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FINAL PALYNOLOGY OF BHPP ERIC THE RED #1

OFFSHORE OTWAY BASIN, VICTORIA, AUSTRALIA

BY

ROGER MORGAN AND NIGEL HOOKER

for BHP PETROLEUM

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I SUMMARY

373.5m(swc), 388.0m(swc) : apparently middle *asperus* Zone : Late Eocene : very nearshore marine : immature

429.0(swc) : lower *asperus* zone (*australicum* dinoflagellate zone) : Middle Eocene : nearshore marine : immature

467.0m(swc) : upper *diversus* Zone : Early Eocene : nearshore marine : immature

553.0m(swc), 562.0m(swc), 569.0m(swc), 599.0m(swc) : *longus* Zone (553.5m *druggii* dinoflagellate zone, 599.0m *korojonense* dinoflagellate zone) : Maastrichtian : nearshore to very nearshore marine : immature

612.5m(swc), 642.0m(swc) : extremely lean *senectus* Zone or younger : Campanian-Maastrichtian : possibly non-marine (no dinoflagellates seen)

664.5m(swc), 689.5m(swc), 720.5m(swc), 746.0m(swc) upper *senectus* Zone (664.5m swc upper *australis* dinoflagellate zone, 689.5m-720.5m lower *australis* dinoflagellate zone) : Campanian : nearshore and very nearshore marine : immature

812.5m(swc) : middle *senectus* Zone (*aceras* dinoflagellate zone) Campanian : nearshore marine : immature

876.0m(swc), 893.5m(swc), 970.0m(swc) upper *apoxyexinus* Zone (876.0m upper *cretacea* dinoflagellate zone, 893.0m-970.0m lower *cretacea* dinoflagellate zone): Santonian : nearshore marine : marginally mature

1010.0m(swc), 1025(cutts) : middle *apoxyexinus* Zone (*porifera* dinoflagellate zone) : Santonian : nearshore marine : marginally mature

1080m(cutts) : lower *apoxyexinus* Zone : Santonian : nearshore marine : marginally mature

1097.0m(swc), 1151.0m(swc), 1177.0m(swc), 1180(cutts) : apparently all upper *mawsonii* Zone : ?Coniacian : non-marine and nearshore : marginally mature

1219.5m(swc), 1250.5m(swc), 1275.0m(swc), 1306m(cutts), 1316.0m(swc), 1328.5m(swc), 1334.0m(swc), 1336.0(swc),1364.5m(swc), 1437.0m(swc) : *mawsonii* Zone (1437.0m *infusorioides* dinoflagellate zone) : Coniacian-Turonian : mixed non-marine and nearshore marine : marginally mature

1452m(cutts), 1515m(cutts) : *distocarinatus* or *mawsonii* Zones (P. *mawsonii* may be caved in these cuttings) (*infusorioides* dinoflagellate zone) : Turonian-Cenomanian : marginally marine : marginally mature

1575.0m(swc), 1602.0m(swc), 1630.0m(swc), 1667.0m(swc), 1678.0m(swc), 1703.0m(swc), 1719.0m(swc) : *distocarinatus* zone (*infusorioides* dinoflagellate zone at 1719m unless the single *C. edwardsii* is mud contamination) : mixed non-marine and brackish : early mature for oil, early marginally mature for gas/condensate

1749.5m(swc), 1754.5m(swc), 1790.0m(swc), 1813.5m(swc) : extremely lean and indeterminate : early mature for oil, early marginally mature for gas/condensate.

II INTRODUCTION

During drilling six cuttings samples were studied on an urgent basis and were reported in 2 faxed reports. After well completion, a further forty two swcs were submitted for detailed study. All results were summarised herein.

Palynomorph occurrence data are shown as Appendix I and form the basis for the assignment of the samples to twelve spore-pollen units of Cenomanian to Eocene age. The Cretaceous spore-pollen zonation is essentially that of Dettmann and Playford (1969), but has been significantly modified and improved by various authors since, and most recently discussed in Helby et al (1987), as shown on Figure 1. The Late Cretaceus zonation has been modified by Morgan (1992) in project work for BHPP. Eocene zones are essentially those of Partridge (1976).

Maturity data was generated in the form of Spore Colour Index, and is plotted on Figure 3 Maturity Profile of Eric the Red #1. The oil and gas windows on Figure 3 follow the general consensus of geochemical literature. The oil window corresponds to spore colours of light-mid brown (Staplin Spore Colour Index of 2.7) to dark brown (3.6). These correspond to vitrinite reflectance values of 0.6% to 1.3%. Geochemists argue variations on kerogen type, basin type and basin history. The maturity interpretation is thus open to reinterpretation using the basic colour observations as raw data. However, the range of interpretation philosophies is not great, and probably would not move the oil window by more than 200 metres.

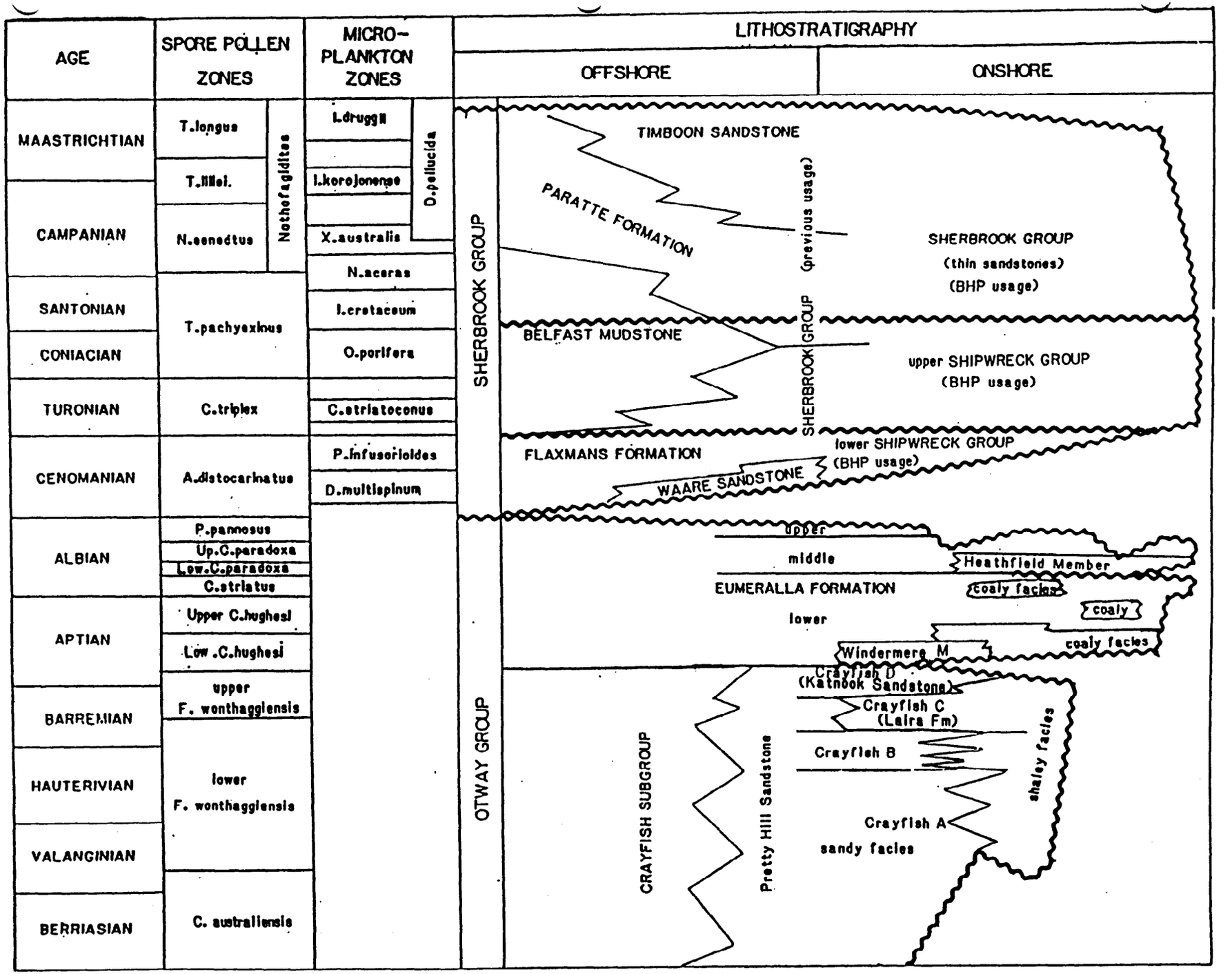

FIGURE 1. CRETACEOUS REGIONAL FRAMEWORK, OTWAY BASIN

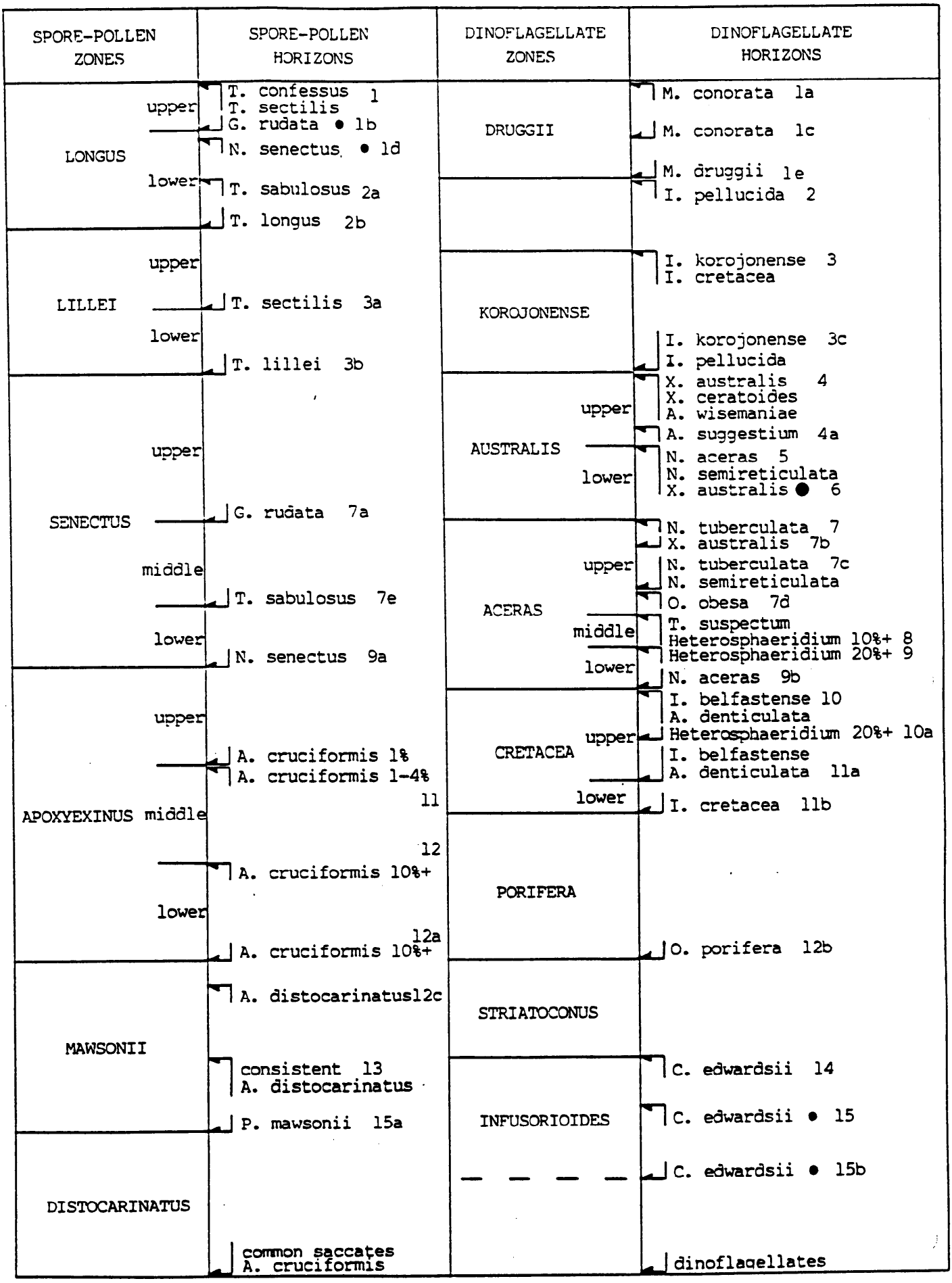

FIGURE 2 ZONATION USED HEREIN SHOWING THE NUMBERED HORIZONS AGAINST THE EXISTING FORMAL ZONATION.
• = frequent (4-10%) ● = common (11-30%)

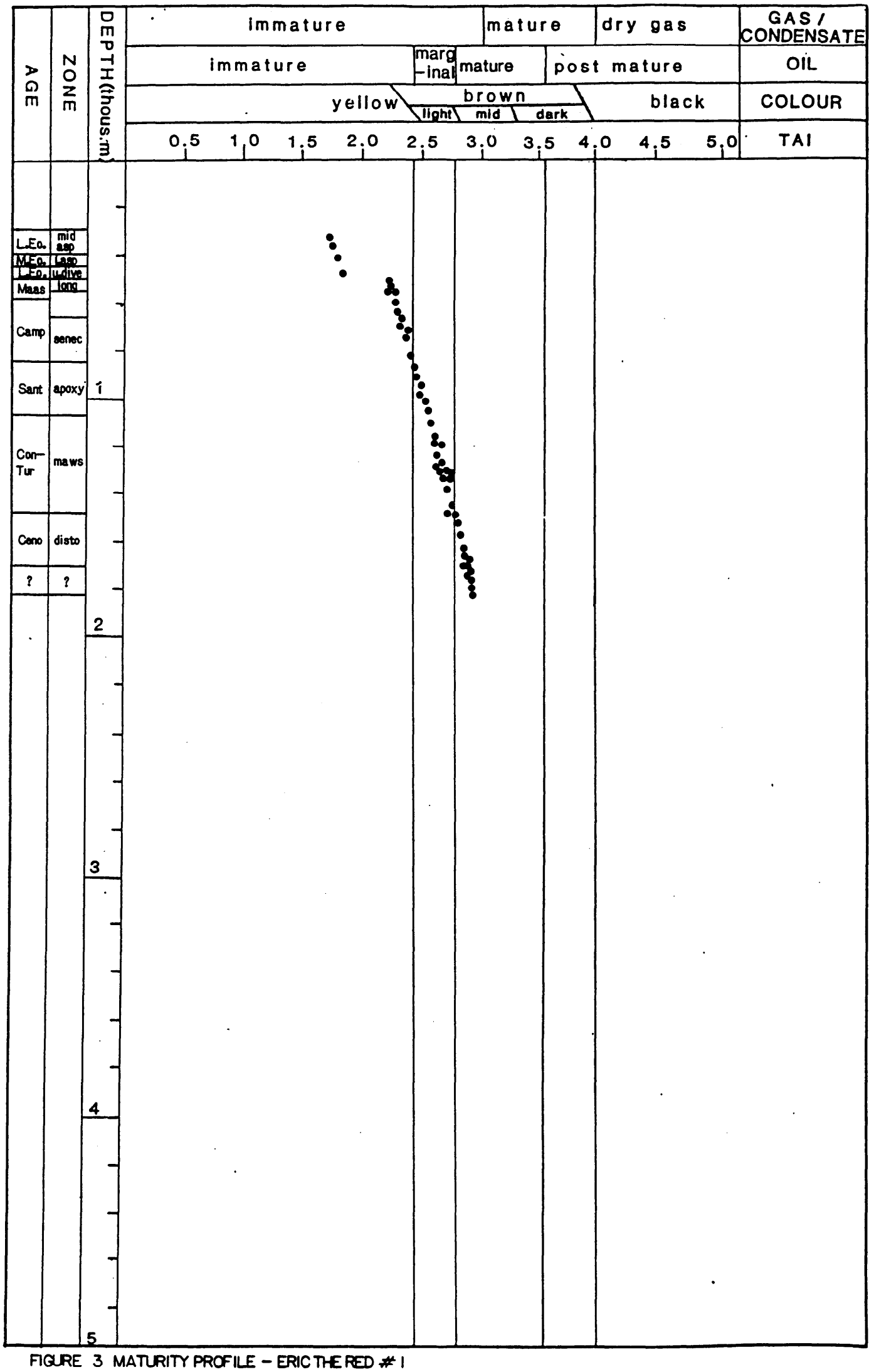

FIGURE 3 MATURITY PROFILE – ERIC THE RED #1

III PALYNOSTRATIGRAPHY

A 373.5m(swc), 388.0m(swc) : apparently middle *asperus* Zone

Assemblages are lean and bland, but probable *Triorites magnificus* in both samples suggest the middle *Nothofagidites asperus* Zone of Late Eocene age. Other spores and pollen consistent with this zone include *Beaupreadites verrucosus, Kuylisporites waterbolkii, Nothofagidites falcatus, Polycolpites esobalteus, Proteacidites kopiensis, P. pachypolus* and *Santalumidites cainozoicus*. Dominant taxa include *Proteacidites* spp and *Haloragacidites harrisii* while *Nothofagidites* spp, *Cyathidites* spp and *Falcisporites* spp are common.

Amongst the rare dinocysts, frequent *Phthanoperidinium comatum* (373.5m) and rare *Vozzhennikovia extensa* (388.0m) suggest the *Corrudinium incompositum* dinocyst zone, correlative with the middle *asperus* spore-pollen zone. Dinocysts are rare and of low diversity.

Nearshore to marginal marine environments are suggested by the scarce dinocysts (3-5%) and their low diversity, and the dominant and diverse spore-pollen.

Colourless palynomorphs indicate immaturity for hydrocarbons.

B 429.0m(swc) : lower *asperus* Zone

Assignment to the lower *N. asperus* Zone of Middle Eocene age is indicated at the top by youngest *Intratriporopollenites notabilis* and at the base by oldest *Nothofagidites deminutus* and the dinoflagellate data. Of the spore pollen, *Dilwynites* and *H. harrisii* are common with *Proteacidites, Cyathidites* and *Ericipites* frequent. Rare elements include *Polycolpites esobalteus, Proteacidites asperopolus, P. leightonii, P. pachypolus* and *P. tuberculiformis.* Rare Permian reworking was noted.

The dinoflagellates include *Deflandrea phosphoritica* and *Areosphaeridium australicum*, indicating the *A. australicum* dinoflagellate zone, correlative with most of the lower *asperus* spore pollen zone. *A. australicum* is common with *Spiniferites* rare and other elemenents very rare.

Nearshore marine environments are indicated by the subordinate dinoflagellates (20%) and their low diversity, the dominant and diverse spores and pollen, and the common cuticle.

Colourless palynomorphs indicate immaturity for hydrocarbon generation.

C 467.0m(swc) : upper *diversus* Zone

Assignment to the upper *Malvacipollis diversus* Zone of early Eocene age is indicated by oldest *P. pachypolus* without younger markers. Age significant datums consistent with the assignment include youngest *Intratriporopollenites notabilis, Proteacidites tuberculiformis* and *P. ornatus* and oldest *Anacolosidites acutullus, Periporopollenites demarcatus* and *P. tuberculiformis*. Common taxa are *Dilwynites granulatus* and *Proteacidites* spp with *Malvacipollis subtilis* and *Falcisporites* frequent. Dinocysts are extremely rare and not age diagnostic.

Marginally marine environments are indicated by the rare dinocysts (3%), and their low diversity. Spores and pollen are abundant and diverse. Freshwater algae (*Botryococcus* at 3%) are significant, suggesting some lacustrine influence.

Colourless spores indicate immaturity for hydrocarbon generation.

D 553.0m(swc), 562.0m(swc), 569m(swc), 599.0m(swc) : *longus* Zone

Assignment to the *Tricolpites longus* Zone of Maastrichtian age is indicated at the top by youngest *Amosopollis cruciformis, Tricolpites confessus, T. longus, T. waipawaensis, Tricolporites lillei* and *Triporopollenites sectilis* and at the base by oldest *Tetracolporites verrucosus* and *Tricolpites longus*. Dinocyst data also confirm the zonal assignment as discussed below. Within the zone, oldest *Tripunctisporis punctatus* occurs at 553.5m and *Nothofagidites* out number *Gambierina rudata* at 569.0m and below, providing intra zone correlation. Within the interval, *Proteacidites* and *Falcisporites* are common, with *Nothofagidites, G. rudata, Gleicheniidites, Ceratosporites* and *Phyllocladicites* frequent.

Amongst the dinocysts, *Manumiella coronata* at 553.5m indicates the *Manumiella druggii* Zone of latest Maastrichtian age,and *Isabelidinium korojonense* and *I.*

pellucidum at 599m indicate the *I. korojonense* Zone of earliest Maastrichtian and Campanian age.

Very nearshore to marginally marine environments are indicated by the low dinocyst content (3%, 8%, 3%, 7%) and their low diversity. Spores and pollen are abundant and diverse and freshwater algae occur especially at 553.5m (6% *Botryococcus* and 4% *Paralecaniella*).

Yellow spore colours indicate immaturity for hydrocarbons.

E 612.5m(swc), 642.0m(swc) : extremely lean *senectus* Zone or younger

These two swcs are extremely lean and cannot be confidently assigned to any one zone. The presence of *Nothofagidites endurus, N. senectus, Gambierina rudata* and *Tricolpites sabulosus* however, indicate an upper *senectus* or younger zone. Saccate pollen (*Falcisporites* and *Microcachryidites*) are frequent to common, with *Proteacidites* also frequent. From the stratigraphic position, the *lillei* zone seems likely.

Non-marine environments are suggested by the total absence of dinoflagellates. The 642m samples is so lean that this is not necessarily conclusive. At 612.5m, common algal acritarchs (*Nummus* sp, *Paralecaniella, Botryococcus*) suggest freshwater lake environments.

Yellow spore colours indicate immaturity for hydrocarbons.

F 664.5m(swc), 689.5m(swc), 720.5m(swc), 746.0m(swc) : upper *senectus* Zone

Assignment to the upper *Nothofagidites senectus* Zone of early Campanian age is indicated at the top by the absence of younger indicators and confirmed by the dinoflagellate data and at the base by oldest *G. rudata.* Within the interval, saccate pollen are dominant (*Falcisporites, Microcachryidites* and *Podosporites*) with *Phyllocladidites mawsonii, Proteacidites* and *Nothofagidites* frequent. Minor Triassic and Permian reworking was seen.

Amongst the dinoflagellates, *Xenikoon australis* without older markers indicates the upper *australis* dinoflagellate zone of early Campanian age at 664.5m. Youngest *Nelsoniella semireticulata* at 689.5m indicates the lower *australis*

dinoflagellate zone over the interval 689.5-720.5m and youngest *Areosphaeridium suggestium* at 720.5m is consistent. *X. australis* occurs in all except 746.0m. Of the very rare dinoflagellates, the most consistent are *Heterosphaeridium heteracanthum*, *X. australis* and *N. semireticulata* with none being frequent. A single *Nelsoniella tuberculata* at 720.5m is considered reworked.

Environments are nearshore marine and very nearshore marine with dinoflagellate contents of <1%, 4%, 10% and 2% respectively. Algal acritarchs are very rare (1% or less) indicating only very minor lacustrine influence. The very strong terrestrial influence is shown by the common cuticle and the very dominant and diverse spore-pollen.

Yellow to light brown spore colours indicate immaturity for hydrocarbons but approaching early marginal maturity.

G 812.5m(swc) : middle *senectus* Zone

Assignment to the middle *N. senectus* Zone of early Campanian age is indicated by oldest *T. sabulosus*, here coincident with oldest *N. senectus*. Saccate pollen continue to dominate (*Falcisporites*, *Microcachryidites* and *Podosporites*) but *Proteacidites* is also common. Rare elements include *Amosopollis cruciformis*, *Ornamentifera sentosa* and *Tricolpites confessus*. Rare Permian reworking was noted.

Dinoflagellates include *Nelsoniella aceras* without *X. australis*, indicating the *aceras* dinoflagellate zone, but the dinoflagellate subzone is unclear in the absence of closer spaced cuttings samples. *H. heteracanthum* is the most common dinoflagellate (6%) and other significant taxa include *Odontochitina porifera*, *Maduradinium pentagonum* and *Heterosphaeridium* cf *laterobrachius*. The upper *aceras* dinoflagellate zone seems most likely.

Nearshore marine environments are indicated by the dinoflagellate content (9%) and their moderate diversity. Major terrestrial influence is shown by the abundant cuticle and common and diverse spore pollen.

Yellow to light brown spore colours indicate immaturity approaching early marginal maturity for oil.

H 876.0m(swc), 893.5m(swc), 970.0m(swc) : upper *apoxyexinus* Zone

Assignment to the upper *Tricolporites apoxyexinus* Zone of Santonian age is indicated at the top by the absence of younger indicators and confirmed by the dinoflagellate data, and at the base by the absence of older indicators, also confirmed by dinoflagellate data. Within the interval, saccate pollen (mostly *Falcisporites similis*) are common to abundant while spores are also prominent (*Cyathidites* common, *Osmundacidites* frequent). *Amosopollis cruciformis is* very rare (<1%) while *Proteacidites* spp are also very rare (1% and less in contrast to 5-15% above). Minor Permian reworking was seen in all samples.

Amongst the dinoflagellates, the presence of *Isabelidinium belfastense, Amphidiadema denticulata, Chatangiella victoriensis* and *Heterosphaeridium* 20%+ at 876.0m(swc), indicates assignment to the upper *cretacea* dinoflagellate zone, correlative with the upper part of the upper *apoxyexinus* spore-pollen zone. The two deeper samples contain *Isabelidinium cretacea* without younger indicators and are assigned to the lower *cretacea* dinoflagellate zone, correlative with the lower part of the upper *apoxyexinus* spore-pollen zone. At 876.0m, *Heterosphaeridium* dominates (28%) while the two deeper samples contain frequent *Heterosphaeridium* and rare *I. cretacea.*

Environments are nearshore marine becoming more marine towards the top as shown by the low but increasing dinoflagellate content in time (40%, 13% and 10% downhole), and their low, increasing to moderate, diversity. Spores and pollen are abundant and diverse.

Light brown spore colours indicate early marginal maturity for oil generation.

I 1010.0m(swc), 1025m(cutts) : middle *apoxyexinus* Zone

Assignment to the middle *Tricolporites apoxyexinus* Zone of Santonian age is indicated at the top by the downhole influx of *A. cruciformis* (3-5% within this interval, <1% above) and at the base by the absence of older markers. Within the interval, saccate pollen dominate (*Falcisporites* 25-30%, *Microcachryidites* 8-12%, *Podosporites* 1-7%) with frequent spores (*Cyathidites* 9-17%, *Osmundacidites* 4-1%). *Proteacidites* (1-3%) are rare with *A. cruciformis* significant (3-5%). Minor Permian reworking was seen.

Amongst the dinoflagellates, *Isabelidinium rectangularis* occurs and its presence without *I. cretacea* indicates the upper *Odontochitina porifera* Zone. Youngest *Circulodinium deflandrei* occurs at 1010m and is consistent with the mid *apoxyexinus* spore-pollen zone. *Heterosphaeridium* spp are the most consistent dinoflagellate element.

Environments are nearshore marine with significant freshwater lacustrine influence. Dinoflagellates comprise 9% and 7% respectively and are of moderate to low diversity. *Botryococcus* comprises 5% and 3% indicating significant input from freshwater lakes. Spores and pollen are dominant and diverse.

Light brown spore colours indicate marginal maturity for oil but immaturity for gas/condensate.

J 1080m(cutts) : lower *apoxyexinus* Zone

Assignment to the lower *T. apoxyexinus* Zone of Santonian age is indicated at the top and base by the numerical acme of *A. cruciformis* (15%) contrasting with 3-5% immediately above and below. *Cyathidites*, *Falcisporites* and *A. cruciformis* are all common. Minor early Cretaceous reworking was seen.

Dinoflagellates include *Isabelidinium rectangularis* but it may be caved at this point. *Heterosphaeridium* spp are common, and *C. deflandrei* is consistent.

Nearshore marine environments are indicated by the low dinoflagellate content (20%) and low diversity.

Light brown spore colours indicate marginal maturity for oil and immaturity for gas/condensate.

K 1097.0m(swc), 1151.0m(swc), 1177.0m(swc), 1180m(cutts) : upper *mawsonii* Zone

These samples are assigned on the absence of younger markers seen above (the *A. cruciformis* acme at 1080m) and older markers seen below (youngest *A. distocarinatus* at 1219.5m). Within the interval, saccate pollen dominate (*Falcisporites* 5-48%, *Microcachryidites* 2-24%, *Podosporites* 1-30%), with

spores relatively minor and lacking in diversity. Minor Permian and Early Cretaceous reworking was seen. Dinoflagellates are rare and not age diagnostic. Youngest *Aptea* sp occurs at 1180m and is usually intra *apoxyexinus*.

Non-marine and very nearshore marine environments are indicated by the generally very low dinoflagellate content (60%, <1%, 1% and 1%, the last in cuttings) and very low dinoflagellate diversity (mostly one or two species). At 1097.0m the high dinoflagellate content (60%) is anomolous representing just two species and is caused by freak environmental conditons. At 1180m(cutts), the dinoflagellates appear to all be caved. At 1151.0m(swc), abundant *Botryococcus* (52%) suggests a major freshwater lake.

Light brown spore colours indicate marginal maturity for oil but immaturity for gas/condensate.

L **1219.5m(swc), 1250.5m(swc), 1275.0m(swc), 1306m(cutts), 1316.0m(swc), 1328.5m(swc), 1334.0m(swc), 1336.0m(swc), 1364.5m(swc), 1437.0m(swc) : *mawsonii* Zone**

These samples are all assigned to the *Phyllocladidites mawsonii* Zone of Turonian-Coniacian age on youngest consistent *Appendicisporites distocarinatus* at the top and oldest *P. mawsonii* at the base. Oldest consistent *Clavifera triplex* occurs at 1334.0m. Within the interval, saccate pollen continue to dominate (*Falcisporites* 13%-30%, *Microcachryidites* 73%-26%, *Podosporites* 2%-15% and *Phyllocladidites* 1%-21%) with spores generally subordinate. *Dilwynites granulatus* is frequent to common (mostly 10-29%). Very rare Triassic and Permian reworking was seen. Youngest *Camerozonosporites robusta* (1275.0m), *Liliacidites kaitangataensis* and *Senectotetradites varireticulosus* (both at 1334.0m) are consistent with the *mawsonii* zonal assignment.

Of the very rare dinoflagellates, only youngest *Cribroperidinium edwardsii* at 1437.0m is age significant and indicates the *Palaeohystrichophora infusorioides* Zone. Very few dinoflagellates occur in some samples with *Heterosphaeridium* and *Odontochitina operculata* most consistent.

Environments are mixed non-marine and very nearshore marine with dinoflagellate contents dowhole of absent, absent, absent, 1% but in cuttings 2%, 10%, absent, absent, absent and 1%. Those lacking dinoflagellates are non-

marine and several have significant algal content (1219.5m 16%, 1306m 4%, 1334m 5%, 1364.5m 3%) suggesting lacustrine influence. Those containing dinoflagellates are very nearshore marine. Abundant cuticle fragments and abundant and diverse spores and pollen are present throughout.

Light brown spore colours indicate marginal maturity for oil but immaturity for gas/condensate.

M 1452m(cutts), 1515m(cutts) : *distocarinatus* or *mawsonii* Zones

These cuttings samples cannot be confidently assigned to either of these zones. Oldest *P. mawsonii* and *C. triplex* at 1515m suggests assignment to the *mawsonii* Zone, but it could be caved at this point into the *distocarinatus* Zone. Common taxa are *Falcisporites* (23% and 11%), *Microcachryidites* (17% and 10%), *Podosporites* 7% and 20% and *Dilwynites* (17% and 23%). *A. distocarinatus* is consistent throughout while rare spores include *Coptospora pileosa*, *Trilobosporites trioreticulosus* and *Lileacidites kaitangataensis*.

Dinoflagellates are extremely rare but include *C. edwardsii*, indicating the *P. infusorioides* dinoflagellate zone, although these elements could be caved into non-marine section.

Environments appear to be marginally marine with <1% and 1% very low diversity dinoflagellates, but these could be caved. *Botryococcus* is present in both (2% and 7%), suggesting significant lacustrine influence. Vast cuticle and abundant and diverse spore pollen attest to the strong terrestrial influence.

Light brown spore colours indicate marginal maturity for oil, but immaturity for gas/condensate.

N 1575.0m(swc), 1602.0m(swc), 1630.0m(swc), 1667.0m(swc), 1678.0m(swc), 1703.0m(swc), 1719.0m(swc) : *distocarinatus* Zone

Assignment to the *Appendicisporites distocarinatus* Zone of Cenomanian age is indicated at the top and base by *A. distocarinatus* without younger or older markers. Within the interval, several samples are extremely lean to barren (1602.0m, 1667.0m 1703.0m) and cannot be confidently assigned on their assemblages. Amongst the others, saccate pollen generally dominate

(*Falcisporites* and *Microcachryidites*) but two (1678.0m and 1703.0m) are spore dominated and probably represent swamp or swamp margin environments. Minor Permian reworking was noted in several samples.

Dinoflagellates are mostly absent but at 1719m, a single specimen of *C. edwardsii* suggests the *infusorioides* dinoflagellate zone.

Environments are mixed non-marine to brackish with dinoflagellate contents of 1%, barren, absent, barren, absent, barren and <1% dowhhole. High algal content at 1630.0m (10% without dinoflagellates) suggests a freshwater lake while high algal contents at 1575.0m (3%) and 1719.0m (9%) with dinoflagellates suggests brackish lakes with strong freshwater influence. Vast cuticle and tracheid together with dominant and diverse spore pollen indicate very strong terrestrial influence.

Light to mid brown spore colours indicate early maturity for oil and early marginal maturity for gas/condensate.

1749.5m(swc), 1754.5m(swc), 1790.0m(swc), 1813.5m(swc) : indeterminate

These samples are extremely lean and the taxa seen may all comprise mud contamination of these sandy swcs. Neither *A. distocarinatus* nor *Coptospora paradoxa* were seen and so these cannot be assigned to any zones. Saccate pollen are common (mostly *Falcisporites* and *Microcachryidites*), but spores also represent a significant proportion (mostly *Cyathidites* and *Osmundacidites*).

Environments appear to be brackish with dinoflagellates totally absent and spiny acritarchs (*Micrhystridium* and *Veryhachium*) rare. *Botryococcus* is present in most samples, suggesting significant lacustrine influence. However, too few specimens were seen to exclude the possibility of stronger marine influence, or that most of the taxa seen might represent mud contamination of these sandy swcs.

Light to mid brown spore colours indicate early maturity for oil and early marginal maturity for gas/condensate.

IV CONCLUSIONS

At the top, a thick probably incomplete Eocene was sampled in very nearshore marine facies. The Paleocene appears to be missing on an unconformity, but could be present but unsampled in the 86m sample gap.

Beneath this, an apparently complete Late Cretaceous section (Cenomanian to Maastrichtian) occurs in mostly nearshore to occasionally non-marine facies.

The section appears to be early mature for oil only at its base.

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