proteacidites dierama* ms.

Middle *Nothofagidites asperus* Zone 928-990m Late Eocene

SWC samples taken at 928m, 966m and 989m yielded abundant structured kerogen but negligible spore-pollen. Occurrences of typically Paleocene taxa such as *Nothofagidites endurus* and *Phyllocladidites verrucosus* imply most of the latter are derived from drilling mud.

Conversely, three cuttings samples from within the same interval yielded low to moderate numbers of poorly preserved (oxidized) Eocene spores, pollen and dinoflagellates. Well-preserved palynomorphs were rare, indicating that down-hole caving has been minimal. All samples included low numbers of reworked Mesozoic-Paleocene spores and gymnosperm pollen and unidentified chorate dinoflagellates.

The sample picked as the lower boundary of the zone (990m) includes the index species of the Middle *N. asperus* Zone (*Triorites magnificus*) and its correlative dinoflagellate zone, the *C. incompositum* (*Corrudinium incompositum*). Both provide a highly reliable Late Eocene date assuming they are *in situ*. The same age limits are reliably indicated by the association of *Proteacidites stipplatus*, *P. recavus* and *P. leightonii*. The maximum age limit is Middle Eocene, Lower *N. asperus* Zone based on the dinoflagellate *Systematophora placacantha*.

The samples at 942m and 930m are no older than Middle *N. asperus Zone* based on *Proteacidites stipplatus* and (930m) *Proteacidites rectomarginis P. reticulatus* and *Corrudinium incompositum*. The upper age limit for the latter sample is Middle *N. asperus* Zone based on *P. recavus*, *P. rugulatus* and *Triporopollenites delicatus*.

The upper boundary is provisionally picked at 928m, a SWC including *Aglaoreidia qualumis*.

REFERENCES

Helby, R., Morgan, R. & Partridge, A.D. (1987). A palynological zonation of the Australian Mesozoic. *Association of Australasian Palaeontologists, Memoir* **4**: 1-94.

Macphail, M.K. (1989). Palynological analysis of samples from Nerita-1A, Torquay Sub-basin. *Shell Company of Australia Palaeontological Report*, 1 September 1989.

Stover, L.E. & Partridge, A.D. (1973). Tertiary and Late Cretaceous spores and pollen from the Gippsland Basin, Southeastern Australia. *Proceedings of the Royal Society of Victoria* **85**: 237-286.

TABLE 1: SUMMARY OF INTERPRETATIVE PALYNOLOGICAL DATA

SWC	DEPTH (m)	ZONE S-P	ZONE DINO	CONF. RTG.	COMMENT
15	928	M. N.a	-	2	No older than zone
ctg	930	M. N.a.	C. incom.	3	C. incompositum, P. leightonii, P. recavus P. rectomarginis
ctg	942	M. N.a.	-	4	P. stipplatus
12	966	indet.	-	-	mud contaminants only
11	989	indet.	-	-	mud contaminants only
ctg	990	M. N.a.	C. incom.	3	T. magnificus, C. incompositum
10	1008	U. L.b.	-	0	L. balmei, M. subtilis
09	1014.5	U. L.b.	-	0	C. bullatus, P. annularis
08	1054.5	U. L.b.	-	0	As above
07	1110	N. sen.	-	1	N. senectus, F. sabulosus,
05	1152	N. sen.	-	1	As above
04	1161	Early Cretaceous		-	E. Cretaceous spp.
02	1191	Early Cretaceous		-	Mostly mud contaminants
01	1220	C. str.	-	1	C. striatus, P. notensis

M. N.a. = Middle N. asperus Zone
C. incom. = Corrudinium incompositum Zone
U. L.b. = Upper L. balmei
N. sen. = Nothofagidites senectus Zone
C. str. = Crybelosporites striatus Zone

TABLE 2: SUMMARY OF BASIC PALYNOLOGICAL DATA

SWC	DEPTH (m)	YIELD S.-P.	YIELD DINO	DIVERSITY S-P	DIVERSITY DINO	PRES.
15	928	very low	-	low	-	poor
ctg	930	medium	low	high	medium	poor
ctg	942	low	low	low	low	poor
12	966	very low	-	low	low	moderate
11	989	very low	-	low	-	variable
ctg	990	medium	medium	medium	low	moderate
10	1008	medium	-	high	-	poor
09	1014.5	low	-	high	-	moderate
08	1054.5	very high	very low	high	low	good
07	1110	medium	-	high	-	good
05	1152	low	very low	medium	low	moderate
04	1161	very low	-	low	-	very poor
02	1191	very low	-	low	-	very poor
01	1220	low	-	medium	-	moderate

PE901814

This is an enclosure indicator page.
The enclosure PE901814 is enclosed within the container PE900191 at this location in this document.

The enclosure PE901814 has the following characteristics:

ITEM_BARCODE = PE901814
CONTAINER_BARCODE = PE900191
NAME = Wild Dog 1 Palyostratigraphy
BASIN = Otway
PERMIT = VIC/P28
TYPE = WELL
SUBTYPE = DIAGRAM
DESCRIPTION = Wild Dog 1 Palyostratigraphy
REMARKS =
DATE_CREATED = 1/03/93
DATE_RECEIVED = 4/11/93
W_NO = W1074
WELL_NAME = Wild Dog 1
CONTRACTOR = *
CLIENT_OP_CO = SHELL DEVELOPMENT (AUSTRALIA) PTY LTD

(Inserted by DNRE - Vic Govt Mines Dept)

MICROPALAEONTOLOGICAL ANALYSIS
WILD DOG-1, PERMIT VIC-P-28
~~GIPPSLAND~~ OTWAY BASIN

FOR

SHELL DEVELOPMENT (AUSTRALIA) PTY LTD

J.P. REXILIUS
S.L. POWELL

AUGUST, 1993

INTERNATIONAL STRATIGRAPHIC CONSULTANTS PTY LTD
A.C.N. 009 183 555

UNIT 2, 10 STATION STREET
P.O. BOX 26
COTTESLOE 6011
WESTERN AUSTRALIA
PHONE 3852571 FAX 3843257

CONTENTS

I. SUMMARY

Wild Dog-1 was drilled in offshore petroleum permit VIC-P-28, Gippsland Basin to a depth of 1222mKB. A total of 3 sidewall core samples from the interval 784m to 860m have been examined for foraminifera and calcareous nannoplankton. A summary of the biostratigraphic breakdown of the respective microfossil groups and environment sub-division is given below:-

Planktonic Foraminiferal Sub-division

784m-790m	Zone K	Late Eocene
860m	Zone K or older	indeterminate

Calcareous Nannoplankton Sub-division

784m-790m	Zone NP19	mid Late Eocene
860m	Zones NP17/16	late Middle Eocene

Integrated Biostratigraphic Sub-division

784m-790m	Zones K & NP19	mid Late Eocene
860m	Zones NP17/16, K or older	late Middle Eocene

Environment of Deposition

784m, 790m & 860m	middle neritic

II. INTRODUCTION

A total of 3 sidewall core samples from the interval 784m to 860m have been examined for foraminifera and calcareous nannoplankton in Wild Dog-1.

Fossil assemblages identified in the well section have been plotted on the distribution chart (Appendix No. 2).

III. BIOSTRATIGRAPHIC ANALYSIS

The planktonic foraminiferal letter scheme of Taylor (in prep.) and the NP calcareous nannoplankton zonal scheme of Martini (1971) are used for biostratigraphic sub-division.

A. Planktonic Foraminiferal Sub-division

1. 784m–790m : Zone K (Late Eocene)

Assignment to Zone K is based on the association of *Subbotina linaperta* and *Subbotina angiporoides*.

2. 860m : Zone K or older (Late Eocene or older)

The sidewall core sample includes a single specimen of *Subbotina linaperta* and lacks other index species. On this basis the sample is considered to be Zone K or older in age.

B. Calcareous Nannoplankton Sub-division

1. 784m–790m : Zone NP19 (mid Late Eocene)

The occurrence of *Cribrocentrum reticulatus* and lack of *Chiasmolithus grandis* in high yielding and diverse nannoplankton assemblages in the interval, indicates assignment to Zone NP19.

2. 860m : Zones NP17/16 (late Middle Eocene)

The association of *Cribrocentrum reticulatus, Chiasmolithus grandis, Reticulofenestra umbilica and Dictyococcites bisectus* indicates assignment to Zones NP17 and NP16.

IV. ENVIRONMENT OF DEPOSITION

Environment sub-division of the Eocene section in Wild Dog-1 is based on experience of Gippsland Basin foraminiferal biofacies.

1. 784m, 790m & 860m : Middle neritic

The diverse benthonic foraminiferal faunas in the samples in the interval include the following bathymetrically-significant taxa: *Globocassidulina subglobosa* (common), *Trifarina bradyi* (frequent) and *Siphouvigerina canariensis* in association with high numbers of *Cibicides* taxa. Deposition in a middle neritic setting is envisaged.

V. REFERENCES

MARTINI, E., 1971. Standard Tertiary and Quaternary calcareous nannoplankton zonation. In: FARINACCI, A., (Ed). *Proc. 2nd Plank. Conf., Roma.* : 739–785.

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

APPENDIX NO. 1 : SUMMARY OF MICROPALAEONTOLOGICAL DATA, WILD DOG-1

DEPTH (m)	FORAM YIELD	FORAM PRESERV.	FORAM DIVERSITY	NANNO YIELD	NANNO PRESERV.	NANNO DIVERSITY
SWC22, 784	high	moderate	high	high	moderate	moderate-high
SWC21, 790	high	moderate	high	high	moderate	moderate-high
SWC19, 860	moderate	moderate	high	mod-low	poor	moderate

APPENDIX NO. 2: DISTRIBUTION FORAMINIFERA AND NANNOPLANKTON, WILD DOG-1

SPECIES /SAMPLES	SWC, 784m	SWC, 790m	SWC, 860m
BENTHONIC FORAMI NIFERA			
Globocassidulina subglobosa	c	c	c
Guttelina aff. yabei	s		
Quinqueloculina spp.	c	f	
Massilina spp.	s		
Bueningia creeki	f		
Cibicides semiperforatus	s		
Dorothia spp.	r		
Gyroidina zealandica	r	s	
Textularia spp.	r		
Cibicides mediocris	c	r	
Haplophragmoides spp.	s		c
Cibicides perforatus	c	c	
Eponides subhaidingeri	f	f	f
Guttelina problema	r	s	r
Epistominella spp.	r		
Trifarina parva	s	r	
Anomalinoides macroglabra	f	f	r
Fissurina spp.	r	r	f
Cibicides vortex	f	f	r
Sphaeroidina bulloides	r	r	
Favulina spp.	s		
Cibicides spp.	f	c	f
Sigmoilina spp.	s		
Ceratobulimina aff. pacificus	s		
Trifarina bradyi	f	f	f
Hanzawaia spp.	r	s	s
Hoeglundina elegans	s	r	r
Anomalinoides pinguiglabra	s		
Pullenia bulloides	s	s	
Nodosaria spp.	s	s	
Triloculina spp.	s	s	
Siphouvigerina canariensis	s	r	f
Rosalina ponticulus	s		
Brizalina spp.	r	r	
Astrononion spp.	r		r
Lagena spp.	s	s	r
Cibicides inflatus	s		
Cibicides thiara		r	
Cassidulina bradyi		s	
Heronallenia lingulata		s	
Cibicides lobulatus		r	
Pullenia quinqueloba		s	s
Cassidulina laevigata		f	
Lenticulina spp.		r	s
Anomalina spp.		r	
Baggina ampla		s	
Discorbinella spp.		s	
Bolivina spp.		s	r
Angulogenerina angulosa		r	r
?Eggerella spp.			s

s = single, r = rare, f = frequent, c = common, a = abundant.

Sigmoidella elegantissima			r
Nodosaria longiscata			f
Hyperammina spp.			s
Quadrimorphina laevigata			r
Baggina spp.			r
Biloculina spp.			s
Trochammina spp.			s
Reussella spp.			s
Rotamorphina spp.			s
PLANKTONIC FORAMINIFERA			
Subbotina linaperta	r	r	s
Globigerina spp.	s	r	
Small planktonics	f	c	f
Subbotina angiporoides angiporoides		s	
Chiloguembelina cubensis			f
Turborotalia spp.			s
CALCAREOUS NANNOPLANKTON			
Reticulofenestra umbilica	f	f	f
Cyclicargolithus floridanus	a	a	f
Coccolithus pelagicus	f	r	f
Dictyococcites productus	r	r	
Neococcolithus dubius	r		s
Braarudosphaera bigelowii	s	r	
Dictyococcites bisectus	f	f	f
Zygrhablithus bijugatus	r	f	f
Rhabdosphaera spp.	r	r	f
Sphenolithus moriformis	r	s	
Cribrocentrum reticulatus	r	r	s
Transversopontis spp.	s	s	
Chiasmolithus spp.	s		
Pontosphaera multipora	r	s	
Cyclococcolithina spp.		s	
Isthmolithus recurvus		r	
Pontosphaera spp.		s	r
Helicosphaera spp.		s	r
Chiasmolithus grandis			s
OTHER SKELETAL MATERIAL			
Bivalve fragments	c	f	
Gastropods	f	f	s
Echinoid debris	c	f	c
Bryozoan debris	c	c	
Otoliths	s		
Ostracods	s	s	s
Sponge spicules			s

s = single, r = rare, f = frequent, c = common, a = abundant.

APPENDIX C

PETROPHYSICS

APPENDIX C PETROPHYSICAL EVALUATION OF WILD DOG-1, TORQUAY SUB-BASIN

1. LOG EVALUATION SUMMARY

Wireline logs run by Halliburton Logging Services (HLS) are summarised in table C1.

The objective zone of Wild Dog-1, the late Eocene, shallow marine Boonah Formation, was found to be fully water bearing. Some mafic volcanoclastics were found intercalated with the clean marine sands.

Formation	Top (mBRT)	Bottom (mBRT)	Net (m)	Net/Gross (%)	Porosity (%)	Hysat (%)
Boonah	927	1007	79.7	99.6	32.1	0
Eastern View	1007	1160	45.6	29.8	31.1	0

The RFT pressure measurements indicated the Boonah sands to be hydrostatic.

2. LOG QUALITY

The log quality and repeatability of the basic open hole logs is satisfactory (fig. C1). The density log was adversely affected by hole rugosity in the top of the objective sands (interval 938 - 946 m). Over this interval a maximum porosity of 36% was set.

The Sequential Formation Tester (SFT) was run with a quartz pressure gauge.

3. EVALUATION PROCEDURES

3.1 General

The final log evaluation was carried out using Shell's LOGIC computer program.

3.2 Net reservoir rock definition

Net reservoir rock was defined as having a Gamma-Ray reading of less than 60 API. In the top section of the Boonah Formation significant intercalations of mafic volcanoclastics are interpreted. These volcanoclastics have a dolomite character on the density-neutron crossplot (fig. C2), however, no dolomite was described in the cuttings. The values calculated for M and N from the anomalous points in the Upper Boonah Formation plot in the shale region of the standard Schlumberger chart, however they have low Gamma Ray values and no kaolinite was described in the cuttings. Igneous minerlogy plots from Khatchikian (1983) indicate these values most likely indicate the presence of clastics derived from mafic volcanics. Further evidence is that hydrocarbon saturations calculated assuming dolomite were quite unrealistic. The volcanoclastics have a good porosity and therefore are also deemed net reservoir rock.

3.3 Porosity calculation

The (total) porosity in the sandstones was calculated using the density log. The density-neutron crossplot indicated the sands to be mainly quartzitic. Therefore a grain density of 2.65 g/cc was used. A fluid density of 1.00 g/cc (mud filtrate density) was used. The density log did not require borehole corrections.

In view of the unknown matrix density of the volcanoclastics, the porosities of these layers were back calculated with the Archie formula after it was established that all the surrounding sands were fully water-bearing.

3.4 Hydrocarbon saturation computation

The Pickett plot (fig. C3), with the Laterolog deep reading as R_{true}, was used to establish the porosity exponent 'm', the related tortuosity factor 'a' and formation water resistivity 'Rw'. The saturation exponent 'n' was assumed to be 2.00. The Laterolog deep log did not require borehole correcting. The Archie formula was used to compute the water saturations.

For the summary of evaluation parameters used, refer to table C2.

4. FORMATION PRESSURES

The five RFT formation pressure readings unambiguously show a formation fluid gradient of 1.412 psi/m which indicate a formation fluid specific gravity of 1.00 g/cc (fig. C4). This density fits water with 30 000 ppm NaCl at 1400 psi and 60°C.

The formation fluid pressure at 1000 mSS is 1450 psia (100 bar). This indicates the sands to be hydrostatically pressured.

C5 Formation temperatures

The true formation temperature was calculated from the logged bottom-hole temperatues using CTCYM's in IBS91. Assuming a surface temperatue of 15°C, the true formation temperature at 1222 mBRT is 76.3°C with a geothermal gradient of 5.0°C/100 m.

6. RESULTS

The petrophysical data log is included as figure C5.

7. REFERENCES

KHATCHIKIAN, A., 1983 - Log evaluation of oil-bearing igneous rocks. *World Oil*, December.

TABLE C1 WILD DOG-1 WIRELINE LOGS RUN

Contractor: Halliburton Logging Services

Suite (Hole Size)	Date	Log No.	Log Type	Depth interval (metre BDF)	Max. Temp. (^{o}C)	Time Taken (hr)	Lost Time (hr)	Remarks
Suite 1 (12 1/4")	1/1/93	1	SDL/LSS/GR/DTD	325 - 743 (GR to seabed)	41.7	14 3/4	6 1/4	Time lost with tool hanging up on ledge. Ran wiper trip.
Suite 2 (8 1/2")	4/1/93	1	DLL(SP)/MSFL/LSS/GR/DTD	734 - 1222	60.0	6	2	Human error while making up tool
	4/1/93	2	SDL/DSN/GR/DTD	734 - 1222	64.4	3 1/4	1/4	-
	4/1/93	3	SED/GR/DTD (dipmeter)	734 - 1222	67.7	5 1/4	-	TOC 9 5/8" csg also
	5/1/93	4	SFT/QPG/GR	928 - 1046	-	4 1/2	-	Reduced programme
	5/1/93	5	WELLSHOOT (SEISMOGRAPH SERVICES LTD)	225 - 1220	-	3	1/2	11 levels/2 repeats
	5/1/93	6	SWS	747 - 1220	-	4	-	24 shot/17 recovered

TABLE C2 PETROPHYSICAL PARAMETERS AND PROCEDURES

WELL :	Wild Dog-1 VIC/P28 Torquay Sub-basin	**FORMATION:**	Boonah + Eastern View
OPERATOR:	Shell Australia	**LITHOLOGY:**	Sand-shale- volcanoclastics
DATE EVAL.:	Jan. '93	**FORM. INTERV.:**	927-1160 m
TYPE EVAL.:	LOGIC single well	**RESERV. FLUID:**	water

NET ROCK DEFINITION: GR < 60 API

POROSITY CALCULATION: from density log
(In volcanoclastics from Archie)

HYSAT CALCULATION: Archie

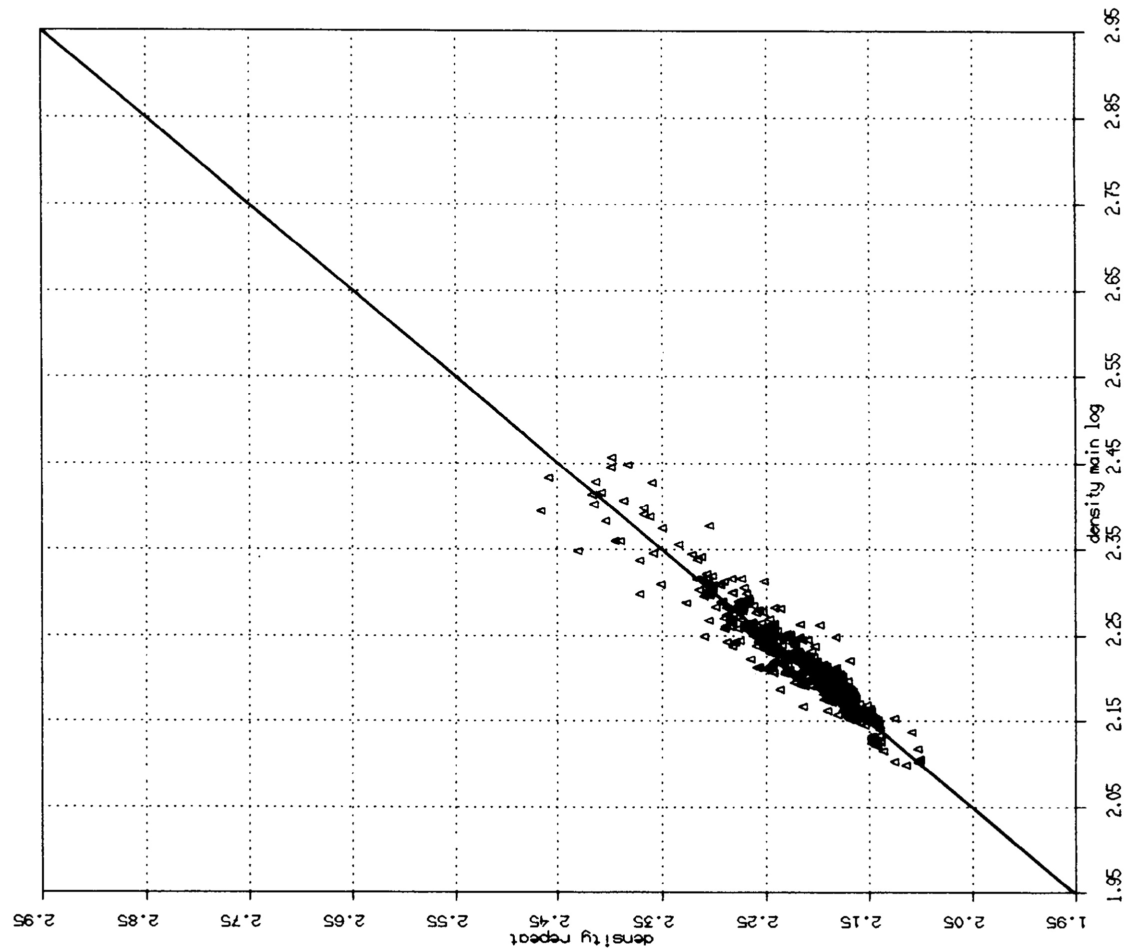
Parameter	Value	Source/Remarks
rho matrix (g/cc)	2.64	log indications
rho fluid	1.00	mud filtrate
a	1.00	Pickett plot
m	1.80	Pickett plot
n	2.00	assumed
Rw (Ohm.m)	0.12	Pickett plot
form. salinity (ppm NaCl)	30,000	Rw and T
form. Temp. (^{o}C)	60	log
Rt	LLD	

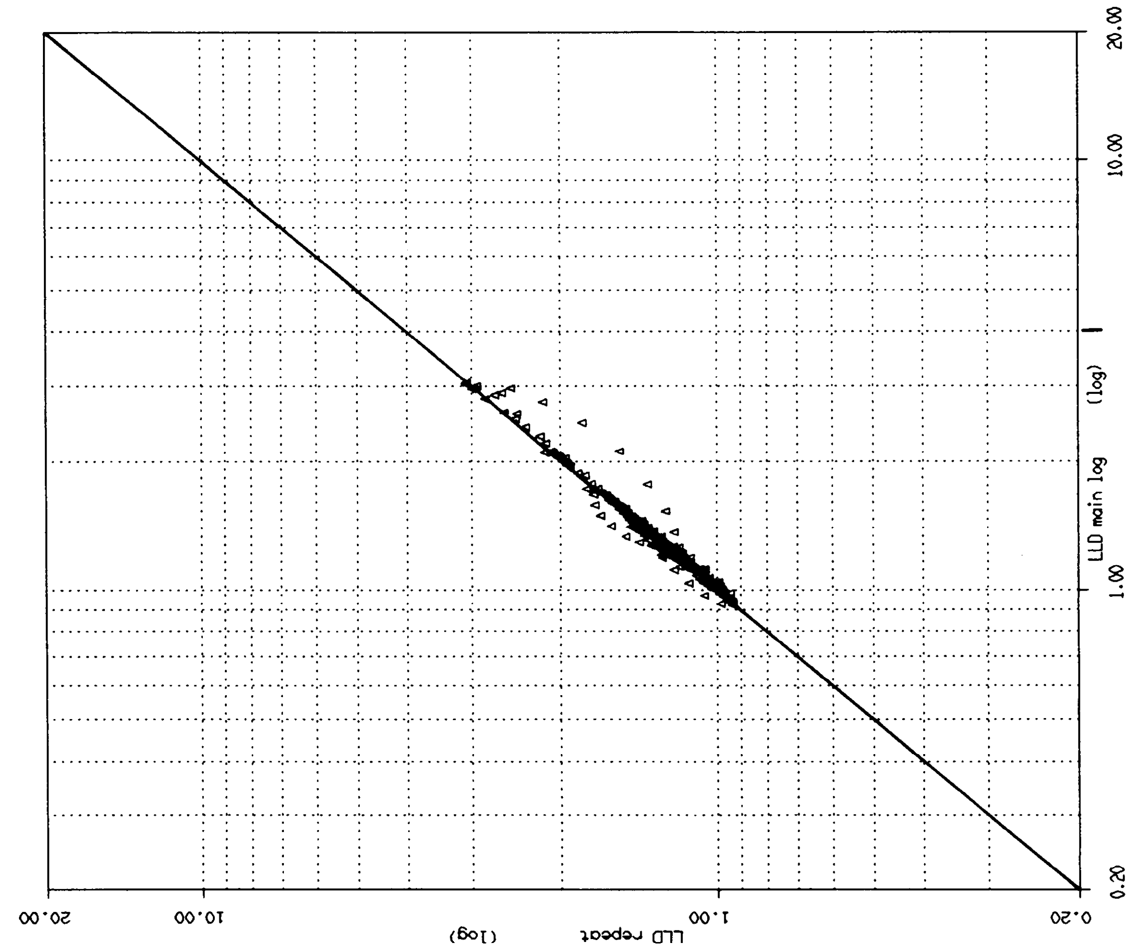
FURTHER CUT-OFF CRITERIA: none

FORMATION TESTS: 5 SFT pressure tests

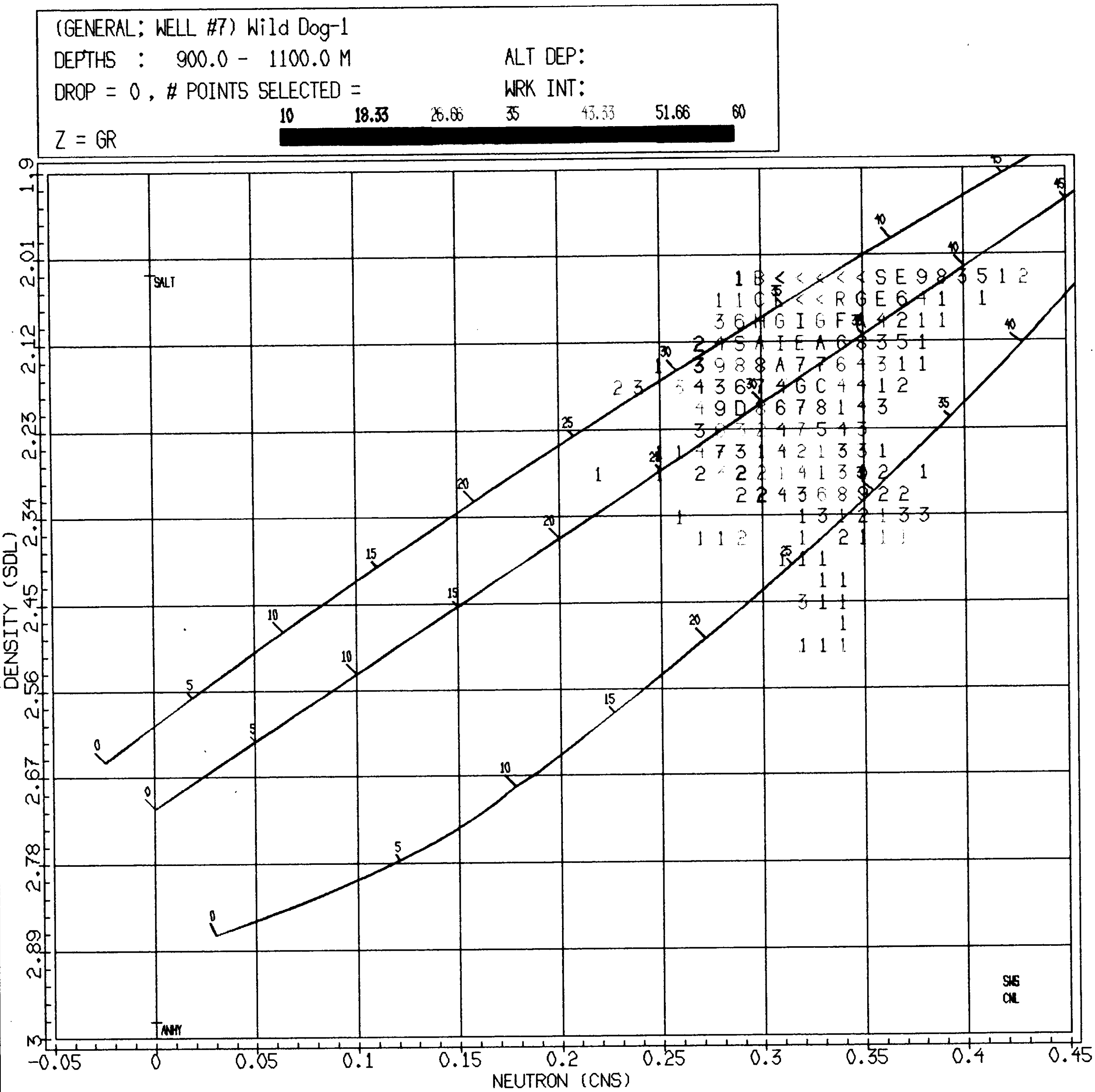
CORE DATA: No core

REMARKS: none





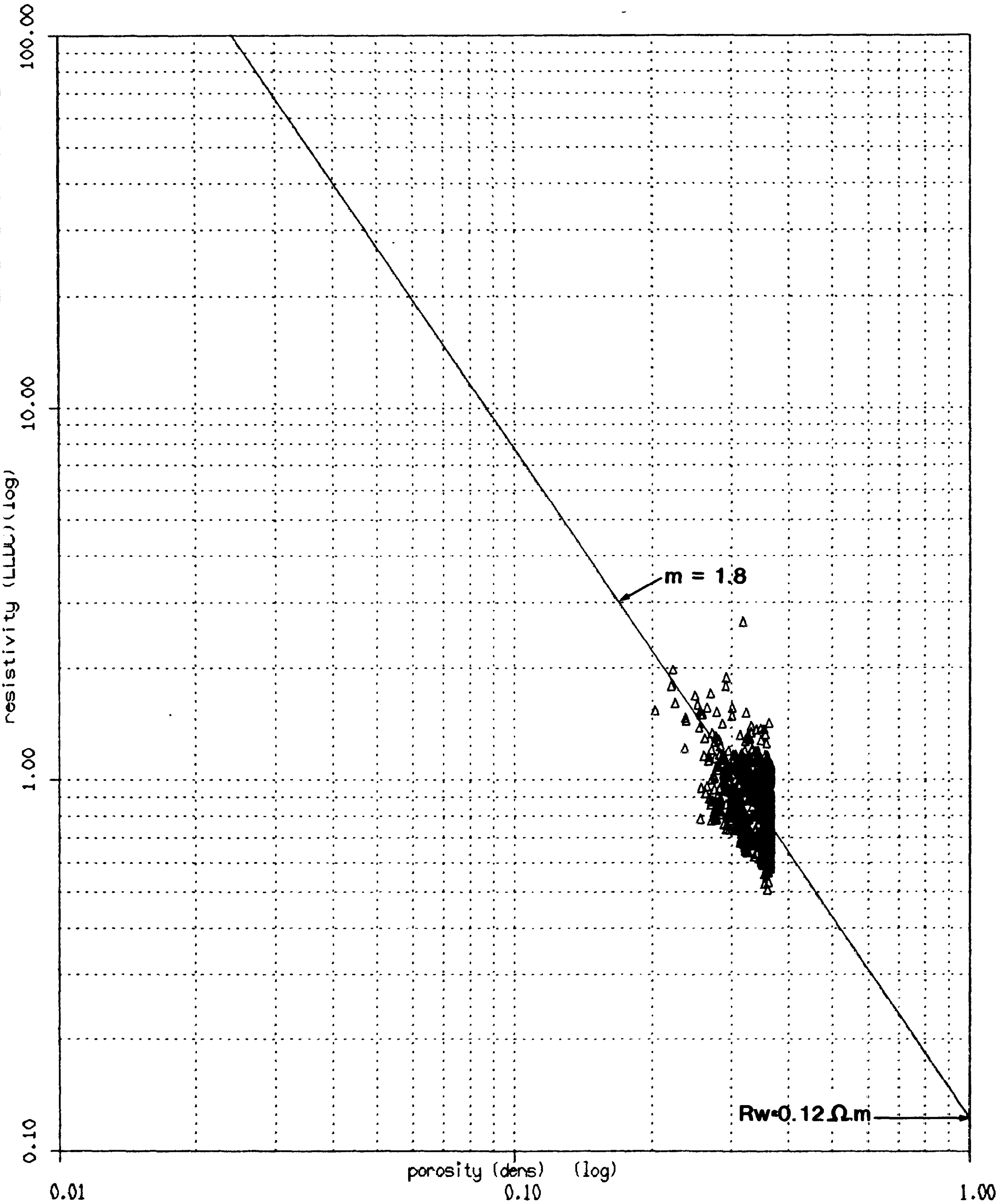
SHELL AUSTRALIA UPSTREAM OIL & NATURAL GAS	TORQUAY SUB-BASIN				Figure
	REPEAT SECTIONS CHECKPLOTS, WILD DOG-1				C1
	Author: EEP/3	Report No.: SDA 1085	Date: FEBRUARY 1993	Drawing No.: 28299	



TORQUAY SUB-BASIN

DENSITY-NEUTRON CROSSPLOT, WILD DOG-1

SHELL AUSTRALIA UPSTREAM OIL & NATURAL GAS	Author: EEP/3	Report No.: SDA 1085	Date: FEBRUARY 1993	Drawing No.: 28300	Figure C2



SHELL AUSTRALIA UPSTREAM OIL & NATURAL GAS

TORQUAY SUB-BASIN

PICKETT PLOT, WILD DOG-1

Figure C3

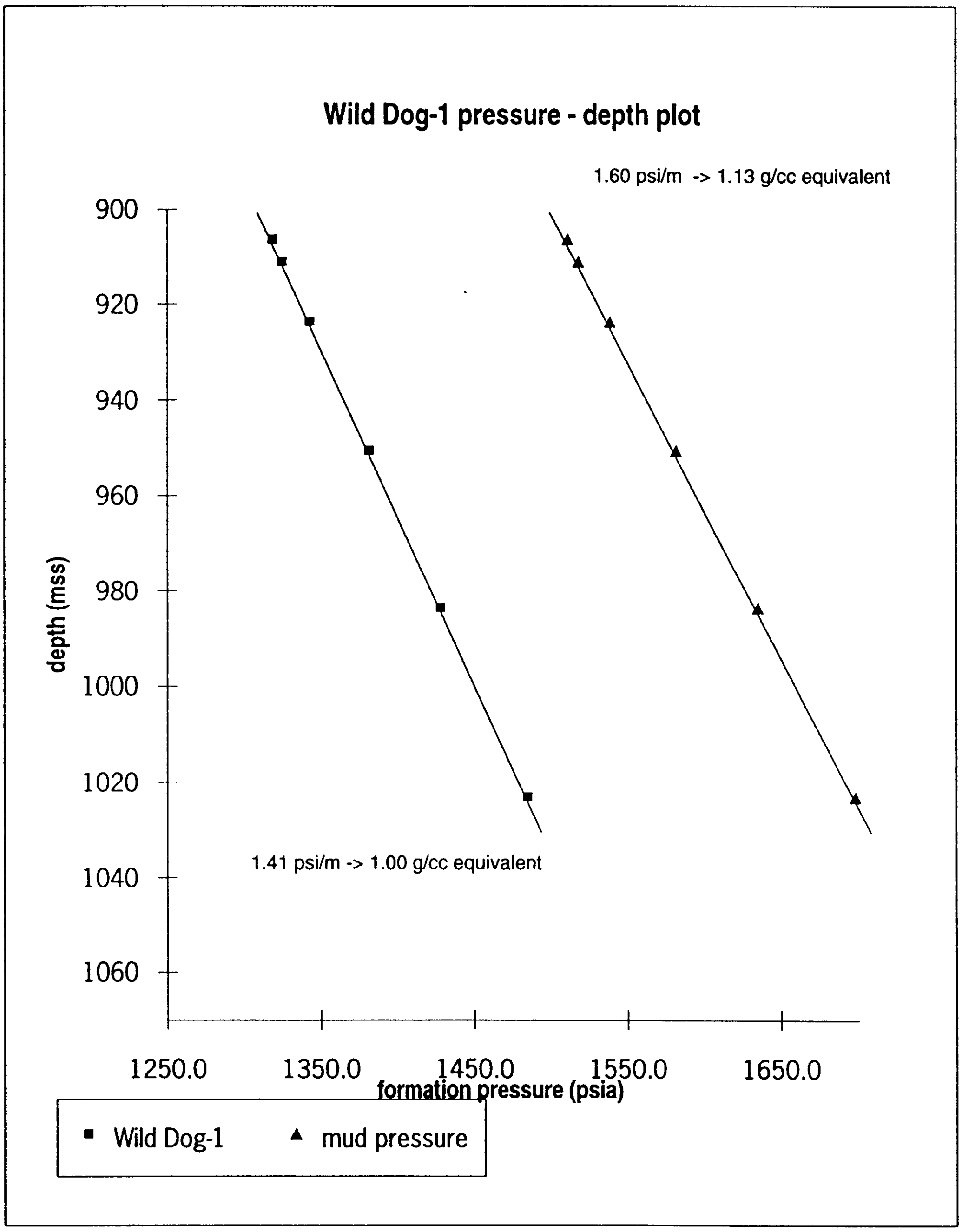
Author: EEP/3	Report No.: SDA 1085	Date: FEBRUARY 1993	Drawing No.: 28301

WILD DOG-1 SFT DATA

RT = 22.3 m above msl   crystal gauge used

m RT	mss	form. pressure psia	form. pressure Bar	mud pressure psia	mud pressure Bar	calc. perm mDarcy
928.7	906.4	1318.8	90.93	1511	104.18	728
933.5	911.2	1324.9	91.35	1518	104.66	1,500
946.0	923.7	1342.8	92.58	1539	106.11	971
973.0	950.7	1381.2	95.23	1582	109.08	1,082
1006.0	983.7	1428.0	98.46	1635	112.73	720
1045.5	1023.2	1484.9	102.38	1698	117.07	1,162

Note: 1 Bar = 100 kPa = 14.504 psi



SHELL AUSTRALIA UPSTREAM OIL & NATURAL GAS

TORQUAY SUB-BASIN

PRESSURE–DEPTH PLOT, WILD DOG–1

Author: EEP/3 | Report No.: SDA 1085 | Date: FEBRUARY 1993 | Drawing No.: 28302

Figure C4

PE600582

This is an enclosure indicator page.
The enclosure PE600582 is enclosed within the container PE900190 at this location in this document.

The enclosure PE600582 has the following characteristics:

ITEM_BARCODE = PE600582
CONTAINER_BARCODE = PE900190
NAME = Petrophysical Data Log, Figure C5
BASIN = Otway
PERMIT = VIC/P28
TYPE = WELL
SUBTYPE = WELL_LOG
DESCRIPTION = Petrophysical Data Log, Figure C5, WCR Vol 2, Appendix B
REMARKS =
DATE_CREATED = 28/02/93
DATE_RECEIVED = *
W_NO = W1074
WELL_NAME = Wild Dog 1
CONTRACTOR = SHELL DEVELOPMENT (AUSTRALIA) PTY LTD
CLIENT_OP_CO = SHELL DEVELOPMENT (AUSTRALIA) PTY LTD

(Inserted by DNRE - Vic Govt Mines Dept)

PE600582

PE600582

APPENDIX D

SEAL CAPACITY STUDY

17 March 1993

The Shell Company of Australia Ltd
1 Spring Street
MELBOURNE VIC 3000

Attention: Mark Trupp

REPORT: FF/203

CLIENT REFERENCE:	ITC 48345
MATERIAL:	Sidewall Core
LOCALITY:	Wild Dog - 1
WORK REQUIRED:	Special Core Analysis

Please direct technical enquiries regarding this work to the signatory below under whose supervision the work was carried out.

ROBERT D EAST
Technical Services Manager
on behalf of Amdel Core Services Pty Ltd

Adelaide Office: P.O. Box 109, Eastwood, SA 5063 Australia.
~~Telephone: (08) 372 2834 Facsimile: (08) 372 2861~~
Telephone: (08) 379 9888 Facsimile: (08) 379 9288
Amdel Core Services Pty Limited
(Incorporated in South Australia)
ACN: 008 273 005

CONTENTS

1. INTRODUCTION

One sidewall core plug from Wild Dog -1 was received from Shell for determination of seal capacity.

2. CAPILLARY PRESSURE - Mercury Injection (Air-Mercury)

The mercury injection apparatus used is a semi-automatic Micromeritics Autopore 9200 which operates up to a pressure of 60,000 psia, and can measure intrusions as small as 0.0001 cm^3 per gram of sample. This instrument was chosen for these analyses as opposed to the standard mercury pump because of its greater accuracy and ability to reach very high pressures.

The Micromeritics Autopore records mercury intrusion by measuring the capacitance change between the capillary of mercury contained in the penetrometer and an outer metal sheath as mercury invades the sample. For pressures up to 24 psia, air pressure is used. Hydraulic oil is used to achieve the higher pressures. No volume corrections for pressure effects are made, since below 24 psia they are negligible, whilst for higher pressures, the penetrometer experiences equal external and internal pressures and mercury compression is offset by penetrometer compression.

The sample was dried in a vacuum oven at temperatures not exceeding 90°C and placed into calibrated glass penetrometers. These consist of a sample chamber and attached precision bore capillary. The sample sizes are selected so that the estimated pore volume is less than the capillary volume.

Once the sample is placed into the penetrometer a vacuum is applied until less than 50 micro-metres of mercury has been achieved. Mercury is then introduced into the penetrometer and the run commences along pre-defined pressure points on a logarithmic scale. After equilibration at each pressure point a capacitance reading was taken which was then converted into an equivalent intrusion volume.

3. THEORY

In the laboratory tests we are examining seals on a microscale. Macro properties such as faulting, fracturing, thickness and lateral variation cannot be accounted for.

Watts (1987) defined two types of seal - those that fail by capillary leakage (membrane seals) and those which have capillary entry pressures so high that seal failure preferentially occurs by fracturing and/or wedging open of faults (hydraulic seals).

Stratigraphic units identified as having the capillary properties of seals need to be examined carefully prior to sampling for lithological uniformity. If the unit changes laterally, then it is important to measure the capillary properties of the "weak link", ie the least effective seal.

Thickness of the seal should also be considered. A unit containing a thin shale (a few inches thick) can theoretically trap a large column height of hydrocarbons, but the chance that the unit will not contain fractures or some other migration pathways is slim.

Ductility is also an important general consideration. Brittle rocks will tend to fracture rather than flow under regional stress. The following table from Downey (1984) lists lithologies in order of ductility:

- Salt
- Anhydrite
- Kerogen Rich Shales
- Clay Shales
- Silty Shales
- Carbonate Mudstone
- Cherts

4. DISCUSSION OF RESULTS

From the data, mercury porosity can be calculated using the following equation:

$$\text{Porosity} = \frac{\text{Total Intrusion}}{\text{Bulk Volume}} \times 100\%$$

For Sample SWC 16 we have:

$$\text{Porosity} = \frac{0.509}{2.005} \times 100\%$$

$$= 25.4\%$$

For Column Height Determination:

If you examine the pressure versus intrusion curve and draw a line from the straight-line portion of the curve to the X-axis you obtain the breakthrough pressure. The breakthrough pressure refers to the pressure at which a continuous filament of mercury, oil or gas forms in that sample.

The following values were obtained using this method:

Sample No	Breakthrough Pressure psia
SWC 16	620

The capillary breakthrough pressure for a hydrocarbon system, at subsurface conditions can be calculated using the following equation:-

$$Pc_{h/w} = \frac{\gamma_{h/w} \times \cos\theta_{h/w}}{\gamma_{m/a} \times \cos\theta_{m/a}} \times Pc_{m/a}$$

where : $Pc_{h/w}$ = breakthrough pressure for hydrocarbon/water system

$Pc_{m/a}$ = breakthrough pressure for mercury/air system (= P from above equation)

$\gamma_{h/w}$ = subsurface interfacial tension of hydrocarbon/water

$\gamma_{m/a}$ = interfacial tension of mercury/air

$\theta_{h/w}$ = contact angle of hydrocarbon/water system

$\theta_{m/a}$ = contact angle of mercury/air

To convert to an oil - water system :

$$Pc_{m/a} = 620$$

$$\gamma_{m/a} = 484 \text{ dynes/cm}$$

$$\cos\theta_{m/a} = -0.766$$

$$\gamma_{h/w} \approx 30 \text{ dynes/cm}$$

$$\cos\theta_{h/w} \approx 0.866$$

which for the sample tested gives a $Pc_{h/w}$ of 43.4 psi.

The column height of hydrocarbons that this seal could support can be determined from the following equation (assuming standard values for the water/oil gradients).

$$\text{Column height} = \frac{Pc_{h/w}}{\rho_w - \rho_o}$$

where: ρ_w = water gradient (0.44 psi/ft)

ρ_o = oil gradient (0.33 psi/ft)

$$\therefore \text{column height} = \frac{43.4}{0.11} = 395 \text{ feet}$$

5. INTERPRETATION

Early points on the pore throat diameter versus incremental intrusion curve are possibly due to mercury filling microfractures induced during the sampling process. The plateau of the capillary pressure curve is not pronounced making determination of the breakthrough pressure somewhat subjective, despite this comment we feel the data is reliable within error limits of plus or minus 20%.

6. REFERENCES

Watts, N.L., 1987, Theoretical aspects of cap-rock and Fault Seals for Two Phase Hydrocarbon Columns: Marine and Petroleum Geology, Vol. 4 pp. 274-307.

Downey, M.W., 1984, Evaluating seals for Hydrocarbon Accumulations: AAPG bulletin, Vol.68, pp. 1752-1763.

Other References

Berg, R.R., 1975, Capillary Pressures in Stratigraphic Traps: AAPG bulletin, Vol. 59 pp. 939-956.

England, W.A., Mackenzie, A.S., et al 1987, The Movement and Entrapment of Petroleum Fluids in The Subsurface: Jrnl. Geol. Soc. Lon., Vol. 63, pp. 327-347.

Scholwalter, T.T., 1979, Mechanics of Secondary Hydrocarbon Migration and Entrapment: AAPG bulletin, Vol. 63, pp. 723-760.

AAPG. Treatise of Petroleum reprint series, No.7. 1988, Traps and Seals II, Stratigraphic/Capillary traps:

TABLE 1

MERCURY INJECTION DATA

TABLE 1

MERCURY INJECTION DATA

Company The Shell Company of Australia
Well Wild Dog #1

Sample SWC 16
Depth 926m
Porosity .254 fraction
Total Intrusion .509cc

Pressure psia	Cumulative Intrusion ml	Cumulative Intrusion %	Incremental Intrusion %	Pore Diameter microns
2.47	0	0	0	86.63968
2.89	0.003	0.589391	0.589391	74.04844
3.45	0.007	1.375246	0.785855	62.02899
4.08	0.009	1.768173	0.392927	52.45098
4.8	0.014	2.750491	0.982318	44.58333
5.71	0.018	3.536346	0.785855	37.47811
6.76	0.022	4.3222	0.785855	31.6568
8.03	0.026	5.108055	0.785855	26.65006
9.52	0.029	5.697446	0.589391	22.47899
11.31	0.034	6.679764	0.982318	18.92131
13.44	0.038	7.465619	0.785855	15.92262
15.96	0.041	8.05501	0.589391	13.40852
18.95	0.045	8.840864	0.785855	11.29288
21.93	0.048	9.430255	0.589391	9.758322
24.92	0.051	10.01965	0.589391	8.58748
32.66	0.053	10.41257	0.392927	6.552358
38.91	0.055	10.8055	0.392927	5.499871
45.86	0.057	11.19843	0.392927	4.666376
54.6	0.06	11.78782	0.589391	3.919414
64.86	0.063	12.37721	0.589391	3.299414
76.88	0.067	13.16306	0.785855	2.783559
91.25	0.069	13.55599	0.392927	2.345205
107.73	0.072	14.14538	0.589391	1.986448
127.29	0.075	14.73477	0.589391	1.6812
150.63	0.078	15.32417	0.589391	1.4207
179.12	0.081	15.91356	0.589391	1.19473
213.66	0.085	16.69941	0.785855	1.001591
253.9	0.09	17.68173	0.982318	0.842852
290.56	0.094	18.46758	0.785855	0.736509
359.19	0.101	19.84283	1.375246	0.595785
424.92	0.108	21.21807	1.375246	0.503624
507.85	0.116	22.78978	1.571709	0.421384
603.32	0.124	24.36149	1.571709	0.354704
715.66	0.134	26.32613	1.964637	0.299025
849.7	0.146	28.68369	2.357564	0.251854
1011.38	0.159	31.23772	2.554028	0.211592
1202	0.172	33.79175	2.554028	0.178037
1429.41	0.188	36.93517	3.143418	0.149712
1701.51	0.205	40.27505	3.339882	0.125771

TABLE 1

2021.82	0.224	44.00786	3.732809	0.105845
2394.69	0.245	48.1336	4.125737	0.089364
2855.63	0.272	53.43811	5.304519	0.07494
3421.2	0.304	59.72495	6.286837	0.062551
4041.58	0.335	65.81532	6.090373	0.05295
4838.39	0.367	72.10216	6.286837	0.04423
5752.1	0.394	77.40668	5.304519	0.037204
6842.35	0.415	81.53242	4.125737	0.031276
8135.38	0.433	85.06876	3.536346	0.026305
9669.37	0.448	88.01572	2.946955	0.022132
11492.01	0.459	90.17682	2.1611	0.018622
13682.06	0.469	92.14145	1.964637	0.015641
16270.51	0.477	93.71316	1.571709	0.013153
19364.72	0.485	95.28487	1.571709	0.011051
23043.41	0.492	96.66012	1.375246	0.009287
27392.48	0.497	97.64244	0.982318	0.007812
32576.54	0.501	98.42829	0.785855	0.006569
38698.16	0.505	99.21415	0.785855	0.00553
46077.02	0.509	100	0.785855	0.004644

FIGURE 1

PRESSURE VS CUMULATIVE INTRUSION

FIGURE 1

HF201.XLC

Pressure vs Cumulative Intrusion

Wild Dog #1 Sample: SWC 16

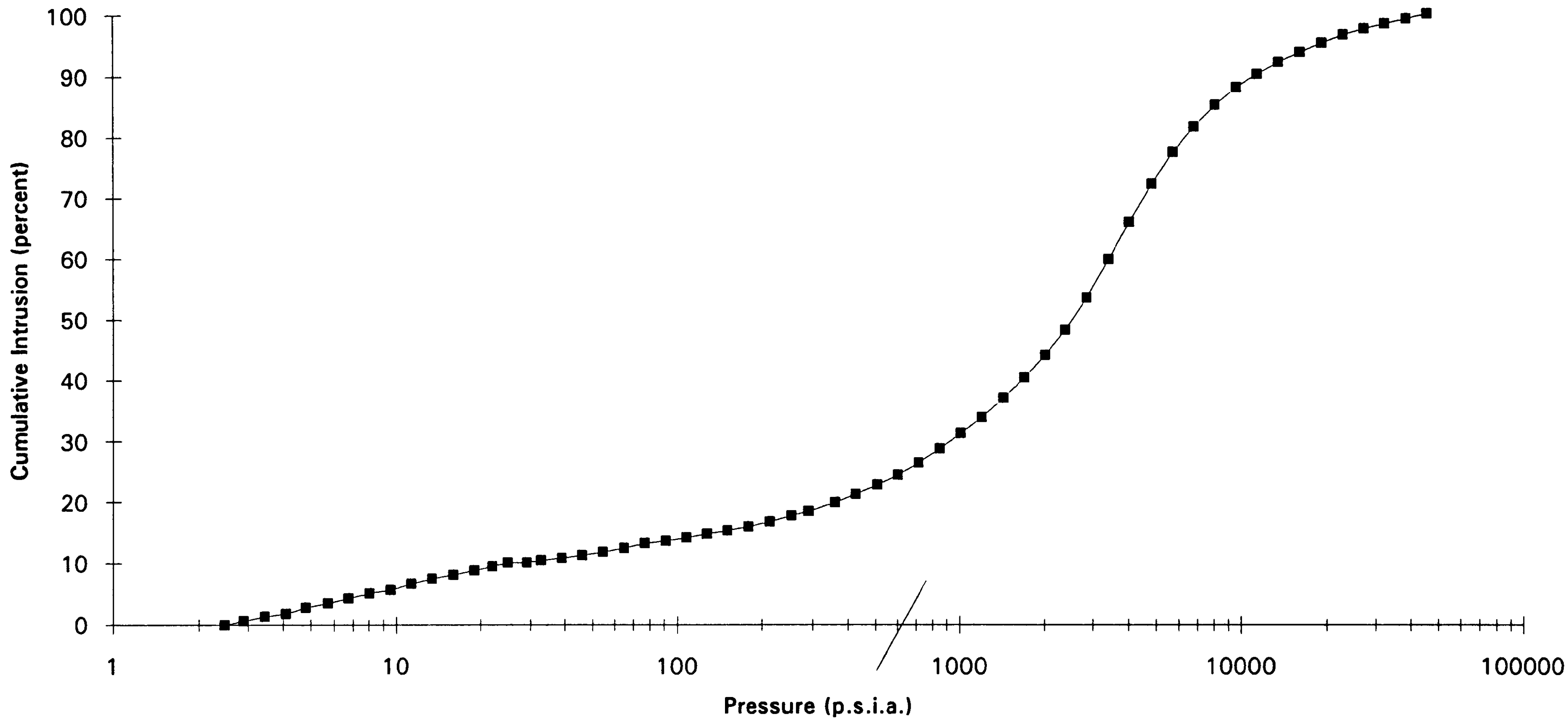
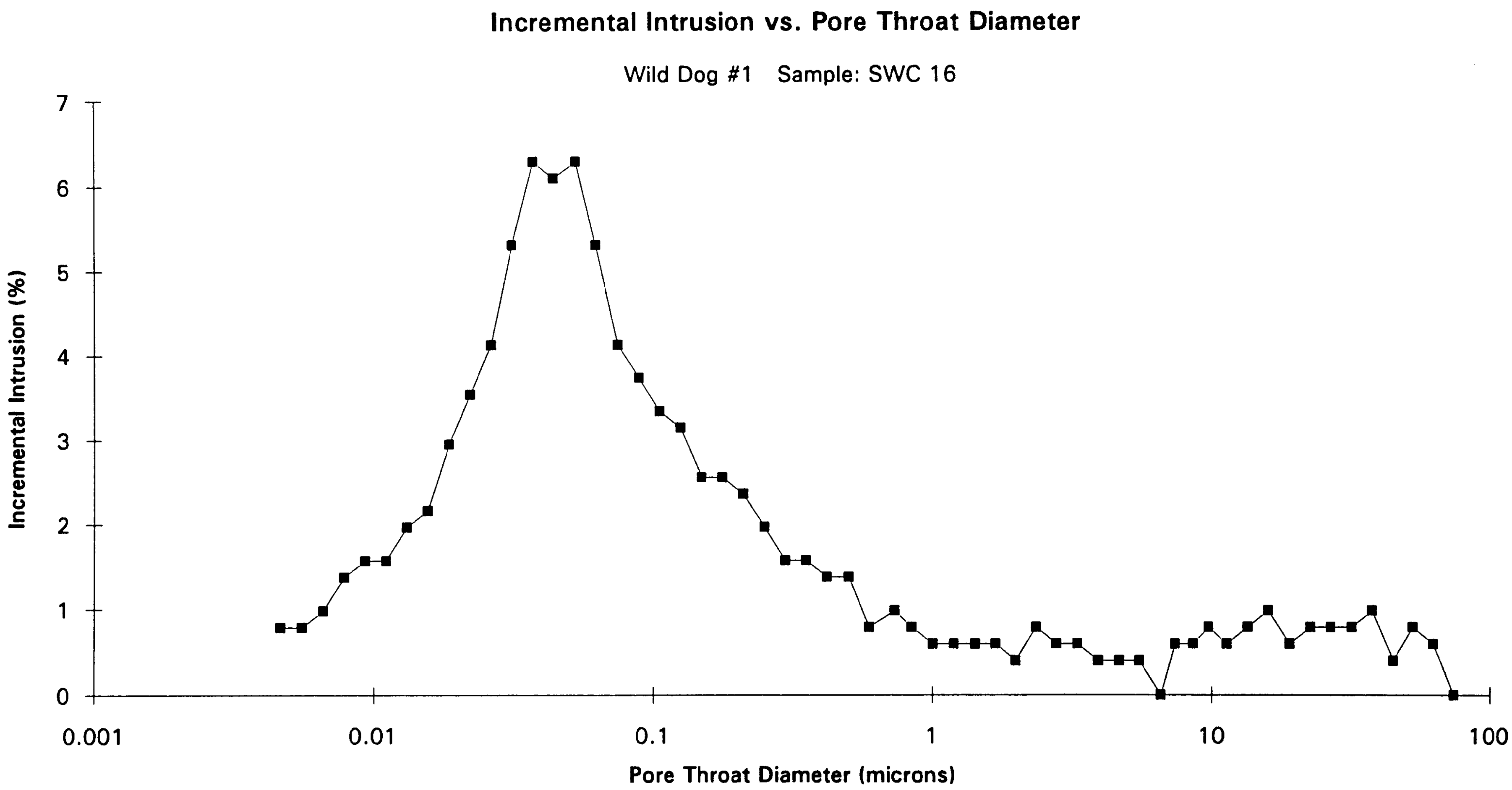


FIGURE 2

INCREMENTAL INTRUSION VS PORE THROAT DIAMETER

FIGURE 2

HF201I.XLC



PE901813
This is an enclosure indicator page.
The enclosure PE901813 is enclosure within the
container PE900190 at this location in this document.

The enclosure PE901813 has the following characteristics:

ITEM_BARCODE	=	PE901813
CONT AINER_BARCODE	=	PE900190
NAME	=	Wild Dog 1 Seismic Line OS90A-13
BASIN	=	OTWAY
PERMIT	=	VIC/P28
TYPE	=	SEISMIC
SUBTYPE	=	SECTION
DESCRIPTION	=	Wild Dog 1 Seismic Line OS90A-13
DATE_CREATED	=	31/08/1993
DATE_RECEIVED	=	
W_NO	=	W1074
WELL_NAME	=	Wild Dog 1
CONTRATOR	=	SHELL DEVELOPMENT (AUSTRALIA) PTY LTD
CLIENT_OP_CO	=	SHELL DEVELOPMENT (AUSTRALIA) PTY LTD

PE600127

This is an enclosure indicator page.
The enclosure PE600127 is enclosed within the container PE900190 at this location in this document.

The enclosure PE600127 has the following characteristics:

ITEM_BARCODE = PE600127
CONTAINER_BARCODE = PE900190
NAME = Wild Dog 1 Composite Well Log, WCR Vol 2, Enclosure 1
BASIN = Otway
PERMIT = VIC/P28
TYPE = WELL
SUBTYPE = COMPOSITE_LOG
DESCRIPTION = Wild Dog 1 Composite Well Log, WCR Vol 2, Enclosure 1
REMARKS =
DATE_CREATED = 30/09/93
DATE_RECEIVED = 4/11/93
W_NO = W1074
WELL_NAME = Wild Dog 1
CONTRACTOR = SHELL DEVELOPMENT (AUSTRALIA) PTY LTD
CLIENT_OP_CO = SHELL DEVELOPMENT (AUSTRALIA) PTY LTD

(Inserted by DNRE - Vic Govt Mines Dept)

PE600128

This is an enclosure indicator page.
The enclosure PE600128 is enclosed within the container PE900190 at this location in this document.

The enclosure PE600128 has the following characteristics:

ITEM_BARCODE = PE600128
CONTAINER_BARCODE = PE900190
NAME = Wild Dog 1 Synthetic Seismogram, WCR Vol 2, Enclosure 2
BASIN = Otway
PERMIT = VIC/P28
TYPE = WELL
SUBTYPE = SYNTH_SEISMOGRAPH
DESCRIPTION = Wild Dog 1 Synthetic Seismogram, WCR Vol 2, Enclosure 2
REMARKS =
DATE_CREATED = 31/08/93
DATE_RECEIVED = 4/11/93
W_NO = W1074
WELL_NAME = Wild Dog 1
CONTRACTOR = SHELL DEVELOPMENT (AUSTRALIA) PTY LTD
CLIENT_OP_CO = SHELL DEVELOPMENT (AUSTRALIA) PTY LTD

(Inserted by DNRE - Vic Govt Mines Dept)