APPENDIX-9

NALANGIL-1

PALNOLOGY

W1035

PALYNOLOGICAL ANALYSIS, NALANGIL-1

PEP 100, OTWAY BASIN

by

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INTRODUCTION

Eleven sidewall cores, representing the interval 107.5m to 345.0m in Nalangil-1 were processed and examined for spore-pollen and dinoflagellates.

Yields and preservation are adequate to high, allowing most samples to be dated with confidence. The exception is the interval between 261.0-288.5m where either or both downhole caving and reworking has resulted in mixed Eocene and Mesozoic palynofloras.

Palynological determinations and interpreted lithological units are summarized below. Interpretative and basic data are given in Tables 1 and 2 respectively. Estimated TAI values of and dominant kerogen types present in each sample are given in Table 3. The stratigraphic distribution of all species is recorded in the attached range chart. Electric log data were unavailable.

SUMMARY

AGE	UNIT	ZONE	DEPTH RANGE (m)	ENVIRONMENT
Early Miocene?	HEYTESBURY GP	T. bellus	107.5	restricted marine
Oligocene - Early Miocene	"	P. tuberculatus	163.0	"
Late Eocene	NIRRANDA GP	Middle N. asperus	202.0 - 236.0	marginal marine
Middle Eocene?	NIRRANDA GP?	Lower N. asperus?	261.0 - 288.5	fluvio-lacustrine?
- - - - -	- - - - -	- UNCONFORMITY	- - - - -	- - - - -
Lower Albian	EUMERALLA FM	C. striatus Zone	291.0 - 245.0	lacustrine

TD 363.0m

GEOLOGICAL COMMENTS

1. Lower Albian, C. striatus Zone lacustrine sediments which locally form the top of the Eumeralla Formation in Nalangil-1 are overlain sequentially by (a) Middle Eocene, marginal marine facies provisionally assigned to the Nirranda Group and (b) Late Oligocene-Early Miocene, restricted marine facies provisionally assigned to the Heytesbury Group. There is no evidence that the well intersected Late Cretaceous or Paleocene sediments. The sample spacing is too coarse to verify the existence or not of any unconformity between the Nirranda and Heytesbury Group facies.

2. The composition of the Tertiary palynofloras more closely resembles those found in the central west Murray Basin than in basins to the south-east. Based on time-range data from the Murray Basin, it is possible that:

   (a) The T. bellus Zone sample at 107.5m is Late Oligocene-late Early Miocene in age, i.e. will correlate with P. tuberculatus Zone units elsewhere (see Biostratigraphy Section).

   (b) The Middle N. asperus Zone sample at 202.0m may be as young as latest Eocene-Early Oligocene, Upper N. asperus Zone.

3. The basal 30m of the Nirranda Group are likely to be Lower N. asperus Zone. This (non-marine?) unit, between 261.0-288.5m, appears to be part of a claystone facies, largely formed of reworked Eumeralla Formation and Permo -Triassic sediments and therefore lithologically similar to the underlying Eumeralla Formation at and below 291.0m.

   A less likely hypothesis is that the Early Cretaceous palynomorphs in this interval are in situ and therefore the top of the Eumeralla Formation occurs between 236.0-261.0m.

4. The Lower Albian, C. striatus Zone date for the SWC at 291.0m agrees well with age-determinations for the top of the Eumeralla Formation in the onshore Otway Basin, e.g. Anglesea-1 and Hindhaugh Creek-1 in the Torquay Sub-basin.

5. TAI values of 2+ to 3- indicate that sediments between

163.0-345.0m are within the mature phase of liquid hydrocarbon generation. Whilst these estimates need to be verified using vitrinite reflectance, it is certain that TAI values do not reach the over-mature values [3+ to 4] found at similar depths [910 ft.] in e.g. Hindhaugh Creek-1. The observation that TAI values reach a maximum at 261.0m [3- to 3] might imply local heating through e.g. hydrothermal activity. Kerogen extracts throughout are dominated by biodegraded structured and unstructured terrestrial material.

6. The well terminated within the Eumeralla Formation (C. striatus Zone sediments).

PALAEOENVIRONMENTS

1. The relative abundance of marine dinoflagellates and spore-pollen indicate a progressive strengthening of the marine influence at Nalangil-1 from the Late Eocene to the Early Miocene. At this time restricted marine conditions prevailed at the wellsite.

2. It is unclear whether the SWC at 163.0m represents (i) a Middle N. asperus Zone marginal marine facies that has been bioturbated in situ during an Late Oligocene-Early Miocene highstand or (ii) a P. tuberculatus Zone restricted marine facies derived from reworking of Late Eocene and Early Cretaceous sediments. Both scenarios imply relatively low rates of sedimentation.

3. There is no definite evidence of any marine influence during the deposition of the claystone unit between 261.0-288.5m. Conversely algal cysts derived from the underlying Eumeralla Formation are frequent (see below).

4. Frequent occurrences of the algal cyst Spheripollenites psilatus demonstrate that the depositional environment during the C. striatus Zone was lacustrine. Low but persistent numbers of the acritarchs Micrhystridium and Veryhachium imply a brackish influence, probably more due to an influx of mineralized groundwater from volcanic activity than to dry climates.

BIOSTRATIGRAPHY

Zone and age-determinations have been made using criteria proposed by Stover & Partridge (1973), Helby et al. (1987), Macphail & Truswell (1989) and unpublished observations made on Gippsland, Bass and Otway Basin wells. Zone names have not been altered to take account of nomenclatural changes to nominate species such as Triporopollenites bellus [now Canthiumidites bellus: see Mildenhall & Pocknall, 1989].

It is noted that spore-pollen criteria used to define the Late Eocene-Early Miocene Middle N. asperus, P. tuberculatus and T. bellus Zones are not always reliable away from the Gippsland Basin. This need for caution is emphasized by the occurrence in Nalangil-1 of a number of spore-pollen species previously recorded in South-east Australia only in the Murray Basin.

For example, Anacolosidites sectus and Tricolpites thomasii are diagnostic of Middle N. asperus Zone sediments in the Gippsland Basin but range upwards into Early Oligocene, Upper N. asperus Zone strata in central west Murray Basin boreholes (see Macphail & Truswell, ibid) and it is possible that the extended time distributions apply to wells in the northwestern sector of PEP 100.

Similarly, the late Early Miocene-Late Miocene index species of the T. bellus Zone, Canthiumidites (Triporopollenites) bellus, has been recorded in association with Late Oligocene forams. An analogous situation is possible in Nalangil-1 (see below). The problem is compounded by the fact that index species such as Canthiumidites bellus are uncommon, often small and therefore usually difficult to locate in very rich or poorly preserved palynofloras. As a result, picks for the T. bellus/P. tuberculatus Zone boundary are often imprecise.

Dinoflagellates may provide an alternative method (see Partridge, 1976) but to date the relevant, independently dated formations in the Gippsland Basin have not closely sampled or all the species systematically recorded. Again some distributions appear to be time-transgressive, e.g. Corrudinium incompositum, which in the Gippsland Basin is an index species for the Middle N. asperus Zone, ranges into the Upper N. asperus Zone in the Murray Basin. An unexplained specimen occurs in P. tuberculatus Zone sediments in the PEP 100 well, Ingleby-1 (Macphail, 1991).

Crybelosporites striatus Zone 291.0-345.0m Early Albian

Samples within this interval are dominated by long-ranging Mesozoic spores and gymnosperm species, in particular frequent to abundant Cyathidites australis/minor, Cicatricosisporites australiensis and Baculatisporites comaumensis. Most contain low numbers of caved Tertiary angiosperm pollen as well as reworked Permo-Triassic types. All samples yielded lacustrine algal cysts, in particular Spheripollenites psilatus and the acritarchs Micrhystridium and Veryhachium.

The lowermost sample analysed [SWC 1 at 345.0m] yielded low numbers of the zone index species Crybelosporites striatus and therefore is no older than C. striatus Zone. Cyclosporites hughesii is present but, unusual for this zone, Cicatricosisporites australiensis is uncommon.

Conversely both C. striatus and C. australiensis are common in the very rich and diverse palynoflora at 311.5m. Associated Early Cretaceous spores including Dictyotosporites filosus, D. speciosus, frequent Foraminisporis asymmetricus and F. wonthaggiensis, Pilosisporites notensis, P. parvus and Trilobosporites trioreticulosus.

The upper boundary is placed at 291.0m, the highest sample containing an in situ Early Cretaceous palynoflora which includes Crybelosporites striatus. The rare related species Crybelosporites punctatus occurs in this diverse assemblage.

Lower N. asperus Zone 261.0-288.5m Middle Eocene

Palynofloras in this interval are a mixture of long-ranging Eocene and Mesozoic species, the relative proportions of which vary from Eocene-dominant at 288.5m to Mesozoic-dominant at 261.0m. The Early Cretaceous component lacks the high diversity of palynofloras at and below 291.0m and are assumed to be reworked.

The interval is provisionally dated as Lower N. asperus Zone, based on Nothofagidites falcatus at 283.5m and 288.5m and the absence of Middle N. asperus Zone indicators. Alternatively, if the Tertiary component is caved, then the interval is C. paradoxa/C. striatus Zone, based on Crybelosporites hughesii at 283.5m.

Apart from one (caved?) specimen of Spiniferites at 288.5m and an unexplained dinocyst resembling the Early Cretaceous species Prolixosphaeridium parvispinum at 283.5m, marine dinoflagellates are absent. Conversely algal cysts and acritarchs characteristic of the Eumeralla Formation palynofloras are frequent.

Middle Nothofagidites asperus Zone 202.0-236.0m Late Eocene

The lower boundary of this zone is tightly defined by the association of Anacolosidites sectus, Tricolpites thomasii, Proteacidites incurvatus, P. leightonii and P. reticulatus at 236.0m. Dinoflagellates present include Corrudinium corrugatum, Hystrichokolpoma rigaude, Rhombodinium glabrum and Schematophora speciosa.

The palynoflora is extremely diverse and includes a number of rare species or uncommon records for this zone, e.g. Asseretospora sp. of Foster 1982, Cyperaceaepollis neogenicus, Dicolpopollis cf metroxylonoides, Proteacidites tuberculiformis, Ricciaesporites kawaraensis and Tricolpites trioblatus.

The upper boundary is defined by the highest in situ records of Anacolosidites sectus, Proteacidites confragosus, P. reticulatus and Tricolpites thomasii. The dinocyst flora includes the (Gippsland Basin) Middle N. asperus Zone index species Corrudinium incompositum. An Early Oligocene, Upper N. asperus Zone age is possible although unlikely since the assemblage lacks definite Oligocene-Miocene indicators such as Acaciapollenites miocenicus and Corsinipollenites.

Proteacidites tuberculatus Zone 163.0m Oligocene-late Early Miocene

One sample is provisionally assigned to this zone, based on occurrences of the zone index species Cyatheacidites annulatus, Chenopodipollis chenopodiaceoides, Foveotriletes lacunosus, Tubulifloridites antipoda and multiple specimens of the Oligocene dinocyst Protoellipsodinium simplex.

The palynoflora is a complex one and contains in addition to longer-ranging Eocene-Miocene species:

(a) Reworked Albian spores, including Foraminisporis asymmetricus and Trilobosporites trioreticulosus.

(b) Middle N. asperus Zone pollen, including the zone index species Triorites magnificus as well as other species restricted to, or typically ranging no higher than, the Middle N. asperus Zone, e.g. Beaupreadites verrucosus, Dicotetradites meridianus, Proteacidites crassus, P. reticulatus and Tricolpites thomasii and the dinocyst Apteodinium australiense. All are assumed to be reworked.

(c) The Plio-Pleistocene spore Cingulatisporites bifurcatus.

(d) The rare species Diporites aspis, Proteacidites isopogiformis, Psilodiporites (Alyxia) sp. and Perisyncolporites pokornyi. The last represent the first record outside the Murray Basin of this tropical species in southern Australia.

Triporopollenites bellus Zone 107.5m Early Miocene?

The sample at 107.5m yielded a single specimen of the zone index species Canthiumidites (Triporopollenites) bellus and, in accordance with current zone concepts, must be assigned to this zone.

Nevertheless it is noted that the palynoflora is more typical of the Late Oligocene-late Early Miocene, P. tuberculatus Zone based on (i) dominance by Nothofagidites emarcidus-heterus, Araucariacites australis, Haloragacidites harrisii and Spiniferites spp and (ii) occurrences of species not known to range above the P. tuberculatus Zone, viz. Beaupreadites verrucosus and Proteacidites grandis.

On present indications it is probable that the specimen of Canthiumidites bellus represents an anomalously early occurrence and therefore that the sample is older than late Early Miocene. Cyatheacidites annulatus and Cyathidites subtilis demonstrate that the sample is no older than P. tuberculatus Zone.

Rare species present in the sample include Banksieaeidites sp. cf Banksia serratifolia, Droseraceae, Guettardidites sp., Haloragacidites haloragoides, Malvacearumpollis sp., Perisyncolporites pokornyi, Polypodiaceoisporites sp. cf P. retirugatus, Psilodiporites (Alyxia) sp. and Tetraporites sp. All are characteristic of Oligo-Miocene floras in the Murray basin (compare Macphail & Truswell, 1989).

REFERENCES

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

MACPHAIL, M.K. & TRUSWELL, E.M. (1989). Palynostratigraphy of the central west Murray Basin. BMR Journal Australian Geology and Geophysics **11**: 301-331.

MACPHAIL, M.K. (1991). Palynological analysis of Ingleby-1, PEP 100, Otway Basin. Gas & Fuel N/L. Palaeontological Report, 15 February.

MILDENHALL, D.C. & POCKNALL, D.T. (1989). Miocene - Pleistocene spores and pollen from Central Otago, South Island, New Zealand. New Zealand Geological Survey Palaeontological Bulletin **59**: 1-128.

PARTRIDGE, A.D. (1976). The geological expression of eustacy in the Early Tertiary of the Gippsland Basin. APEA Journal 16 : 73-79.

STOVER, L.E. & PARTRIDGE, A.D. (1973). Tertiary and Late Cretaceous spores and pollen from the Gippsland Basin, Southeastern Australia. Proceedings 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
23	107.5	T. bellus	-	1	Early occurrence?
22	163.0	P. tuberc.	-	2	Mixed P. tuberc. & Mid. N. asperus spp
21	202.0	M. N. asp.	C. incom.	1	No younger than Up. N. asperus Zone —
20	236.0	M. N. asp.	-	1	Corrud. corrugatum
10	261.0	L. N. asp.	-	2	Mixed Eocene, Early Cretaceous spp.
09	283.5	Indeterminate		-	As for SWC 10
07	288.5	L. N. asp.	-	2	As for SWC 10
06	291.0	C. striat.	-	1	No older than this zone
05	296.5	C. striatus		2	
03	311.5	C. striatus		1	C. striatus freq.
01	345.0	C. striatus		1	C. striatus

TABLE 2: **BASIC DATA**

SWC	DEPTH (m)	YIELD S-P	YIELD DINO	DIVERSITY S-P	DIVERSITY DINO	PRES.	LITH.*
23	107.5	v. high	med.	high	med.	good	calc. clyst.
22	163.0	v. high	med.	high	med.	good	calc. clyst.
21	202.0	low	low	high	med.	good	clyst. slty, calc.
20	236.0	v. high	low	high	med.	good	clyst. sandy
10	261.0	med.	-	med.	-	mod.	clyst.
09	283.5	med.	-	med.	-	good	clyst.
07	288.5	low	low	med.	low	poor	clyst./sst.
06	291.0	high	-	high	-	good	clyst. green
05	296.5	v. high	-	low	-	good	clyst., slty
03	311.5	v. high	-	high	-	good	clyst., slty
01	345.0	med.	-	med.	-	good	clyst., slty

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

TABLE 3: **BRIEF KEROGEN DESCRIPTIONS**

SWC	DEPTH (m)	EST. TAI*	DOMINANT KEROGEN TYPE(S)#
23	107.5	2- to 2	struct. & unstruct. amorphous
22	163.0	2+ to 3-	struct. & unstruct. amorphous
21	202.0	2- to 2+	struct. & unstruct. amorphous
20	236.0	2+ to 3-	structured amorphous
10	261.0	3- to 3	structured amorphous
09	283.5	3-	struct. amorph. (semi-opaque)
07	288.5	2+ to 3-	struct. & unstruct. amorphous
06	291.0	2+ to 3-	structured amorphous
05	296.5	3-	struct. & unstruct. amorphous
03	311.5	3- to 3	struct. & unstruct. amorphous
01	345.0	2+ to 3-	struct. & unstruct. amorphous

* TAI estimates based on the chart of "Spore-pollen exine coloration with geothermal maturation" published as Colour Plate 1 in Traverse A. (1988) "Palaeo-palynology", Unwin Hyman, Boston. In this (standard) scale, TAI values of 1 to 2 are immature, TAI values of 2+ to 3 represent the mature phase of liquid hydrocarbon generation and TAI values of 3+ to 5 represent dry gas or barren.

\# Kerogen types are based on the classification of organic matter in clastic systems published by Hart, G.F. (1986) Palynology **10**: 1-23. The majority of samples yielded significant amounts of fines of indeterminate origin.