INTERPRETATIVE DATA
Palynological analysis of sidewall core and cuttings samples between 2280 and 3288 metres in Normanby-1, offshore Otway Basin.

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Summary

Palynological analyses have been performed on 28 sidewall cores and two cuttings samples between 2280 and 3288m from the offshore Normanby-1 well with the results presented in Table 1. The palynological assemblages provide age dates ranging from Turonian to Santonian and substantially change the interpreted correlation of the lithological succession with the standard formation nomenclature of the Sherbrook Group. What was identified between 3084 and 3308mTD as the Waarre Formation in the Well Completion Report is now interpreted as comprising an upper section equivalent to Units A and basal B of the Waarre (the former renamed Unit Ab), and a new non-marine lacustrine lower section named Unit Aa of the Waarre. The latter unit is possibly the oldest section of Waarre Formation penetrated in the Otway Basin. What was originally identified as Belfast Mudstone between 2400 and 3084m can now be demonstrated to represent a continuous distal marine section that is equivalent to the upper Unit B and the whole of Units Ca and Cb of the Waarre, which are in turn overlain by the Flaxman Formation and Unit A of the Belfast Mudstone. The use of the name Morum Formation being preferred for the last unit. The presence of the *Isabelidinium cretaceum* microplankton Zone could not be verified in sidewall cores analysed from either the top of the shale section or base of the Paaratte Formation, and therefore earlier interpretations of the base of this zone are now suspect. The consequent extension of the top of the Morum Formation to the top of the shale section at 2400m suggests that the major fault could lie at this boundary between the Morum and Paaratte formations.

Table 1. Stratigraphic and Palynological Summary of Normanby–1.

AGE	STRATIGRAPHY	SPORE-POLLEN ZONES (MICROPLANKTON ZONES)	DEPTHS
Campanian to Santonian	Paaratte Formation 1485 to 2400m	*T. apoxyexinus* Zone (*O. porifera* to *I. cretaceum* Zones)	2280 to 2329m (2280 to 2329m)
?Santonian to Coniacian	Morum Formation 2400 to 2536m	*G. ancorus* Subzone (*Trithyrodinium* Subzone)	2476 to 2524.4m (2476 to 2524.4m)
Mid to Late Turonian	Flaxman Formation 2536 to 2787	*G. ancorus* Subzone (*K. polypes* Subzone)	2561.4 to 2773m (2561.4 to 2773m)
Mid to Late Turonian	Waarre Unit Cb 2787 to 2873m	Probable *L. musa* Subzone (*P. infusorioides* Zone)	2833 to 2847m (2833 to 2847m)
Mid to Late Turonian	Waarre Unit Ca 2873 to 3041m	Probable *H. trinalis* Subzone (*Heterosphaeridium* Acme)	2935 to 3035m (2989.5 to 3035m)
Early to mid Turonian	Waarre Unit B 3041 to 3112m	*H. trinalis* Subzone (*C. edwardsii* Acme)	3047 to 3087m (3047 to 3075.5m)
Early to mid Turonian	Waarre Unit Ab 3112 to 3206m	*H. trinalis* Subzone (*P. infusorioides* Zone)	3157 to 3181m (3145 to 3181m)
Early Turonian	Waarre Unit Aa 3206 to 3308mTD	*H. trinalis* Subzone (*Metaridium* Acme)	3220 to 3288m (3266 to 3288m)

Introduction

This new palynological study of the offshore Normanby-1 well was undertaken for Essential Petroleum Resources Limited at the request of Gordon Wakelin-King with the primary objective of more precisely defining the limits of the Units A, B, Ca and Cb within the Waarre Formation. Secondary objectives were to better understand the basal 100 metres penetrated in the well, which has been designated as Waarre Unit Aa, and to clarify the age dating and stratigraphic assignment of the uppermost Belfast Mudstone and its relationship to the overlying Paaratte Formation.

In the Well Completion Report (Templeton & Peattie, 1986) the well was simplistically interpreted to have penetrated a 684 metre thick Belfast Mudstone before penetrating 224 metres of Waarre Formation. The original palynological report by Morgan (1986) did not dispute the stratigraphic assignment of the section penetrated. The latter is not surprising, as at the time the well was drilled the cross-correlation of the formations and palynological zones originally advocated by Dettmann & Playford (1969; table 9:2) was accepted as a reasonable approximation, and within this early model all formations were interpreted to be time diachronous to greater or lesser extent.

However, subsequent more detailed palynological studies undertaken during the mid 1990s through the lower part of the Sherbrook Group, and including the type sections of the formations in the Port Campbell Embayment, have lead to the erection of a new suite of palynological subzones (Figure 1), which in turn provided a better palynological characterisation of the formations (Partridge, 1996, 1997, 1999, 2001). Applying this new knowledge to the palynological succession reported by Morgan (1986) in Normanby-1 lead to the recognition that the designated formation nomenclature was anomalous compared to elsewhere in the basin. The key anomaly was that the youngest common to abundant occurrence of the dinocyst *Cribroperidinium edwardsii*, which was recorded on the range charts of Morgan (1986) as ending within the basal part of the Belfast Mudstone. As this key event had been established as a reliable marker for the top of the Waarre Unit B in the Port Campbell Embayment it suggested that the formation terminology had been inappropriately applied to the Normanby-1 well. An additional anomaly was the presence of a basal shaly section between 3206 and 3308mTD, which lacked any significant marine microplankton. As marine dinocysts had been recorded to the very base of the Waarre Formation in the Port Campbell Embayment it was unclear whether Normanby-1 may have actually penetrated the Eumeralla Formation, or alternatively whether there was additional non-marine section at the base of the Waarre Formation, which had not been penetrated elsewhere in the basin. Exacerbating the evaluation of Normanby-1 is the fact that the original palynological slides studied by Morgan (1986) were never relinquished by the operator. After several unsuccessful attempts by various parties to locate them for re-examination, it has finally been concluded that the slides have been lost.

The above two problems were initially addressed in Partridge (2000) by the examination of five cuttings samples between 3050 and 3306m. This study concluded that the basal part of the "Belfast Mudstone" actually correlated with Unit B of the Waarre Formation and that the reservoir sands of Unit C were either not present in Normanby-1 or were only represented by the thin sand at 2870 to 2873m. The study also confirmed that the well had not penetrated the Eumeralla Formation, but could not unequivocally demonstrate that the basal section below 3206m represented an additional Waarre unit owing to the presence of marine dinocysts in the cuttings. The latter are now interpreted to be caved from the overlying section, as marine dinocysts were not recorded in the deepest sidewall cores analysed in this report. Next, Partridge (2003a,b) analysed a further eight cuttings samples between 2410 and 2925m. These two later reports confirmed that the Waarre Unit Cb was best identified as the log interval 2787 to 2873m, and contains only minor sandstones.

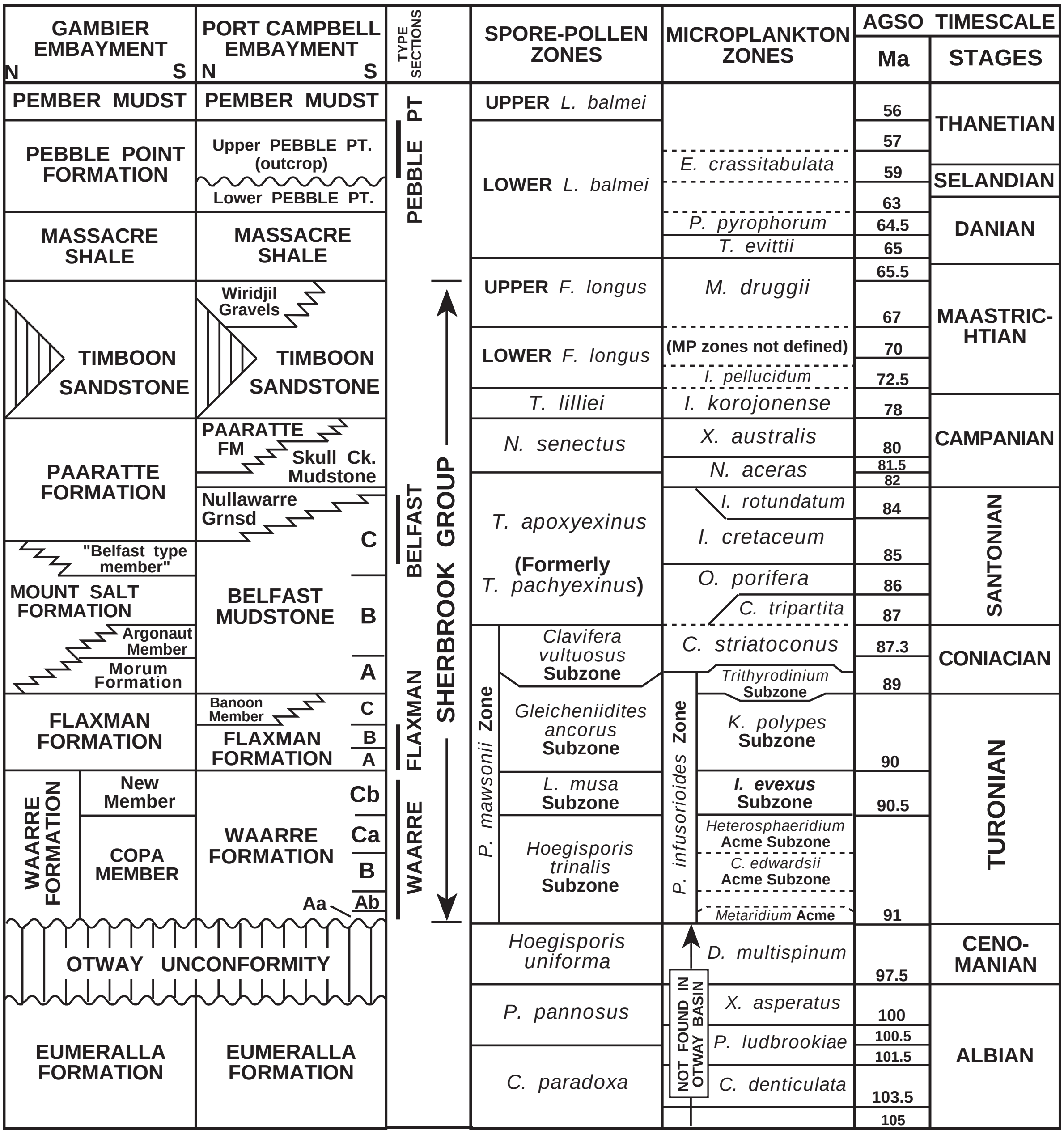

Figure 1. Revised stratigraphy, palynological zonation and ages for Sherbrook Group proposed by Partridge (1999, 2001) with suggested correlations to international stages and the AGSO chronometric timescale of Young & Laurie (1996).

The top of the Flaxman Formation was also shown to lies above 2610m, and the remaining shaly interval up to 2400m was interpreted to contained all component microplankton zones diagnostic of the Belfast Mudstone.

Following the completion of the above two most recent reports the previously missing sidewall cores from the Normanby-1 wells were unexpectedly located at the Werribee Core Library. This discovery was not acted upon until a difference of opinion arose concerning the most appropriate log delineation of Units A, B, Ca and Cb in the well. As the two competing interpretations had considerable bearing on other exploration prospects, and could not be resolved from the available palynological data, it was decide to resample and reprocess the remaining available sidewall cores for a new palynological study.

Materials and Methods

For this latest study 30 samples, comprising 28 sidewall cores and 2 cuttings samples have been analysed from the Normanby-1 between 2280 and 3288m. The well was drilled by BP Petroleum Development Ltd to a TD of 3308m, and is located in permit VIC/P42, offshore Otway Basin. The samples were collected by the author from the Werribee Core Library on Friday 5th July and sent to the Santos Ltd palynological laboratory for processing. Palynological slides from the most critical samples were returned between 14th July and 2nd August and the initial results of the microscope analysis was provided in three Provisional Reports issued between 18th July and 3rd August. Additional data was provided in draft StrataBugs™ range charts. The final zone picks on all the samples are provided in Table 2.

Basic sample data comprising the lithologies and weights of the samples processed are given on Table 3, while the basic assemblage data comprising the visual organic residues yields, the concentration and preservation of the palynomorphs observed on the slides, and the number of species of spore-pollen (SP) and microplankton (MP) recorded from individual samples are provided in Table 4. In summary, an average of 8 grams of each sample was processed to give mainly moderate residue yields containing mostly moderate concentration of palynomorphs, whose preservation is poor to fair. Spore-pollen diversity was moderate to high averaging 27+ species per sample while microplankton diversity ranged from low to moderate with a maximum diversity of 17+ species per sample.

The distribution of the palynomorphs identified in the samples are presented on the accompanying StrataBugs™ range chart, which displays the recorded palynomorph species in the samples proportional to their depth in the well and in terms of their relative abundance (as a percentage). The palynomorphs recorded are also split between different categories. The terrestrial spore and pollen are divided between spores, gymnosperm pollen and angiosperm pollen, which are plotted in separate panels. The next panel labelled Neves effect represents the percentage sum of all species of the gymnosperm pollen *Araucariacites* and *Dilwynites* in the spore-pollen count. This is followed by a panel showing the total count of marine and non-marine microplankton, and as a separate category the colonial algae *Amosopollis cruciformis*, as percentages relative to the combined spore-pollen and microplankton counts. Next the percentage abundance of individual species in the microplankton count are displayed in the panel labelled Microplankton. Then plotted are Other Palynomorphs, with abundances expressed as a percentage of sum of the total Spore-Pollen plus Other Palynomorphs counted. Because the majority of samples are sidewall cores the species are plotted within the panels according to their deepest or oldest occurrences.

The following codes or abbreviations apply to the individual species occurrences and abundances on the range chart:

Numbers	=	Abundances expressed as percentage
+	=	Species outside of count
C	=	Caved species
R	=	Reworked species
?	=	Questionable identification of species.

Author citations for the recorded spore-pollen species can be sourced from papers by Dettmann (1963), Dettmann & Playford (1968), Helby *et al.* (1987) and Stover & Partridge (1973), while the author citations for the microplankton species can be sourced from the indexes for dinocysts and other organic-walled microplankton prepared by Fensome *et al.* (1990) and Williams *et al.* (1998). Manuscript species names and combinations are indicated by “sp. nov.” or “comb. nov.” on the range chart, and “ms” after their binomials names in the text and tables.

Geological Discussion.

The reprocessing and palynological analysis of available sidewall cores between 2280m and TD provides significant new insights into the stratigraphic succession drilled in Normanby-1. The study provides much needed confidence in the principal conclusions reached from the palynological analysis of cuttings by Partridge (2000, 2003a-b), and provides additional information on the age of the succession that could not be obtained from the cuttings. In the following section the results of the palynology are applied to interpreting the stratigraphic succession with the units recognised discussed in ascending order:

Waarre Unit Aa (3206 to 3308mTD): The five deepest sidewall cores analysed contain non-marine palynological assemblages, which are distinct from the marine assemblages found at the base of the Waarre Formation at its type area in the Port Campbell Embayment. The spore-pollen component of the assemblages contain the index species *Hoegisporis trinalis* ms and *Appendicisporites distocarinatus* (with abundances up to 16%), and possibly *Phyllocladidites mawsonii* (based on one poorly preserved specimen at 3266m), and lack any index species diagnostic of the underlying Eumeralla Formation. The composition of the assemblage can be characterised by common to abundant *Microcachryidites antarcticus* (up to 22%), common bryophyte spores of *Triporoletes reticulatus* (10 to 15%), frequent *Coptospora pileolus* ms (up to 3.5%), and the presence of megaspores (mostly *Balmeisporites holodictyus* and a related new species). Typically rare and even absent from most samples are *Gleicheniidites circinidites, Laevigatosporites ovatus, Stereisporites antiquasporites, Cupressacites* sp. and all angiosperm pollen. The palynological assemblages also lack marine dinocyst (aside from specimens interpreted as caved contaminants), but do contain non-marine algal cysts and acritarchs. The former are represented by rare *Rimosicysta* and a new algal cyst named *Bonneycysta* gen. et sp. nov., while the latter are represented by the distinctive *Metaridium solidispinum* Riding *et al.* 1998. Overall the assemblages are distinct from those recorded from typical Waarre Unit A in other wells in the Otway Basin (with a couple of notable exceptions that will not be discussed here), and are also distinct from older Cenomanian assemblages referred to the *Hoegisporis uniforma* Zone in the Duntroon and other basins further to the west (Figure 1). The environment of deposition is non-marine to lacustrine and to distinguish it from younger units in the Waarre it is here designated Unit Aa.

Waarre Unit Ab (3112 to 3206m): The original Unit A of Buffin (1989) is here redesignated as Unit Ab. On the gamma ray log the unit is approximately equal sand and shale (~58% sand) and the three sidewall cores analysed from this interval average <3% marine microplankton. The two cuttings samples contain significantly higher abundances of marine microplankton (average 27%), but that is interpreted to indicate the presence of substantial cavings within the cuttings. The spore-pollen assemblages are typical of the *H. trinalis* Subzone, but unfortunately the associated microplankton assemblages are of relatively low diversity and can only be assigned to the broad *P. infusorioides* Zone. Overall the environment of deposition is marginal marine.

Waarre Unit B (3041 to 3112m): This middle unit of the Waarre Formation straddles what was interpreted as the Belfast/Waarre boundary at 3084m in the Well Completion Report (Templeton & Peattie, 1986). On the gamma ray log the unit is characterised by a prominent lower shale (3095-3112m), from which no sidewall cores were available for analysis, and a more subdued upper shale (3041 to 3084m) sampled by two sidewall cores containing the distinctive *Cribroperidinium edwardsii* Acme. Based on an average marine microplankton abundance of 28% in the three productive sidewall cores the depositional environment of the interval is interpreted as more distal marine than the underlying Unit Ab.

Waarre Unit Ca (2873 to 3041m): On the gamma ray log this is a homogeneous shale package broken only by two thin one metre thick sands at 3006m and 3025m. The bottom of the interval is correlated with Unit Ca based on the presence of the *Heterosphaeridium* Acme in sidewall cores at 2989.5 and 3035m. These assemblages contain abundant microplankton (average 47%). In marked contrast, the two shallower sidewall cores at 2935 and 2975m contain very low microplankton abundances (average 6%), and cannot be reliably assigned to any of the microplankton subzones. Overall the environment of deposition remains distal marine based on lithology and microplankton content, but there is clearly a more regressive or shallowing influence throughout the upper part of the unit.

Waarre Unit Cb (2787 to 2873m): Unit Cb is the best reservoir unit elsewhere in the basin, but in Normanby-1 the section contains only a thin basal sand at 2870 to 2873m, and two very poor sands at 2787–2795m and 2797.5–2807m near the top of the unit. Unfortunately, the two sidewall cores analysed from this unit were very disappointing with low recovery of palynomorphs and low abundances (<5%) and diversities of microplankton. Neither was considered diagnostic. Correlation of this interval with the Unit Cb is instead based on the two cuttings at 2805-10m and 2870-80m analysed by Partridge (2003a,b), which contain the oldest recorded occurrence in the well of abundant *Amosopollis cruciformis* (average 16% of SP + MP count), and the oldest frequent occurrence of *Isabelidinium evexus* ms (average 6% of MP count). Both these latter features are considered diagnostic of Unit Cb in the Port Campbell Embayment. The environment of deposition of this section is also interpreted as mainly distal marine, although less so than either the underlying or overlying units. It is conceded however that the poor recovery from the two sidewall cores and obvious cavings, from the overlying Flaxman Formation in the cuttings, confuses the interpretation**.**

Flaxman Formation equivalent (2536 to 2787m): Sidewall cores were only reprocessed from the base and top of this unit and all contain the distinctive assemblages of the *K. polypes* Subzone, which are considered characteristic of the Flaxman Formation. Microplankton abundance and diversity is moderate (averages of 9.5% for marine microplankton, 16% for *Amosopollis cruciformis*, and 14+ species per sample). The gamma ray log character is very homogeneous and the top of the unit is essentially arbitrarily picked as there is no clear log break. Environment of deposition continues to be interpreted as distal marine, and for this unit is supported by the presence of a relatively strong Neves effect, represented by common to abundant occurrences of *Dilwynites* pollen.

Morum Formation or Belfast Mudstone Unit A (2400 to 2536m): Only the uppermost ~136 metres of the original 684 metres assigned to the Belfast Mudstone in the Well Completion Report is now considered to correlate with the classic sections of this formation in the Port Campbell Embayment, and even then it only correlates with the basal Unit A (Figure 1). A better stratigraphic assignment for the interval is to the Morum Formation following the arguments of Partridge (2001). The interval contains microplankton diagnostic of the *Trithyrodinium* Subzone (Figure 1), but notably lacks the index species *Conosphaeridium striatoconum* which is most prominent in the upper part of the Morum Formation. Based on the absence of the latter species, and comparing the ~136 metres found in Normanby-1 with the average 530 metre thickness assigned to the Morum Formation in the similar offshore wells Morum-1, Copa-1, Argonaut-1 and Breaksea Reef-1, suggests that a substantial part of the formation may be missing at the major fault in Normanby-1.

Another related complication is that the original palynological study by Morgan (1986) reports the younger zone index species *Isabelidinium cretaceum* from the SWC at 2417.5m and this has been the basis for earlier interpretations that the major fault was located within the upper 50 metres of the shale section. However, this key species occurrence could not be verified in the reprocessed portion of the SWC at 2417.5m analysed in this report, and in the author's opinion the original record should now be interpreted as most likely downhole or laboratory contamination of that sidewall core. When this deepest occurrence of the *I. cretaceum* Zone is rejected as anomalous it becomes much more logical to place the major fault at the top of the shale section, and to argue that up to 400 metres of the Morum Formation has been removed at the fault. This also provides a neat explanation for the missing *C. striatoconum* Zone in Normanby-1.

Paaratte Formation (1485 to 2400m): The shallowest three sidewall cores analysed are from the bottom 120 metres of the 915 metre thick Paaratte Formation identified in the Well Completion Report (Templeton & Peattie, 1986). Although marine microplankton are abundant in the recovered assemblages (average 22%), diversity is low (average of 7 species per sample), and the confidence in the microplankton zone assignment is only moderate. In the original study by Morgan (1986) and in all subsequent reviews the base of the sandy Paaratte section has been interpreted to lie within the *I. cretaceum* Zone, based primarily on the records of the eponymous zone species in the sidewall cores at 2379m and 2471.5m. Unfortunately, the index species *Isabelidinium cretaceum* was not found in the reprocessed SWC at 2471.5m, nor in the shallower samples at 2329m and 2307.2m, while in the shallowest sample at 2280m the species identification is questionable.

In the author's opinion the older occurrence of *I. cretaceum* recorded by Morgan (1986) must now be regarded as anomalous, and reflect either contamination of the sidewall cores or laboratory contamination. The true position of the *I. cretaceum* Zone is instead interpreted to lie higher in the well, and to be represented by the assemblages recovered from the sidewall cores at 2087.9m and 2147.6m, where additional index species for the zone are recorded by Morgan (1986). Consequent on this revision the underlying more sandy lower portion of the Paaratte Formation between 2220 and 2400m is considered better assigned to the next older *Odontochitina porifera* Zone. In terms of the revised stratigraphic terminology of Partridge (2001) this latter interval would be equivalent to Unit B of the Belfast Mudstone, or the lower part of the Mount Salt Formation, and would possibly also include equivalents of the Argonaut Member.

Biostratigraphy.

The samples analysed in Normanby–1 are classified according to the Australian standard spore-pollen and microplankton zonation schemes established by Helby *et al.* (1987), which in the Otway Basin have been updated and refined by Partridge (1999, 2001), and are summarised in Figure 1. A recent review of these zonation schemes can also be found in the latest edition of the *Geology of*

Victoria (Partridge & Dettmann, 2003). The separate spore-pollen and microplankton zones identified are discussed below in ascending stratigraphic order:

***Phyllocladidites mawsonii* spore-pollen Zone**
Interval: 2476 to 3288 metres
Age: Turonian to Coniacian.

Assemblages assigned to the *P. mawsonii* Zone are recorded from samples analysed over the bottom 900 metres penetrated in the well, effectively through all of the “Belfast” shale section and the underlying sandy “Waarre” sections designated in the Well Completion Report (Templeton & Peattie, 1986). The eponymous species *Phyllocladidites mawsonii* and former the zone index *Clavifera triplex* are recorded respectively in 7 and 9 out of 23 productive sidewall cores analysed. The rarity of these two species (especially towards the base of the zone) is typical of the lower part of the Sherbrook Group and is the reason much more emphasis is usually given to the identification of the subzones. The important point to be stressed about the gross character of the assemblages is that they lack all key index species of the older Cenomanian *Hoegisporis uniforma* Zone and the younger Santonian *Tricolporites apoxyexinus* Zone. Three of the four established subzones within the parent zone are described below in ascending stratigraphic order:

***Hoegisporis trinalis* spore-pollen Subzone**
Interval: 3087 to 3288 metres, probably extending as shallow as 2989.5 metes
Age: Early to mid Turonian.

The index species *Hoegisporis trinalis* ms is recorded in 8 out of 11 sidewall core samples up to 3087m, but not in any of the next six sidewall cores up to the top of the Unit Ca of the Waarre at 2873m. However, within the latter interval the species was recorded in the composite cuttings samples at 2070-80m and 2920-25m previously analysed by Partridge (2000a), and therefore the subzone is considered to range to the top of Unit Ca. Unfortunately, there appears to be no other species that are reliably and consistently restricted to the subzone, and which are also recorded in this well. The spores *Appendicisporites distocarinatus, Verrucosisporites admirabilis* ms and *Coptospora pileolus* ms are more consistent and common in the subzone, but all three dribble upwards throughout the remainder of the parent zone. The species *Balmeisporites holodictyus, Crybelosporites brennerii, Interulobites intraverrucatus, Phyllocladidites eunuchus* ms, *Reticulosporis albertonensis* and the relic Early Cretaceous species *Crybelosporites striatus* and *Foraminisporis asymmetricus* appear on the range chart to be restricted, but are known from other wells to range higher. *Cyatheacidites tectifera, Densoisporites muratus* ms, and *Proteacidites* spp. are the most notable species with oldest occurrences within the subzone.

The assemblages are equally dominated by *Podocarpidites* spp. (22%) and *Cyathidites* spp. (22%), with *Araucariacites australis, Dilwynites* spp., *Microcachryidites antarcticus, Gleicheniidites circinidites* and striate spores of the *Cicatricosisporites/Ruffordiaspora* complex all having averages of about 5%.

***Laevigatosporites musa* spore-pollen Subzone**
Interval: 2833 to 2847 metres, extending down to composite cuttings at 2870-80 metres
Age: Early to mid Turonian.

Confidence in the identification of this subzone is poor as the two reprocessed sidewall cores gave only low residue yields with low concentrations of spores and pollen. The eponymous species *Laevigatosporites musa* ms is recorded in the shallower sample at 2833m but not from the deeper at 2847m. Although notionally the next four deeper sidewall cores between 2935 and 3035m could be argue to belong to this subzone because they contain *Laevigatosporites musa* ms but lack *Hoegisporis trinalis* ms the occurrence of both index species in the composite cuttings at 2870-80m previously analysed by Partridge (2000a) favours placing the subzone boundary at that sample. The two sidewall cores assemblages are dominated by *Podocarpidites* spp. (average 38%), *Cyathidites* spp. (average 19%) and *Gleicheniidites circinidites* (average 5%), but that in part reflects the fact that these are junk-basket categories that often receive more than their fair share of specimens when counting poorly preserved assemblages.

***Gleicheniidites ancorus* spore-pollen Subzone**
Interval: 2476 to 2773 metres
Age: Mid Turonian to early Coniacian.

This subzone is characterised in Normanby-1 by the common to abundant occurrence of *Dilwynites* spp. (average 20%) and the consistent presence in all sidewall cores of *Clavifera triplex* and *Cupressacites* sp. The eponymous species *Gleicheniidites ancorus* ms occurs in 3 of the 6 samples, and the parent zone index species *Phyllocladidites mawsonii* in 3 of the 6 samples. Other secondary index species occurring in at least half of the sidewall cores are *Appendicisporites distocarinatus*, *Coptospora pileolus* ms and *Verrucosisporites admirabilis* ms. It is noteworthy that the next younger index species *Clavifera vultuosus* ms was not recorded in the shallowest two samples and therefore it seems likely the base of the *C. vultuosus* Subzone needs to be moved upwards with respect to the associated microplankton subzones (Figure 1).

***Tricolporites apoxyexinus* spore-pollen Zone**
Interval: 2280 to 2329 metres
Age: Santonian

This zone is identified by the rise in angiosperm pollen in the assemblages (average 11% compared to <5% through the *P. mawsonii* Zone) and the oldest occurrence of a variety of secondary index species including *Latrobosporites amplus* and *Phyllocladidites verrucosus* at 2329m, *Forcipites* spp. at 2307.2m, and *Ilexpollenites primus* ms at 2280m. The eponymous species *Tricolporites apoxyexinus* was not recorded. Similar to the underlying *P. mawsonii* Zone the assemblages are dominated by *Podocarpidites* spp. (average 23%), and spores of *Cyathidites* spp. (average 22%) and *Gleicheniidites circinidites* (average 10%). A position low in the zone is suggested by the relatively low abundance of *Proteacidites* pollen (average 4%).

***Palaeohystrichophora infusorioides* microplankton Zone**
Interval: 2476 to 3181 metres
Age: Turonian to possible early Coniacian.

The formal definition of this zone is the stratigraphic interval from the LAD (Last Appearance Datum) of *Pseudoceratium ludbrookiae* to the FAD (First Appearance Datum) of *Conosphaeridium striatoconum* (Helby *et al.* 1987; p.62). This definition is not too practical in the Otway Basin as the former species has never been recorded (because the base of the marine succession in the Sherbrook Group is everywhere younger), while the incoming of the latter species is proving to be difficult to document in the more marginal marine facies occurring in the western part of the basin. The species has not been found in the Normanby-1 well, most likely because the *C. striatoconum* Zone interval has been cut out by a major fault.

Marine dinocyst considered consistent with the *P. infusorioides* Zone in the Otway Basin are recorded in Normanby-1 from nearly all sidewall cores from 3181m up to 2476m. The exceptions are the sidewall cores at 3084m and 2833m which gave the lowest yields and lowest concentrations of palynomorph on reprocessing. Morgan (1986) also records low microplankton diversity from these two samples. Within the sidewall core succession three of the previous four established subzones are recognised and these are discussed below in ascending stratigraphic order. In addition, the sidewall cores samples from the section below 3206m also contain a low diversity suite of non-marine algal cysts and acritarchs which are assigned to the new *Metaridium* Acme, while at the top of the succession the recently proposed *Trithyrodinium* Subzone is now included within this parent zone.

***Metaridium* microplankton Acme Subzone**
Interval: 3266 to 3288 metres, probably extending as shallow as 3220 metres
Age: ?Early Turonian.

The palynological assemblages from the shaly interval on the gamma ray log between 3206 and 3308mTD (Unit Aa of the Waarre Formation), can be characterised by the absence of *in situ* marine dinocysts, and the presence of a limited suite of algal cysts and acritarchs, which are interpreted to be indicative of a non-marine lacustrine depositional environment. Although rare marine dinocysts were recorded (but outside of the assemblage count) from the shallowest sidewall core at 3220m all the specimens identified are interpreted to be caved contaminants as none of the species where recorded in the original analysis of that samples by Morgan (1986).

The most distinctive putative non-marine species is the acritarch *Metaridium solidispinum* Riding *et al.* 1998 recorded in the sidewall cores at 3266m and 3288m. This species was also recorded in cuttings analysed by Partridge (2000) at 3285-3300m and 3304-05m under the name of *Dorocysta* sp., and is thought to be what Morgan (1986) has identified as *Cauca* sp. in his original analysis. Morgan (1986) records *Cauca* sp. from 8 out of 12 sidewall cores analysed below 3206m, as well as from the shallower sidewall cores at 3176.5m and 3187m. The latter occurrences have not however been confirmed by the new study of those two samples herein.

The commonest non-marine species is a new algal cyst named *Bonneycysta* gen et sp. nov., which is a distinctive small reticulate spherical cyst. Other species are rare but include *Rimosicysta* spp., *Circulisporites parvus* and *Sigmopollis carbonis*. In total the algal cysts and acritarch species represent a distinctive assemblage of microplankton which have not been found in the type area of the Waarre Formation in the Port Campbell Embayment.

***Cribroperidinium edwardsii* microplankton Acme Subzone**
Interval: 3047 to 3075.5 metres, probably extending down to 3181 metres
Age: Early to mid Turonian.

The two sidewall core samples at 3047 and 3075.5m are assigned to the subzone base on the common occurrence of *Cribroperidinium edwardsii*, which represents from 4 to 15% of the combined SP + MP count, and from 19 to 35% of the MP count. The samples also contain the secondary index species *Cyclonephelium compactum* and *Palaeoperidinium cretaceum* and are amongst the highest diversity of all assemblages recorded from the Waarre Formation. The colonial algae *Amosopollis cruciformis*, somewhat surprisingly, was not recorded from either sample.

The eponymous species *C. edwardsii* is also recorded from the deeper sidewall cores at 3087m, 3157m and 3181m, but it is impossible to judge whether the species is common or abundant, because all microplankton are simply too rare to make a meaningful count. It should also be noted that Morgan (1986) reports *C. edwardsii* from an additional 6 sidewall cores between 3119 and 3197m, which were not analysed in this report. The species is also recorded from the 5 cuttings samples analysed between 3050-60m and 3304-06m by Partridge (2000), but the species abundances recorded are not considered reliable owing to the presence of substantial downhole cavings.

Heterosphaeridium microplankton Acme Subzone
Interval: 2989.5 to 3035 metres
Age: Early to mid Turonian.

Two samples are assigned to the subzone based on the abundant occurrence of *Heterosphaeridium* spp. which averages 25% of the combined SP + MP count, and >80% of the MP count. Both samples also contain *Palaeoperidinium cretaceum* and surprisingly appear to completely lack *Amosopollis cruciformis*. The older index species *Cribroperidinium edwardsii* was only tentatively identified in the shallow sample at 2989.5m. Within the Port Campbell Embayment this acme is recorded from Unit Ca of the Waarre Formation and occurs above the *Cribroperidinium edwardsii* Acme, which is characteristic of Unit B of the Waarre Formation.

The next two shallower samples at 2935m and 2975m within what has been identified as Unit Ca of the Waarre lack any abundance of *Heterosphaeridium* spp. and therefore cannot be considered part of the acme. The deeper sample at 2975m is dominated by *Cribroperidinium* sp. cf *C. cooksoniae*, which represents >40% of the MP count and also contains the LAD of *Palaeoperidinium cretaceum*. The shallower sample at 2935m contains much lower numbers of microplankton without any one species being particularly prominent. At the moment neither assemblage can be assigned to a named subzone.

Isabelidinium evexus microplankton Subzone
Cuttings interval: 2805 to 2880 metres
Age: Early to mid Turonian.

The *I. evexus* Subzone has not been recovered in any of sidewall cores but is interpreted to be represented in the cuttings sample at 2805-10m and the composite cuttings samples at 2870-80m previously analysed by Partridge (2003a-b). These samples contain frequent *Isabelidinium evexus* ms (respectively 4% to 8%) and abundant *Amosopollis cruciformis* (respectively 64% and 35%) in the MP count, both being diagnostic features of the subzone. The two sidewall cores analysed within the interval at 2833m and 2847m unfortunately contain only low microplankton abundances and diversity and are not diagnostic.

Kiokansium polypes microplankton Subzone
Interval: 2561.4 to 2773 metres
Age: Mid Turonian to early Coniacian.

The FAD of *Valensiella griphus* and LADs of *Kiokansium polypes* and *V. griphus* define the base and top of this subzone. The bottom of the subzone can therefore be confidently placed at 2773m, based on the oldest occurrence of *V. griphus*, and the top of the zone placed at 2561.4m based on the youngest occurrence of *K. polypes*, with the youngest occurrence of *V. griphus* recorded at 2580.8m. All the assemblages are dominated by the colonial algae *Amosopollis cruciformis*.

Trithyrodinium microplankton Subzone
Interval: 2476 to 2524.5 metres
Age: Early Coniacian?

An additional subzone is added to the top of the *P. infusorioides* Zone to encompass microplankton assemblages above the LAD of *K. polypes* and below the FAD of *C. striatoconum* (Figure 1). This additional time interval is most obvious in the thicker stratigraphic successions investigated in the western part of the Otway Basin (eg. Caroline-1 and Mount Salt-1). In contrast, the subzone is difficult to recognise in the Port Campbell Embayment where the equivalent interval at the base of the Belfast Mudstone is highly condensed, and currently inadequately sampled by either sidewall or conventional cores. The subzone is identified by the FAD of the genus *Trithyrodinium* which is abundantly recorded (41% of MP count) at 2524.5m. The assemblage also contains common *Heterosphaeridium* spp. (29%) but lacks *Amosopollis cruciformis*. In contrast, the shallower sidewall core at 2476m contains abundant *Heterosphaeridium* spp. (51%) and *A. cruciformis* (34%) while *Trithyrodinium* spp. is relatively rare (<3%).

Odontochitina porifera **microplankton Zone or younger**
Interval: 2280 to 2329 metres
Age: Santonian

The three shallowest samples analysed contain relatively low diversity assemblages dominated by *Heterosphaeridium* spp (average >50% of MP count). The assemblages are not older than the *O. porifera* Zone based on the FADs of *Chatangiella victoriensis* at 2329m, *Trithyrodinium vermiculatum* at 2307.2m, and *Odontochitina cribropoda* recorded by Morgan (1986) at 2280m. Aside from a questionable fragment recorded from the shallowest sample there was no evidence of *Isabelidinium cretaceum* or any other index species diagnostic of the younger *I. cretaceum* Zone in any of the assemblages. Based on this negative evidence the occurrences of *I. cretaceum* recorded by Morgan (1986) in the deeper sidewall cores at 2379m and 2417.5m are interpreted to be out-of-place and most likely down-hole contamination of the samples.

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Table 2a: Interpretative assemblage data for Normanby-1, Otway Basin.

Sample Type	Depth metres	Spore-Pollen Zones (Microplankton Zones)	CR*	Comments and Key Species Present
SWC 15	2280.03	*T. apoxyexinus* Zone (*O. porifera* to *I. cretaceum* Zones)	B2 B3	Marine MP 17%, dominated by *Heterosphaeridium* spp.; *Amosopollis cruciformis* AC% = 4%. Zone assignment based on FADs *Odontochitina porifera*, questionable *Isabelidinium cretaceum* and *Ilexpollenites primus* ms.
SWC 14	2307.18	*T. apoxyexinus* Zone (*O. porifera* Zone or younger)	B2 B4	Marine MP 22%, dominated by *Heterosphaeridium* spp.; AC% = <1%. Assemblage with FADs of *Trithyrodinium vermiculatum* and common *Proteacidites* spp. (7%).
SWC 12	2329.01	*T. apoxyexinus* Zone (*O. porifera* Zone or younger)	B2 B4	Marine MP 26%, dominated by *Heterosphaeridium* spp.; *Amosopollis cruciformis* not recorded. FADs of dinocyst *Chatangiella victoriensis* and spore *Latrobosporites amplus*.
SWC 9	2417.51	Indeterminate		Low yield and low diversity SP assemblage. MP not recorded.
SWC 8	2476.01	*G. ancorus* Subzone (*Trithyrodinium* Subzone)	B2 B3	Marine MP 21%, dominated by *Heterosphaeridium* spp.; AC% = 11%. SP assemblage with LADs of *Appendicisporites distocarinatus* and *Verrucosisporites admirabilis* ms and also containing youngest abundant *Dilwynites* spp. (19%).
SWC 7	2524.38	*G. ancorus* Subzone (*Trithyrodinium* Subzone)	B4 B2	Marine MP 45%; FAD and dominated by *Trithyrodinium* spp.; *Amosopollis cruciformis* not recorded. SP Assemblage with LAD of *Balmeisporites glenelgensis* & *Dilwynites* spp. (10%)
SWC 6	2561.43	*G. ancorus* Subzone (*K. polypes* Subzone)	B4 B2	Marine MP 10%, dominated by *Heterosphaeridium* spp.; AC% = 10%. Assemblage with LAD of *Kiokansium polypes* and abundant *Dilwynites* spp. (20%).
SWC 5	2580.82	*G. ancorus* Subzone (*K. polypes* Subzone)	B2 B2	Marine MP 7%; AC% = 6%. Assemblage with LAD of *Valensiella griphus* and very abundant *Dilwynites* spp. (32%).
SWC 89	2756	*G. ancorus* Subzone (*K. polypes* Subzone)	B4 B2	Marine MP 16%, dominated by *Valensiella griphus* (23%) AC% = 28%. SP dominated by *Dilwynites* spp. (23%).
SWC 88	2773	*G. ancorus* Subzone (*K. polypes* Subzone)	B3 B3	Marine MP 5%; AC% = 4%. Assemblage with FAD of *Valensiella griphus* and common *Dilwynites* spp. (16%).
SWC 86	2833	*L. musa* Subzone	B3	Marine MP not recorded. AC% = <1%. SP assemblage contains LAD of *Laevigatosporites musa* ms and is dominated by *Podocarpidites* spp. (49%).
SWC 85	2847	?*L. musa* Zone (*P. infusorioides* Zone)	B4 B5	Marine MP 5%; AC% = 3%. Poor low diversity sample with LAD of dinocyst *Cyclonephelium compactum*.
SWC 81	2935	?*H. trinalis* Subzone (*P. infusorioides* Zone)	B5 B5	Marine MP 8%; *A. cruciformis* not recorded.
SWC 79	2975	?*H. trinalis* Subzone (*P. infusorioides* Zone)	B5 B2	Marine MP 4%; dominated by *Cribroperidinium* sp. (>40% of MP count) with LAD of *Palaeoperidinium cretaceum*.
SWC 78	2989.5	?*H. trinalis* Subzone (*Heterosphaeridium* Acme)	B4 B3	Marine MP 59%; dominated by *Heterosphaeridium* spp. (>75% of MP count). SP assemblage not diagnostic.
SWC 75	3035	?*H. trinalis* Subzone (*Heterosphaeridium* Acme)	B4 B3	Marine MP 36%; dominated by *Heterosphaeridium* spp. (>85% of MP count). *A. cruciformis* not recorded. SP assemblage not particularly diagnostic.
SWC 74	3047	?*H. trinalis* Subzone (*C. edwardsii* Acme)	B4 B3	Marine MP 23%; with LAD of common *Cribroperidinium edwardsii* (19% of MP count).
SWC 72	3075.5	?*H. trinalis* Subzone (*C. edwardsii* Acme)	B4 B3	Marine MP 41%; dominate by *Cribroperidinium edwardsii* (35% of MP count).

Table 2b: Interpretative assemblage data for Normanby-1, Otway Basin.

Sample Type	Depth metres	Spore-Pollen Zones (Microplankton Zones)	CR*	Comments and Key Species Present
SWC 71	3084	Indeterminate		Essentially barren with less than 10 palynomorphs per slide.
SWC 70	3087	*H. trinalis* Subzone (*P. infusorioides* Zone)	B2 B4	Marine MP 21%; dominated by *Cyclonephelium compactum* (36% of MP count), with *Cribroperidinium edwardsii* <3%. LAD of pollen *Hoegisporis trinalis* ms in SWCs.
Cuttings	3145-50	*P. mawsonii* Zone (*P. infusorioides* Zone)	D4 D4	Marine MP 21%; dominated by *Heterosphaeridium* spp. (45% of MP count), with *Cribroperidinium edwardsii* <5%.
SWC 58	3157	*H. trinalis* Subzone (*P. infusorioides* Zone)	B2 B5	Marine MP <2%. SP assemblage with multiple specimens of *Hoegisporis trinalis* ms & *Appendicisporites distocarinatus*.
Cuttings	3165-70	*H. trinalis* Subzone (*P. infusorioides* Zone)	D3 D4	Marine MP 33%; dominated by *Heterosphaeridium* spp. (46% of MP count) and probably largely caved.
SWC 55	3176.5	*H. trinalis* Subzone (*P. infusorioides* Zone)	B2 B4	Marine MP <3%; and of low diversity, not very significance but consistent with broad *P. infusorioides* MP Zone
SWC 54	3181	*P. mawsonii* Zone (*P. infusorioides* Zone)	B2 B4	Marine MP <4%. FAD of interpreted *in situ* marine dinocysts and microforaminiferal liners in SWCs.
SWC 47	3220	*H. trinalis* Subzone	B2	Non-marine MP ~1%. Youngest confident identification of new algal cyst *Bonneycysta* gen et sp. nov. Marine dinocysts outside of count interpreted as caved contaminants.
SWC 43	3246.5	*H. trinalis* Subzone	B4	Non-marine MP <1%. Conspicuous *Appendicisporites distocarinatus* >16% and *Triporoletes reticulatus* 4%.
SWC 39	3266	*H. trinalis* Subzone (*Metaridium* Acme)	B4 B3	Non-marine MP ~1%. LAD of acritarch *Metaridium solidispinum*; spore *Triporoletes reticulatus* 15%
SWC 37	3272.5	Indeterminate		Poor assemblage with <60 specimens per slide, mostly large angular opaque to semi-opaque kerogen pieces.
SWC 32	3288	*H. trinalis* Subzone (*Metaridium* Acme)	B2 B3	Non-marine MP ~3%. FADs of *Hoegisporis trinalis, Appendicisporites distocarinatus* and *Metaridium solidispinum* with spore *Triporoletes reticulatus* 15%.

SP & MP = Spore-Pollen and Microplankton; FAD & LAD = First and Last Appearance Datums
MP% = Percentage abundance of marine microplankton relative to spore-pollen and *Amosopollis cruciformis*.
AC% = Percentage abundance of *Amosopollis cruciformis* relative to spore-pollen and other microplankton.

*Confidence Ratings used in STRATDAT database and applied to Table 2.

Alpha codes: Linked to sample		**Numeric codes:** Linked to fossil assemblage		
A	Core	**1**	**Excellent confidence:**	High diversity assemblage recorded with key zone species.
B	Sidewall core	**2**	**Good confidence:**	Moderately diverse assemblage with key zone species.
C	Coal cuttings	**3**	**Fair confidence:**	Low diversity assemblage recorded with key zone species.
D	Ditch cuttings	**4**	**Poor confidence:**	Moderate to high diversity assemblage without key zone species.
E	Junk basket	**5**	**Very low confidence:**	Low diversity assemblage without key zone species.

Table 3: Basic sample data for Normanby-1, Otway Basin.

Sample Type	Depth metres	Brief Lithological Description	Approx. Weight †
SWC 15	2280.03	Light grey siltstone	6g
SWC 14	2302.18	Light-medium grey mudstone	7g
SWC 12	2329.01	Medium grey mudstone	7g
SWC 9	2417.51	Reddish-brown siltstone	11g
SWC 8	2476.01	Medium-dark grey mudstone	11g
SWC 7	2524.38	Medium-dark grey mudstone	10g
SWC 6	2561.43	Medium grey mudstone	6g
SWC 5	2580.82	Medium-dark grey mudstone	10g
SWC 89	2756	Dark grey mudstone	6g
SWC 88	2773	Dark grey shale	11g
SWC 86	2833	Light grey siltstone	6g
SWC 85	2847	Dark grey mudstone	12g
SWC 81	2935	Dark grey shale	4g
SWC 79	2975	Medium grey mudstone	10g
SWC 78	2989.5	Medium grey mudstone	13g
SWC 75	3035	Medium grey mudstone	14g
SWC 74	3047	Medium grey mudstone	10g
SWC 72	3075.5	Medium grey mudstone	8g
SWC 71	3084	Brown siltstone	9g
SWC 70	3087	Medium grey silty-shale	3g
Cuttings	3145-50	Mudstone 70%, sand 30%	10g
SWC 58	3157	Medium grey siltstone	5g
Cuttings	3165-70	Mudstone 60%, sand 40%	10g
SWC 55	3176.5	Medium grey shale	2g
SWC 54	3181	Medium grey shale	12g
SWC 47	3220	Medium grey siltstone	4g
SWC 43	3246.5	Medium grey shale	5g
SWC 39	3266	Medium grey shale	8g
SWC 37	3272.5	Light grey shale	4g
SWC 32	3288	Medium grey siltstone	8g
		Average:	8 grams

† Sample weight only approximate as it is based on simple spring scale.

Table 4: Basic assemblage data for Normanby-1, Otway Basin.

Sample Type	Depth metres	Visual Yield	Palynomorph Concentration	Preservation	No. SP Species	No. MP Species
SWC 15	2280.03	Moderate	Moderate	Poor	31+ (1+)	12+
SWC 14	2302.18	Moderate	Moderate	Poor-fair	35+ (4+)	5+
SWC 12	2329.01	Moderate	Moderate	Poor-fair	36+ (3+)	4+
SWC 9	2417.51	Low	Low	Very poor	19+ (2+)	NR
SWC 8	2476.01	High	Moderate	Poor	35+ (1+)	13+
SWC 7	2524.38	Moderate	Moderate	Poor	29+ (1+)	8+
SWC 6	2561.43	Moderate	Moderate	Poor-fair	32+ (2+)	14+
SWC 5	2580.82	Moderate	High	Very poor	32+	13+
SWC 89	2756	High	Moderate	Poor-fair	27+ (2+)	17+
SWC 88	2773	High	Moderate	Poor-fair	32+ (2+)	14+ (1+)
SWC 86	2833	Low	Low	Poor-fair	20+	2+
SWC 85	2847	Low	Low	Poor	25+	9+
SWC 81	2935	Low	Very low	Poor	28+	11+
SWC 79	2975	Moderate	Moderate	Poor-fair	29+	11+
SWC 78	2989.5	Moderate	Moderate	Poor-fair	29+ (1+)	15+
SWC 75	3035	Moderate	Moderate	Poor-fair	24+ (2+)	10+
SWC 74	3047	Moderate	Low	Poor	20+	14+
SWC 72	3075.5	High	Moderate	Poor-good	26+	15+
SWC 71	3084	Moderate	Very low	Poor	4+	1+
SWC 70	3087	Low	Moderate	Poor	28+	11+
Cuttings	3145-50	Moderate	Moderate	Poor	22+	13+
SWC 58	3157	Moderate	High	Poor	41+ (2+)	7+
Cuttings	3165-70	Moderate	Moderate	Poor	21+ (2+)	12+
SWC 55	3176.5	Moderate	Moderate	Poor	34+ (6+)	8+
SWC 54	3181	Moderate	Moderate	Poor	24+ (1+)	8+
SWC 47	3220	High	Moderate-high	Poor	34+ (6+)	1+ (7+)
SWC 43	3246.5	High	High	Poor-fair	30+ (6+)	1+
SWC 39	3266	High	High	Poor-fair	26+ (3+)	3+
SWC 37	3272.5	Moderate	Low	Poor	19+ (3+)	NR
SWC 32	3288	High	High	Poor-fair	38+ (3+)	6+
				Averages:	27+ (1+)	8+ (<1)

Numbers in brackets in two right-hand columns refer to species which are caved or contaminants.
NR = Not Recorded.

Normanby-1

Well Name : Normanby-1
Spudded : 07 March 1986
Completed: 29 April 1986
Lat/Long : 38°14' 11.55"S 141° 5' 3.26"E
Interval : 2260m - 3320m
Scale : 1:2000
Chart date: 22 September 2005

INTERPRETATIVE Range Chart
Sample interval 2280 to 3288m
Microscope analysis by Alan D. Partridge

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