EXXON EXPLORATION COMPANY

Palynostratigraphic Zonation and Paleoenvironments of the Turrum-6 Well, Gippsland Basin, Australia

Thomas D. Davies

TECHNOLOGY DEPARTMENT
GLOBAL STUDIES - GEOLOGICAL SERVICES DIVISION
BIOSTRATIGRAPHY SECTION
EEC.19A.BIO.96
MAY, 1996

BIOSTRATIGRAPHY REPORT

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TECHNOLOGY DEPARTMENT
GLOBAL STUDIES/DATABASE DIVISION

April 30, 1996

Mr. Brodie Thomson
Esso Australia Limited
360 Elizabeth Street
Melbourne, Victoria
Australia 3000

Attn: Peter Glenton

Dear Brodie:

Attached are three copies of the biostratigraphy report "Palynostratigraphic Zonation and Paleoenvironments of the Turrum-6 Well, Gippsland Basin, Australia" (EEC.19A.BIO.96) by Thomas D. Davies. This report summarizes the results of examination of the palynologic assemblages and biofacies in sidewall core samples from the Turrum-6 Well. This work was originally requested by Peter Glenton.

The purposes of this palynologic study focused on 1) stratigraphic control based on the age/stratigraphic position of sidewall core samples relative to Exxon's Gippsland Basin palynological zonation and 2) constraints on depositional environments. The section studied from 2144 to 2819 mKB ranges in age from basalmost lower Eocene to Upper Maastrichtian.

Nine zones were recognized in this well from the lower Eocene to Upper Maastrichtian. The section from 2144 to 2439 mKB is considered marginal marine to marine, based on abundance, type, and diversity of dinoflagellate cysts. From 2466 to 2496.5 m, no marine microfossils were recovered and this section is interpreted to be nonmarine. Samples 2535 and 2540 m contain abundant dinocysts, but low diversity suggesting a marginal marine environment of deposition. The section from 2559 to 2695.5 m is barren or nearly barren of marine form microfossils and is considered to be nonmarine. Marine dinoflagellates reappear in relatively small numbers in samples in the basal part of the well from 2697.5 to 2819 m and suggest some marine influences at these depths.

This report is unclassified, with all proprietary interpretations removed, so it may be distributed outside Exxon without further permission from EEC.

The Biostratigraphy Section appreciates this opportunity to work with you in ensuring the effective application of biostratigraphy to your project. If you have any questions regarding this work or require any further assistance, please contact Pete at 423-5988 or Tom at 423-5992.

Yours truly,

B. A. Vining

by
Peter P. McLaughlin, Jr.

TDD

c: B. A. Vining
R. D. Hammond
Doug A. Shwebel

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Palynostratigraphic Zonation and Paleoenvironments of the Turrum-6 Well, Gippsland Basin, Australia

Thomas D. Davies

EXECUTIVE SUMMARY

- The palynology of the Turrum-6 Well was studied to provide stratigraphic control based on age and biostratigraphic position of sidewall core samples from 2144 to 2819 mKB and environments of deposition.

- Biostratigraphy enables subdivision of Paleocene reservoir section into seven palynology zones. One additional zone is recognized above the reservoir section, and one below in the Upper Maastrichtian.

- Palynology demonstrates that Biozone Rb occurs within the Bottle Green sequence about 25 m above the Bottle Green SB, that the top of Zone Rc occur just below Bottle Green SB, and that MFS "E" SB falls within Zone Rc. Near Top L-200 falls near the boundary between Rc and Rd, within the base of Zone Rc. Naples Yellow SB sits in the indeterminate interval between Rd and Re. Zone Re is first recognized at 2535 m just below MFS "B" SB. The top of Zone Rf occurs in the base of the Pink sequence about 20 m above Pink SB picked at 2595.5 m. The base of Rf is approximately 25 m above MFS "A" SB at 2696 m. Zone Rg is identified at 2722 m just above the 450 Marker, but it could occur as high as 2697.5 m. Definitive Upper Maastrichtian is at 2768 m. The possible highest depth for the Cretaceous is 2748 m.

- Many of the "shales" associated with the reservoir sandstone, particularly above the MFS "B" SB, contain common to abundant marine dinoflagellate cysts. Four intervals were identified that contain relatively rich and diverse marine assemblages. These intervals correlate with the marine flooding events associated with MFS "B" SB, Near Top L-200, and MFS "E" SB.

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ESSO AUSTRALIA, LTD **Turrum-6 Well**
Gippsland Basin, Australia

INTRODUCTION

At the request of Esso Australia Limited (Peter Glenton), forty-two samples were studied from the Turrum-6 Well, Gippsland Basin. Samples were analyzed for age and paleoenvironment, and the results of these analyses were integrated with Exxon's Turrum Field palynological zonation recently proposed by Davies (1995).

The main purposes of this palynologic study were to provide: 1) stratigraphic control based on the age and biostratigraphic position of sidewall core samples relative to Exxon's Gippsland Basin palynological zonation, and 2) constraints on the depositional environments.

The age and paleoenvironmental interpretations are based on comparisons with materials from Askin (1990); Besems (1993); Churchhill (1973); Cookson and Eisenack (1965 and 1967); Damassa et al. (1994); Davies (1995, 1996a, and 1996b); Davey et al. (1966); Germeraad et al. (1968); Haq et al. (1987); Heilmann-Clausen (1985); Helby et al. (1987); Marshall (1985); Muller (1964); Partridge (1976 and 1988); Powell (1992); Stover and Evans (1969 and 1973); Stover and Partridge (1973 and 1984); Wilson (1984 and 1988); and Wrenn and Hart (1988).

Interpretations of paleoecology were made based on observed changes in the spore-pollen (S/P) assemblages and biofacies analyses from kerogen slides. Relative abundance abbreviations used below are: 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, F - foraminifera. Depths given are in meters KB.

DATABASE AND PRODUCTS

Approximately 125 microscope slides were studied from forty-two Turrum-5 sidewall core samples for palynology and paleoenvironments. These sidewall core samples were processed by EEC's Biostratigraphic Lab in Houston.

Microscope slides: The palynology and kerogen microscope slides from the forty-seven sidewall core samples (2144 to 2819 m) from the Turrum-6 well are stored at EEC's biostratigraphy laboratory in Houston.

BIOSTRATIGRAPHY AND PALEOENVIRONMENTAL SUMMARY

Approximately 125 microscope slides were studied from forty-two Turrum-6 sidewall core samples in the interval from 2144 to 2819 m. Marine dinoflagellate cysts are common to abundant in many of the samples from 2144 to 2540 m, particularly at 2144, 2206.4, 2253, 2308.5*, 2360, 2391.5, 2407*, 2439*, 2535*, 2540, and 2768* m. (Those depths annotated with an asterisk are interpreted as intervals of maximum marine incursions based on dinoflagellate cyst diversity and type.) The section from 2559 to about 2690 is interpreted to be mostly nonmarine, as no indigenous marine microfossils were recovered. Marine dinocysts occur again, mainly in small numbers, in the basal part of this well from 2697.5 to 2819 m. Terrestrially derived spores and pollen are common to abundant in most of the samples, but are often poorly preserved.

Nine palynozones are recognized in the lower Eocene to Upper Maastrichtian section of this well and are summarized below. Questioned depths shown in parenthesis, e.g. (?2748), denotes possible shallowest depth of the zone top.

2144-2206.4	Zone Sz; lower Eocene
2253	Probably Zone Ra; upper Paleocene
2276	Zone Rb
2283	Indeterminate
2308.5-2391.5	Zone Rc
2407-2439	Zone Rd1
2466-2496.5	Indeterminate (possible Rd2 at 2366)
2535-2540	Zone Re
2559-2570	Indeterminate
2577-2668.5	Zone Rf
2674.5-2711.5	Indeterminate (possible Rg at 2697.5)
2722	Rg
(?2748) 2768-2819	Zone Ma; Upper Maastrichtian

Intervals of maximum flooding occur in samples 2308.5*, 2407*, 2439*, 2535*, and 2768* m. These intervals correlate with the marine flooding events associated with MFS "B" SB, Near Top L-200, MFS "E" SB, and the Upper Maastrichtian.

DISCUSSION OF RESULTS

Zone Sz was identified in samples at 2144 to 2206.4 m. Appendix A, following the references, gives a sample-by-sample listing of the important species.

Zone Ra is provisionally assigned to samples from 2253 m. Preservation is poor, partially due to common pyrite scarring, and identification of marker species is difficult. There are no samples between 2206.4 and 2253 m, so the top of Zone Ra is undefined.

Although diagnostic species are rare, the microfossil assemblage and biofacies suggest sample 2276 m is in Zone Rb (Appendix A). Sample 2283 m is indeterminate.

The top Zone Rc (early part of late Paleocene), is placed at 2308.5 m. Samples 2374 and 2391.5 m are also placed to the zone.

The section from 2407 to 2439 m is placed in Zone Rd (probably Rd1). This interval contains an assemblage similar to that attributed to Zone Rd in the other Turrum wells. The zonation of the interval from 2466 to 2496.5 m is indeterminate, however the assemblage recovered from sample 2466 m resembles that noted in Turrum-5 at the top of Zone Rd2.

The top of Zone Re was picked at 2535 m. The assemblage associated with this zone continues down through sample 2540 m. Subzone Re1 and Re2 are not differentiated. Samples 2559 and 2570 m are indeterminate.

Markers for Zone Rf occurs in samples from 2577 to 2668.5 m.

The interval from 2674.5 to 2711.5 m is indeterminate. However palynofacies suggest that the sample at 2697.5 m may be in Zone Rg. The top of definitive Zone Rg is picked at 2722 m, based on an assemblage that is consistent with this zone in the other well in the area.

The top of the Upper Maastrichtian, Zone Ma is tentatively placed at 2748 m. Definitive Maastrichtian is picked at 2768 m.

PALYNOSTRATIGRAPHIC CORRELATION

The palynologic assemblages recovered from this well are similar to those reported for the other wells studied from the Turrum field (Davies, 1995, 1996a, and 1996b). Nine biozones were recognized in this well, based on first, last, and peak occurrences, and concurrent ranges which were compared with ranges previously established in the area by Stover and Partridge (1971 and 1973), Stover and Evans (1973), Helby, Morgan, and Partridge (1987), Wilson (1984, 1988), Wrenn and Hart (1988), and others. The picks for the palynozones were done independently of the stratigraphic picks, resulting in good correlation control, which is consistent with EAL's log picks.

Zone Sz occur in samples from 2144 to 2206.4 m, which is above the reservoir section and above BGF4 at 2224.5 m (as picked by EAL). No samples were provided between 2206.4 and 2253 m, so the top of Zone Ra is unknown. The assignment of sample 2253 m to Zone Ra is provisional, as the identification of marker species is difficult due to preservation state. This sample coincides with EAL's pick for the Blue Grey Sequence Boundary and Blue Grey FS1.

The sample from 2276 m is placed in Zone Rb, but the confidence level is moderate to low, as marker species are very rare. The sample occurs about 20 m below the Blue Grey SB and Blue Grey FS1 picked at 2253 m. The top of Zone Rb occurs at or just below the Blue Grey SB in Turrum-4, Turrum-3, Turrum-2, and Marlin-4 (Davies, 1995), and Turrum-5 (Davies, 1996a).

The top of Palynozone Rc is placed at 2308.5 m and it continues down to 2391.5, which is just below MFS "E" SB. The Bottle Green SB picked by EAL at 2331 m is within the upper part of This zone. Zone Rc was recorded in most of the Turrum field wells and Bottle Green SB occurs within the top of this zone in Marlin-2, possible in Turrum-4, and in Turrum-1.

The Near Top L-200 surface usually occurs between the base of zone Rc and the top of Rd (Davies, 1995). The top of Subzone Rd1 in this well was recorded at 2407 m, which is 6 m beneath the Near Top L-200 surface picked at 2401 m. Near Top L-200 falls between the last pick of Rc at 2391.5 m and the first downhole pick of Rd1 at 2401 m. Subzone Rd1 was recognized in most of the Turrum well, except Marlin-2. Subzone Rd2 was not definitively identified in this well. However, the sample at 2366 m may possibly be in Zone Rd2. Naples Yellow SB which was picked at 2469 m is just beneath this sample. Where this zone was identified, Naples Yellow occurred within it (Davies, 1995; 1996a; 1996b).

Top Zone Re occurs first at 2535 m. MFS "B" SB usually occurs within this zone. The physical surface at about 2531 m, picked by EAL as MFS "B" SB, is just above the recognized top of Re. The top of Zone Re may sit somewhere in the unsampled interval between 2496.5 and 2535 m. This zone was recognized with certainly in Marlin-2, Turrum-4, Turrum-3, and Turrum-2 and in Turrum-5 and Marlin A24 (Davies, 1995, 1996a, and 1996b). Subzone Re2 was not differentiated in this well.

The top of the Rf Zone, which is typically located just above the Pink SB, was recognized at 2577 m. Pink SB, picked by EAL at 2595 m, occurs within the top of Zone Rf. This zone is recognized down to 2668.5 m. MFS "A" SB, which usually occurs in the basal part of Zone Rf is placed by EAL down at 2696 m. To maintain this surface within Rf, alternative picks for MFS "A" SB are beneath the coal at about 2601 m, or beneath the coal at about 2605 m.

Zone Rg top, which generally sits close to the 450 Marker, occurs at 2722 m, or possibly as high as 2697.5 m. This zone was identified with certainty in the six of the Turrum field wells, Turrum-5, Turrum-4, Turrum-3, Turrum-2, Marlin-4, and Marlin A24 (Davies, 1995; 1996a; 1996b). The 450 Marker is placed at 2728.5 m. An alternative for the 450 Marker is the transgressive surface at about 2698 m, which will keep the 450 Marker within or at the top of Zone Rg.

The top of Upper Maastrichtian Palynozone Ma typically appears beneath the Oriental Blue SB at the base of the section and is provisionally placed at 2748 m and certainly at 2768 m. The Oriental Blue SB was picked by EAL at 2755 m. An alternative to this depth is the surface at about 2741 m.

PALEOENVIRONMENTS

Results indicate that deposition of the interval studied from the Turrum-6 well took place in a marginal to non-marine environment with periodic and short-lived marine floods. The middle and upper portions of the reservoir sequence above approximately 2540 m appeared to have experienced more numerous and extensive flooding, whereas the basal part of the section contains fewer marine records. Although many of the shales associated with the reservoir sands above 2540 m contain at least some fossils indicative of marine influence, four horizons were identified that contain rich, relatively diverse marine palynomorph assemblages. These occur near the MFS "B" SB, Near Top L-200, and MFS "E" SB surfaces at 2308.5, 2407, 2439, and 2535. Most of these samples contain relatively diverse dinocyst assemblages. Appendix A give the sample-by-sample interpretation of the paleoenvironments.

The Late Maastrichtian climate in this area was apparently humid and mild, with a cooling trend near the Cretaceous/Tertiary boundary (Askin, 1990). The composition of the palynomorphs and palynofacies assemblage in the basal part (uppermost Maastrichtian to lower Paleocene) of the reservoir section implies a cool and wet climate. A decrease in frequency of indicators of humid environments upward in the section, suggest that conditions became slightly drier during deposition of most of the upper part of the reservoir section.

Pyrite, which is common to transitional marine to nonmarine settings, is abundant in most of the samples, suggesting deposition took place near shore, where there was possibility of some marine influence.

RECOMMENDATIONS

Zones Ra and Rb are not well defined in this well. If further definition of the top of these zones is required, we recommend augmenting the SWC's with a few cuttings samples selected from fine-grained lithologies in the upper part of the well from about 2206 to 2308.5 mKB. To gain confidence in the upper limit of Zone Rc, we recommend studying two or three additional samples in the interval from 2315 to 2360 mKB.

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Appendix A

TURRUM-6 WELL, GIPPSLAND BASIN, AUSTRALIA

BIOSTRATIGRAPHY AND PALEOENVIRONMENTAL SUMMARY

T. D. Davies

2144

Paleoenvironment: Marine to marginal marine
Kerogen: woody/coaly (C); amorphous (C-A); biodegraded terr. (R); S/P (VA); dinoflagellates (A-C); pyrite (R-F), poor pres.
Spiniferites spp. (D) (indicative of open marine) (VR)
Hafniasphaera septatus (D) (indicative of open marine) (VR)
Senegalinium dilwynense (D) (F)
?Apectodinium spp. (D) (F)
Cleistosphaeridium spp. (D) (R-F)
Impagidinium spp. (D) (R)
Systematophora cf. placacantha (D) (F)
Nothofagidites spp. (SP) (F)
Nothofagidites endurus (SP) (R)
Proteacidites spp. (SP) (F)
Proteacidites annulatus (SP) (VR-R)
Stereisporites antiquasporites (SP) (F-C)
Phyllocladidites spp. (SP) (F)
Lygistipollenites balmei (SP) (F)
Lygistipollenites florinii (SP) (F)
Bisaccates (SP) (A)

2184

Paleoenvironment: Nonmarine
Kerogen: woody/coaly (F-C); amorphous (VA); biodegraded terr. (F); S/P (F-C); dinoflagellates (barren); pyrite (A), very poor pres.
Nothofagidites spp. (SP) (VR)
Proteacidites spp. (SP) (F)
Stereisporites antiquasporites (SP) (R)
Lygistipollenites balmei (SP) (VR)
Lygistipollenites florinii (SP) (VR)
Bisaccates (SP) (F)

2206.4

Paleoenvironment: marginal marine
Kerogen: woody/coaly (F-C); amorphous (VA); biodegraded terr. (F); S/P (A); dinoflagellates (C); pyrite (VVA), poor pres.
Senegalinium dilwynense (D) (C)
Nothofagidites spp. (SP) (F)
Nothofagidites emarcidus-heterus (SP) (R)
Nothofagidites endurus (SP) (R)
Nothofagidites bracyspinulosus (SP) (R)
Proteacidites spp. (SP) (F)

Proteacidites annulatus (SP) (VR)
Stereisporites antiquasporites (SP) (R)
Stereisporites (Tripunctisporis) (SP) (R)
Phyllocladidites spp. (SP) (F)
Phyllocladidites mawsonii (SP) (R)
Phyllocladidites microsaccatus (SP) (R)
Podosporites antarcticus (SP) (R)
Lygistipollenites balmei (SP) (VR)
Lygistipollenites florinii (SP) (VR)
Bisaccates (SP) (C-A)

2253

Paleoenvironment: Marginal marine
Kerogen: woody/coaly (F-C); amorphous (VA); biodegraded terr. (F); S/P (C); dinoflagellates (A); pyrite (VA), poor pres.
Hafniasphaera septatus (D) (VR)
Senegalinium dilwynense (D) (VA, increase)
Gambierina rudata (SP) (VR)
Nothofagidites spp. (SP) (R-F)
Nothofagidites endurus (SP) (R)
Proteacidites spp. (SP) (F)
Proteacidites cf. angulatus (SP) (VR)
Australopollis obscurus (SP) (F, increase)
Stereisporites antiquasporites (SP) (R)
Stereisporites (Tripunctisporis) (SP) (R)
Phyllocladidites spp. (SP) (F)
Phyllocladidites microsaccatus (SP) (R)
Podosporites antarcticus (SP) (F)
Lygistipollenites balmei (SP) (F, increase)
Lygistipollenites florinii (SP) (R)
Bisaccates (SP) (C)

2276

Paleoenvironment: Marginal marine
Kerogen: woody/coaly (F-C); amorphous (A); biodegraded terr. (F); S/P (C); dinoflagellates (R); pyrite (VA), poor pres.
Spiniferites spp. (D) (indicative of open marine) (VR)
?Apectodinium spp. (D) (R)
Cerodinium sp. S (D) (VR)
Paleocystodinium golzowense (D) (VR)
Glaphyrocysta retiintexta (D) (~no lower than upper Paleocene) (VR)
Nothofagidites spp. (SP) (R)
Nothofagidites emarcidus-heterus (SP) (lower part of lower Eoc. to Paleoc.) (R)
Australopollis obscurus (SP) (R, decrease)
Proteacidites spp. (SP) (F)
Proteacidites angulatus (SP) (R)
Stereisporites antiquasporites (SP) (R)
Stereisporites (Tripunctisporis) (SP) (R)
Phyllocladidites microsaccatus (SP) (R)
Podosporites antarcticus (SP) (F)

Lygistipollenites balmei (SP) (F-R)
Lygistipollenites florinii (SP) (R)
Bisaccates (SP) (C)

2283

Paleoenvironment: Nonmarine
Kerogen: woody/coaly (F-C); amorphous (VA); biodegraded terr. (F); S/P (C); dinoflagellates (barren); pyrite (VVA), poor pres.
Nothofagidites spp. (SP) (R)
Nothofagidites endurus (SP) (R)
Nothofagidites emarcidus-heterus (SP) (R)
Nothofagidites brachyspinulosus (SP) (VR)
Australopollis obscurus (SP) (C-F)
Proteacidites spp. (SP) (F)
Stereisporites antiquasporites (SP) (R)
Phyllocladidites microsaccatus (SP) (R)
Podosporites antarcticus (SP) (F)
Lygistipollenites balmei (SP) (R)
Lygistipollenites florinii (SP) (R)
Bisaccates (SP) (C)

2308.5

Paleoenvironment: Marine
Kerogen: woody/coaly (C); amorphous (A); biodegraded terr. (F); S/P (C); dinoflagellates (C); pyrite (A), very poor pres. of s/p
Cyclopsiella spp. (D) (F)
Spiniferites spp. (D) (VR)
Hafniasphaera septatus (D) (VR)
Spinidinium-type (D) (VR)
Vozzhennikovia spp. (D) (F)
Senegalinium dilwynense (D) (F)
?Apectodinium spp. (D) (C)
Alisocysta circumtabulata (D) (R)
Isabelidinium spp. (D) (R-F)
Isabelidinium bakeri (D) (R)
Isabelidinium cf. cingulatum (D) (VR)
Cerodinium sp. S (D) (R-F)
Paleocystodinium golzowense (D) (F)
Glaphyrocysta spp. (D) (F)
Glaphyrocysta retiintexta (D) (C-A, increase)
Gambierina rudata (SP) (R)
Nothofagidites spp. (SP) (R)
Nothofagidites bracyspinulosus (SP) (VR)
Proteacidites spp. (SP) (F)
Tricolpites gillii (SP) (R)
Stereisporites antiquasporites (SP) (R)
Phyllocladidites microsaccatus (SP) (R)
Podosporites antarcticus (SP) (F)
Lygistipollenites balmei (SP) (R-F)
Lygistipollenites florinii (SP) (R)

Bisaccates (SP) (C)

2360

Paleoenvironment: Marginal marine to marine
Kerogen: woody/coaly (C); amorphous (A); biodegraded terr. (F); S/P (C); dinoflagellates (A); pyrite (VA), very poor pres. of S/P
Senegalinium dilwynense (D) (R)
Cerodinium sp. S (D) (F-R)
Paleocystodinium golzowense (D) (C)
Paleocystodinium australinum (D) (C)
Glaphyrocysta spp. (D) (R)
Glaphyrocysta retiintexta (D) (F)
Stereisporites antiquasporites (SP) (VR)
Phyllocladidites microsaccatus (SP) (R)
Lygistipollenites balmei (SP) (VR)
Bisaccates (SP) (F)

2374

Paleoenvironment: Marginal marine
Kerogen: woody/coaly (C); amorphous (A-C); biodegraded terr. (F); S/P (C); dinoflagellates (F); pyrite (A), very poor pres. of S/P
Cyclopsiella spp. (D) (A)
Spiniferites spp. (D) (R-F)
Cerodinium sp. S (D) (VR)
Paleocystodinium golzowense (D) (R)
Paleocystodinium cf. australinum (D) (VR)
cf. Paleocystodinium pyrophorum (D) (VR)
Glaphyrocysta retiintexta (D) (F)
Cleistosphaeridium spp. (D) (VR)
Proteacidites spp. (SP) (F)
Phyllocladidites spp. (SP) (F)
Phyllocladidites microsaccatus (SP) (R)
Lygistipollenites balmei (SP) (R)
Bisaccates (SP) (F)

2391.5

Paleoenvironment: Marginal marine to marine
Kerogen: woody/coaly (C); amorphous (A); biodegraded terr. (F); S/P (C); dinoflagellates (F); pyrite (VA), very poor pres. of S/P; mud contam.
Spiniferites spp. (D) (indicative of open marine) (R)
Senegalinium dilwynense (D) (R-F)
Cerodinium sp. S (D) (C-A)
Paleocystodinium golzowense (D) (C-A)
Paleocystodinium australinum (D) (C-A)
Glaphyrocysta spp. (D) (F)
Glaphyrocysta retiintexta (D) (C)
Cleistosphaeridium spp. (D) (R)
Proteacidites spp. (SP) (F)
Phyllocladidites spp. (SP) (F-R)
Lygistipollenites balmei (SP) (R)
Bisaccates (SP) (F)

2407

Paleoenvironment: Marine to marginal marine

Kerogen: woody/coaly (C-A); amorphous (C-A); biodegraded terr. (C); S/P (C); dinoflagellates (A); pyrite (VA), very poor pres. of S/P; mud contam.
Spiniferites spp. (D) (R)
Spinidinium spp. (D) (C)
Spinidinium densispinatum (D) (F-C)
Vozzhennikovia spp. (D) (A)
Senegalinium dilwynense (D) (R-F)
Isabelidinium cf. bakeri (D) (VR)
Isabelidinium cf. cingulatum (D) (VR)
Cerodinium sp. S (D) (R-F)
Paleocystodinium golzowense (D) (R)
Glaphyrocysta spp. (D) (F)
Glaphyrocysta retiintexta (D) (F-C)
Cordosphaeridium spp. (D) (VR)
Nothofagidites spp. (SP) (R)
Nothofagidites endurus (SP) (VR)
Nothofagidites bracyspinulosus (SP) (VR)
Proteacidites spp. (SP) (F)
Proteacidites cf. angulatus (SP) (VR)
Tricolpites gillii (SP) (R)
Phyllocladidites spp. (SP) (F-R)
Lygistipollenites balmei (SP) (R-F)
Bisaccates (SP) (F)

2439

Paleoenvironment: Marine to marginal marine
Kerogen: woody/coaly (C-A) amorphous (VA); biodegraded terr. (C); S/P (C); dinoflagellates (F); pyrite (A-C); very poor pres. of S/P
Hafniasphaera septatus (D) (VR)
Spinidinium spp. (D) (R)
Vozzhennikovia spp. (D) (R)
Senegalinium dilwynense (D) (R)
?Apectodinium spp. (D) (F)
Paleocystodinium golzowense (D) (R)
Paleocystodinium australinum (D) (VR)
cf. Paleocystodinium pyrophorum (D) (VR)
Glaphyrocysta spp. (D) (F)
Glaphyrocysta retiintexta (D) (F, mud contam.?)
Cordosphaeridium spp. (D) (VR)
Nothofagidites spp. (SP) (VR)
Nothofagidites endurus (SP) (VR)
Australopollis obscurus (SP) (R)
Proteacidites spp. (SP) (R-F)
Proteacidites cf. angulatus (SP) (VR)
Phyllocladidites spp. (SP) (F-R)
Lygistipollenites balmei (SP) (R-F)
Bisaccates (SP) (F)

2466

Paleoenvironment: Non to marginal marine; (?Zone Rd2)
Kerogen: woody/coaly (VA); amorphous (R); biodegraded terr. (C); S/P (F); dinoflagellates (nearly barren); pyrite (R); very poor pres. of S/P; mud contam.
Spinidinium densispinatum (D) (VR)

Gambierina edwardsii (SP) (R)
Australopollis obscurus (SP) (R)
Proteacidites spp. (SP) (C-A)
Proteacidites angulatus (SP) (F-C)
Tricolpites spp. (SP) (VR)
Stereisporites antiquasporites (SP) (VR)
Phyllocladidites spp. (SP) (F-R)
Lygistipollenites balmei (SP) (R-F)
Bisaccates (SP) (F)

2496.5

Paleoenvironment: Nonmarine
Kerogen: woody/coaly (C-A); amorphous (R); biodegraded terr. (A); S/P (F); dinoflagellates (barren); pyrite (R); very poor pres. of S/P; mud contam.
Australopollis obscurus (SP) (R)
Proteacidites spp. (SP) (C)
Tricolpites gillii (SP) (VR)
Stereisporites antiquasporites (SP) (VR)
Phyllocladidites spp. (SP) (F-R)
Lygistipollenites balmei (SP) (R)
Bisaccates (SP) (R)

2535

Paleoenvironment: Marginal marine to marine
Kerogen: woody/coaly (C); amorphous (R-F); biodegraded terr. (C); S/P (F); dinoflagellates (C-A); pyrite (R); very poor pres. of S/P; mud contam.
Spinidinium spp. (D) (F)
Spinidinium densispinatum (D) (F)
Vozzhennikovia spp. (D) (R)
Senegalinium dilwynense (D) (R-F)
Cerodinium spp. (D) (F)
Cerodinium sp. S (D) (C)
Paleocystodinium golzowense (D) (R)
Proteacidites spp. (SP) (C)
Lygistipollenites balmei (SP) (R)
Lygistipollenites florinii (SP) (R)
Bisaccates (SP) (R)

2540

Paleoenvironment: Marginal marine to marine
Kerogen: woody/coaly (C); amorphous (F-C); biodegraded terr. (C); S/P (F); dinoflagellates (A); pyrite (F); very poor pres. of S/P; mud contam.
Spinidinium spp. (D) (F)
Spinidinium densispinatum (D) (F)
Vozzhennikovia spp. (D) (R)
Cerodinium spp. (D) (F)
Cerodinium sp. S (D) (F-C)
Proteacidites spp. (SP) (F)
Lygistipollenites balmei (SP) (R)
Lygistipollenites florinii (SP) (R)
Bisaccates (SP) (R)

2559

Paleoenvironment: Nonmarine
Kerogen: woody/coaly (C-F); amorphous (A); biodegraded terr. (C); S/P (F); dinoflagellates (barren); pyrite (F); very poor pres. of S/P; mud contam.
?Spinidinium densispinatum (D) (VR)
Australopollis obscurus (SP) (R)
Proteacidites spp. (SP) (F)
Proteacidites angulatus (SP) (R)
Phyllocladidites mawsonii (SP) (R)
Bisaccates (SP) (R-F)

2570

Paleoenvironment: Nonmarine
Kerogen: woody/coaly (F); amorphous (F); biodegraded terr. (A); S/P (F); dinoflagellates (barren); pyrite (F); very poor pres. of S/P; mud contam.
Gambierina rudata (SP) (VR)
Nothofagidites spp. (SP) (VR)
Australopollis obscurus (SP) (F-C)
Proteacidites spp. (SP) (F)
?Tricolpites cf. confessus (SP) (VR)
Proteacidites angulatus (SP) (VR)
Phyllocladidites microsaccatus (SP) (R)
Lygistipollenites balmei (SP) (VR)
Bisaccates (SP) (R-F)

2577

Paleoenvironment: Nonmarine
Kerogen: woody/coaly (F); amorphous (F-C); biodegraded terr. (A); S/P (A); dinoflagellates (barren); pyrite (R); poor to fair pres. of S/P.
Gambierina edwardsii (SP) (R, slight increase)
Australopollis obscurus (SP) (F-C)
Proteacidites spp. (SP) (F)
Proteacidites angulatus (SP) (R, slight increase)
Tricolpites spp. (SP) (VR)
Tricolpites cf. confessus (SP) (F)
Tetracolporites verrucosus (SP) (R-F, increase)
Stereisporites antiquasporites (SP) (VR)
Stereisporites (Tripunctisporis) (SP) (R)
Phyllocladidites mawsonii (SP) (VR)
Phyllocladidites microsaccatus (SP) (R-F)
Lygistipollenites balmei (SP) (VR)
Bisaccates (SP) (C)

2590

Paleoenvironment: Nonmarine
Kerogen: woody/coaly (C); amorphous (C-A); biodegraded terr. (C); S/P (C); dinoflagellates (barren); pyrite (A); very poor pres. of S/P
Australopollis obscurus (SP) (F-C)
Proteacidites spp. (SP) (F)
Proteacidites angulatus (SP) (R)
Tricolpites spp. (SP) (VR)
Tricolpite cf. confessus (SP) (VR)
Stereisporites antiquasporites (SP) (VR)

Phyllocladidites microsaccatus (SP) (R-F)
Bisaccates (SP) (C)

2591

Paleoenvironment: Nonmarine
Kerogen: woody/coaly (C-A); amorphous (A); biodegraded terr. (F); S/P (A); dinoflagellates (barren); pyrite (C-F); poor pres. of S/P
Monocolpopollenites spp. (SP) (F)
Gambierina rudata (SP) (R)
Gambierina edwardsii (SP) (VR)
Australopollis obscurus (SP) (C)
Proteacidites spp. (SP) (F)
Proteacidites angulatus (SP) (R-F)
Tricolpites gillii (SP) (R-F)
Tricolpites spp. (SP) (R)
Tetracolporites verrucosus (SP) (VR)
Stereisporites antiquasporites (SP) (VR)
Phyllocladidites mawsonii (SP) (R-F)
Phyllocladidites microsaccatus (SP) (R-F)
Lygistipollenites balmei (SP) (R-F)
Lygistipollenites florinii (SP) (R)
Bisaccates (SP) (C)

2606.5

Paleoenvironment: Nonmarine
Kerogen: woody/coaly (C); amorphous (A-C); biodegraded terr. (F); S/P (A); dinoflagellates (barren); pyrite (F); poor-fair pres. of S/P; (2607.5m indeter.)
Australopollis obscurus (SP) (R)
Proteacidites spp. (SP) (F)
Proteacidites angulatus (SP) (C)
Tricolpites gillii (SP) (R)
Tricolpites spp. (SP) (R-F)
Tricolpites cf. confessus (SP) (R-F)
Tetracolporites verrucosus (SP) (C, influx)
Ephedripites spp. (SP) (VR)
Phyllocladidites microsaccatus (SP) (R-F)
Bisaccates (SP) (C)

2629; 2631

Paleoenvironment: Nonmarine
Kerogen: woody/coaly (A); amorphous (F); biodegraded terr. (F); S/P (VA); dinoflagellates (barren); pyrite (R); poor-fair pres. of S/P
Gambierina rudata (SP) (R)
Gambierina edwardsii (SP) (VR)
Australopollis obscurus (SP) (R)
Proteacidites spp. (SP) (F)
Proteacidites angulatus (SP) (F)
Tricolpites gillii (SP) (R)
Tricolpites cf. confessus (SP) (VR)
Stereisporites antiquasporites (SP) (VR)
Phyllocladidites mawsonii (SP) (R)
Phyllocladidites microsaccatus (SP) (C-A)
Bisaccates (SP) (VA)

2631; 2651.2

Paleoenvironment: Nonmarine
Kerogen: woody/coaly (A); amorphous (F-R); biodegraded terr. (F); S/P (VA); dinoflagellates (barren); pyrite (R); fair pres. of S/P

Gambierina rudata (SP) (R)
?Gambierina edwardsii (SP) (VR)
Australopollis obscurus (SP) (F-C)
Proteacidites spp. (SP) (F)
Proteacidites angulatus (SP) (F)
Tricolpites gillii (SP) (F-C)
Tricolpites cf. confessus (SP) (VR-R)
Stereisporites antiquasporites (SP) (R)
Stereisporites (Tripunctisporis) (SP) (R-F)
Phyllocladidites mawsonii (SP) (F)
Phyllocladidites microsaccatus (SP) (C-A)
Bisaccates (SP) (VA)

2667; 2668.5

Paleoenvironment: Nonmarine
Kerogen: woody/coaly (A); amorphous (F-C); biodegraded terr. (C); S/P (C); dinoflagellates (barren); pyrite (R-F); poor pres. of S/P
Gambierina rudata (SP) (R)
Nothofagidites spp. (SP) (VR)
Nothofagidites endurus (SP) (VR)
Proteacidites spp. (SP) (F)
Proteacidites angulatus (SP) (F)
Tricolpites gillii (SP) (R)
Tricolpites cf. confessus (SP) (VR-R)
Stereisporites antiquasporites (SP) (R)
Stereisporites (Tripunctisporis) (SP) (VR)
Phyllocladidites mawsonii (SP) (F)
Phyllocladidites microsaccatus (SP) (F)
Lygistipollenites balmei (SP) (R)
Bisaccates (SP) (VA)

2674.5

Paleoenvironment: Nonmarine; (Zonation indeterminate)
Kerogen: woody/coaly (VA); amorphous (F); biodegraded terr. (C); S/P (F); dinoflagellates (barren); pyrite (R-F); poor pres. of S/P
Proteacidites spp. (SP) (R)
Tetracolporites verrucosus (SP) (VR)
Phyllocladidites mawsonii (SP) (R)
Phyllocladidites microsaccatus (SP) (R)
Bisaccates (SP) (R)

2690

Paleoenvironment: Nonmarine; (Zonation indeterminate)
Kerogen: woody/coaly (VA); amorphous (F); biodegraded terr. (C); S/P (F); dinoflagellates (nearly barren); pyrite (R-F); poor preserv.
Spinidinium spp. (D) (VR, mud contam.?)
Senegalinium spp. (D) (VR)
Proteacidites spp. (SP) (F)
Proteacidites angulatus (SP) (R-F)
Tricolpites gillii (SP) (R)
Tricolpites spp. (SP) (R)
Phyllocladidites mawsonii (SP) (F-R)
Phyllocladidites microsaccatus (SP) (F)
Lygistipollenites balmei (SP) (R)

Bisaccates (SP) (C)

2696.5; 2697.5

Paleoenvironment: Marginal marine; (?Zone Rg)
Kerogen: woody/coaly (C); amorphous (C-VA); biodegraded terr. (C); S/P (C); dinoflagellates (rare); pyrite (F-C); very poor preserv.
?Trithyrodinium spp. (D) (R)
Paleocystodinium bulliforme (D) (VR)
Gambierina rudata (SP) (R)
Nothofagidites spp. (SP) (VR)
Australopollis obscurus (SP) (R)
Proteacidites spp. (SP) (F)
Tricolpites gillii (SP) (R)
Tricolpites spp. (SP) (R)
Tricolpites cf. confessus (SP) (VR)
Stereisporites antiquasporites (SP) (VR)
Stereisporites (Tripunctisporis) (SP) (VR)
Phyllocladidites mawsonii (SP) (F-R)
Phyllocladidites microsaccatus (SP) (F)
Bisaccates (SP) (C)

2711.5

Paleoenvironment: Nonmarine; (Zonation indeterminate)
Kerogen: woody/coaly (C-A); amorphous (C-A); biodegraded terr. (C); S/P (C); dinoflagellates (barren); pyrite (C); very poor pres.; mud contam.
Spinidinium spp. (D) (VR, mud contam.?)
Gambierina rudata (SP) (VR)
Gambierina edwardsii (SP) (VR)
Nothofagidites spp. (SP) (VR)
Proteacidites spp. (SP) (F)
Proteacidites angulatus (SP) (VR)
Tricolpites gillii (SP) (F)
Tricolpites spp. (SP) (R)
Stereisporites antiquasporites (SP) (R)
Phyllocladidites mawsonii (SP) (F-R)
Phyllocladidites microsaccatus (SP) (F)
Bisaccates (SP) (C)

2722

Paleoenvironment: Marginal marine
Kerogen: woody/coaly (C-A); amorphous (C-A); biodegraded terr. (C); S/P (C); dinoflagellates (rare); pyrite (C); very poor pres.; mud contam.
?Trithyrodinium spp. (D) (VR)
Hystichosphaeridium sp. T (D) (R-F)
Gambierina rudata (SP) (R)
Australopollis obscurus (SP) (R)
Proteacidites spp. (SP) (F-C)
Proteacidites angulatus (SP) (VR)
Tricolpites gillii (SP) (R-F)
Tricolpites cf. confessus (SP) (VR)
Phyllocladidites mawsonii (SP) (F-R)
Lygistipollenites balmei (SP) (R)
Lygistipollenites florinii (SP) (VR)
Bisaccates (SP) (C)

2748; 2750

Paleoenvironment: Non- to marginal marine
Kerogen: woody/coaly (C-A); amorphous (A-F); biodegraded terr. (C-A); S/P (C); dinoflagellates (nearly barren); pyrite (A-VA); very poor pres.; mud contam.
Gambierina rudata (SP) (R)
Nothofagidites spp. (SP) (VR)
Australopollis obscurus (SP) (R)
Proteacidites spp. (SP) (F)
Proteacidites angulatus (SP) (VR)
Tricolpites gillii (SP) (R)
Stereisporites antiquasporites (SP) (R)
Stereisporites (Tripunctisporis) (SP) (R)
Onamentifera sentosa (SP) (VR)
Phyllocladidites mawsonii (SP) (R)
Phyllocladidites microsaccatus (SP) (F)
Bisaccates (SP) (C)

2759

Paleoenvironment: Nonmarine
Kerogen: woody/coaly (C); amorphous (A); biodegraded terr. (C-A); S/P (C); dinoflagellates (nearly barren); pyrite (VA); very poor pres.; mud contam.
Nothofagidites spp. (SP) (VR)
Australopollis obscurus (SP) (R)
Proteacidites spp. (SP) (F)
Proteacidites angulatus (SP) (VR)
Tricolpites gillii (SP) (R)
Tricolpites cf. confessus (SP) (R)
Stereisporites antiquasporites (SP) (F)
Stereisporites (Tripunctisporis) (SP) (R)
Onamentifera sentosa (SP) (VR)
Phyllocladidites mawsonii (SP) (R)
Phyllocladidites microsaccatus (SP) (F)
Bisaccates (SP) (C)

2768

Paleoenvironment: Marine to marginal marine
Kerogen: woody/coaly (C-A); amorphous (A); biodegraded terr. (C-A); S/P (C); dinoflagellates (freq.); pyrite (A); very poor pres.; mud contam.
Spiniferites spp. (D) (indicative of open marine) (R, mud contam.?)
Hafniasphaera septatus (D) (VR, mud contam.?)
Manumiella spp. (D) (R-F)
Manumiella druggii (D) (R-F)
Isabelidinium spp. (D) (VR)
Cerodinium spp. (D) (VR)
Cerodinium sp. S (D) (VR, mud contam?)
Paleocystodinium golzowense (D) (VR)
Glaphyrocysta retiintexta (D) (R-F, mud contam.?)
Cordosphaeridium spp. (D) (VR)
Gambierina rudata (SP) (R-F)
Australopollis obscurus (SP) (R)

Proteacidites spp. (SP) (C)
Proteacidites reticulconcavus (SP) (VR)
Proteacidites angulatus (SP) (VR)
Tricolpites gillii (SP) (R)
Tricolpites spp. (SP) (R)
Tricolpites cf. confessus (SP) (R)
Stereisporites antiquasporites (SP) (F)
Stereisporites (Tripunctisporis) (SP) (R)
Phyllocladidites mawsonii (SP) (R)
Phyllocladidites microsaccatus (SP) (F)
Podosporites antarcticus (SP) (R)
Bisaccates (SP) (C)

2781

Paleoenvironment: Non- to marginal marine
Kerogen: woody/coaly (C); amorphous (A); biodegraded terr. (A); S/P (C); dinoflagellates (rare); pyrite (A); very poor pres.; mud contam.
?Manumiella spp. (D) (R-F)*
Glaphyrocysta retiintexta (D) (R-F, mud contam.?)
Gambierina rudata (SP) (R)
Gambierina edwardsii (SP) (R)
Nothofagidites spp. (SP) (VR)
Nothofagidites cf. senectus (SP) (VR)
Proteacidites spp. (SP) (C)
Tricolpites gillii (SP) (R)
Tricolpites spp. (SP) (R)
Stereisporites antiquasporites (SP) (F)
Stereisporites (Tripunctisporis) (SP) (VR)
Phyllocladidites mawsonii (SP) (R)
Phyllocladidites microsaccatus (SP) (F)
Podosporites antarcticus (SP) (R)
Bisaccates (SP) (C)

2789

Paleoenvironment: Marginal marine
Kerogen: woody/coaly (C); amorphous (A); biodegraded terr. (A); S/P (C); dinoflagellates (rare-few); pyrite (A); very poor pres.; mud contam.
Manumiella spp. (D) (R-F)
Manumiella coronata (D) (R)
Gambierina rudata (SP) (C)
Proteacidites spp. (SP) (C)
Tricolpites gillii (SP) (F)
Stereisporites antiquasporites (SP) (F)
Stereisporites (Tripunctisporis) (SP) (R)
Phyllocladidites mawsonii (SP) (R)
Phyllocladidites microsaccatus (SP) (F)
Podosporites antarcticus (SP) (R)
Bisaccates (SP) (C)

2811

Paleoenvironment: Marginal marine
Kerogen: woody/coaly (C); amorphous (A); biodegraded terr. (A); S/P (C); dinoflagellates (freq.); pyrite (A); very poor pres.; mud contam.
Manumiella spp. (D) (C)
Manumiella coronata (D) (F-C)
Paleocystodinium golzowense (D) (VR)
Gambierina rudata (SP) (R-F)

Gambierina edwardsii (SP) (R)
Proteacidites spp. (SP) (C)
Tricolpites gillii (SP) (F)
Tricolpites cf. confessus (SP) (VR)
Stereisporites antiquasporites (SP) (R)
Stereisporites (Tripunctisporis) (SP) (R)
Phyllocladidites mawsonii (SP) (R)
Phyllocladidites microsaccatus (SP) (F)
Podosporites antarcticus (SP) (R)
Bisaccates (SP) (C)

2819

Paleoenvironment: Marginal marine to nonmarine
Kerogen: woody/coaly (C); amorphous (A); biodegraded terr. (A); S/P (C); dinoflagellates (very rare.); pyrite (A); very poor pres.; mud contam.
?Manumiella spp. (D) (R)
Gambierina rudata (SP) (R)
Proteacidites spp. (SP) (C)
Tricolpites gillii (SP) (R)
Tricolpites longus (SP) (VR)
Tricolpites spp. (SP) (R)
Stereisporites antiquasporites (SP) (R)
Stereisporites (Tripunctisporis) (SP) (R)
Phyllocladidites mawsonii (SP) (R)
Phyllocladidites microsaccatus (SP) (F)
Bisaccates (SP) (C)