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# GSWA EDAGGEE 1 WELL COMPLETION REPORT (INTERPRETIVE) GASCOYNE PLATFORM SOUTHERN CARNARVON BASIN WESTERN AUSTRALIA

by M. Dixon, D. W. Haig, A. J. Mory, J. Backhouse, K. A. R. Ghori, R. Howe, and P. A. Morris

Geological Survey of Western Australia

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

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## Gascoyne Platform, Southern Carnarvon Basin
## Western Australia

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M. Dixon[1], D. W. Haig[1], A. J. Mory, J. Backhouse[1], K. A. R. Ghori,
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by
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## Abstract

Edaggee 1 is a stratigraphic well drilled at latitude 25°21'27.0"S, longitude 114°14'04.9"E on the Gascoyne Platform, Southern Carnarvon Basin, and continuously cored from 216.9 m to the total depth of 351 m. Beneath 39.5 m of alluvium, the Cretaceous Toolonga Calcilutite, Haycock Marl, and Winning Group (Gearle Siltstone, Windalia Radiolarite, Muderong Shale, and Birdrong Sandstone) are present above the Devonian Sweeney Mia Formation, in which drilling was terminated. The core has yielded foraminifera, nannofossils, and palynomorphs, which provide excellent palaeontological control for the Cretaceous section.

The Sweeney Mia Formation consists mainly of dolomite and ferruginous dolomitic mudstone, probably deposited in an arid, evaporitic environment. The overlying transgressive Barremian Birdrong Sandstone, Barremian – lower Aptian Muderong Shale, upper Aptian – lower Albian Windalia Radiolarite, and lower Albian 'lower Gearle Siltstone' record broadly increasing water depths (50–100 m). Low levels of dissolved oxygen were probably, initially at least, related to deposition within a low-gradient embayment. The Gearle Siltstone contains a significant disconformity and is accordingly divided into a lower and upper unit. The argillaceous mudstone of the Cenomanian part of the unit is more calcareous than the lower part, and foraminiferal assemblages indicate more-open marine deposition. The uppermost Cenomanian to middle Turonian Haycock Marl, formally recognized within the Southern Carnarvon Basin for the first time, consists of alternating carbonaceous mudstone and clayey calcilutite, and is probably conformable on the Gearle Siltstone. The transition between the units is marked by black shale that probably represents the Cenomanian–Turonian boundary oceanic anoxic event and possibly coincides with a significant increase in water depth. Within the Toolonga Calcilutite there is a basal condensed interval of probable late Coniacian age, overlain by a thick Santonian and Campanian section. Water depths during deposition of the Haycock Marl and Toolonga Calcilutite were probably around 100–200 m.

The petroleum potential of the Cretaceous section is limited by its thermal immaturity, but otherwise has fair to excellent source-rock characteristics. All but one of the Cretaceous samples are organically rich, with a TOC range of 0.59 – 26.8% and potential yield of 1.11 – 55.00 mg/g rock, and are dominated by oil- and gas-generating type-II kerogen. The organically richest samples are from the Haycock Marl, 'lower Gearle Siltstone', and Windalia Radiolarite. The Sweeney Mia Formation has poor hydrocarbon-generating potential.

**KEYWORDS**: Cretaceous, Devonian, stratigraphy, Winning Group, Haycock Marl, Sweeney Mia Formation, Gascoyne Platform, Southern Carnarvon Basin

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# Introduction

The Geological Survey of Western Australia's (GSWA) Edaggee 1 is a stratigraphic well drilled just east of Edaggee Station, 78 km southeast of Carnarvon. The well is located 500 m due east of the homestead, which lies 19 km east of the North West Coastal Highway (Fig. 1). The nearest wells are Yaringa East 1, 62 km to the south-southeast, and Mooka 1, 70 km to the northeast. To the north and west the closest wells are Quobba 1, 138 km north-northwest, and Dirk Hartog 17B, 129 km west-southwest (Fig. 2). Edaggee 1 was located after examining wireline logs and cuttings from Water and Rivers Commission (WRC) bores drilled as part of their artesian bore refurbishment program (WRC website). The structure in the vicinity of the hole is uncertain as the nearest seismic section (W65S-001B) lies 13 km to the north. No hydrocarbons or significant mineralization were encountered.

The primary objective of Edaggee 1 was to continuously core the Winning Group and underlying Palaeozoic strata. Coring of the upper part of the well was undertaken in conjunction with the University of Western Australia as

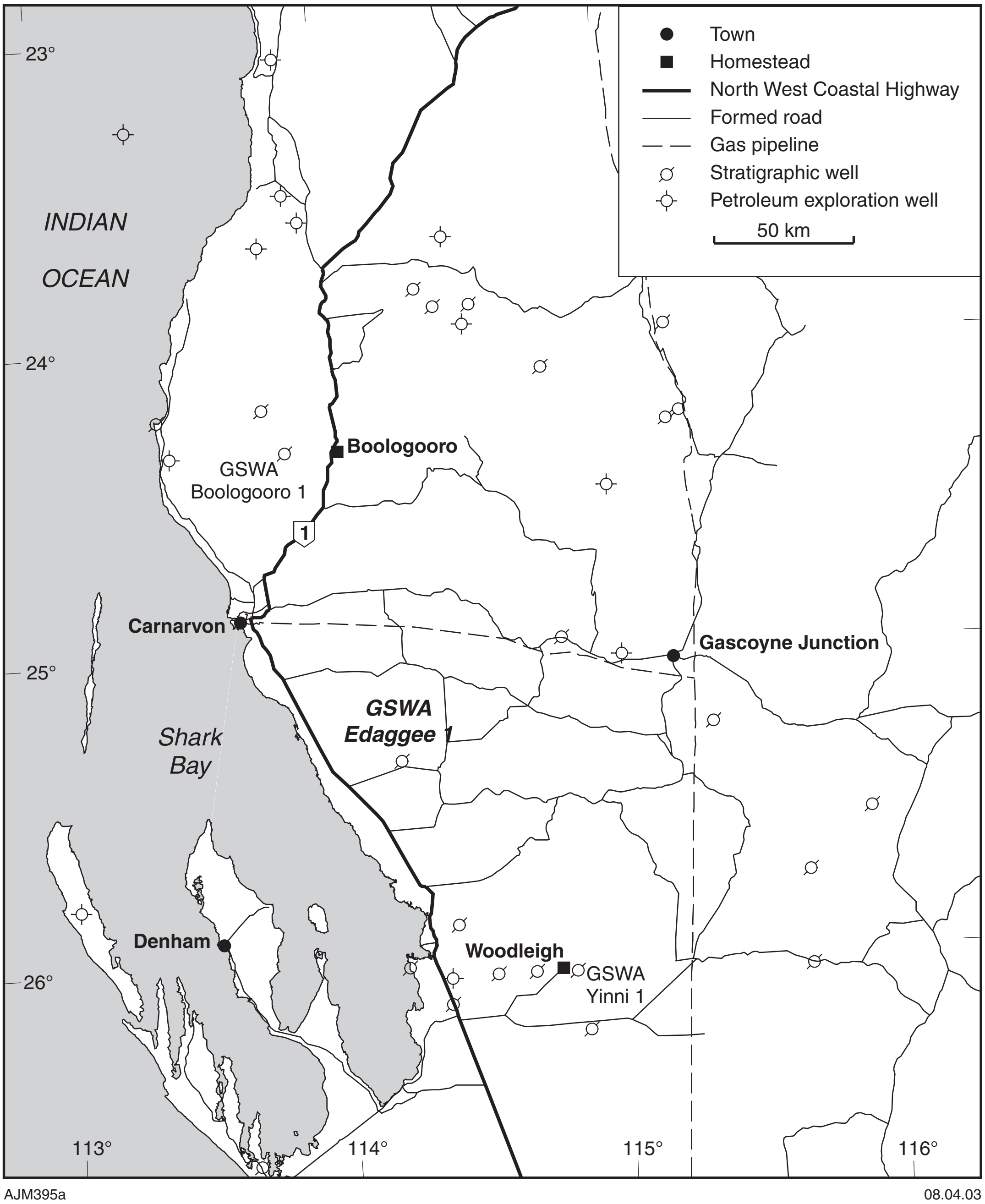



**Figure 1. Well location and access map**

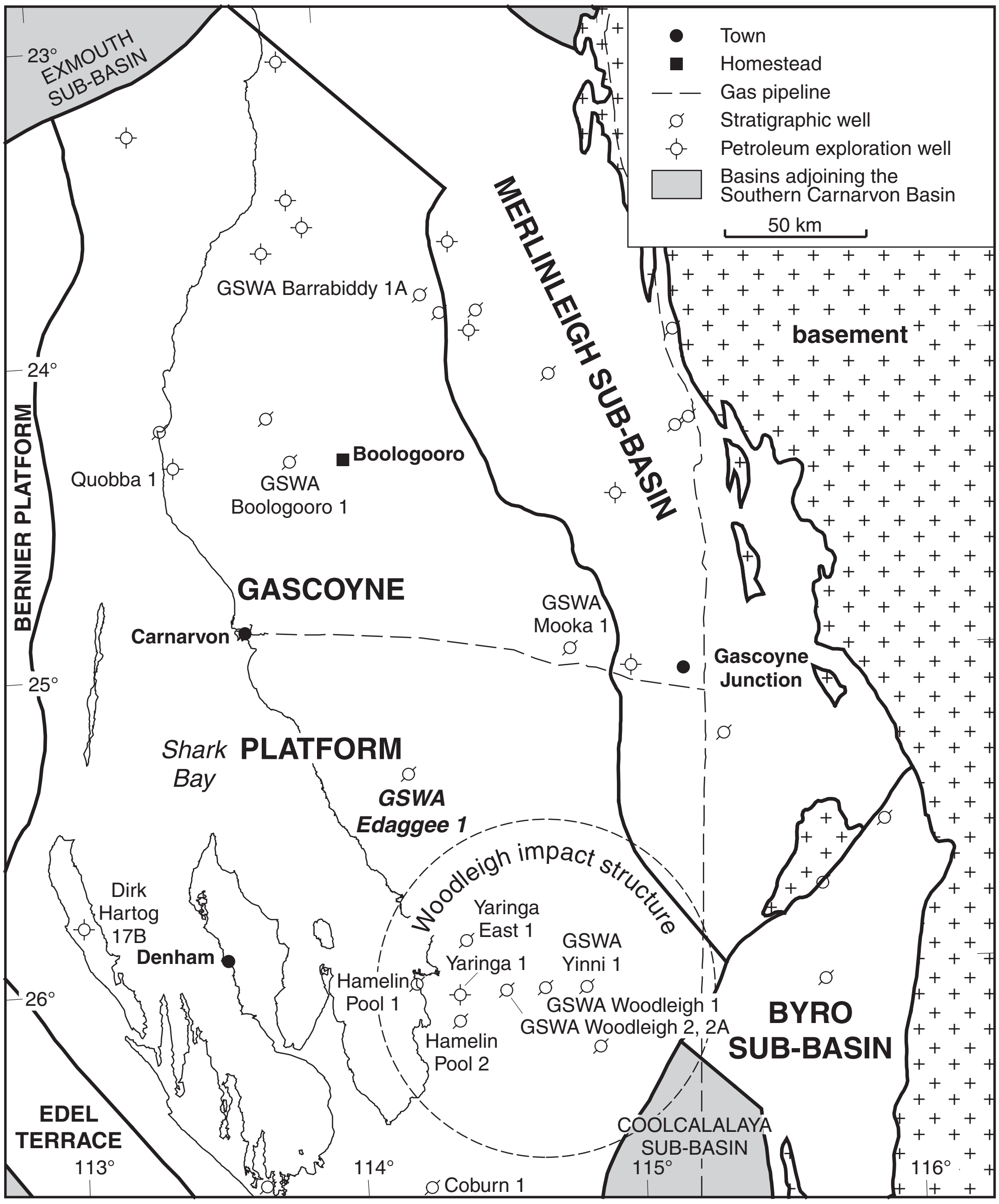



**Figure 2. Tectonic elements map showing location of wells and geological features mentioned in text**

part of an Australian Research Council project on the Cretaceous, whereas the underlying Palaeozoic section was cored to evaluate the petroleum prospectivity of the Gascoyne Platform. The joint project also involved two other wells, Yinni 1 and Boologooro 1, 94 km to the south-southeast and 120 km to the north-northwest respectively (Fig. 3; Mory and Dixon, 2002a,b). Edaggee 1 was terminated within the Sweeney Mia Formation to avoid the strong artesian flow from the underlying Kopke Sandstone. At abandonment the well was plugged in the Windalia Radiolarite to contain a minor artesian flow from the Birdrong Sandstone. The hole was not geophysically logged because of logistical difficulties with the logging company — the logs from the artesian bore 420 m to the west, logged during the WRC bore refurbishment program, were used instead. Information on the Kopke Sandstone in that water bore, below the cored interval in Edaggee 1, has been incorporated into Mory and Dixon (2002c) and this Record.

This Record provides palaeontological and geochemical data for Edaggee 1 and interpretations based on those data, including: biostratigraphy and depositional environments deduced from foraminifera (Appendix 1), palynomorphs (Appendix 2), nannofossils (Appendix 3), petroleum geochemistry (Appendix 4), and whole-rock chemistry

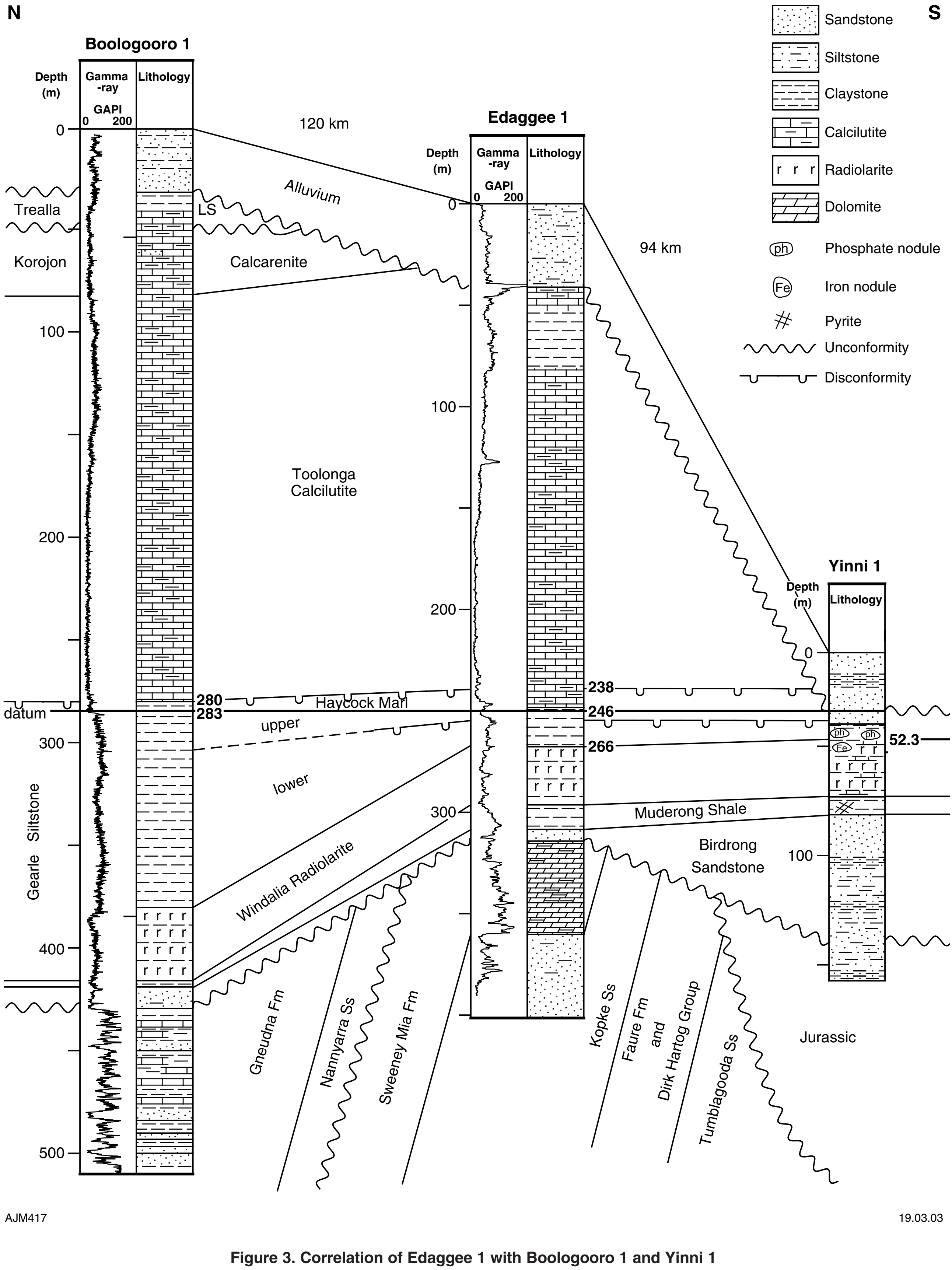



**Figure 3. Correlation of Edaggee 1 with Boologooro 1 and Yinni 1**

(Appendix 5). A gazetteer of place and well names mentioned (Appendix 6), a well index sheet (Appendix 7), and a composite well log (Plate 1) are also presented. Further data on the drilling operations, as well as the core tray images, are presented in Mory and Dixon (2002c, appendix 1), which is included on the compact disk accompanying this Record.

# Well history

## General data

| | |
|---|---|
| Permit: | vacant |
| Location: | Latitude 25°21'27.0"S, Longitude 114°14'04.9"E (GDA94), Northing 7192590, Easting 221700 (MGA Zone 50), determined from Global Positioning System (GPS) |
| Derivation of name: | Edaggee Station |
| Total depth (TD): | 351.0 m (driller) |
| Date spudded: | 9 May 2001 |
| Reached TD: | 16 May 2001 |
| Logging: | No geophysical logs were run |
| Date completed: | 17 May 2001 |
| Elevation: | 35 m Australian Height Datum (AHD), estimated from height of the homestead water bore and using the Edaggee (1747) 1:100 000 topographic map |
| Drill Floor: | Ground level |
| Status: | Plugged and abandoned |

## Drilling data

| | |
|---|---|
| Drilling contractor: | Mt Magnet Drilling, 33 Paramount Drive, Wangara, W.A. 6065 |
| Rig: | Hydco SD 1000 |
| Rig datum: | Ground level |
| Hole size: | |
| 0–1 m | 280 mm with PVC casing |
| 1–13 m | 200 mm with PW casing cemented into place |
| 13–69 m | 175 mm with PW casing cemented into place |
| 69 – 216.9 m | 114 mm with HWT casing (removed after drilling) |
| 216.9 – 351.0 m | 96 mm open hole |
| Mud: | Mixture of KCl and polymer-based muds |
| Core recovery: | |
| 216.9 – 351 m | HQ3 (63.5 mm diameter) recovered 129.43 m (98%) |
| Hole deviation: | Not measured |
| Plug: | A HQ van Ruth plug at 272 m, capped by about 50 m of cement |

# Regional structural setting

Edaggee 1 was drilled in the southwestern part of the Gascoyne Platform in the Southern Carnarvon Basin. The Gascoyne Platform is a structurally high area containing up to 5000 m of faulted and folded Ordovician–Devonian strata (Iasky and Mory, 1999, fig. 3). It lies west of a major mid-Carboniferous – Permian depocentre (incorporating the Merlinleigh, Byro, and Coolcalalaya Sub-basins) and east of the Bernier Platform and Edel Terrace (Fig. 2; Hocking et al., 1987, 1994; Iasky and Mory, 1999), and is covered by generally flat-lying Cretaceous and, locally, Lower Jurassic strata. The Wandagee and Ajana Ridges mark the raised eastern rim of the Gascoyne Platform.

The local structural position of the well is uncertain, as it was located primarily on the basis of data from artesian bores, and seismic control in the region is sparse and of poor quality. Dips in the well are generally less than 2° in the Cretaceous section and 3–4° in the underlying section (Mory and Dixon, 2002c, table 1), consistent with the nearest seismic section (W65S-001B, 13 km to the north), which shows low dips to the west in the Palaeozoic section and virtually none in the Cretaceous. Correlation with the Edaggee 2 water bore 12.5 km to the west (Fig. 4) indicates a regional dip of 0.3° to the west for the Cretaceous section. The top of the Kopke Sandstone in Edaggee 2 is about 400 m higher than could be expected if the 2° dip of the Palaeozoic section in Edaggee 1 is to the west. However, a fault cannot be inferred between these two bores, as this dip is uncertain.

# Stratigraphy

The southern Gascoyne Platform contains mainly Ordovician – Middle Devonian and Cretaceous units (Fig. 5). Carboniferous and Permian units are restricted to the northern part of the platform, whereas Jurassic strata are restricted to the Woodleigh impact structure south of the wellsite. Edaggee 1 was spudded into Quaternary sediments, below which the Cretaceous Toolonga Calcilutite was intersected. Continuous coring commenced near the base of this unit and continued through the Cretaceous Haycock Marl and Winning Group (Gearle Siltstone, Windalia Radiolarite, Muderong Shale, and Birdrong Sandstone), before penetrating gently dipping dolomite and shale of the mid-Devonian Sweeney Mia Formation (Fig 6; Mory and Dixon, 2002c, table 1). Data from the nearby homestead water bore, which continues into the underlying Lower–Middle Devonian Kopke Sandstone, are included in this Record. A summary of the Cretaceous stratigraphy and biostratigraphy is shown in Figure 7. The calculated rate of deposition, as shown alongside palaeobathymetry in Figure 8, assumes that the stage boundaries are consistent with the ages designated by Gradstein et al. (1994). Ages of units are related to the highest and lowest occurrence (HO and LO) of various species in the well.

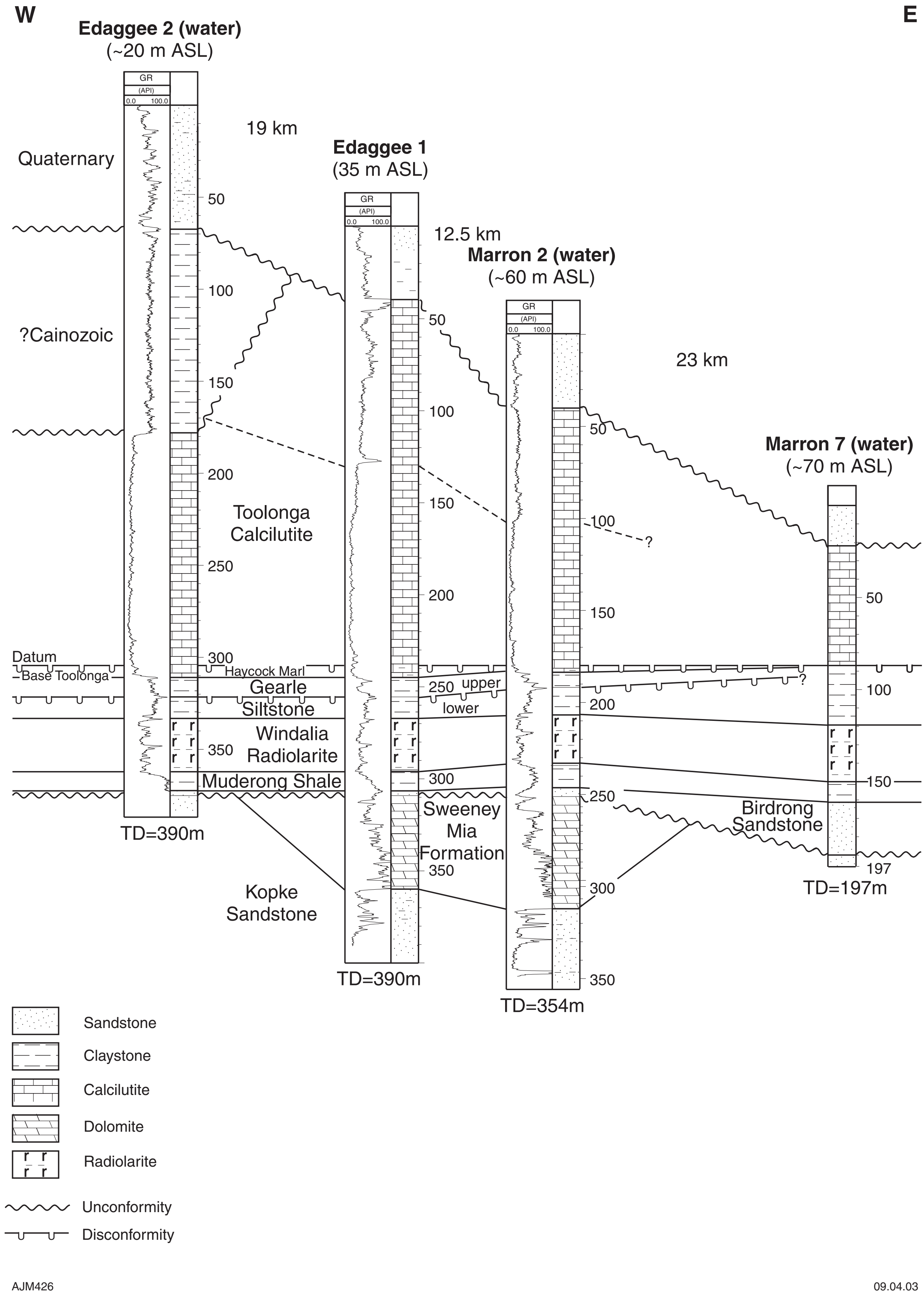



**Figure 4. Correlation Edaggee 1 with nearby water bores (note that the gamma-ray log shown for Edaggee 1 is from a water bore 420 m to the west)**

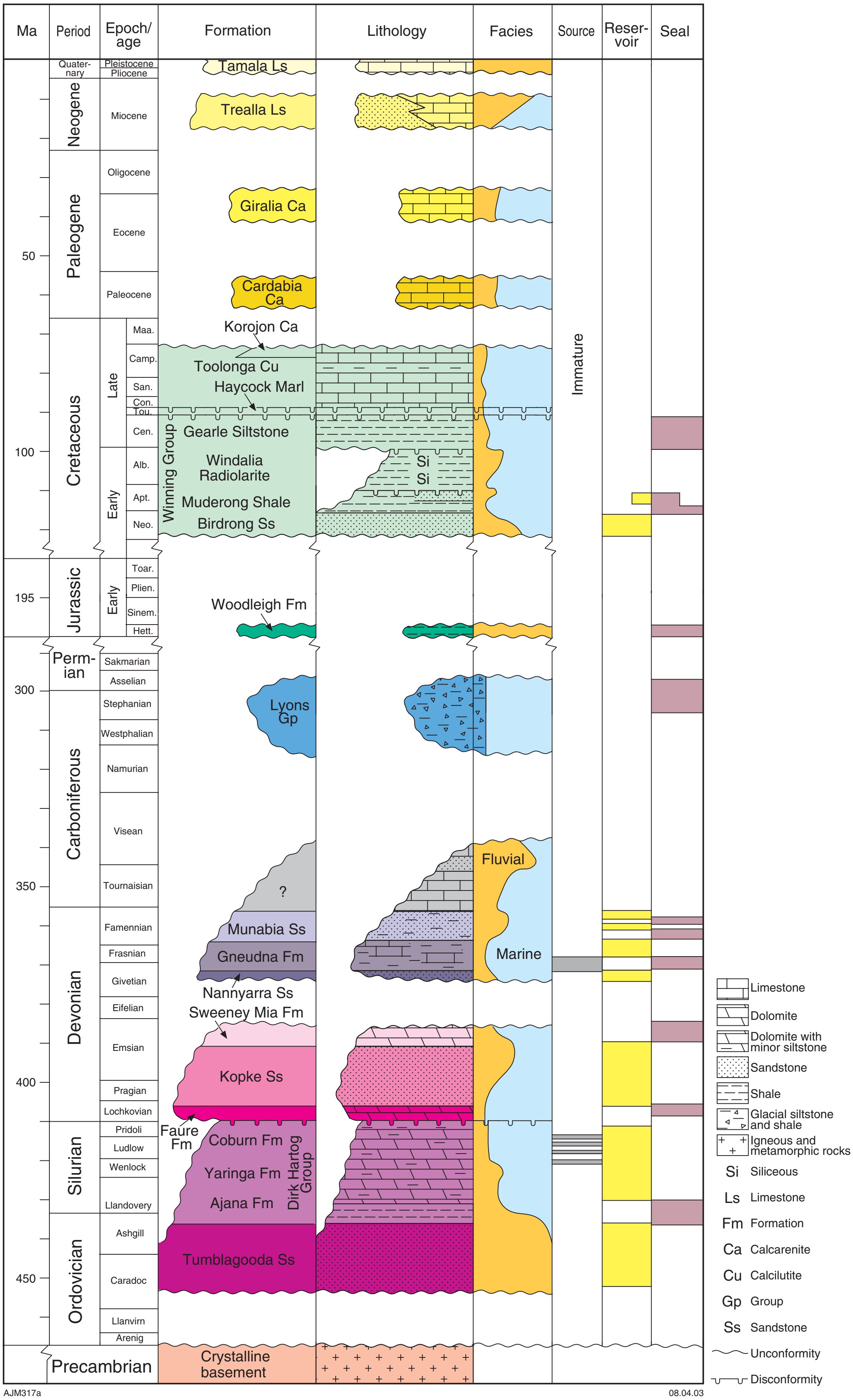



**Figure 5. Regional stratigraphy of Gascoyne Platform (modified from Iasky and Mory, 1999)**

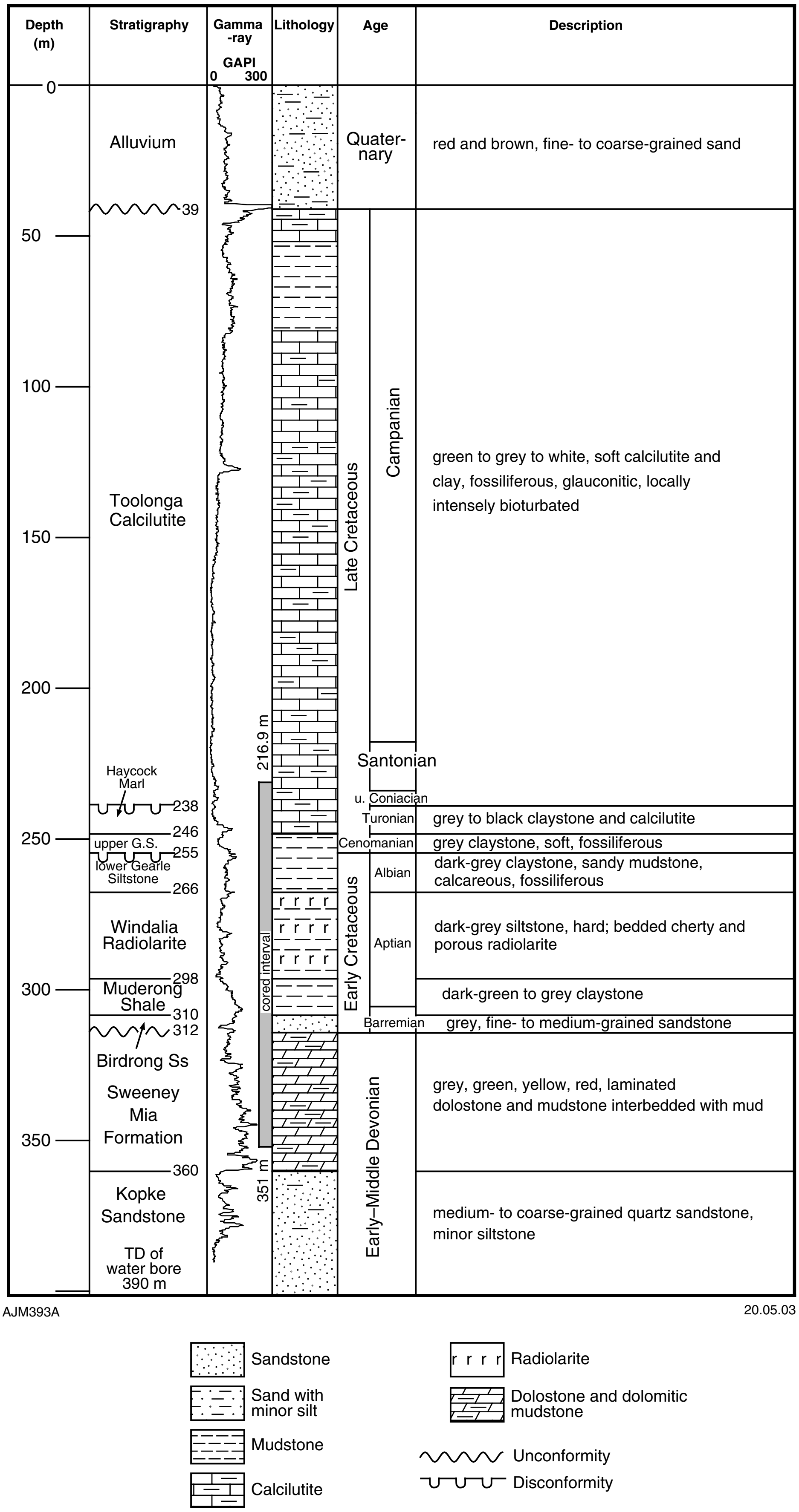



**Figure 6.** **Edaggee 1 stratigraphy extended below TD (351 m) using data (including gamma-ray log) from adjacent water bore**

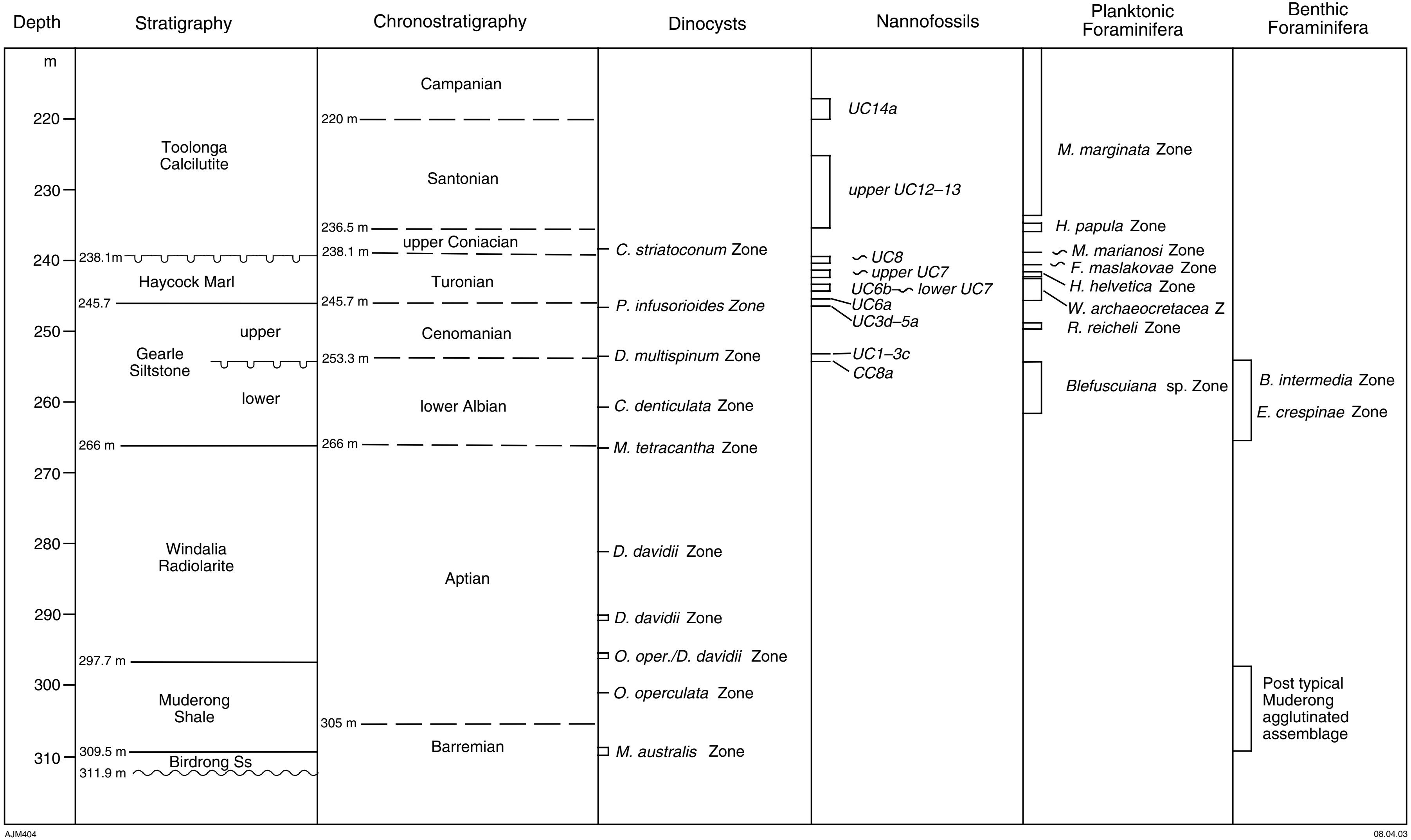



**Figure 7. Cretaceous stratigraphy and biostratigraphy in Edaggee 1**

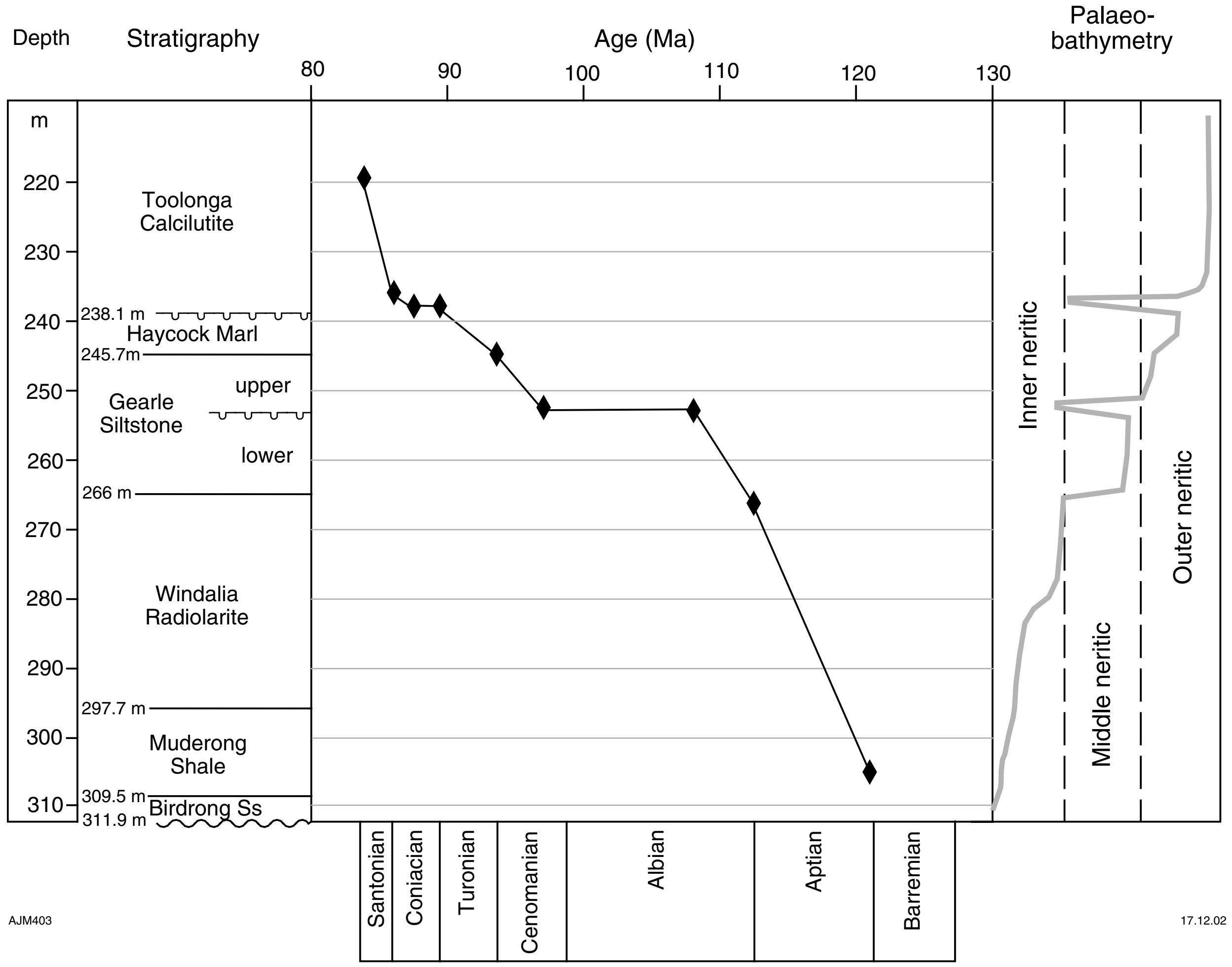



**Figure 8. Palaeobathymetry and rates of deposition for Cretaceous units in Edaggee 1, assuming that the stage boundaries are consistent with the ages designated by Gradstein et al. (1994)**

## Quaternary sediments

Sediments in the upper 39.5 m of Edaggee 1 rapidly fine down-hole from soft, red-brown, eolian, quartzose, sandy mud to red-brown silty clay containing rare clasts of white clay, presumably derived from the underlying Toolonga Calcilutite. Interbeds of loose, light-brown fluvial quartz sand are present within the intervals 6–12 m and 36–39 m.

## Toolonga Calcilutite

The Toolonga Calcilutite is present between 39.5 and 238.1 m. The early Campanian – late Coniacian age assigned to this interval is based on:

- the highest occurrence (HO) of the dinoflagellate cyst *Nelsoniella aceras* at 69 m;
- the HO of the planktonic foraminifera *Archaeo-globigerina cretacea* at 122–134 m;
- the HO of the nannofossil *Aspidolithus parcus parcus* at 216.9 m; and
- the HO of the dinoflagellate *Conosphaeridium striatoconus* at 238.05 m.

### Lithostratigraphy

The Toolonga Calcilutite was continuously cored below 216.9 m. Above about 68 m the unit is represented by leached, white or light-green clay. Below the weathered zone it consists of dark-green, clayey nannofossil-foraminiferal calcilutite, which lightens downhole to pale green at around 160 m. Total organic content (TOC) from a sample at 69 m is moderate (0.59%) with all maceral groups being rare except for inertinite (Appendix 4), indicating that there has been some oxidation at this depth.

The cored part of the formation between 216.9 and 236.6 m includes a small number of conspicuous clayey intervals (e.g. at 217.5 – 218 m, 219.9 – 220.5 m, 224.5 – 224.9 m, and 228.8 – 229.5 m), some of which contain scattered carbonaceous clasts up to 1 cm in length. Below 233 m the calcilutite becomes greener again, with a rapid change to a 1.5 m-thick, dark-green, heavily bioturbated interval below 236.6 m. The lower boundary of the formation is placed at the base of this bed (at 238.1 m), at the sharp contact with the grey, clayey calcilutite of the underlying Haycock Marl. Representative examples of the Toolonga Calcilutite are shown in Figure 9.

Within the Toolonga Calcilutite, the sand fraction of the calcilutite is generally rich in foraminifera, with variable abundances of *Inoceramus* (bivalve) fragments, echinoid spines, ostracods, and sparse small brachiopods. Abundant fish remains are also present within the lowermost dark-green bed. The mud fraction contains nannofossils and dinocysts, with very rare terrestrial spores and pollen (making up less than 1% of palynomorph counts). Within the cored interval, moderately abundant trace fossils, in particular *Planolites* and *Chondrites*, are partially disguised by the uniform lithology.

The abundances of planktonic foraminifera in the cored section alternate from low (e.g. 226.1 – 229.0 m, 233 – 238.1 m) to moderate and high (e.g. 216.9 – 225.1 m, 230.0 – 232.0 m; Appendix 1). Selective dissolution of the highly porous, thin-walled planktonic tests may explain this distribution pattern, because in many samples the planktonic tests show partial dissolution and fragmentation. The more robust benthic tests do not display an equivalent pattern. Nannofossil preservation is poor to moderate throughout the formation (Appendix 3), whereas preservation of palynomorphs is excellent.

## Chronostratigraphy

Cuttings from 69 m belong to the dinoflagellate *Nelsoniella aceras* Zone, and those from the interval 122–134 m belong to the planktonic foraminiferal *Archaeoglobigerina cretacea* Zone (Appendices 1 and 2). These zones indicate an early Campanian age based on the correlations of Helby et al. (1987) and Huber (1992), although the Santonian–Campanian boundary has not been formally defined by the International Commission on Stratigraphy (ICS). Using the HO of the crinoid *Marsupites testudinarius* as a possible marker for the boundary (Gale et al., 1995; Lamolda and Hancock, 1996), Burnett (1998) showed that the LO of the nannofossil *A. parcus parcus* is above the macrofossil '*testudinarius/granulata*' Zone in North-West Germany, and within the '*lingua/quadrata*' Zone. He considered the latter level to be within the lower Lower Campanian. Because of a lack of other indicators for the Santonian–Campanian boundary in Edaggee 1, the LO of *A. parcus parcus* (rare in Edaggee 1 at 216.9 and 220.0 m) is tentatively chosen to mark this boundary within the interval 220 – 225.05 m. This boundary lies above the LO of the benthic foraminifera *Loxostomum eleyi* and at, or below, the LOs of *Cibicides excavata* and *Anomalinoides eriksdalensis* — species that seem to have consistent ranges throughout the Southern Carnarvon Basin.

The interval from 225.05 to 235.05 m belongs to the nannofossil upper UC12–13 Zones (Appendix 3), although

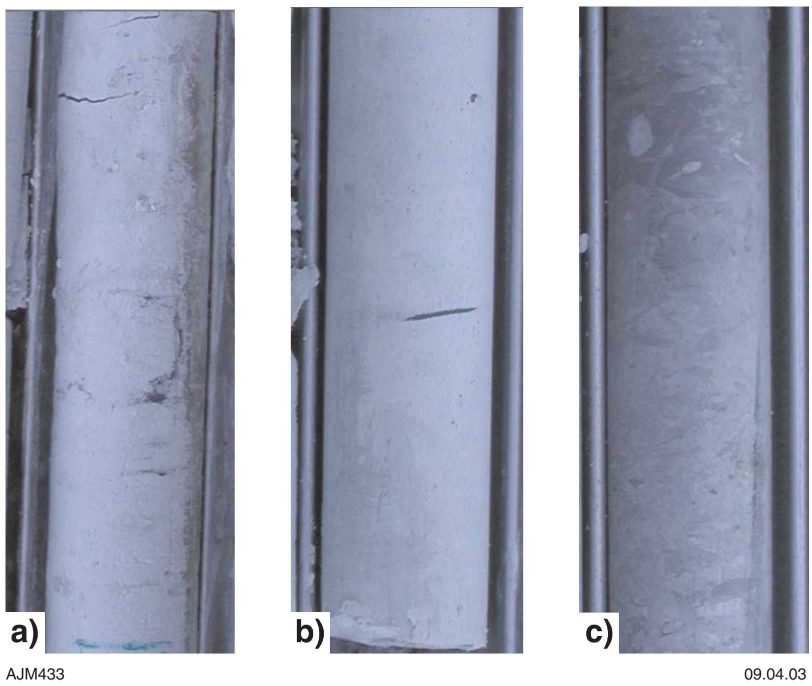



**Figure 9. Representative core photographs of the Toolonga Calcilutite in Edaggee 1: a) 217.7 – 218.0 m: typical appearance of the Santonian, showing *Inoceramus* fragments and diffuse carbonaceous-rich patches; b) 231.1 – 231.35 m: bioturbation weakly displayed probably due to paucity of carbonaceous material; and c) 237.4 – 237.65 m: representative interval within the Coniacian showing well-defined bioturbation (*Planolites* and *Chondrites*)**

species used by Burnett (1998) to define the UC12–13 zonal boundary and the base of the UC12 Zone have not been recovered from Edaggee 1. The base of the UC12 Zone was taken by Burnett (1998) to be the base of the middle Santonian, although the Coniacian–Santonian boundary has not been formally defined by the ICS. The section in Edaggee 1 covering the planktonic foraminiferal *Heterohelix papula* Zone is taken to be lower Santonian (following Petrizzo, 2000). However, if the LOs of the nannofossils *Lucianorhabdus cayeuxii* and *Lithastrinus grillii* fall within the upper Coniacian as suggested by Burnett (1998), then based on the correlation of nannofossil and planktonic foraminiferal datum levels indicated by Petrizzo (2000) for Exmouth Plateau sections, the *H. papula* Zone may be upper Coniacian rather than lower Santonian.

The planktonic foraminiferal *Marginotruncana marianosi* Zone and the dinoflagellate *Conosphaeridium striatoconus* Zone have been identified at 238.05 m, and, following correlations by Petrizz (2000) and Helby et al. (1987), suggest that this level belongs to the upper Coniacian.

## Regional correlations

Based on foraminiferal datum-level correlations (Appendix 1, Table 1.4), the cored interval between 216.9 and 236.1 m in Edaggee 1 correlates to the part of the Toolonga Calcilutite that was originally designated 'Toolonga Chalk' in the type area (below 8 m in the 19 m-thick type section; Clarke and Teichert, 1948; Lynch, 1991), about 250 km south of Edaggee 1. This interval also correlates to the lower 13 m of the 20 m-thick Gingin Chalk type section in the Perth Basin. The equivalent interval in Boologooro 1, about 100 km to the north of Edaggee 1, is over 30 m thick.

## Depositional environment

Horizontal stratification and regional stratigraphic correlations of this pelagic carbonate unit indicate that it was deposited over a broad, very low gradient continental shelf with little terrestrial sediment input. The abundant nannofossils and planktonic foraminifera indicate water depths within the outer-neritic or bathyal zone.

Variable abundances of planktonic foraminifera within the cored interval may be a result of dissolution cycles or water-mass changes. The conspicuous clayey intervals may reflect Milankovitch cyclicity, which is clearly evident from changes in clay versus carbonate ratios within Campanian calcilutites on the Exmouth Plateau (Golovchenko et al., 1992; Huang et al., 1992).

The benthic foraminifera belong to the open-marine *Marssonella* Association of Haig (1979). Changes in dominant benthic species through the succession (Appendix 1) may reflect slight variations in bottom-water conditions, especially dissolved oxygen and temperature, which in turn may be related to bathymetric change. Where dissolution has not taken place, planktonic foraminifera generally make up 30–70% of the total foraminiferal assemblage in the 150 µm to 2 mm fraction. Overall, the fauna suggests outer-neritic water depths (100–200 m; Fig. 8). A comparison of the benthic foraminiferal distributions (Appendix 1, Tables 1.2 and 1.3) with Late Cretaceous bathymetric models proposed by Koutsoukos and Hart (1990), Nyong and Olsson (1984), Olsson and Nyong (1984), and Sliter and Baker (1972) imply that the interval 230–238 m in Edaggee 1 was deposited in the shallowest part of the outer-neritic zone, whereas the interval 216–218 m was the deepest part of this zone. During the Santonian, the sedimentation rate of the Toolonga Calcilutite in the Edaggee region was at least 8 m/m.y. (Fig. 8), whereas during the Campanian it was at least 15 m/m.y., assuming that the stage boundaries are consistent with the ages designated by Gradstein et al. (1994). Only the uppermost Coniacian seems to be present at the base of the unit, and therefore the sedimentation rate of this section is poorly constrained.

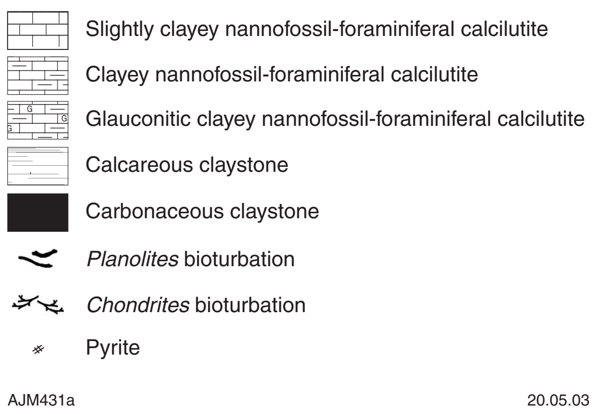
# Haycock Marl

The interval from 238.1 to 245.7 m correlates with the Haycock Marl. The latest Cenomanian to middle Turonian age assigned to this interval is based on:

- the HO of planktonic foraminifera *Whiteinella archaeocretacea* at 240.5 m;
- the LO of the nannofossil *Marthasterites furcatus* at 235.05 m and the HO of nannofossil *Eprolithus eptapetalus* at 239.10 m; and
- the LO of the nannofossil of *Eprolithus eptapetalus* at 244.05m.

## Lithostratigraphy

The Haycock Marl was originally described in the Northern Carnarvon Basin by Heath and Apthorpe (1984), who distinguished the formation from the overlying Toolonga Calcilutite by its argillaceous content, and from the Gearle Siltstone by its strongly calcareous beds. Although Heath and Apthorpe (1987) included the unit in the Winning Group, it is excluded here; although it is lithologically transitional between the dominantly siliciclastic Winning Group and carbonate of the Toolonga Calcilutite, it has more in common with the Toolonga Calcilutite (Fig. 10). The unit has previously not been formally recognized in the Southern Carnarvon Basin.



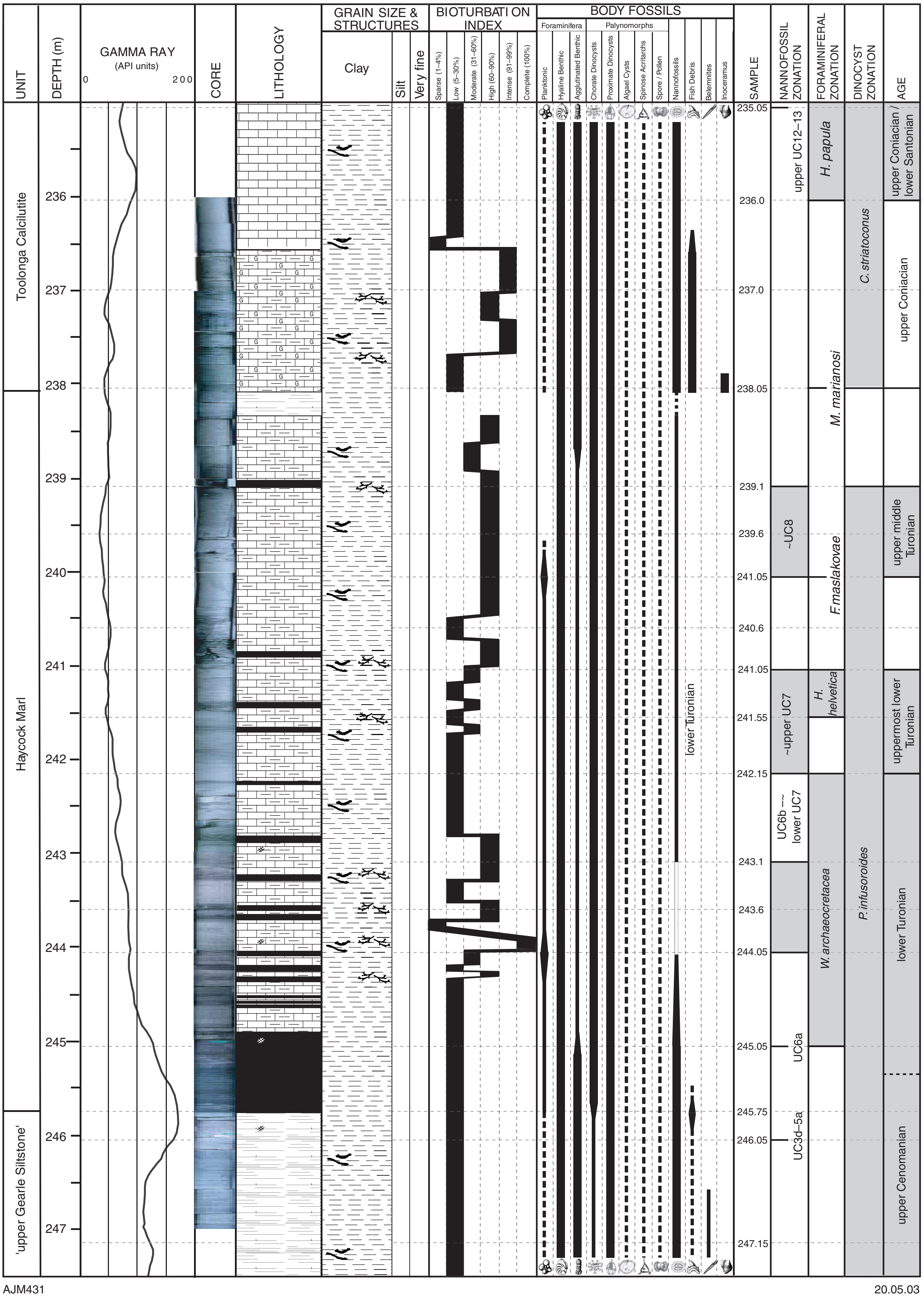



**Figure 10. Stratigraphic log and biostratigraphy of the Haycock Marl in Edaggee 1 (see legend on opposite page)**

In Edaggee 1, the upper 0.3 m of the Haycock Marl consists of pale-grey, soft, clayey calcilutite, which is conspicuously different from the green calcilutite of the overlying Toolonga Calcilutite. Below the pale-grey bed, most of the unit (6.4 m from 238.4 to 244.8 m) is characterized by decimetre-scale beds of grey or light-grey calcilutite, alternating with thinner, dark-grey (more carbonaceous), clayey calcilutite (Fig. 10). Lighter calcilutite beds are extensively bioturbated, with millimetre- to centimetre-scale burrows (mainly *Planolites* and *Chondrites*) penetrating darker, clayey beds and partly homogenizing some of these layers (Fig. 11a). Dark, clayey beds, and spatially associated *Chondrites* bioturbation, become increasingly wider spaced up-section. There are abundant benthonic and planktonic foraminifera, nannofossils, and dinocysts within both bed types, and, within the resolution of sampling, there seems little difference in assemblages between adjacent light and dark beds. Instead, all fossil groups show an upward trend towards greater diversity within the interval (Appendices 1–3). Terrestrial spores and pollen are extremely rare, making up less than 1% of palynomorph counts (Appendix 3).

The basal 0.9 m of the Haycock Marl (244.8 – 245.7 m) consists of a black, laminated claystone (Fig. 11b) with extremely high TOC of 26.8% (Appendix 4). Abundant but low diversity nannofossil assemblages, very rare thin-walled dinocysts, and benthonic foraminifera are the main fossil groups present. The base of the formation (245.7 m) is at a sharp lithological contact between dark-grey, highly carbonaceous claystone above, and pale-grey calcareous claystone ('upper Gearle Siltstone') below.

## Chronostratigraphy

Nannofossils indicate that the interval 239.1 – 240.05 m, assigned to the UC8 Zone (Appendix 3), is middle Turonian to lower Coniacian, based on the presence of *E. eptapetalus*. The planktonic foraminifera at 240.05 m indicate a level within the lower part of the *Falsotruncana maslakovae* Zone (Appendix 1), which is consistent with an upper middle Turonian position (following correlations of Robaszynski and Caron, 1995). Although no age determinations have been made for the uppermost Haycock Marl above 239.1 m, the available data imply that a substantial hiatus (separating the middle Turonian and upper Coniacian) may exist at the top of the unit.

The interval 241.05 – 242.05 m is assigned to the nannofossil UC7 Zone (Appendix 3), which Burnett (1998) places within the uppermost lower Turonian. The 241.05 m level belongs to the uppermost part of the zone. Planktonic foraminifera from the interval 241.05 – 241.55 m indicate that this level belongs to the *Helvetoglobotruncana helvetica* Zone, which according to Bengston (1996) and Robaszynski and Caron (1995) is within the lower–middle Turonian. The planktonic foraminiferal *Whiteinella archaeocretacea* Zone includes the interval 242.15 – 245.05 m. Within this zone, the 242.15 m level belongs to the UC7 Zone, the interval 243.1 – 244.05 m is attributed to the UC6b to lower UC7 Subzones, and 245.05 m belongs to the UC6a Subzone. According to the correlations of Burnett (1998), UC6a Subzone lies near the base of the Turonian. Therefore, the entire planktonic foraminiferal *W. archaeocretacea* Zone in Edaggee 1 is probably equivalent to the lower Turonian. Elsewhere it may range into the uppermost Cenomanian (Bengston, 1996).

The basal black, laminated, carbonaceous-rich claystone between 244.8 and 245.7 m may represent the worldwide Cenomanian–Turonian oceanic anoxic event (OAE 2; Jenkyns, 1980). Organic matter within this bed is of marine origin (Appendix 4). The Cenomanian–Turonian boundary is placed somewhat arbitrarily at 245.2 m, just below an earliest Turonian nannofossil sample (245.05 m: UC6a Subzone; Appendix 3), which is consistent with the proposed Turonian global stratotype, where the Cenomanian–Turonian boundary is a short distance below the top of the OAE 2 bed (Bengston, 1996). The lowest level sampled for microfossils in the Haycock Marl in Edaggee 1 (black shale at 245.75 m) contains a benthic foraminiferal assemblage that includes organic-cemented agglutinated species belonging to the *Textulariopsis*? *kurillinensis* Zone of the *Ammobaculites* Association, and calcite-cemented agglutinated and calcareous hyaline foraminifera belonging to the *Textulariopsis* sp. 2 Zone of the *Marssonella* Association. These are local zones, which at lower levels include definite Cenomanian strata. The benthic assemblage differs from that in the overlying *W. archaeocretacea* Zone of the lower Turonian (Appendix 1).

Based on the correlations discussed above, the Haycock Marl in Edaggee 1 belongs to the uppermost Cenomanian to middle Turonian as summarized in Figure 10. The correlation may change when the ICS formally defines stage and substage boundaries.

## Regional correlations

In the Northern Carnarvon Basin the Haycock Marl is a lateral equivalent of the Gearle Siltstone, and is of Albian to earliest Santonian age (Heath and Apthorpe, 1984). Typical thicknesses of the unit in that part of the basin are in the range of 100–200 m. In some areas it interfingers with the Gearle Siltstone. The Haycock Marl is partly equivalent to the Beedagong Claystone described by Shafik (1990) from Rough Range 1 (Exmouth Sub-basin), where it is 83 m thick, but that unit appears to span a break between the Turonian and Coniacian.

In the Southern Carnarvon Basin, the Haycock Marl is a thin but widespread unit of mainly Turonian age. In Edaggee 1 it is considerably thicker (7.4 m) than in the other known sections in the basin (2.1 m in Boologooro 1, and less than 1 m at C–Y Creek to the north and at Murchison House Station in the south; Haig et al., in prep.; Howe et al., 2000; Haig, 2002). At C–Y Creek and Murchison House Station the Haycock Marl is preserved as discontinuous lenses below an unconformity (Howe et al., 2000; Haig, 2002), and this may partially explain its absence from many outcrops and wells elsewhere on the Gascoyne Platform. It is also likely that the unit has not been differentiated from the Gearle Siltstone or Toolonga Calcilutite, especially in uncored boreholes. Gamma-ray logs in nearby water bores (Fig. 4) show a good correlation to the log used for Edaggee 1 (from a water bore only 420 m away), and should provide a useful correlation tool for this unit.

## Depositional environments

Regional correlations suggest that the Haycock Marl is widespread, implying deposition on a very low gradient continental shelf across much of the Southern Carnarvon Basin. The very low relative abundance (less than 1%) of spores and pollen in the palynomorph preparations suggests an offshore environment, as does the abundance of nannofossils and planktonic foraminifera. Following Howe et al. (2000), outer-neritic water depths (100–200 m) are suggested for the benthic foraminiferal species (Appendix 1), which are characteristic of the open-marine *Marssonella* Association of Haig (1979). The very high percentage of large-size planktonic foraminifera at 244.05 m may reflect the deepest-water deposition.

The characteristic depositional cycles in the Haycock Marl, delineated by alternating carbonaceous clay and bioturbated calcilutite layers, may reflect changes in levels of dissolved oxygen in the bottom waters. These cycles may be associated with global oceanic anoxic events. The sedimentation rate of the Haycock Marl in the Edaggee region was about 1.5 m/m.y. (Fig. 8).

# Winning Group

All units of the Winning Group (Gearle Siltstone, Windalia Radiolarite, Muderong Shale, and Birdrong Sandstone in descending stratigraphic order) are present in Edaggee 1. The group differs from overlying units by the absence of pelagic carbonates. In Edaggee 1 the Gearle Siltstone contains a major disconformity and is accordingly divided into the 'upper Gearle Siltstone' and 'lower Gearle Siltstone'. These designations are informal, and do not correspond to those used in the Northern Carnarvon Basin prior to 1990, where the 'upper Gearle Siltstone' was synonymous with the Beedagong Claystone (Shafik, 1990).

## Upper Gearle Siltstone

The interval from 245.7 to 253.3 m correlates with the 'upper Gearle Siltstone'. The Cenomanian age assigned to this interval is based on:

- the HO of the nannofossil *Axopodorhabdus biramiculatus* at 246.05 m;
- The LO of the nannofossil *Eiffellithus turriseiffellii* and the HO of the nannofossil *Gartnerago nanum* at 252.9 m; and
- the presence of the planktonic foraminifera *Rotalipora reicheli* at 248 and 249 m.

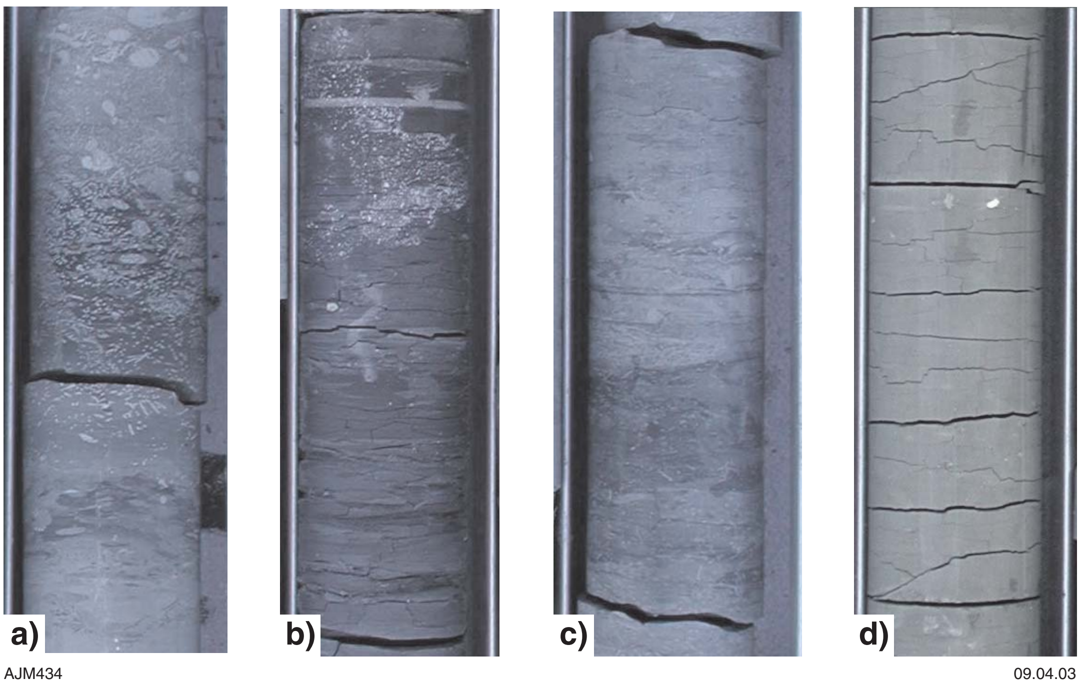



**Figure 11. Representative core photographs of the Haycock Marl and Gearle Siltstone in Edaggee 1: a) 242.8 – 243.05 m: interbedded light- and dark-grey calcareous mudstones of the Haycock Marl with typical well-defined bioturbation (*Planolites* and *Chondrites*). *Chondrites* bioturbation is more abundant in darker beds; b) 245.3 – 245.6 m: dark, carbonaceous-rich, laminated mudstone of the basal part of the unit, probably representing the Cenomanian–Turonian oceanic anoxic event; c) 247.2 – 247.55 m: relatively uniform, light-grey calcareous mudstone of the 'upper Gearle Silstone' with *Planolites* and *Chondrites*; and d) 262.55 – 262.8 m: dark-grey, fissile, very uniform mudstone of the 'lower Gearle Silstone'**

### Lithostratigraphy

The 7.6 m-thick 'upper Gearle Siltstone' (245.7 – 253.3 m) consists of variably light- to dark-grey, strongly calcareous, pyritic claystone (Fig. 11c), which becomes more uniformly grey below about 250 m. Pervasive, indistinct, centimetre-scale bioturbation appears to be similar to that within the Haycock Marl and Toolonga Calcilutite. Phosphatic nodules and siderite are common, in contrast to their absence in the 'lower Gearle Siltstone'. In sand fractions of the claystone, benthic foraminifera are abundant compared to planktonic foraminifera, fish debris, belemnite guards, echinoid spines, ostracods, and dinocysts (Appendix 1). Brachiopods are rare and radiolaria are absent.

The upper boundary of the 'upper Gearle Siltstone' is placed at the base of a black carbonaceous claystone at 245.7 m. The disconformity between the 'upper' and 'lower' Gearle Siltstone is placed at the base of a nodule horizon at 253.3 m.

### Chronostratigraphy

A nannofossil sample (246.05 m) just below the top of the 'upper Gearle Siltstone' in Edaggee 1 belongs within the UC3d–5a Subzones (Appendix 3), which Burnett (1998) assigned to the middle part of the upper Cenomanian (upper *Calycoceras guerangeri* to *Metoicoceras geslinianum* Zones of the European ammonite succession). Nannofossils from near the base of the 'upper Gearle Siltstone' at 252.9 m belong within the UC1–3c Subzones (Appendix 3) of the lower or middle Cenomanian (Burnett, 1998). These stage correlations are consistent with the presence of the planktonic foraminiferal *Rotalipora reicheli* Zone at 248 and 249 m, which has been correlated with the upper lower to middle Cenomanian (Appendix 1; Caron, 1985). The 'upper Gearle Siltstone' therefore ranges from within the lower or middle Cenomanian to at least the middle part of the upper Cenomanian. If the upper part of the upper Cenomanian (corresponding to nannofossil UC5b–c Subzones) is present, then it lies in a condensed section between 246.05 and 245.05 m.

### Regional correlations

Within the Gearle Siltstone a similar disconformity is known to the south of Edaggee 1 in the Murchison River area, where the Alinga Formation (equivalent to the 'lower Gearle Siltstone') is unconformably overlain in places by the 'upper Gearle Siltstone' (Haig, 2002). The 'lower Gearle Siltstone' is unconformably overlain by the Toolonga Calcilutite in other sections in this region (e.g. Coburn 1; Yasin and Mory, 1999a). To the north of Edaggee 1, in Boologooro 1, Cynamid 3, and in the Giralia Anticline, continuous deposition is apparent. In the type area of the Gearle Siltstone in the Giralia Anticline, the Cenomanian 'upper Gearle Siltstone' was identified by Howe et al. (2000), but an exact thickness could not be measured, as the base is not exposed. In Cynamid 3 on Hill Springs Station, the unit is just over 10 m thick, and in Boologooro 1 it is just over 20 m thick. To the south of Edaggee 1, in the lower Murchison River area, the 'upper Gearle Siltstone' forms discontinuous lenses up to several metres thick beneath the Haycock Marl or the Toolonga Calcilutite.

### Depositional environments

Regional correlations suggest that the 'upper Gearle Siltstone' was deposited as a widespread argillaceous unit on a very low gradient continental shelf, across much of the Southern Carnarvon Basin. The benthic foraminiferal assemblage contains elements of the open-marine *Marssonella* Association, and the more restricted marine *Ammobaculites* Association, and is similar to the assemblage from the 'upper Gearle Siltstone' in the Giralia Anticline, for which Howe et al. (2000) interpret middle-neritic water depths of 50–100 m. The relatively sparse, low-diversity planktonic foraminiferal assemblage supports this bathymetric interpretation. Among the nannofossils, the presence of *Seribiscutum primitivum* (a high-latitude Austral Province species) and *Rhagodiscus asper* (generally considered to be a low- to mid-latitude Tethyan Province species) suggest temperate surface waters. The sedimentation rate of the 'upper Gearle Siltstone' in the Edaggee region was about 2.5 m/m.y. (Fig. 8).

## Lower Gearle Siltstone

The interval from 253.3 to 266.0 m correlates with the 'lower Gearle Siltstone'. The early Albian age assigned to this interval is based on:

- the LO of calcareous benthic foraminifera *Berthelina intermedia* at 265.1 m, and the HO of *Lingulogavelinella indica* at 253.85 m;
- the range of agglutinated foraminifera *Eomarssonella crespinae* from 253.85 to 264.05 m;
- the range of planktonic foraminifera *Blefuscuiana* sp. from 253.85 to 261.0 m; and
- the LO of the nannofossils *Prediscosphaera columnata* at 253.85 m.

### Lithostratigraphy

The 'lower Gearle Siltstone' (253.3 – 266.0 m) in Edaggee 1 is 12.7 m thick and is mainly dark-grey, fissile, calcareous claystone (Fig. 11d), which is conspicuously more uniform in appearance than the 'upper Gearle Siltstone'. The upper boundary of the unit is placed at 253.3 m at the base of a nodule horizon. In the upper part of the section, the claystone contains abundant glauconite and includes centimetre-scale burrows (mainly *Planolites*). Towards the base of the unit, very small scale bioturbation (mainly *Chondrites*) is pervasive. Benthonic foraminifera are abundant, and are dominated by organic-cemented agglutinated forms, with variable abundances of calcitic and aragonitic hyaline forms. Fish debris, belemnites, brachiopods, radiolaria, and dinocysts are also abundant, whereas echinoid spines and planktonic foraminifera are rare (Appendix 1). The lower boundary of the formation is placed at 266.0 m at the contact between a calcareous sandy mudstone above and a less calcareous, more indurated mudstone with larger-scale burrow systems below.

### Chronostratigraphy

The upper part of the 'lower Gearle Siltstone' at 253.85 m is no older than nannofossil Subzone CC8a (Appendix 3), which is confined to the lower Albian according to Burnett (1998). The presence of the planktonic foraminiferal *Blefuscuiana* sp. Zone (*Hedbergella planispira* Zone of Haig, 1979) also supports this correlation. The benthic foraminiferal *Berthelina intermedia* and *Eomarssonella crespinae* Zones are no earlier than lower Albian (Haig, 1979; Haig and Lynch, 1993; Campbell and Haig, 1999). The 'lower Gearle Siltstone' in Edaggee 1 is therefore confined to the lower Albian. Based on the nannofossil and planktonic foraminiferal correlations described above, the dinoflagellate *Canninginopsis denticulata* Zone in Edaggee 1 belongs to the lower Albian. The hiatus between the 'lower' and 'upper' Gearle Siltstone includes the middle and late Albian.

### Regional correlation

The type area of the Gearle Siltstone within the Giralia Anticline, described by Haig et al. (1996), has similar foraminiferal and nannofossil assemblages to those in the 'lower Gearle Siltstone' in Edaggee 1. However, the full thickness of the 'lower Gearle Siltstone' could not be measured in the Giralia Anticline section. In Barrabiddy 1/1A, at least 17 m of lower Albian (*Blefuscuiana* Zone) strata was cored, and in Coburn 1 the equivalent unit (dinoflagellate *C. denticulata* Zone) is probably about 31 m thick. In the lower Murchison River area, the Alinga Formation (coeval with the 'lower Gearle Siltstone') ranges in thickness from 3 to 8 m.

### Depositional environments

Regional correlations suggest that the 'lower Gearle Siltstone' was deposited as a widespread argillaceous unit on a very low gradient continental shelf across much of the Southern Carnarvon Basin. Based on the foraminiferal assemblages, which are transitional between the *Ammobaculites* and *Marssonella* Associations of Haig (1979), maximum water depths at the time of deposition of the 'lower Gearle Siltstone' in Edaggee 1 were probably within the mid-neritic range (50–100 m), following the interpretation by Haig et al. (1996) for similar coeval assemblages in the Giralia Anticline. Bottom waters probably had lower dissolved-oxygen levels than those during deposition of the Cenomanian 'upper Gearle Siltstone', and water depths may have fluctuated more during the early Albian than during the Cenomanian. The sedimentation rate of the 'lower Gearle Siltstone' in the Edaggee region was about 3 m/m.y. (Fig. 8).

## Windalia Radiolarite

The interval from 266.0 to 297.7 m correlates with the Windalia Radiolarite. The middle to late Aptian age assigned to this interval is based on:

- the HO of the dinocyst *Muderongia tetracantha* at 266.1 m; and
- the range of the dinocyst *Diconodinium davidii* from 280.8 to 289.9 m.

### Lithostratigraphy

The Windalia Radiolarite (266.0 – 297.7 m) is characterized by distinctly siliceous, radiolarian-rich, dark-grey siltstone (Fig. 12a). Sand fractions from the siltstone are generally made up of abundant radiolaria, a variable presence of benthic foraminifera, shell fragments (probably of a linguloid brachiopod), fish debris, and rare sponge spicules and plant debris. Palynomorph preparations include abundant dinocysts; spores and pollen constitute 13–33% of assemblages between 290.0 and 290.6 m, and 14–18% in higher samples.

In Edaggee 1, the Windalia Radiolarite is about 30 m thick. The upper boundary is tentatively placed at 266.0 m, at the facies change between the more calcareous and friable mudstone of the 'lower Gearle Siltstone' above, and a more indurated, less calcareous mudstone below. The lower boundary is positioned at the contact between a relatively indurated, sandy mudstone above and the friable greenish grey claystone of the Muderong Shale below.

### Chronostratigraphy

The dinoflagellate *Muderongia tetracantha* Zone is identified at 266.1 m, in the uppermost part of the unit. In Barrabiddy 1/1A, this zone is associated with the planktonic foraminiferal *Blefuscuiana* Zone of the lower Albian (Mory and Yasin, 1999). Disaggregated samples at 274.1 and 280.8 m have yielded abundant radiolaria equivalent to the microfauna described by Ellis (1993) from the type section of the Windalia Radiolarite, where ammonites indicate a correlation with the upper Aptian. Samples in the interval 280.8 – 290.6 m belong to the dinoflagellate *Diconodinium davidii* Zone of the upper Aptian (according to the correlation outlined by Helby et al., 1987). Therefore, the main portion of the Windalia Radiolarite in Edaggee 1 belongs to the upper Aptian with the uppermost part extending into the lower Albian. The position of the Aptian–Albian boundary is uncertain, but is placed arbitrarily just below 266.1 m.

### Regional correlations

The Windalia Radiolarite is widespread in the Southern Carnarvon Basin, both in outcrop and the subsurface. The 30 m thickness of the unit in Edaggee 1 is comparable to the 34 m-thick type section at Windalia Hill (Ellis, 1993). In Barrabiddy 1/1A, the formation is 47 m thick (Mory and Yasin, 1999), and in the Giralia Anticline it is at least 30 m thick (based on its thickness in Giralia 1; McLoughlin et al., 1995). To the south of Edaggee 1, the Windalia Radiolarite was not positively identified in Coburn 1 (Yasin and Mory, 1999a), but is represented by about 12 m of strata in the lower Murchison River area (Haig, 2002).

### Depositional environment

Regional correlations suggest that the Windalia Radiolarite was deposited as a widespread argillaceous unit on a very low gradient continental shelf across much of the Southern Carnarvon Basin. The radiolarian-rich facies has been interpreted to reflect mid-neritic (around 50 m) maximum

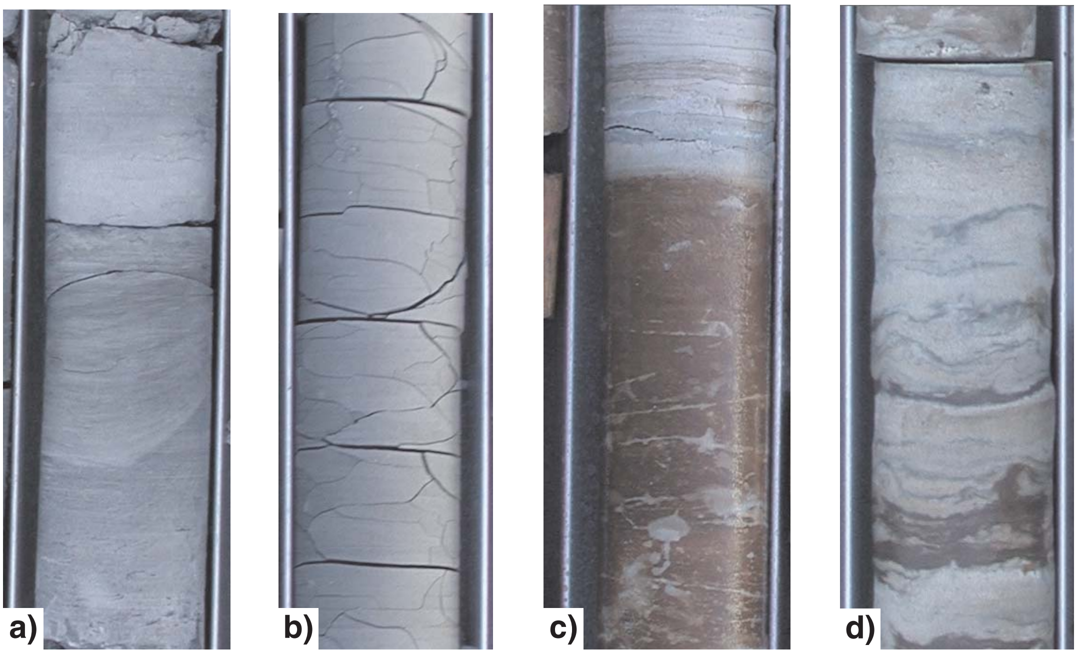



**Figure 12. Representative core photographs of the lower Winning Group and Sweeney Mia Formation in Edaggee 1: a) 273.45 – 273.7 m: typical Windalia Radiolarite core showing strong induration, brittle fracturing, alternating dark mud content, and laminated and diagenetically deformed bedding; b) 303.15 – 303.40 m: uniform dark-grey mudstone of the Muderong Shale; c) 327.3 – 327.55 m: alternating laminated white dolomite and more-massive, strongly ferruginized dolomitic mudstone of the upper Sweeney Mia Formation; and d) 341.40 – 341.65 m: interbedded recrystallized dolomite and green mudstones within the lower Sweeney Mia Formation**

water depths (Haig et al., 1996). The absence of diverse benthic foraminifera suggests low levels of dissolved oxygen in the bottom waters. The sedimentation rate of the Windalia Radiolarite in the Edaggee region was about 5 m/m.y. (Fig. 8).

## Muderong Shale

The interval from 297.7 to 309.5 m correlates with the Muderong Shale. The early Aptian age assigned to this interval is based on the LO of dinocyst *Muderongia mcwhaei* at 301.15 m.

### *Lithostratigraphy*

In Edaggee 1, the Muderong Shale (297.7 – 309.5 m) is an 11.8 m-thick, greenish-grey, friable claystone (Fig. 12b). Quartz sandstone is present in the interval 306.1 – 307.6 m. Pyrite is common throughout the formation in the form of sand-size aggregates and cylindrical rods. The sand fraction of the claystone contains abundant siliceous organic-cemented agglutinated foraminifera, rare to abundant fish debris, rare to abundant pyritized diatoms, and rare small linguloid brachiopods. Glauconitic radiolarian moulds are common at two levels (299.05 and 306.05 m). In palynological preparations, dinocysts are predominant, with spore–pollen percentages varying from 6% at 301.15 m to 38–43% in the interval 308.8 – 309.65 m.

In Edaggee 1 the upper boundary (297.7 m) is placed at the contact between a relatively indurated sandy mudstone of the Windalia Radiolarite above and the friable, greenish grey claystone below. The lower boundary (309.5 m) is placed at the contact between dark-green to grey claystone above, and muddy quartz sandstone of the Birdrong Sandstone below.

### *Chronostratigraphy*

Sample 301.15 m belongs to the dinoflagellate *Odontochitina operculata* Zone, which was assigned by Helby et al. (1987) to the lower Aptian. A sample at 308.80 m belongs to the upper part of the *Muderongia australis* Zone of the Barremian (according to correlations by Helby et al., 1987). Therefore the Barremian–Aptian boundary is placed arbitrarily at 305 m. The benthic foraminiferal assemblages in the 297.7 – 309.5 m interval are not age diagnostic and also lack key species recorded by Taylor and Haig (2001) from the type section of the Muderong Shale and in Barrabiddy 1/1A. It is uncertain whether this suggests an age difference between the Edaggee 1 succession and the type section of the Muderong Shale.

### *Regional correlations*

The thickness of the Muderong Shale in Edaggee 1 (11.8 m) is similar to that in the type section (Taylor and Haig, 2001), but is thinner than in Barrabiddy 1/1A (which penetrated 32.5 m of sandstone overlying 5.5 m of claystone in the *O. operculata* and *M. australis* Zones; Mory and Yasin, 1999) and Giralia 1 (which penetrated almost 10 m of sandstone overlying 65 m of claystone in the equivalent interval; Taylor and Haig, 2001). In Mooka 1, to the east of Edaggee 1, the Muderong Shale is less than 4 m thick (Mory and Yasin, 1998), and to the south in Coburn 1 the unit has been recognized over a 38-m interval consisting of 32.5 m of sandstone overlying 5.5 m of mainly claystone (Yasin and Mory, 1999a).

### *Depositional environments*

Regional correlations suggest that the Muderong Shale was deposited on a very low gradient embayment across much of northern part of the Southern Carnarvon Basin (Taylor and Haig, 2001). The foraminiferal assemblages are characteristic of the *Ammobaculites* Association (Haig, 1979). The character of these assemblages generally resembles that interpreted by Taylor and Haig (2001) to indicate inner-neritic maximum water depths for the unit elsewhere in the onshore part of the basin.

## Birdrong Sandstone

The interval from 309.5 – 311.9 m correlates with the Birdrong Sandstone. The Barremian age assigned to this interval is based on the identification of the upper *M. australis* Dinoflagellate Zone at 308.8 and 309.65 m.

### *Lithostratigraphy*

The Birdrong Sandstone (309.5 – 311.9 m) consists of grey, fine- to medium-grained sandstone with inter-bedded dark-grey to green clay and friable pebbly sandstone. The sand fraction is composed of abundant quartz, with rare feldspar and glauconite. As in the overlying Muderong Shale, the muddy sandstone at 309.65 m contains abundant siliceous organic-cemented agglutinated foraminifera, and rare small linguloid brachiopods and fish debris. The upper boundary of the unit is marked by the change from claystone above, to muddy sandstone at 309.5 m. The lower boundary is placed at 311.9 m, below a 1.1-m section of core loss that is assumed to have been loose sand, at a conspicuous unconformity separating the formation from soft mudstones of the uppermost Sweeney Mia Formation.

### *Biostratigraphy*

A sample from near the top of the formation (at 309.65 m) belongs to the upper part of the *M. australis* Zone, which is attributed to the Barremian (following Helby et al., 1987).

### *Regional correlations*

The Birdrong Sandstone is the basal unit of the Cretaceous succession across much of the Southern Carnarvon Basin. It is up to 79 m thick on Woodleigh Station (Mory et al., 2001), but in the central part of the basin it is typically less than 10 m thick.

### *Depositional environments*

The benthic foraminiferal assemblage from 309.65 m is typical of the *Ammobaculites* Association (Haig, 1979). The unit was probably deposited under low-energy shoreface conditions in the innermost-neritic zone during the initial Cretaceous marine transgression across the basin (Hocking, 2000).

# Sweeney Mia Formation

## Lithostratigraphy

The Sweeney Mia Formation is present in the interval 311.9 m to TD (351.0 m). In the nearby homestead water bore it continues to a depth of 360.0 m, where it overlies the Kopke Sandstone. The uppermost metre of the formation is composed of soft, massive, grey mudstone. Beneath this, the formation mainly consists of centimetre- to decimetre-scale interbeds of red, yellow, or green dolomitic mudstones and dolomite (Figs 12c,d). Despite extensive ferruginous mottling, common primary features, such as planar laminations, andrare features, such as erosional surfaces, rip-up clasts, soft-sediment deformation, and brecciation, are apparent in the upper part of the formation. Some dolomites may be algal laminated. Rare centimetre-scale interbeds of green or red mudstone are present, often with wavy laminations.

Below 324.5 m, coarse-grained sucrosic dolomite is conspicuous within dolomitic mudstones. Wavy laminated, coarse-grained sucrosic dolomite beds below 324.5 m are at decimetre scale, but become thicker and more common down to 341 m. No macrofossils were recovered from the formation.

## Regional correlations and age

The Sweeney Mia Formation has been identified unambiguously from only four other wells, which are all 60 to 80 km to the south of Edaggee 1: Hamelin Pool 1 and 2, Yaringa 1, and Yaringa East 1 (Fig. 2; Mory et al., 1998). In these wells the formation is much more variable than it is in Edaggee 1, with a coarser-grained siliciclastic component. The only direct evidence for the age of the unit is from Yaringa East 1, which yielded a sparse palynoflora of probable Late Silurian or Early Devonian age and worn fish scales likely to be Middle–Late Devonian in age (Yasin and Mory, 1999b). These samples lie 426 m above an Early Devonian conodont fauna in the well, so an Early–Middle Devonian age is likely for the Sweeney Mia Formation.

## Depositional environments

The Sweeney Mia Formation was probably deposited in an arid climate in low-energy, evaporitic environments such as sabkha or playa lakes. Stable isotopes from evaporites within the unit in Yaringa East 1 suggest that it was non-marine (e.g. playa lake; Yasin and Mory, 1999b). The lower part of the formation in Edaggee 1 was probably deposited in deeper water conditions and not subject to periodic exposure.

## Kopke Sandstone

Although not intersected in Edaggee 1, the Kopke Sandstone is present between 360 and 390 m (TD) in the nearby water bore, the wireline logs of which are used in this Record. Cuttings samples from this interval consist of medium- to coarse-grained sandstone. The unit is likely to be Lower–Middle Devonian based on a correlation with Yaringa East 1, from which a Lochkovian (Early Devonian) conodont fauna was recovered from low in the unit (Yasin and Mory, 1999b). In Yaringa East 1 the unit is interpreted to have been deposited in a range of environments, including eolian, fluvial, lacustrine, and very shallow marine.

# Petroleum geochemistry

## Source potential

All but one of the Cretaceous samples in Edaggee 1 (Appendix 4) are organically rich, with a TOC range of 0.59 – 26.8% and a potential yield ($S_1$+$S_2$) of 1.11 – 55.00 mg/g rock, and dominated by oil- and gas-generating type-II kerogen. The organically richest samples are from the Haycock Marl, with TOC values of 11.4 – 26.8%, and potential yield ($S_1$+$S_2$) of 37.83 – 55.00 mg/g rock. One sample from the Muderong Shale has good organic richness and hydrocarbon-generating potential. All other Cretaceous samples are organically rich with fair hydrocarbon-generating potential. By comparison, samples from the Lower Devonian Sweeney Mia Formation are organically lean, with a TOC of less than 0.2%, and were not analysed further for source potential.

## Maturation

Mean vitrinite reflectance (%Ro) values in the Cretaceous samples range from 0.34 to 0.36%, indicating that these units are immature for oil generation and were not buried more than a few hundred metres than they are at present. Rock-Eval $T_{max}$ values and thermal alteration of spores are consistent with such a low thermal maturation. Samples from the Sweeney Mia Formation did not contain dispersed organic matter, so its thermal maturity could not be assessed. To the south of Edaggee 1, reflectance values from Palaeozoic samples are typically less than 0.7%, indicating relatively minor erosion prior to deposition of the Cretaceous succession.

## Reservoir character

No analyses of reservoir parameters were made, but the weakly cemented nature of the Birdrong Sandstone in Edaggee 1 and its hydrological properties, as indicated from nearby water bores, imply reasonable porosity and permeability. Although the unit is just 2.4 m thick, it produced a small artesian flow. By comparison, the Lower–Middle Devonian Kopke Sandstone yields a strong artesian flow, implying excellent reservoir properties for the unit in this region. The only other unit intersected that may be considered as a potential reservoir, the Windalia Radiolarite, was strongly cemented with little indication of fracture porosity.

Potential seals penetrated in Edaggee 1 include mudstone and tight radiolarite of the Winning Group, which form an effective aquitard to the underlying Birdrong Sandstone, and fine-grained dolomite of the Sweeney Mia Formation above the Kopke Sandstone.

# Whole-rock chemistry

As part of a pilot study, 27 samples from three drillholes (Edaggee 1, Yinni 1, and Boologooro 1) from the Gascoyne Platform have been analysed for 48 components to determine if whole-rock chemistry is an effective correlation tool and whether there is any indication of mineralization. Whole-rock chemistry has been successfully used in several studies to track the provenance and weathering history of sedimentary rocks (e.g. Nesbitt and Young, 1984; Nesbitt et al., 1996).

Twelve of the samples analysed (10 sedimentary rocks, a pyrite nodule, and a barite vein) are from Edaggee 1 (Appendix 5), and cover part of the Cretaceous (Aptian to Turonian: Windalia Radiolarite, Gearle Siltstone, and Haycock Marl) and Middle Devonian (Sweeney Mia Formation) sections. Statistical analyses have been applied to test both within- and between-hole variations in the chemistry of the Gearle Siltstone, and whether anomalous values for some elements in regolith derived from the Gearle Siltstone on the WINNING POOL – MINILYA 1:250 000 map sheet (Sanders and McGuinness, 2001) are also found in drillcore.

The concentrations of analytes such as Ba, S, Sr, CaO, and $SiO_2$ vary widely in the Gearle Siltstone. Variations in Ba, $P_2O_5$, Sb, and Y values may reflect localized development of barite veining, and phosphate and pyrite nodules, whereas differences in $Fe_2O_3$ and V values could be due to variable ferruginization. However, the low number of statistically different median values for the Gearle Siltstone in Edaggee 1 and Boologooro 1 indicate compositional homogeneity within this unit over long distances. In terms of mineralization, the median values in the Gearle Siltstone for precious metals Pd and Pt are close to detection level. There were insufficient samples in this unit for analyses of Au concentrations. Levels of Cu, Zn, Pb, Ni, and As in the Gearle Siltstone are also unremarkable. Despite the presence of phosphate nodules in the core, $P_2O_5$ levels are typically low in most of the samples analysed, which is consistent with only localized development of nodules, probably along erosion surfaces. Similarly, although some pyrite nodules have high $Fe_2O_3$, As, and S contents, they are also only locally developed.

A statistical comparison of median values from the 'lower' and 'upper' Gearle Siltstone, including data from Boologooro 1 and Yinni 1, shows that the 'upper Gearle Siltstone' has a higher carbonate content (higher median values for CaO, loss-on-ignition, Co, Li, Sr, and $CaO/SiO_2$; lower median values for $SiO_2$, MgO, and $Na_2O$), which may mean that there is a gradual increase in carbonate content up-section into the overlying Haycock Marl. In a comparison between the Gearle Siltstone and the Haycock Marl, account must be taken of the wide range in concentrations of some components (e.g. CaO) of the Haycock Marl. This means that for such components, there is no statistical difference in median values. Despite this, the higher carbonate content of the Haycock Marl is shown by a statistically higher $CaO/SiO_2$ concentration, and lower median values for MgO, $Na_2O$, Ba, and Rb. Statistically higher median values for Co, Ni, Pd, and chalcophile index (CI) for the Haycock Marl indicates a higher mineralization potential.

Stream-sediment samples derived from the Gearle Siltstone over the Giralia Anticline show several anomalous groups of elements (Sanders and McGuinness, 2001), but this variation is not apparent in core samples of the Gearle Siltstone (Appendix 5). Although this may be explained by basic lithological differences, a statistical comparison of the Gearle Siltstone between drillholes shows little difference in composition. A more likely explanation is that stream sediment geochemistry represents the effects of barite veining and associated secondary alteration, combined with surface silicification and subsequent mechanical sorting and chemical weathering during the regolith-forming process.

# Contributions to geological knowledge

The continuously cored section in Edaggee 1 allows the relationship between palynology, nannofossil, and foraminiferal zones to be examined in detail. More detailed work than presented in this Record is required to clarify the LO and HO datums of some species.

The Toolonga Calcilutite contains an expanded Santonian and Campanian section above a condensed ?upper Coniacian interval.

The uppermost Cenomanian – middle Turonian Haycock Marl, which consists of alternating carbonaceous mudstone and clayey calcilutite, is formally recognized within the Southern Carnarvon Basin for the first time. The transition between it and the underlying Gearle Siltstone is marked by black shale that probably represents the Cenomanian–Turonian boundary oceanic anoxic event, and possibly coincides with a significant increase in water depth.

Assuming that the stage boundaries are consistent with the ages designated by Gradstein et al. (1994), rates of deposition range from 1.5 to 8 m/m.y., with the greatest rate in the Santonian–Campanian part of the Toolonga Calcilutite, and the lowest rate in the Turonian Haycock Marl. This analysis suggests that the break between the 'upper' and 'lower' Gearle Siltstone spans about 15 m.y., whereas the other obvious break within the Cretaceous, between the Haycock Marl and Toolonga Calcilutite, is about 3 million years. Although the transition from predominantly terrigenous to carbonate sedimentation in the Turonian was accompanied by low rates of deposition, in Edaggee 1 there is no significant difference between rates in terrigenous sedimentation to the end of the Cenomanian (Winning Group) and rates in post-Turonian, largely pelagic, carbonate deposition (Toolonga Calcilutite).

Foraminifera indicate a general increase in palaeobathymetry throughout the Cretaceous, from low-energy shoreface conditions in the innermost-neritic zone during the initial Barremian transgressive phase (Birdrong Sandstone), to outer-neritic (100–200 m) water depths in the Santonian–Campanian (Toolonga Calcilutite). The most significant increases in palaeobathymetry coincide with the boundary between the Windalia Radiolarite and 'lower Gearle Siltstone', the breaks between the 'upper' and 'lower' Gearle Siltstone, and the disconformity between the Haycock Marl and Toolonga Calcilutite. Regional correlations indicate that all of the Cretaceous section was deposited over a broad, very low gradient continental shelf.

The Sweeney Mia Formation, of probable Early–Middle Devonian age, extends 60 km north of the Woodleigh impact structure, as interpreted by Mory et al. (2000) and Iasky et al. (2001).

The petroleum potential of the section in Edaggee 1 is limited due to the low thermal maturity of the Cretaceous and the oxidized nature of the Devonian Sweeney Mia Formation. Nevertheless, the hydrocarbon-generating potential of the Muderong Shale, Windalia Radiolarite, and 'lower Gearle Siltstone' in the Winning Group is significant. The oceanic anoxic event at the Cenomanian–Turonian boundary and higher levels within the Turonian Haycock Marl are classified as excellent potential oil- and gas-source rocks, showing excellent organic richness (TOC up to 26.8%) and hydrocarbon-generating potential ($S_1$+$S_2$ of up to 55 mg/g rock).

A statistical comparison of whole-rock chemistry for several lithological units in drillcore from wells over a distance greater than 100 km suggests little variation in provenance for the Gearle Siltstone throughout the area. Although the Gearle Siltstone is fundamentally different to the underlying Windalia Radiolarite in terms of lithology, mudstone in the overlying Haycock Marl appears to be similar, with a small increase in carbonate content compared to the upper part of the Gearle Siltstone. Extreme concentrations of some elements may be due to the localized development of pyrite and phosphate nodules and barite veins. Anomalous concentrations of some elements in regolith derived from the Gearle Siltstone are not found in core samples of this unit. It is likely that this anomaly can at least, in part, be attributed to the influence of vein development and surface silicification, combined with mechanical and chemical weathering. Additionally, no relationship between whole-rock chemistry and palaeobathymetry, sediment or water chemistry, or biostratigraphic divisions is evident.

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## Appendix 1

# Cretaceous foraminiferal biostratigraphy

by

D. W. Haig[1]

## Introduction

Washed sand residues of 72 samples of core from the 216.9 – 309.65 m interval in Edaggee 1 were examined for foraminifera (Tables 1.1 – 1.11). Selected cuttings from 122–200 m were also analysed. The samples were disaggregated in boiling water, and then wet-sieved over 63 µm, 150 µm, and 2 mm meshes. Comprehensive picks of microfossils were made from each sample.

## General observations

### 122–134 m (cuttings), *Archaeoglobigerina cretacea* Planktonic Zone

This interval is placed within the *Archaeoglobigerina cretacea* Zone as defined by Huber (1992) for the Austral Realm. The planktic assemblage from this interval includes common *Archaeoglobigerina cretacea*, with less common *Globotruncana* spp., *Globigerinelloides* spp., *Hedbergella* spp., and *Heterohelix reussi*, but lacks *Marginotruncana* spp. (Table 1.3). Huber (1992) used the extinction of *Marginotruncana marginata* to mark the lower boundary of the *A. cretacea* Interval Zone. The upper boundary of this zone was placed at the lowest occurrence (LO) of *Globigerinelloides impensus* Sliter 1977. Huber (1992) indicated that *A. cretacea* ranged only to the lowest part of the *G. impensus* Zone in southern high-latitudes and was rare towards the top of its range.

On the Exmouth Plateau, Petrizzo (2000) found *A. cretacea* at only a few levels in the *Dicarinella asymetrica* Zone directly below the *Globotruncanita elevata* Zone (time equivalent, in part, to the *A. cretacea* Zone of Huber, 1992). Petrizzo (2000) recorded the LO of *G. impensus* within the *D. asymetrica* Zone, but her illustrated specimens of *G. impensus* seem atypical of this species and may not be conspecific.

### 188–200 m (cuttings), 216.9 – 233.0 m (core), *Marginotruncana marginata* Planktonic Zone

This interval is placed in the *M. marginata* Zone, which has been amended from the definitions of Huber (1992) and Petrizzo (2001) for the Austral Realm. It corresponds approximately to Wonders' (1992) *Marginotruncana* spp. Zone on the Exmouth Plateau. Huber's (1992) *M. marginata* Zone was originally defined between the LO of *A. cretacea* and the highest occurrence (HO) of *M. marginata*. Petrizzo (2001) amended the definition of the lower boundary to be at the LO of *Heterohelix papula*. In the Southern Carnarvon Basin, *H. papula* has a narrow stratigraphic range that forms a well-defined zone (see below). Therefore, the *M. marginata* Zone as recognized here is taken to lie between the HO of *H. papula* and the HO of *M. marginata*.

*M. marginata* has its highest definite occurrence in cuttings from 197–200 m, and is also tentatively identified in cuttings from 188–191 m. The highest recorded occurrence of *H. papula* is in core from 234.05 m.

The general composition of foraminiferal assemblages found in core samples from this zone is recorded in Table 1.1, and species occurrences in this interval are documented in Tables 1.2 and 1.3. Foraminiferal datum levels considered important for regional correlation are listed in Table 1.4, including the positions of these levels in Edaggee 1, Boologooro 1, Coburn 1, and in the type sections of the Toolonga Calcilutite and Gingin Chalk.

The cored succession, shown in Table 1.1, includes intervals in which the abundance of planktonic foraminifera is low (e.g. 226.05 – 228.95 m; 233.0 m) alternating with sections in which planktonic abundance is moderate to high (e.g. 216.9 – 225.05 m; 230.0 – 232.0 m). Selective dissolution of the highly porous, thin-walled planktonic tests may be the reason for this distribution pattern, because in many samples the planktonic tests show partial dissolution and fragmentation. The more robust benthic tests do not display an equivalent pattern, or a pattern that suggests significant changes in depositional water depth through time.

Whereas the planktonic assemblage is characterized mainly by long-ranging species, there are significant changes in the distribution of common benthic species through the succession (Tables 1.2 and 1.3). These changes, illustrated in part by datum levels listed in Table 1.4, are represented in a similar order in widely spaced sections throughout the region. Important benthic datum levels in the cored section of this zone include: LOs of *Osangularia* sp. (218.1 – 219.0 m), *Anomalinoides eriksdalensis* (220.0 – 221.1 m), *Cibicides excavata* (220.0 – 221.1 m), and *Loxostomum eleyi* (225.1 – 226.1); and HOs of *Anomalinoides undulatus* (226.1 – 227.1),

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**Table 1.1. General features of foraminiferal assemblages found in core samples from 216.9 – 238.1 m (Toolonga Calcilutite)**

| | *Depth (m)* | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *216.9* | *218.1* | *219.0* | *220.0* | *221.1* | *222.1* | *223.05* | *224.05* | *225.05* | *226.05* | *227.05* | *228.05* | *228.95* | *230.0* | *231.0* | *232.0* | *233.0* | *234.05* | *235.05* | *236.05* | *237.0* | *238.05* |
| **Benthic foraminifera (% of total benthic count)** | | | | | | | | | | | | | | | | | | | | | | |
| Organic-cemented agglutinates | – | – | – | 4 | 4 | – | 5 | 5 | 4 | 2 | 0 | 1 | – | 1 | 6 | 1 | 8 | 2 | 1 | 5 | 4 | 1 |
| Calcite-cemented agglutinates | 11 | 4 | 10 | 17 | 15 | 18 | 22 | 28 | 34 | 25 | 21 | 24 | 17 | 28 | 34 | 21 | 28 | 11 | 9 | 34 | 44 | 21 |
| Porcelaneous (Miliolida) | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 0 |
| Hyaline (Lagenida) | 8 | 12 | 10 | 15 | 6 | 12 | 10 | 18 | 8 | 12 | 5 | 13 | 10 | 10 | 3 | 14 | 4 | 6 | 7 | 3 | – | 3 |
| Hyaline (Buliminida) | 44 | 4 | 18 | 14 | 1 | 24 | 2 | 1 | – | – | 2 | – | – | 2 | 3 | 1 | 10 | 27 | 24 | 7 | 2 | 0 |
| Hyaline (Rotaliida) | 38 | 79 | 61 | 50 | 74 | 46 | 62 | 49 | 54 | 61 | 71 | 61 | 73 | 58 | 54 | 64 | 49 | 55 | 59 | 52 | 50 | 74 |
| **Planktonic foraminifera (% of total planktonic count)** | | | | | | | | | | | | | | | | | | | | | | |
| Keeled trochospiral | 25 | 56 | 20 | 11 | 16 | 26 | 37 | 16 | 33 | 63 | 25 | 73 | 50 | 42 | 67 | 75 | 100 | 67 | 67 | 33 | – | 100 |
| Non-keeled trochospiral | 60 | 32 | 68 | 79 | 74 | 59 | 41 | 74 | 44 | 11 | 25 | 23 | – | 30 | 15 | 19 | – | – | – | 33 | – | – |
| Planispiral | 10 | 7 | 5 | 1 | 3 | 15 | 20 | 2 | 6 | 11 | 25 | 5 | – | 20 | 5 | 3 | – | – | – | – | – | – |
| Biserial | 6 | 5 | 7 | 9 | 7 | – | 2 | 8 | 17 | 16 | 25 | – | 50 | 8 | 13 | 3 | – | 33 | 33 | 33 | – | – |
| **Planktonic foraminifera (% of total count)** | 73 | 38 | 57 | 39 | 58 | 42 | 23 | 32 | 30 | 9 | 6 | 11 | 2 | 51 | 51 | 40 | 6 | 4 | 2 | 5 | 0 | 0.5 |

**NOTE:** Numbers are percentages calculated from systematic counts of the 150 μm to 2 mm sediment fractions
Totals may not add up to 100% due to rounding errors
–: not present

**Table 1.2. Distribution of benthic foraminifera (agglutinates, Miliolida, and Lagenida) in Toolonga Calcilutite in Edaggee 1**

| | cuttings (m) | | | | core (m) | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 122–125 | 131–134 | 188–191 | 197–200 | 216.90 | 218.10 | 219.00 | 220.00 | 221.10 | 222.10 | 223.05 | 224.05 | 225.05 | 226.05 | 227.05 | 228.05 | 228.95 | 230.00 | 231.00 | 232.00 | 233.00 | 234.05 | 235.05 | 236.05 | 237.00 | 238.05 |
| **Organic-cemented agglutinates** | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Ammobaculites* sp. | – | X | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Ammodiscus glabratus* Cushman and Jarvis 1928 | – | X | – | – | – | – | – | – | – | X | – | – | X | – | X | 1 | – | – | X | X | X | X | X | X | – | X |
| *Ammodiscus* sp. | – | – | – | – | – | – | X | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Bathysiphon brosgei* Tappan 1957 | – | – | – | – | – | – | – | – | – | X | – | – | – | – | – | – | – | – | X | X | – | X | X | X | X | – |
| *Evolutinella* sp. | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | X | – |
| *Glomospira charoides* (Jones and Parker 1860) | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | X | – | – | – | – | – | – | – | – | – |
| *Glomospirella gaultina* (Berthelin 1880) | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 1 | – | – | – | – | X |
| *Recurvoides*? sp. 1 | – | – | – | – | – | X | – | – | – | – | – | – | – | 1 | – | X | X | – | X | – | X | X | X | 1 | 3 | X |
| *Spiroplectammina grzybowskii* Frizzell 1943 | X | X | X | X | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Spiroplectammina* sp. | – | – | – | X | – | – | X | – | X | – | 1 | – | X | – | X | X | – | – | 1 | – | X | 1 | 1 | 2 | 1 | 1 |
| *Vialovella parri* (Cushman 1936) | – | X | X | X | X | – | – | 4 | 4 | – | 4 | 5 | 4 | 1 | 1 | 1 | X | 1 | 5 | 1 | 8 | 1 | X | 1 | – | – |
| *Trochammina?* sp. | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | X | – | – | – | – | – | – | X |
| **Calcite-cemented agglutinates** | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Clavulinoides trifidus* Belford 1960 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | X | 3 | 5 | 6 | X | 3 | 13 | 5 | 7 |
| *Dorothia bulletta* Carsey 1926 | – | – | X | X | – | – | – | X | – | – | X | – | – | – | – | X | – | X | X | – | – | – | – | – | – | – |
| *Dorothia conicula* Belford 1960 | – | – | – | – | X | X | – | – | – | – | 3 | – | 1 | 1 | X | – | – | – | – | – | – | – | – | – | – | – |
| *Dorothia* sp. cf. *D. biformis* Finlay 1939 | X | – | X | X | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Gaudryina* sp. cf. *G. pyramidata* Cushman 1926 | – | – | – | – | X | 1 | X | – | X | X | X | – | X | 1 | 1 | 1 | – | 3 | 4 | X | 10 | 4 | 2 | 3 | 2 | 2 |
| *Gaudryina rugosa* d'Orbigny 1840 (sensu stricto Belford 1960) | – | – | X | – | – | – | – | 2 | X | 4 | 4 | 6 | 8 | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Gaudryina* sp. 1 | X | X | X | X | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Gaudryinoides pressa* Geodakchan 1969 | – | – | – | – | – | – | – | – | – | X | – | – | – | – | – | – | – | X | X | X | X | – | 1 | – | X | 1 |
| *Goesella chapmani* Cushman 1936 | – | – | X | X | 6 | 3 | 10 | 12 | 9 | 13 | 13 | 17 | 20 | 20 | 17 | 15 | 12 | 9 | X | X | X | – | – | – | – | – |
| *Marssonella* sp. cf. *M. ellisorae* Cushman 1936 | – | – | – | – | – | – | – | – | – | – | – | 1 | 2 | 3 | 2 | 8 | X | X | X | X | X | – | – | – | – | – |
| *Marssonella oxycona* (Reuss 1860) | – | – | – | – | – | – | – | X | – | X | – | 2 | X | – | – | – | 4 | 2 | 23 | 14 | 12 | 6 | 3 | 13 | 37 | 7 |
| *Orectostomina? paula* (Belford 1960) | – | X | X | X | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Spiroplectina compressiuscula* (Chapman 1917) | – | – | – | – | – | X | – | 2 | 3 | 1 | 2 | 1 | X | 1 | – | 1 | – | 14 | 3 | 2 | X | 1 | 1 | 5 | 1 | 2 |
| *Spiroplectinella cretosa* (Cushman 1932) | – | – | X | X | 3 | – | – | – | – | X | – | 2 | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – |
| **Porcelaneous (Miliolida)** | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Massilina ginginensis* Chapman 1917 | X | X | X | X | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | X | 1 |
| **Hyaline (Lagenida)** | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Astacolus jarvisi* (Cushman 1938) | X | – | – | – | 1 | X | X | – | – | 1 | 1 | X | – | 1 | X | – | X | – | X | X | X | X | X | X | – | – |
| *Astacolus richteri* (Brotzen 1936) | – | – | – | X | – | – | X | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Astacolus* sp. 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | X | X | X |
| *Astacolus* sp. | – | – | – | – | X | – | X | – | – | – | – | – | – | X | X | X | – | – | – | – | – | – | – | – | – | – |
| *Bullopora* sp. 1 | – | – | – | – | – | – | – | – | – | 5 | – | – | – | 1 | – | – | – | – | – | – | – | – | – | – | – | – |
| *Chrysalogonium texanum* Cushman 1936 | – | – | – | – | – | – | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Citharina beisseli* Hagn 1953 | – | – | – | – | – | – | – | – | – | – | X | – | – | – | – | – | – | – | X | X | X | – | X | – | – | – |
| *Citharina* sp. | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | X |
| *Dentalina admodicostata* Belford 1960 | – | – | X | – | X | – | X | X | – | X | – | X | – | X | – | – | X | – | – | X | – | – | X | – | – | – |
| *Ellipsocristellaria* sp. cf. *E. sequana* (Berthelin 1880) | – | – | – | X | X | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |

**Table 1.2.** (continued)

| | cuttings (m) | | | | core (m) | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *122–125* | *131–134* | *188–191* | *197–200* | *216.90* | *218.10* | *219.00* | *220.00* | *221.10* | *222.10* | *223.05* | *224.05* | *225.05* | *226.05* | *227.05* | *228.05* | *228.95* | *230.00* | *231.00* | *232.00* | *233.00* | *234.05* | *235.05* | *236.05* | *237.00* | *238.05* |
| *Frondicularia aclissima* Pozaryska 1957 | – | – | – | – | – | – | X | X | – | – | – | – | – | – | – | – | X | – | – | – | X | – | X | – | – | – |
| *Frondicularia mucronata* Reuss 1845 | – | – | – | – | – | – | – | – | – | 1 | – | – | – | – | X | – | – | X | X | X | – | – | X | – | – | – |
| *Frondicularia* sp. cf. *F. undulosa* Cushman 1936 | – | – | – | – | – | – | – | X | – | – | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Frondicularia verneuiliana* d'Orbigny 1840 | – | X | X | X | – | X | 1 | 1 | X | X | X | – | X | 1 | X | X | 1 | 1 | X | 1 | 1 | 1 | 2 | X | X | – |
| *Frondicularia* sp. | – | – | – | – | – | – | – | – | – | – | – | – | – | X | – | – | – | – | – | – | – | – | – | – | – | – |
| *Glandulina* sp. cf. *G. pygmaea* Reuss 1851 | – | – | – | – | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Globulina lacrima* Reuss 1845 | X | X | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Globulina prisca* Reuss 1863 | X | X | X | – | X | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Hemirobulina hamulus* (Chapman 1894) | – | – | – | – | – | – | – | X | X | X | – | – | X | – | – | – | X | – | – | – | – | – | X | – | – | |
| *Hemirobulina* sp. | X | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Laevidentalina basiplanata* (Cushman 1938) | X | X | X | – | – | – | X | X | – | X | – | X | – | X | X | X | X | X | X | – | X | – | X | – | – | – |
| *Laevidentalina cylindroides* (Reuss 1860) | – | – | – | – | – | – | – | – | – | – | – | – | – | X | – | – | – | – | – | – | – | – | – | – | – | – |
| *Laevidentalina inepta* (Cushman 1947) | – | X | – | X | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | X | – | – |
| *Laevidentalina luma* (Belford 1960) | – | – | – | – | X | – | X | – | – | – | – | – | – | – | – | X | – | X | – | – | X | – | – | – | – | – |
| *Laevidentalina oligostegia* Reuss 1845 | – | X | – | – | – | – | – | – | – | X | – | – | X | X | X | – | X | X | X | – | – | – | X | – | – | – |
| *Laevidentalina* sp. cf. *L. pseudonana* ten Dam 1950 | X | – | X | – | – | – | – | – | – | X | – | – | X | – | X | – | X | – | – | – | – | – | – | – | – | X |
| *Laevidentalina sororia* (Reuss 1863) | – | – | – | X | – | – | – | – | – | – | – | – | – | – | – | X | – | X | – | – | – | – | X | – | – | – |
| *Laevidentalina* sp. | – | – | – | – | – | – | – | – | – | – | – | 1 | – | 8 | – | 1 | – | – | – | – | – | – | – | – | – | – |
| *Lagena* sp. 1 | X | X | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Lagena* sp. 4 | – | – | – | – | X | – | – | – | – | – | X | – | – | – | – | – | – | – | – | X | – | – | – | – | – | – |
| *Lenticulina muensteri* (Roemer 1839) | – | – | – | – | – | – | – | – | – | – | – | – | – | – | X | 1 | – | – | – | – | 1 | 1 | – | 2 | – | 2 |
| *Lenticulina* spp. | – | – | X | X | 4 | 6 | 5 | 8 | 2 | X | 4 | 14 | 5 | – | 3 | 11 | 4 | 6 | 2 | 9 | X | – | – | – | – | X |
| *Lingulina pygmaea* Reuss 1874 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | X |
| *Marginulinopsis decurse-costata* Thalmann 1937 | – | – | X | X | – | – | X | – | 2 | – | 1 | – | – | – | – | – | – | – | – | – | – | – | X | – | – | – |
| *Marginulinopsis* sp. cf. *M. kohkoae* Yasuda 1986 | – | – | – | – | – | – | X | X | X | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Neoflabellina rugosa* (d'Orbigny 1840) | – | – | X | X | – | X | X | 1 | X | 1 | – | 1 | – | – | – | – | – | X | – | – | – | – | – | – | – | – |
| *Neoflabellina* sp. | – | – | – | – | – | – | – | – | X | | X | X | X | X | X | X | X | X | X | X | X | – | – | – | – | – |
| *Nodosaria*? *aspera* Reuss 1845 | – | – | – | – | – | – | – | X | – | – | X | – | X | X | X | – | – | – | – | – | X | 1 | X | X | – | – |
| *Nodosaria limbata* d'Orbigny 1840 | – | – | – | – | – | – | X | – | – | – | – | – | – | – | – | X | – | – | – | – | – | – | X | – | – | – |
| *Oolina morsei* Kline 1943 | – | – | – | – | – | – | X | – | – | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | X | – |
| *Planularia bradyana* (Chapman 1894) | – | – | – | X | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Planularia* sp. 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | X | X | – | – | – | – | – | – | – | – |
| *Pseudonodosaria manifesta* (Reuss 1851) | X | X | X | X | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Psilocitharella geisendorferi* (Franke 1928) | – | X | – | X | X | – | – | – | X | – | – | – | – | – | – | – | X | X | X | – | – | X | X | – | – | – |
| *Pyramidulina obscura* (Reuss 1845) | – | – | – | – | – | X | – | – | – | – | – | – | – | 1 | X | X | X | X | – | X | X | – | – | – | – | – |
| *Pyramidulina prismatica* (Reuss 1860) | – | – | – | – | – | – | – | – | – | – | X | – | X | – | – | – | – | X | X | X | X | – | X | X | – | X |
| *Ramulina cretacea* Schacko 1897 | – | – | X | – | X | 1 | – | – | – | – | 1 | – | X | – | X | – | 1 | 1 | 1 | X | – | – | – | – | – | X |
| *Ramulina* sp. 1 | – | – | – | – | X | – | X | 2 | – | – | X | X | – | X | – | X | X | X | – | – | X | – | X | X | X | X |
| *Saracenaria jarvisi* (Brotzen 1936) | – | – | – | X | – | X | X | – | 2 | X | – | – | X | X | X | X | X | X | – | – | – | – | X | X | – | – |
| *Saracenaria triangularis* (d'Orbigny 1840) | – | – | – | – | 1 | 4 | X | – | – | – | – | – | – | – | – | X | – | – | – | 1 | – | – | | – | – | – |
| *Saracenaria* sp. | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | X | – | – | – | – | – |
| *Tribrachia westfalica* Bartenstein and Brand 1950 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | X | – | – | – |

**NOTES**: X: rare occurrence
–: not present
numbers are % of benthic count

**Table 1.3. Distribution of foraminifera (Buliminida, Rotaliida, and planktonic species) in the Toolonga Calcilutite in Edaggee 1**

| | cuttings (m) | | | | core (m) | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *122–125* | *131–134* | *188–191* | *197–200* | *216.90* | *218.10* | *219.00* | *220.00* | *221.10* | *222.10* | *223.05* | *224.05* | *225.05* | *226.05* | *227.05* | *228.05* | *228.95* | *230.00* | *231.00* | *232.00* | *233.00* | *234.05* | *235.05* | *236.05* | *237.00* | *238.05* |
| **Hyaline (Buliminida)** | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Bolivina kushensis* (Vasilenko 1961) | – | – | – | – | X | – | 1 | X | X | X | X | X | X | X | X | X | – | ? | – | – | | ? | – | – | – | – |
| *Bolivina* sp. | – | – | – | – | – | – | – | – | – | X | – | – | – | X | – | – | – | | – | – | X | – | X | – | – | X |
| *Bolivinoides strigillata* (Chapman 1892) | – | – | X | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Coryphostoma* sp. cf. *C. incrassata* (Reuss 1851) | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | X | – | X | – | – | – | – | – |
| *Coryphostomella minutissimum* (Cushman 1938) | – | – | – | – | X | – | – | – | X | – | X | – | – | – | – | X | X | – | – | X | – | – | X | – | – | – |
| *Coryphostomella* sp. 1 | – | – | – | – | – | – | – | – | – | – | – | – | X | X | – | X | – | X | – | – | – | – | X | – | – | – |
| *Eouvigerina cretacea* (Heron-Allen and Earland 1910) | – | – | X | X | – | – | – | – | – | – | – | – | – | X | – | X | – | – | – | – | – | | – | – | – | – |
| *Eouvigerina gracilis* Cushman 1926 | – | – | – | X | X | X | 1 | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| *Loxostomum eleyi* (Cushman 1927) | – | – | – | – | – | X | X | X | X | X | X | X | X | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Nodosarella solida* Brotzen 1936 | X | X | – | X | X | X | X | – | X | X | – | – | X | – | X | X | – | X | X | X | X | – | X | – | X | – |
| *Pleurostomella subnodosa* Reuss 1860 | – | X | – | – | – | – | X | 1 | – | – | 1 | – | – | X | – | – | – | – | – | – | – | X | X | X | | 1 |
| *Praebulimina reussi* (Morrow 1934) | – | – | – | X | X | X | X | X | X | X | X | X | X | X | – | X | X | X | X | X | X | X | X | X | X | X |
| *Praebulimina* sp. | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | X | – | – | 1 | 1 | X | – | – | – | – | – |
| *Pyramidina* sp. | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | X |
| *Quadratobuliminella* sp. cf. *quadrilobata* (de Klasz et al. 1963) | – | – | – | – | – | – | – | – | – | – | – | – | – | – | X | X | – | X | X | X | – | – | X | X | | – |
| *Quadratobuliminella?* sp. 1 | X | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Quadratobuliminella?* sp. 2 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | X |
| *Reussella* sp. 1 | – | – | – | – | 44 | 4 | 16 | 13 | 1 | 24 | 1 | – | – | – | 2 | – | – | – | 3 | – | 10 | 26 | 24 | 7 | 2 | – |
| *Reusella* sp. 2 | – | – | X | X | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Sitella* sp. cf. *S*? *ventricosa* (Brotzen 1936) | X | X | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Stilostomella* sp. 1 | – | – | – | – | X | – | – | – | – | – | – | – | – | – | – | – | – | X | – | – | – | – | – | – | – | – |
| **Hyaline (Rotaliida)** | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Alabamina australis* Belford 1960 | – | – | – | – | X | X | – | – | X | X | – | – | – | – | – | – | X | X | – | – | – | – | X | – | – | – |
| *Allomorphina minuta* Cushman 1936 | – | – | – | – | X | – | X | – | – | – | – | – | – | – | – | – | – | X | – | – | – | – | – | – | – | – |
| *Anomalinoides eriksdalensis* (Brotzen 1936) | X | X | X | X | 11 | 16 | 6 | X | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Anomalinoides undulatus* Belford 1960 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | X | ? | – | X | X | – | 3 | 9 | 14 | 10 | 27 | 27 |
| *Anomalinoides* sp. | – | – | – | – | – | – | – | – | – | – | 3 | 5 | – | 1 | – | – | – | 2 | – | 1 | 6 | 6 | 4 | – | – | – |
| *Berthelina* sp. X | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 1 |
| *Berthelina* sp. Y | – | – | – | – | 5 | 3 | 3 | 6 | 17 | 5 | 3 | X | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Cibicides excavata* Brotzen 1936 | – | – | X | X | 1 | X | 3 | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Cibicides ribbingi* Brotzen 1936 | – | – | X | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Globimorphina trochoides* (Reuss 1845) | – | X | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Globorotalites conicus* (Carsey 1926) | – | – | – | X | 5 | – | X | – | 2 | 1 | – | 6 | 1 | X | – | – | 1 | 5 | 1 | 3 | 1 | 1 | – | – | X | – |
| *Gyroidinoides* sp. cf. *G. lenticulus* (Reuss 1845) | – | – | – | – | X | – | 1 | – | – | 1 | 2 | 1 | – | X | X | X | – | 1 | 2 | 1 | X | X | 1 | 1 | – | – |
| *Gyroidinoides* sp. cf. *G. nitidus* (Reuss 1844) | X | X | X | X | 8 | 1 | 22 | 12 | 20 | 12 | 17 | 14 | 6 | 13 | 16 | 11 | 6 | 9 | 3 | 4 | 3 | 3 | 9 | 14 | X | 1 |
| *Gyroidinoides* sp. 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 3 | 1 |
| *Lingulogavelinella insculpta* (Belford 1960) | X | X | X | X | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Lingulogavelinella stellula* (Belford 1960) | – | – | – | X | – | 16 | 5 | 6 | 1 | 7 | 19 | – | – | – | – | – | – | – | – | – | X | – | – | – | – | – |
| *Notoplanulina rakauroana* (Finlay 1939) | X | X | X | X | – | – | X | 9 | – | – | – | 1 | 27 | 21 | 31 | 27 | 26 | 19 | 34 | 27 | 15 | 11 | 9 | 20 | 8 | 5 |
| *Nuttallinella coronula* (Belford 1958) | – | – | X | X | X | – | – | – | – | – | – | – | – | 6 | X | 1 | – | – | – | – | – | – | – | – | – | – |
| *Osangularia* sp. | – | – | – | X | 4 | 25 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Paralabamina*? sp. cf. *P*? *concinna* (Brotzen 1936) | X | X | X | X | 1 | 15 | 9 | 13 | 12 | 13 | 11 | 9 | 7 | 12 | 14 | 18 | 28 | 19 | 9 | 16 | 14 | 17 | 18 | 5 | 2 | 4 |
| *Paralabamina diversa* (Belford 1960) | – | – | X | – | – | X | X | – | 1 | X | 3 | 4 | 9 | 4 | 2 | 1 | 4 | 1 | 3 | X | – | X | 2 | X | 3 | 3 |

**Table 1.3.** (continued)

| | *cuttings (m)* | | | | *core (m)* | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *122–125* | *131–134* | *188–191* | *197–200* | *216.90* | *218.10* | *219.00* | *220.00* | *221.10* | *222.10* | *223.05* | *224.05* | *225.05* | *226.05* | *227.05* | *228.05* | *228.95* | *230.00* | *231.00* | *232.00* | *233.00* | *234.05* | *235.05* | *236.05* | *237.00* | *238.05* |
| *Paralabamina* sp. | – | – | – | X | – | – | – | X | 3 | 3 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Pullenia marssoni* Cushman and Todd 1943 | – | X | X | X | X | X | 1 | X | X | 1 | – | 2 | X | X | 1 | X | X | X | X | 3 | 1 | 1 | – | 1 | X | 1 |
| *Pullenia reussi* Cushman and Todd 1943 | X | X | – | X | – | – | – | – | – | – | – | – | – | – | – | X | X | – | X | – | – | – | – | X | – | – |
| *Quadrimorphina allomorphinoides* (Reuss 1860) | | – | – | X | X | – | X | – | X | – | – | 1 | – | – | – | – | X | X | X | 1 | X | – | – | – | – | – |
| *Riminopsis* sp. | X | X | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Scheibnerova*? sp. 1 | – | X | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Stensioeina erugata* (Belford 1960) | X | X | – | X | 1 | X | 6 | 3 | 2 | 1 | 4 | 4 | 2 | 3 | 5 | 3 | 7 | X | 3 | 7 | 3 | 2 | 2 | 1 | 1 | 5 |
| *Stensioeina* sp. cf. *S. exsculpta* (Reuss 1860) | X | X | X | X | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Stensioeina truncata* Belford 1960 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | X | – | – | – | – | – |
| *Stensioeina* sp. | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 2 |
| *Valvulinoides* sp. | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 7 | 14 |
| **Planktonic species** | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Archaeoglobigerina blowi* Pessagno 1967 | – | – | – | – | – | – | – | – | – | – | X | – | – | X | – | – | – | X | X | X | | – | – | – | – | – |
| *Archaeoglobigerina bosquensis* Pessagno 1967 | – | – | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | – | – | – | – | – |
| *Archaeoglobigerina cretacea* (d'Orbigny 1840) | X | X | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Costellagerina bulbosa* (Belford 1960) | – | – | – | X | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Dicarinella canaliculata* (Reuss 1854) | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | X |
| *Dicarinella imbricata* (Mornod 1949) | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | X |
| *Globigerinelloides ultramicra* (Subbotina 1949) | – | X | – | X | X | X | X | X | X | X | X | X | – | X | – | X | X | X | X | X | X | X | X | – | – | – |
| *Globigerinelloides caseyi* (Bolli, Loeblich, and Tappan 1957) | – | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | – | X | – | X | – | – |
| *Globigerinelloides* sp. 2 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | X | – | – |
| *Globotruncana arca* (Cushman 1926) | X | X | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Globotruncana bulloides* Vogler 1941 | X | – | X | X | X | X | – | – | X | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Globotruncana hilli* Pessagno 1967 | – | – | X | X | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Globotruncana lapparenti* Brotzen 1936 | – | – | – | – | X | – | – | X | – | X | X | X | – | X | X | – | X | X | – | – | – | – | – | – | – | – |
| *Globotruncana linneiana* (d'Orbigny 1839) | X | – | X | X | X | X | X | X | X | – | – | – | X | – | – | – | – | X | – | – | – | – | – | – | – | – |
| *Globotruncana ventricosa* White 1928 | – | X | – | – | X | – | – | X | X | – | X | – | – | – | – | – | – | X | – | – | – | – | – | – | – | – |
| *Hedbergella delrioensis*(Carsey 1926) | – | – | – | – | – | – | X | – | – | X | – | – | – | – | X | X | X | X | X | X | X | X | – | – | – | – |
| *Hedbergella flandrini* Porthault 1970 | – | X | X | X | X | – | – | X | – | X | X | – | X | X | – | X | X | X | X | X | – | – | – | – | – | – |
| *Hedbergella holmdelensis* Olsson 1964 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | X | – | – | – | – | – | – | – | X | – | – |
| *Hedbergella planispira* (Tappan 1940) | – | X | – | – | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | – | – |
| *Hedbergella* sp. | – | – | X | – | X | X | X | X | X | – | – | X | X | X | X | X | X | X | X | X | X | X | X | X | – | – |
| *Heterohelix papula* (Belford 1960) | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | X | X | X | – | – |
| *Heterohelix planata* (Cushman 1938) | – | – | – | – | – | – | – | X | X | – | – | – | X | X | – | X | X | X | X | X | – | – | – | – | – | – |
| *Heterohelix reussi* (Cushman 1938) | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | X | X | – | – | – |
| *Marginotruncana coronata* (Bolli 1945) | – | – | – | – | – | – | – | – | X | – | – | – | – | – | – | – | X | – | X | X | X | – | – | – | – | – |
| *Marginotruncana marginata* (Reuss 1845) | – | – | ? | X | X | – | – | – | X | – | – | – | X | – | – | – | – | – | X | X | X | X | X | – | – | – |
| *Marginotruncana pseudolinneiana* (Pessagno 1967) | – | – | ? | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | – | X |
| *Marginotruncana renzi* (Gandolfi 1942) | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | X |

**NOTES:** X: rare occurrence
?: possible occurrence
–: not present
numbers are % of benthic count

**Table 1.4. Selected foraminiferal datum levels in the Toolonga Calcilutite in Edaggee 1 and correlation to other sections**

| *Datum level* | *Species type* | *Edaggee 1*[(a)] | *Boologooro 1*[(a)] | *Coburn 1*[(a)] | *Toolonga type section*[(b)] | *Gingin type section*[(b)] |
|---|---|---|---|---|---|---|
| LAD *Valvulinoides* sp. | B | 236.1 – 237.0 | 274.05 – 275.05 | – | 0.05 – 0.5 | 2 – 2.5 |
| FAD *Heterohelix papula* | P | 236.1 – 237.0 | 272.9 – 274.05 | – | 0.05 – 0.5 | <0.2 |
| LAD *Heterohelix papula* | P | 233.0 – 234.1 | 265.95 – 265.05 | – | 0.5 – 1.0 | 1.5 – 2.0 |
| LAD *Stensioeina truncata* | B | 232.0 – 233.0 | 265.05 – 265.95 | – | 0.5 – 1.0 | 1.0 – 1.5 |
| LAD *Clavulinoides trifidus* | B | 229.0 – 230.0 | 262.05 – 262.9 | >79 | 2.0 – 2.5 | 3.0 – 3.5 |
| LAD *Anomalinoides undulatus* | B | 226.1 – 227.1 | 257.95 – 259.1 | 79–78 | 3.0 – 3.5 | 5.0 – 6.0 |
| FAD *Loxostomum eleyi* | B | 225.1 – 226.1 | 257.95 – 259.1 | 79–78 | 1.5 – 2.0 | 5.0 – 6.0 |
| FAD *Cibicides excavata* | B | 220.0 – 221.1 | 253.05 – 254.05 | 79–78 | 4.0 – 4.5 | 5.0 – 6.0 |
| FAD *Anomalinoides eriksdalensis* | B | 220.0 – 221.1 | 253.05 – 254.05 | 76.6 – 78 | 4.0 – 4.5 | 7.0 – 8.0 |
| FAD *Osangularia* sp. | B | 218.1 – 219.0 | 242.9 – 245.85 | 76.6 – 78 | 4.5 – 5.0 | 8.0 – 9.0 |
| FAD *Lingulogavelinella insculpta* | B | <216.9 | 239.05 – 241.1 | 75.8 – 74.2 | 7.0 – 7.5 | 15.0 – 16.0 |
| FAD *Bolivinoides strigillata* | B | <216.9 | 235.95 – 236.9 | 74.2 – 73 | 7.0 – 7.5 | 12.0 – 13.0 |
| LAD *Lingulogavelinella stellula* | B | 188–197 | 226.05 – 227.05 | 70.6 – 68.7 | 8.0 – 8.5 | 15.0 – 16.0 |
| LAD *Notoplanulina* sp. 1 | B | 188–197 | 222.9 – 223.9 | 70.6 – 68.7 | 8.0 – 8.5 | 15.0 – 16.0 |
| FAD *Orectostomina? paula* | B | <216.9 | 230.1 – 230.9 | 65.8 – 68.7 | 8.0 – 8.5 | 13.0 – 14.0 |
| FAD *Spiroplectammina grzybowskii* | B | <216.9 | 226.05 – 227.05 | 65.8 – 68.7 | 8.0 – 8.5 | 15.0 – 16.0 |

**NOTES**: B: benthic; P: planktic; (a) metres downhole; (b) meters above base; FAD: first appearance datum; LAD: last appearance datum; –: not present

For each datum level, the metre interval denotes accuracy to which the datum has been located

*Clavulinoides trifidus* (229.0 – 230.0 m), and *Stensioeina truncata* (232.0 – 233.0 m; Table 1.4). In Edaggee 1, the LOs of *Lingulogavelinella insculpta*, *Bolivinoides strigillata*, *Gaudryina* sp. 1, *Orectostomina? paula*, and *Spiroplectammina grzybowskii* are higher than the cored section (i.e. above 216.9 m) and cannot be determined in the cuttings. The HOs of *Lingulogavelinella stellula* and *Osangularia* sp. apparently lie between 188 and 197 m as indicated by their presence in cuttings below this interval.

In terms of the overall benthic assemblage, the interval 216–218 m is dominated by *Reussella* sp. 1, *A. eriksdalensis*, *Osangularia* sp., and *Paralabamina*? cf. *concinna*. The interval 219–224.05 m contains abundant *Goesella chapmani*, *Gyroidinoides* cf. *nitidus*, *L. stellula*, *P.*? cf. *concinna*, and *Reussella* sp.. Dominant species in the interval 225.05 – 230 m include *Notoplanulina rakauroana*, *P.?* cf. *concinna*, *G. chapmani*, *G.* cf. *nitidus*, and *Paralabamina diversa*. In the interval 230 – 238.05 m the dominant species are *Marssonella oxycona*, *A. undulatus*, *N. rakauroana*, *P.?* cf. *concinna*, *Reussella* sp., *Clavulinoides trifidus*, *Gaudryina* cf. *pyramidata*, and small *G.* cf. *nitidus*. Where dissolution has not occurred, planktonic foraminifera typically make up 30–70% of the total foraminiferal assemblage in the 150 µm to 2 mm sediment fraction.

## 234.05 – 236.05 m (core), *Heterohelix papula* Planktonic Zone

This zone is defined by the total range of *H. papula* — a biserial planktonic species found over a narrow interval throughout the Southern Carnarvon Basin. Belford (1960) originally described the species from the base of the Toolonga Calcilutite on Murchison House Station.

The general composition of foraminiferal assemblages found in the two core samples from this zone are recorded in Table 1.1, and species occurrences in this interval are documented in Tables 1.2 and 1.3. The correlation of LO and HO datum levels for *H. papula* across the region are shown in Table 1.4.

Planktonic foraminiferal abundance in the zone is very low (2–5% of total foraminiferal count in the >150 µm fraction). Of the planktonic specimens recovered from >150 µm sediment fractions in the zone, 33–67% are keeled types, 33% are biserial forms, and 0–33% are non-keeled trochospiral types (Table 1.1). The benthic assemblage is dominated by hyaline species belonging to the Orders Rotaliida and Buliminida. The main benthic species in the zone are *Reussella* sp. 1, *P.?* cf. *concinna*, *N. rakauroana*, *A. undulatus*, *G.* cf. *nitidus*, and *M. oxycona*.

In Edaggee 1, the LO of the planktonic *H. papula* coincides with the HO of benthic *Valvulinoides* sp., and the HO of *H. papula* coincides with or lies below the HO of the benthic *S. truncata*. Across the region, the only divergence to this pattern is the relatively higher HO of *Valvulinoides* sp. in the Gingin Chalk type section (Perth Basin). The latter may be due to reworking of the species in that section because the basal beds appear to be disturbed (Haig, 2002).

## 237.0 m (core), unzoned

No planktic foraminifera were recovered from this sample. The benthic assemblage is dominated by hyaline types belonging to the Order Rotaliida, and to agglutinated foraminifera with calcareous cement. The main benthic species are *M. oxycona*, *A. undulatus*, *N. rakauroana*, and *Valvulinoides* sp. (Tables 1.2 and 1.3). In terms of foraminiferal datum levels important for regional correlation (Table 1.4), the sample lies below the HO of *Valvulinoides* sp..

## 238.05 m (core), *Marginotruncana marianosi* Planktonic Zone

This zone was defined by Petrizzo (2000) in the Exmouth Plateau as the interval between the HO of *Falsotruncana maslakovae* and the LO of *D. asymetrica*. Petrizzo (2000) found that the LO of *H. papula* was close (just below) the LO of *D. asymetrica*.

Although the planktonic assemblage in this sample forms less than 1% of the total foraminiferal count from the >150 µm sediment fraction (Table 1.1), sufficient specimens are present to confidently determine that *H. papula* is absent and that the *Dicarinella–Marginotruncana* assemblage (Table 1.3; including *M. renzi*, *D. canaliculata*, and *D. imbricata*) is substantially different from that in the overlying *H. papula* and *M. marginata* Zones.

The benthic assemblage is related to those in overlying zones rather than to the underlying assemblages. Predominant species include *A. undulatus* and *Valvulinoides* sp..

## 239.1 – 239.6 m (core), unzoned

The general composition of foraminiferal assemblages found in core samples from 239.1 m and 239.6 m are recorded in Table 1.5. Benthic species occurrences in this interval are documented in Table 1.6. No planktonic foraminifera were recovered from this interval. The sparse assemblage of benthic foraminifera from 239.1 m contrasts with abundant benthic foraminifera found at 239.6 m, where a mainly hyaline microfauna is present (dominated by the Order Rotaliida). *Berthelina* ex gr. *B. berthelini* is the predominant species. All species found in this interval are also known from the underlying *F. maslakovae*, *Helvetoglobotruncana helvetica*, and *Whiteinella archaeocretacea* Zones. *Pleurostomella* sp., *B.* ex gr. *B. berthelini*, *Stensioeina*? sp., and *Valvulinoides* sp. 1 are not known in higher zones.

## 240.05 m, *Falsotruncana maslakovae* Planktonic Zone

Based on sections from the Exmouth Plateau, Petrizzo (2000) defined the *F. maslakovae* Zone as the interval between the HO of *H. helvetica* and the HO of *F. maslakovae*.

Petrizzo (2000) recorded the LO of *F. maslakovae* slightly above the HO of *H. helvetica*. Because these species are absent in the sample from 240.05 m, it probably belongs to the lower part of the *F. maslakovae* Zone, above the HO of *H. helvetica* (Table 1.7). Although more primitive forms of *Falsotruncana* are present at this level, *F. maslakovae* has not been located. In Edaggee 1, *Marginotruncana pseudolinneiana* is rare at this level, and the genus has not been found in lower samples. Petrizzo (2000) recorded the LO of marginotruncanids within the *H. helvetica* Zone, with species of *Marginotruncana* becoming dominant in the *F. maslakovae* Zone.

General features of the foraminiferal assemblage at this level are recorded in Table 1.5, and species from sample 240.05 m are listed on Table 1.6. Planktonic specimens make up almost 29% of the foraminifera counted in the >150 µm sediment fraction, and 43.2% of the planktonic types are keeled trochospiral species of *Dicarinella* and *Marginotruncana*. The benthic assemblage is dominated by hyaline foraminifera of the Order Rotaliida and by calcareous agglutinated species. Dominant benthic species

**Table 1.5. General features of foraminiferal assemblages in core samples from 239.1 – 245.05 m (Haycock Marl) in Edaggee 1**

| | *Sample depth (m)* | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | *239.10* | *239.60* | *240.05* | *240.60* | *241.05* | *241.55* | *242.15* | *243.10* | *243.60* | *244.05* | *245.05* |
| **Benthic count (%; >150 µm fraction)** | | | | | | | | | | | |
| Organic-cemented agglutinated species | sa | 2.0 | 0.9 | sa | 0.3 | 0.5 | 1.0 | 2.8 | sa | 10.9 | sa |
| Calcite-cemented agglutinated species | sa | 7.1 | 45.9 | sa | 28.3 | 27.0 | 17.1 | 8.3 | sa | – | sa |
| Porcelaneous species (Miliolida) | sa | – | – | sa | – | – | – | – | sa | – | sa |
| Hyaline species (Lagenida) | sa | 4.1 | 5.5 | sa | 5.9 | 7.7 | 14.6 | 13.9 | sa | 10.9 | sa |
| Hyaline species (Buliminida) | sa | – | – | sa | – | 0.5 | – | – | sa | – | sa |
| Hyaline species (Rotaliida) | sa | 86.7 | 47.7 | sa | 65.6 | 64.4 | 67.3 | 75.0 | sa | 78.3 | sa |
| **Planktonic count (%; >150 µm fraction)** | | | | | | | | | | | |
| Keeled trochospiral species | sa | – | 43.2 | sa | 25.0 | 60.0 | 58.6 | 19.0 | sa | 1.9 | sa |
| Non-keeled trochospiral species | sa | – | 56.8 | sa | 75.0 | 40.0 | 41.4 | 81.0 | sa | 98.0 | sa |
| Planispiral species | sa | – | – | sa | – | – | – | – | sa | 0.2 | sa |
| Biserial species | sa | – | – | sa | – | – | – | – | sa | – | sa |
| **Planktonic foraminifera (%of total count)** | sa | 0.0 | 28.8 | sa | 3.1 | 1.1 | 8.4 | 12.7 | sa | 92.8 | sa |

**NOTE**: sa: sparse assemblage –: not present

**Table 1.6. Distribution of benthic foraminifera from 239.1 – 245.05 m (Haycock Marl) in Edaggee 1**

| | Sample depth (m) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | *239.10* | *239.60* | *240.05* | *240.60* | *241.05* | *241.55* | *242.15* | *243.10* | *243.60* | *244.05* | *245.05* |
| **Organic-cemented agglutinated species** | | | | | | | | | | | |
| *Ammodiscus glabratus* Cushman and Jarvis 1928 | – | R | R | – | R | R | R | – | – | – | R |
| *Bathysiphon* sp. | – | – | R | R | – | – | – | – | – | – | – |
| *Gaudryinopsis filiformis* (Berthelin 1880) | – | – | – | – | – | – | R | R | – | – | – |
| *Glomospira charoides* (Jones and Parker 1860) | – | | – | – | – | R | – | – | – | – | – |
| *Glomospirella gaultina* (Berthelin 1880) | – | R | R | – | – | – | – | – | – | – | – |
| *Recurvoides* sp. 2 | – | – | – | – | R | R | R | R | – | – | – |
| *Spiroplectammina* sp. 1 | – | – | R | – | – | – | – | – | R | – | – |
| *Spiroplectammina* sp. 2 | – | – | – | – | – | R | – | – | – | – | – |
| **Calcite-cemented agglutinated species** | | | | | | | | | | | |
| *Gaudryina* sp. 1 | – | – | R | – | – | – | – | – | – | – | – |
| *Marssonella oxycona* (Reuss 1860) | R | R | A | – | A | A | A | R | – | – | – |
| *Spiroplectinata annectens* (Parker and Jones 1863) | – | – | R | – | R | R | R | R | – | – | – |
| *Spiroplectinata bettenstaedti* Grabert 1959 | – | – | R | – | R | – | R | – | – | – | – |
| **Porcelaneous species (Miliolida)** | | | | | | | | | | | |
| *Pseudosigmoilina* sp. 1 | – | – | R | – | – | R | R | R | R | – | – |
| **Hyaline species (Lagenida)** | | | | | | | | | | | |
| *Astacolus calliopsis* (Reuss 1863) | – | – | R | R | R | R | R | R | – | – | – |
| *Citharina debilis* (Berthelin 1880) | – | – | R | – | R | R | R | R | – | – | – |
| *Citharina* sp. | – | – | – | – | – | – | – | – | R | – | – |
| *Dentalina* sp. cf. *D. delicatula* Cushman 1938 | – | – | – | – | – | – | R | R | – | – | – |
| *Frondicularia* sp. cf. *F. archiaciana* d'Orbigny 1840 | – | – | R | – | R | R | R | R | – | – | – |
| *Frondicularia mucronata* Reuss 1845 | – | – | R | – | – | – | – | – | – | – | – |
| *Frondicularia planifolium* Chapman 1894 | – | – | – | – | R | – | – | – | – | – | – |
| *Frondicularia* sp. A | – | – | – | – | R | – | – | – | – | – | – |
| *Frondicularia* sp. B | – | – | R | – | – | – | – | – | – | – | – |
| *Hemirobulina hamulus* (Chapman 1894) | – | – | R | R | – | R | – | – | – | – | – |
| *Hemirobulina* sp. | – | – | – | – | – | – | R | – | – | R | – |
| *Laevidentalina luma* (Belford 1960) | – | – | R | – | – | – | – | R | – | – | – |
| *Laevidentalina* sp. | – | – | R | – | R | – | R | – | R | – | – |
| *Lenticulina muensteri* (Roemer 1839) | – | R | R | – | C | A | A | C | – | R | R |
| *Lenticulina pulchella* (Reuss 1863) | – | – | R | – | – | – | R | R | C | R | R |
| *Oolina morsei* Kline 1943 | – | – | R | – | – | – | – | – | – | – | – |
| *Planularia bradyana* (Chapman 1894) | – | – | – | R | R | – | R | – | – | – | – |
| *Planularia* sp. | – | – | – | – | – | – | R | – | – | – | – |
| *Pyramidulina* sp. cf. *P. obscura* (Reuss 1845) | – | – | – | – | – | R | – | – | – | – | – |
| *Pyramidulina prismatica* (Reuss 1860) | – | – | R | – | R | R | – | R | – | – | – |
| *Pyramidulina sceptrum* (Reuss 1863) | – | – | R | – | R | R | – | – | – | – | – |
| *Pyramidulina* sp. | – | – | – | – | – | – | – | – | R | – | – |
| *Ramulina cretacea* Schacko 1897 | – | – | R | – | R | – | R | R | – | – | – |
| *Ramulina* sp. A of Belford 1960 | – | – | R | – | R | – | R | – | – | – | – |
| *Saracenaria triangularis* (d'Orbigny 1840) | – | – | R | – | R | – | – | – | – | – | – |
| **Hyaline species (Buliminida)** | | | | | | | | | | | |
| *Bolivina* sp. A | – | – | – | – | – | R | R | R | – | – | R |
| *Bolivina?* sp. B | – | – | R | – | – | – | – | – | – | – | – |
| *Cassidella?* sp. cf. *C? tegulata* (Reuss 1845) | – | – | – | – | – | – | C | R | R | – | – |
| *Neobulimina albertensis* (Stelck and Wall 1954) | – | – | – | – | – | – | – | – | – | R | – |
| *Nodosarella* sp. of Howe, Haig, and Apthorpe 2000 | – | – | R | – | R | – | R | R | – | – | – |
| *Pleurostomella* sp. of Howe, Haig, and Apthorpe 2000 | – | R | A | – | R | R | C | C | R | R | R |
| *Praebulimina reussi* (Morrow 1934) | – | R | A | – | R | C | C | A | C | C | R |
| *Pyramidina* sp. | – | – | R | – | – | – | – | C | R | – | – |
| *Tappanina* sp. cf. *T. laciniosa* Eicher and Worstell 1970 | – | – | A | – | R | R | C | A | C | R | – |
| **Hyaline species (Rotaliida)** | | | | | | | | | | | |
| *Berthelina* ex gr. *B. berthelini* (Keller 1935) | R | A | A | – | A | A | A | A | C | C | R |
| *Berthelina* sp. cf. *B. tenuissima* (Gawor-Biedowa 1992) | – | – | – | – | – | – | – | – | C | R | R |
| *Berthelina?* sp. cf. *Anomalina tenuis* of Bukalova 1958 | – | – | – | – | R | R | – | – | – | – | – |
| *Berthelina* sp. | – | – | R | – | R | R | R | – | – | – | – |
| *Berthelina* sp. | – | – | R | – | – | – | – | – | – | – | – |
| *Conorotalites?* sp. 1 | – | – | R | – | – | R | R | R | R | – | – |
| *Conorotalites?* sp. 2 | – | – | – | – | – | – | R | R | – | – | – |
| *Gyroidinoides* sp. cf. *G. lenticulus* (Reuss 1845) | – | R | R | – | R | R | R | R | R | R | – |
| *Gyroidinoides* sp. cf. *G. nitidus* (Reuss 1844) | – | R | R | – | R | R | R | – | R | R | – |
| *Lingulogavelinella* sp. cf. *L. convexa* Carter and Hart 1977 | – | – | – | – | R | – | R | R | – | R | – |
| *Paralabamina? diversa* (Belford 1960) | – | – | R | – | R | R | R | R | – | R | – |
| *Stensioeina?* sp. of Howe, Haig, and Apthorpe 2000 | R | R | R | R | C | R | R | C | – | – | – |
| *Valvulinoides* sp. 1 | R | R | R | R | R | R | R | R | R | – | – |

**NOTES**: A: abundant C: common R: rare (by visual estimation) –: not present

**Table 1.7. Distribution of planktonic foraminifera (Globigerinida) from 239.1 - 245.05 m (Haycock Marl) in Edaggee 1**

| | Sample depth (m) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | *239.10* | *239.60* | *240.05* | *240.60* | *241.05* | *241.55* | *242.15* | *243.10* | *243.60* | *244.05* | *245.05* |
| *Dicarinella algeriana* (Caron 1966) | – | – | – | – | – | – | – | R | – | R | – |
| *Dicarinella canaliculata* (Reuss 1854) | – | – | R | – | – | R | R | – | ?R | – | – |
| *Dicarinella hagni* (Schiebnerova 1962) | – | – | A | – | R | – | C | R | – | R | – |
| *Dicarinella* sp. interconnect *D. hagni* and *M. marianosi* | – | – | R | – | – | – | – | – | – | – | – |
| *Dicarinella imbricata* (Mornod 1949) | – | – | R | – | R | R | R | – | – | – | – |
| *Globigerinelloides ultramicra* (Subbotina 1949) | – | – | R | – | R | R | R | R | A | C | C |
| *Falsotruncana* sp. interconnect *douglasi* and *maslakovae* | – | – | ? | – | R | – | – | – | – | – | – |
| *Hedbergella delrioensis* (Carsey 1926) | – | – | R | – | R | R | R | R | C | C | R |
| *Hedbergella* sp. cf. *H. delrioensis* (Carsey 1926) | – | – | – | – | – | – | – | – | R | R | – |
| *Hedbergella planispira* (Tappan 1940) | – | – | – | – | R | R | R | – | – | – | – |
| *Hedbergella simplex* (Morrow 1934) | – | – | – | – | – | – | R | R | – | – | – |
| *Hedbergella* sp. | – | – | C | – | R | R | C | C | A | R | C |
| *Helvetoglobotruncana helvetica* (Bolli 1945) | – | – | – | – | R | R | – | – | – | – | – |
| *Heterohelix* sp. interconnect *H. moremani* and *H. reussi* | – | – | R | – | R | – | R | R | R | C | R |
| *Marginotruncana pseudolinneiana* Pessagno 1967 | – | – | R | – | – | – | – | – | – | – | – |
| *Praeglobotruncana stephani* (Gandolfi 1942) | – | – | – | – | – | – | – | – | R | R | – |
| *Schackoina cenomana* (Schacko 1897) | – | – | – | – | R | – | – | R | R | – | – |
| *Whiteinella archaeocretacea* Pessagno 1967 | – | – | R | – | R | – | R | C | C | A | R |
| *Whiteinella brittonensis* (Loeblich and Tappan 1961) | – | – | R | – | – | – | – | R | R | R | – |

**NOTES**: A: abundant; C: common; R: rare (by visual estimation); ?: possible occurrence; –: not present

include *B.* ex gr. *B. berthelini*, *Tappanina* sp. cf. *T. laciniosa*, *Praebulimina reussi*, *Pleurostomella* sp., and *M. oxycona* (Table 1.6).

## 240.60 m, unzoned

The sample from this level contains a very sparse foraminiferal assemblage. Planktonic foraminifera have not been recovered, and the benthic species (Table 1.6) include types known from the overlying and underlying zones.

## 241.05 – 241.55 m, *Helvetoglobotruncana helvetica* Planktonic Zone

This zone is defined by the total range of *H. helvetica* (Petrizzo, 2000). Abundant foraminifera are present and include planktonic types that make up about 1–3% of the total foraminiferal assemblage in the >150 μm sediment fraction (Table 1.5). Among the planktonic forms, keeled trochospiral species constitute 25–60% of specimens. The benthic microfauna is dominated by the Order Rotaliida, and also has common calcareous agglutinated representatives. The dominant benthic species are *B.* ex gr. *B. berthelini*, *M. oxycona*, and *Lenticulina muensteri* (Table 1.6).

## 242.15 – 245.05 m, *Whiteinella archaeocretacea* Planktonic Zone

This zone is defined as the interval between the HO of *Rotalipora cushmani* (Morrow 1934) and the LO of *H. helvetica* (following Caron, 1985). *R. cushmani* has not been found in Edaggee 1. The lower boundary of the zone is placed at the LO of a planktonic assemblage including *W. archaeocretacea*, *Heterohelix* sp., *Hedbergella* sp., *Hedbergella delrioensis*, and *Globigerinelloides ultramicra*. Planktonic assemblages from the underlying zone lack *W. archaeocretacea* and *G. ultramicra*. According to Caron (1985), *W. archaeocretacea* does not extend below the *W. archaeocretacea* Zone. *Dicarinella* is rare in the zone in Edaggee 1, and is represented by primitive species such as *D. algeriana*, *D. canaliculata*, and *D. hagni* (Table 1.7).

The abundance of planktonic foraminifera varies from almost 93% of the total foraminiferal count in the >150 μm sediment fraction in the sample from 244.05 m, to 1–3% in some higher samples (Table 1.5). The Order Rotaliida dominates the benthic assemblage. Common benthic species include *B.* ex gr. *B. berthelini*, *P. reussi*, *Pleurostomella* sp., *T.* sp. cf. *T. laciniosa*, and *Lenticulina* spp. (Table 1.6).

## 245.75 – 252.9 m, *Textulariopsis* sp. 2 Benthic Zone (*Marssonella* Association)
## 245.75 – 252.9 m, *Textulariopsis*? *kurillinensis* Benthic Zone (Ammobaculites Association)
## 248.0 – 249.0 m, *Rotalipora reicheli* Planktonic Zone

There are elements of two faunal associations among the benthic foraminifera in the interval 245.75 – 252.9 m. The microfauna is transitional between the *Ammobaculites* and *Marssonella* Associations as defined by Haig (1979b) and

Haig and Lynch (1993). The *Textulariopsis* sp. 2 Zone is defined by the total range of this species in association with other calcareous agglutinated and hyaline benthic species characteristic of the *Marssonella* Association. The *Textulariopsis*? *kurillinensis* Zone is defined by the total range of this species in association with other organic-cemented agglutinated species characteristic of the *Ammobaculites* Association (Haig, 1979b).

Planktonic species in this interval are rare, and dominated by long-ranging *Hedbergella planispira* and *H. delrioensis*. The *Rotalipora reicheli* Planktonic Zone is recognized only in the interval 248–249 m and is defined by the total range of the nominate species (following Caron, 1985).

General composition of the sand fractions of core samples from 245.75 – 252.9 m is recorded in Table 1.8. Foraminiferal species occurrences in this interval are documented in Tables 1.9 – 1.11. The benthic assemblage is dominated by: *Evolutinella* sp. 1, *Recurvoides* sp. 1, and *Textulariopsis? kurillinensis* among the organic-cemented agglutinated species (Table 1.9); *Dorothia conicula* and *Textulariopsis* sp. 2 among the calcite-cemented agglutinated foraminifera; and *L. muensteri* (Table 1.10), *P. reussi*, and *B. berthelini* (Table 1.11) among the hyaline calcitic types. The assemblage is similar to that described by Howe et al. (2000) from the uppermost part of the Gearle Siltstone in the Giralia Anticline.

## 253.85 – 265.1 m, *Berthelina intermedia* Benthic Zone (*Marssonella* Association) 253.85 – 264.05 m, *Eomarssonella crespinae* Benthic Zone (*Ammobaculites* Association) 253.85 – 261.0 m, *Blefuscuiana* sp. Planktonic Zone

Among the benthic foraminifera in the 253.85 – 265.1 m interval, there are elements of two faunal associations. The microfauna is transitional between the *Ammobaculites* and *Marssonella* Associations as defined by Haig (1979b) and Haig and Lynch (1993). The base of the *Berthelina intermedia* Zone is defined by the LO of the nominate species, and the top of the zone is placed at the HO of *Lingulogavelinella indica*, which is commonly found with *B. intermedia* in the *Marssonella* Association in this zone. The *Eomarssonella crespinae* Zone is defined by the total range of the nominate species in association with other species of the *Ammobaculites* Association.

Based on planktonic foraminifera, the *Blefuscuiana* sp. Zone is defined by the range of this species (originally recorded as *Hedbergella planispira* by Playford et al., 1975; Haig, 1979a; Haig and Lynch 1993; Haig et al. 1996; Campbell and Haig 1999) below the LO of muricate *Hedbergella*.

The general composition of the sand fractions of core samples from 253.85 to 266.05 m is recorded in Table 1.8. Foraminiferal occurrences in this interval are documented in Tables 1.9 to 1.11. Benthic foraminifera are common to abundant in most samples. The agglutinated foraminifera are dominant and are represented only by organic-cemented types in all but one sample. The sample at 265.1 m contains rare specimens of the calcite-cemented agglutinated *Spiroplectinata* sp. (Table 1.9). Calcareous hyaline benthic species (mostly calcitic, but also some aragonitic forms) are variable in abundance (Table 1.8). The benthic foraminiferal assemblage throughout the interval 253.85 – 265.1 m is similar to that found by Haig et al. (1996) in the basal Gearle Siltstone in the Giralia Anticline. The assemblage is dominated by *Recurvoides* sp. 1 among the organic-cemented agglutinated species (Table 1.9), and *B. intermedia*, *L. indica* and *Epistomina chapmani* among the calcareous hyaline forms (Table 1.11). Planktonic foraminifera are very rare and present in only three samples (253.85, 259.1, and 261 m).

## 266.05 – 280.8 m, unzoned

Much of this interval consists of mudstone (radiolarite) too indurated for foraminiferal extraction. Three samples were examined (Tables 1.8 to 1.11), and contain only sparse and poorly preserved foraminifera that are non-diagnostic for zonal purposes.

Samples from 274.1 and 280.8 m contain abundant radiolaria including *Arachnosphaera exilis* (Hinde 1893), *Archaeodictyomitra vulgaris* Pessagno 1977, *Archaeospongoprunum* sp., *Crucella messinae* Pessagno 1977, *Orbiculiforma depressa* Wu 1986, *Praeconocaryomma prisca* Pessagno 1977, *Spongopyle* sp., *Spongodiscus renillaeformis* Campbell and Clark 1944, and *Tricolocapsa antiqua* Squinabol 1903 recorded from the type section of the Windalia Radiolarite by Ellis (1993).

## 297.1 – 309.65 m, zone of organic-cemented agglutinated foraminifera (*Ammobaculites* Association)

This interval contains abundant organic-cemented agglutinated foraminifera. No calcareous foraminifera are present. The general composition of the sand fractions of core samples from 297.1 to 309.65 m is recorded in Table 1.8. Foraminiferal occurrences in this interval, which has been included in the Muderong Shale, are documented in Table 1.9. There is some differentiation in the fauna through the section (Table 1.9). For example, *Ammobaculties humei* is present through most of the interval; *Textulariopsis*? sp. and *Spiroplectammina* sp. are confined in the interval 297.1 – 304.05 m; *Verneuilinoides howchini* ranges from 299.05 to 309.65 m (and is known higher in the Albian in Edaggee 1); and *Recurvoides* sp. cf. *R. obskiiensis* ranges from 301.15 to 309.65 m. The significance of the distribution patterns is uncertain.

The agglutinated assemblage differs from that recorded by Taylor and Haig (2001) from the type section of the Muderong Shale and from the formation in Barrabiddy 1/1A, in that it lacks *Simobaculites raghavapuramensis* (Bhalla 1965) and *Bykoviella* sp. cf. *B. elenae* (Dain 1958). These are common components of the typical Muderong assemblage. In addition, the presence of *Ammobaculites* sp. cf. *A. hofkeri* and *Trochammina minuta* indicates an affinity with assemblages from 163.7 – 167.0 m in Coburn 1 (Haig, 1999).

**Table 1.8. General features of washed sand residues from 245.75 m (Haycock Marl) and 246.05 – 309.65 m (Winning Group) in Edaggee 1**

| | *Sample depth (m)* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *245.75* | *246.05* | *247.15* | *248* | *249* | *250* | *251.05* | *252.05* | *252.9* | *253.85* | *255* | *256.05* | *257* | *258* | *259.1* | *260.1[(a)]* | *261* | *262.05* | *263.2* | *264.05* | *265.1* | *266.05* | *274.1* | *280.8* | *297.1* | *298.1* | *299.05* | *300.05* | *301.15* | *302.05* | *303.05* | *304.05* | *305.1* | *306.05* | *307.45* | *308.1* | *308.8* | *309.05* | *309.65* |
| **Lithogenic and authigenic components** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| quartz >150 µm | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | R | – | – | – | – | – | – | – | – | – | R | A | – | – | – | A |
| quartz 63-150 µm | – | – | – | – | – | – | – | – | C | – | – | – | – | – | – | – | – | – | – | – | – | – | – | R | – | – | – | – | – | – | – | – | R | A | A | – | – | – | A |
| feldspar >150 µm | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | R |
| feldspar 63-150 µm | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | R |
| glauconite >150 µm | – | – | – | – | – | – | – | – | – | A | A | A | A | – | – | – | – | – | – | – | – | A | – | – | – | – | – | – | – | – | – | – | – | A | – | – | – | – | – |
| glauconite 63–150 µm | – | – | – | – | R | R | – | – | R | A | A | A | A | – | – | – | – | – | – | – | R | A | – | C | – | – | – | – | – | – | – | – | R | A | C | – | – | – | R |
| pyrite (aggregates) >150 µm | R | C | C | – | A | R | C | C | – | C | R | A | A | A | C | – | A | C | C | A | C | C | R | A | C | – | – | R | R | C | C | C | C | A | C | R | – | C | – |
| pyrite (aggregates) 63–150 µm | C | R | C | R | C | R | R | R | R | C | – | C | R | R | C | – | A | C | C | A | C | – | A | C | C | R | – | C | C | A | A | – | C | R | C | A | A | C | R |
| pyrite (cylinders) >150 µm | R | – | C | R | C | – | R | – | R | R | R | C | – | – | – | – | – | – | R | A | R | C | R | – | – | – | – | – | – | R | C | C | R | – | C | – | – | R | – |
| pyrite (cylinders) 63–150 µm | – | – | R | – | – | – | – | C | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | R | – | – | R | – | – | – | – | – | – |
| gypsum >150 µm | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | ?A | ?A | ?A | – | – | ?C | ?C | ?A | – | – | – | – | – | – | – |
| gypsum 63–150 µm | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | ?C | – | – | ?C | – | – | – | – | – | – | – | – | – |
| siderite >150 µm | – | – | – | – | – | C | A | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| siderite 63–150 µm | – | – | – | – | C | A | A | A | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| phosphatic nodules >150 µm | ?A | – | – | – | – | – | – | – | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| phosphatic nodules 63–150 µm | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| **Biogenic components** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| agglutinated foraminifera[1] | A | A | A | A | A | A | A | A | A | A | R | A | A | A | A | – | A | A | C | C | C | R | A | R | A | C | A | A | A | A | A | A | A | A | A | A | A | A | A |
| agglutinated foraminifera[2] | – | A | A | A | A | A | A | A | A | – | – | – | – | – | – | – | – | – | – | – | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| calcitic hyaline benthic foraminifera | – | A | A | A | A | A | A | A | A | A | R | C | R | R | A | R | A | A | A | R | R | R | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| aragonitic hyaline benthic foraminifera | – | – | – | – | – | – | – | – | – | – | R | C | | R | C | – | R | R | C | C | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| planktonic foraminifera | – | R | R | R | C | C | C | – | R | R | – | – | – | – | R | – | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| shell fragments[3] | – | – | – | – | | – | – | – | – | R | R | C | – | – | – | – | – | – | C | R | – | R | A | A | – | – | – | – | – | – | R | R | – | – | R | A | A | R | R |
| belemnite guard fragments | – | – | C | R | R | – | R | C | A | C | C | C | C | C | R | – | R | R | R | R | R | C | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| echinoid spines | – | – | R | – | – | – | – | – | – | – | R | R | – | R | – | – | – | – | R | R | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| fish debris | A | R | R | R | R | – | C | A | A | C | C | A | C | A | C | – | A | C | – | R | R | A | R | C | C | C | – | R | R | R | C | C | R | C | A | A | A | A | R |
| scolecodonts | – | – | – | – | – | – | – | R | – | – | – | – | – | R | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | R | – | – | – | – | – | – | – | – | – |
| ostracods | – | – | – | – | – | R | R | – | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| radiolaria | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | ?A | – | – | – | – | A | | C | A | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| radiolaria (glauconitic) | – | – | – | – | – | – | – | – | – | – | A | A | A | – | – | – | – | – | – | – | – | – | – | – | – | – | C | – | – | – | – | – | – | C | – | – | – | – | – |
| radiolaria (pyritized) | – | – | – | – | – | – | – | – | – | – | – | – | – | – | R | – | – | R | – | – | – | – | C | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| Sponge spicules | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | R | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| diatoms (pyritic) 63–150 µm | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | R | – | – | C | C | C | C | A | R | R | C | A | C | R | R |
| dinocysts 63–150 µm | – | – | – | – | – | – | – | – | – | R | – | – | – | – | – | – | – | R | – | R | R | – | – | – | R | R | R | R | R | R | C | A | A | R | C | A | R | A | C |
| plant debris (wood) >150 µm | – | – | – | – | – | R | – | – | R | R | – | R | R | – | – | – | – | – | – | – | – | – | – | R | – | – | – | – | – | – | – | – | C | – | – | – | – | – | – |
| plant debris (cuticle and wood) 63–150 µm | R | – | – | – | – | – | – | – | – | – | – | R | – | – | – | – | – | – | R | – | – | – | – | R | – | – | – | – | – | – | – | – | – | – | C | – | C | A | C |

**NOTES**:
A: abundant;
C: common
R: rare (by visual estimation)

1: organic-cemented; benthic
2: calcite-cemented; benthic
3: ?lingulid-like brachiopods

?: possible occurrence
(a): indurated
–: not present

**Table 1.9. Distribution of agglutinated foraminifera from 245.75 m (Haycock Marl) and 246.05 – 309.65 m (Winning Group) in Edaggee 1**

| | Sample depth (m) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *245.75* | *246.05* | *247.15* | *248* | *249* | *250* | *251.05* | *252.05* | *252.9* | *253.85* | *255* | *256.05* | *257* | *258* | *259.1* | *260.1* | *261* | *262.05* | *263.2* | *264.05* | *265.1* | *266.05* | *274.1* | *280.8* | *297.1* | *298.1* | *299.05* | *300.05* | *301.15* | *302.05* | *303.05* | *304.05* | *305.1* | *306.05* | *307.45* | *308.1* | *308.8* | *309.05* | *309.65* |
| **Organic-cemented agglutinated species** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Ammobaculites* sp. cf. *A. hofkeri* Bhalla 1965 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | R | R | R | – | – | – | R | – | R | – |
| *Ammobaculites humei* Nauss 1947 | R | – | – | R | R | – | – | R | R | R | – | R | R | R | – | – | R | R | R | – | – | – | – | – | R | C | A | A | ? | C | – | R | R | R | C | C | A | C | R |
| *Ammobaculites* sp. | – | – | – | – | – | R | R | R | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Ammodiscus glabratus* Cushman and Jarvis 1928 | – | R | R | – | R | R | R | R | R | – | – | R | R | R | R | – | C | R | R | R | R | – | C | – | – | – | – | – | R | R | R | – | A | R | – | – | – | – | – |
| *Ammodiscus* sp. A of Haig and Lynch 1993 | – | | A | – | R | R | R | R | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Bathysiphon brosgei* Tappan 1957 | C | – | C | – | R | R | C | C | – | – | R | – | – | R | R | – | – | R | R | – | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Bathysiphon* sp. | – | – | – | – | R | R | R | R | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Bimonilina* sp. | – | – | – | – | – | – | – | – | R | – | – | – | R | R | – | – | – | – | – | R | – | – | – | – | – | – | – | – | – | R | R | R | A | – | – | – | – | – | – |
| *Bulbobaculites inconstans* (Bartenstein and Brand 1951) | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | ? | – | – | – | – | – | – | – | R | R | R |
| *Eomarssonella crespinae* (Ludbrook 1966) | – | – | – | – | – | – | – | – | – | R | – | – | R | R | C | – | R | – | – | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Eomarssonella* sp. | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | A | R | A | R | A | A | A | A | R | – | – | R | – | R | – |
| *Evolutinella* sp. cf. *E. perturbans* (Ludbrook 1966) | – | – | – | – | – | – | – | – | – | C | – | R | – | – | A | – | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Evolutinella* sp. 1 of Howe, Haig, and Apthorpe 2000 | A | – | R | – | R | C | A | A | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Gaudryinella* sp. cf. *G. sherlocki* Bettenstaedt 1952 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | R | – | – | – | – | ?R | A | A | – | – | – | – | – |
| *Gaudryinella* sp. of Howe, Haig, and Apthorpe 2000 | – | – | – | – | R | – | R | R | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | R | – | – | – | – | – | – | – | – |
| *Gaudryinopsis filiformis* (Berthelin, 1880) | – | – | – | R | R | – | C | R | R | C | – | R | R | A | C | – | R | – | – | R | R | – | – | – | – | R | C | C | R | C | – | – | – | – | – | – | – | – | – |
| *Gaudryinopsis senonica* (Balakhmatova 1960) | – | – | – | R | – | – | R | R | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Gaudryinopsis* sp. of Haig, Watkins, and Ellis 1996 | – | – | – | – | – | – | – | R | R | – | – | – | R | – | – | – | – | – | – | – | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Gaudryinopsis* sp. | – | – | – | – | – | R | R | – | R | – | – | – | – | – | – | – | – | – | – | – | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Glomospirella gaultina* (Berthelin 1880) | – | R | – | – | R | R | – | – | – | – | – | – | R | R | R | – | R | R | R | R | – | R | – | – | – | – | R | R | – | R | – | – | – | – | – | – | – | – | – |
| *Haplophragmoides* sp. cf. *H. minor* Nauss 1947 | – | – | – | – | – | ?R | – | – | – | R | – | R | R | R | – | – | – | – | – | R | R | – | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Haplophragmoides* sp. cf *H. hyalinus* (Haeusler 1885) | – | – | – | – | – | – | – | – | – | – | – | R | R | R | R | – | C | – | R | R | R | – | – | – | ? | – | – | – | – | R | – | – | – | – | R | R | R | R | – |
| *Haplophragmoides* sp. D of Haig and Lynch 1993 | – | R | – | – | R | – | R | – | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Haplophragmoides* sp. of Taylor and Haig 2001 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | R | – | – | – |
| *Hyperammina gaultina* ten Dam 1950 | – | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | R | – | C | – | – | R | – | R | A | R | R | – |
| *Lagenammina alexanderi* (Loeblich and Tappan 1950) | – | – | – | – | – | – | – | ?R | – | – | – | – | – | – | – | – | R | – | – | – | – | – | – | – | – | – | – | R | – | – | – | – | – | – | – | – | – | – | – |
| *Lagenammina* sp. 1 of Haig, Watkins, and Ellis 1996 | – | – | – | – | – | – | – | – | – | – | – | – | – | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Miliammina ischnia* Tappan 1957 | – | – | – | – | – | – | – | – | – | – | – | R | R | – | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Psammosphaera laevigata* White 1928 | R | – | R | – | – | R | R | R | R | – | ?R | – | – | R | – | – | R | – | – | – | – | – | R | – | – | – | – | – | – | R | – | R | C | R | – | – | – | – | – |
| *Recurvoides* sp. cf. *R. obskiiensis* Romanova 1960 | – | – | – | – | – | – | – | – | R | – | – | – | – | – | – | – | – | R | R | R | R | – | ?C | – | – | – | – | – | A | A | A | C | A | R | A | A | A | A | A |
| *Recurvoides* sp. 1 | A | R | C | R | C | R | R | R | – | R | R | A | A | C | A | – | A | C | R | R | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Reophax geniculatus* Ludbrook 1966 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | R | – | – | – | – | – | – | – | – | – |
| *Reophax* sp. of Howe, Haig, and Apthorpe 2000 | – | – | – | – | – | – | – | R | A | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Rhizammina* sp. | – | – | – | – | – | R | R | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Spiroplectammina* sp. | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | C | – | R | A | – | R | R | C | – | – | – | – | – | – | – |
| *Textulariopsis? kurillinensis* (Ludbrook 1966) | C | R | R | R | R | A | C | C | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Textulariopsis?* sp. | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | R | R | R | R | R | R | R | R | – | – | – | – | – | – | – |
| *Trochammina minuta* Crespin 1953 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | ? | – | – | – | – | – | – | – | – | – | – | – | – | R | R | – | – | – | C | A | A | R | C |
| *Trochammina subinflata* Crespin 1963 | – | – | – | – | – | – | – | – | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Trochammina* sp. 1 | – | – | – | – | – | – | – | – | R | – | – | – | – | – | – | – | R | – | R | R | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Trochammina* sp. 2 | – | – | – | – | – | R | R | – | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Verneuilinoides howchini* (Crespin 1953) | – | – | – | – | – | – | – | – | – | – | – | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | R | R | A | C | R | C | R | – | – | R | R | R | R |

**Table 1.9.** (continued)

| | *Sample depth (m)* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *245.75* | *246.05* | *247.15* | *248* | *249* | *250* | *251.05* | *252.05* | *252.9* | *253.85* | *255* | *256.05* | *257* | *258* | *259.1* | *260.1* | *261* | *262.05* | *263.2* | *264.05* | *265.1* | *266.05* | *274.1* | *280.8* | *297.1* | *298.1* | *299.05* | *300.05* | *301.15* | *302.05* | *303.05* | *304.05* | *305.1* | *306.05* | *307.45* | *308.1* | *308.8* | *309.05* | *309.65* |
| **Calcite-cemented agglutinated species** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Dorothia conicula* Belford 1960 | – | A | C | R | A | R | A | A | A | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Kadriayina* sp. cf. *K. gradata* (Berthelin 1880) | – | – | – | C | R | – | R | R | C | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Pseudogaudryinella* sp. B of Haig and Lynch (1993) | – | – | – | – | – | A | C | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Spiroplectinata annectens* (Parker and Jones 1863) | – | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Spiroplectinata bettenstaedti* (Grabert 1959) | – | C | – | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Spiroplectinata complanata* (Reuss 1860) | – | C | – | R | R | – | – | R | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Spiroplectinata* sp. | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Textulariopsis* sp. 1 of Howe, Haig, and Apthorpe 2000 | – | R | R | R | R | – | – | A | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Textulariopsis* sp. 2 of Howe, Haig, and Apthorpe 2000 | – | A | A | A | R | A | A | R | C | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |

**NOTES**: A: abundant
C: common
R: rare (by visual estimation)
?: possible occurrence
–: not present

**Table 1.10. Distribution of calcareous benthic foraminifera (Miliolida, Lagenida, and Buliminida) from 245.75 m (Haycock Marl) and 246.05 – 309.65 m (Winning Group) in Edaggee 1**

| | Sample depth (m) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
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| | 245.75 | 246.05 | 247.15 | 248 | 249 | 250 | 251.05 | 252.05 | 252.9 | 253.85 | 255 | 256.05 | 257 | 258 | 259.1 | 260.1 | 261 | 262.05 | 263.2 | 264.05 | 265.1 | 266.05 | 274.1 | 280.8 | 297.1 | 298.1 | 299.05 | 300.05 | 301.15 | 302.05 | 303.05 | 304.05 | 305.1 | 306.05 | 307.45 | 308.1 | 308.8 | 309.05 | 309.65 |
| **Porcelaneous benthic foraminifera (Miliolida)** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Pseudosigmoilina* sp. 1 | – | C | A | C | A | R | R | – | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Spiroloculina* sp. | – | – | – | – | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| **Hyaline calcitic benthic foraminifera (Lagenida)** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Astacolus calliopsis* (Reuss 1863) | – | – | R | R | R | – | – | – | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Citharina* sp. cf. *C. kernensis* Church 1968 | – | R | R | R | R | – | C | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Citharina* sp. cf. *C. angustissima* (Reuss 1863) | – | R | R | – | R | – | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Frondicularia* sp. cf. *F. archiaciana* d'Orbigny 1840 | – | ?R | ?R | R | – | R | – | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Frondicularia* sp. cf. *F. planifolium* Chapman 1894 | – | – | – | – | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Globulina lacrima* Reuss 1845 | – | – | – | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Hemirobulina hamulus* (Chapman 1894) | – | R | R | R | R | – | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Kyphopyxa* sp. 1 | – | – | – | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Laevidentalina inepta* (Cushman 1947) | – | – | – | – | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Laevidentalina luma* (Belford 1960) | – | – | – | R | R | – | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Laevidentalina oligostegia* (Reuss 1845) | – | – | – | – | R | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Laevidentalina* sp. cf. *L. subcommunis* (d'Orbigny 1850) | – | R | – | R | R | – | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Laevidentalina* sp. | – | – | – | – | – | – | – | – | – | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Lenticulina muensteri* (Roemer 1839) | – | R | C | C | A | A | A | A | R | C | – | – | – | ? | C | – | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Lenticulina pulchella* (Reuss 1863) | – | – | – | – | – | R | R | – | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Lingulina* sp. | – | – | – | – | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Marginulina* sp. 2 | – | – | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Marginulinopsis jonesi* (Reuss 1863) | – | – | – | – | – | R | C | – | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Marginulinopsis* sp. cf. *M. jonesi* (Reuss 1863) | – | – | – | – | – | – | – | – | – | R | – | – | R | – | – | – | – | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Marginulinopsis muelleri* (Reuss 1863) | – | – | – | – | – | – | – | – | – | R | – | – | R | – | R | – | R | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Marginulinopsis* sp. 2 of Haig, Watkins, and Ellis 1996 | – | – | – | – | – | – | – | – | – | – | R | R | R | R | A | – | R | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Marginulinopsis* sp. | – | – | – | – | – | – | – | – | – | – | – | – | – | R | R | – | – | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Planularia bradyana* (Chapman 1894) | – | R | R | R | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Psilocitharella recta* (Reuss 1863) | – | – | – | – | – | – | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Psilocitharella thoerenensis* (Bartenstein and Brand 1951) | – | – | – | – | – | – | – | – | – | – | – | – | – | – | R | – | – | – | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Pyramidulina flexocarinata* (Khan 1950) | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | R | ? | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Pyramidulina obscura* (Reuss 1845) | – | – | R | – | – | – | R | R | R | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Pyramidulina sceptrum* (Reuss 1863) | – | – | – | R | – | – | R | – | – | R | – | – | – | – | R | – | – | – | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Pyramidulina prismatica* (Reuss 1860) | – | R | R | R | R | – | R | R | R | – | – | – | – | – | – | – | R | – | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Pyramidulina* sp. 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | R | R | – | R | R | R | – | – | – | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Ramulina* sp. A of Belford 1960 | – | – | R | R | A | – | R | – | – | R | – | – | – | – | – | – | – | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Ramulina* sp. 2 | – | R | – | – | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Ramulina* sp. | – | – | – | – | – | – | – | – | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Saracenaria bononiensis* (Berthelin 1880) | – | – | – | – | – | – | R | – | – | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Saracenaria pyramidata* (Reuss 1863) | – | R | – | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Saracenaria triangularis* (d'Orbigny 1840) | – | – | R | R | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Tricarinella excavatum* (Reuss 1863) | – | R | – | R | R | – | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |

**Table 1.10.** (continued)

| | *Sample depth (m)* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
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| | *245.75* | *246.05* | *247.15* | *248* | *249* | *250* | *251.05* | *252.05* | *252.9* | *253.85* | *255* | *256.05* | *257* | *258* | *259.1* | *260.1* | *261* | *262.05* | *263.2* | *264.05* | *265.1* | *266.05* | *274.1* | *280.8* | *297.1* | *298.1* | *299.05* | *300.05* | *301.15* | *302.05* | *303.05* | *304.05* | *305.1* | *306.05* | *307.45* | *308.1* | *308.8* | *309.05* | *309.65* |
| **Hyaline calcitic benthic foraminifera (Buliminida)** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Cassidella?* sp. cf. *C? tegulata* (Reuss 1845) | – | R | R | R | R | – | R | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Coryphostoma* sp. of Haig, Watkins, and Ellis 1996 | – | – | – | – | – | – | – | – | – | A | – | – | – | – | – | – | – | R | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Cribropleurostomella* sp. | – | – | – | ?R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Neobulimina albertensis* (Stelck and Wall 1954) | – | – | – | R | – | – | – | – | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Pleurostomella reussi* Berthelin 1880 | – | – | – | | | | | – | – | R | – | – | – | – | R | – | R | C | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Pleurostomella* sp. cf. *P. subnodosa* Reuss 1860 | – | R | R | R | C | R | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Pleurostomella* sp. | – | R | R | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Praebulimina reussi* (Morrow 1934) | – | C | A | C | A | R | R | – | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Tappanina* sp. 1 | – | R | C | C | C | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Turrilina evexa* (Loeblich and Tappan 1949) | – | – | R | R | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Turrilina* sp. cf. *T. evexa* (Loeblich and Tappan 1949) | – | – | R | R | R | – | – | – | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |

**NOTES**: A: abundant
C: common
R: rare (by visual estimation)
?: possible occurrence
–: not present

**Table 1.11. Distribution of calcareous benthic foraminifera (Rotaliida and Robertinida) and planktonic foraminifera from 245.75 m (Haycock Marl) and 246.05 – 309.65 m (Winning Group) in Edaggee 1**

| | Sample depth (m) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
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| | 245.75 | 246.05 | 247.15 | 248 | 249 | 250 | 251.05 | 252.05 | 252.9 | 253.85 | 255 | 256.05 | 257 | 258 | 259.1 | 260.1 | 261 | 262.05 | 263.2 | 264.05 | 265.1 | 266.05 | 274.1 | 280.8 | 297.1 | 298.1 | 299.05 | 300.05 | 301.15 | 302.05 | 303.05 | 304.05 | 305.1 | 306.05 | 307.45 | 308.1 | 308.8 | 309.05 | 309.65 |
| **Hyaline calcitic benthic foraminifera (Rotaliida)** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Berthelina berthelini* (Keller 1935) | – | A | A | C | A | A | A | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Berthelina intermedia* (Berthelin 1880) | – | – | – | – | – | – | R | R | R | A | – | R | R | R | A | – | C | C | A | R | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Berthelina* sp. cf. *B. intermedia* (Berthelin 1880) | – | – | – | – | – | – | R | R | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Berthelina* sp. cf. *B. tenuissima* (Gawor-Biedowa 1992) | – | – | – | – | – | – | – | – | – | R | – | – | – | – | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Berthelina* sp. B of Haig and Lynch 1993 | – | R | R | R | R | – | – | ?R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Berthelina*? sp. cf. *Anomalina tenuis* of Bukalova 1958 | – | R | – | C | R | – | A | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Berthelina*? sp. | – | – | – | R | R | – | – | – | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Conorotalites*? sp. | – | R | R | R | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Gyroidinoides* sp. cf. *G. nitidus* (Reuss 1844) | – | – | R | C | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Gyroidinoides* sp. A | – | – | R | A | R | – | C | – | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Gyroidinoides* sp. B | – | – | – | – | – | – | – | – | – | R | – | – | – | – | R | – | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Lingulogavelinella* sp. cf. *L. convexa* Carter and Hart 1977 | – | R | R | R | A | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Lingulogavelinella indica* (Scheibnerova 1974) | – | – | – | – | – | – | – | – | – | A | – | – | R | R | A | – | C | A | C | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Lingulogavelinella santoodnae* (Ludbrook 1966) | – | – | – | – | – | – | – | – | – | R | – | – | – | – | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Osangularia schloenbachi* (Reuss 1863) | – | – | – | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Quadrimorphina* sp. | – | – | R | R | R | – | – | – | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Stensioeina*? sp. of Howe, Haig, and Apthorpe 2000 | – | A | R | A | C | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Valvulinoides* sp. 2 | – | – | – | R | C | R | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Valvulinoides* sp. 3 | – | – | – | C | R | – | R | R | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Valvulinoides* sp. 4 | – | C | C | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| **Hyaline aragonitic benthic foraminifera (Robertinida)** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Epistomina chapmani* ten Dam 1948 | – | – | – | – | – | – | – | – | – | – | – | C | – | R | C | – | R | R | C | C | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Epistomina spinulifera* (Reuss 1863) | – | – | – | – | – | – | – | – | – | – | R | R | – | – | R | – | – | – | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Reinholdella* sp. | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| **Planktonic foraminifera (Globigerinida)** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Blefuscuiana* sp. | – | – | – | – | – | – | – | – | – | R | – | – | – | – | R | – | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Hedbergella delrioensis* (Carsey 1926) | – | R | C | A | A | C | C | – | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Hedbergella planispira* (Tappan 1940) | – | R | R | R | A | R | R | – | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Hedbergella* sp. | – | – | – | – | R | R | – | – | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Heterohelix* sp. | – | – | R | R | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Rotalipora reicheli* Mornod 1950 | – | – | – | R | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |

**NOTES**: A: abundant
C: common
R: rare (by visual estimation)
?: possible occurrence
–: not present

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### Appendix 2

# Palynology

by

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## Introduction

Palynological results from Edaggee 1 are based on the samples listed in Table 2.1. Estimates of organic yield are based on the amount of residue produced after acid digestion. A range chart arranged by lowest occurrence (LO) is presented in Table 2.2 for all Cretaceous samples. The sample from 216.9 m is barren, and identifications from two low-yielding samples at 291.0 and 295.4 m are recorded as present (P). The remaining samples were counted and the results presented in Table 2.2 as percentages of the total palynomorph count. A breakdown of spores and pollen is not presented because better biostratigraphic resolution is obtained from the dinocysts. Dinocysts, as listed in Table 2.3, are named largely following Williams et al. (1998).

The major zonal subdivision used in the Cretaceous and Jurassic is based on Helby et al. (1987). Informal subzones used in the Cretaceous are based on unpublished work by B. S. Ingram, N. Hooker, and R. Morgan, and on proposed subzones presented by Foster (2001).

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## Palynological observations and comments

### 69.0 m, *Nelsoniella aceras* Dinoflagellate Zone

This is the highest palynologically productive sample. The zonal assignment is based on the presence of *Nelsoniella aceras* and *Nelsoniella semireticulata*, and the absence of *Xenikoon australis*. A significant number of the dinocysts in this sample are undescribed species. Spores and pollen constitute nearly 38% of the palynomorph assemblage, and small acritarchs (*Micrhystridium* spp.) make up over 14% of the assemblage.

### 238.05 m, *Conosphaeridium striatoconms* Dinoflagellate Zone

The presence of several specimens of *Conosphaeridium striatoconus* is strong evidence for assignment to this zone. *Palaeohystrichophora infusorioides* and *Spiniferites* spp. are abundant, and *Gillinia hymenophora* is common. Pollen and spores comprise 2.3% in this sample.

**Table 2.1. Summary of palynological zones in Edaggee 1**

| *Depth (m)* | *Sample type* | *GSWA no.* | *Microfossil yield* | *Preservation* | *Zone* |
|---|---|---|---|---|---|
| 69.00 | cuttings | 176805 | moderate | good | *N. aceras* |
| 216.90 | core | 177623 | barren | – | – |
| 238.05 | core | 177644 | low | fair | *C. striatoconum* |
| 246.05 | core | 177652 | low | fair | *P. infusorioides* |
| 252.90 | core | 177659 | high | good | *D. multispinum* |
| 260.10 | core | 177666 | moderate | good | *C. denticulata* |
| 266.10 | core | 177671 | moderate | good | *M. tetracantha* |
| 280.80 | core | 177686 | moderate | fair | *D. davidii* |
| 289.90 | core | 177694 | moderate | poor | *D. davidii* |
| 290.60 | core | 177695 | high | good | *D. davidii* |
| 295.40 | core | 177701 | moderate | good | *O. operculata/D. davidii* |
| 296.00 | core | 177703 | moderate | good | *O. operculata/D. davidii* |
| 301.15 | core | 177708 | high | good | lower *O. operculata* |
| 308.80 | core | 177716 | high | good | upper *M. australis* |
| 309.65 | core | 177718 | high | good | upper *M. australis* |
| 313.00 | core | 176804 | – | – | caved material |
| 321.85 | core | 176802 | barren | – | – |
| 331.05 | core | 176801 | barren | – | – |
| 345.80 | core | 176803 | low | good | indeterminate (pre-Upper Devonian) |

**NOTE:** –: not applicable

**Table 2.2. Distribution of Cretaceous species in Edaggee 1**

| *Depth* | *309.65* | *308.8* | *301.15* | *296.0* | *295.4* | *291.0* | *290.6* | *289.9* | *280.8* | *266.1* | *260.1* | *252.9* | *246.05* | *238.05* | *216.9* | *69.0* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **DINOCYSTS** | | | | | | | | | | | | | | | | |
| Dinocysts indet. | 11.9 | 5.1 | 24.4 | 20.4 | – | – | 9.2 | 17.6 | 17.3 | 14.2 | 15.9 | 10.7 | 12.9 | 12.4 | – | 13.4 |
| *Apteodinium granulatum* | 0.5 | 1.1 | 0.0 | 0.0 | – | – | 0.0 | 0.0 | 0.5 | 0.4 | 1.2 | 0.6 | 0.0 | 0.0 | – | 0.0 |
| *Batioladinium micropodum* | 1.0 | 0.6 | 0.0 | 0.4 | – | – | 0.4 | 0.7 | 0.5 | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 | – | 0.0 |
| *Cassiculosphaeridia magna* | 0.5 | 0.6 | 1.2 | 0.0 | – | – | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | – | 0.0 |
| *Cassiculosphaeridia reticulata* | 1.0 | 1.7 | 14.0 | 5.7 | – | – | 3.5 | 2.0 | 11.7 | 1.9 | 4.3 | 1.2 | 0.4 | 0.0 | – | 0.0 |
| *Circulodinium hirtellum* | 0.5 | 0.6 | 2.4 | 0.0 | – | – | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | – | 0.0 |
| *Cribroperidinium muderongense* | 0.5 | 0.6 | 3.0 | 1.1 | P | – | 0.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | – | 0.0 |
| *Dingodinium cerviculum* | 2.4 | 1.1 | 3.7 | 1.8 | P | P | 0.8 | 3.4 | 2.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | – | 0.0 |
| *Discorsia nanna* | 0.5 | 0.0 | 0.0 | 0.4 | – | – | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | – | 0.0 |
| *Dissiliodinium* sp. cf. *D. curiosum* | 3.3 | 2.2 | 1.2 | 0.7 | – | – | 1.5 | 0.0 | 0.0 | 0.4 | 0.6 | 0.6 | 0.0 | 0.0 | – | 0.0 |
| *Exochosphaeridium* spp. | 0.5 | 0.6 | 0.6 | 0.4 | – | – | 0.8 | 0.0 | 3.6 | 1.9 | 3.0 | 3.0 | 1.9 | 1.4 | – | 0.0 |
| *Kallosphaeridium coninckii* | 1.4 | 5.6 | 0.0 | 1.1 | – | – | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | – | 0.0 |
| *Kiokansium polypes* | 1.0 | 0.6 | 0.0 | 0.0 | – | – | 0.0 | 0.0 | 0.0 | 0.4 | 0.0 | 0.6 | 0.0 | 0.0 | – | 0.0 |
| *Kleithriaspharidium eoinoides* | 0.5 | 0.0 | 0.0 | 0.4 | – | – | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | – | 0.0 |
| *Muderongia australis* | 0.5 | 0.6 | 0.6 | 0.0 | – | – | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | – | 0.0 |
| *Muderongia crucis* | 0.5 | 0.6 | 0.6 | 0.0 | P | – | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | – | 0.0 |
| *Oligosphaeridium* spp. | 2.4 | 6.2 | 1.2 | 0.7 | – | – | 0.8 | 1.4 | 1.0 | 0.4 | 0.0 | 1.8 | 5.7 | 0.9 | – | 0.0 |
| *Prolixosphaeridium parvispinum* | 0.5 | 1.1 | 0.0 | 0.4 | – | – | 0.4 | 0.7 | 0.5 | 0.0 | 0.6 | 0.0 | 0.0 | 0.0 | – | 0.0 |
| *Pyxidiella tumida* | 1.0 | 0.6 | 0.0 | 0.0 | – | – | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | – | 0.0 |
| *Sentusidinium aptiense* | 7.6 | 9.0 | 7.9 | 10.8 | – | – | 17.7 | 33.1 | 2.5 | 8.8 | 0.0 | 0.0 | 0.0 | 0.0 | – | 0.0 |
| *Sentusidinium* spp. | 1.4 | 1.7 | 7.3 | 0.4 | – | – | 1.5 | 4.1 | 12.2 | 9.2 | 19.5 | 13.1 | 0.0 | 0.0 | – | 1.0 |
| *Spiniferites* spp. | 1.9 | 2.8 | 6.1 | 1.8 | – | – | 4.2 | 2.0 | 4.6 | 14.2 | 8.5 | 14.3 | 17.5 | 25.3 | – | 8.0 |
| *Angustidinium acribes* | 0.0 | 0.6 | 0.0 | 3.9 | P | – | 1.2 | 0.7 | 0.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | – | 0.0 |
| *Batioladinium jaegeri* | 0.0 | 0.6 | 0.6 | 0.4 | – | – | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | – | 0.0 |
| *Canninginopsis* sp.A (Morgan) | 0.0 | 0.6 | 0.0 | 0.7 | P | – | 0.4 | 0.0 | 0.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | – | 0.0 |
| *Impagidinium* spp. | 0.0 | 0.6 | 0.6 | 4.3 | – | – | 1.2 | 2.0 | 1.0 | 2.7 | 2.4 | 1.8 | 2.7 | 0.5 | – | 0.0 |
| *Tanyosphaeridium* spp. | 0.0 | 0.6 | 0.0 | 0.7 | – | – | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 | 1.2 | 0.0 | 0.0 | – | 1.0 |
| *Wrevittia helicoidea* | 0.0 | 0.6 | 0.0 | 0.0 | – | – | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | – | 0.0 |
| *Batioladinium longicornutum* | 0.0 | 0.0 | 0.6 | 0.0 | – | – | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | – | 0.0 |
| *Canninginopsis colliveri* | 0.0 | 0.0 | 0.6 | 0.4 | – | – | 0.0 | 0.0 | 0.0 | 0.0 | 0.6 | 1.8 | 0.0 | 0.0 | – | 0.0 |
| *Chlamydophorella nyei/C. ambigua* | 0.0 | 0.0 | 6.1 | 2.9 | – | – | 2.7 | 6.1 | 0.0 | 8.0 | 7.9 | 1.8 | 14.4 | 0.0 | – | 0.0 |
| *Circulodinium attadalicum* | 0.0 | 0.0 | 0.6 | 0.0 | – | – | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | – | 0.0 |
| *Coronifera oceanica* | 0.0 | 0.0 | 1.8 | 0.4 | – | – | 0.0 | 0.0 | 0.0 | 1.1 | 1.2 | 0.6 | 0.0 | 0.0 | – | 0.0 |
| *Hystrichodinium pulchrum* | 0.0 | 0.0 | 0.6 | 0.4 | P | – | 0.8 | 1.4 | 2.0 | 0.4 | 1.8 | 1.2 | 2.7 | 3.7 | – | 1.5 |
| *Impagidinium phlyctaena* | 0.0 | 0.0 | 0.6 | 2.2 | – | – | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | – | 0.0 |
| *Microdinium* spp. | 0.0 | 0.0 | 1.2 | 13.3 | – | – | 0.0 | 0.0 | 0.0 | 0.0 | 0.6 | 0.6 | 0.0 | 0.0 | – | 0.5 |
| *Muderongia mcwhaei* | 0.0 | 0.0 | 0.6 | 0.0 | – | – | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | – | 0.0 |
| *Odontochitina operculata* | 0.0 | 0.0 | 0.6 | 0.0 | P | P | 0.4 | 0.0 | 1.0 | 0.4 | 0.6 | 0.6 | 0.0 | 0.0 | – | 0.0 |
| *Palaeoperidinium cretaceum* | 0.0 | 0.0 | 0.6 | 0.4 | P | – | 0.0 | 0.0 | 0.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | – | 0.0 |
| *Yalkalpodinium scutum* | 0.0 | 0.0 | 0.6 | 0.4 | – | – | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | – | 0.0 |
| *Aldorfia deflandrei* | 0.0 | 0.0 | 0.0 | 0.4 | – | – | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | – | 0.0 |
| *Aprobolocysta alata* | 0.0 | 0.0 | 0.0 | 0.4 | – | – | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | – | 0.0 |
| *Avellodinium lepidum* | 0.0 | 0.0 | 0.0 | 0.4 | P | – | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | – | 0.0 |
| *Batiacasphaera* spp. | 0.0 | 0.0 | 0.0 | 2.9 | - | - | 8.8 | 0.7 | 3.0 | 3.8 | 0.0 | 0.6 | 0.0 | 0.0 | - | 0.0 |

**Table 2.2.** (continued)

| *Depth* | *309.65* | *308.8* | *301.15* | *296.0* | *295.4* | *291.0* | *290.6* | *289.9* | *280.8* | *266.1* | *260.1* | *252.9* | *246.05* | *238.05* | *216.9* | *69.0* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Carpodinium granulatum* | 0.0 | 0.0 | 0.0 | 0.4 | P | – | 0.4 | 0.7 | 0.0 | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 | – | 0.0 |
| *Cleistosphaeridium* spp | 0.0 | 0.0 | 0.0 | 1.4 | – | – | 1.2 | 0.0 | 0.5 | 5.0 | 0.0 | 4.2 | 4.9 | 11.5 | – | 3.0 |
| *Occisucysta tenuiceras* | 0.0 | 0.0 | 0.0 | 0.7 | – | – | 0.0 | 0.0 | 2.5 | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 | – | 0.0 |
| *Muderongia tetracantha* | 0.0 | 0.0 | 0.0 | 0.0 | P | P | 1.2 | 0.7 | 2.0 | 1.9 | 0.0 | 0.0 | 0.0 | 0.0 | – | 0.0 |
| *Canninginopsis intermedia* | 0.0 | 0.0 | 0.0 | 0.0 | – | P | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | – | 0.0 |
| *Endoceratium turneri* | 0.0 | 0.0 | 0.0 | 0.0 | – | P | 0.0 | 0.0 | 0.5 | 0.0 | 0.6 | 0.0 | 0.0 | 0.0 | – | 0.0 |
| *Fibradinium variculum* | 0.0 | 0.0 | 0.0 | 0.0 | – | – | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | – | 0.0 |
| *Diconodinium davidii* | 0.0 | 0.0 | 0.0 | 0.0 | – | – | 0.0 | 0.7 | 4.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | – | 0.0 |
| *Trichodinium* spp. | 0.0 | 0.0 | 0.0 | 0.0 | – | – | 0.0 | 1.4 | 0.0 | 0.0 | 0.0 | 1.2 | 1.5 | 0.9 | – | 0.0 |
| *Ascodinium serratum?* | 0.0 | 0.0 | 0.0 | 0.0 | – | – | 0.0 | 0.0 | 1.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | – | 0.0 |
| *Cribroperidinium edwardsii* | 0.0 | 0.0 | 0.0 | 0.0 | – | – | 0.0 | 0.0 | 1.0 | 2.3 | 0.6 | 0.6 | 0.0 | 0.0 | – | 0.5 |
| *Florentinia* spp. | 0.0 | 0.0 | 0.0 | 0.0 | – | – | 0.0 | 0.0 | 1.0 | 0.8 | 0.0 | 1.8 | 0.0 | 1.4 | – | 0.0 |
| *Ovoidinium striatum* | 0.0 | 0.0 | 0.0 | 0.0 | – | – | 0.0 | 0.0 | 0.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | – | 0.0 |
| *Callaiosphaeridium asymmetricum* | 0.0 | 0.0 | 0.0 | 0.0 | – | – | 0.0 | 0.0 | 0.0 | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 | – | 0.0 |
| *Chlamydophorella* spp. | 0.0 | 0.0 | 0.0 | 0.0 | – | – | 0.0 | 0.0 | 0.0 | 5.7 | 0.0 | 0.0 | 9.9 | 0.0 | – | 1.0 |
| *Wrevittia cassidata* | 0.0 | 0.0 | 0.0 | 0.0 | – | – | 0.0 | 0.0 | 0.0 | 0.8 | 1.2 | 0.6 | 0.4 | 0.0 | – | 0.0 |
| *Aptea polymorpha* | 0.0 | 0.0 | 0.0 | 0.0 | – | – | 0.0 | 0.0 | 0.0 | 0.0 | 0.6 | 0.6 | 0.0 | 0.0 | – | 0.0 |
| *Batiacaspha scrobiculata* | 0.0 | 0.0 | 0.0 | 0.0 | – | – | 0.0 | 0.0 | 0.0 | 0.0 | 1.2 | 0.6 | 0.0 | 0.0 | – | 0.0 |
| *Cribroperidinium apione* | 0.0 | 0.0 | 0.0 | 0.0 | – | – | 0.0 | 0.0 | 0.0 | 0.0 | 0.6 | 0.6 | 0.0 | 0.0 | – | 0.0 |
| *Diconodinium pusillum* | 0.0 | 0.0 | 0.0 | 0.0 | – | – | 0.0 | 0.0 | 0.0 | 0.0 | 1.8 | 1.2 | 0.0 | 0.0 | – | 0.5 |
| *Dinopterygium tuberculatum* | 0.0 | 0.0 | 0.0 | 0.0 | – | – | 0.0 | 0.0 | 0.0 | 0.0 | 1.2 | 0.6 | 0.0 | 0.0 | – | 0.0 |
| *Litosphaeridium arundum* | 0.0 | 0.0 | 0.0 | 0.0 | – | – | 0.0 | 0.0 | 0.0 | 0.0 | 1.2 | 0.6 | 0.0 | 0.0 | – | 0.0 |
| *Protoellipsodinium densispinum* | 0.0 | 0.0 | 0.0 | 0.0 | – | – | 0.0 | 0.0 | 0.0 | 0.0 | 0.6 | 0.0 | 0.0 | 0.0 | – | 0.0 |
| *Spinidinium styloniferum* | 0.0 | 0.0 | 0.0 | 0.0 | – | – | 0.0 | 0.0 | 0.0 | 0.0 | 1.2 | 0.0 | 0.0 | 0.0 | – | 0.0 |
| *Balcattia cirribarbata* | 0.0 | 0.0 | 0.0 | 0.0 | – | – | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.6 | 0.0 | 0.0 | – | 0.0 |
| *Balcattia cirrifera* | 0.0 | 0.0 | 0.0 | 0.0 | – | – | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.6 | 0.0 | 0.0 | – | 0.0 |
| *Cyclonephelium compactum* | 0.0 | 0.0 | 0.0 | 0.0 | – | – | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.6 | 0.4 | 0.0 | – | 0.0 |
| *Diconodinium psilatum* | 0.0 | 0.0 | 0.0 | 0.0 | – | – | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.6 | 0.0 | 0.0 | – | 0.0 |
| *Diconodinium multispinum* | 0.0 | 0.0 | 0.0 | 0.0 | – | – | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.2 | 0.0 | 0.0 | – | 0.0 |
| *Endoceratium ludbrookiae* | 0.0 | 0.0 | 0.0 | 0.0 | – | – | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.6 | 0.0 | 0.0 | – | 0.0 |
| *Heslertonia striata* | 0.0 | 0.0 | 0.0 | 0.0 | – | – | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.6 | 0.4 | 0.0 | – | 0.0 |
| *Heterosphaeridium heteracanthum* | 0.0 | 0.0 | 0.0 | 0.0 | – | – | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.8 | 0.8 | 0.0 | – | 0.0 |
| *Hystrichosphaeropsis galeata* | 0.0 | 0.0 | 0.0 | 0.0 | – | – | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.6 | 0.0 | 0.0 | – | 0.0 |
| *Laciniadinium? inflatum* | 0.0 | 0.0 | 0.0 | 0.0 | – | – | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.6 | 0.0 | 0.0 | – | 0.0 |
| *Leberidocysta chlamydata* | 0.0 | 0.0 | 0.0 | 0.0 | – | – | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 3.0 | 0.4 | 0.5 | – | 0.0 |
| *Litosphaeridium siphoniphorum* | 0.0 | 0.0 | 0.0 | 0.0 | – | – | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.4 | 1.1 | 0.0 | – | 0.0 |
| *Odontochitina striatoperforata* | 0.0 | 0.0 | 0.0 | 0.0 | – | – | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.6 | 1.5 | 0.5 | – | 0.0 |
| *Psaligonyaulax deflandrei* | 0.0 | 0.0 | 0.0 | 0.0 | – | – | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.6 | 0.4 | 0.0 | – | 0.0 |
| *Xiphophoridium alatum* | 0.0 | 0.0 | 0.0 | 0.0 | – | – | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 3.0 | 0.0 | 0.0 | – | 0.0 |
| *Ascodinium* sp. cf. *A. parvum* | 0.0 | 0.0 | 0.0 | 0.0 | – | – | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.7 | 0.9 | – | 0.0 |
| *Cyclonephelium membraniphorum* | 0.0 | 0.0 | 0.0 | 0.0 | – | – | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.1 | 0.0 | – | 0.0 |
| *Hystrichosphaeridium paracostatum* | 0.0 | 0.0 | 0.0 | 0.0 | – | – | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.4 | 0.9 | – | 0.0 |
| *Kleithriaspharidium readei* | 0.0 | 0.0 | 0.0 | 0.0 | – | – | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.1 | 0.0 | – | 0.0 |
| *Palaeohystrichophora infusorioides* | 0.0 | 0.0 | 0.0 | 0.0 | – | – | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.9 | 23.0 | – | 3.5 |
| *Pervosphaeridium paucispinum* | 0.0 | 0.0 | 0.0 | 0.0 | – | – | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.4 | 0.0 | – | 0.0 |

**Table 2.2.** (continued)

| *Depth* | *309.65* | *308.8* | *301.15* | *296.0* | *295.4* | *291.0* | *290.6* | *289.9* | *280.8* | *266.1* | *260.1* | *252.9* | *246.05* | *238.05* | *216.9* | *69.0* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Prolixosphaeridium conulum* | 0.0 | 0.0 | 0.0 | 0.0 | – | – | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.4 | 0.0 | – | 0.0 |
| *Apteodinium deflandrei* | 0.0 | 0.0 | 0.0 | 0.0 | – | – | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.9 | – | 0.0 |
| *Conosphaeridium striatoconus* | 0.0 | 0.0 | 0.0 | 0.0 | – | – | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.4 | – | 0.0 |
| *Disphaeria macropyla* | 0.0 | 0.0 | 0.0 | 0.0 | – | – | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.4 | – | 0.5 |
| *Gillinia hymenophora* | 0.0 | 0.0 | 0.0 | 0.0 | – | – | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 4.6 | – | 0.5 |
| *Odontochitina cribropoda* | 0.0 | 0.0 | 0.0 | 0.0 | – | – | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.5 | – | 0.0 |
| *Xenascus asperatus* | 0.0 | 0.0 | 0.0 | 0.0 | – | – | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.5 | – | 0.0 |
| *Dinogymnium* spp. | 0.0 | 0.0 | 0.0 | 0.0 | – | – | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | – | 1.5 |
| *Heterosphaeridium* spp. | 0.0 | 0.0 | 0.0 | 0.0 | – | – | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | – | 9.0 |
| *Nelsoniella aceras* | 0.0 | 0.0 | 0.0 | 0.0 | – | – | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | – | 0.5 |
| *Nelsoniella semireticulata* | 0.0 | 0.0 | 0.0 | 0.0 | – | – | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | – | 0.5 |
| *Xenascus sarjeantii* | 0.0 | 0.0 | 0.0 | 0.0 | – | – | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | – | 0.5 |
| **ALGAL CYSTS & ACRITARCHS** | | | | | | | | | | | | | | | | |
| *Botryococcus* spp. | 0.5 | 0.0 | 0.0 | 0.0 | – | – | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | – | 0.0 |
| *Brazilea* spp. | 10.5 | 5.6 | 0.0 | 0.0 | – | – | 0.0 | 0.7 | 0.0 | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 | – | 0.0 |
| *Cymatiosphaera* spp. | 0.5 | 0.0 | 0.0 | 0.0 | – | – | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | – | 0.0 |
| *Fromea amphora* | 0.5 | 0.6 | 0.6 | 0.0 | – | – | 0.0 | 0.0 | 0.5 | 0.0 | 0.6 | 0.0 | 0.0 | 0.0 | – | 0.0 |
| *Leiosphaeridia* spp. | 2.9 | 0.6 | 0.0 | 0.0 | – | – | 0.0 | 0.0 | 0.0 | 0.4 | 0.0 | 0.6 | 0.0 | 2.3 | – | 1.0 |
| *Micrhystridium* spp. | 1.0 | 0.6 | 0.0 | 0.0 | – | – | 0.8 | 0.0 | 3.0 | 0.0 | 0.0 | 0.0 | 0.4 | 0.0 | – | 14.4 |
| *Pterospermella* spp. | 2.9 | 1.7 | 1.2 | 1.4 | – | – | 0.0 | 0.0 | 0.0 | 0.4 | 0.6 | 0.0 | 0.0 | 0.0 | – | 0.0 |
| *Tasmanites* spp. | 0.5 | 0.0 | 0.0 | 0.0 | – | – | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | – | 0.0 |
| *Veryhachium* spp. | 1.4 | 0.6 | 1.2 | 1.4 | – | – | 0.0 | 0.0 | 0.5 | 0.4 | 0.6 | 6.0 | 1.1 | 0.0 | – | 0.0 |
| *Fromea monilifera* | 0.0 | 0.6 | 0.0 | 0.4 | P | – | 0.4 | 0.7 | 1.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | – | 0.0 |
| *Platycystidia eisenacki* | 0.0 | 0.6 | 0.0 | 0.0 | – | – | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | – | 0.0 |
| *Wallodinium krutschii* | 0.0 | 0.0 | 0.6 | 0.4 | – | – | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | – | 0.0 |
| *Rhombodella paucispina* | 0.0 | 0.0 | 0.0 | 0.4 | – | – | 2.7 | 0.7 | 0.5 | 0.4 | 1.2 | 0.6 | 0.0 | 0.0 | – | 0.0 |
| Acritarchs indet. | 0.0 | 0.0 | 0.0 | 0.0 | – | – | 0.8 | 0.0 | 0.0 | 0.0 | 1.2 | 1.2 | 4.6 | 1.4 | – | 0.0 |
| *Fromea fragilis* | 0.0 | 0.0 | 0.0 | 0.0 | – | – | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.4 | 0.0 | – | 0.0 |
| *Spheripollenites psilatus* | 0.0 | 0.0 | 0.0 | 0.0 | – | – | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.8 | 0.0 | – | 0.0 |
| **OTHER** | | | | | | | | | | | | | | | | |
| Foraminiferal linings | 0.5 | 0.6 | 0.0 | 0.0 | – | – | 0.0 | 0.7 | 0.0 | 0.0 | 0.6 | 1.2 | 3.0 | 0.9 | – | 0.0 |
| Scolecodont | 0.0 | 0.0 | 0.0 | 0.0 | – | – | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | – | 0.0 |
| **SPORES & POLLEN** | 38.1 | 42.7 | 6.1 | 13.3 | P | P | 33.5 | 18.2 | 14.7 | 11.9 | 15.2 | 4.8 | 1.9 | 2.3 | – | 37.8 |
| **Zone** | ***M. australis*** | ***M. australis*** | ***O. operculata*** | ***O. perc./D. davidii*** | ***O. perc./D. davidii*** | ***D. davidii*** | ***D. davidii*** | ***D. davidii*** | ***D. davidii*** | ***M. tetracantha*** | ***C. denticulata*** | ***D. multispinum*** | ***P. infusorioides*** | ***C. striatoconus*** | **Barren** | ***N. aceras*** |

**NOTE:** P: present –: not present

**Table 2.3. List of taxa mentioned in text and Table 2.2**

**Dinocysts**

*Angustidinium acribes (*Davey and Verdier 1971) Goodman and Evitt 1981
*Aprobolocysta alata* Backhouse 1987
*Aptea polymorpha* Eisenack 1958
*Apteodinium deflandrei* (Clarke and Verdier 1967) Lucas-Clarke 1987
*Apteodinium granulatum* Eisenack 1958
*Ascodinium serratum?* Cookson and Eisenack 1960
*Ascodinium* sp. cf. *A. parvum* (Cookson and Eisenack 1958) Cookson and Eisenack 1960
*Avellodinium lepidum* Backhouse 1988
*Balcattia cirribarbata* Cookson and Eisenack 1982
*Balcattia cirrifera* Cookson and Eisenack 1974
*Batiacasphaera scrobiculata* (Deflandré and Cookson 1955) Burger 1980b
*Batioladinium jaegeri* (Alberti 1961) Brideaux1975
*Batioladinium longicornutum* (Alberti 1961) Brideaux 1975
*Batioladinium micropodum* (Eisenack and Cookson 1960) Brideaux 1975
*Callaiosphaeridium asymmetricum* (Deflandré and Courteville 1939) Davey and Williams 1966
*Canninginopsis colliveri* (Cookson and Eisenack 1960) Backhouse 1988
*Canninginopsis intermedia* Morgan 1980
*Canninginopsis* sp. A (Morgan 1980)
*Carpodinium granulatum* Cookson and Eisenack 1962
*Cassiculosphaeridia magna* Davey 1974
*Cassiculosphaeridia reticulata* Davey 1969
*Chlamydophorella ambigua* Cookson and Eisenack 1958
*Chlamydophorella nyei* Cookson and Eisenack 1958
*Circulodinium attadalicum* (Cookson and Eisenack 1962) Helby 1987
*Circulodinium hirtellum* Alberti 1961
*Conosphaeridium striatoconus* (Deflandré and Cookson) Cookson and Eisenack 1969
*Coronifera oceanica* Cookson and Eisenack 1958
*Cribroperidinium apione* (Cookson and Eisenack 1958) Morgan 1980
*Cribroperidinium edwardsii* (Cookson and Eisenack 1958) Davey 1969
*Cribroperidinium muderongense* (Cookson and Eisenack 1958) Davey 1969
*Cribroperidinium? tenuiceras* (Eisenack 1958) Poulsen 1996
*Cyclonephelium compactum* Deflandré and Cookson 1955
*Cyclonephelium membraniphorum* Cookson and Eisenack 1962
*Diconodinium davidii* Morgan 1975
*Diconodinium multispinum* (Deflandré and Cookson 1955) Eisenack and Cookson 1960
*Diconodinium psilatum* Morgan 1977
*Diconodinium pusillum* Singh 1971
*Dingodinium cerviculum* Cookson and Eisenack 1958
*Dinopterygium tuberculatum* (Eisenack and Cookson 1960) Stover and Evitt 1978
*Discorsia nannus* (Davey 1974) Duxbury 1977
*Disphaeria macropyla* Cookson and Eisenack 1960
*Dissiliodinium* sp. cf. *D. curiosum* Burger and Sargeant 1995
*Endoceratium ludbrookiae* (Cookson and Eisenack 1958) Loeblich Jr and Loeblich III 1966
*Endoceratium turneri* (Cookson and Eisenack 1958) Stover and Evitt 1978
*Fibradinium variculum* Stover and Helby 1987
*Gillinia hymenophora* Cookson and Eisenack 1960
*Heslertonia striata* (Eisenack and Cookson 1960) Norvick 1976
*Heterosphaeridium heteracanthum* (Deflandré and Cookson 1955) Eisenack and Kjellström 1972
*Hystrichodinium pulchrum* Deflandré 1935
*Hystrichosphaeridium paracostatum* Cookson and Eisenack 1974
*Hystrichosphaeropsis galeata* (Cookson and Eisenack 1960) Gocht 1976
*Impagidinium phlyctaena* Stover and Helby 1987
*Kallosphaeridium coninckii* (Burger 1980) Burger 1980
*Kiokansium unituberculatum* (Tasch *in* Tasch et al. 1964) Stover and Evitt 1978
*Kleithriasphaeridium eoinoides* (Eisenack 1958) Davey 1974
*Kleithriasphaeridium readei* (Davey and Williams 1966) Davey and Verdier 1976
*Laciniadinium? inflatum* (Eisenack and Cookson 1960) Morgan 1977
*Leberidocysta chlamydata* (Cookson and Eisenack 1962) Stover and Evitt 1978
*Litosphaeridium arundum* (Eisenack and Cookson 1960) Davey 1979
*Litosphaeridium siphoniphorum* (Cookson and Eisenack 1958) Davey and Williams 1966
*Muderongia australis* Helby 1987
*Muderongia crucis* Neale and Sarjeant 1962
*Muderongia mcwhaei* Cookson and Eisenack 1958
*Muderongia tetracantha* (Gocht 1957) Alberti 1961
*Nelsoniella semireticulata* Cookson and Eisenack 1960
*Nelsoniella aceras* Cookson and Eisenack 1960
*Odontochitina costata* Alberti 1961
*Odontochitina cribropoda* Deflandré and Cookson 1955
*Odontochitina operculata* (Wetzel 1933) Deflandré and Cookson 1955
*Ovoidinium cinctum* (Cookson and Eisenack 1958) Davey 1970
*Ovoidinium striatum* Riding and Helby 2001
*Palaeohystrichophora infusorioides* Deflandré 1935
*Palaeoperidinium cretaceum* (Pocock1962) Lentin and Williams 1976
*Pervosphaeridium paucispinum* (Eisenack and Cookson 1960) Jan du Chene et al. 1986
*Prolixosphaeridium conulum* Davey 1969
*Prolixosphaeridium parvispinum* (Deflandré 1937) Davey et al. 1969
*Protoellipsodinium densispinum* Morgan 1980
*Psaligonyaulax deflandrei* Sarjeant 1966
*Pyxidiella tumida* Stover and Helby 1987
*Sentusidinium aptiense* (Burger 1980a) Burger 1980b
*Spinidinium styloniferum* Cookson and Eisenack 1962
*Wrevittia cassidata* (Eisenack and Cookson 1960) Helenes and Lucas-Clark 1997
*Wrevittia helicoidea* (Eisenack and Cookson 1960) Helenes and Lucas-Clark 1997
*Xenascus asperatus* Stover and Helby 1987
*Xenascus sarjeantii* (Corradini 1973) Stover and Evitt 1978
*Xenikoon australis* Cookson and Eisenack 1960
*Xiphophoridium alatum* (Cookson and Eisenack 1962) Sarjeant 1966
*Yalkalpodinium scutum* Morgan 1980

**Algal cysts and acritarchs**

*Fromea amphora* Cookson and Eisenack 1958
*Fromea fragilis* (Cookson and Eisenack 1962b) Stover and Evitt 1978
*Fromea monilifera* Backhouse 1987
*Platycystidia eisenacki* (Mehrotra and Sarjeant 1984c) Backhouse 1988
*Rhombodella paucispina* (Alberti 1961) Duxbury 1980
*Spheripollenites psilatus* Couper 1958
*Wallodinium krutschii* (Alberti 1961) Habib 1972

## 246.05 m, *Palaeohystrichophora infusorioides* Dinoflagellate Zone

This sample lacks *Endoceratium ludbrookiae* and *C. striatoconus*, and is therefore tentatively assigned to the *P. infusorioides* Zone. *Diconodinium multispinum* is not recorded in this assemblage, which is dominated by *Chlamydophorella* spp. and *Spiniferites* spp. The spore–pollen count is about 2%.

## 252.9 m, *Diconodinium multispinum* Dinoflagellate Zone

The presence of *E. ludbrookiae* and *D. multispinum* places this sample in the *D. multispinum* Zone. Small *Sentusidinium* spp. and *Spiniferites* spp. are common, and *Leberidocysta chlamydata* and *Xiphophoridium alatum* are prominent species. The spore–pollen count is low (less than 5%).

## 260.1 m, *Canninginopsis denticulata* Dinoflagellate Zone

The sample contains *Diconodinium pusillum* and *Dinopterygium tuberculatum*, and lacks *E. ludbrookiae* and *D. multispinum*, indicating the *C. denticulata* Zone. *Sentusidinium* spp., *Chlamydophorella ambigua,* and *Spiniferites* spp. are the most common dinocysts. Spores and pollen constitute over 15% of the assemblage.

## 266.1 m, *Muderongia tetracantha* Dinoflagellate Zone

This sample contains *Muderongia tetracantha*, but lacks *Diconodinium davidii*, which is the index species for the underlying *D. davidii* Zone. Index species for the overlying *C. denticulata* Zone are also absent. The overall dinocyst assemblage is similar to the sample above, and is dominated by *Sentusidinium* spp., *Spiniferites* sp., and *C. ambigua*. Spores and pollen make up about 12% of the assemblage.

## 280.8 – 290.6 m, *Diconodinium davidii* Dinoflagellate Zone

The interval is assigned to the *D. davidii* Zone based on the presence of the nominate species up to the highest sample at 280.8 m and, the presence of *Endoceratium turneri* in an uncounted sample at 291.0 m. *Ovoidinium striatum*, an index species for the middle to upper part of the zone, is only recorded in the 280.8 m sample. *Sentusidinium* spp., *Spiniferites* spp., and *Cassiculosphaeridia reticulata* are numerically dominant in the interval. Spores and pollen constitute over 33% of the assemblage in the lowest sample, but 14–18% in the higher samples.

## 295.4 – 296.0 m, *Diconodinium davidii or upper Odontochitina operculata* Dinoflagellate Zone

The sample at 296.0 m contains an assemblage broadly similar to the lower samples of the overlying *D. davidii* Zone, but appears to be below the range of *E. turneri*. The assemblage from 295.4 m is sparse, but similar to that from 296.0 m, although it includes *M. tetracantha*. It is unclear whether the samples from 295.4 and 296.0 m are in the lowest part of the *D. davidii* Zone, or should be assigned to the upper *O. operculata* Subzone — further work is required to elucidate this interval. The 296.0 m sample contains over 13% spores and pollen.

## 301.15 m, *Odontochitina operculata* Dinoflagellate Zone (lower)

This sample contains *O. operculata* and the LO of *Muderongia mcwhaei*. *Sentusidinium* spp., *Spiniferites* spp., *C. ambigua*, *Dingodinium cerviculum,* and *C. reticulata* are common species. The spore–pollen count is particularly low (6.1%).

## 308.8 – 309.65 m, *Muderongia australis* Dinoflagellate Zone (upper)

The absence of *M. mcwhaei* and the presence of *Muderongia australis* place this interval in the *M. australis* Zone. The absence of *Ovoidinium cinctum* and index species for the middle and lower parts of the zone suggest that this interval correlates with the upper part of the *M. australis* Zone, as used informally by B.S. Ingram and R. Morgan. *Sentusidinium aptiense* is the most common dinocysts, with significant numbers of *Oligosphaeridium* spp. and *Kallosphaeridium coninckii* in the higher sample. The spore–pollen count is high (38–43%).

## 321.85 – 345.8 m, indeterminate

Three samples were examined from the lowest interval in Edaggee 1: 321.8 m, 331.05 m, and 345.8 m. Organic material in these samples consists largely of amorphous, unstructured material and rounded, unstructured opaque fragments. Only the lowest sample contains recognizable palynomorphs — small semi-transparent palynomorphs that are possibly algal in origin. The age is probably pre-Late Devonian.

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## Appendix 3

# Albian to lower Campanian calcareous nannofossils

by

R. W. Howe[1]

## Introduction

Fifteen samples from 216.90 to 253.85 m in the cored interval of Edaggee 1 were examined for calcareous nannofossil biostratigraphy. Smear slides were prepared using the techniques outlined in Perch-Nielsen (1985) and Bown and Young (1998). A small amount of fresh rock was scraped onto a coverslip and then smeared evenly with a wet toothpick. The coverslip was then dried on a hotplate before being glued to a glass slide using Norland optical adhesive. The slides were then examined at 1250× magnification using a Zeiss Universal cross-polarizing microscope, and taxa were recorded semi-quantitatively.

The overall nannofossil abundance in each sample was recorded on a distribution chart (Table 3.1). As the nannofossil assemblage in a sample can show overgrowth of some species, and dissolution of others, only the overall preservation state of the assemblage is recorded.

A total of 133 species were recorded. All of the samples examined contained relatively abundant nannofossils, and were assigned to both the Upper Cretaceous (UC) nannofossil zones of Burnett (1998), and the Cretaceous coccolith (CC) zones of Sissingh (1977) and Perch-Nielsen (1985), as summarized in Table 3.2. The CC zonation is most applicable to Tethyan provinces, whereas the UC zonation was developed in an attempt to correlate between faunal provinces. Many of the marker species in these zonations were not found to be useful, so other biostratigraphically useful species have been used instead. An alphabetical list of species names referred to is provided in Table 3.3. A comprehensive list of references on Cretaceous calcareous nannofossils can be found in Perch-Nielsen (1985) and Bown (1998).

## General observations

### 216.90 – 220.00 m, UC14a, CC18a Subzones

The nannofossil assemblages in this interval show high abundances and poor to moderate preservation. Diversity is high, with between 59 and 61 species present (single specimens are considered as possible occurrences). The interval is assigned to the UC14a and CC18a Subzones, based on the presence of *Aspidolithus parcus parcus,* the lowest occurrence (LO) of which marks the base of the UC14 and CC18 Zones, and the absence of *Aspidolithus parcus constrictus* (Hattner et al. 1980)*,* the LO of which marks the base of the UC14b and CC18b Subzones.

### 225.05 – 235.05 m, upper UC12–13, upper CC16–17 Zones

The nannofossil assemblages in this interval show high abundances and poor to moderate preservation. Diversity is high, with between 50 and 55 species present. The interval belongs to the upper UC12–13 and upper CC16–17 Zones, based on the absence of *A. parcus parcus,* the LO of which marks the base of the UC14 and CC18 Zones, and the presence of *Cylindralithus crassus,* the LO of which is within the UC12 and CC16 Zones.

### 239.1 – 240.05 m, ~UC8, ~CC12 Zones

This interval has nannofossil assemblages with moderate to high abundances and poor to moderate preservation. Diversity is moderate to high, with between 37 and 52 species present. The interval belongs to ~UC8 and ~CC12 Zones, based on: the absence of *Marthasterites furcatus,* the LO of which marks the base of the UC9 and CC13 Zones; the highest occurrence (HO) of *Eprolithus eptapetalus,* near the top of the UC8 and CC12 Zones; and the presence of *Eiffellithus eximius,* the LO of which marks the base of the UC8 and CC12 Zones. In this interval *E. eptapetalus* is relatively common.

### 241.05 – 242.15 m, ~upper UC7, ~upper CC11 Zones

This interval has nannofossil assemblages with high abundance and poor to moderate preservation. Diversity is moderate, with between 39 and 42 species present. The interval belongs to the ~upper UC7 and ~upper CC11 Zones, based on: the absence of *E. eximius,* the LO of which marks the base of the UC8 and CC12 Zones; the presence of *Eprolithus rarus* at 241.05m, the HO of which is within the uppermost part of the UC7 and CC11 Zones; and the absence of *Eprolithus octopetalus,* the HO of which is within the UC7 and CC11 Zones, below the HO of *E. rarus.*

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**Table 3.1. Calcareous nannofossil distribution chart for the Albian - lower Turonian section of Edaggee 1**

| | ***Stratigraphic height (m)*** | *216.90* | *220.00* | *225.05* | *230.00* | *235.05* | *239.10* | *240.05* | *241.05* | *242.15* | *243.10* | *244.05* | *245.05* | *246.05* | *252.90* | *253.85* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ***GSWA sample number*** | *177623* | *177626* | *177631* | *177636* | *177641* | *177645* | *177646* | *177647* | *177648* | *177649* | *177650* | *177651* | *177652* | *177659* | *177660* |
| | ***Nannofossil abundance*** | *H* | *H* | *H* | *H* | *H* | *M–H* | *M–H* | *H* | *H* | *M* | *M* | *H* | *H* | *L–M* | *M* |
| | ***Nannofossil preservation*** | *P* | *P–M* | *P–M* | *P–M* | *P–M* | *P* | *P–M* | *P–M* | *P–M* | *P–M* | *P–M* | *P–M* | *M–G* | *P–M* | *P–M* |
| | ***Species richness* (not including stems)*** | *60* | *58* | *50* | *54* | *49* | *35* | *50* | *39* | *42* | *37* | *37* | *26* | *37* | *37* | *28* |
| 1 | *Ahmuellerella octoradiata* | F | F | R | R | R | R | F | – | R | R | R | – | – | – | – |
| 2 | *Ahmuellerella plebius* | R | R | R | R | R | – | – | – | – | – | – | – | – | – | – |
| 3 | *Amphizygus brooksii brooksii* | – | – | – | – | – | – | – | – | R | R | – | – | – | – | – |
| 4 | *Amphizygus brooksii nanus* | R | R | R | R | R | – | – | – | – | – | – | – | – | – | – |
| 5 | *Arkhangelskiella cymbiformis* var. NT | – | R | – | – | – | – | – | – | – | – | – | – | – | – | – |
| 6 | *Aspidolithus enormis* | C | C | C | F | F | R | – | – | R | – | R | – | – | – | – |
| 7 | *Aspidolithus parcus expansus* | R | R | – | – | – | – | – | – | – | – | – | – | – | – | – |
| 8 | *Aspidolithus parcus parcus* | R | R | – | – | – | – | – | – | – | – | – | – | – | – | – |
| 9 | *Axopodorhabdus biramiculatus (=A. albianus)* | – | – | – | – | – | – | – | – | – | – | – | – | R | R | – |
| 10 | *Bidiscus rotatorius* | R | R | R | – | – | – | – | – | – | R | R | – | – | – | – |
| 11 | *Biscutum 'bergenii'* | – | – | – | S | – | – | – | – | – | – | – | – | – | – | – |
| 12 | *Biscutum constans* | R | R | F | R | F | R | F | – | R | – | R | R | F | – | R |
| 13 | *Broinsonia arta* | – | – | – | – | – | – | R | – | – | – | – | – | – | – | – |
| 14 | *Broinsonia matalosa* | – | – | – | – | – | – | – | R | R | – | – | – | – | – | – |
| 15 | *Broinsonia signata* | F | F | R | F | R | – | R | – | R | – | S | – | – | – | – |
| 16 | *Broinsonia stenostaurion* | – | – | – | – | – | – | – | – | – | – | – | – | R | – | – |
| 17 | *Bukrylithus ambiguus* | – | – | – | – | – | – | R | – | – | – | – | – | S | S | R |
| 18 | *Calculites obscurus* | R | R | R | R | – | – | – | – | – | – | – | – | – | – | – |
| 19 | *Calculites ovalis* | – | – | – | S | – | – | – | – | – | – | – | – | – | – | – |
| 20 | *Ceratolithina cruxii capitanea* | – | – | – | – | – | – | – | – | – | – | – | – | – | S | – |
| 21 | *Ceratolithina cruxii cruxii* | – | – | – | – | – | – | – | – | – | – | – | – | – | R | – |
| 22 | *Chiastozygus amphipons* | C | C | C | F | F | R | – | R | – | – | – | R | – | – | – |
| 23 | *Chiastozygus garrissonii* | R | R | R | R | R | – | – | – | – | – | – | – | – | – | – |
| 24 | *Chiastozygus platyrhethum* | – | – | – | – | – | – | – | – | R | R | R | R | R | R | R |
| 25 | *Corollithion madagaskarensis* | R | R | – | – | – | – | – | – | – | – | – | – | – | – | – |
| 26 | *Corollithion signum* | – | – | – | R | – | – | – | – | – | – | – | – | – | R | – |
| 27 | *Cretarhabdus conicus* | – | – | – | – | – | – | – | – | – | – | – | – | – | – | R |
| 28 | *Cretarhabdus loriei* | – | – | – | – | – | – | – | – | – | – | – | – | – | S | R |
| 29 | *Cribrosphaerella colatus* | F | R | F | R | F | – | R | – | – | – | – | – | – | – | – |
| 30 | *Cribrosphaerella ehrenbergii* | C | C | C | C | C | – | – | – | – | – | – | – | – | – | – |
| 31 | *Crucicribrum anglicum* | – | – | – | – | – | – | – | – | – | – | – | – | – | – | R |
| 32 | *Cylindralithus crassus* | R | R | R | – | R | – | – | – | – | – | – | – | – | – | – |
| 33 | *Cylindralithus nudus* | R | R | R | R | – | – | R | R | – | R | – | – | R | – | – |
| 34 | *Eburites minimus* | – | R | R | – | – | – | – | – | – | – | – | – | – | – | – |
| 35 | *Eifellithus paragogus (=B. glabra)* | – | – | – | – | – | – | – | – | – | – | – | – | – | – | S |
| 36 | eiffelithid stem | F | F | F | F | F | R | F | F | F | R | R | R | F | R | – |
| 37 | *Eiffellithus albinotus* | – | ?S | – | – | – | – | – | – | – | – | – | – | – | – | – |
| 38 | *Eiffellithus eximius* | C | C | C | C | C | ?R | ?R | – | – | – | – | – | – | – | – |
| 39 | *Eiffellithus gorkae* | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| 40 | *Eiffellithus turriseiffellii* | R | R | R | R | F | F | C | C | C | F | F | F | F | F | – |

**Table 3.1.** (continued)

| | ***Stratigraphic height (m)*** | *216.90* | *220.00* | *225.05* | *230.00* | *235.05* | *239.10* | *240.05* | *241.05* | *242.15* | *243.10* | *244.05* | *245.05* | *246.05* | *252.90* | *253.85* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ***GSWA sample number*** | *177623* | *177626* | *177631* | *177636* | *177641* | *177645* | *177646* | *177647* | *177648* | *177649* | *177650* | *177651* | *177652* | *177659* | *177660* |
| | ***Nannofossil abundance*** | *H* | *H* | *H* | *H* | *H* | *M–H* | *M–H* | *H* | *H* | *M* | *M* | *H* | *H* | *L–M* | *M* |
| | ***Nannofossil preservation*** | *P* | *P–M* | *P–M* | *P–M* | *P–M* | *P* | *P–M* | *P–M* | *P–M* | *P–M* | *P–M* | *P–M* | *M–G* | *P–M* | *P–M* |
| | ***Species richness* (not including stems)*** | *60* | *58* | *50* | *54* | *49* | *35* | *50* | *39* | *42* | *37* | *37* | *26* | *37* | *37* | *28* |
| 41 | *Eprolithus eptapetalus* | – | – | – | – | – | F | F | F | R | R | R | – | – | – | – |
| 42 | *Eprolithus floralis* | – | – | – | – | – | F | C | F | C | F | R | F | F | R | R |
| 43 | *Eprolithus octopetalus* | – | – | – | – | – | – | – | – | – | F | R | – | – | – | – |
| 44 | *Eprolithus rarus* | – | – | – | – | – | – | – | R | – | – | – | – | – | – | – |
| 45 | *Flabellites biforaminis* | – | – | – | – | – | – | – | R | – | – | – | – | – | – | – |
| 46 | *Gartnerago nanum* | – | – | – | – | – | – | – | – | – | – | – | – | – | R | – |
| 47 | *Gartnerago obliquum* | F | F | F | R | F | R | R | F | R | R | R | ?R | R | – | – |
| 48 | *Glaukolithus bicrescenticus* | F | F | – | R | R | F | F | – | F | R | R | – | – | – | – |
| 49 | *Glaukolithus diplogrammus* | – | – | – | – | R | F | R | R | – | F | F | R | F | R | F |
| 50 | *Gorkaea pseudanthophorus* | – | – | – | – | – | F | R | F | F | F | R | R | S | – | – |
| 51 | *Grantarhabdus coronadventis* | F | R | – | F | R | R | R | R | – | – | – | – | – | R | R |
| 52 | *Haquis circumradiatus* | – | – | S | – | S | S | – | – | – | S | – | – | – | – | – |
| 53 | *Harwoodites asserculatus* | – | S | – | – | – | – | – | – | – | – | – | – | – | – | – |
| 54 | *Helenea chiastia* | – | – | – | – | – | – | – | – | – | – | – | – | F | R | – |
| 55 | *Helicolithus* cf *compactus* (<6 μm) | – | – | – | – | – | – | F | R | F | R | R | R | – | R | – |
| 56 | *Helicolithus compactus* (≥6 μm) | – | – | – | – | – | – | – | – | F | R | S | – | – | – | – |
| 57 | *Helicolithus cuneatus* (≥6 μm) | – | R | – | – | R | – | – | – | – | – | – | – | – | – | – |
| 58 | *Helicolithus trabeculatus* (<6 μm) | R | – | R | – | R | – | R | – | – | – | S | – | – | – | – |
| 59 | *Kamptnerius magnificus* | F | F | F | F | R | – | – | – | – | – | – | – | – | – | – |
| 60 | *Kamptnerius sculptus* (with central cross) | – | – | – | – | – | R | F | R | – | – | – | – | – | – | – |
| 61 | *Kamptnerius tabulatus* (no flange) | – | – | – | – | – | – | – | R | – | – | – | – | – | – | – |
| 62 | *Lithastrinus grillii* | S | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| 63 | *Lithraphidites carniolensis* | F | F | F | F | F | – | F | – | F | – | R | R | R | R | R |
| 64 | *Loxolithus 'vagus'* | F | F | F | F | F | – | – | – | – | – | – | – | – | – | – |
| 65 | *Loxolithus armilla* | – | – | – | – | – | F | F | R | F | F | – | – | R | R | – |
| 66 | *Lucianorhabdus cayeuxii* | C | F | F | R | – | – | – | – | – | – | – | – | – | – | – |
| 67 | *Lucianorhabdus maleformis* | R | R | R | R | – | – | – | – | – | – | – | – | – | – | – |
| 68 | *Manivitella pemmatoidea* | R | R | R | R | R | R | R | F | R | – | – | – | F | F | F |
| 69 | *Marthasterites furcatus* | – | – | – | – | R | – | – | – | – | – | – | – | – | – | – |
| 70 | *Microrhabdulus belgicus* | R | – | F | R | R | – | R | – | – | R | – | – | – | – | – |
| 71 | *Microrhabdulus decoratus* | R | – | R | R | F | – | – | – | – | – | – | – | – | – | – |
| 72 | *Micula cubiformis* | R | – | F | R | R | – | – | – | – | – | – | – | – | – | – |
| 73 | *Micula decussata* | R | R | F | R | F | – | – | – | – | – | – | – | – | – | – |
| 74 | *Miravetesina ficula* | – | – | – | – | – | – | R | – | – | – | – | – | – | – | – |
| 75 | *Monomarginatus* sp. A | R | S | R | R | – | – | – | – | – | – | – | – | – | – | – |
| 76 | *Nannoconus elongatus* | – | – | – | – | – | – | S | – | – | – | – | – | – | – | – |
| 77 | *Octocyclus magnus* | – | – | – | – | – | – | – | – | S | – | – | – | – | – | – |
| 78 | *Percivalia marginata* | – | – | – | – | – | – | S | – | R | F | – | – | – | – | – |
| 79 | *Pickelhaube furtiva* | – | – | – | – | – | – | – | – | – | – | – | – | – | S | – |
| 80 | *Placozygus gemmoides* | – | – | S | – | – | – | – | – | – | – | – | – | – | – | – |

**Table 3.1.** (continued)

| | | 216.90 | 220.00 | 225.05 | 230.00 | 235.05 | 239.10 | 240.05 | 241.05 | 242.15 | 243.10 | 244.05 | 245.05 | 246.05 | 252.90 | 253.85 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ***Stratigraphic height (m)*** | *216.90* | *220.00* | *225.05* | *230.00* | *235.05* | *239.10* | *240.05* | *241.05* | *242.15* | *243.10* | *244.05* | *245.05* | *246.05* | *252.90* | *253.85* |
| | ***GSWA sample number*** | *177623* | *177626* | *177631* | *177636* | *177641* | *177645* | *177646* | *177647* | *177648* | *177649* | *177650* | *177651* | *177652* | *177659* | *177660* |
| | ***Nannofossil abundance*** | *H* | *H* | *H* | *H* | *H* | *M–H* | *M–H* | *H* | *H* | *M* | *M* | *H* | *H* | *L–M* | *M* |
| | ***Nannofossil preservation*** | *P* | *P–M* | *P–M* | *P–M* | *P–M* | *P* | *P–M* | *P–M* | *P–M* | *P–M* | *P–M* | *P–M* | *M–G* | *P–M* | *P–M* |
| | ***Species richness* (not including stems)*** | *60* | *58* | *50* | *54* | *49* | *35* | *50* | *39* | *42* | *37* | *37* | *26* | *37* | *37* | *28* |
| 81 | *Placozygus howei* | – | – | – | – | – | F | F | F | C | F | F | R | C | F | F |
| 82 | *Placozygus ponticulus* | R | R | – | R | R | – | R | – | R | – | – | R | – | – | – |
| 83 | *Placozygus praesigmoides* | F | F | – | R | R | – | – | – | – | – | – | – | – | – | – |
| 84 | *Placozygus primigenius* | – | R | – | R | – | – | – | – | – | – | – | – | – | – | – |
| 85 | *Placozygus spiralis* | R | R | – | R | – | – | – | – | R | – | – | – | – | – | – |
| 86 | *Placozygus xenotus* | – | – | – | – | – | – | – | R | – | – | – | – | – | – | – |
| 87 | *Prediscosphaera bukryi* | F | F | F | R | F | – | – | – | – | – | – | – | – | – | – |
| 88 | *Prediscosphaera columnata* | – | – | – | – | – | R | R | R | R | R | R | R | F | R | F |
| 89 | *Prediscosphaera cretacea* | C | C | C | C | C | F | C | F | F | F | R | F | F | – | – |
| 90 | *Prediscosphaera cretacea* type stem | F | F | F | F | F | F | F | R | F | R | R | R | R | – | – |
| 91 | *Prediscosphaera grandis* | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| 92 | *Prediscosphaera honjoi* | F | F | F | F | F | – | – | – | – | – | – | – | – | – | – |
| 93 | *Prediscosphaera spinosa* | F | F | F | F | F | R | F | R | R | – | – | – | R | – | – |
| 94 | *Quadrum eneabrachium* | – | – | – | – | S | S | – | – | – | – | S | R | – | – | – |
| 95 | *Quadrum eptabrachium* | – | – | – | – | – | – | S | – | – | S | – | – | – | – | – |
| 96 | *Quadrum intermedium* | – | – | – | – | – | R | R | – | S | – | – | – | – | – | – |
| 97 | *Radiolithus orbiculatus* | – | – | – | – | – | F | – | R | F | F | R | R | R | R | R |
| 98 | *Radiolithus planus* | – | – | – | – | – | – | – | R | – | R | – | – | R | R | – |
| 99 | *Reinhardites anthophorus* | F | F | F | F | F | R | F | R | R | – | – | – | – | – | – |
| 100 | *Reinhardites elegans* | C | C | F | F | F | – | – | – | – | – | – | – | – | – | – |
| 101 | *Repagulum parvidentatum* | – | – | – | – | – | – | – | – | – | – | – | – | – | R | R |
| 102 | *Retecapsa* spp. | C | C | C | C | C | – | C | F | – | C | F | C | F | F | F |
| 103 | *Rhagodiscus achlyostaurion* | – | – | – | – | – | – | – | – | – | – | – | – | R | – | – |
| 104 | *Rhagodiscus angustus* | – | R | – | – | – | – | R | R | R | R | R | – | R | – | S |
| 105 | *Rhagodiscus asper* | – | – | – | – | – | – | – | – | – | – | – | – | – | R | F |
| 106 | *Rotelapillus asymmetricus* | – | – | – | – | – | – | – | R | – | – | – | – | – | – | – |
| 107 | *Rotelapillus cancellus* | – | – | – | – | – | R | R | – | – | S | – | – | – | – | – |
| 108 | *Rotelapillus laffittei* | R | R | – | R | R | – | R | R | R | – | R | – | R | R | R |
| 109 | *Seribiscutum primitivum* | – | – | – | – | – | – | – | – | – | – | – | – | F | R | F |
| 110 | *Stoverius achylosus* | – | – | – | – | – | R | F | F | – | R | R | – | F | – | – |
| 111 | *Stoverius baldiae* | – | – | – | – | – | – | – | R | R | R | R | – | – | – | – |
| 112 | *Stoverius biarcus* | R | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| 113 | *Stoverius* gr. *coronatus* | R | R | F | R | R | – | – | – | – | – | – | – | – | – | – |
| 114 | *Tegumentum stradneri* | – | – | – | – | R | – | R | – | R | R | S | – | R | – | R |
| 115 | *Tetrapodorhabdus decorus* coccolith | R | R | R | R | – | – | R | – | R | – | – | R | – | – | S |
| 116 | *Tetrapodorhabdus decorus* type stem | – | – | – | – | – | – | R | – | R | – | R | – | S | R | – |
| 117 | *Tranolithus exiguus* | R | R | F | R | F | F | F | F | F | F | F | F | F | R | – |
| 118 | *Tranolithus gabalus* | R | – | – | – | – | – | R | S | R | R | R | S | R | – | – |
| 119 | *Tranolithus phacelosus* | F | F | F | F | F | R | R | – | – | – | – | – | – | – | – |
| 120 | *Tubodiscus* sp. | – | – | – | – | – | – | – | – | – | – | – | – | – | R | R |

**Table 3.1.** (continued)

| | | 216.90 | 220.00 | 225.05 | 230.00 | 235.05 | 239.10 | 240.05 | 241.05 | 242.15 | 243.10 | 244.05 | 245.05 | 246.05 | 252.90 | 253.85 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ***Stratigraphic height (m)*** | *216.90* | *220.00* | *225.05* | *230.00* | *235.05* | *239.10* | *240.05* | *241.05* | *242.15* | *243.10* | *244.05* | *245.05* | *246.05* | *252.90* | *253.85* |
| | ***GSWA sample number*** | *177623* | *177626* | *177631* | *177636* | *177641* | *177645* | *177646* | *177647* | *177648* | *177649* | *177650* | *177651* | *177652* | *177659* | *177660* |
| | ***Nannofossil abundance*** | *H* | *H* | *H* | *H* | *H* | *M–H* | *M–H* | *H* | *H* | *M* | *M* | *H* | *H* | *L–M* | *M* |
| | ***Nannofossil preservation*** | *P* | *P–M* | *P–M* | *P–M* | *P–M* | *P* | *P–M* | *P–M* | *P–M* | *P–M* | *P–M* | *P–M* | *M–G* | *P–M* | *P–M* |
| | ***Species richness* (not including stems)*** | *60* | *58* | *50* | *54* | *49* | *35* | *50* | *39* | *42* | *37* | *37* | *26* | *37* | *37* | *28* |
| 121 | *Vagalapilla angusta* | – | – | – | – | – | – | – | – | S | – | – | – | S | – | – |
| 122 | *Vagalapilla ara* | R | R | R | S | – | – | – | – | – | – | – | – | – | – | – |
| 123 | *Vagalapilla gausorhethium* | F | F | F | R | R | R | R | R | R | R | R | R | – | R | R |
| 124 | *Watznaueria barnesae* | C | C | C | A | C | C | C | A | C | C | C | C | C | C | C |
| 125 | *Watznaueria biporta* | – | R | R | R | – | R | – | R | – | – | R | R | – | R | – |
| 126 | *Watznaueria britannica* | – | – | – | – | – | – | – | – | – | – | – | – | – | R | – |
| 127 | *Watznaueria ovata* | R | – | R | R | R | R | R | R | – | – | – | R | R | R | R |
| 128 | *Zeugrhabdotus biperforatus* | R | F | F | R | F | – | – | – | – | – | – | – | – | – | – |
| 129 | *Zeugrhabdotus embergeri* | – | R | – | – | – | – | – | – | – | – | – | – | R | – | – |
| 130 | *Zeugrhabdotus fibulus* | – | – | – | – | – | – | – | – | – | – | – | – | – | – | S |
| 131 | *Zeugrhabdotus moulladei* | – | – | – | – | – | F | F | – | – | – | F | R | – | R | – |
| 132 | *Zeugrhabdotus scutula* | – | – | – | – | – | F | F | F | F | F | – | F | F | R | R |
| 133 | *Zeugrhabdotus* spp. indet. | F | F | F | F | F | F | F | F | F | F | F | F | F | F | F |

**NOTES:** * Species richness: total number of different species identified in a sample, not including stems or possible occurrences

Species abundances:
A: abundant (>10 specimens per field of view)
C: common (1–10 specimens per field of view)
F: few (2–10 specimens per 10 fields of view)
R: rare (1 specimen per 10 fields of view)
S: single specimen observed
?: possible occurrence
–: not present

Nannofossil abundance:
L: low
M: medium
H: high

Nannofossil preservation:
P: poor
M: medium
G: good

**Table 3.2. Summary of calcareous nannofossil biostratigraphy for Edaggee 1**

| *Stratigraphic height (m)* | *GSWA sample no.* | *Zones of Burnett (1998)* | *Zones of Sissingh (1997)* | *Stage* | *Nannofossil events* |
|---|---|---|---|---|---|
| 216.90 | 177623 | UC14a | CC18a | lower Lower Campanian | – |
| 220.00 | 177626 | UC14a | CC18a | lower Lower Campanian | LO *A. parcus parcus* |
| 225.05 | 177631 | upper UC12–13 | upper CC16–17 | Upper Santonian | – |
| 230.00 | 177636 | upper UC12–13 | upper CC16–17 | Upper Santonian | – |
| 235.05 | 177641 | upper UC12–13 | upper CC16–17 | Upper Santonian | LO *C. crassus, M. furcatus, Z. biperforatus* |
| 239.10 | 177645 | ~UC8 | ~CC12 | upper Middle – ?upper Turonian | HO *E. eptapetalus, M. ficula* |
| 240.05 | 177646 | ~UC8 | ~CC12 | upper Middle – ?upper Turonian | ?LO *E. eximius* |
| 241.05 | 177647 | ~upper UC7 | ~upper CC11 | lower Middle Turonian | LO/HO *E. rarus* |
| 242.15 | 177648 | ~upper UC7 | ~upper CC11 | lower Middle Turonian | – |
| 243.10 | 177649 | UC6b – ~lower UC7 | ~upper CC10b – ~mid-CC11 | Lower Turonian | HO *E. octopetalus* |
| 244.05 | 177650 | UC6b – ~lower UC7 | ~upper CC10b – ~mid-CC11 | Lower Turonian | LO *A. octoradiata, E. eptapetalus, E. octopetalus* |
| 245.05 | 177651 | UC6a | ~lower CC10b | Lowermost Turonian | – |
| 246.05 | 177652 | UC3d–5a | ~mid-CC10a | Middle – Upper Cenomanian | HO *A. biramiculatus, H. chiastia* |
| 252.90 | 177659 | UC1–3c | ~lower CC10a | upper Lower–Middle Cenomanian | HO/LO *G. nanum, E. turriseiffellii* |
| 253.85 | 177660 | – | CC8a | Lower Albian | – |

**NOTE:** HO: highest occurrence
LO: lowest occurrence
na: not applicable
–: not LO/HO of zone-defining nannofossil

**Table 3.3. Alphabetical list of nannofossil species cited from Edaggee 1**

| Species |
|---|
| *Ahmuellerella octoradiata* (Gorka 1957) Reinhardt 1966 |
| *Ahmuellerella plebius (*Perch-Nielsen 1968) |
| *Amphizygus brooksii brooksii* Bukry 1969 |
| *Amphizygus brooksii nanus* Bukry 1969 |
| *Arkhangelskiella cymbiformis* Vekshina 1959 var. NT Varol 1989 |
| *Aspidolithus enormis* (Shumenko 1968) Rio and Villa 1983 |
| *Aspidolithus parcus* (Stradner 1963) Nöel 1969 *expansus* Wise and Watkins *in* Wise (1983) |
| *Aspidolithus parcus* (Stradner 1963) Nöel 1969 *parcus* (Stradner 1963) |
| *Axopodorhabdus biramiculatus (=A. albianus* of many authors) Stover 1966 |
| *Bidiscus rotatorius* Bukry 1969 |
| *Biscutum constans* (Gorka 1957) Black *in* Black and Barnes (1959) |
| *Biscutum* sp. 1 |
| *Broinsonia matalosa* (Stover 1966) Burnett *in* Gale et al. (1996) |
| *Broinsonia signata* (Nöel 1969) Nöel 1970 |
| *Broinsonia* sp. 1 |
| *Broinsonia stenostaurion* (Hill 1976) |
| *Bukrylithus ambiguus* Black 1971 |
| *Calculites obscurus* (Deflandré 1959) Prins and Sissingh *in* Sissingh (1977) |
| *Calculites ovalis* (Stradner 1963) Prins and Sissingh *in* Sissingh (1977) |
| *Ceratolithina cruxii* Perch-Nielsen 1988 *capitanea* Burnett 1997 |
| *Ceratolithina cruxii* Perch-Nielsen 1988 *cruxii* Perch-Nielsen 1988 |
| *Chiastozygus amphipons* (Bramlette and Martini 1964) Gartner 1968 |
| *Chiastozygus garrissonii* Bukry 1969 |
| *Chiastozygus platyrhethum* Hill 1976 |
| *Corollithion acutum* Thierstein *in* Roth and Thierstein (1972) |
| *Corollithion madagaskarensis* Perch-Nielsen 1973 |
| *Corollithion signum* Stradner 1963 |
| *Cretarhabdus conicus* Bramlette and Martini 1964 |
| *Cretarhabdus loriei* Gartner 1968 |
| *Cribrosphaerella ehrenbergii* (Arkhangelsky 1912) Deflandré *in* Piveteau (1952) |
| *Cribrosphaerella romanica* Reinhardt 1964 |
| *Crucicribrum anglicum* Black 1973 |
| *Cylindralithus crassus* Stover 1966 |
| *Cylindralithus nudus* Bukry 1969 |
| *Discolithus ponticulus* Deflandré *in* Deflandré and Fert (1954) |
| *Eiffellithus* cf *eximius* (bars ~15–20° off major axes) |
| *Eiffellithus eximius* (bars <15° off major axes) (Stover 1966) Perch-Nielsen 1968 |
| *Eiffellithus gorkae* Reinhardt 1965 |
| *Eiffellithus paragogus (=Bownia glabra* or *Vagallapilla matalosa* of many authors) Gartner 1993 |
| *Eiffellithus* sp. 1 |
| *Eiffellithus turriseiffellii* (Deflandré *in* Deflandré and Fert, 1954) Reinhardt 1965 |
| *Eprolithus eptapetalus* Varol 1992 |
| *Eprolithus floralis* (Stradner 1962) Stover 1966 |
| *Eprolithus octopetalus* Varol 1992 |
| *Eprolithus rarus* Varol 1992 |
| *Flabellites biforaminis* Thierstein 1973 |
| *Gartnerago nanum* Thierstein 1974 |
| *Gartnerago obliquum* (Stradner 1963) Nöel 1970 |
| *Gorkaea pseudanthophorus* (Bramlette and Martini 1964) Varol and Girgis 1994 |
| *Grantarhabdus coronadventis* (Reinhardt 1966) Grün *in* Grün and Allemann (1975) |
| *Haquis circumradiatus* (Stover 1966) Roth 1978 |
| *Helenea chiastia* Worsley 1971 |
| *Helicolithus* cf *compactus* (<6 µm) (Bukry 1969) Varol and Girgis 1994 |
| *Helicolithus compactus* (=6 µm) (Bukry 1969) Varol and Girgis 1994 |
| *Helicolithus trabeculatus* (large =6 µm) (Gorka 1957) Verbeek 1977 |
| *Helicolithus trabeculatus* (small <6 µm) (Gorka 1957) Verbeek 1977 |
| *Kamptnerius magnificus* Deflandré 1959 |
| *Kamptnerius sculptus* (with central cross) Bukry 1969 |
| *Kamptnerius tabulatus* (no flange) Perch-Nielsen 1968 |
| *Lithastrinus grillii* Stradner 1962 |
| *Lithraphidites carniolensis* Deflandré 1963 |
| *Loxolithus armilla* (Black *in* Black and Barnes 1959) Nöel 1965 |
| *Loxolithus* sp. 1 |
| *Lucianorhabdus cayeuxii* Deflandré 1959 |
| *Lucianorhabdus maleformis* Reinhardt 1966 |
| *Manivitella pemmatoidea* (Deflandré *in* Manivit 1965) Thierstein 1971 |
| *Marthasterites furcatus* (Deflandré *in* Deflandré and Fert 1954) Deflandré 1959 |
| *Microrhabdulus belgicus* Haye and Towe 1963 |
| *Microrhabdulus decoratus* Deflandré 1959 |
| *Micula cubiformis* Forchheimer 1972 |
| *Micula decussata* Vekshina 1959 |
| *Miravetesina ficula* (Stover 1966) Bergen *in* Bralower and Bergen (1998) |
| *Monomarginatus* sp. A |
| *'Nannoconus'* sp. 1 |
| *Octocyclus magnus* Black 1972 |
| *Percivalia* sp. 1 |
| *Pickelhaube furtiva* (Roth 1983) Applegate et al. *in* Covington and Wise (1987) |
| *Placozygus* sp. 1 |
| *Placozygus* sp. 2 |
| *Placozygus spiralis* (Bramlette and Martini 1964) Hoffman 1970 |
| *Prediscosphaera bukryi* Perch-Nielsen 1973 |
| *Prediscosphaera columnata* (Stover 1966) Perch-Nielsen 1984 |
| *Prediscosphaera cretacea* (Arkhangelsky 1912) Gartner 1968 |
| *Prediscosphaera grandis* Perch-Nielsen 1979 |
| *Prediscosphaera honjoi* Bukry 1969 |
| *Prediscosphaera spinosa* (Bramlette and Martini 1964) Gartner 1968 |
| *Quadrum eneabrachium* Varol 1992 |
| *Quadrum eptabrachium* Varol 1992 |
| *Quadrum intermedium* Varol 1992 |
| *Radiolithus orbiculatus* (Forchheimer 1972) Varol 1992 |
| *Radiolithus planus* Stover 1966 |
| *Reinhardites anthophorus* (Deflandré 1959) Perch-Nielsen 1968 |
| *Reinhardites elegans* (Gartner 1968) Wise 1983 |
| *Reinhardtites scutula* Bergen 1994 |
| *Repagulum parvidentatum* (Deflandré and Fert 1954) Forchheimer 1972 |
| *Retecapsa* spp. |
| *Rhagodiscus achlyostaurion* Hill 1976 |
| *Rhagodiscus angustus* (Stradner 1963) Reinhardt 1971 |
| *Rhagodiscus asper* (Stradner 1963) Reinhardt 1967 |
| *Rotelapillus laffittei* (Nöel 1957) Howe *in* Howe et al. (2000) |
| *Rotelapillus* sp. 1 |
| *Seribiscutum primitivum* (Thierstein 1974) Filewicz et al. *in* Wise and Wind (1977) |
| *Stoverius achylosus* (Stover 1966) Perch-Nielsen 1986 |
| *Stoverius asymmetricus* (Bukry 1969) Perch-Nielsen 1984 |
| *Stoverius baldiae* (Stradner and Adamiker 1966) Perch-Nielsen 1984 |
| *Stoverius biarcus* (Bukry 1969) Perch-Nielsen 1984 |
| *Stoverius* gr. *coronatus* (Bukry 1969) Perch-Nielsen 1984 |
| *Tegumentum stradneri* Thierstein *in* Roth and Thierstein (1972) |
| *Tetrapodorhabdus decorus* (Deflandré *in* Deflandré and Fert 1954) Wind and Wise *in* Wise and Wind (1977) |
| *Tranolithus exiguus* Stover 1966 |
| *Tranolithus gabalus* Stover 1966 |
| *Tranolithus minimus* (Bukry 1969) Perch-Nielsen 1984 |
| *Tranolithus phacelosus* Stover 1966 |
| *Tubodiscus* sp. 1 |
| *Vagalapilla angusta* (Stover 1966) Roth 1981 |
| *Vagalapilla ara* (Gartner 1968) Bukry 1969 |
| *Vagalapilla gausorhethium* Hill 1976 |
| *Watznaueria barnesae* (Black *in* Black and Barnes 1959) Perch-Nielsen 1968 |
| *Watznaueria biporta* Bukry 1969 |
| *Watznaueria Britannica* (Stradner 1963) Reinhardt 1964 |
| *Watznaueria ovata* Bukry 1969 |
| *Zeugrhabdotus bicrescenticus* (Stover 1966) Burnett *in* Gale et al. (1996) |
| *Zeugrhabdotus biperforatus* (Gartner 1968) Burnett 1998 |
| *Zeugrhabdotus diplogrammus* (Deflandré *in* Deflandré and Fert 1954) Burnett *in* Gale et al. (1996) |
| *Zeugrhabdotus embergeri* (Nöel 1958) Perch-Nielsen 1984 |
| *Zeugrhabdotus howei* Bown *in* Kennedy et al. (2000) |
| *Zeugrhabdotus moulladei* Bergen *in* Bergen and Bralower (1998) |
| *Zeugrhabdotus praesigmoides* Burnett 1998 |
| *Zeugrhabdotus* spp. indet. |
| *Zeugrhabdotus xenotus* (Stover 1966) Burnett *in* Gale et al. (1996) |
| *Zygolithus fibulus* (Lecal-Schlauder 1951) Gorka 1957 |

**NOTE**: References not cited here can be found in Perch-Nielsen (1985) and Bown (1998)

### 243.1 – 244.05 m, UC6b to ~lower UC7, ~upper CC10b to ~mid-CC11 Subzones

This interval has nannofossil assemblages with moderate abundance and poor to moderate preservation. Diversity is moderate, with 37 species present in both samples from the interval. The interval belongs to the UC6b to ~lower UC7 Subzones and ~upper CC10b to ~mid-CC11 Subzones, based on the presence of *E. octopetalus,* the HO of which is within the UC7 and CC11 Zones, and *E. eptapetalus* (*E. moratus* (Stover 1966) of many authors), the LO of which marks the base of the UC6b Subzone, and which lies within the CC10b Subzone.

### 245.05 m, UC6a, ~lower CC10b Subzones

This sample has a nannofossil assemblage with high abundances and poor to moderate preservation. Diversity is low, with 26 species present. The sample belongs to the UC6a and ~lower CC10b Subzones, based on the absence of *E. eptapetalus*, the LO of which marks the base of the UC6b Subzone, and the absence of *Helenea chiastia,* the HO of which marks the top of the UC5 Zone and the CC10a Subzone.

### 246.05 m, UC3d–5a, ~mid-CC10a Subzones

This sample has a nannofossil assemblage with a high abundance and moderate to good preservation. Diversity is moderate, with 37 species present. The sample belongs to the UC3d–5a and ~mid-CC10a Subzones, based on: the presence of *Axopodorhabdus biramiculatus* (*A. albianus* (Black 1967) of many authors)*,* the HO of which marks the top of the UC5a Subzone, and which is present within the CC10a Subzone; and the absence of *Gartnerago nanum,* the HO of which marks the top of the UC3c Subzone, and which lies within the CC10a Subzone, below the HO of *A. biramiculatus.*

### 252.90 m, UC1–3c, CC9c – ~lower CC10a Subzones

This sample has a nannofossil assemblage with a low to moderate abundance and poor to moderate preservation. Diversity is moderate, with 37 species present. The sample belongs to the UC1–3c and CC9c to ~lower 10a Subzones, based on the presence of *Eiffellithus turriseiffellii,* the LO of which marks the base of the UC0 and CC9 Zones, and *G. nanum,* the LO of which is very close to the LO of *Corollithion kennedyi* (Crux 1981)*,* which marks the base of the UC1 Zone and the CC9c Subzone. The HO of *G. nanum* marks the top of the UC3c Subzone, and is within the middle part of the CC10a Subzone.

### 253.85 m, CC8a Subzone

This sample has a nannofossil assemblage with a moderate abundance, and poor to moderate preservation. Diversity is low, with 28 species present. The sample belongs to Subzone CC8a, which is marked by the presence of *Prediscosphaera columnata*, the LO of which marks the base of Subzone CC8a, in the absence of *Tranolithus phacelosus,* the HO of which marks the base of Subzone CC8b.

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## Appendix 4

# Petroleum geochemistry

by

K. A. R. Ghori

## Introduction

The hydrocarbon-generating potential and thermal maturity of the succession in Edaggee 1 (TD 351 m) was evaluated from 12 core samples and two cuttings samples. Of these, two are from the Lower Devonian section and 12 from the Cretaceous (Table 4.1). Core samples were selected from likely source-rock lithologies (fine-grained intervals of light to dark grey). One cuttings sample was analysed to determine if any mud-additive contaminants were used that might affect the results. Figure 4.1 summarizes the hydrocarbon-generating potential, kerogen type, and thermal maturity in Edaggee 1.

Total organic carbon (TOC), Rock-Eval pyrolysis, pyrolysis-gas chromatography (PGC), and gas chromatography and mass spectrometry (GC-MS) were undertaken to characterize source-rock potential, whereas organic petrology and the Rock-Eval parameter $T_{max}$ indicate the level of thermal maturity. Geotechnical Services Pty Ltd (Geotech) carried out the TOC and Rock-Eval pyrolysis analyses and Keiraville Konsultants Pty Ltd did the organic petrology. The number and type of geochemical analyses carried out are summarized in Table 4.2.

## Source rock potential

Hydrocarbon-generating potential is quantified from TOC content (a measure of organic richness) and potential yield ($S_1$+$S_2$) from Rock-Eval pyrolysis. The two samples from the Lower Devonian Sweeney Mia Formation are organically lean, with a TOC of 0.09 and 0.12%, and were not analysed further for source potential. All Cretaceous samples are organic rich with a TOC range of 0.59 – 26.8%. Their potential yields are 1.11 – 55.00 mg/g rock, except for the sample from 249.0 m in the 'upper Gearle Siltstone', which is low in both organic richness (0.62% TOC) and potential yield (0.17 mg/g rock; Table 4.3). The analytical results show that samples from the Sweeney Mia Formation cannot be considered source rocks. Of the Cretaceous samples, the organically richest are from the Haycock Marl, with TOC values of 11.4 – 26.8%, and potential yield of 37.83 – 55.00 mg/g rock. One sample from the Muderong Shale has good organic richness and hydrocarbon-generating potential. All other Cretaceous samples are organic rich with fair hydrocarbon-generating potential (Table 4.3, Fig. 4.2).

## Source-rock type

Pyrolysis-gas chromatography was used to supplement Rock-Eval pyrolysis to determine the type of kerogen present.

**Rock-Eval pyrolysis:** A plot of the Rock-Eval parameters, hydrogen index (HI) versus $T_{max}$, indicate that the kerogen present in samples with good to excellent hydrocarbon-generating potential is oil- and gas-generating type II. By comparison, samples with only fair

**Table 4.1. Core and cuttings samples selected for geochemical analyses from Edaggee 1**

| *Depth (m)* | *GSWA No.* | *Formation* | *Lithology* | *Age* |
|---|---|---|---|---|
| 69* | 176805 | Toolonga Calcilutite | claystone | early–middle Campanian |
| 197–200 | 175286 | Toolonga Calcilutite | claystone | early–middle Campanian |
| 239.05 | 172706 | Toolonga Calcilutite | dark-grey claystone | Coniacian–Santonian |
| 245.30 | 172707 | Haycock Marl | black claystone | Turonian |
| 249.00 | 172708 | upper Gearle Siltstone | light-grey claystone | Cenomanian |
| 256.00 | 172709 | lower Gearle Siltstone | dark-grey claystone | early–middle Albian |
| 262.05 | 172710 | lower Gearle Siltstone | dark-grey claystone | early–middle Albian |
| 271.20 | 172711 | Windalia Radiolarite | dark-grey mudstone | late Aptian |
| 274.20 | 172712 | Windalia Radiolarite | grey claystone | late Aptian |
| 301.10 | 172713 | Muderong Shale | grey claystone | early Aptian |
| 308.10 | 172714 | Muderong Shale | grey claystone | early Aptian |
| 321.85 | 176802 | Sweeney Mia Fm | silty claystone | early Devonian |
| 345.80 | 176803 | Sweeney Mia Fm | light-grey claystone | early Devonian |

**NOTES**: * sample recovered from clore bit

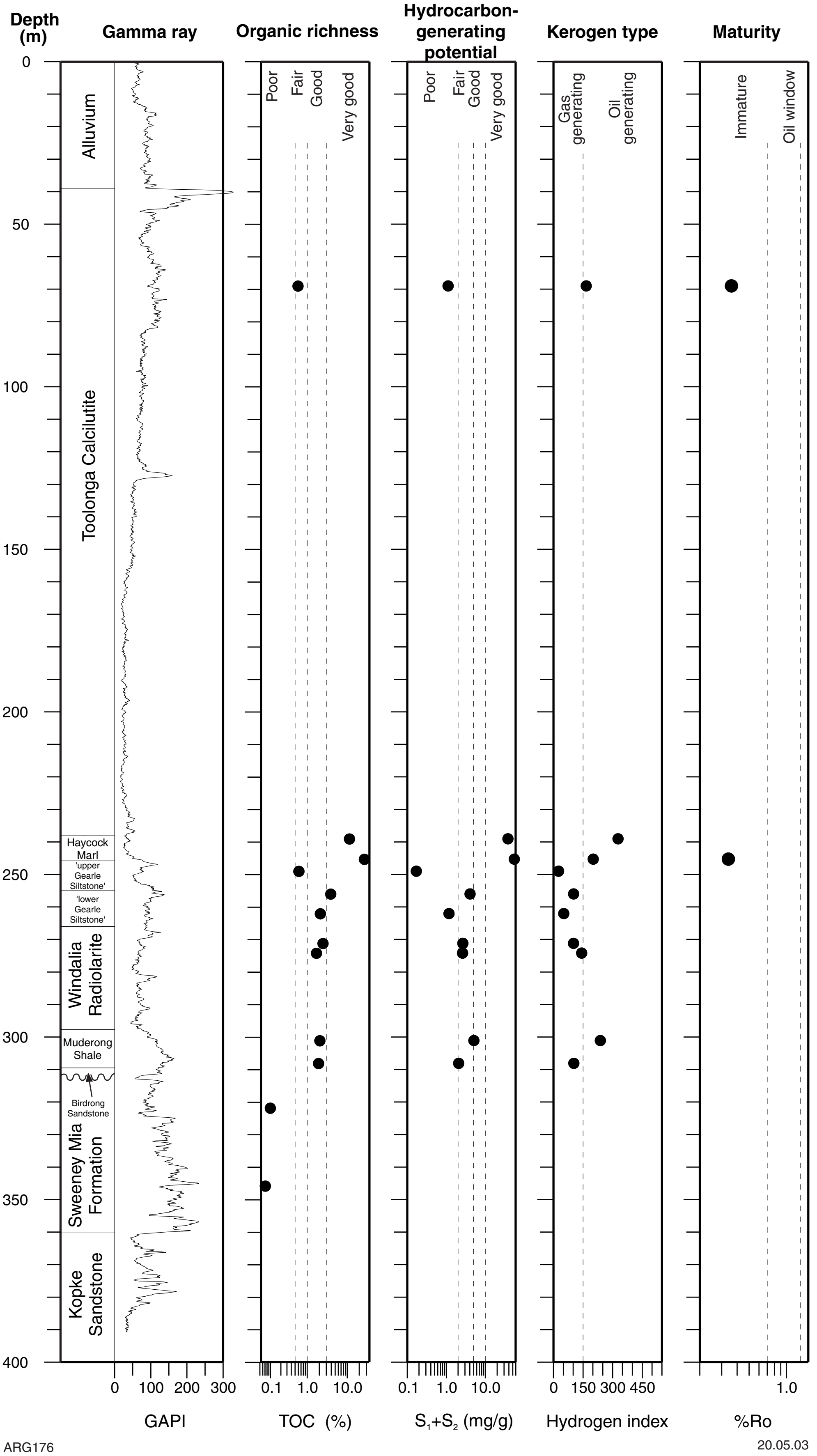



**Figure 4.1. Hydrocarbon source-rock generating potential, kerogen type, and thermal maturity, Edaggee 1**

**Table 4.2. Geochemical analyses carried out on core and cuttings samples from Edaggee 1**

| *Analysis type* | *Samples* | *Purpose* | *Analyst* |
|---|---|---|---|
| Total organic carbon (TOC) | 12 | source potential | Geotech |
| Rock-Eval pyrolysis | 11 | source potential | Geotech |
| Pyrolysis-gas chromatography | 4 | source potential | Geotech |
| Gas chromatography/mass spectrometry | 1 | source potential | Geotech |
| Whole extract GC-MS (mud additives) | 1 | contaminants | Geotech |
| Organic petrology | 3 | source maturity | Keiraville Konsultants |

hydrocarbon-generating potential contain predominantly gas-generating type-III kerogen (Fig. 4.3).

**Pyrolysis-gas chromatography:** Four Cretaceous core samples were analysed by PGC (Fig. 4.4) to confirm the quality of the kerogen because it provides a more accurate guide to the oil- versus gas-generating potential of kerogen than Rock-Eval pyrolysis. These samples include one from the Muderong Shale (301.1 m), one from the Windalia Radiolarite (271.2 m), and two from the Haycock Marl (239.05 and 245.3 m). Tables 4.4 – 4.6 list basic analytical data, alkene and alkane components, and selected PGC parameters, respectively. Oil proneness ($C_5$ to $C_{31}$ alkanes + alkenes) versus the gas–oil generation index (GOGI; $(C_1–C_5)/C_{6+}$) indicates that the organically richest sample from the Haycock Marl (245.3 m) contains predominantly gas-generating kerogen (Fig. 4.5). For the same sample, Rock-Eval pyrolysis data indicate that it contains oil- and gas-generating kerogen (Fig. 4.3). The other three samples contain oil- and gas-generating kerogen (Fig. 4.5), consistent with Rock-Eval pyrolysis data.

**Extract analysis:** A core sample from 245.3 m (Haycock Marl) was extracted and analysed for saturated

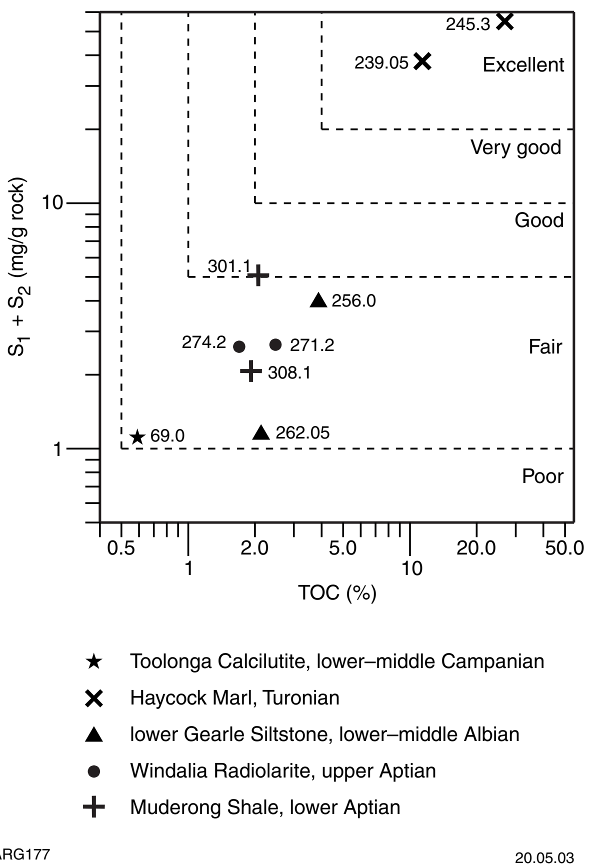



**Figure 4.2. Hydrocarbon-generating potential of nine core samples from Edaggee 1**

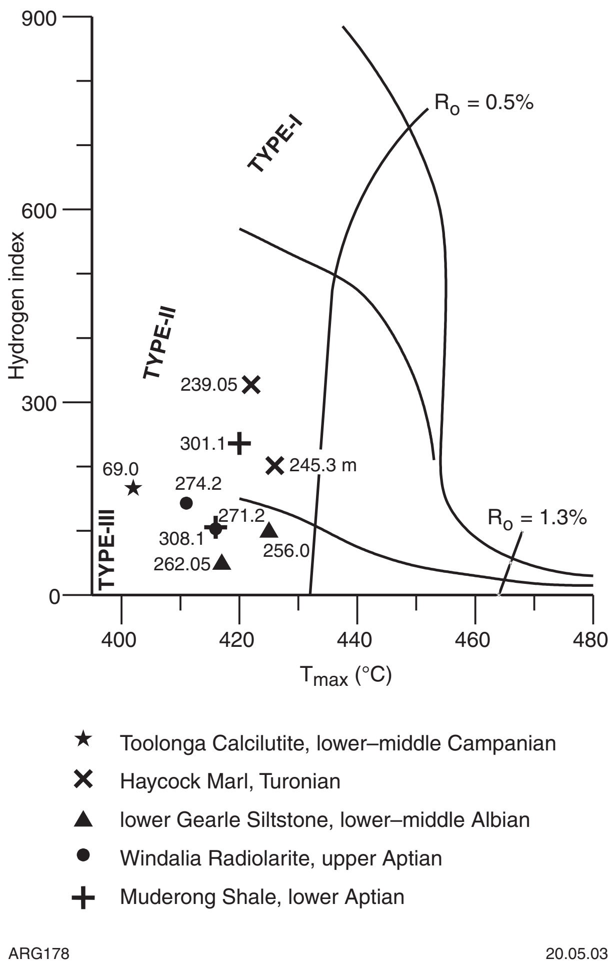



**Figure 4.3. Kerogen typing by Rock-Eval pyrolysis of nine core samples from Edaggee 1**

**Table 4.3. TOC and Rock-Eval pyrolysis data of core and cuttings samples from Edaggee 1**

| *Depth (m)* | *Sample type* | *TOC (%)* | $T_{max}$ (°C) | $S_1$ | $S_2$ | $S_3$ | $S_1+S_2$ | $S_2/S_3$ | *PI* | *HI* | *OI* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (mg/g rock) | | | | | | | |
| 69* | cuttings | 0.59 | 402 | 0.13 | 0.98 | 0.50 | 1.11 | 1.96 | 0.12 | 166 | 85 |
| 197–200 | cuttings | nd | 398 | 0.14 | 0.26 | 2.94 | 0.40 | 0.09 | 0.35 | nd | nd |
| 239.05 | core | 11.38 | 422 | 0.58 | 37.25 | 8.23 | 37.83 | 4.53 | 0.02 | 327 | 72 |
| 245.30 | core | 26.80 | 426 | 1.00 | 54.00 | 9.50 | 55.00 | 5.68 | 0.02 | 201 | 35 |
| 249.00 | core | 0.62 | nd | 0.01 | 0.16 | 0.91 | 0.17 | 0.18 | 0.06 | 26 | 147 |
| 256.00 | core | 3.87 | 425 | 0.10 | 3.95 | 1.74 | 4.05 | 2.27 | 0.02 | 102 | 45 |
| 262.05 | core | 2.13 | 417 | 0.06 | 1.11 | 1.03 | 1.17 | 1.08 | 0.05 | 52 | 48 |
| 271.20 | core | 2.48 | 416 | 0.13 | 2.52 | 1.13 | 2.65 | 2.23 | 0.05 | 102 | 46 |
| 274.20 | core | 1.70 | 411 | 0.17 | 2.43 | 0.57 | 2.60 | 4.26 | 0.07 | 143 | 34 |
| 301.10 | core | 2.07 | 420 | 0.16 | 4.92 | 0.69 | 5.08 | 7.13 | 0.03 | 238 | 33 |
| 308.10 | core | 1.92 | 416 | 0.09 | 1.98 | 0.74 | 2.07 | 2.68 | 0.04 | 103 | 39 |
| 321.85 | core | 0.12 | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| 345.80 | core | 0.09 | nd | nd | nd | nd | nd | nd | nd | nd | nd |

**NOTES**:
* sample recovered from clore bit
HI: hydrogen index
nd: not determined
OI: oxygen index
PI: production index
T: temperature of maximum pyrolytic yield ($S_2$)
TOC: total organic carbon
$S_1$: existing hydrocarbons (HC)
$S_2$: pyrolytic yield (HC)
$S_3$: organic carbon dioxide
$S_1+S_2$: potential yield

**Table 4.4. Basic analytical data from pyrolysis-gas chromatography of core samples from Edaggee 1**

| *Compound* | *Sample (m) 239.05* | *245.30* | *271.20* | *301.10* | *Compound* | *Sample (m) 239.05* | *245.30* | *271.20* | *301.10* |
|---|---|---|---|---|---|---|---|---|---|
| $C_5$ *n-alkene* | 1.46 | 0.67 | 1.53 | 1.41 | $C_{22}$ *n-alkane* | 0.06 | 0.04 | 0.05 | 0.05 |
| $C_5$ *n-alkane* | 0.60 | 0.61 | 1.07 | 1.41 | $C_{23}$ *n-alkene* | 0.05 | 0.03 | 0.00 | 0.00 |
| $C_6$ *n-alkene* | 0.95 | 0.67 | 1.29 | 1.51 | $C_{23}$ *n-alkane* | 0.05 | 0.04 | 0.03 | 0.04 |
| $C_6$ *n-alkane* | 0.52 | 0.37 | 0.63 | 0.80 | $C_{24}$ *n-alkene* | 0.04 | 0.02 | 0.00 | 0.00 |
| $C_7$ *n-alkene* | 0.61 | 0.34 | 0.87 | 0.92 | $C_{24}$ *n-alkane* | 0.04 | 0.03 | 0.02 | 0.02 |
| $C_7$ *n-alkane* | 0.54 | 0.35 | 0.90 | 1.13 | $C_{25}$ *n-alkene* | 0.02 | 0.01 | 0.00 | 0.00 |
| $C_8$ *n-alkene* | 0.45 | 0.36 | 0.54 | 0.55 | $C_{25}$ *n-alkane* | 0.03 | 0.02 | 0.01 | 0.01 |
| $C_8$ *n-alkane* | 0.34 | 0.26 | 0.51 | 0.59 | $C_{26}$ *n-alkene* | 0.00 | 0.01 | 0.00 | 0.00 |
| $C_9$ *n-alkene* | 0.40 | 0.27 | 0.41 | 0.40 | $C_{26}$ *n-alkane* | 0.00 | 0.02 | 0.01 | 0.01 |
| $C_9$ *n-alkane* | 0.28 | 0.21 | 0.31 | 0.33 | $C_{27}$ *n-alkene* | 0.00 | 0.01 | 0.00 | 0.00 |
| $C_{10}$ *n-alkene* | 0.28 | 0.18 | 0.36 | 0.30 | $C_{27}$ *n-alkane* | 0.00 | 0.01 | 0.00 | 0.00 |
| $C_{10}$ *n-alkane* | 0.29 | 0.23 | 0.25 | 0.23 | $C_{28}$ *n-alkene* | 0.00 | 0.00 | 0.00 | 0.00 |
| $C_{11}$ *n-alkene* | 0.38 | 0.26 | 0.47 | 0.49 | $C_{28}$ *n-alkane* | 0.00 | 0.00 | 0.00 | 0.00 |
| $C_{11}$ *n-alkane* | 0.25 | 0.23 | 0.23 | 0.35 | $C_{29}$ *n-alkene* | 0.00 | 0.00 | 0.00 | 0.00 |
| $C_{12}$ *n-alkene* | 0.26 | 0.20 | 0.27 | 0.26 | $C_{29}$ *n-alkane* | 0.00 | 0.00 | 0.00 | 0.00 |
| $C_{12}$ *n-alkane* | 0.18 | 0.15 | 0.22 | 0.23 | $C_{30}$ *n-alkene* | 0.00 | 0.00 | 0.00 | 0.00 |
| $C_{13}$ *n-alkene* | 0.21 | 0.15 | 0.33 | 0.36 | $C_{30}$ *n-alkane* | 0.00 | 0.00 | 0.00 | 0.00 |
| $C_{13}$ *n-alkane* | 0.23 | 0.21 | 0.24 | 0.32 | $C_{31}$ *n-alkene* | 0.00 | 0.00 | 0.00 | 0.00 |
| $C_{14}$ *n-alkene* | 0.20 | 0.14 | 0.20 | 0.18 | $C_{31}$ *n-alkane* | 0.00 | 0.00 | 0.00 | 0.00 |
| $C_{14}$ *n-alkane* | 0.28 | 0.19 | 0.36 | 0.41 | $C_1$–$C_4$ | 36.36 | 52.68 | 32.35 | 21.21 |
| $C_{15}$ *n-alkene* | 0.19 | 0.11 | 0.17 | 0.00 | $C_5$ | 4.36 | 2.15 | 6.35 | 6.75 |
| $C_{15}$ *n-alkane* | 0.24 | 0.15 | 0.21 | 0.29 | $C_6$–$C_8$ | 18.06 | 12.38 | 21.13 | 22.63 |
| $C_{16}$ *n-alkene* | 0.14 | 0.08 | 0.13 | 0.00 | $C_9$–$C_{14}$ | 24.40 | 16.17 | 26.12 | 34.05 |
| $C_{16}$ *n-alkane* | 0.16 | 0.11 | 0.17 | 0.21 | $C_{15}$–$C_{31}$ | 16.82 | 16.62 | 14.05 | 15.36 |
| $C_{17}$ *n-alkene* | 0.15 | 0.09 | 0.05 | 0.00 | *Benzene* | 0.37 | 0.17 | 0.85 | 0.54 |
| $C_{17}$ *n-alkane* | 0.14 | 0.09 | 0.16 | 0.13 | *Toluene* | 0.89 | 0.57 | 1.59 | 1.46 |
| $C_{18}$ *n-alkene* | 0.11 | 0.06 | 0.07 | 0.00 | *Ethylbenzene* | 0.39 | 0.30 | 0.69 | 0.85 |
| $C_{18}$ *n-alkane* | 0.10 | 0.06 | 0.12 | 0.13 | *m- + p-xylene* | 0.95 | 0.68 | 1.12 | 1.47 |
| $C_{19}$ *n-alkene* | 0.10 | 0.07 | 0.03 | 0.00 | *Styrene* | 0.162 | 0.083 | 0.153 | 0.328 |
| $C_{19}$ *n-alkane* | 0.09 | 0.06 | 0.11 | 0.15 | *o-xylene* | 0.416 | 0.267 | 0.672 | 0.685 |
| $C_{20}$ *n-alkene* | 0.08 | 0.05 | 0.03 | 0.00 | *Phenol* | 0.394 | 0.273 | 0.581 | 0.689 |
| $C_{20}$ *n-alkane* | 0.07 | 0.06 | 0.09 | 0.09 | *o-cresol* | 0.000 | 0.000 | 0.000 | 0.000 |
| $C_{21}$ *n-alkene* | 0.09 | 0.04 | 0.00 | 0.00 | *m- + p-cresol* | 0.000 | 0.000 | 0.000 | 0.000 |
| $C_{21}$ *n-alkane* | 0.07 | 0.05 | 0.06 | 0.06 | *C2 phenol* | 0.000 | 0.000 | 0.000 | 0.000 |
| $C_{22}$ *n-alkene* | 0.07 | 0.04 | 0.00 | 0.00 | *C2 phenol* | 0.000 | 0.000 | 0.000 | 0.000 |

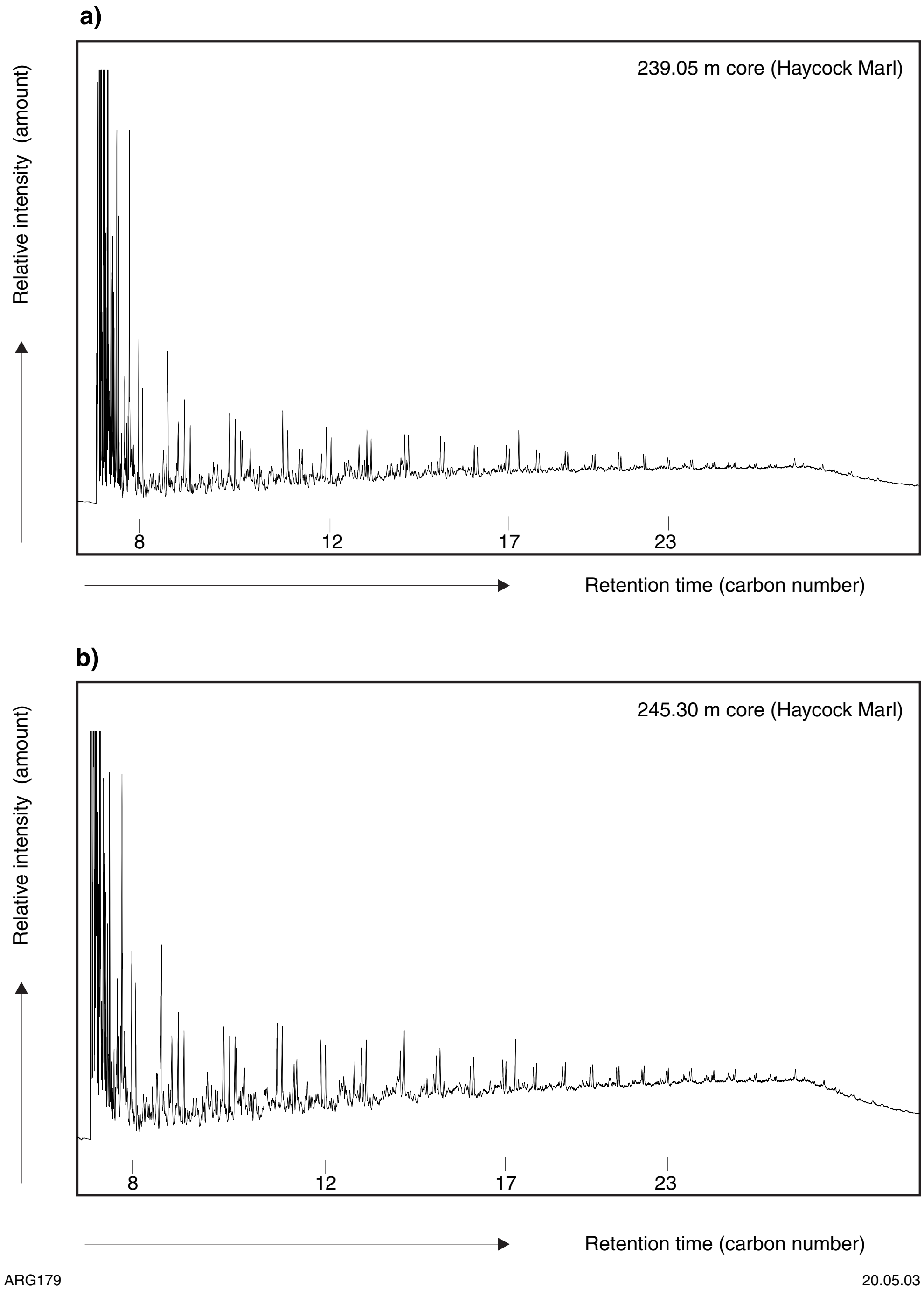
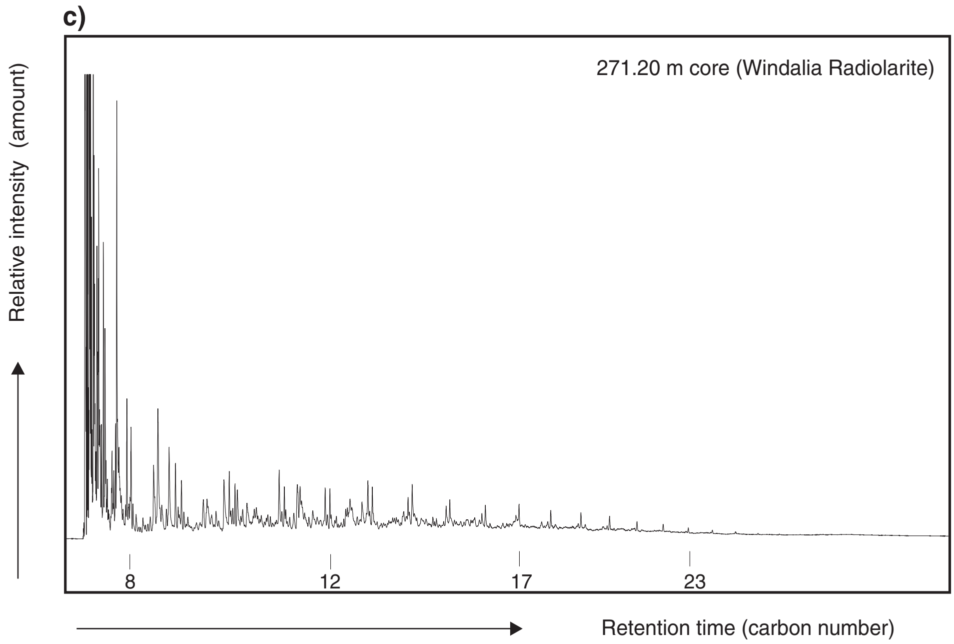



**Figure 4.4. Gas chromatograms from pyrolysis-gas chromatography of four core samples from Edaggee 1: a) 239.05 m and b) 245.3 m from the Haycock Marl; c) 271.2 m from the Windalia Radiolarite; d) 301.1 m from the Muderong Shale**



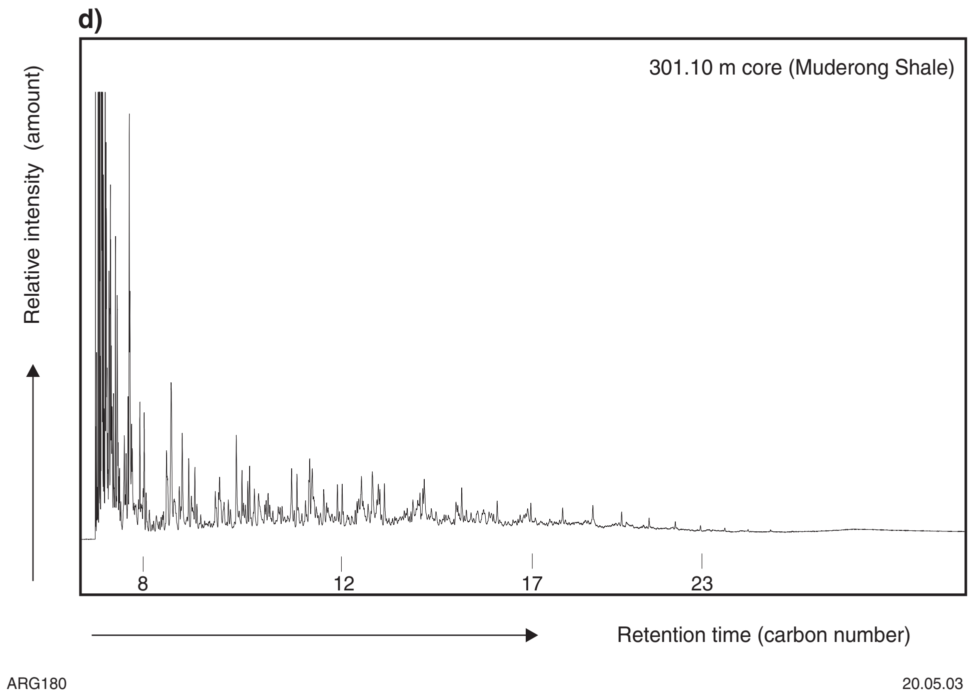




**Figure 4.4.** (continued)

**Table 4.5. Alkene and alkane components from pyrolysis-gas chromatography of core samples from Edaggee 1**

| *Depth* | *Carbon* | *Alkane* | *+* | *Alkene* | | *Alkane* | | | *Alkene* | | *Alkane/* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *(m)* | *number* | *A* | *B* | *C* | *A* | *B* | *C* | *A* | *B* | *C* | *Alkene* |
| 239.05 | 1 | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| | 2 | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| | 3 | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| | 4 | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| | 5 | 2.062 | 0.768 | 0.067 | 0.602 | 0.224 | 0.020 | 1.460 | 0.544 | 0.048 | 0.41 |
| | 6 | 1.471 | 0.548 | 0.048 | 0.521 | 0.194 | 0.017 | 0.950 | 0.354 | 0.031 | 0.55 |
| | 7 | 1.151 | 0.429 | 0.038 | 0.539 | 0.201 | 0.018 | 0.612 | 0.228 | 0.020 | 0.88 |
| | 8 | 0.794 | 0.296 | 0.026 | 0.342 | 0.127 | 0.011 | 0.452 | 0.168 | 0.015 | 0.76 |
| | 9 | 0.683 | 0.254 | 0.022 | 0.284 | 0.106 | 0.009 | 0.399 | 0.149 | 0.013 | 0.71 |
| | 10 | 0.561 | 0.209 | 0.018 | 0.285 | 0.106 | 0.009 | 0.275 | 0.103 | 0.009 | 1.04 |
| | 11 | 0.628 | 0.234 | 0.021 | 0.251 | 0.094 | 0.008 | 0.377 | 0.140 | 0.012 | 0.67 |
| | 12 | 0.441 | 0.164 | 0.014 | 0.184 | 0.069 | 0.006 | 0.257 | 0.096 | 0.008 | 0.72 |
| | 13 | 0.438 | 0.163 | 0.014 | 0.227 | 0.084 | 0.007 | 0.211 | 0.079 | 0.007 | 1.08 |
| | 14 | 0.479 | 0.178 | 0.016 | 0.283 | 0.105 | 0.009 | 0.196 | 0.073 | 0.006 | 1.45 |
| | 15 | 0.425 | 0.158 | 0.014 | 0.235 | 0.088 | 0.008 | 0.189 | 0.070 | 0.006 | 1.24 |
| | 16 | 0.306 | 0.114 | 0.010 | 0.164 | 0.061 | 0.005 | 0.143 | 0.053 | 0.005 | 1.15 |
| | 17 | 0.285 | 0.106 | 0.009 | 0.138 | 0.051 | 0.005 | 0.147 | 0.055 | 0.005 | 0.94 |
| | 18 | 0.212 | 0.079 | 0.007 | 0.100 | 0.037 | 0.003 | 0.112 | 0.042 | 0.004 | 0.89 |
| | 19 | 0.185 | 0.069 | 0.006 | 0.087 | 0.032 | 0.003 | 0.098 | 0.037 | 0.003 | 0.88 |
| | 20 | 0.150 | 0.056 | 0.005 | 0.071 | 0.027 | 0.002 | 0.079 | 0.029 | 0.003 | 0.91 |
| | 21 | 0.159 | 0.059 | 0.005 | 0.068 | 0.025 | 0.002 | 0.091 | 0.034 | 0.003 | 0.75 |
| | 22 | 0.124 | 0.046 | 0.004 | 0.058 | 0.021 | 0.002 | 0.066 | 0.025 | 0.002 | 0.87 |
| | 23 | 0.095 | 0.036 | 0.003 | 0.046 | 0.017 | 0.002 | 0.049 | 0.018 | 0.002 | 0.93 |
| | 24 | 0.084 | 0.031 | 0.003 | 0.040 | 0.015 | 0.001 | 0.044 | 0.016 | 0.001 | 0.92 |
| | 25 | 0.046 | 0.017 | 0.002 | 0.028 | 0.010 | 0.001 | 0.018 | 0.007 | 0.001 | 1.53 |
| | 26 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | nd |
| | 27 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | nd |
| | 28 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | nd |
| | 29 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | nd |
| | 30 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | nd |
| | 31 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | nd |
| 245.30 | 1 | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| | 2 | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| | 3 | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| | 4 | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| | 5 | 1.281 | 0.692 | 0.026 | 0.610 | 0.329 | 0.012 | 0.671 | 0.362 | 0.014 | 0.91 |
| | 6 | 1.043 | 0.563 | 0.021 | 0.369 | 0.200 | 0.007 | 0.673 | 0.364 | 0.014 | 0.55 |
| | 7 | 0.686 | 0.371 | 0.014 | 0.349 | 0.188 | 0.007 | 0.338 | 0.182 | 0.007 | 1.03 |
| | 8 | 0.618 | 0.334 | 0.012 | 0.262 | 0.141 | 0.005 | 0.356 | 0.192 | 0.007 | 0.74 |
| | 9 | 0.483 | 0.261 | 0.010 | 0.214 | 0.116 | 0.004 | 0.269 | 0.145 | 0.005 | 0.80 |
| | 10 | 0.417 | 0.225 | 0.008 | 0.232 | 0.125 | 0.005 | 0.185 | 0.100 | 0.004 | 1.25 |
| | 11 | 0.489 | 0.264 | 0.010 | 0.230 | 0.124 | 0.005 | 0.259 | 0.140 | 0.005 | 0.89 |
| | 12 | 0.343 | 0.185 | 0.007 | 0.148 | 0.080 | 0.003 | 0.195 | 0.105 | 0.004 | 0.76 |
| | 13 | 0.364 | 0.196 | 0.007 | 0.212 | 0.115 | 0.004 | 0.151 | 0.082 | 0.003 | 1.40 |
| | 14 | 0.328 | 0.177 | 0.007 | 0.189 | 0.102 | 0.004 | 0.140 | 0.075 | 0.003 | 1.35 |
| | 15 | 0.255 | 0.138 | 0.005 | 0.146 | 0.079 | 0.003 | 0.109 | 0.059 | 0.002 | 1.35 |
| | 16 | 0.191 | 0.103 | 0.004 | 0.111 | 0.060 | 0.002 | 0.080 | 0.043 | 0.002 | 1.38 |
| | 17 | 0.183 | 0.099 | 0.004 | 0.090 | 0.049 | 0.002 | 0.092 | 0.050 | 0.002 | 0.98 |
| | 18 | 0.119 | 0.064 | 0.002 | 0.062 | 0.033 | 0.001 | 0.057 | 0.031 | 0.001 | 1.09 |
| | 19 | 0.125 | 0.068 | 0.003 | 0.060 | 0.032 | 0.001 | 0.065 | 0.035 | 0.001 | 0.92 |
| | 20 | 0.105 | 0.057 | 0.002 | 0.055 | 0.030 | 0.001 | 0.050 | 0.027 | 0.001 | 1.11 |
| | 21 | 0.093 | 0.050 | 0.002 | 0.051 | 0.028 | 0.001 | 0.042 | 0.023 | 0.001 | 1.22 |
| | 22 | 0.079 | 0.043 | 0.002 | 0.042 | 0.023 | 0.001 | 0.037 | 0.020 | 0.001 | 1.13 |
| | 23 | 0.063 | 0.034 | 0.001 | 0.037 | 0.020 | 0.001 | 0.026 | 0.014 | 0.001 | 1.42 |
| | 24 | 0.051 | 0.028 | 0.001 | 0.031 | 0.017 | 0.001 | 0.020 | 0.011 | 0.000 | 1.50 |
| | 25 | 0.038 | 0.021 | 0.001 | 0.025 | 0.013 | 0.001 | 0.013 | 0.007 | 0.000 | 1.86 |
| | 26 | 0.035 | 0.019 | 0.001 | 0.023 | 0.013 | 0.000 | 0.012 | 0.006 | 0.000 | 1.98 |
| | 27 | 0.024 | 0.013 | 0.000 | 0.014 | 0.008 | 0.000 | 0.010 | 0.005 | 0.000 | 1.49 |
| | 28 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | nd |
| | 29 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | nd |
| | 30 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | nd |
| | 31 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | nd |
| 271.20 | 1 | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| | 2 | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| | 3 | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |

**Table 4.5.** (continued)

| *Depth (m)* | *Carbon number* | *Alkane A* | *+ B* | *Alkene C* | *Alkane* | | | *Alkene* | | | *Alkane/ Alkene* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | *A* | *B* | *C* | *A* | *B* | *C* | |
| | 4 | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| | 5 | 2.599 | 0.065 | 0.026 | 1.072 | 0.027 | 0.011 | 1.527 | 0.038 | 0.016 | 0.70 |
| | 6 | 1.924 | 0.048 | 0.020 | 0.634 | 0.016 | 0.006 | 1.290 | 0.033 | 0.013 | 0.49 |
| | 7 | 1.766 | 0.044 | 0.018 | 0.897 | 0.023 | 0.009 | 0.869 | 0.022 | 0.009 | 1.03 |
| | 8 | 1.047 | 0.026 | 0.011 | 0.505 | 0.013 | 0.005 | 0.541 | 0.014 | 0.006 | 0.93 |
| | 9 | 0.719 | 0.018 | 0.007 | 0.310 | 0.008 | 0.003 | 0.408 | 0.010 | 0.004 | 0.76 |
| | 10 | 0.613 | 0.015 | 0.006 | 0.252 | 0.006 | 0.003 | 0.360 | 0.009 | 0.004 | 0.70 |
| | 11 | 0.700 | 0.018 | 0.007 | 0.230 | 0.006 | 0.002 | 0.471 | 0.012 | 0.005 | 0.49 |
| | 12 | 0.490 | 0.012 | 0.005 | 0.217 | 0.005 | 0.002 | 0.274 | 0.007 | 0.003 | 0.79 |
| | 13 | 0.575 | 0.014 | 0.006 | 0.240 | 0.006 | 0.002 | 0.335 | 0.008 | 0.003 | 0.72 |
| | 14 | 0.560 | 0.014 | 0.006 | 0.356 | 0.009 | 0.004 | 0.204 | 0.005 | 0.002 | 1.75 |
| | 15 | 0.376 | 0.009 | 0.004 | 0.208 | 0.005 | 0.002 | 0.168 | 0.004 | 0.002 | 1.24 |
| | 16 | 0.296 | 0.007 | 0.003 | 0.167 | 0.004 | 0.002 | 0.129 | 0.003 | 0.001 | 1.30 |
| | 17 | 0.212 | 0.005 | 0.002 | 0.157 | 0.004 | 0.002 | 0.054 | 0.001 | 0.001 | 2.89 |
| | 18 | 0.190 | 0.005 | 0.002 | 0.122 | 0.003 | 0.001 | 0.068 | 0.002 | 0.001 | 1.81 |
| | 19 | 0.137 | 0.003 | 0.001 | 0.107 | 0.003 | 0.001 | 0.030 | 0.001 | 0.000 | 3.63 |
| | 20 | 0.122 | 0.003 | 0.001 | 0.090 | 0.002 | 0.001 | 0.031 | 0.001 | 0.000 | 2.87 |
| | 21 | 0.062 | 0.002 | 0.001 | 0.062 | 0.002 | 0.001 | 0.000 | 0.000 | 0.000 | nd |
| | 22 | 0.049 | 0.001 | 0.001 | 0.049 | 0.001 | 0.001 | 0.000 | 0.000 | 0.000 | nd |
| | 23 | 0.031 | 0.001 | 0.000 | 0.031 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | nd |
| | 24 | 0.023 | 0.001 | 0.000 | 0.023 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | nd |
| | 25 | 0.014 | 0.000 | 0.000 | 0.014 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | nd |
| | 26 | 0.008 | 0.000 | 0.000 | 0.008 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | nd |
| | 27 | 0.003 | 0.000 | 0.000 | 0.003 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | nd |
| | 28 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | nd |
| | 29 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | nd |
| | 30 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | nd |
| | 31 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | nd |
| 301.10 | 1 | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| | 2 | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| | 3 | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| | 4 | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| | 5 | 2.820 | 0.139 | 0.067 | 1.411 | 0.069 | 0.034 | 1.409 | 0.069 | 0.033 | 1.00 |
| | 6 | 2.304 | 0.113 | 0.055 | 0.797 | 0.039 | 0.019 | 1.507 | 0.074 | 0.036 | 0.53 |
| | 7 | 2.053 | 0.101 | 0.049 | 1.132 | 0.056 | 0.027 | 0.921 | 0.045 | 0.022 | 1.23 |
| | 8 | 1.146 | 0.056 | 0.027 | 0.593 | 0.029 | 0.014 | 0.553 | 0.027 | 0.013 | 1.07 |
| | 9 | 0.730 | 0.036 | 0.017 | 0.333 | 0.016 | 0.008 | 0.396 | 0.020 | 0.009 | 0.84 |
| | 10 | 0.529 | 0.026 | 0.013 | 0.227 | 0.011 | 0.005 | 0.302 | 0.015 | 0.007 | 0.75 |
| | 11 | 0.833 | 0.041 | 0.020 | 0.346 | 0.017 | 0.008 | 0.487 | 0.024 | 0.012 | 0.71 |
| | 12 | 0.490 | 0.024 | 0.012 | 0.235 | 0.012 | 0.006 | 0.256 | 0.013 | 0.006 | 0.92 |
| | 13 | 0.676 | 0.033 | 0.016 | 0.320 | 0.016 | 0.008 | 0.357 | 0.018 | 0.008 | 0.90 |
| | 14 | 0.590 | 0.029 | 0.014 | 0.406 | 0.020 | 0.010 | 0.184 | 0.009 | 0.004 | 2.21 |
| | 15 | 0.290 | 0.014 | 0.007 | 0.290 | 0.014 | 0.007 | 0.000 | 0.000 | 0.000 | nd |
| | 16 | 0.209 | 0.010 | 0.005 | 0.209 | 0.010 | 0.005 | 0.000 | 0.000 | 0.000 | nd |
| | 17 | 0.132 | 0.007 | 0.003 | 0.132 | 0.007 | 0.003 | 0.000 | 0.000 | 0.000 | nd |
| | 18 | 0.128 | 0.006 | 0.003 | 0.128 | 0.006 | 0.003 | 0.000 | 0.000 | 0.000 | nd |
| | 19 | 0.153 | 0.008 | 0.004 | 0.153 | 0.008 | 0.004 | 0.000 | 0.000 | 0.000 | nd |
| | 20 | 0.095 | 0.005 | 0.002 | 0.095 | 0.005 | 0.002 | 0.000 | 0.000 | 0.000 | nd |
| | 21 | 0.064 | 0.003 | 0.002 | 0.064 | 0.003 | 0.002 | 0.000 | 0.000 | 0.000 | nd |
| | 22 | 0.047 | 0.002 | 0.001 | 0.047 | 0.002 | 0.001 | 0.000 | 0.000 | 0.000 | nd |
| | 23 | 0.036 | 0.002 | 0.001 | 0.036 | 0.002 | 0.001 | 0.000 | 0.000 | 0.000 | nd |
| | 24 | 0.020 | 0.001 | 0.000 | 0.020 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | nd |
| | 25 | 0.010 | 0.000 | 0.000 | 0.010 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | nd |
| | 26 | 0.013 | 0.001 | 0.000 | 0.013 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | nd |
| | 27 | 0.004 | 0.000 | 0.000 | 0.004 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | nd |
| | 28 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | nd |
| | 29 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | nd |
| | 30 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | nd |
| | 31 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | nd |

**NOTES**: A: % of resolved compounds in $S_2$ B: mg/g rock (Rock-Eval) C: (mg/g rock)/TOC nd: not determined

**Table 4.6. Selected parameters from pyrolysis-gas chromatography of core samples from Edaggee 1**

| *Depth (m)* | *Parameter* | *Value* *A* | *B* | *C* | *D* |
|---|---|---|---|---|---|
| 239.05 | $C_1$–$C_4$ abundance (all compounds) | 36.36 | 13.54 | 1.19 | – |
| | $C_5$–$C_8$ abundance (all resolved compounds) | 22.42 | 8.35 | 0.73 | – |
| | $C_5$–$C_8$ abundance (alkanes + alkenes) | 5.48 | 2.04 | 0.18 | – |
| | $C_9$–$C_{14}$ abundance (all resolved compounds) | 24.40 | 9.09 | 0.80 | – |
| | $C_9$–$C_{14}$ abundance (alkanes + alkenes) | 3.23 | 1.20 | 0.11 | – |
| | $C_{15}$–$C_{31}$ abundance (all resolved compounds) | 16.82 | 6.27 | 0.55 | – |
| | $C_{15}$–$C_{31}$ abundance (alkanes + alkenes) | 2.07 | 0.77 | 0.07 | – |
| | $C_9$–$C_{31}$ abundance (all resolved compounds) | 41.22 | 15.36 | 1.35 | – |
| | $C_9$–$C_{31}$ abundance (alkanes + alkenes) | 5.30 | 1.97 | 0.17 | – |
| | $C_5$–$C_{31}$ abundance (all resolved compounds) | 63.64 | 23.71 | 2.08 | – |
| | $C_5$–$C_{31}$ abundance (alkanes + alkenes) | 10.78 | 4.01 | 0.35 | – |
| | $C_5$–$C_{31}$ alkane abundance | 4.55 | 1.70 | 0.15 | – |
| | $C_5$–$C_{31}$ alkene abundance | 6.22 | 2.32 | 0.20 | – |
| | $C_5$–$C_8$ alkane/alkene | – | – | – | 0.58 |
| | $C_9$–$C_{14}$ alkane/alkene | – | – | – | 0.88 |
| | $C_{15}$–$C_{31}$ alkane/alkene | – | – | – | 1.00 |
| | $C_5$–$C_{31}$ alkane/alkene | – | – | – | 0.73 |
| | $(C_1$–$C_5)/C_{6+}$ | – | – | – | 0.69 |
| | R | – | – | – | 2.11 |
| 245.30 | $C_1$–$C_4$ abundance (all compounds) | 52.68 | 28.45 | 1.06 | – |
| | $C_5$–$C_8$ abundance (all resolved compounds) | 14.53 | 7.85 | 0.29 | – |
| | $C_5$–$C_8$ abundance (alkanes + alkenes) | 3.63 | 1.96 | 0.07 | – |
| | $C_9$–$C_{14}$ abundance (all resolved compounds) | 16.17 | 8.73 | 0.33 | – |
| | $C_9$–$C_{14}$ abundance (alkanes + alkenes) | 2.42 | 1.31 | 0.05 | – |
| | $C_{15}$–$C_{31}$ abundance (all resolved compounds) | 16.62 | 8.97 | 0.33 | – |
| | $C_{15}$–$C_{31}$ abundance (alkanes + alkenes) | 1.36 | 0.74 | 0.03 | – |
| | $C_9$–$C_{31}$ abundance (all resolved compounds) | 32.79 | 17.70 | 0.66 | – |
| | $C_9$–$C_{31}$ abundance (alkanes + alkenes) | 3.79 | 2.04 | 0.08 | – |
| | $C_5$–$C_{31}$ abundance (all resolved compounds) | 47.32 | 25.55 | 0.95 | – |
| | $C_5$–$C_{31}$ abundance (alkanes + alkenes) | 7.41 | 4.00 | 0.15 | – |
| | $C_5$–$C_{31}$ alkane abundance | 3.56 | 1.92 | 0.07 | – |
| | $C_5$–$C_{31}$ alkene abundance | 3.85 | 2.08 | 0.08 | – |
| | $C_5$–$C_8$ alkane/alkene | – | – | – | 0.78 |
| | $C_9$–$C_{14}$ alkane/alkene | – | – | – | 1.02 |
| | $C_{15}$–$C_{31}$ alkane/alkene | – | – | – | 1.22 |
| | $C_5$–$C_{31}$ alkane/alkene | – | – | – | 0.93 |
| | $(C_1$–$C_5)/C_{6+}$ | – | – | – | 1.21 |
| | R | – | – | – | 1.92 |
| 271.20 | $C_1$–$C_4$ abundance (all compounds) | 32.35 | 0.82 | 0.33 | – |
| | $C_5$–$C_8$ abundance (all resolved compounds) | 27.48 | 0.69 | 0.28 | – |
| | $C_5$–$C_8$ abundance (alkanes + alkenes) | 7.34 | 0.18 | 0.07 | – |
| | $C_9$–$C_{14}$ abundance (all resolved compounds) | 26.12 | 0.66 | 0.27 | – |
| | $C_9$–$C_{14}$ abundance (alkanes + alkenes) | 3.66 | 0.09 | 0.04 | – |
| | $C_{15}$–$C_{31}$ abundance (all resolved compounds) | 14.05 | 0.35 | 0.14 | – |
| | $C_{15}$–$C_{31}$ abundance (alkanes + alkenes) | 1.52 | 0.04 | 0.02 | – |
| | $C_9$–$C_{31}$ abundance (all resolved compounds) | 40.17 | 1.01 | 0.41 | – |
| | $C_9$–$C_{31}$ abundance (alkanes + alkenes) | 5.18 | 0.13 | 0.05 | – |
| | $C_5$–$C_{31}$ abundance (all resolved compounds) | 67.65 | 1.70 | 0.69 | – |
| | $C_5$–$C_{31}$ abundance (alkanes + alkenes) | 12.52 | 0.32 | 0.13 | – |
| | $C_5$–$C_{31}$ alkane abundance | 5.76 | 0.15 | 0.06 | – |
| | $C_5$–$C_{31}$ alkene abundance | 6.76 | 0.17 | 0.07 | – |
| | $C_5$–$C_8$ alkane/alkene | – | – | – | 0.74 |
| | $C_9$–$C_{14}$ alkane/alkene | – | – | – | 0.78 |
| | $C_{15}$–$C_{31}$ alkane/alkene | – | – | – | 2.18 |
| | $C_5$–$C_{31}$ alkane/alkene | – | – | – | 0.85 |
| | $(C_1$–$C_5)/C_{6+}$ | – | – | – | 0.63 |
| | R | – | – | – | 2.07 |
| 301.10 | $C_1$–$C_4$ abundance (all compounds) | 21.21 | 1.04 | 0.50 | – |
| | $C_5$–$C_8$ abundance (all resolved compounds) | 29.38 | 1.45 | 0.70 | – |
| | $C_5$–$C_8$ abundance (alkanes + alkenes) | 8.32 | 0.41 | 0.20 | – |
| | $C_9$–$C_{14}$ abundance (all resolved compounds) | 34.05 | 1.68 | 0.81 | – |
| | $C_9$–$C_{14}$ abundance (alkanes + alkenes) | 3.85 | 0.19 | 0.09 | – |
| | $C_{15}$–$C_{31}$ abundance (all resolved compounds) | 15.36 | 0.76 | 0.36 | – |
| | $C_{15}$–$C_{31}$ abundance (alkanes + alkenes) | 1.20 | 0.06 | 0.03 | – |
| | $C_9$–$C_{31}$ abundance (all resolved compounds) | 49.41 | 2.43 | 1.17 | – |
| | $C_9$–$C_{31}$ abundance (alkanes + alkenes) | 5.05 | 0.25 | 0.12 | – |
| | $C_5$–$C_{31}$ abundance (all resolved compounds) | 78.79 | 3.88 | 1.87 | – |
| | $C_5$–$C_{31}$ abundance (alkanes + alkenes) | 13.37 | 0.66 | 0.32 | – |
| | $C_5$–$C_{31}$ alkane abundance | 7.00 | 0.34 | 0.17 | – |
| | $C_5$–$C_{31}$ alkene abundance | 6.37 | 0.31 | 0.15 | – |
| | $C_5$–$C_8$ alkane/alkene | – | – | – | 0.90 |
| | $C_9$–$C_{14}$ alkane/alkene | – | – | – | 0.94 |
| | $C_{15}$–$C_{31}$ alkane/alkene | – | – | – | nd |
| | $C_5$–$C_{31}$ alkane/alkene | – | – | – | 1.10 |
| | $(C_1$–$C_5)/C_{6+}$ | – | – | – | 0.39 |
| | R | – | – | – | 2.67 |

**NOTES**:
A: % of resolved compounds in $S_2$
B: mg/g rock (Rock-Eval)
C: (mg/g rock)/TOC
D: no units
nd: not determined
R: m+p-xylene/n-octene
–: not applicable

hydrocarbons by GC-MS. Tables 4.7a–d summarize the extract, liquid, and saturate GC-MS data. Figure 4.6 shows the chromatogram of saturated hydrocarbons and Figure 4.7 is a plot of isoprenoid to normal paraffin ratios and indicates that kerogen from this sample is type II but close to type II/III. The kerogen in this sample is interpreted as type II/III, based on Rock-Eval pyrolysis, PGC, and GC-MS data.

The cuttings sample analysed for mud additives provided no evidence of contaminants (Fig. 4.8) that can affect the interpretation of the geochemical results.

## Source-rock maturity

Organic petrology was used to supplement the Rock-Eval pyrolysis to determine the levels of thermal maturity.

**Organic petrology:** The organic petrology of the three samples analysed is summarized in Table 4.8 (basic data) and Table 4.9 (data summary), whereas Figure 4.9 provides histograms drawn from the basic vitrinite reflectance data. The sample from the Sweeney Mia Formation did not contain dispersed organic matter and no readings were possible. Mean vitrinite reflectance values in the Cretaceous samples range from 0.34 to 0.36%Ro, indicating that these units are immature for oil generation and were not buried more than few hundred meters than their present depth (Table 4.9).

**Rock-Eval pyrolysis:** $T_{max}$ is a maturation parameter measured in degrees Celcius at which the pyrolytic yield of hydrocarbons from a rock sample reaches its maximum. The two samples selected from the Sweeney Mia Formation

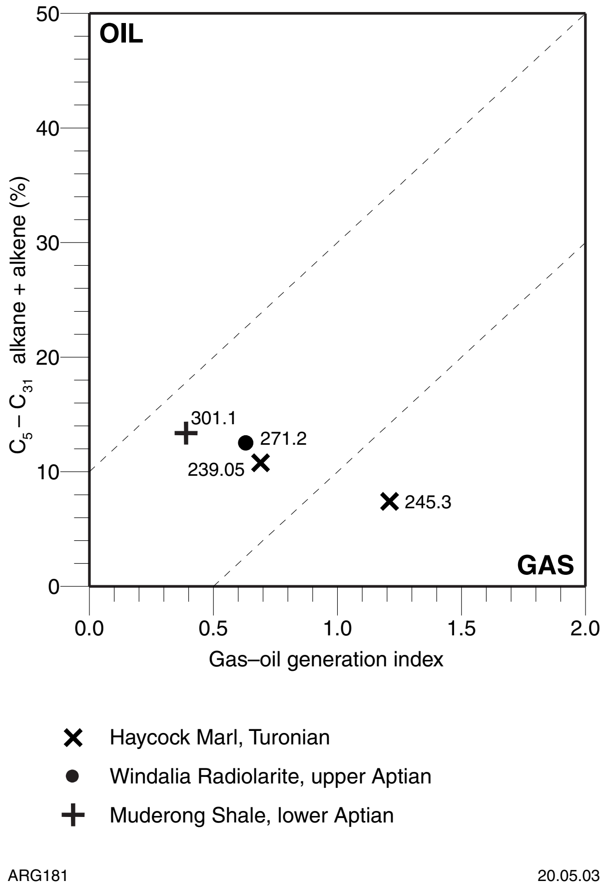



**Figure 4.5. Kerogen typing by pyrolysis-gas chromatography of four core samples from Edaggee 1**

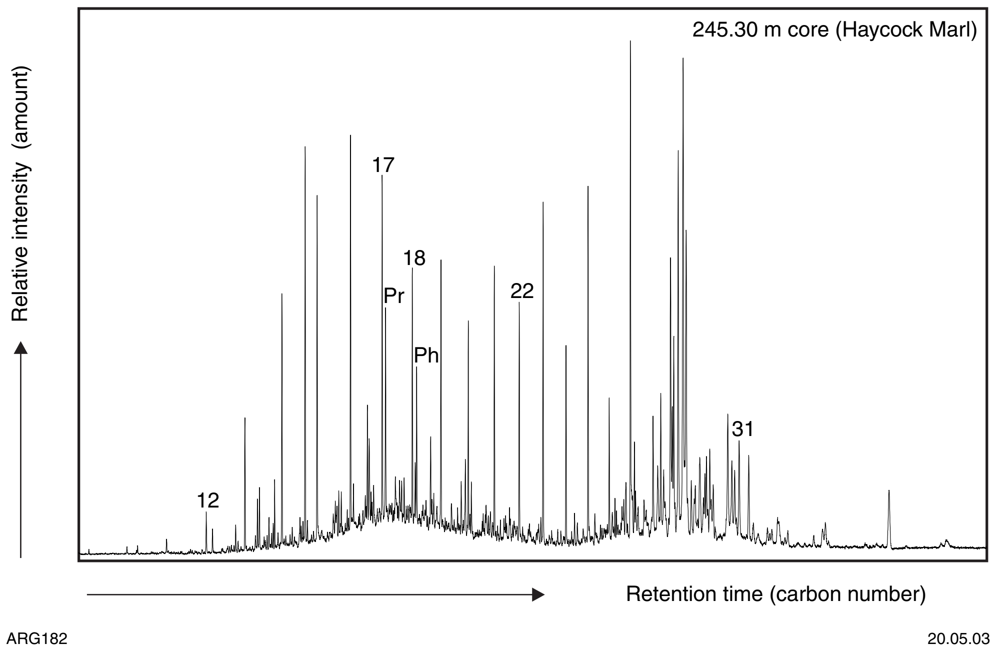



**Figure 4.6. Chromatogram of saturated hydrocarbon from GC-MS analysis for a core sample (245.3 m) from the Haycock Marl in Edaggee 1. Pr = pristane, Ph = phytane**

**Table 4.7a. Extract concentrations from extraction and liquid chromatography of core and cuttings samples from Edaggee 1**

| *Depth (m)* | *Rock extracted (g)* | *Total extract (ppm)* | *Loss on column (ppm)* | *Hydrocarbons* *Saturates (ppm)* | *Aromatics (ppm)* | *Total (ppm)* | *Nonhydrocarbons* *NSOs (ppm)* | *Asphaltene (ppm)* | *Total (ppm)* |
|---|---|---|---|---|---|---|---|---|---|
| 197–200 | 45.5 | 59.4 | nd | nd | nd | nd | nd | nd | nd |
| 245.30 | 10.5 | 2127.3 | 227.9 | 199.4 | 95.0 | 294.4 | 1604.9 | nd | 1604.9 |

**NOTES**: nd: not determined
NSO: nitrogen, sulphur, oxygen compounds

**Table 4.7b Extract composition from liquid chromatography for a core sample (245.30 m) from the Haycock Marl in Edaggee 1**

| *Depth (m)* | *Hydrocarbons* *Saturates (%)* | *Aromatics (%)* | *Total (%)* | *Nonhydrocarbons NSO's (%)* | *Saturates/ Aromatics (ratio)* | *Hydrocarbons/ Nonhydrocarbons (ratio)* |
|---|---|---|---|---|---|---|
| 245.30 | 10.5 | 5.0 | 15.5 | 84.5 | 2.1 | 0.2 |

**NOTE:** NSO: nitrogen, sulphur, oxygen compounds

**Table 4.7c. Alkane composition from saturates GC-MS for a core sample (245.30 m) from the Haycock Marl in Edaggee 1**

| *Depth (m)* | *Pristane / phytane (ratio)* | *Pristane / n-$C_{17}$ (ratio)* | *Phytane / n-$C_{18}$ (ratio)* | *CPI (1)* | *CPI (2)* | *($C_{21}$+$C_{22}$) / ($C_{28}$+$C_{29}$) (ratio)* |
|---|---|---|---|---|---|---|
| 245.30 | 1.28 | 0.64 | 0.69 | 3.05 | 2.79 | 0.75 |

**NOTE:** CPI: Carbon Preference Index

**Table 4.7d. Normal alkane distributions from saturates GC-MS for a core sample (245.30 m) from the Haycock Marl in Edaggee 1**

| *Depth (m)* | *n-$C_{12}$* | *n-$C_{13}$* | *n-$C_{14}$* | *n-$C_{15}$* | *n-$C_{16}$* | *n-$C_{17}$* | *n-$C_{19}$* | *n-$C_{18}$* | *n-$C_{20}$* | *n-$C_{19}$* | *n-$C_{20}$* | *n-$C_{21}$* | *n-$C_{22}$* | *$n-_3$ $C_{23}$* | *n-$C_{24}$* | *n-$C_{25}$* | *n-$C_{26}$* | *n-$C_{27}$* | *n-$C_{28}$* | *n-$C_{29}$* | *n-$C_{30}$* | *n-$C_{31}$* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | **percent (%)** | | | | | | | | | | | |
| 245.30 | 0.8 | 2.4 | 4.3 | 6.0 | 6.9 | 6.1 | 3.9 | 4.5 | 3.1 | 4.9 | 3.6 | 4.6 | 4.3 | 6.1 | 3.5 | 6.3 | 2.4 | 9.8 | 2.6 | 9.3 | 1.3 | 3.2 |

are organically lean and were not analysed by Rock-Eval pyrolysis (Table 4.3). The Cretaceous samples have $T_{max}$ values of between 402 and 426°C, which is below the range typical of the oil-generative window (435–470°C), thereby indicating that the Cretaceous section is immature for oil generation (Table 4.3). These results are consistent with those from the organic petrology.

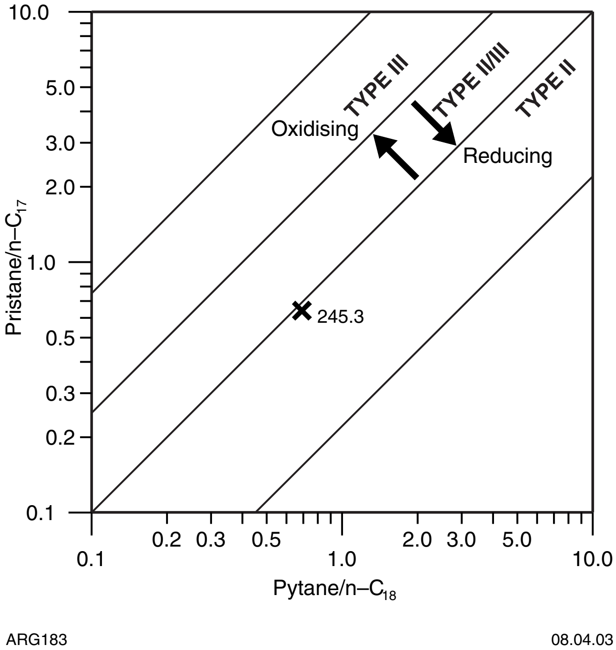



**Figure 4.7. Kerogen typing by isoprenoid/n-paraffin ratios from saturated hydrocarbon GC-MS analysis for a core sample (245.3 m) from the Haycock Marl in Edaggee 1**

**Table 4.8. Organic petrological basic data for core samples from Edaggee 1**

| *Depth (m)* | *Sample type* | *Maceral* | *%Ro* | *Readings* |
|---|---|---|---|---|
| 69* | cuttings | First generation vitrinite | 0.32 | 1 |
| | | First generation vitrinite | 0.40 | 1 |
| | | Inert | 0.66 | 1 |
| | | Inert | 0.74 | 1 |
| | | Inert | 0.78 | 1 |
| | | Inert | 0.98 | 1 |
| | | Inert | 1.14 | 1 |
| | | Inert | 1.22 | 1 |
| | | Inert | 1.66 | 1 |
| | | Inert | 1.80 | 1 |
| | | Inert | 1.82 | 1 |
| 245.3 | core | First generation vitrinite | 0.22 | 1 |
| | | First generation vitrinite | 0.23 | 1 |
| | | First generation vitrinite | 0.24 | 2 |
| | | First generation vitrinite | 0.25 | 2 |
| | | First generation vitrinite | 0.26 | 1 |
| | | First generation vitrinite | 0.27 | 1 |
| | | First generation vitrinite | 0.30 | 1 |
| | | First generation vitrinite | 0.31 | 2 |
| | | First generation vitrinite | 0.32 | 2 |
| | | First generation vitrinite | 0.33 | 1 |
| | | First generation vitrinite | 0.34 | 2 |
| | | First generation vitrinite | 0.35 | 1 |
| | | First generation vitrinite | 0.39 | 1 |
| | | First generation vitrinite | 0.40 | 1 |
| | | First generation vitrinite | 0.41 | 1 |
| | | First generation vitrinite | 0.42 | 1 |
| | | First generation vitrinite | 0.47 | 1 |
| | | First generation vitrinite | 0.50 | 1 |
| | | First generation vitrinite | 0.51 | 1 |
| | | First generation vitrinite | 0.56 | 1 |

NOTE: * sample recovered from clore bit

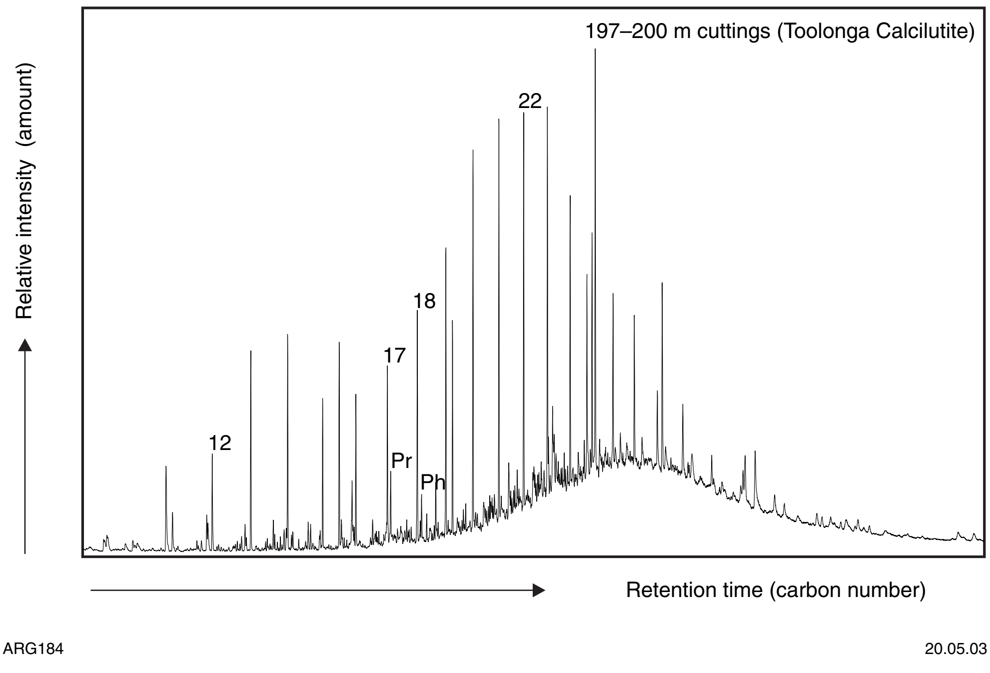



**Figure 4.8. Chromatogram from whole-extract analysis by GC-MS for cuttings sample from 197–200 m, analysed for mud-additive contaminants in Edaggee 1. Pr = pristane, Ph = phytane**

**Table 4.9. Summary of organic petrologic data for samples from Edaggee 1**

| *Depth (m)* | *Type* | *$\bar{R}$max (%Ro)* | *Rmax range (%Ro)* | *No of readings* | *Sample description, including liptinite fluorescence, maceral abundance, and mineral fluorescence* |
|---|---|---|---|---|---|
| | | | | | **Toolonga Calcilutite** |
| 69* | $R_V$max | 0.36 | 0.32 – 0.40 | 2 | Rare liptodetrinite yellow to yellowish orange. (Claystone. DOM rare, I>L>V. All maceral groups rare. Mineral fluorescence pervasive to patchy moderate orange. Iron oxides common. Pyrite common to abundant.) |
| | $R_I$max | 1.20 | 0.66 – 1.82 | 9 | |
| | | | | | **Haycock Marl** |
| 245.3 | $R_V$max | 0.34 | 0.22 – 0.56 | 25 | Abundant resinite yellowish orange to orange, abundant lamalginite yellow to yellowish orange, abundant ?bituminite dull brown. (Calcareous claystone. DOM major, 'V'>L>I. 'Vitrinite' and liptinite major, inertinite sparse, and abundant micrinite associated with 'vitrinite'. Mineral fluorescence pervasive weak dull orange. Fish bones abundant. Pyrite abundant.) |
| | | | | | **Sweeney Mia Formation** |
| 321.9 | – | – | – | – | Fluorescing liptinite absent. (Calcareous silty claystone. DOM absent, all maceral groups absent. Rare diffuse humic organic matter. Mineral fluorescence pervasive moderate dull orange. Pyrite sparse.) |

The section is immature. The Haycock Marl has a similar organic facies to a sample from 293.1 m in Boologooro 1, assigned to the 'upper Gearle Siltstone'. The Sweeney Mia Formation sample lacks DOM, but some diffuse humic organic matter is present.

**NOTES:** DOM: dispersed organic matter; I: inertinite; L: liptinite; $R_I$max: maximum inertinite reflectance; $R_V$max: maximum vitrinite reflectance; $\bar{R}$max: mean Rmax value; V: vitrinite; *: sample recovered from clore bit; –: no data

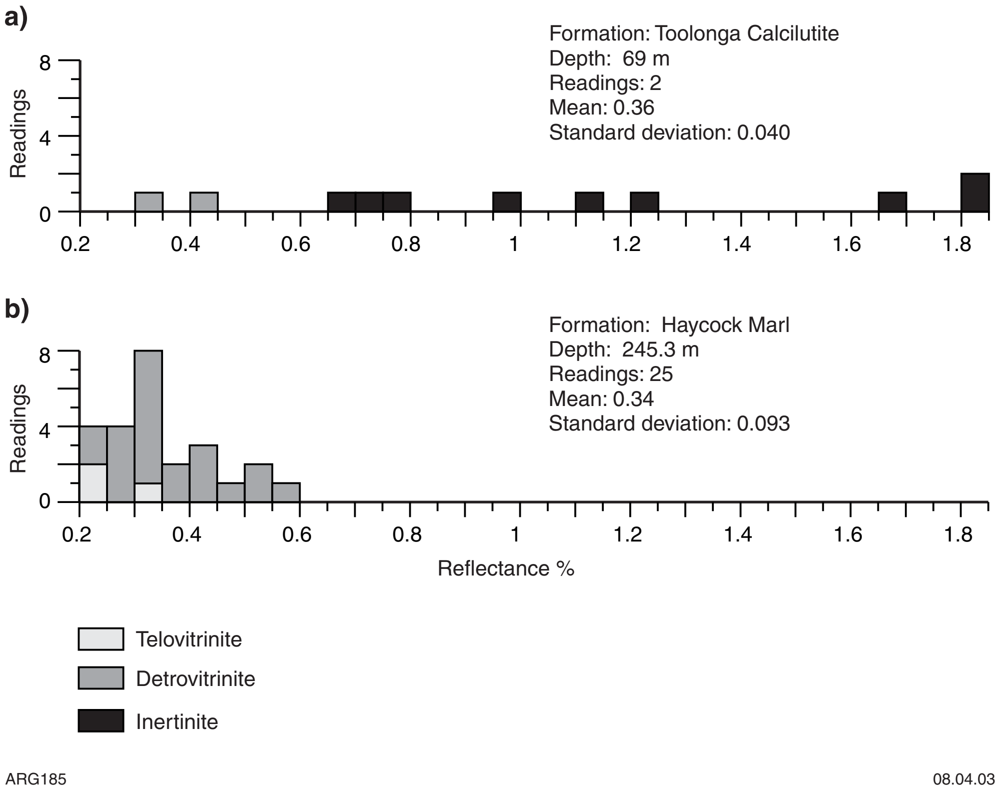



**Figure 4.9. Percent reflectance histograms for core samples from Edaggee 1: a) 69 m, Toolonga Calcilutite; b) 245.3 m, Haycock Marl**

## Conclusions

Total organic carbon, Rock-Eval, PGC, and organic petrology indicate that:

- The samples from the Lower Devonian Sweeney Mia Formation have poor organic richness and are not considered source rocks.
- The samples from the Haycock Marl have excellent organic richness and hydrocarbon-generating potential and are classified as excellent potential oil and gas source rocks.
- One of the two samples from the Muderong Shale has good organic richness and hydrocarbon-generation potential and is classified as good potential oil and gas source rock.
- The samples for the Windalia Radiolarite and 'lower Gearle Siltstone' have good organic richness with fair gas-generating potential.
- The samples from the 'upper Gearle Siltstone' and Toolonga Calcilutite are poor in both organic richness and hydrocarbon-generating potential.
- All these samples are immature for oil and gas generation.

**Appendix 5**

# Whole-rock chemistry

**by**

**P. A. Morris**

## Introduction

Analyses of eight sedimentary rock samples were carried out on the Aptian to Turonian (Cretaceous) section (Windalia Radiolarite, Gearle Siltstone, and Haycock Marl), as well as two samples from the Lower–Middle Devonian Sweeney Mia Formation in Edaggee 1 (Table 5.1). The analyses have been used to determine if whole-rock chemistry is a useful tool in lithostratigraphic correlation, and if the Gearle Siltstone in the subsurface is compositionally similar to regolith derived from the same unit on parts of the WINNING POOL – MINILYA* 1:250 000 map sheet, where the unit hosts silver–lead–zinc nodules.

A total of 27 core samples have been analysed from Edaggee 1, Boologooro 1, and Yinni 1 in the Southern Carnarvon Basin, comprising six from the Windalia Radiolarite, 17 from the Gearle Siltstone (12 from the 'lower Gearle Siltstone' and five from the 'upper Gearle Siltstone'), and four from the overlying Haycock Marl. Analyses of pyrite nodules from the Gearle Siltstone and a barite vein from the Windalia Radiolarite have not been considered in any lithological comparisons. Analyses of the Toolonga Calcilutite (two samples) and Sweeney Mia Formation (two samples) are also not discussed in statistical comparisons, due to the small population size. Genalysis Laboratory Services Ltd carried out all analyses under conditions discussed in Morris (2000).

The chemical analyses of 15 stream-sediment samples from the Gearle Siltstone over the Giralia Anticline the WINNING POOL – MINILYA (Sanders and McGuinness, 2001) are compared to those from drillcore. The analytical methodology for these samples is summarized by Sanders and McGuinness (2001) and Morris (2000). Stream sediments provide the closest approximation to bedrock chemistry compared to other regolith types sampled in the GSWA regolith geochemistry program (i.e. sandplain, soil, colluvium, lake sediment, sheetwash; Morris and Sanders, 2001).

Two indices have been calculated for all samples. The chalcophile index (CI) is the summed standard scores for As, Ag, Bi, Cd, Sb, Mo, W, and Se. Smith et al. (1989) used a similar type of index to identify chalcophile element corridors in Archaean greenstones of the Yilgarn Craton. Their approach has been adopted and modified for the GSWA regolith program (and in this Record) by first calculating the standard scores for each element so that the concentrations of elements can be compared directly, rather than using the additive index. The CI is calculated for all samples discussed here, and is therefore an index particular to this dataset. The ratio $CaO/SiO_2$ gives some indication of the siliciclastic or carbonate content of the sample.

Statistical comparisons of sample populations were made using the Mann-Whitney U test (also known as the Wilcoxon Rank Sum test), which compares population medians based on ranked data. Compared to other tests (e.g. Student's t-test, which compares population means), it is less sensitive to the effects of outliers, and is therefore more robust (Swan and Sandilands, 1995). Medians have been compared at the 95% level of significance, provided the median value is at least ten times the level of detection for both populations. Values below this level have been excluded, as they may be influenced by low precision near the minimum level of detection.

Visual inspection of the whole-rock chemistry data, summary logs of each hole, and lithological descriptions provided in Sanders and McGuinness (2001) show that the Cretaceous succession contains locally heterogeneous assemblages, in terms of both host lithologies (e.g. carbonate, carbonaceous, and siliciclastic units), and the development of pyrite and phosphate nodules and barite veining. For the 15 samples from the Gearle Siltstone the standard deviation is high (occasionally exceeding the mean value) for some analytes, such as Ba (mean 614 ppm, standard deviation 675 ppm), S (8080, 6925 ppm), Sr (293, 161 ppm), CaO (7.4, 7.6%), and $SiO_2$ (52.7, 13.6%). In the same unit, pyrite nodules have high values for some analytes. These include 62.1% $Fe_2O_3$, 371 ppm As, and 475 800 ppm S in sample 176847 from the 'lower Gearle Siltstone' in Edaggee 1, and 59.59% $Fe_2O_3$ and 382 336 ppm S, but only 6 ppm As in nodule 176854B. Thus, there is the possibility that there is a greater compositional variation within, rather than between, units. The small population size for some groupings means that some statistical comparisons (e.g. between the Toolonga Calcilutite and Sweeney Mia Formation, and between sample populations from Yinni 1) are not possible.

* Capitalized names refer to standard 1:250 000 map sheets.

**Table 5.1. Whole-rock analyses of sedimentary rocks from Edaggee 1**

| *Component* | *DL* | *Sample/depth (m)* | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *176874* | *176875* | *176843* | *176844* | *176845* | *176846* | *176877* | *176878* | *176848* | *176849* |
| | | *239.1* | *245.6* | *247.15* | *253.45* | *261* | *265.2* | *266.8* | *278.9* | *328.05* | *342* |
| | | | | | | **Percent (%) unless otherwise shown** | | | | | |
| $SiO_2$ | 0.1 | 6.0 | 52.3 | 31.2 | 47.8 | 47.8 | 53.3 | 63.3 | 69.4 | 52.4 | 57.7 |
| $TiO_2$ | 0.05 | 0.10 | 0.84 | 0.53 | 0.72 | 0.57 | 0.59 | 0.60 | 0.49 | 0.59 | 0.56 |
| $Al_2O_3$ | 0.02 | 1.82 | 18.06 | 10.39 | 12.77 | 14.14 | 12.84 | 11.01 | 9.16 | 10.66 | 10.26 |
| $Fe_2O_3$ | 0.01 | 1.42 | 8.38 | 4.55 | 6.49 | 5.36 | 5.08 | 6.04 | 5.13 | 5.74 | 6.14 |
| MnO (ppm) | 1 | 71 | 153 | 200 | 124 | 102 | 86 | 78 | 57 | 443 | 427 |
| MgO | 0.01 | 0.34 | 2.12 | 1.31 | 1.98 | 2.68 | 2.73 | 2.69 | 2.27 | 5.52 | 4.37 |
| CaO | 0.1 | 47.8 | 1.7 | 24.4 | 7.3 | 7.0 | 4.9 | 4.1 | 2.4 | 6.1 | 5.0 |
| $Na_2O$ | 0.02 | 0.24 | 0.68 | 0.56 | 0.74 | 1.06 | 1.49 | 0.74 | 0.75 | 0.34 | 0.27 |
| $K_2O$ | 0.02 | 0.50 | 3.15 | 2.14 | 2.95 | 2.90 | 2.42 | 2.93 | 2.22 | 5.88 | 5.79 |
| $P_2O_5$ | 0.01 | 0.22 | 0.49 | 0.17 | 0.43 | 0.14 | 0.15 | 0.24 | 0.84 | 0.12 | 0.15 |
| LOI | 0.01 | 40.38 | 10.84 | 22.79 | 14.89 | 13.89 | 11.91 | 9.61 | 10.03 | 10.59 | 9.28 |
| | | | | | | **Parts per million (ppm) unless otherwise shown** | | | | | |
| Ag | 0.1 | 0.5 | 0.2 | 0.2 | – | – | 0.1 | 0.3 | 0.3 | – | – |
| As | 1 | – | 9 | 6 | 15 | 9 | 8 | 13 | 20 | 3 | 4 |
| Au (ppb) | 0.1 | 1.1 | 2.8 | I/S | I/S | I/S | I/S | 1.0 | 1.0 | 0.9 | 0.5 |
| Ba | 0.1 | 39.5 | 144.8 | 1686 | 2007.7 | 1708.8 | 929.8 | 11952 | 3075 | 495.2 | 552.9 |
| Be | 0.1 | 0.3 | 2.3 | 1.2 | 1.7 | 1.1 | 1.4 | 1.7 | 1.6 | 1.9 | 2.1 |
| Bi | 0.01 | 0.18 | 0.56 | 0.38 | 0.76 | 0.70 | 0.42 | 0.50 | 0.36 | 0.41 | 0.43 |
| Cd | 0.1 | 0.5 | 0.2 | 0.1 | 0.2 | 0.2 | 0.1 | 0.4 | 0.6 | – | – |
| Ce | 0.01 | 14.85 | 56.67 | 54.00 | 86.3 | 75.76 | 64.09 | 34.30 | 40.40 | 74.52 | 75.31 |
| Co | 0.1 | 16.0 | 33.6 | 14.1 | 18.1 | 13.7 | 12.9 | 13.6 | 6.5 | 9.0 | 7.7 |
| Cr | 2 | 86 | 159 | 101 | 164 | 123 | 112 | 102 | 97 | 50 | 42 |
| Cu | 1 | 38 | 52 | 31 | 58 | 46 | 42 | 20 | 41 | 10 | 11 |
| Ga | 0.1 | 2.3 | 24.8 | 14.0 | 18.1 | 18.8 | 18.3 | 14.0 | 12.8 | 14.2 | 13.5 |
| In | 0.01 | 0.03 | 0.12 | 0.07 | 0.13 | 0.07 | 0.07 | 0.08 | 0.06 | 0.05 | 0.04 |
| La | 0.01 | 13.00 | 31.36 | 23.91 | 43.71 | 32.84 | 28.09 | 14.61 | 18.93 | 37.23 | 37.84 |
| Li | 0.1 | 6.0 | 88.8 | 55.7 | 47.1 | 56.3 | 37.3 | 43.4 | 41.3 | 38.6 | 19.0 |
| Mo | 0.1 | 1.2 | 1.8 | 0.3 | 3.0 | 3.5 | 1.8 | 5.4 | 13.5 | 0.8 | 0.5 |
| Nb | 10 | – | 19 | – | 11 | 10 | 19 | 16 | 14 | 19 | 12 |
| Ni | 1 | 68 | 81 | 45 | 80 | 65 | 60 | 58 | 77 | 24 | 19 |
| Pb | 2 | 2 | 22 | 15 | 17 | 21 | 16 | 14 | 11 | 15 | 19 |
| Pd (ppb) | 1 | 5 | 7 | – | 2 | 2 | 2 | 1 | 3 | – | – |
| Pt (ppb) | 1 | 3 | 3 | – | 1 | 2 | 2 | 2 | 3 | – | – |
| Rb | 0.05 | 12.92 | 117.85 | 80.94 | 118.09 | 102.15 | 95.32 | 85.29 | 66.00 | 161.24 | 162.98 |
| S | 10 | 5000 | 4387 | 3600 | 12000 | 3800 | 6100 | 16658 | 15841 | 1100 | 5200 |
| Sb | 0.05 | 0.65 | 0.65 | 0.43 | 0.51 | 0.46 | 0.38 | 0.63 | 1.40 | 0.44 | 0.36 |
| Sc | 1 | – | 22 | 13 | 17 | 16 | 15 | 14 | 14 | 10 | 8 |
| Se | 0.5 | 6.6 | 3.3 | 1.5 | 2.9 | 1.7 | 1.7 | 1.6 | 6.3 | – | – |
| Sn | 0.1 | 0.5 | 3.0 | 2.0 | 2.7 | 2.8 | 2.1 | 2.7 | 1.7 | 2.5 | 2.2 |
| Sr | 0.05 | 756.31 | 147.58 | 518.1 | 290.14 | 278.14 | 458.25 | 495.16 | 229.94 | 109.1 | 272.54 |

**Table 5.1.** (continued)

| *Component* | *DL* | *Sample/depth (m)* | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *176874* | *176875* | *176843* | *176844* | *176845* | *176846* | *176877* | *176878* | *176848* | *176849* |
| | | *239.1* | *245.6* | *247.15* | *253.45* | *261* | *265.2* | *266.8* | *278.9* | *328.05* | *342* |
| Ta | 0.1 | – | 0.8 | 0.6 | 1 | 0.8 | 0.8 | 1.1 | 0.6 | 1.1 | 0.9 |
| Te | 0.1 | – | 0.7 | – | – | – | 0.1 | – | – | – | – |
| Th | 0.01 | 1.04 | 13.81 | 9.43 | 14.52 | 17.03 | 13.75 | 9.18 | 9.04 | 15.40 | 13.50 |
| U | 0.01 | 1.85 | 3.37 | 2.19 | 5.56 | 4.99 | 4.23 | 2.72 | 6.64 | 2.76 | 2.34 |
| V | 2 | 80 | 181 | 108 | 128 | 99 | 98 | 89 | 95 | 82 | 70 |
| W | 0.1 | 0.6 | 2.2 | 1.2 | 1.5 | 1.1 | 1.1 | 1.2 | 1.1 | 1.4 | 1.2 |
| Y | 0.05 | 17.33 | 22.33 | 18.55 | 34.58 | 19.99 | 21.73 | 9.33 | 19.02 | 17.83 | 17.61 |
| Zn | 1 | 125 | 132 | 88 | 124 | 111 | 104 | 87 | 118 | 54 | 43 |
| Zr | 5 | 29 | 139 | 77 | 140 | 92 | 103 | 107 | 75 | 213 | 238 |

**NOTES**: DL: detection level
I/S: insufficient sample for analysis
–: less than detection level

176874, 176875: Haycock Marl
176843, 176844: ‘upper Gearle Siltstone’
176845, 176846: ‘lower Gearle Siltstone’
176877, 176878: Windalia Radiolarite
176848, 176849: Sweeney Mia

Analysis by Genalysis Laboratory Services. Methodology summarized in Morris (2000).

# Correlation of lithostratigraphic units using drillhole data

## Comparison of Gearle Siltstone between drillcore from Boologooro 1 and Edaggee 1

Although there are only four samples of the Gearle Siltstone from Edaggee 1, a statistical comparison was made to examine the degree of lithological homogeneity within the Gearle Siltstone between the Edaggee 1 and Boologooro 1, which are about 100 km apart. Median values for the Gearle Siltstone in the two wells are shown in Table 5.2. There are insufficient samples from Yinni 1 (n=3) to include it in the comparison.

The Mann-Whitney U test shows that there is a greater than 95% possibility that median values are different between the two populations for seven analytes. The median value for Ba of 1697 ppm in Edaggee 1 is an order of magnitude higher than in Boologooro 1 (183 ppm), and median values for $P_2O_5$ and Y are also higher in Edaggee 1. Median values for $Fe_2O_3$, V, and Be are lower in Edaggee 1 than in Boologooro 1. One explanation is that differences in Ba, $P_2O_5$, and Y reflect localized development of barite and phosphate nodules, whereas differences in $Fe_2O_3$ and V could reflect different degrees of ferruginization. Following from this, nodule and vein development, and ferruginization could be secondary processes superimposed on a relatively homogenous parent lithology.

## Comparison of the 'lower' and 'upper' Gearle Siltstone

Median values for the 'lower Gearle Siltstone' (11 samples) and 'upper Gearle Siltstone' (four samples) from the three wells (Table 5.3) show that the 'lower Gearle Siltstone' has statistically higher median values for $SiO_2$, MgO, and $Na_2O$, and lower median values for CaO, loss-on-ignition (LOI), Co, Li, Sr, and $CaO/SiO_2$. The association of higher CaO (and $CaO/SiO_2$), LOI, and Sr values, along with lower $SiO_2$, MgO, and $Na_2O$ values, indicates a higher carbonate content (lower siliciclastic component) in the 'upper Gearle Siltstone'. As the overlying Haycock Marl is more carbonate rich than the 'upper Gearle Siltstone', this is taken to reflect a gradual increase in carbonate content throughout the section.

Only eight median values are statistically different between the lower and upper parts of the Gearle Siltstone, indicating that the unit is largely homogeneous, which is consistent with the comparison of the Gearle Siltstone between Boologooro 1 and Edaggee 1.

## Comparison of Gearle Siltstone and Windalia Radiolarite

A statistical comparison shows that the Windalia Radiolarite (five samples) has higher median values for $SiO_2$, $P_2O_5$, Mo, and CI (Table 5.3), and lower median values for $TiO_2$, $Al_2O_3$, $Fe_2O_3$, MgO, Pb, Rb, Sc, Th, V, Y, Zn, and Zr than the Gearle Siltstone (15 samples). There is no difference in $CaO/SiO_2$. This statistical exercise shows the more siliceous nature of the Windalia Radiolarite (median value of 70.5% compared to the Gearle Siltstone median of 54.3%), with the higher CI values and higher values for 12 other analytes indicating a more diverse composition.

## Comparison of the Gearle Siltstone and Haycock Marl

This comparison is made with only four samples from the Haycock Marl, compared to 15 from the Gearle Siltstone. The wide range in concentration of some analytes (e.g. CaO within Haycock Marl; Fig. 5.1) means that there is no statistical difference between some median values.

Comparison of median values (Table 5.3) shows that the Gearle Siltstone has higher median values for $SiO_2$, MgO, $Na_2O$, Ba, Ce, Rb, and Th, and statistically lower median values for $P_2O_5$, LOI, Co, Ni, Pd, Se, $CaO/SiO_2$, and CI. Overall, this shows the more carbonate-rich nature of the Haycock Marl, although its wide range in carbonate content (Fig. 5.1) means that this is only evident in terms of comparing $CaO/SiO_2$ rather than CaO. Similarly, the higher siliciclastic (lower carbonate) content of the Gearle Siltstone is shown by its higher median values for components such as MgO, $Na_2O$, Ba, and Rb. The statistically higher Co, Ni, Pd, and CI median values for the Haycock Marl indicate a greater potential for mineralization.

## Comparison of Gearle Siltstone in drillcore with stream sediments derived from the unit on WINNING POOL – MINILYA

Regolith from the Gearle Siltstone over the Giralia Anticline has exceptionally high concentrations of Ba (average 3543 ppm), along with high values for $Fe_2O_3$, CaO, LOI, As, Mo, Ni, Se, U, and Zn, with some samples also having high $P_2O_5$, Co, Cu, In, Pd, S, Sn, and V (Sanders and McGuinness, 2001). High concentrations of Ba in regolith is probably associated with barite mineralization in the Cardabia Creek area of the Giralia Anticline, where there are beds of barite crystals in shales and siltstones up to 30 cm thick. On the western flank of this anticline, nodules of barite up to 30 cm in diameter are found over an area extending to about 25 km from Cardabia Creek.

Statistics for the 15 stream sediments from the Giralia Anticline region on WINNING POOL – MINILYA (Sanders and McGuinness, 2001) show wide variations in the concentrations of some elements, such as CaO (mean 8.41%, standard deviation 11.34%), $Na_2O$ (0.25, 0.52%), Ba (3840, 5878 ppm), Cr (44, 27 ppm), S (3200, 5967 ppm), Sr (376, 334 ppm), Zn (48, 23 ppm), and Zr (115, 62 ppm), and thus affect any comparison of median values.

A statistical comparison shows that stream sediments have higher median values for $SiO_2$, As, Ba, and Mo, and

**Table 5.2. Median values for the Gearle Siltstone in Edaggee 1 and Boologooro 1**

| *Component* | *DL* | *Edaggee 1 n=4* | *Boologooro 1 n=8* |
|---|---|---|---|
| | | **Percent (%)** | |
| $SiO_2$ | 0.1 | 47.8 | 54.7 |
| $TiO_2$ | 0.01 | 0.6 | 0.6 |
| $Al_2O_3$ | 0.02 | 12.8 | 12.6 |
| $Fe2O_3$ | 0.01 | 5.2 | 6.4 |
| MnO | 1 | 0.0 | 0.0 |
| MgO | 0.01 | 2.3 | 2.1 |
| CaO | 0.1 | 7.2 | 2.7 |
| $Na_2O$ | 20 | 0.9 | 1.3 |
| $K_2O$ | 0.02 | 2.7 | 2.6 |
| $P_2O_5$ | 50 | 0.2 | 0.1 |
| LOI | 0.01 | 14.4 | 10.7 |
| | **Parts per million (ppm) unless otherwise shown** | | |
| Ag | 0.1 | 0.2 | 0.1 |
| As | 1 | 8.5 | 7.5 |
| Au (ppb) | 1 | I/S | I/S |
| Ba | 0.1 | 1697 | 185 |
| Be | 0.1 | 1.3 | 1.7 |
| Bi | 0.01 | 0.6 | 0.4 |
| Cd | 0.1 | 0.2 | 0.2 |
| Ce | 0.01 | 70 | 60 |
| CO | 0.1 | 14 | 15 |
| Cr | 2 | 118 | 125 |
| Cu | 1 | 44 | 41 |
| Ga | 0.1 | 18 | 17 |
| In | 0.01 | 0.1 | 0.1 |
| La | 0.01 | 30 | 27 |
| Li | 0.1 | 51 | 41 |
| Mo | 0.1 | 2.4 | 3.7 |
| Nb | 0.5 | 11 | 13 |
| Ni | 1 | 63 | 65 |
| Pb | 2 | 17 | 19 |
| Pd (ppb) | 1 | 2 | 1 |
| Pt (ppb) | 1 | 2 | 1.5 |
| Rb | 0.05 | 99 | 99 |
| S | 100 | 4950 | 10000 |
| Sb | 0.05 | 0.445 | 0.52 |
| Sc | 2 | 16 | 15 |
| Se | 0.5 | 1.7 | 1.5 |
| Sn | 0.1 | 2.4 | 2.2 |
| Sr | 0.05 | 374 | 294 |
| Ta | 0.1 | 0.8 | 0.7 |
| Te | 0.1 | | 0.2 |
| Th | 0.01 | 14 | 12 |
| U | 0.01 | 5 | 3 |
| V | 2 | 104 | 131 |
| W | 0.1 | 1.2 | 1.3 |
| Y | 0.05 | 21 | 18 |
| Zn | 1 | 108 | 126 |
| Zr | 1 | 98 | 97 |
| CI | – | 0.90 | 0.47 |
| $CaO/SiO_2$ | – | 0.15 | 0.05 |

**NOTES**: DL: detection level
–: less than detection level
I/S: insufficient sample for analysis
n: number of samples

**Table 5.3. Median values for lithological units encountered in drillholes Yinni 1, Boologooro 1, and Edaggee 1**

| *Component* | *DL* | *Gearle Siltstone n=15* | *'lower Gearle Siltstone' n=11* | *'upper Gearle Siltstone' n=4* | *Windalia Radiolarite n=5* | *Haycock Marl n=4* | *Stream sediments n=15* |
|---|---|---|---|---|---|---|---|
| | | | | **Percent (%)** | | | |
| $SiO_2$ | 0.1 | 54.3 | 55.8 | 35.2 | 70.5 | 9.9 | 73.1 |
| $TiO_2$ | 0.01 | 0.6 | 0.6 | 0.6 | 0.3 | 0.2 | 0.3 |
| $AL_2O_3$ | 0.02 | 12.7 | 12.7 | 11.7 | 6.2 | 3.0 | 4.2 |
| $Fe_2O_3$ | 0.01 | 6.2 | 5.8 | 6.5 | 4.1 | 6.0 | 5.3 |
| MnO | 1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| MgO | 0.01 | 2.1 | 2.2 | 1.4 | 1.7 | 0.5 | 0.8 |
| CaO | 0.1 | 4.9 | 2.6 | 17.6 | 2.4 | 23.6 | 3.8 |
| $Na_2O$ | 20 | 1.1 | 1.3 | 0.8 | 0.7 | 0.4 | 0.1 |
| $K_2O$ | 0.02 | 2.5 | 2.5 | 2.4 | 1.2 | 0.7 | 0.9 |
| $P_2O_5$ | 50 | 0.1 | 0.1 | 0.2 | 0.2 | 1.0 | 0.1 |
| LOI | 0.01 | 11.5 | 9.4 | 18.4 | 9.6 | 27.9 | 9.0 |
| | | | | **Parts per million (ppm) unless otherwise shown** | | | |
| Ag | 0.1 | 0.1 | 0.1 | 0.1 | 0.3 | 0.4 | 0.0 |
| As | 1 | 8 | 8 | 6 | 13 | 10 | 16 |
| Au (ppb) | 1 | I/S | I/S | I/S | 1 | 1 | 1 |
| Ba | 0.1 | 221 | 221 | 905 | 1624 | 59 | 1 040 |
| Be | 0.1 | 1.6 | 1.5 | 1.7 | 0.8 | 0.7 | 0.0 |
| Bi | 0.01 | 0.4 | 0.4 | 0.4 | 0.3 | 0.2 | 0.0 |
| Cd | 0.1 | 0.2 | 0.2 | 0.1 | 0.4 | 0.6 | 0.0 |
| Ce | 0.01 | 59 | 58 | 64 | 27 | 25 | 29 |
| Co | 0.1 | 14 | 12 | 16 | 7 | 27 | 6 |
| Cr | 2 | 116 | 123 | 107 | 96 | 120 | 31 |
| Cu | 1 | 41 | 41 | 32 | 20 | 45 | 19 |
| Ga | 0.1 | 17 | 17 | 16 | 8 | 5 | 6 |
| In | 0.01 | 0.1 | 0.1 | 0.1 | 0.0 | 0.1 | 0.0 |
| La | 0.01 | 27 | 28 | 26 | 15 | 23 | 17 |
| Li | 0.1 | 39 | 37 | 61 | 28 | 11 | 12 |
| Mo | 0.1 | 2.7 | 3.2 | 0.4 | 5.4 | 1.75 | 6 |
| Nb | 0.5 | 12 | 12 | 18 | 15 | 15 | 10 |
| Ni | 1 | 61 | 61 | 68 | 58 | 87 | 24 |
| Pb | 2 | 17 | 17 | 18 | 7 | 5 | 14 |
| Pd (ppb) | 1 | 1.5 | 1 | 2 | 2.5 | 6 | 1 |
| Pt (ppb) | 1 | 2 | 2 | 1 | 2.5 | 3 | 1 |
| Rb | 0.05 | 97 | 97 | 92 | 46 | 25 | 37 |
| S | 100 | 6 100 | 5 700 | 11 050 | 15 464 | 7 944.5 | 2 000 |
| Sb | 0.05 | 0.5 | 0.5 | 0.5 | 0.6 | 1.3 | – |
| Sc | 2 | 15 | 15 | 15 | 8 | 15 | 4 |
| Se | 0.5 | 1.5 | 1.7 | 1.3 | 1.6 | 7.5 | 1.1 |
| Sn | 0.1 | 2.1 | 2.1 | 2.2 | 1.2 | 0.75 | 2 |
| Sr | 0.05 | 288 | 278 | 454 | 77 | 386 | 279 |
| Ta | 0.1 | 0.7 | 0.7 | 0.7 | 0.3 | 0.5 | – |
| Te | 0.1 | 0.2 | 0.1 | – | – | – | – |
| Th | 0.01 | 13 | 13 | 12 | 5.99 | 2 | 7.1 |
| U | 0.01 | 4 | 4 | 3 | 3 | 8 | 4 |
| V | 2 | 115 | 115 | 118 | 69 | 110 | 98 |
| W | 0.1 | 1.2 | 1.2 | 1.5 | 1.1 | 1 | – |
| Y | 0.05 | 19 | 18 | 19 | 9 | 23 | 9 |
| Zn | 1 | 111 | 111 | 104 | 61 | 129 | 42 |
| Zr | 1 | 94 | 92 | 96.5 | 52 | 41.5 | 98 |
| CI | – | 0.60 | 1.30 | 0.17 | 4.33 | 6.25 | -3.55 |
| $CaO/SiO_2$(ratio) | – | 0.09 | 0.05 | 0.52 | 0.03 | 4.05 | 0.05 |

**NOTES**: CI: chalcophile index (dimensionless)
DL: detection level
n: number of samples
I/S: insufficient sample for analysis
–: medians not calculated due to too many values less than detection level

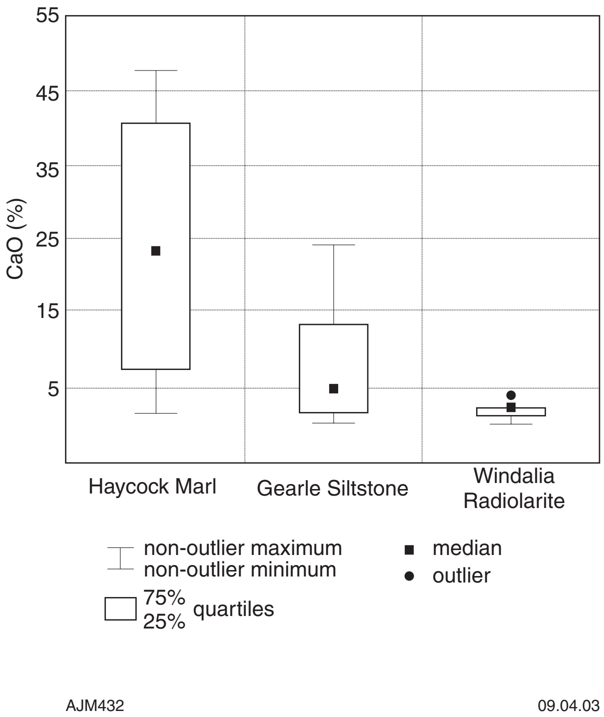



**Figure 5.1. Box and whisker plot for CaO median values for the Haycock Marl, Gearle Siltstone, and, Windalia Radiolarite (all rock samples) showing the wide range in carbonate content of the Haycock Marl compared to other units**

lower median values for $TiO_2$, $Al_2O_3$, MgO, $Na_2O$, $K_2O$, Au, Ce, Co, Cr, Cu, Ga, La, Li, Nb, Ni, Pb, Rb, S, Sc, Th, Y, Zn, and CI (Table 5.3). There is no statistical difference between median values for CaO, LOI, Sn, Sr, U, V, Zr, and $CaO/SiO_2$. Overall, the core samples show considerable differences in composition to the stream sediments. Sanders and McGuinness (2001) noted the presence of carbonate-rich duricrust and surface silicification in the Giralia Anticline region; the latter may explain the higher median $SiO_2$ value in the stream sediments. Local development of barite in the Giralia Anticline region, also discussed by Sanders and McGuinness (2001), is reflected in regolith samples by the wide variation in Ba content. It is therefore likely that the fundamental differences in chemistry between the Gearle Siltstone in the subsurface and derived stream sediment reflects a combination of lithological variability, coupled with localized development of barite, and subsequent mechanical and chemical weathering.

## Discussion

Statistical comparisons of the Gearle Siltstone between drillholes, and between lower and upper parts of the same unit, show limited chemical heterogeneity despite the development of pyrite and phosphate nodules and barite veins, and some heterogeneity in terms of lithology (e.g. carbonaceous and carbonate-rich, as well as siliciclastic, rock types). This is surprising, considering the extreme values for analytes such as S, As, Fe, and Ba in veins or nodules. The statistical comparison of the 'lower' and 'upper' Gearle Siltstone has shown an increase in carbonate content with stratigraphic height, which is consistent with the higher carbonate content of the overlying Haycock Marl. Compared to units above and below, the Gearle Siltstone has higher median values for MgO, Rb, and Th, and lower median values for $P_2O_5$ and CI.

The large number of median values that are statistically different between the Windalia Radiolarite and Gearle Siltstone indicate that the two formations have fundamentally different compositions, as could be expected.

In drillcore the Gearle Siltstone shows little in common with stream sediments derived from the unit on WINNING POOL – MINILYA, whereas there is little variation in the unit between Edaggee 1 and Boologooro 1. An explanation for this is that the stream sediments represent the combined effects of barite veining and low-temperature alteration, in addition to surface silicification and subsequent mechanical sorting and chemical weathering during the regolith forming process.

Further work on the usefulness of sedimentary-rock chemistry from drillholes could include examination of provenance and some estimation of the parent rock and degree of weathering, as was done by Nesbitt and Young (1984) and Nesbitt et al. (1996). However, these studies have focused on siliciclastic assemblages, and before their application, it is necessary to account for both carbonate and phosphate components in analysed samples.

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## Appendix 6

# Gazetteer of place and well names

| *Name* | *Latitude (S)* | *Longitude (E)* |
|---|---|---|
| **Localities** | | |
| C–Y Creek | 24°44'52" | 113°56'31" |
| Cardabia Creek | 23°06'50" | 114°10'30" |
| Edaggee Homestead | 25°21'30" | 114°14'00" |
| Exmouth Plateau | 20°00' | 113°00' |
| Giralia Anticline | 23°01'50" | 114°05'10" |
| Hill Springs Station | 24°18' | 114°30' |
| Murchison House Station | 27°38'50" | 114°14'10" |
| type section Birdrong Sandstone | 24°14'50" | 114°49'50" |
| type section Gingin Chalk | 31°19' | 115°54' |
| type section Muderong Shale | 24°08'10" | 114°45'50" |
| type section Toolonga Calcilutite | 27°36'30" | 114°12'35" |
| Windalia Hill | 23°16'10" | 114°47'10" |
| Woodleigh Station | 26°03' | 114°45' |
| **Wells & water bores** | | |
| Barrabiddy 1/1A | 23°49'52" | 114°20'05" |
| Boologooro 1 | 24°19'27" | 113°53'53" |
| Coburn 1 | 26°41'59" | 114°13'36" |
| Cynamid 3 | 24°16'15" | 114°33'55" |
| Dirk Hartog 17B | 25°52'03" | 113°04'47" |
| Edaggee 1 | 25°21'27" | 114°14'05" |
| Edaggee 2 (water) | 25°18'58" | 114°00'20" |
| Giralia 1 | 22°59'34" | 114°10'10" |
| Hamelin Pool 1 | 26°01'31" | 114°12'28" |
| Hamelin Pool 2 | 26°08'55" | 114°21'24" |
| Marron 2 (water) | 25°22'02" | 114°21'29" |
| Marron 7 (water) | 25°22'06" | 114°35'32" |
| Mooka 1 | 24°58'31" | 114°48'25" |
| Quobba 1 | 24°20'40" | 113°26'14" |
| Rough Range 1 | 22°25'07" | 114°05'05" |
| Yaringa 1 | 26°03'54" | 114°21'40" |
| Yaringa East 1 | 25°53'36" | 114°23'32" |
| Yinni 1 | 26°03'23" | 114°48'59" |

## Appendix 7

# Well index sheet

| | | |
|---|---|---|
| **ORGANIZATION:** Geological Survey of Western Australia and University of Western Australia | | **Statutory Petroleum** |
| **WELL:** GSWA Edaggee 1 | **BASIN:** Carnarvon Basin | **Exploration Report No.:** S20734 v1 |
| **SPUDDED:** 9 May 2001 | **SUB-BASIN:** Gascoyne Platform | **TYPE:** Stratigraphic |
| **COMPLETED:** 17 May 2001 | **ELEVATION GL:** ~35 m AHD | |
| **TD:** 351.0 m | **LATITUDE:** 25°21'27.0"S; **LONGITUDE:** 114°14'04.9"E (GDA 94) | |
| **STATUS:** Plugged and abandoned | **NORTHING:** 7192590 **EASTING:** 221700 (MGA Zone 50) | |

| **FORMATION** | **TOPS (m)** | | **LITHOLOGICAL SUMMARY** |
|---|---|---|---|
| | **DRILL** | **SUBSEA** | |
| Alluvium | Surface | +35 | Light-brown, medium-grained sand; minor silty clay |
| Toolonga Calcilutite | 39.5 | 4.5 | Green to grey to white soft calcilutite and clay, fossiliferous, glauconitic, locally intensely bioturbated |
| Haycock Marl | 238.1 | 203.1 | Grey to black claystone, soft, minor calcilutite |
| upper Gearle Siltstone | 245.7 | 210.7 | Grey claystone, soft, fossiliferous |
| lower Gearle Siltstone | 253.3 | 218.3 | Dark-grey claystone, pyritic, soft, fossiliferous |
| Windalia Radiolarite | 266.0 | 231.0 | Dark-grey siltstone, hard; bedded cherty and porous radiolarite |
| Muderong Shale | 297.7 | 262.7 | Dark-green to grey claystone, minor very fine grained sandstone |
| Birdrong Sandstone | 309.5 | 274.5 | Medium-grey, fine- to coarse-grained sandstone, minor glauconite, carbonaceous siltstone |
| Sweeney Mia Formation | 311.9 | 276.9 | Laminated dolostone and mudstone interbedded with fine-grained silty sandstone |
| Kopke Sandstone[(a)] | 360.0 | 325.0 | Medium- to coarse-grained quartz sandstone, minor siltstone |

| | | |
|---|---|---|
| **CORES** | Continuously cored: | **NQ:** 216.9 – 351 m (91.2% recovery) |
| **LOGS** | Gamma–caliper[(a)] | 2–612 m |
| **CASING** | PW (OD 140 mm, ID 127 mm):<br>HWT (OD 114 mm, ID 102 mm): | 0–69 m cemented into place<br>0 – 216.9 m retrieved before abandonment |

**NOTE:** (a) data from water bore 420 m to west

Department of Industry and Resources
HON. CLIVE BROWN, M.L.A.
MINISTER FOR STATE DEVELOPMENT
JIM LIMERICK
DIRECTOR GENERAL

Geological Survey of Western Australia
TIM GRIFFIN
DIRECTOR

# GSWA Edaggee 1 composite well log

| | |
|---|---|
| Company | Geological Survey of WA |
| Well Name | GSWA Edaggee 1 |
| Rig | Hydco SD1000 |
| Latitude | 25° 21' 27.0" S |
| Longitude | 114° 14' 04.9" E |
| Permanent Datum | MSL |
| Elevation of DF | 35 m |
| Elevation Log Zero | 35 m |
| Log measured from | DF |
| Drill measured from | DF |
| Well class | Stratigraphic |
| Basin | Southern Carnarvon |
| Sub-Basin | Gascoyne Platform |
| Tenement/Concession | vacant |
| Geographic datum | GDA 94 |
| On-Shore Flag | yes |
| Date spudded | 9 May 2001 |
| Date completed | 17 May 2001 |

## LITHOLOGIES

Shale
Mudstone
Calcareous mudstone
Sandy mudstone
Dolomite
Siltstone
Sandstone
Radiolarite
Calcilutite

## SYMBOLS

Erosional boundary
Planar laminations
Wavy bedding
Soft-sediment deformation
Pyrite
Pyrite nodules
Pyrite veinlets
Silica veinlets
*Inoceramus* fragments
Belemnites
Bivalves
Wood fragments
Burrow networks
Cb Carbonaceous
G Glauconite


## STRATIGRAPHY AND DESCRIPTION

**0 – 39.5 m** **ALLUVIUM**
0 – 14 Sandy mud: red-brown, with interbeds of quartz sand (light brown, medium grained, minor feldspar)
14 – 39.5 Silty clay: red-brown

**39.5 – 238.1 m** **TOOLONGA CALCILUTITE**
39.5 – 45 Clay: white, leached
45 – 68 Clay: light green, leached
68 – 101 Calcilutite: dark green
101 – 137 Calcilutite: dark green grading to light green, abundant smectite
137 – 217 Calcilutite: light green grading to pale green, rare pyrite

217.0 – 232.5 Calcilutite: pale green, variably indurated, rare pyrite, common medium-scale burrows, *Inoceramus* prisms grading from common to rare, black carbonaceous fragments associated with less indurated intervals
232.5 – 236.6 Calcilutite: green, glauconitic, common medium-scale burrows, rare *Inoceramus* prisms
236.6 – 238.1 Calcilutite: interbedded dark grey-green and green, glauconitic, carbonaceous, common pyrite, abundant medium- and small-scale burrows

**238.1 – 245.7 m** **HAYCOCK MARL**
238.1 – 238.3 Clay: pale grey, calcareous
239.5 – 244.8 Calcilutite: interbedded light to dark grey, carbonaceous
239.5 – 244.8 Calcilutite: interbedded light to dark grey, carbonaceous, abundant medium- and small-scale burrows
244.8 – 245.7 Claystone: black, carbonaceous, planar laminated with thin interbeds of siltstone (dark grey), rare pyrite nodules

**245.7 – 253.3 m** **'UPPER GEARLE SILTSTONE'**
245.7 – 254.2 Claystone: light grey, calcareous, carbonaceous, rare carbonate nodules, rare pyrite, common medium-scale burrows, rare belemnites and bivalves towards the bottom of the interval
254.2 – 253.3 Mudstone: dark grey-green, glauconitic, abundant glauconite pellets, rare belemnites

**253.3 – 266.0 m** **'LOWER GEARLE SILTSTONE'**
255.0 – 264.5 Claystone: dark grey, calcareous, carbonaceous, rare pyritic, fissile, belemnites
264.5 – 266.0 Mudstone: dark grey, sandy, calcareous, carbonaceous, pyritic, minor sand composed of carbonate, belemnites

**266.0 – 296.7 m** **WINDALIA RADIOLARITE**
266.0 – 272.2 Radiolarite: grey, porous, thin interbeds of claystone (dark grey-brown, calcareous, carbonaceous), silica and pyrite veinlets, pyrite nodules, rare medium- and small-scale burrows, common belemnites
272.2 – 278.8 Radiolarite: grey, porous, rare silica and pyrite veinlets, pyrite nodules, rare medium-scale burrows, rare belemnites
278.8 – 281.9 Radiolarite: grey, porous, rare thin interbeds of claystone (grey-brown, calcareous, carbonaceous, pyritic), pyrite nodules, common medium-scale burrows, common belemnites
281.9 – 286.8 Decimetre-scale interbeds of radiolarite (grey, porous) and sandy mudstone (grey-brown, calcareous, carbonaceous, planar laminated), laminae disrupted by patchy silicification, silica veinlets, pyrite nodules
286.8 – 291.0 Radiolarite: grey, porous, with rare thin interbeds of mud (grey-brown, calcareous, carbonaceous), rare pyrite veinlets, pyrite nodules, rare medium-scale bioturbation, rare wood fragments
291.0 – 295.0 Decimetre-scale interbeds of sandy muddy radiolarite (grey, porous), mud (dark grey, calcareous, carbonaceous), and sandy mudstone (grey-brown, calcareous, carbonaceous planar laminated), pyrite veinlets, rare medium-scale burrows, rare wood fragments
295.0 – 297.7 Mudstone: sandy (dark green-grey), carbonaceous, glauconitic, thin interbeds of mud (dark grey, carbonaceous), abundant medium-scale burrows, rare wood fragments

**297.7 – 309.5 m** **MUDERONG SHALE**
296.7 – 296.9 Claystone: green, leached, abundant calcite veinlets
296.9 – 306.1 Claystone: dark green-grey, carbonaceous, increasingly pyritic, fissile, rare medium-scale burrows
306.1 – 307.6 Quartz sandstone: dark green-grey, very fine grained, well sorted, glauconitic, pyritic, pyritized fecal pellets
307.6 – 309.5 Claystone: dark green-grey, carbonaceous, fissile

**309.5 – 311.9 m** **BIRDRONG SANDSTONE**
309.5 – 309.8 Quartz sand: grey, muddy, with thin interbeds of clay (dark green-grey, carbonaceous)
309.8 – 310.7 Quartz sand: light grey, well sorted medium grained to poorly sorted pebbly sand, well rounded
310.7 – 311.9 No return ?as above

**311.9 – 360 m** **SWEENEY MIA FORMATION**
311.9 – 313.1 Mudstone: pale grey, carbonaceous, leached
313.1 – 324.5 Dolomitic mudstone (mottled red, pale green, and yellow, heavily ferruginized, common planar and wavy laminations, erosional surfaces, rip-up clasts, brecciation and soft-sediment deformation features), with thin interbeds of mud (mainly green, rarely red and ferruginized)
324.5 – 351.0 Decimetre- and metre-scale interbeds of dolomitic mudstone (mottled red, pale green, and yellow, heavily ferruginized, coarse dolomite partial recrystallization) and dolomite (massive, recrystallized, coarse grained), thin interbeds of mud (mainly green, rarely red and ferruginized), broadly increasing dolomite recrystallization and ferruginization, planar and wavy laminations

Note: Information below 351 m is from a WRC artesian bore, 420 m to the west

351.0 – 360 as above

**360 – 390 m** **KOPKE SANDSTONE**
360 – 375 Quartz sandstone: medium grained, interbedded with siltstone
375 – 390 Quartz sandstone: (clean) medium to coarse grained

STRATIGRAPHY AND DESCRIPTION