Exxon Exploration Company

Biostratigraphic Zonation and Paleoecology of the Upper Cretaceous R Reservoir in West Tuna W-39 and West Tuna W-44, Gippsland Basin, Australia

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Geological Services Division
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EXECUTIVE SUMMARY

- Palynology and kerogen analyses of the West Tuna W-39 and W-44 wells provide: 1) a detailed biostratigraphic subdivision of the reservoir section, 2) biostratigraphic events that have local and potentially regional correlatable value, and 3) paleoenvironmental interpretations to better constrain sequence stratigraphic interpretations, facies models, and paleogeographic reconstructions.

- Five of the seven biozones defined for this area (Davies and Farley, 1997) are recognized and can be used for correlation of the R reservoir sands.

- Palynozone are defined on downhole occurrences, where possible, but they also are characterized by influxes and base occurrences, as well as trends in overall assemblage composition.

- The youngest sediments analyzed from 2470 m MD in W-39 and 2945.4 m MD in W-44 are in the Lower Maastrichtian West Tuna Palynozone Mb 1.

- The lowest zone assigned with certainty is the Upper-?Middle Campanian zone Mb 6, which is recognized in W-39 at 2635m.

- The palynological assemblages indicate that deposition of the Upper Cretaceous R reservoir sediments was primarily in a non-marine fluvial setting fluctuating from a humid to somewhat less humid, cool to warm temperate climate. However, there is evidence for some minor marine ingressions, based on occurrences of rare marine dinoflagellate cysts recovered at W-39 in cuttings 2575-2580 m, and at W-44 in SWC 2962.5 m and core sample 3170 m.

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INTRODUCTION

At the request of Esso Australia Ltd. (Dave Moreton), we examined samples from the West Tuna field R reservoir interval from two wells in the Gippsland Basin, Australia. This study presents results of biostratigraphic analyses of cuttings samples from West Tuna W-39, and sidewall cores and cuttings from West Tuna W-44. The stratigraphic section studied comprises the Late Cretaceous Latrobe Group and top of the Golden Beach Group. The stratigraphic breakdown for each well over this interval is summarized on page 2 and discussed in detail in Biostratigraphic Discussion section beginning on page 3

The purpose of the study was:

- to provide a palynologic and biofacies evaluation of the studied intervals,
- to describe both potentially regionally correlative and local (subzonal) biostratigraphic events from the Lower Cretaceous R reservoir interval, and
- to provide paleoenvironmental interpretations to better constrain sequence stratigraphic interpretations, facies models, and paleogeographic reconstructions.

The results of this study are based on analyses of about 100 palynology and kerogen microscope slides from ten W-39 cuttings, and fifteen sidewall core and cuttings samples from W-44.

The identification of correlatable biostratigraphic zones forms the basis of the stratigraphic interpretations of these wells. Where possible these palynozone are defined on downhole occurrences, but they also are characterized by influxes and base occurrences, as well as trends in overall assemblage composition. Each unit is defined as the stratigraphic interval between two distinctive biostratigraphic events. The key biostratigraphic events that define the palynozones are given in the Biostratigraphic Discussion section. The age interpretations for this Late Cretaceous section are approximate, as little independent information has been obtained to correlate the Gippsland spore-pollen, and are those shown on the current Global Cycle Chart (Hardenbol and others, in press).

The age and paleoenvironmental interpretations are based on comparisons with materials from Askin (1990); Burger (1990); Churchhill (1973); Davies (1995); Davies and Farley (1997); Dettman and Jarzen (1990a, 1990b, 1991, 1996); Dettman, Pocknall and others (1990); Germeraad and others (1968); Helby and others (1987); Macphail (1985); Partridge (1973, 1976, 1988); Powell (1992); Stover (1972); Stover and Evans (1973); Stover and Partridge (1971, 1973, 1984); and Wilson (1984, 1988).

Interpretations of paleoecology were made based on observed changes in the spore-pollen (S/P) assemblages and biofacies from kerogen slides. Appendix A following the references, gives a sample-by-sample listing of the distribution of important species. Relative abundance abbreviations used are: EA - extremely abundant; VA - very abundant; A - abundant; C - common; F - few; R - rare; and VR - very rare. Other abbreviations used are: SP - spores and pollen, D - dinoflagellates, A - acritarchs; F - foraminifera.

BIOSTRATIGRAPHIC ZONATION

WEST TUNA W-39

Age	Palynozone	Depth (m MD)
Lower Maastrichtian	Mb 1a Mb 1b	No samples 2470 (highest sample)
	Unassigned (?Mb 1b/2)	2500-2505
Lower Maastrichtian-Upper Campanian	?Mb 3 Mb 3 ?Mb3	2530-2535 2555-2560 2575-2580
Upper Campanian	Mb 4 / ?5 (mixed) Mb ?4 / 5 (mixed)	2595-2600 2615-2620
Upper-Middle? Campanian	Mb 6 ?Mb 6	2635-2640 2650-2655
Middle Campanian	Unassigned (?Mb 7)	2730-2735

WEST TUNA W-44

Age	Palynozone	Depth (m MD)
Lower Maastrichtian	Mb 1a? / b Mb 1b ?Mb 1b	2945.5 2962.5 2995.85
	Unassigned	3031.5, 3046
	?Mb 2	3064.5
Lower Maastrichtian-Upper Campanian	Mb 3 / 4 (mixed)	3090-3095, 3133
Upper Campanian	?Mb 5	3145
	Unassigned	3170, 3189, 3200, 3211
	Unassigned (?Mb 7)	3264
	Unassigned	3284

An isolated specimen of a marine dinoflagellates cysts was recovered at W-39 in cuttings samples 2575-2580 m, and rare dinocysts were noted at W-44 in SWC 2962.5 m and core sample 3170 m (Appendix A) suggesting minor marine influence at, or about these levels.

BIOSTRATIGRAPHIC DISCUSSION

This section describes the results of the biostratigraphic analyses and highlights those event that are potentially of local or regional correlatable value. The zones assigned in this report are those recently developed for the West Tuna field (Davies and Farley, 1997) and may have limited utility outside the area.

WEST TUNA W-39

Interval: **2470-2475 m MD**

Age: **Lower Maastrichtian**

Interval zones:

2470-2475m - palynozone Mb 1b

Palynology:

- palynozone Mb 1 is divided into two subzones. Only subzone Mb 1b is recognized in this well.

- the highest cuttings sample analyzed at 2470-2475 m contains very rare *Gambierina rudata* of Stover and Partridge, 1973, *Triporopollenites sectilis* and *Tetracolporites verrucosus,* rare *Tricolpites gillii,* rare-few *Nothofagidites* spp., frequent *Stereisporites* spp., and common *Proteacidites* spp. (Appendix A) which are considered to indicate the Lower Maastrichtian, subzone Mb 1b.

- the occurrences of common moisture-loving *Proteacidites* spp., fern spores, and *Stereisporites* spp., rare *Gephyrapollenites wahooensis* (tropical-temperate indicator), and rare to few *Nothofagidites* spp. (cool, humid indicator) indicate that the depositional environment was humid and probably temperate.

- zone Mb 1 is recorded from W39 in the section above the reservoir package and above EAL's TLPKN surface.

Interval: **2500-2505 m MD**

Age: **Indeterminate**

Interval zones:

2500-2505m - Unassigned (undifferentiated palynozone Mb 1b / 2)

Palynology:

- the preservation and recovery of fossils in this sample is poor, and this sample contains a mixed assemblage. However, the decrease in abundance of *Nothofagidites* spp. and *Stereisporites* spp., together with continued presence of frequent *Proteacidites* spp. (Appendix A) suggest that this sample is in the Lower Maastrichtian palynozones Mb 1b to Mb 2.

- the slight decrease in numbers of *Nothofagidites* spp. (cool, humid indicator) and moisture-loving *Stereisporites* spp. suggests that the depositional setting of this interval was slightly warmer and perhaps a little less moist than the overlying zone.

Interval: **2530-2580 m MD**

Age: **Lower part of Lower Maastrichtian - upper part of Upper Campanian**

Interval zones:

2530-2535m - palynozone Mb 3?
2555-2560m - palynozone Mb 3
2575-2580m - palynozone Mb 3?

Palynology:

- increase in numbers of *Tricolpites confessus* at 2530-2535 m and slight increase in *Stereisporites* spp., together with common *Proteacidites* spp. (Appendix A) suggest probable penetration of the Lower Maastrichtian - Upper Campanian, palynozone Mb 3.

- the increase in numbers of *Nothofagidites* spp., and occurrences of frequent *Tricolpites confessus* and *Proteacidites* spp., and rare *Tetracolporites verrucosus* at 2555 m (Appendix A) indicates a Lower Maastrichtian - Upper Campanian, palynozone Mb 3.

- the last definitive occurrence of *Tetracolporites verrucosus* at 2575-2580 m (Appendix A) marks the base of palynozone Mb 3 and indicates this sample is no lower than the uppermost part of the Upper Campanian. Although recovery is poor, this sample contains frequent *Nothofagidites* spp. and *Proteacidites* spp., and rare *Stereisporites* spp. and is assigned tentatively to zone Mb 3.

- the increase in *Nothofagidites* spp. (cool, humid indicator) and frequent-rare moisture-loving *Stereisporites* spp. suggests that the depositional setting of this interval was cooler and moist. Recovery of two specimens of an undifferentiated marine dinoflagellate at cuttings sample 2575-2580 m, suggest some minor marine influence at this level, if in place and not caved from above.

Interval: **2595-2620 m MD**

Age: **Upper Campanian**

Interval zones:

2595-2600m - zones Mb 4 / 5?; recovery and preservation poor
2615-2620m - zones Mb 4? / 5; recovery and preservation poor

Palynology:

- the occurrence of common *Cyathidites* spp. at 2595-2600 m, together with common *Proteacidites* spp., and common *Nothofagidites* spp. (Appendix A) is indicative of the Upper Campanian palynozone Mb 4. Because of the presence of frequent-common *Stereisporites* spp., which is a characteristic of zone Mb 5, this samples broadly placed in zones Mb 4 / 5?. Other taxa present that support this assignment are rare to few *Tricolpites confessus* and *Tricolpites gillii*, and very rare *Tricolpites lilliei*.

- the decrease of *Nothofagidites* spp. and increase in amorphous kerogen would typically signal penetration of Mb 5. However, preservation and recovery of fossils is poor, so sample 2615-2620 m is placed in zones Mb 4? / 5. Frequent moisture-loving *Cyathidites* spp., *Stereisporites* spp., and *Proteacidites* spp., and rare *Aequitriradites* spp. also were recorded in this sample (Appendix A).

- the influx of moisture-loving *Cyathidites* spp. at 2595 m, together with frequent moisture-loving *Stereisporites* spp., common-abundant rainforest taxa *Proteacidites* spp., and relatively common *Nothofagidites* spp., which are indicative of a cool, humid environment, suggests deposition took place under cool, humid conditions. The decrease in *Nothofagidites* spp. (cool, humid indicator) at 2615 m indicate that the depositional environment was humid, but slightly warmer than above.

Interval: **2635-2655 m MD**

Age: **Upper - Middle? Campanian**

Interval zones:

2635-2640m - palynozone Mb 6

Palynology:

- the decrease in number of *Proteacidites* spp. and *Stereisporites* spp., and increase in *Nothofagidites* spp., together with a few *Phyllocladidites* spp., trilete spores, and rare *T. gillii* in the two cuttings samples from 2635 to 2655 m (Appendix A), characterize the Upper-Middle? Campanian, zone Mb 6.

- other taxa recorded are *Tricolpites confessus*, *Australopollis obscurus,* and a single (caved?) *Tricolporites lilliei* (Appendix A).

- the increase in *Nothofagidites* spp. and moisture-loving fern spores indicate that the depositional environment was perhaps a littler wetter and slightly cooler than above.

Interval: **2730-2735 m MD**

Age: **Middle Campanian**

Interval zones:

2730-2735m - probably zone Mb 7; poor preservation

Palynology:

- the decrease in number of fern spores, including *Cyathidites* spp. and an increase in *Phyllocladidites* spp., together with frequent-rare *Nothofagidites* spp. and few-rare *Stereisporites* spp. at 2730-2735 m (Appendix A), is characteristic of palynozone Mb 7. Because of poor preservation, this sample is only tentatively placed in Zone Mb 7.

- other taxa recorded consistent with this zonal assignment include *Proteacidites* spp., *Tricolpites confessus*, and *Tricolpites gillii* (Appendix A).

- the decrease in number of moisture-loving fern spores, together with relatively frequent-rare *Nothofagidites* spp. (cool, humid indicator), and an increase in *Phyllocladidites* spp. suggest the depositional setting for this interval is cool, but slightly drier than above.

WEST TUNA W-44

Interval: **2945.5-2995.85 m MD**

Age: **Lower Maastrichtian**

Interval zones:

2945.5m - palynozone Mb 1a? / 1b
2962.5m - palynozone Mb 1b
2995.85m - palynozone Mb 1b / Mb 2.

Palynology:

- the highest SWC sample analyzed at 2945.5 m contains frequent *Stereisporites* spp. and *Proteacidites* spp., and frequent-rare *Nothofagidites* spp. (Appendix A), which are considered to indicate the Lower Maastrichtian, subzone Mb 1a? / b.

- the decrease in number of *Nothofagidites* spp. and frequent-common *Stereisporites* spp. at 2962.5 m (Appendix A) is consistent with an Mb 1b age. This SWC sample contains one dinoflagellate specimen and may indicate minor marine influence at, or near this level.

- the further decrease in *Nothofagidites* spp. and slight increase in *Proteacidites* spp. at 2995.85 typically would signal penetration of zone Mb 2. However, because of the continued common occurrences of *Stereisporites* spp., which is characteristic of palynozone Mb 1b, we retain this sample tentatively in Zone Mb 1b.

- the occurrence of only frequent-rare *Nothofagidites* spp. (cool, humid indicator), but common moisture-loving *Proteacidites* spp., fern spores, and *Stereisporites* spp. indicate that the depositional environment was humid and temperate. The decrease in *Nothofagidites* spp. at of 2962.5 m suggest that the climate may have been slight warmer toward the base of this interval. The presence of one dinoflagellate specimen in this SWC may indicates minor marine influence at, or near this level, if in place.

Interval: **3031.5-3046 m MD**

Age: **Lower Maastrichtian, based on age of overlying and underlying strata**

Interval zones:

3031.5m - Unassigned (poor recovery and preservation)

Palynology:

- spores and pollen grains are poorly preserved and very sparse in these samples (Appendix A).

Interval: **3064.5 m MD**

Age: **Lower Maastrichtian**

Interval zones:

3064.5m - palynozone Mb 2?

Palynology:

- the decrease of *Stereisporites* spp. and further decrease of *Nothofagidites* spp. in core chip sample 3064.5 m, relative to fossiliferous samples above, is characteristic of the Lower Maastrichtian palynozone Mb 2. This sample, although poorly preserved contains a palynomorph assemblage similar to that of Zone Mb 2.

- other taxa recorded are *Tricolpites confessus, Tricolpites gillii, Tetracolporites verrucosus,* and *Gambierina rudata* (Appendix A).

- the decrease in moisture-loving *Stereisporites* spp. and fern spores, and the further decrease of *Nothofagidites* spp. in this sample, suggest the depositional setting was warmer and perhaps slightly drier than above.

Interval: **3090-3133 m MD**

Age: **Lower part of Lower Maastrichtian - upper part of Upper Campanian**

Interval zones:

3090-3133m - mixed assemblage of zones Mb 3 /4

Palynology:

- the marked increase of *Nothofagidites* spp. at 3090-3095 and 3133 m, together with common *Proteacidites* spp., and few-rare *Stereisporites* spp., (Appendix A) would indicates a Lower Maastrichtian - Upper Campanian, palynozone Mb 3. However, there is also and increase in *Cyathidites* spp., which characterizes zone Mb 4. Therefore, we assign this interval broadly to the Mb 3 / 4 zones.

- *Tetracolporites verrucosus*, *Tricolpites gillii,* and *Tricolpites confessus* also were noted in these samples (Appendix A).

- the influx of common *Nothofagidites* spp. (cool, humid indicator) and increase in fern and moss spores suggests that the depositional setting of this interval was cool and moderately moist.

Interval: **3145 m MD**

Age: **Probably Upper Campanian**

Interval zones:

3145m - palynozone Mb 5?

Palynology:

- the marked decrease in *Nothofagidites* spp., and a slight decrease in number of *Proteacidites* spp. at 3145 m (Appendix A) characterizes the Upper Campanian, palynozone Mb 5. However, the characteristic increase in amorphous kerogen noted in other well in the area, was note recorded at this level, so the assignment to zone Mb 5 is tentative.

- other taxa recorded are rare *Gambierina rudata* and *G. edwardsii* of Stover and Partridge 1973, a few fern spores, and frequent to common *Phyllocladidites* spp. (Appendix A). ?*Tetracolporites verrucosus*, which typically is not seen below zone Mb 3, was also recorded in this sample.

- the decrease in number of *Nothofagidites* spp. (cool, humid indicator), and frequent moisture-loving fern spores indicate that the depositional environment was humid, but perhaps slightly warmer than above.

Interval: **3170-3211 m MD**

Age: **Upper - Middle? Campanian, based on overlying and underlying strata**

Interval zones:

3170-3211m - Unassigned

Palynology:

- spore-pollen are sparse and poorly preserved in this interval.

- rare marine dinoflagellate cysts occur at 3170 m, suggesting some marine influence at this level

Interval: **3264 m MD**

Age: **Probably Middle Campanian**

Interval zones:

3264m - Unassigned (possibly Mb 7)

Palynology:

- rare fern spores, including *Cyathidites* spp. and an increase in *Phyllocladidites* spp., together with frequent *Proteacidites* spp. and very rare to barren *Stereisporites* spp. at this level (Appendix A) is consistent with palynozone Mb 7. Since the preservation is poor, this sample is only tentatively placed in Mb 7.

- other taxa recorded from this interval include *Tricolpites confessus, Tricolpites gillii,* and *Tricolporites lilliei.*

- the decrease in number of moisture-loving fern spores, together with rare *Nothofagidites* spp. (cool, humid indicator) suggest the depositional setting for this interval is slightly drier than above.

Interval: **3284 m MD**

Age: **Middle Campanian, based on age of overlying strata**

Interval zones:

3284m - Unassigned

Palynology:

- spore-pollen are very rare and poorly preserved in this samples.

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APPENDIX A

BIOSTRATIGRAPHY AND PALEOENVIRONMENTAL DATA

WEST TUNA W-39

Palynozone Mb 1b (Lower Maastrichtian)
(2470-2475 m MD)

2470-2475 m cuttings

Paleoenvironment: Nonmarine **(subzone Mb 1b)**
Kerogen: 1-2% amorph; 90-95% woody/coaly (dk); 5% biodeg terr.; 2-3% S/P
Spore/pollen (A); Dinoflagellates (barren); Pyrite (R?); fair preserv.
Tricolpites confessus (SP) (R)
Tricolpites gillii (SP) (R)
Triporopollenites sectilis (VR)
Tetracolporites verrucosus (SP) (base Upper T. lilliei) (VR)
Tricolporites lilliei (SP) (T. longus-T. lilliei) (VR)
Gambierina rudata (SP) (VR)
Proteacidites spp. (SP, moisture-loving) (C-F)
Nothofagidites spp. (SP, cool, humid indicator) (R-F)
Nothofagidites cf. endurus (SP) (VR)
Nothofagidites cf. senectus (SP) (VR)
Gephyrapollenites wahooensis (SP, tropical-temperate indicator) (L.L.balmei-T. lilliei) (VR) 11
Araucariacites spp. (SP) (R)
Phyllocladidites spp. (SP) (C)
Phyllocladidites mawsonii (SP) (R)
Phyllocladidites microsaccatus (SP) (F)
Stereisporites antiquasporites (SP, moisture-loving) (R-F)
Trilete spores ornamented (SP, moisture-loving) (R)
Herkosporites elliottii (VR)
Lycopodium spp. (R)
Cyathidites spp. (SP) (VR)
Laevigatosporites spp. (SP) (F)

Indeterminate
(2500-2505 m MD)

2500-2505 m cuttings

Paleoenvironment: Nonmarine **(zones ?Mb 1b / 2; poor recovery)**
Kerogen: 1-2% amorph; 90-95% woody/coaly (dk); 5% biodeg terr.; 2-3% S/P
Spore/pollen (C-R, decr.); Dinoflagellates (barren); Pyrite (R?); poor preserv./recovery
Tricolpites confessus (SP) (R)
Tricolporites lilliei (SP) (T. longus-T. lilliei) (VR)
Tetracolporites verrucosus (SP) (base Upper T. lilliei) (VR) 11
Gambierina rudata (SP) (VR)
Proteacidites spp. (SP, moisture-loving) (F)
Nothofagidites spp. (SP, cool, humid indicator) (R)
Nothofagidites cf. endurus (SP) (VR-R)
Nothofagidites cf. senectus (SP) (VR)
Australopollis obscurus (SP) (R-VR)
Araucariacites spp. (SP) (R)
Phyllocladidites spp. (SP) (C-F)
Phyllocladidites mawsonii (SP) (R)
Phyllocladidites microsaccatus (SP) (F)
Stereisporites antiquasporites (SP, moisture-loving) (R)
Trilete spores ornamented (SP, moisture-loving) (R)
Lycopodium spp. (R)
Cyathidites spp. (SP) (VR)
Laevigatosporites spp. (SP) (F)

Probably Palynozone Mb 3 (lower part of Lower Maastrichtian-upper part of Upper Campanian)
(2530-2535 m MD)

2530-2535 m cuttings

Paleoenvironment: Nonmarine **Mb 3?**
Kerogen: 3-5% amorph (incr.); 85-90% woody/coaly; 5% biodeg terr.; 2-3% S/P
Spore/pollen (C); Dinoflagellates (barren); Pyrite (R?); fair-poor preserv. (under oxidized))
Tricolpites confessus (SP) (F, increase)
Tricolpites gillii (SP) (VR)
Tetracolporites verrucosus (SP) (base Upper T. lilliei) (VR)
Proteacidites spp. (SP, moisture-loving) (F-C)
Nothofagidites spp. (SP, cool, humid indicator) (R)
Australopollis obscurus (SP) (VR)
Gephyrapollenites wahooensis (SP, tropical-temperate indicator) (L.L.balmei-T. lilliei) (VR) 1
Phyllocladidites spp. (SP) (F)
Phyllocladidites mawsonii (SP) (R)
Phyllocladidites microsaccatus (SP) (F)
Stereisporites antiquasporites (SP, moisture-loving) (F-R, slight increase)
Stereisporites regium (SP) (VR)
Cyathidites spp. (SP) (VR)
Gleicheniidites spp. (VR)
Laevigatosporites spp. (SP) (F)

Palynozone Mb 3 (lower part of Lower Maastrichtian-upper part of Upper Campanian)
(2555-2560 m MD)

2555-2560 m cuttings

Paleoenvironment: Nonmarine **Mb 3**
Kerogen: 3-5% amorph (incr.); 85-90% woody/coaly; 5% biodeg terr.; 2-3% S/P
Spore/pollen (C); Dinoflagellates (barren); Pyrite (R?); fair-poor preserv. (under oxidized))
Tricolpites confessus (SP) (R-F)
Tetracolporites verrucosus (SP) (base Upper T. lilliei) (VR-R)
Proteacidites spp. (SP, moisture-loving) (F-R)
Nothofagidites spp. (SP, cool, humid indicator) (F, slight increase)
Nothofagidites cf. endurus (SP) (VR-R)
Nothofagidites cf. senectus (SP) (VR-R)
Australopollis obscurus (SP) (VR)
Araucariacites spp. (SP) (R)
Phyllocladidites spp. (SP) (F-C)
Phyllocladidites mawsonii (SP) (R)
Phyllocladidites microsaccatus (SP) (F)
Stereisporites antiquasporites (SP, moisture-loving) (F, ?some cavings, based on color)
Stereisporites regium (SP) (VR)
Trilete spores ornamented (SP, moisture-loving) (R)
Lycopodium spp. (R)
Cyathidites spp. (SP) (VR)
Gleicheniidites spp. (R-F)
Laevigatosporites spp. (SP) (F)

Probably Palynozone Mb 3 (lower part of Lower Maastrichtian-upper part of Upper Campanian)
(2575-2580 m MD)

2575-2580 m cuttings

Paleoenvironment: **Nonmarine-?Estuarine Mb 3?; poor recovery**
Kerogen: 3-5% amorph (incr.); 85-90% woody/coaly (dk); 5% biodeg terr.; 2-3% S/P
Spore/pollen (C-F); Dinoflagellates (ER, cavings?); Pyrite (R?); poor preserv./recovery
Dino indeter. (Cleistosphaeridium-type) (VR)
Tricolpites confessus (SP) (R)
Tricolpites gillii (SP) (VR)
Tetracolporites verrucosus (SP) (base Upper T. lilliei) (VR) 11
Proteacidites spp. (SP, moisture-loving) (F-R)
Nothofagidites spp. (SP, cool, humid indicator) (F-R)
Nothofagidites cf. senectus (SP) (VR-R)
Gephyrapollenites wahooensis (SP, tropical-temperate indicator) (L.L.balmei-T. lilliei) (VR) 1
Australopollis obscurus (SP) (VR-R)
Phyllocladidites spp. (SP) (F)
Phyllocladidites mawsonii (SP) (R)
Phyllocladidites microsaccatus (SP) (F-R)
Stereisporites antiquasporites (SP, moisture-loving) (R-F)
Cyathidites spp. (SP) (R)
Latrobosporites ohaiensis (SP) (VR)
Lycopodium spp. (VR)

Gleicheniidites spp. (R)
Laevigatosporites spp. (SP) (R)

Palynozone Mb 4/5 (Upper Campanian)
(2595-2620 m MD)

2595-2600 m cuttings

Paleoenvironment: Nonmarine **Mb 4/5?; mixed assemblage**
Kerogen: 2-3% amorph; 90-92% woody/coaly (dk); 5% biodeg terr.; 2-3% S/P
Spore/pollen (C-A); Dinoflagellates (barren); Pyrite (R-F?); poor preserv./recovery
Tricolpites confessus (SP) (R)
Tricolpites gillii (SP) (VR-R)
Tetracolporites verrucosus (SP) (base Upper T. lilliei) (VR, caved?) 1
Tricolporites lilliei (SP) (T. longus-T. lilliei) (VR)
Triporopollenites sectilis (SP) (base consistent Upper T. lilliei) (VR)
Gambierina rudata (SP) (VR)
Proteacidites spp. (SP, moisture-loving) (F-C, increase)
Nothofagidites spp. (SP, cool, humid indicator) (F-C)
Nothofagidites senectus (SP) (VR-R)
Gephyrapollenites wahooensis (SP, tropical-temperate indicator) (L.L.balmei-T. lilliei) (VR) 1
Araucariacites spp. (SP) (R)
Phyllocladidites spp. (SP) (C)
Phyllocladidites mawsonii (SP) (R)
Phyllocladidites microsaccatus (SP) (F-C)
Stereisporites antiquasporites (SP, moisture-loving) (F)
Stereisporites regium (SP) (VR)
Lycopodium spp. (VR)
Cyathidites spp. (SP) (F, increase)
Latrobosporites ohaiensis (SP) (R)
Gleicheniidites spp. (R)
Herkosporites elliottii (VR)
Laevigatosporites spp. (SP) (F)
cf. Aequitriradites sp. (SP) (VR)

2615-2620 m cuttings

Paleoenvironment: Nonmarine **Mb 5?**
Kerogen: 3-5% amorph; 90% woody/coaly (dk); 5% biodeg terr.; 3-5% S/P
Spore/pollen (C); Dinoflagellates (barren); Pyrite (R-F?); poor-fair preserv./recovery
Tricolpites confessus (SP) (R)
Tricolpites gillii (SP) (VR)
Gambierina cf. rudata (SP) (VR)
Proteacidites spp. (SP, moisture-loving) (F, slight decrease from above)
Nothofagidites spp. (SP, cool, humid indicator) (R, decrease)
Phyllocladidites spp. (SP) (C)
Phyllocladidites mawsonii (SP) (R)
Phyllocladidites microsaccatus (SP) (F-C)
Stereisporites antiquasporites (SP, moisture-loving) (F)
Stereisporites regium (SP) (VR)
Cyathidites spp. (SP) (F-R)
Latrobosporites ohaiensis (SP) (VR)
Lycopodium spp. (VR)
Gleicheniidites spp. (R-F, incr.)
Aequitriradites sp. (pustulate/spinose) (SP) (VR)

Palynozone Mb 6 (Upper-Middle? Campanian)
(2635-2655 m MD)

2635-2640 m cuttings

Paleoenvironment: Nonmarine **Mb 6**
Kerogen: 2-3% amorph; 90-92% woody/coaly (dk); 5% biodeg terr.; 3-5% S/P
Spore/pollen (C); Dinoflagellates (barren); Pyrite (R?); fair preserv.
Tricolpites confessus (SP) (R)
Tricolpites gillii (SP) (VR-R)
Proteacidites spp. (SP, moisture-loving) (R, decrease)
Nothofagidites spp. (SP, cool, humid indicator) (R-F)
Nothofagidites cf. endurus (SP) (VR-R)
Australopollis obscurus (SP) (R)
Phyllocladidites spp. (SP) (C)
Phyllocladidites mawsonii (SP) (F)
Phyllocladidites microsaccatus (SP) (F-C)
Stereisporites antiquasporites (SP, moisture-loving) (R, decrease)
Trilete spores ornamented (SP, moisture-loving) (F)

Lycopodium spp. (VR)
Cyathidites spp. (SP) (F)
Latrobosporites ohaiensis (SP) (VR)
Gleicheniidites spp. (R-F)
Laevigatosporites spp. (SP) (F, incr)
Aequitriradites sp. (SP) (VR)

2650-2655 m cuttings

Paleoenvironment: Nonmarine **Mb 6?**
Kerogen: 3-5% amorph; 88-90% woody/coaly (dk); 5-10% biodeg terr.; 3-5% S/P
Spore/pollen (C); Dinoflagellates (barren); Pyrite (R-F?); fair preserv.
Tricolpites confessus (SP) (R-F)
Tricolpites gillii (SP) (VR-R)
Tricolporites lilliei (SP) (T. longus-T. lilliei) (VR) 105/9.4*
Tetracolporites verrucosus (SP) (base Upper T. lilliei) (ER, broken, caved?) 1
Proteacidites spp. (SP, moisture-loving) (R)
Gambierina rudata (SP) (VR)
Nothofagidites spp. (SP, cool, humid indicator) (R)
Gephyrapollenites wahooensis (SP, tropical-temperate indicator) (L.L.balmei-T. lilliei) (VR) 1
Phyllocladidites spp. (SP) (C)
Phyllocladidites mawsonii (SP) (R)
Phyllocladidites microsaccatus (SP) (F-C)
Stereisporites antiquasporites (SP, moisture-loving) (VR)
Trilete spores ornamented (SP, moisture-loving) (F)
Herkosporites elliottii (VR)
Lycopodium spp. (R)
Cyathidites spp. (SP) (F)
Gleicheniidites spp. (R)
Laevigatosporites spp. (SP) (F)

Indeterminate (Prob. Palynozone Mb 7 (Middle Campanian) (2730-2735 m MD)

2730-2735 m cuttings

Paleoenvironment: Nonmarine **Mb 7?**
Kerogen: 1-2% amorph; 90-95% woody/coaly (dk); 3-5% biodeg terr.;3-5% S/P
Spore/pollen (C); Dinoflagellates (barren); Pyrite (R?); poor preserv.
Tricolpites spp. (pachyexinus-type) (VR-R)
Tricolpites confessus (SP) (VR)
Proteacidites spp. (SP, moisture-loving) (R)
Nothofagidites spp. (SP, cool, humid indicator) (R-F)
Nothofagidites cf. endurus (SP) (VR)
Araucariacites spp. (SP) (R-F)
Phyllocladidites spp. (SP) (F-C)
Phyllocladidites mawsonii (SP) (R)
Phyllocladidites microsaccatus (SP) (F-C)
Stereisporites antiquasporites (SP, moisture-loving) (VR, decrease)
Stereisporites regium (SP) (VR)
Trilete spores ornamented (SP, moisture-loving) (R, decrease)
Herkosporites elliottii (VR)
Lycopodium spp. (VR)
Cyathidites spp. (SP) (R, decrease)
Gleicheniidites spp. (VR)
Laevigatosporites spp. (SP) (R, decrease)

Palynozone Mb 1 (Lower Maastrichtian)
(2945.5-?2995.5 m MD)

2945.5 m SWC
Paleoenvironment: Nonmarine **(subzone Mb 1a?/b)**
Kerogen: 1% amorph; 90-92% woody/coaly (dk); 3-8% biodeg terr./herb; 5-10% S/P
Spore/pollen (C-A); Dinoflagellates (barren); Pyrite (R?); poor preserv.
Tricolpites confessus (SP) (R)
Tricolpites gillii (SP) (VR-R)
Proteacidites spp. (SP, moisture-loving) (F)
Nothofagidites spp. (SP, cool, humid indicator) (F-R)
Nothofagidites cf. endurus (SP) (VR-R)
Gephyrapollenites wahooensis (SP, tropical-temperate indicator) (L.L.balmei-T. lilliei) (VR) 1
Araucariacites spp. (SP) (R-F)
Phyllocladidites spp. (SP) (C)
Phyllocladidites mawsonii (SP) (F)
Phyllocladidites microsaccatus (SP) (F)
Stereisporites antiquasporites (SP, moisture-loving) (F)
Trilete spores ornamented (SP, moisture-loving) (C)
Gleicheniidites spp. (SP) (VR)
Camarozonosporites spp. (SP) (VR)
Latrobosporites ohaiensis (SP) (R)
Lycopodiumsporites spp. (SP) (R-F)
Baculatisporites spp. (SP) (R)
Herkosporites elliottii (VR)
Cyathidites spp. (SP) (R)
Laevigatosporites spp. (SP) (R)

2962.5 m SWC
Paleoenvironment: **Nonmarine-?Estuarine (subzone Mb 1b)**
Kerogen: <1% amorph; 95% woody/coaly (dk); 1-2% biodeg terr./herb; 5-8% S/P
Spore/pollen (C-A); Dinoflagellates (ER); Pyrite (F-R?); poor preserv.
Dino indeterminate (num, pointed spines) (VR) -93.5/10
Tricolpites confessus (SP) (VR)
Tricolpites longus (VR)
Tricolpites gillii (SP) (R-VR)
Proteacidites spp. (SP, moisture-loving) (F-C)
Nothofagidites spp. (SP, cool, humid indicator) (VR-R, decrease)
Gephyrapollenites wahooensis (SP, tropical-temperate indicator) (L.L.balmei-T. lilliei) (VR) 1
Phyllocladidites spp. (SP) (F-C)
Phyllocladidites mawsonii (SP) (F)
Phyllocladidites microsaccatus (SP) (F)
Stereisporites antiquasporites (SP, moisture-loving) (C-F)
Stereisporites regium (SP) (VR-R)
Trilete spores ornamented (SP, moisture-loving) (C)
Camarozonosporites spp. (SP) (R)
Latrobosporites ohaiensis (SP) (F)
Lycopodiumsporites spp. (SP) (R-F)
Baculatisporites spp. (SP) (R)
Herkosporites elliottii (VR)
Cyathidites spp. (SP) (R)
Laevigatosporites spp. (SP) (R)

2995.85m core chip
Paleoenvironment: Nonmarine-?Estuarine **(subzone Mb 1b/?2)**
Kerogen: 2-5% amorph; 85% woody/coaly (dk); 8-10% biodeg terr./herb; 5-8% S/P
Spore/pollen (VA); Dinoflagellates (barren); Pyrite (F?); fair preserv.
Tricolpites confessus (SP) (VR)
Tricolpites longus (VR) 11 +-103/10.8*
Tricolpites gillii (SP) (R-F?)
Tetracolporites verrucosus (SP) (base Upper T. lilliei) (VR) 1
Proteacidites spp. (SP, moisture-loving) (C)
Proteacidites reticuloconcavus (T. longus-U. T. liliei) (VR) 96/13.5
Nothofagidites spp. (SP, cool, humid indicator) (VR)
Phyllocladidites spp. (SP) (F-C)
Phyllocladidites mawsonii (SP) (F)
Phyllocladidites microsaccatus (SP) (F)
Stereisporites antiquasporites (SP, moisture-loving) (C)
Stereisporites regium (SP) (VR-R)
Trilete spores ornamented (SP, moisture-loving) (C)

Camarozonosporites spp. (SP) (R)
Latrobosporites ohaiensis (SP) (R)
Lycopodiumsporites spp. (SP) (R)
Baculatisporites spp. (SP) (VR)
Herkosporites elliottii (R)
Cyathidites spp. (SP) (R-F)
Laevigatosporites spp. (SP) (F)

Indeterminate
(3031.5-3046 m MD)

3031.5 m SWC

Paleoenvironment: Nonmarine
Kerogen: <1% amorph; 95-98% woody/coaly (dk); 1-2% biodeg terr./herb; 1% S/P
Spore/pollen (R-F, very sparse); Dinoflagellates (barren); Pyrite (F?); poor preserv.;
Tricolpites gillii (SP) (VR)
Proteacidites spp. (SP, moisture-loving) (R)
Nothofagidites spp. (SP, cool, humid indicator) (VR)
Phyllocladidites spp. (SP) (R)
Phyllocladidites mawsonii (SP) (R)
Gleicheniidites spp. (SP) (VR)
Lycopodiumsporites spp. (SP) (VR)
Cyathidites spp. (SP) (VR)

3046 m SWC

Paleoenvironment: Nonmarine
Kerogen: Sparse
Spore/pollen (VR); Dinoflagellates (barren); Pyrite (F?); v. poor preserv.;
Phyllocladidites spp. (SP) (VR)
Stereisporites antiquasporites (SP, moisture-loving) (VR)

Possibly Palynozone Mb 2 (Lower Maastrichtian)
(3064.5 m MD)

3064.5 m core chip

Paleoenvironment: Nonmarine **(Zone Mb 2)**
Kerogen: 2-5% amorph; 85-90% woody/coaly (dk); 8-10% biodeg terr./herb; 1-2% S/P
Spore/pollen (F-C); Dinoflagellates (barren); Pyrite (F-R?); v poor preserv.;
Tricolpites confessus (SP) (VR)
cf. Tricolpites longus (T. longus-Upr T. lilliei) (VR)
Tricolpites gillii (SP) (VR-R)
Tetracolporites verrucosus (SP) (base Upper T. lilliei) (VR)
Gambierina rudata (SP) (VR-R)
Proteacidites spp. (SP, moisture-loving) (F)
Nothofagidites spp. (SP, cool, humid indicator) (R-VR)
Phyllocladidites spp. (SP) (F)
Phyllocladidites mawsonii (SP) (R)
Phyllocladidites microsaccatus (SP) (R)
Stereisporites antiquasporites (SP, moisture-loving) (R-VR, decrease)
Camarozonosporites spp. (SP) (VR)
Latrobosporites ohaiensis (SP) (VR)
Lycopodiumsporites spp. (SP) (R)
Cyathidites spp. (SP) (R)
Laevigatosporites spp. (SP) (R)

Probably Palynozone Mb 3 / 4 (Lower Maastrichtian-Upper Campanian)
(3090-3133 m MD)

3090-3095 m cuttings

Paleoenvironment: Nonmarine **(subzone Mb 3/4)**
Kerogen: 2-5% amorph; 80-82% woody/coaly (dk); 15-20% biodeg terr./herb; 3-5% S/P
Spore/pollen (VA); Dinoflagellates (barren); Pyrite (F?); poor-fair preserv.;
Tricolpites spp. (pachyexinus-type) (VR-R)
Tricolpites confessus (SP) (F, increase)
Tricolpites gillii (SP) (VR)
Tetracolporites verrucosus (SP) (base Upper T. lilliei) (VR) 1
Gambierina edwardsii (SP) (R) +94.5/7.8
Proteacidites spp. (SP, moisture-loving) (F)
Nothofagidites spp. (SP, cool, humid indicator) (F, increase)
Australopollis obscurus (SP) (R)
Gephyrapollenites wahooensis (SP, tropical-temperate indicator) (L.L.balmei-T. lilliei) (VR) 1
Phyllocladidites spp. (SP) (C)
Phyllocladidites mawsonii (SP) (F)

Phyllocladidites microsaccatus (SP) (F-C)
Stereisporites antiquasporites (SP, moisture-loving) (F)
Stereisporites regium (SP) (VR)
Gleicheniidites spp. (SP) (F-C)
Camarozonosporites spp. (SP) (R)
Latrobosporites ohaiensis (SP) (R)
Lycopodiumsporites spp. (SP) (F)
Baculatisporites spp. (SP) (R)
Cyathidites spp. (SP) (F-C, increase)
Laevigatosporites spp. (SP) (R)
Aequitriradites sp. (pustulate/spinose) (SP) (VR)

3133m

Paleoenvironment: Nonmarine **(subzone Mb 3/?4)**
Kerogen: 2-3% amorph; 70-80% woody/coaly (dk); 15-20% biodeg terr./herb;5-10% S/P
Spore/pollen (VA); Dinoflagellates (barren); Pyrite (F?); poor-fair preserv.;
Tricolpites confessus (SP) (VR)
Tricolpites gillii (SP) (VR)
Tetracolporites verrucosus (SP) (base Upper T. lilliei) (VR-R) -96/9.3
Tricolporites lilliei (SP) (T. longus-T. lilliei) (VR)
Gambierina rudata (SP) (VR-R)
Proteacidites spp. (SP, moisture-loving) (F)
Nothofagidites spp. (SP, cool, humid indicator) (A)
Australopollis obscurus (SP) (VR)
Gephyrapollenites wahooensis (SP, tropical-temperate indicator) (L.L.balmei-T. lilliei) (VR) 1
Araucariacites spp. (SP) (R)
Phyllocladidites spp. (SP) (F)
Phyllocladidites mawsonii (SP) (R-F)
Phyllocladidites microsaccatus (SP) (R)
Stereisporites antiquasporites (SP, moisture-loving) (VR-R)
Gleicheniidites spp. (SP) (VR)
Herkosporites elliottii (VR)
Cyathidites spp. (SP) (R-F)
Laevigatosporites spp. (SP) (F)

Probably Palynozone Mb 5? (Upper Campanian)
(3145 m MD)

3145m

Paleoenvironment: Nonmarine **(subzone Mb 5?)**
Kerogen: <1% amorph; 85-90% woody/coaly (dk); 3-5% biodeg terr./herb (darker); 2-3% S/P (darker)
Spore/pollen (F); Dinoflagellates (barren); Pyrite (R?); poor preserv./recovery
Tricolpites confessus (SP) (VR)
Tricolpites gillii (SP) (VR)
?Tetracolporites verrucosus (SP) (base Upper T. lilliei) (R) 103.5/15.5
Gambierina rudata (SP) (VR)
Gambierina edwardsii (SP) (VR) -96.8/9.5
Proteacidites spp. (SP, moisture-loving) (F-C, increase)
Nothofagidites spp. (SP, cool, humid indicator) (R-F, decrease)
Araucariacites spp. (SP) (R-F)
Phyllocladidites spp. (SP) (F-R, decr))
Phyllocladidites mawsonii (SP) (R)
Phyllocladidites microsaccatus (SP) (V)
Stereisporites antiquasporites (SP, moisture-loving) (ER)
Latrobosporites ohaiensis (SP) (VR)
Lycopodiumsporites spp. (SP) (R-F)
Baculatisporites spp. (SP) (VR)
Cyathidites spp. (SP) (R-F)
Laevigatosporites spp. (SP) (R-F)

Indeterminate
(3170-3284 m MD)

3170m

Paleoenvironment: **Estuarine-shallow marine**
Kerogen: <1% amorph; 92-98% woody/coaly (dk); 1% biodeg terr./herb; <1% S/P
Spore/pollen (R); Dinoflagellates (rare); Pyrite (R?); poor-fair preserv.;
Dino indeterminate (apical horn) (VR) 11
Cleistosphaeridium-type (VR) 11 +94.8/13.9;94.7/14.4
Nothofagidites spp. (SP, cool, humid indicator) (VR)
Phyllocladidites spp. (SP) (VR)

3189m

Paleoenvironment: Nonmarine
Kerogen: <1% amorph; 95-98% woody/coaly (dk); 1% biodeg terr./herb; <1% S/P
Spore/pollen (R); Dinoflagellates (barren); Pyrite (R?); poor-fair preserv.;
Phyllocladidites spp. (SP) (VR)
Cyathidites spp. (SP) (R)

3200m

Paleoenvironment: Nonmarine
Kerogen: 5% amorph; 90-95% woody/coaly (dk); 1-2% biodeg terr./herb; 1% S/P
Spore/pollen (VR); Dinoflagellates (ER); Pyrite (R?); poor-fair preserv.;
Cordosphaeridium-type (ER)
Gambierina rudata (SP) (VR)
Proteacidites spp. (SP, moisture-loving) (VR)
Phyllocladidites spp. (SP) (VR)
Cyathidites spp. (SP) (R)

3211m

Paleoenvironment: Nonmarine
Kerogen: 5% amorph; 90-95% woody/coaly (dk); 1% biodeg terr./herb; 1-2% S/P
Spore/pollen (F); Dinoflagellates (barren); Pyrite (R?); poor preserv.;
Tricolpites confessus (SP) (VR)
Proteacidites spp. (SP, moisture-loving) (VR)
Phyllocladidites spp. (SP) (F)
Phyllocladidites mawsonii (SP) (R-F)
Phyllocladidites microsaccatus (SP) (R)
Stereisporites antiquasporites (SP, moisture-loving) (VR)
Gleicheniidites spp. (SP) (R)
Latrobosporites ohaiensis (SP) (VR)
Cyathidites spp. (SP) (R)

3264m

Paleoenvironment: Nonmarine **Zone Mb 7?**
Kerogen: <1% amorph; 80-85% woody/coaly (dk); 15-10% biodeg terr./herb; 4-5% S/P
Spore/pollen (F-C); Dinoflagellates (barren); Pyrite (R?); poor preserv.;
Tricolpites spp. (VR-R)
Tricolpites confessus (SP) (VR)
Tricolpites gillii (SP) (VR)
Tricolporites lilliei (SP) (T. longus-T. lilliei) (VR)
Proteacidites spp. (SP, moisture-loving) (F, increase)
Nothofagidites spp. (SP, cool, humid indicator) (VR)
Phyllocladidites spp. (SP) (F-C, increase)
Phyllocladidites mawsonii (SP) (F)
Phyllocladidites microsaccatus (SP) (F)
Gleicheniidites spp. (SP) (R)
Latrobosporites ohaiensis (SP) (VR)
Lycopodiumsporites spp. (SP) (R)
Cyathidites spp. (SP) (R)
Aequitriradites sp. (pustulate/spinose) (SP) (VR)

3284m

Paleoenvironment: Nonmarine
Kerogen: 2-4% amorph; 90-95% woody/coaly (dk); 1-2% biodeg terr./herb; <1% S/P
Spore/pollen (VR); Dinoflagellates (barren); Pyrite (R?); poor preserv.;
Proteacidites spp. (SP, moisture-loving) (VR)
Phyllocladidites spp. (SP) (VR)
Laevigatosporites spp. (SP) (VR)