APPENDIX

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

BY

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1. SUMMARY

Depth (m)	DINOFLAGELLATE ZONES	SPORE-POLLEN ZONES	AGE
1996.8-2001.6	A. HYPERACANTHUM	Lower M. DIVERSUS	Early EOCENE
2256-2266	T. EVITTII	Lower L. BALMEI	Early PALEOCENE
2272.2-2452	-	T. LONGUS	MAASTRICHTIAN
2328	prob. I. DRUGGII	-	Late Maastrichtian
2475.8-2534	-	prob. T. LONGUS	prob. MAASTRICHTIAN
2589-2695	-	T. LILLIEI	CAMPANIAN
2958-3319	-	N. SENECTUS	SANTONIAN/CAMPANIAN
3340	-	prob. N. SENECTUS	prob. SANTONIAN/ CAMPANIAN
3404-3804	-	prob. T.PACHYEXINUS	CONIACIAN/SANTONIAN

(T.D. 3826)

SPORE COLOUR/DEGREE OF ORGANIC METAMORPHISM (D.O.M.)/SOURCE ROCK QUALITY

Transmitted (white) light: from pale yellow (1996.8m) to deep yellow/very light brown (3804m).

Incident U.V. light: bright yellow to golden yellow and orange to dull light brown.

D.O.M.: from immature at 1996.8m to early mature at 3804m.

ENVIRONMENT OF DEPOSITION

1996.8 - 2266m: Marginal marine
2272-3804m : Non-marine (swamp, lake or fluvial deposits)

(3508m : common small acritarchs may indicate brackish conditions).

2. INTRODUCTION AND METHODS

The interval examined palynologically ranged from 1996.8m down to 3804m (T.D. is at 3826m, bdf). A total of 51 sidewall cores and 4 ditchcuttings 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 shales were not available, siltstone samples were prepared. The quality of the sidewall cores was fair to excellent. Several sample gaps of 100-150m were due either to unfavourable lithology or to non-recovery during operations.

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 on the non-oxidised residue was used for palynomaceral studies. Most of the oxidized preparations were stained using Bismarck Brown to enhance contrast of the palynomorphs.

All samples yielded an organic fraction but some proved to be poor to very poor in organic microfossils and did not contribute to the overall interpretation. Preservation was excellent to fair in most samples. Diversity of assemblages varied but was generally good in the Tertiary and good to poor in the Cretaceous part of the examined section.

The palynomorphs were recorded semi-quantitatively. To provide continuity with the work of Harris, 1983, the biostratigraphic 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), (1976) and Helby, et. al. ("in press").

Reworked palynomorphs were regularly encountered, mostly as single occurrences. Almost all were Permo-Triassic in age, with an occasional Jurassic grain. It is not clear how to interpret the regular occurrences of Early and Mid Cretaceous spores. They could be reworked, but, although found in younger sediments than their published ranges would indicate, they may in fact belong. Because the quality of samples in this well was excellent mud contamination was rare.

3. ANALYSIS OF ZONES

A. DINOFLAGELLATE ZONES

1996.8-2001.6m (2 SWS): APECTODINIUM HYPERACANTHUM Zone, Early EOCENE.

Chorate dinoflagellate cysts were common in the assemblages. Other marine indicators present were microforams: chitinous inner linings of foraminifera. The nominate species and A. homomorphum were both well-represented. Fibrocysta bipolare was quite common while Muratodinimum cf. fimbriatum and Deflandrea spp. were present as well. An unknown Glaphyrocysta, tentatively identified as G. reticulosa by Cookson (1965, p138) has been found in Manta-1 at a similar stratigraphic level (2040m).

(2101.8m: no dinoflagellates).

2256.7-2266m (2 SWS): TRITHYRODINIUM EVITTII Zone, Early PALEOCENE.

Both samples were very poor and contained just a few specimens of T. evittii, Palaeoperidinium pyrophorum, Paralecaniella indentata, Eisenackia crassitabulata, Spinidinium sp. and Glaphyrocysta retiintexta. A single specimen of a Renidinium was present also.

2328m (1 SWS): probably ISABELIDINIUM DRUGGII Zone, late Maastrichtian

The nominate species itself was not found but another Deflandrea type that usually accompanies it was present. Although all conform to the same basic morphology, the Deflandria/Isabelidinium group normally found at this stratigraphic level is quite variable in details. A Spinidinium sp. and a chorate cyst were the only other dinoflagellates present.

2381-3804m: no dinoflagellate cysts. Small acritarchs were found at 2452m (a single specimen), 3508m (common) and 3540m (a single specimen).

B. SPORE-POLLEN ZONES

1996.8-2001.6m: Lower MALVACIPOLLIS DIVERSUS Zone, Early EOCENE.

Spinizonocolpites prominatus, Malvacipollis diversus, Matonisporites gigantis, Lycopodiumsporites circiniidites, Proteacidites spp., P. annularis, Nothofagidites spp., and a variety of spores are just a few of the sporomorphs found. The apparent absence of large Proteacidites, such as P.grandis and P. incurvatus, normally prominent in the Early Eocene is puzzling in view of the clear dating that the dinoflagellates gave. It is unlikely to be an environmental question as sporomorphs and other land-derived materials are common.

2101.8m (1 SWS). This sample is practically barren and could not be dated, but it did contain a very curious pollen grain with a triangular opening at each pole and a rather coarse sculpture in the interradial areas. It is, perhaps, syncolpate but this is by no means obvious. It could not be traced in the available literature.

2256-2266m (2 SWS): The samples are almost barren and could only be dated by dinoflagellates. A single specimen of Tricolpites phillipsii, having a base in the LYGISTEPOLLENITES BALMEI Zone, would seem to confirm the Early Paleocene age.

2272-2452m (10 SWS): TRICOLPITES LONGUS Zone, MAASTRICHTIAN.

One sample proved to be barren (2399m) and one too poor (2410m) but the other assemblages were rich, diverse and well preserved. The main markers, T. longus, Tricolpites lilliei and Triporopollenites sectilis were all present as was Quadraplanus brossus, "Grapnelispora evansii", Proteacidites "clinei", P. "gemmatus", P. "wahooensis", P. "reticuloconcavus", P. angulatus, Lygistepollenites balmei, Australopollis obscurus, Stereisporites(Tripunctisporis) sp., S. regium, Kraeuselisporites sp., Ceratosporis equalis, Cicatricosiporites spp., and of course Microcachryidites antarcticus, Phyllocladidites spp. (a.o. P. verrucosus), Gambierina rudata, G. edwardsii, Tricolpites confessus and T.gillii.

2475.8-2534m (4 SWS): probably TRICOLPITES LONGUS ZONE, prob. MAASTRICHTIAN

The ratio of Nothofagidites spp. to Gambierina spp. is clearly in favour of the former which would seem to indicate that the T. LILLIEI Zone has penetrated from 2475.8m down. T. longus is however still present down to 2534m, and so are "Grapnelispora evansii" and Proteacidites "gemmatus". It is therefore likely that the T. LONGUS Zone has its base at 2534m.

(2568.5m: barren of palynomorphs, little organic matter).

2589-2695m (6 SWS): TRICOLPITES LILLIEI ZONE, CAMPANIAN.

The nominate species is present throughout and markers for the T. LONGUS Zone are absent. Assemblages are fairly rich and diverse, and basically of similar composition as those of the overlying zone. A few species not mentioned so far as Gephyrapollenites wahooensis, Baculatisporites comaumensis, Proteacidites amolosexinus, P. palisadus, Tricolpites fissilis,and Caytonipollenites sp.

(2840 and 2886m: too poor in palynomorphs).

2958-3318m (10 SWS): NOTHOFAGIDITES SENECTUS ZONE, SANTONIAN-CAMPANIAN.

5 samples out of 10 were too poor but the others contained reasonably diverse assemblages although not rich in specimens. Nothofagidites spp., mostly N. senectus, occur throughout the interval but are poor in the deeper samples. Other types present include Tricolpites sabulosus, T. gillii, T. confessus, Proteacidites spp., P. amolosexinus, P. scaboratus, Gephyrapollenites wahooensis and Australopollis obscurus. A coarsely reticulate, monosulcate pollen grain, perhaps related to Retimonocolpites peroreticulatus (Brenner) Doyle was present also. It was found in a similar stratigraphic position in Manta-1.

3340m (1 SWS): probably NOTHOFAGIDITES SENECTUS ZONE, prob. SANTONIAN-CAMPANIAN.

The assemblage was not only poor in specimens but poor in preservation as well.

It did contain 2 probable Nothofagidites sp. and some of the grains that could not be determined because of poor preservation may in fact be Nothofagidites as well.

(3365 and 3370m: practically barren).

3404-3804m (8 SWS and 4 ditchcuttings) probably TRICOLPITES PACHYEXINUS ZONE, proably CONIACIAN-SANTONIAN.

Nothofagidites no longer occur in this deepest part of the section but Proteacidites spp. and Phyllocladidites spp. (mostly P. mawsonii) are still present. This puts a lower limit to the interval as both genera have a base occurrence in the CLAVIFERA TRIPLEX Zone (Turonian-Coniacian). It is more difficult to decide if both the T. PACHYEXINUS and the CLAVIFERA TRIPLEX Zones are represented, or, if only one of them, which one. The assemblages are poorly preserved and poor in specimens. Most common are P. mawsonii and other bisaccates, and Lycopodiumsporites circiniidites. Relatively rare were Lygistepollenites cf balmei, Clavifera triplex, Baculatisporites comaumensis, Kraeuselisporites sp., Dictyotosporites speciosus, Phimopollenites pannosus, Ceratosporis equalis, and Cicatricosisporites spp.. It was, however, the occurrence of Proteacidites scaboratus and P. amolosexinus that decided in favour of the TRICOLPITES PACHYEXINUS 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, 1979; standard Legend, 25.5.10). 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 contained 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 Chimaera-1 sporomorph-colour in transmitted (white) light ranged from pale yellow at 1996.8m to deep yellow/very light brown at 3804m. Over the same interval fluorescence-colours of sporomorphs ranged from light yellow to golden yellow and orange to dull brown. Both estimates seem to indicate immature conditions over most of the sections studied, although it is possible that early mature conditions were reached in the deepest part, below 3500m.

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 Chimaera-1 a rough estimate during preparation (i.e. after the acid treatment but before oxidation) showed that, over the interval studied, total organic matter varied from 0.1 to 4.0 millilitre per 10 grams of sample. Highest amounts not surprisingly occurred in carbonaceous shales.

It should be remembered that these estimates may not reflect the true picture, as they are based on samples selected for palynology (e.g. disregarding coarser grained sediments on the one hand and coals on the other). The interval 1996.8m to 2266m is rich in inertinite while plant tissues, pollen, spores and dinoflagellates are present in various amounts, but the fairly low estimates for total amount of organic matter per 10 grams of sample classifies them as poor source rocks. The interval 2272.2m-3804m (again, considering the palynological samples only) shows higher organic matter estimates and probably contains good source rocks. The types of palynomacerals present suggest gas-prone rather than oil-prone sourcerocks.

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 indeterminate 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 particulars 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 Chimaera-1 the interval 1996.8-2266m is clearly marine because dinoflagellates and some microforams are present in most samples. The presence of sporomorphs and particularly of plant tissues indicates a near source/near shore, rather than an open marine environment.

Between 2272.2 and 3804m marine indicators are absent, except at 2328m. This assemblage is marginal marine or perhaps even brackish lagoonal because it lacks diversity in dinoflagellates while plant tissues and sporomorphs are abundantly present. Acritarchs are fairly common at 3508m although only one species is present. The value of acritarchs as marine indicators is debatable: in the Mesozoic they seem to occur in brackish, or even freshwater environments. Single specimens were found at 2452m and 3540m. All other samples between 2272.2m and 3804m are considered to be non-marine (swamp, lake or fluvial deposits).

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