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APPENDIX

PALYNOLOGICAL ANALYSIS OF BIGNOSE-1
(GIPPSLAND BASIN, PERMIT VIC/P19)

by
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1. SUMMARY

Depth (m)	Dinoflagellate Zones	Spore Pollen Zones	Age
2525-2592	A. HYPERACANTHUM	Lower M.DIVERSUS	Late PALEOCENE/ Early EOCENE
2611.5	(Paleocene palynomorphs reworked into Early Eocene)		
2667-2760	T.EVITTII	Lower L.BALMEI	Early PALEOCENE
2806m	I.DRUGGII	T.LONGUS	Late MAASTRICHTIAN
2816-3390	-	T.LONGUS	MAASTRICHTIAN
3470-3993 (TD @ 3996)	-	T.LILLIEI	CAMPANIAN

SPORE COLOUR/DEGREE OF ORGANIC MATURITY (DOM)/SOURCE ROCK QUALITY

Transmitted (white) light: from pale yellow (2525m) to yellow or light brown (3993m).
Incident UV light: from light yellow to yellow/orange
DOM: from immature at 2525m to early mature at TD
Source rock quality: 2525-2760m: poor; 2806-3993m: fair to very good, especially from about 3300-3550m.

EVIRONMENT OF DEPOSITION (Palynofacies)

2525-2592m: marine, probably shallow marine
2667-2760m: marine, near shore, near source of land-derived organic material
2806m: marginal marine
2816-3993m non-marine (swamp, lake, fluvial deposits)

2. INTRODUCTION AND METHODS

The interval examined palynologically ranged from 2525m down to 3993m (TD is at 3996m, bdf). A total of 47 sidewall cores were selected on the basis of lithology. Grey to black, fine-grained sediments (mudstones, shales) are generally richer in palynomorphs than sediments such as silts and sands deposited in higher-energy environments. Where mudstones or shale samples were not available, siltstone samples were prepared. The quality of the sidewall cores was poor to fair.

Samples were prepared in Perth by Exploration Consultants Ltd (ECL) using the "standard" technique for siliciclastic sediments, i.e. hydrochloric and hydrofluoric acid treatment followed by heavy-liquid separation to remove mineral matter; controlled oxidation with nitric acid to reduce unwanted organic constituents and thus concentrate the palynomorphs; and finally washing with sodium hydroxide to remove humic acids. The resulting acid-insoluble residue was mounted in Elvacite to produce permanent microscope preparations. A slide of the non-oxidised residue was used for palynomaceral studies.

All samples yielded an organic fraction and most were productive. Only a few samples were too poor to be of much value. Richness and diversity of the assemblages varied but was generally good in the Tertiary section, becoming gradually poorer in the Cretaceous. Preservation deteriorated as well, particularly in the deeper part.

The palynomorphs were recorded semi-quantitatively. To provide continuity with the work of Harris, 1983, the stratigraphic interpretation of assemblages follows the zonal characteristics given in his "Biostratigraphic Summary" (Harris, undated). The range charts in this "Summary" are largely based on published and unpublished work of Stover and Evans (1974), Stover and Partridge (1973), Partridge (1975), Partridge (1976) and HELBY et. al. (in press).

Reworked palynomorphs were found in several samples but mostly as single occurrences only. Most were Permo-Triassic and Jurassic in age. Early and mid Cretaceous spores were regularly found in the Upper Cretaceous. Perhaps they were reworked but, although found in younger sediments than their published ranges would suggest, they may in fact belong.

Contamination from the mud was present in some samples. Although all samples were carefully cleaned before preparation, a fractured or broken-up sidewall sample cannot always be fully trusted as some contamination with palynomorphs from the mud is unavoidable.

3. ANALYSIS OF ZONES

A. DINOFLAGELLATE ZONES

2525-2592m (7 SWS): A. HYPERACANTHUM Zone, late PALEOCENE/early EOCENE

Based on the presence of Ceratiopsis dartmooria, Apectodinium homomorphum, Muratodinium fimbriatum, Diphyes colligerum, Palaeocystodinium sp. and Kenleyia leptocerata (one specimen only). "Leiosphaeridia" trematophora was very common at 2544.5m. Most samples contained one or more species that could not be identified and may well be undescribed.

2611.5m (1 SWS) (Paleocene palynomorphs reworked into Eocene)

This sample contains a mixture of Paleocene and Eocene markers, especially noticeable from the pollen (see under 3B). Dinoflagellates were present but not common. Ceratiopsis dartmooria and Senegalinium dilwynensis occur together although their ranges normally do not overlap.

2667-2760m (12 SWS): T.EVITTII Zone, Early PALEOCENE

The nominate species is common at 2760m only but Palaeoperidinium pyrophorum occurs throughout the interval. Other dinoflagellate species present are: Ceratiopsis speciosa, Palaeocystodinium sp., Eisenackia crassitabulata, Vozzhennikovia/Spinidinium spp., Hystrichokolpoma sp., Paralecaniella indentata and a variety of chorate cysts.

2806m (1 SWS) I.DRUGGII Zone, late MAASTRICHTIAN

The nominate species was fairly common. No other dinoflagellates were found.

2816-3993m:

Single specimens of dinoflagellates occur in some samples but are either indeterminate or suspected contamination. One specimen of Isabelidinium cretaceum at 3910m is perhaps noteworthy. An unknown Dinogymnium at 3925m may belong as well, although the sample was contaminated.

B. SPORE-POLLEN ZONES

2525-2592m (7 SWS) lower M. DIVERSUS Zone, late PALEOCENE/early EOCENE

Most obvious is a variety of the larger Proteacidites such as:

P. grandis, P. incurvatus, P. kopiensis and P. adenanthoides. These markers have their base occurrence in this pollen zone. Verrucosisporites kopukuensis is present as well. Some of the other sporomorphs found are Nothofagidites spp., M. diversus, Intratriporopollenites notabilis and one specimen of Spinozonocolpites prominatus.

The top of the Lower M.DIVERSUS Zone is immediately below the base of markers indicating the Upper M.DIVERSUS Zone. Such markers have not been found. Evidence from dinoflagellates also indicate that at 2525m the assemblage is indeed not younger than the Lower M.DIVERSUS Zone.

2611.5m (1 SWS) (Paleocene palynomorphs reworked into Eocene)

This assemblage contains marker types that (according to published and unpublished data) are mutually exclusive. Proteacidites incurvatus, P. grandis, Verrucosisporites kopukuensis and Banksiaeidites arcuatus all have their base in the Lower M.DIVERSUS Zone. But markers such as Gambierina rudata, Australopollis obscurus and Proteacidites angulatus have tops in the underlying L.BALMEI Zone. The dinoflagellates provided some evidence for reworking as well (see 3A).

2667-2760m (12 SWS) Lower L.BALMEI Zone, PALEOCENE

Dinoflagellates support an Early Paleocene age but the pollen data are less precise. The combined presence of Proteacidites angulatus and the absence of T.LONGUS zonal markers indicate that the interval belongs to the lower L.BALMEI pollen zone.

2806-3390m (16 SWS) T.LONGUS Zone, MAASTRICHTIAN

Assemblages vary in richness and diversity but are generally poor in sporomorphs. The nominate species occurred in the highest samples together with "Grapnelispora evansii", Camarozonosporites amplus, Proteacidites "reticuloconcavus" and P. "clinei". Amongst other types present in the interval are Stereisporites (Tripunctispora) sp., S. regium, Proteacidites amolosexinus, P. angulatus, P. "otwayensis", P. "gemmatus", Tetracolporites verrucosus, Tricolpites lilliei and Triporopollenites sectilis.

The base of the zone proved to be difficult to locate, as is not unusual. The top of the underlying T.LILLIEI Zone is based on negative evidence, i.e. the absence of markers for the T.LONGUS Zone. The deeper samples are poor in pollen and the absence of zonal markers may therefore not be indicative. At 3390m P. angulatus is still present, together with a fragment of the morphologically highly characteristic "Grapnelispora evansii". However, another feature usually present at the T.LONGUS/T.LILLIEI boundary is not too clear: the ratio of Nothofagidites spp. to Gambierina spp. generally shows a high for the former in the T.LILLIEI Zone and a high for the latter in the T.LONGUS Zone. Applying this criteria indicates an area of uncertainty between 3197 and 3390m. The assemblage at 3137m clearly belongs to the T.LONGUS Zone whereas common Nothofagidites at 3470m suggests the T.LILLIEI Zone. The interval in between (because of poor assemblages) cannot be confidently placed in either one or the other. On balance, however, the boundary is best placed between 3390 and 3470m.

3470-3993m (10 SWS): T.LILLIEI Zone, CAMPANIAN

The deepest assemblage, at 3993m, still contains the nominate species, together with Nothofagidites endurus, Proteacidites scaboratus, Triporopollenites sectilis and Stereisporites regium, while Tricolpites sabulosus is present as well, all indicating that the well bottomed in the T.LILLIEI pollen Zone.

4. SPOROMORPH COLOUR, DEGREE OF ORGANIC METAMORPHISM (D.O.M.) AND SOURCE ROCK POTENTIAL

The colour of palynomorphs changes when subjected to the increasing or prolonged temperatures such as occur during burial. These changes in colour are irreversible and therefore indicate the maximum level of maturity reached. The different stages, yellow to golden-yellow through orange and brown to black can be correlated with changes in chemical composition as hydrocarbons are generated from the organic matter (see Fuchs, 1969; Standard Legend, 23.51.10). The sporomorph colour scale is more subjective than the more commonly used vitrinite reflectance scale. Ideally, a long-ranging sporomorph type should be selected as different types of sporomorph within the same sedimentary section show variations in colour. As observed in transmitted white light the change in colour from light yellow to golden-yellow or orange corresponds with the onset of oil generation, whereas the onset of gas generation is associated with a change in colour from orange to brown. Post-mature source rocks contain black sporomorphs and organic fragments only.

In incident ultraviolet light palynomorphs (and some palynomacerals) exhibit fluorescence colours that not only help in their identification but also increase and decrease according to rank. Fluorescence is maximal at the threshold of the "oil window", decreases with increasing rank and disappears at the end of the "oil window" (1-1.3% R_o, see Robert, 1981).

In Bignose-1 sporomorph-colour in transmitted light ranged from pale-yellow at 2525m to yellow and yellow-light brown at 3993m. Over the same interval fluorescence colours of sporomorphs ranged from golden yellow to yellowish-orange. Both estimates seem to indicate immature conditions at 2525m, changing into early mature for oil at 3993m.

Palynomaceral determination was carried out on a sieved, non-oxidised preparation. The sieving (with a 10 micrometer mesh sieve) was necessary to concentrate the large palynomacerals that otherwise would be diluted by fine, amorphous organic matter. This fine fraction is undoubtedly important for source rock characterisation but its nature and origin cannot be determined by ordinary means.

In Bignose-1 a rough estimate during preparation showed that between 2525 and 2760m total organic matter varied from less than 0.05 to 0.7 millilitre per 10 grammes of sediment, and between 2806-3993m from less than 0.05 to 8.0 millilitre per 10 grammes of sediment. The interval 2525-2592m is dominated by inertinite, with woody tissues and palynomorphs coming second; from 2667 down to 2760m inertinite is still common but so are woody tissues and liptinite; below 2806m liptinite dominates and inertinite, although still present is only occasionally dominant over liptinite.

Source Rock Qualities

The amount and composition of the organic matter would suggest that the best source rocks occur between about 3300-3550m, fair to good source rocks between 2806-3993m and poor source rocks between 2525-2760m. It should however be remembered that these conclusions are drawn from a limited set of samples, selected for palynology and including neither coals nor coarse grained sediments. Results were formulated after a visual examination and not by accurate measurement.

5. ENVIRONMENT OF DEPOSITION/PALYNOFACIES

The relationship between organic matter and grainsize of the sediments has been well-documented and is used to deduce depositional environment (palynofacies) from the type of palynomorphs and palynomacerals present.

The palynomorphs can be divided into marine organisms such as dinoflagellates and Tasmanites (both algae) and foraminiferal test linings; fresh and brackish water organisms such as Botryococcus and Acritarchs; and land derived pollen and spores (Sporomorphs).

Breakdown products of plants (woody fragments, epidermal tissues, cork cells, resin), algal and bacterial remains, animal tissue and many inderterminate organic fragments are collectively known as palynomacerals.

Although wind transport is an important aspect of the initial dispersal of sporomorphs, water transport then carries the sporomorphs and palynomacerals until they settle out of the water column. A continuous process of mechanical abrasion, biological degradation and wave and current action sorts and grades the particles during this transportation phase. Less buoyant, heavy or larger organic particles tend to characterise environments close to source while lighter, more buoyant and smaller particles are carried further afield. Very low sporomorph diversity indicates authochthonous environments (marsh, swamps); allochthonous environments are characterised by more diverse assemblages. Marine microplankton diversity increases in an offshore direction (Whitaker, 1979).

In Bignose-1 the interval 2525-2592m is clearly marine: dinoflagellates are present throughout although not abundantly so and not of diverse composition; the presence of sporomorphs and other land-derived organic matter suggests a shallow marine, near source environment. The interval 2667-22760m is very similar but is richer in sporomorphs and plant tissues which again suggests a marine, but near source/near shore environment. In the interval 2806-3993m only the highest sample (at 2806m) contains dinoflagellates. Only one species is present in low numbers. This probably reflects a very restricted, marginally marine environment. Below 2816m no marine indicators are present (excepting rare, single specimens that could easily be contaminants from the drilling mud). Leiospheres of the *Nummus* type are common at 3910m and at 3925m. Single to several specimens occur in many samples of the T.LONGUS and T.LILLIEI Zons and it is therefore more likely that it is a freshwater organism than a constituent of a marginal marine environment as Morgan (1975) suggests for *Nummus monoculatus*.

The absence of marine indicators and the abundance and variety of (sometimes very large) plant remains, together with the generally low diversity of the sporomorph assemblages suggests a low energy swamp environment or low to medium energy fluvial or lacustrine deposts over most of the interval examined (2816-3993m).

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