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Palynological review of the type sections of the Belfast Mudstone, Flaxman and Waarre Formations in the Port Campbell Embayment, Otway Basin.

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Summary

1. A new palynological study has been made of 24 core samples and 17 cuttings samples from the type sections of the Belfast Mudstone, Flaxman and Waarre Formations.

2. The study has confirmed the revised palynological succession and ages established from palynological studies of wells drilled in Port Campbell Embayment between 1993 and 1995 and relates these to the type sections. In the process the study has resolved anomalous species occurrences in the type sections recorded in earlier palynological work due mainly to caved materials accumulating at and being collected from the tops of the conventional cores.

3. The Waarre Formation is assigned the *P. mawsonii* spore-pollen Zone and *P. infusorioides* microplankton Zone and is entirely Turonian in age, not Cenomanian as previously thought. All shales and siltstones from the Waarre were found to contain rare to common marine dinoflagellates suggesting the formation is predominantly marine.

4. The Flaxman Formation can be characterised by the *K. polypes* Subzone of the *P. infusorioides* Zone. This new subzone can be used to correlate the Flaxman Formation within the Port Campbell Embayment and demonstrates the formation is not diachronous, but does vary significantly in thickness. The age of the Flaxman Formation is late Turonian and it was deposited in a probably deep water distal marine environment.

5. The *C. striatoconus* microplankton Zone is a thin biostratigraphic marker found above the type section of the Flaxman Formation and provides a useful biostratigraphic marker for mapping the upper limit of that formation. However, close palynological sampling is required to locate this marker in most wells.

6. The type section of the Belfast Mudstone is shown to be restrictedo the *I. cretaceum* microplankton Zone of mid to late Santonian age. It was also deposited in a probably deep water distal marine environment. Restricting the use of the term Belfast Mudstone to a concept closer to the type section is recommended to provide a more practical stratigraphic unit. This would require however the introduction of one or more new stratigraphic terms for the interval between the base of the Belfast Mudstone and the top of Flaxman Formation.

Introduction

Late Cretaceous sediments were first identified in the Otway Basin in the Nelson bore in western Victoria (Baker & Cookson, 1955), but the first stratigraphic units were erected in the Port Campbell Embayment following the first modern petroleum wells drilled in that area between 1959 and 1964. The key wells and spud dates are Port Campbell-1 (9 September 1959), Port Campbell-2 (12 July 1960) and Flaxmans-1 (3 May 1961). The units Belfast Mudstone, Flaxman and Waarre Formations were first recognised in stratigraphic succession in these wells, which in turn were subsequently designated to contain the type sections for these formations. The wells have also been designated as the principal reference sections for the *Appendicisporites distocarinatus*, *Clavifera triplex* and *Tricolpites pachyexinus* spore-pollen Zones used for the age dating and correlation of these formations (Dettmann & Playford, 1969).

At the time they were drilled the wells were essentially "state of the art" for retrieval of subsurface stratigraphic information. All three wells contain numerous conventional cores and, for their time, modern and comprehensive suites of electric logs. However, over the last three decades logging technology has advanced considerably and it is now difficult to impossible to achieve an unambiguous correlations to more recent wells with more advanced logs, even when the recent wells are located close to the original holes. The same problem exists with the palynology. Results from recent wells drilled between 1994–1995, which have been comprehensively sampled by sidewall cores, have been difficult to rationalise with either the initial results or later palynological studies of the wells containing the type sections.

In this study the cores and cuttings from Port Campbell-1, Port Campbell-2 and Flaxmans-1 have been re-examined and selectively sampled for palynology with the aim of clarifying the relationship of the type sections of the formations to a finer palynological zonation currently under development.

Previous Palynological Work

The initial palynological work on the three wells by Evans (1962, 1964) and Dettmann (1964a, b) was conducted during the early days of stratigraphic palynology and was hampered by the largely undescribed microflora. Much of the critical descriptive palynology was occurring at around the same time, and spores, pollen, dinoflagellate and algal palynomorph species described from these wells by Cookson (1965); Cookson & Balme (1962) and Dettmann & Playford (1968) have subsequently proved to be important index forms. This early work lead to the establishment of first a microplankton zonation (Evans, 1966) and subsequently a spore-pollen zonation (Dettmann & Playford, 1969). Both zonations refer to intervals in the wells examined in this report as key reference sections.

It was nearly two decades after the initial examinations before further stratigraphic palynological studies were made of these wells. The first study was by Stacy (1981) and involved the collection and processing of 75 new core samples from Port Campbell-1, 2 and 4, and Flaxmans-1. Subsequently the palynological slides from Flaxmans-1 were borrowed and re-examined as part of a regional review of Otway Basin palynology by Morgan (1986). Both these studies were made prior to the finalisation of the major review of Mesozoic palynological zonations by Helby *et al.* (1987) and lack enough reliable detail to unambiguously characterise the type sections of the formations.

The critical need to better characterise the palynology of the type sections of the Belfast Mudstone, Flaxman and Waarre Formations has been highlighted by recent attempts to provide a unified stratigraphy for the Otway Basin (Morton *et al.*, 1994; Tickell *et al.*, 1992) and the need to reconcile the latest palynological results obtained from detailed sidewall core sampling of these formations in the recent wells Langley-1, near Port Campbell 2 (Partridge, 1994b) and Howmains-1, adjacent to Flaxmans-1 (Partridge, 1994c).

Materials and Methods

The 41 core and cuttings samples analysed here were inspected and collected from the department of Energy and Minerals Victoria core storage facility on 11-12 January 1996. Palynological processing of the samples was performed by Laola Pty Ltd in Perth. Descriptions of sample lithologies; quantity of palynological residue extracted; palynomorph concentration, preservation and diversity are recorded on Tables 5 to 7. Zone identification, their Confidence Ratings and comments on microplankton abundance and key species recorded are provided on Tables 2 to 4. All stratigraphically significant species recorded in the samples are tabulated on separate range charts for each of the three wells. Excluded from the range charts are rare species in the samples which are known to occur in older and younger sections, reworked species and species recorded in the cuttings known to be caved from above the section of interest. These species were omitted because they obscured the overall character of the assemblages but are included in the species diversity counts on Tables 5 to 7.

Overall, although residue yields were mostly moderate to high, the palynomorph concentrations were mainly low to moderate. The latter when combined with the generally poor to fair preservation has meant that many key index species were rare and not consistently found. The difficulty of finding key species was most severe in the cuttings samples from the Flaxman Formation in Port Campbell-2 and Flaxmans-1. The cuttings in both wells were badly contaminated by cavings from the Belfast Mudstone and younger units. For all samples spore-pollen diversity was moderate averaging 24+ species per sample. Microplankton diversity was also moderate but lower, averaging 14+ species per sample. Total microplankton abundance is given on Tables 5 to 7 but split between the fresh to presumed brackish water algal cyst *Amosopollis cruciformis* and all other microplankton on Tables 2 to 4. The abundance is expressed as percentage of microplankton relative to combined spore-pollen and microplankton count. The calculation of the spore-pollen and microplankton percentages excludes reworked Permian and Triassic palynomorphs and fungal spores, hyphae and fruiting bodies counted in the assemblage.

Biostratigraphy

This section discusses the zone determinations provided for the individual samples given on Tables 2–4. The zonation applied is the Australia wide Mesozoic spore-pollen and microplankton zonation schemes described by Helby, Morgan & Partridge (1987). Increased biostratigraphic resolution is achieved by recognition of several new local but as yet informal subzones. These new zones are ranked as subzones in order to retain the integrity and age relationships of the existing zones, even though their palynomorph content may make them just as distinctive as the established zones. Also discussed are the formerly used Otway Basin zones for microplankton (Evans, 1966) and spore-pollen (Dettmann & Playford, 1969) which have reference sections in the wells being analysed. As this report has a biostratigraphic focus no attempt is made to discuss species taxonomic or identification problems except where misidentification has caused problems with zone naming and subsequent identification. Instead, the reader is referred for species author citations for spore-pollen to Helby, Morgan & Partridge (1987), Dettmann (1963), Stover & Partridge (1973) or other references cited therein; and for microplankton to the indexes of Lentin & Williams (1993) and Fensome, *et al.*, (1990). Within the text and on the range charts species names followed by "ms" are unpublished manuscript names.

SPORE-POLLEN ZONES

Phyllocladidites mawsonii Zone – Helby *et al.*, 1987

The *P. mawsonii* Zone is shown on samples examined in this study to range through the type section of the Waarre Formation, the type section of the Flaxman Formation and into the basal part of what has been traditionally assigned to the Belfast Mudstone. It is not however associated with the type section of the Belfast Mudstone which is younger.

Although the base of the Waarre Formation in the three wells was not sampled extensively and the quality and results on the available samples was only fair, the results are consistent with the hypothesis that the base of the Waarre Formation is no older than the *P. mawsonii* Zone and is thus largely if not entirely Turonian in age. The hypothesis was first advanced following the analysis of the Iona-2 and Langley-1 wells (Partridge, 1994a, b). The precise age of the base depends on whether the base of the *P. mawsonii* Zone lies within the uppermost Cenomanian, a question which is impossible to answer on the evidence from the Otway Basin because of the presence of a major unconformity at the base of the Waarre Formation and lack of datable calcareous microfossil within the succession.

The assignment of the entire Waarre Formation to the *P. mawsonii* Zone is based on evidence, now available from several wells in the Port Campbell Embayment, that the key index species *Phyllocladidites mawsonii* and *Clavifera triplex*, which define the base of the zone, range down to the base of the Waarre Formation, even though they may not be recorded in every sample. Support for this interpretation is also provided by the assignment of the associated microplankton to the *P. infusorioides* Zone.

Difficulties exist with precisely picking the top of the *P. mawsonii* Zone. This depends on recording the first or oldest appearances of the key index species *Tricolporites apoxyexinus* and *Ornamentifera sentosa* which define the base of the overlying *T. apoxyexinus* Zone. In the Port Campbell Embayment the boundary between these zones lies within a distal and probably deep marine facies at the base of the Belfast Mudstone in which the spore-pollen assemblages are distorted by facies and/or palynomorph distributional problems such as the "Neves Effect" (Traverse, 1988). In this study, where the base ranges of the index species were only recorded in cuttings, no new evidence was obtained to verify or challenge the current cross-correlation between the microplankton and spores-pollen zones established in Helby *et al.* (1987). The uncertainty in the zone assignments is reflected in the low confidence ratings assigned to individual samples (Tables 2-4).

The former zones recorded over the intervals now assigned to the *P. mawsonii* Zone are discussed below:

Appendicisporites distocarinatus Zone — Dettmann & Playford, 1969
The original definition of the *A. distocarinatus* Zone by Dettmann & Playford (1969) was effectively the interval between the last or youngest occurrence of *Coptospora paradoxa* and the last or youngest occurrence of *Appendicisporites distocarinatus*. This was modified by Helby *et al.* (1987) following work that showed the oldest occurrences of both *Clavifera triplex* and *Phyllocladidites mawsonii* (which defined the base of the overlying *C. triplex* [now *P. mawsonii*] Zone) overlapped with the top range of *A. distocarinatus*.

The reference section for the *A. distocarinatus* Zone was given by Dettmann & Playford (1969) as Port Campbell-2 between 8096-8418 ft (cores 8 to 11 from original hole and core 15 from sidetrack hole) even though the index species *Appendicisporites distocarinatus* is not recorded in any of these cores on either of the early range charts by Dettmann (1964a) or Evans (1964) and is only recorded in this study in core-15 the deepest in the reference interval. It can only be assumed that Dettmann had examined additional material prior to selecting Port Campbell-2 as the designated reference section. This study of Port Campbell-2 shows that both *C. triplex* and *P. mawsonii* occur in core samples throughout the reference section effectively destroying its validity as a reference section for the original concept of the zone. The data from the closely sampled Langley-1 does however suggest that *A. distocarinatus* can occur consistently within the Waarre Formation (Partridge, 1996b).

The modified concept of the *A. distocarinatus* Zone used by Helby *et al.* (1987) appears to be exclusively Cenomanian in age and is not considered to be present in the Otway Basin. To avoid ongoing ambiguity it is recommended that both the origninal and revised concepts of the *A. distocarinatus* Zone be abandoned and replaced by another name. Further discussion of this nomenclature change is beyond the scope of this report.

Clavifera triplex Zone — Dettmann & Playford, 1969

The reference section for the original *C. triplex* Zone was given by Dettmann & Playford (1969) as Flaxmans-1 between [illegible] ft (cores 17 to 20). This includes section from the upper part of the Flaxman Formation, and the lower part of the Belfast Mudstone following the original concepts for these units. The section also includes, based on this study, the youngest part of the *P. infusorioides* Zone the entire *C. striatoconus* Zone and the lowest part of the *O. porifera* Zone. As a reference section it would represent only the youngest part of the modified *P. mawsonii* Zone and as well the shallowest samples from core17 in the reference section can now be reassigned to the *T. apoxyexinus* Zone based on the presence of *Latrobosporites ohaiensis* even though the eponymous species was not recorded.

Tricolporites apoxyexinus Zone — Helby *et al.*, 1987

Only the shallowest cores examined in Port Campbell 2 and Flaxmans-1 are assigned to this zone. In Port Campbell-1 two core and a cuttings sample from the type section for the Belfast Mudstone between 4925-5529 ft (Glenie, 1971) can be confidently assigned to the *T. apoxyexinus* Zone based on the presence of the eponymous species in all samples. The common to abundant occurrence of *Proteacidites* spp. from 7% to 20% in these sample is also considered to be characteristic of this zone. The designated reference section for the *T. pachyexinus* Zone (the prior name of the zone before nomenclature changes) in Flaxmans-1 between 4974-5970 ft (cores 8-16) were not sampled or analysed during this study.

MICROPLANKTON ZONES

Palaeohystrichophora infusorioides Zone — Helby *et al.*, 1987

The type sections for both the Waarre and Flaxman Formations as a result of this study can be confidently assigned to the *P. infusorioides* Zone and equally as confidently are largely Turonian in age. The base of the zone may extend down into the very uppermost Cenomanian and the top may range up into the basal Coniacian, but these are issues which cannot be resolved from the Otway Basin data.

In the Port Campbell Embayment the *P. infusorioides* Zone has a total diversity of over 30 marine dinoflagellate species. It conforms to the original observations in Helby *et al.* (1987) in that it is recognised on the negative evidence of the absence of index species for the underlying *D. multispinum* Zone and overlying *C. striatoconus* Zone. Sufficient new wells and samples have been examined in the Otway Basin since the publication of Helby *et al.* (1987) to be confident that the index species *Diconodinium multispinum, Pseudoceratium ludbrookiae, Canninginopsis denticulata* and *Litosphaeridium siphoniphorum* whose last occurrences define the top of the *D. multispinum* Zone are not present in the Otway Basin. Therefore, the base of the Sherbrook Group, everywhere that it has been drilled to date, is younger than the *D. multispinum* Zone and therefore considered younger than the Cenomanian. The top of the *P. infusorioides* Zone is even more confidently defined on the oldest occurrences of *Conosphaeridium striatoconus* which is recorded in the Otway Basin.

Within the *P. infusorioides* Zone two as yet informal subzones are recognised and discussed below:

Cribroperidinium edwardsii Acme Zone
The *C. edwardsii* Acme Zone is found in the lower part of the Waarre Formation (Units A and B of Buffin, 1989) and is typically characterised by assemblages with low microplankton abundance (<10% relative to spore-pollen) in which *Cribroperidinium edwardsii* is the dominant species representing over 15% of all microplankton and often over 30%. *Palaeoperidinium cretaceum* and *Odontochitina operculata* are characteristic accessory species. Although *C. edwardsii* has been recorded in the Waarre Formation above its acme its occurrence is inconsistent and abundance low. *Cribroperidinium edwardsii* is also recorded from the Flaxman Formation but its occurrence is so sporadic it is considered highly likely that it represents reworking of the occurrence acme found in the Waarre Formation.

The *C. edwardsii* Acme is best documented in Langley-1 (Partridge, 1994b). It was recorded in this study only in the deepest cores examined in Port Campbell-2 and Flaxmans-1 and is considered not to be penetrated in Port Campbell-1. Because of the poor quality of the electric logs makes it is difficult to confidently identify Buffin's Units A, B and C in these three early wells it is not possible to confirmed the lithological association.

Kiokansium polypes Subzone
The base of this zone is defined by the oldest local occurrence of *Valensiella griphus* and the top by the youngest local occurrence of *Kiokansium polypes* and *V. griphus*. As so defined its limits in Port Campbell-2 closely approximate the type section of the Flaxman Formation designed between 7676-8184 ft (Glenie, 1971).

Applying this zone criteria to Port Campbell-1 suggests there is less than 50 feet of section time equivalent to the Flaxman Formation. The interval involved certainly extends from the cuttings at 5640-50 ft to top of Waarre sands at 5655 ft (ie15 feet) but may extend as shallow as 5610-20 ft. This latter cuttings containing the shallowest occurrence of *K. polypes*, in association with *C. striatoconus*, and has been assigned to the *C. striatoconus* Zone. It may however be slightly older if *C. striatoconus* is interpreted as caved.

In Flaxmans-1 the correlation is less clear. The *K. polypes* Subzone is clearly present at the top of the Flaxman Formation in cores-18 to 19 between 6606-6626 ft, but the cuttings analysed below these cores between 6690-6870 ft are badly contaminated by down-hole cavings and cannot be confidently interpreted. Note also that all the material from core-21 is caved due to an error in measuring the drill string when cutting this core. In the well completion report this core is recorded as no recovery. Based on the gamma log character the preferred pick for the base of the Flaxman Formation is at 6750 ft considerably above the pick by Glenie (1971) at 6878 ft. Based on the occurrence of the *C. striatoconus* Zone in cuttings at 6590-6600 ft the top of the Flaxman Formation is picked 6600 ft considerably below the pick by Glenie (1971) at 6510 ft. The net reduction in thickness is from 368 feet to 150 feet. This thickness, and the less than 50 feet thickness in Port Campbell-1, contrast markedly with the 508 feet of the Flaxman Formation in the type section.

The microplankton in the interval between the base of the *K. polypes* Subzone and top of the *C. edwardsii* Acme representing the upper part of the Waarre Formation are as yet too poorly characterised to propose a suitable subzone name. Both *Heterosphaeridium* spp. and *Amosopollis cruciformis* increase in abundance in this interval but as these feature are partly facies related it is considered unsatisfactory to name the interval after either. The only species currently identified as having a First Appearance Datum (FAD) within this interval is *Isabelidinium* sp. cf. *I. glabrum,* which is probably the species previously identified as *Ascodinium parvum*. The taxonomic problems with this identification are briefly discussed below. For the purposes of the tables in this report the unclassified interval is referred to as the *Isabelidinium* sp. Subzone.

Ascodinium parvum Zone — Evans, 1966 & 1971

The *A. parvum* Zone was originally defined by Evans (1966) in an unpublished but widely circulated BMR Record. The formal publication of the same work is Evans (197[illegible] [illegible]e zone was originally only recognised in three wells. In Port Campbell-2 it was specifi[illegible] occurring between 5660-5708 ft (cores 6-8) over the type section of the Flaxman Formation. In Port Campbell-1 it was recorded over the interval 7606-8102 ft (cores–22 & 23) in the Waarre Formation even though the index species *Ascodinium parvum* was not recorded. It was also recorded in Geltwood Beach-1 in South Australia but that occurrence has not been reviewed for this report.

Ascodinium parvum can be distinguished by its distinctive outline with a single antapical horn and its combination archeopyle involving both intercalary and apical paraplates. The only problem is that the characteristic archeopyle has not been identified on any specimens in any of the samples in this study or in any other palynological studies on new wells drilled in the Port Campbell Embayment over the last five years. The specimen illustrated by Evans (1966, pl.2, fig.6) from the Otway Basin also does not show the characteristic archeopyle morphology. It therefore must be concluded that *A. parvum*, which was originally described from the Albian? in the Perth Basin, has been misidentified in the Otway Basin.

The species that was being identified as *A. parvum* is here considered to be a undescribed species of *Isabelidinium* with a simple intercalary archeopyle. It is similar to *I. acuminatum* but lacks the apical horn on the endocyst that makes that species so characteristic. In this report it is recorded as *Isabelidinium* sp. cf. *I. glabrum*. It may however be the same species that Roger Morgan has identified as the European species *Isabelidinium cooksoniae* (Alberti, 1959) Lentin & Williams, 1977. Morgan's records are from open file basic data from recent wells in the offshore portion of the Port Campbell Embayment and the palynological slides from these wells have not yet been examinated by the author to confirm or refute this comparison.

Isabelidinium sp. cf. *I. glabrum* on available data is first recorded within the Waarre Formation above the *C. edwardsii* Acme and ranges through the Flaxman Formation to the top of the *P. infusorioides* Zone. It is not confidently identified from the *C. striatoconus* or younger Zones.

Conosphaeridium striatoconus Zone — Helby *et al.*, 1987
The highly distinctive zone index *Conosphaeridium striatoconus* occurs over what appears to be only a very thin interval in each of the three wells. As this thin zone occurs above the type section of the Flaxman Formation in Port Campbell-2 it is also considered to lie above the Flaxman Formation in the other two wells and the top of the formation needs to be adjusted accordingly.

Anomalous occurrences of *C. striatoconus* due to down-hole cavings which have accumulated at the top of the core barrels have been largely responsible for the confusion surrounding the precise age of the Flaxman Formation. The occurrence which originally caused the most confusion was the record of *C. striatoconus* from core-21 (6832-38 ft) in Flaxmans-1 by both Stacy (1981) and Morgan (1986). As the well completion report states that core-21 was not recovered the source of this sample could not initially be explained. However, checking the daily drilling reports for Flaxmans-1 confirmed that core-21 had indeed been cut and fully recovered, but, because a measurement error on the drill string, had been cut above the then T.D. for the well. Checking the actual core preserved at the department of Energy and Minerals Victoria core store confirmed that it was composed of a breccia of rounded pebbles of hard mudstone and the original interpretation that the core was entirely composed of caved material was confirmed. As similar interpretation is possible for the record of *C. striatoconus* from core-23 at 5700-10 ft in Port Campbell-1 by Evans (1964; fig.8). The original lithological description and subsequent inspection of this core confirms it belongs to the Waarre Formation and the new palynology sample analysed gave a older age without any evidence of younger contamination from the *C. striatoconus* Zone. A third caved occurrence of the *C. striatoconus* Zone was recorded by the author in the Port Campbell-2 well from the sample analysed by Stacy (1981) from core-10 at 8306-11 ft. This sample contained *Conosphaeridium tubulosum* and again is interpreted as derived from the cobbles of glauconitic mudstone recovered from the top foot of the core. The remainder of the core is good quartz sandstone typical of the Waarre Formation and is clearly unsuitable for palynology.

The only early record of *C. striatoconus* whose in situ occurrence is confirmed here is that of Cookson (1965) who recorded the species from Port Campbell-2 between core-4 at 7403-08 ft and cuttings at 7440-50 ft.

Odontochitina porifera Zone — Helby *et al.*, 1987
This zone is identified in one sample from each of the three wells and in each it is characterised by the frequent to common occurrence of *Chatangiella tripartita* usually in association with the zone species *Odontochitina porifera* or the closely related *O. cribropoda*.

Isabelidinum cretaceum Zone — Evans 1966 & 1971
This zone was only recorded from the Port Campbell-1 well in this study where it occurs throughout the type section for the Belfast Mudstone. It is identified by the presence of a narrowly defined concept of the eponymous species *Isabelidinium cretaceum* which is closely similar to the holotype with separate apical and antapical pericoels (eg. Helby *et al.*, 1987; fig.42L). As so defined the zone has been found to be more restricted in its distribution in these wells than recorded by either Evans (1966) or Stacy (1981).

Palaeoenvironments

In this review of the type sections of the Waarre, Flaxman and Belfast Formations all samples were found to contained marine dinoflagellates and therefore it is reasonable to conclude that all formations are largely if not entirely marine.

The Waarre Formation contains the only possible non-marine environments in the sequence. These are the carbonaceous partings to possible thin coal seams reported in the cuttings but not seen in the cores, and probably some of the quartz sandstones which have not been analysed for palynology because of their unsuitable lithology. All samples that were analysed contained marine microplankton (mostly dinoflagellates) with abundances ranging from less than 1% to nearly 30% and diversities typically ranging between 5 to 10 species per sample. Also the upper part of the Waarre Formation can contain significant abundance of the fresh to brackish water algal cyst *Amosopollis cruciformis* which may be significantly more abundant than all the marine microplankton. The highest abundance recorded was 38% in core-25 (6902-13ft) in Flaxmans-1.

Samples analysed from the overlying Flaxman Formation and Belfast Mudstone show a significant increase in both abundance and diversity of marine microplankton. The exception are low yielding sample in which the assemblage counts are considered unreliable. In all samples the marine dinoflagellates are more abundant than the algal cyst *Amosopollis cruciformis*. In the three wells studied these two younger formations represent more distal and deeper water environments than the underlying Waarre Formation.

Stratigraphy

This section is summarised the impact of the new palynological results on the age and depositional environment of the type sections. Recommendations are also made on how the correlation and application of the formation names can be improve.

WAARRE FORMATION

The Waarre Formation is argued to lie entirely within the *P. mawsonii* and *P. infusorioides* Zones and for all practical purposes to be entirely Turonian in age and not Cenomanian as previously recorded. The environment of deposition of the fine grained clastic mudstones, shales and siltstones through the formation seem to be always marine, or at least in this part of the Port Campbell Embayment. On lithology the Waarre Formation can be characterised by its quartz sandstone beds and carbonaceous partings and perhaps even thin coal seams. If the top of the type section in Port Campbell-2 was changed from 8184 ft to the shallower depth of ~8145 ft as suggested by the palynological evidence the carbonaceous layers near the base of the type section of the Flaxman Formation would be excluded from the latter formation, thus removing a source of confusion concerning the lithological distinction between the two units.

In Flaxmans-1 the top of the Waarre Formation is raised to 6750 ft to the top of the sands based on the gamma log. Cavings over the interval 6750-6878 ft are considered to mask the sands and give a false base to the Flaxman Formation. This interpretation is supported by the largely caved assemblages obtained from the palynological analysis. In Port Campbell-1 the top of the Waarre Formation is unchanged at 5655 ft.

The palynological analysis also suggests the presence of two microplankton subzones within the Waarre Formation with the potential to provide biostratigraphic subdivision and improved correlation of the unit. A similar subdivision is believed to be possible on the spore-pollen but this could not be convincingly demonstrated on the samples examined in this study. These palynological subdivisions also seem to have some correlation with the lithological subdivision of the Waarre Formation proposed by Buffin (1989).

FLAXMAN FORMATION

It is found in this study that the type section of the Flaxman Formation could be characterised by a distinct microplankton assemblage which could be recognised in the other two wells. The microplankton assemblage is referred to as the *K. polypes* Subzone of the *P. infusorioides* Zone. The zone is late Turonian in age but could possibly extend into the Coniacian. The time duration of the subzone and also of the formation is believed to be relatively short.

The lithology of the Flaxman Formation can be distinguished as a dark grey mudstone to with floating quartz sand or quartz pebbles or with minor fine sandstone laminae. The formation is not conspicuously carbonaceous like the underlying Waarre Formation and the occurrence of glauconite in the unit seems to be irregular, but certainly commoner towards the top of the formation.

Core-8 (8096-8110 ft) from the base of the type section in Port Campbell-2 is a highly characteristic massive homogeneous silty mudstone with up to 15% well rounded quartz pebbles which are up to 15mm in diameter and float without touching in the mudstone. The cuttings at about this level are also characteristic consisting of mudstone with a small percentage of broken shards of large quartz pebbles. When the underlying Waarre is penetrated the character of the quartz and pebbles in the cuttings change as they are loose and whole and not broken or shattered. As the Port Campbell-2 is the thickest section of the Flaxman Formation in the local area the pebbly mudstone lithology could be interpreted as a local Low Stand System Tract deposit. Because the quartz pebbles and sand in the mudstone get rarer and finer higher up in the formation it is suggested they are being reworked from the Waarre Formation and are evidence of a significant unconformity at the top of the Waarre.

The only other sand seen in the Flaxman Formation is the ferruginous sandstone found between 6600-6650 ft in Flaxmans-1. This unit does not appear to be present in the other two wells. However, the high abundance of *Cupressacites* sp. pollen recorded from core-18 (6606-10 ft) and core-20 (6626-36 ft) is considered to be characteristic and provides a correlation to about the level of core-13 (7683-94 ft) in Port Campbell-2. In Port Campbell-1 the Flaxman Formation is too thin and condensed to provide adequate resolution but red-brown fine grained sandstone to siltstone was recorded in the cuttings between 5610-50 ft.

In Port Campbell-2 the type section is redefined as between 7676 ft to 8145 ft. In Flaxmans-1 the Flaxman Formation is redefined as 6600 ft to 6750 ft, while in Port Campbell-1 it probably extends from within the cuttings interval 5610-20 ft to 5655 ft.

BELFAST MUDSTONE

In the defined type section of the Belfast Mudstone between 4925 ft to 5529 ft in Port Campbell-1 both the cores and cuttings are a characteristic dark green to black mudstone with abundant sand size glauconite. The now well dried cuttings in the core store consist essentially of black powder (the mudstone) and black sand (the glauconite). The palynological assemblages from the cores (the cuttings assemblages are distorted by cavings) are characterised by spore-pollen assemblages dominated by the gymnosperm pollen broadly assigned to *Podocarpidites* and *Dilwynites* and their high abundance can be taken as manifestation of the "Neves effect" (Traverse, 1988). These are associated with abundant and diverse marine microplankton. The overall palynological and lithological character is of a distal marine condensed section.

At the type locality the Belfast Mudstone on the samples analysed is restricted to the *I. cretaceum* microplankton Zone and upper part of the *T. apoxyexinus* spore-pollen Zone making it mid to late Santonian in age (Helby *et al.*, 1987). Away from the type locality the Belfast Mudstone has been broadly applied to any thick section of fine grained clastics ranging in age from Turonian to Campanian. Many of these shales or mudstones on the evidence of the palynology are not always contiguous with shales the same age as the type locality.

In the three wells under review the Belfast Mudstone has been extended down to include section in both Port Campbell-2 and Flaxman-1 containing the older *O. porifera* and *C. striatoconus* Zones which are broadly of early Santonian to the Coniacian age. The lithologies however are not the exactly the same. The *O. porifera* Zone samples seem to be typically non-glauconitic mudstones while the underlying *C. striatoconus* Zone sees a return to glauconitic mudstone. A similar change is seen in the sidewall cores in Langley-1 (Partridge, 1994b). While a similar distal marine environment to the type section is indicated by both the lithologies and palynological assemblages there does seem to be sufficient differences in the lithological and palaeontological content to investigate further the possibility of separating these stratigraphic older sections from the Belfast Mudstone and establishing one or more new stratigraphic units. Further discussion of this recommendation is beyond the scope or intent of this report.

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Table–2: Interpretative Palynological Data for Port Campbell-1.

Sample Type	Depths	Spore-Pollen (Microplankton) Zones	CR*	Comments and Key Species Present
Core-20	5026–31ft 1531.9–33.4m	*T. apoxyexinus (I. cretaceum)*	A2 A2	Microplankton 21% *Amosopollis cruciformis* not recorded in count. *Proteacidites* spp. 20%.
Core-21	5223–33ft 1592–95m	*T. apoxyexinus (I. cretaceum)*	A2 A2	Microplankton 23% *Amosopollis cruciformis* <1%. *Proteacidites* spp. ~12.5%. *Forcipites stipulatus* present.
Cuttings	5510–20ft 1679.4–82.5m	*T. apoxyexinus (I. cretaceum)*	D1 D2	Microplankton 21%. *Amosopollis cruciformis* 4%. *Proteacidites* spp. ~7%. *Isabelidinium cretaceum* with *Odontochitina cribropoda* suggests lower part of zone.
Cuttings	5540–49ft 1688.6–91.3m	*O. porifera*	D2	Microplankton 15%. *Amosopollis cruciformis* 9%. *Proteacidites* spp. <1%. *Cupressacites* sp. ~8%. LAD for *C. tripartita* suggests lower part of zone. Spore-pollen zone uncertain.
Cuttings	5610–20ft 1709.9-13m	*P. mawsonii (C. striatoconus)*	D4 D2	Microplankton 15%. *Amosopollis cruciformis* 11%. *Proteacidites* spp. <2%. *Cupressacites* sp. 11%. LADs for *Conosphaeridium striatoconus* and rare *Kiokansium polypes*
Cuttings	5640–50ft 1719.1–22.1m	*P. mawsonii (C. striatoconus* and *K. polypes* Subzone of *P. infusorioides)*	D4 D2	Microplankton 27%. *Amosopollis cruciformis* 6%. *Proteacidites* spp. <3%. *Cupressacites* sp. 5%. Mixed assemblage containing *C. striatoconus, K. polypes* and *Valensiella griphus* which suggests condensed section involving two zones at base of shale sequence.
Core-23	5700–18ft 1737.4–42.8m	*P. mawsonii (P. infusorioides* and *Isabelidinium* sp. Subzone)	A1 A2	Microplankton 13%. *Amosopollis cruciformis* 10%. *Cupressacites* sp. 5%. This core is equivalent to Waarre Formation on both lithology and palynology. Record of *C. striatoconus* in this core by Evans (1962) is interpreted as either caved material from top of core, laboratory contamination or drafting error on range chart.
Core-24	5928–34ft 1806.9–08.7m	*P. mawsonii (P. infusorioides)*	A4 A3	Microplankton 8%. *Amosopollis cruciformis* 4.5%. *Cribroperidinium edwardsii* recorded from sample but is rare on slides. The *C. edwardsii* Acme has probably not been penetrated.

Table-3: Interpretative Palynological Data for Port Campbell-2.

Sample Type	Depths	Spore-Pollen (Microplankton) Zones	CR*	Comments and Key Species Present
*Core-12	7093–103ft 2161.9–65m	*T. apoxyexinus* (*O. porifera*)	A4 A3	Microplankton 30%. *Amosopollis cruciformis* 11% *Chatangiella tripartita* >35% of microplankton. *Latrobosporites amplus* present.
Core-4	7403–09ft 2256.4–58.3	*P. mawsonii* (*C. striatoconus*)	A4 A3	Microplankton 23%. *Amosopollis cruciformis* 26%. Spore-pollen count low not diagnostic.
*Cuttings	7610–20ft 2319.5–22.6m	*P. mawsonii* (*C. striatoconus*)	D4 D2	Microplankton 26%. *Amosopollis cruciformis* 7%. *Proteacidites* spp. <2%. FAD of *Clavifera vultuosus* ms.
*Core-13	7683–94ft 2341.8–45.1m	*P. mawsonii* (*P. infusorioides* Subzone uncertain)	A4 A5	Microplankton 9%. *Amosopollis cruciformis* 10%. *Cupressacites* sp. 12% LAD of *Cyatheacidites tectifera*.
*Cuttings	7800–10ft 2377.4–80.5m	*P. mawsonii* (*P. infusorioides* *K. polypes* Subzone)	D4 D2	Microplankton 21%. *Amosopollis cruciformis* 10%. LADs for *Kiokansium polypes* and *Valensiella griphus* within type section for Flaxman Formation
Core-5	7885–97ft 2403.3–07.0m	*P. mawsonii* (*P. infusorioides* *K. polypes* Subzone)	A4 A2	Microplankton 37%. *Amosopollis cruciformis* 3%. *Cupressacites* sp. ~2%.
*Cuttings	7890–7900ft 2404.9–07.9m	*P. mawsonii* (*P. infusorioides* Subzone uncertain)	D4 D4	Microplankton 26%. *Amosopollis cruciformis* 5%. *Cupressacites* sp. <7%.
Core-6	7904–13ft 2409.1–11.9m	*P. mawsonii* (*P. infusorioides* *K. polypes* Subzone)	A1 A2	Microplankton 24%. *Amosopollis cruciformis* 3%. *Cupressacites* sp. ~9%.
Core-7	7913–30ft 2411.9–17.1m	*P. mawsonii* (*P. infusorioides* *K. polypes* Subzone)	A1 A2	Microplankton 27%. *Amosopollis cruciformis* 6%. *Cupressacites* sp. ~2%. *Palaeohystrichophora infusorioides* dominates microplankton assemblage.
*Cuttings	7960–70ft 2426.2–29.3m	*P. mawsonii* (*P. infusorioides* with caved species from *C. striatoconus* and younger zones)	D4 D5	Microplankton 20%. *Amosopollis cruciformis* 5%. Significant cavings occur in assemblage making it difficult to characterise this part of Flaxman Formation.

*Cuttings	8050–60ft 2453.6–56.7m	*P. mawsonii* (*P. infusorioides* *K. polypes* Subzone)	D5 D2	Microplankton 42%. *Amosopollis cruciformis*3%. *Heterosphaeridium*spp. at >35% dominates microplankton assemblage. *Cupressacites*sp. <1%.

Table-3. Interpretative Palynological Data for Port Campbell-2. cont...

Sample Type	Depths	Spore Pollen (Microplankton) Zones	CR*	Comments and Key Species Present
Core-8	8096-110ft 2467.7-71.9m	*P. mawsonii* (*P. infusorioides* *K. polypes* Subzone)	A4 A2	Microplankton 47%. *Amosopollis cruciformis* 8%. *Heterosphaeridium* spp. at >30% dominates microplankton assemblage. *Cupressacites* sp. ~6%.
*Cuttings	8155-60ft 2485.6-87.2m	*P. mawsonii* (*P. infusorioides* Subzone indeterminate)	D5 D5	Microplankton ~10%. *Amosopollis cruciformis* <4%. Palynomorphs are rare in sample and poorly preserved, and count therefore considered to have low reliability. As cuttings contains first downhole appearance of finely laminated carbonaceous sandstone (laminae ²1mm) and coal fragments this is interpreted as top of Waarre Formation.
Core-9	8174-88ft 2491.4-95.7m	*P. mawsonii* (*P. infusorioides* Possible *Isabelidinium* sp. Subzone)	A5 A5	Palynomorphs were very rare and poorly preserved making assemblage count unreliable. Lithology consists of mottled (bioturbated) muddy siltstone to sandstone with plant fragments but no pebbles.
Core-11	8339-46ft 2541.7-43.9m	*P. mawsonii* (*P. infusorioides*)	A1 A3	Microplankton 6%. *Amosopollis cruciformis* 9%. Sample from shale which is possibly derived from caved material at top of core.
*Core-15	8409-18ft 2563.1-65.8m	*P. mawsonii* (*P. infusorioides*)	A1 A3	Microplankton <<1%. *Amosopollis cruciformis* <<1%. Presence of *Laevigatosporites musa* ms and *Rugulatisporites admirabilis* ms are diagnostic index species for Waarre Formation. Single specimen of algae *Wuroia tubiformis* recorded.
*Core-16	8556-70ft 2607.9-12.1m	*P. mawsonii* (*P. infusorioides* *C. edwardsii* Acme)	A2 A3	Microplankton 15%. *Amosopollis cruciformis* <<1%. *Cribroperidinium edwardsii* represents >50% of microplankton.

Note: Cores and cuttings marked with asterisks are from Sidetrack hole.

Table-4: Interpretative Palynological Data for Flaxmans-1.

Sample Type	Depths	Spore-Pollen (Microplankton) Zones	*CR	Comments and Key Species Present
Core-17	6375-91ft 1944.6-46.1m	*T. apoxyexinus* *(O. porifera)*	A3 A3	Microplankton 18%. *Amosopollis cruciformis* 20%. Frequent *Chatangiella tripartita* *Latrobosporites ohiaensis* present.
Cuttings	6520-30ft 1987.3-90.3m	Indeterminate		Microplankton 55%. *Amosopollis cruciformis* 3%. Cuttings dominated by caved microplankton.
Cuttings	6590-600ft 2008.6-11.7m	*P. mawsonii* *(C. striatoconus)*	D4 D1	Microplankton 25%. *Amosopollis cruciformis* 5%. *Proteacidites* spp. 5% and *Cupressacites* sp. 4%.
Cuttings	6600-10ft 2011.7-14.7m	Indeterminate		Low recovery sample with <50 specimens recorded on all slides. Count not reliable.
Core-18	6606-16ft 2013.5-16.6m	*P. mawsonii* *(P. infusorioides* and *K. polypes* Subzone)	A2 A3	Microplankton 21%. *Amosopollis cruciformis* 4% *Cupressacites* sp. 25%.
Core-19	6616-26ft 2016.6-19.6ft	*P. mawsonii* *(P. infusorioides* and *K. polypes* Subzone)	A4 A3	Microplankton <10%. Yield low, with abundance distorted/biased by low count of only 41 specimens.
Core-20	6626-36ft 2019.6-22.7ft	*P. mawsonii* *(P. infusorioides* and *K. polypes* Subzone)	A2 A2	Microplankton 35%. *Amosopollis cruciformis* 4% *Cupressacites* sp. 14%.
Cuttings	6690-6700ft 2039.1-42.2m	*P. mawsonii* *(P. infusorioides* *K. polypes* Subzone)	D4 D4	Microplankton 26% dominated by *Heterosphaeridium* spp. 55%. of microplankton. *Amosopollis cruciformis* <1%. *Cupressacites* sp. 9%.
Cuttings	6740-50ft 2054.4-57.4m	*P. mawsonii* *(P. infusorioides* and *K. polypes* Subzone)	D4 D4	Microplankton 17.5%. *Amosopollis cruciformis* 1.4%.
Cuttings	6800-10ft 2072.6-75.7m	*P. mawsonii* *(P. infusorioides* and *K. polypes* Subzone)	D4 D4	Microplankton 33%. *Amosopollis cruciformis* 4.7%. Common caved dinoflagellates.
Core-21	6832-38ft 2082.4-84.2m	*P. mawsonii* *(C. striatoconus)*	A2 A2	Microplankton 9%. *Amosopollis cruciformis* 17%. Core-21 sample CAVED from above 6600ft (2012m)
Cuttings	6860-70ft 2090.9-94.0m	*P. mawsonii* *(P. infusorioides* *K. polypes* Subzone)	D5 D4	Microplankton 37%. *Amosopollis cruciformis* 6%. Caved dinoflagellates common.

Table–4: Interpretative Palynological Data for Flaxmans-1.

Sample Type	Depths	Spore-Pollen (Microplankton) Zones	*CR	Comments and Key Species Present
Core-22A	6871–78ft 2994.3-96.4m	*T. apoxyexinus* *(N. aceras)*	A2 A3	Microplankton 44%. *Amosopollis cruciformis* <1%. Core sample CAVED from higher in well.
Core-22B	6871–77ft 2094.3-96.1m	*P. mawsonii* *(P. infusorioides* and *Isabelidinium* sp. Subzone)	A1 A2	Microplankton 29%. *Amosopollis cruciformis* 24%. *Heterosphaeridium* spp. and *K. polypes* are dominant dinoflagellates.
Core-25	6902–13ft 2103.7-07.1m	*P. mawsonii* *(P. infusorioides* and probable *Isabelidinium* sp. Subzone)	A4 A3	Microplankton 15%. *Amosopollis cruciformis* 38%. *Heterosphaeridium* spp. and *Palaeohystrichophora infusorioides* are dominant dinoflagellates.
Core-27	7200–20ft 2194.6-200.7m	*P. mawsonii* *(P. infusorioides* *C. edwardsii* Acme)	A4 A3	Microplankton 12%. *Amosopollis cruciformis* 1%. *Cribroperidinium edwardsii* and *Palaeoperidinium cretaceum* are dominant dinoflagellates.

Confidence Ratings

The Confidence Ratings assigned to the zone identifications on Table-2 are quality codes used in the STRATDAT relational database being developed by the Australian Geological Survey Organisation (AGSO) as a National Database for interpretive biostratigraphic data. Their purpose is to provide a simple relative comparison of the quality of the zone assignments. The alpha and numeric components of the codes have been assigned the following meanings:

Alpha codes: Linked to sample type

A	Core
B	Sidewall core
C	Coal cuttings
D	Ditch cuttings
E	Junk basket
F	Miscellaneous/unknown
G	Outcrop

Numeric codes: Linked to fossil assemblage

1	Excellent confidence:	High diversity assemblage recorded with key zone species.
2	Good confidence:	Moderately diverse assemblage recorded with key zone species.
3	Fair confidence:	Low diversity assemblage recorded with key zone species.
4	Poor confidence:	Moderate to high diversity assemblage recorded without key zone species.
5	Very low confidence:	Low diversity assemblage recorded without key zone species.

BASIC DATA

Table–5: Basic Sample Data—Port Campbell–1.

Sample Type	Depths	Lithology	Residue Yield	Palynomorph Concentration	Palynomorph Preservation	Number S-P Species	Microplankton Abundance	Number MP Species
Core-20	5026-31ft 1531.9-33.4m	Dark green to black, glauconitic mudstone.	Low	Low	Poor	25+	Abundant 21%	13+
Core-21	5223-33ft 1592-95m	Dark green to black mudstone containing sand size glauconitic.	Low	Low	Poor-good	23+	Abundant 23%	11+
Cuttings	5510-20ft 1679.4-82.5m	Dark green-black fine grained glauconite (~80%) and dark grey mudstone (~20%).	Moderate	Moderate	Fair	39+	Abundant 25%	17+
Cuttings	5540-49ft 1688.6-91.3m	Medium grey mudstone without visible glauconite.	High	Moderate	Fair-good	40+	Abundant 24%	18+
Cuttings	5610-20ft 1709.9-13m	Medium grey mudstone with secondary fine grained glauconite in the finer portion of the cuttings, and a trace of red-brown fine grained sandstone.	High	Moderate	Fair	35+	Abundant 26%	17+
Cuttings	5640-50ft 1719.1-22.1m	Red-brown siltstone to fine grained sandstone 60%; medium grey siltstone to mudstone 40%.	High	Moderate	Fair	38+	Abundant 33%	26+
Core-23	5700-18ft 1737.4-42.8m	Medium grey mudstone with irregular sandstone layers or lenses 1-5mm thick.	High	High	Fair-good	36+	Abundant 23%	15+
Core-24	5928-34ft 1806.9-08.7m	Dark grey, hard, carbonaceous and pyriti mudstone.	Moderate	Low	Poor	21+	Common 12%	6+

Table-6: Basic Sample Data—Port Campbell-2.

Sample Type	Depths	Lithology	Residue Yield	Palynomorph Concentration	Palynomorph Preservation	Number S-P Species	Microplankton Abundnace	Number MP Species
Core-12	7093-103ft 2161.9-65m	Dark grey to brown micaceous, pyritic mudstone, not glauconitic.	Low	Low	Poor	21+	Abundant 40%	8+
Core-4*	7403-09ft 2256.4-58.3	Brittle dark grey shale with red-brown nodules of harder mudstone.	Moderate	Low	Poor	16+	Very Abundant 49%	6+
Cuttings	7610-20ft 2319.5-22.6m	Medium-dark grey mudstone.	Moderate	Moderate	Poor-fair	26+	Abundant 33%	18+
Core-13	7683-94ft 2341.8-45.1m	Massive dark grey mudstone with ~10% brown glauconite.	High	Low	Poor	21+	Abundant 19%	10+
Cuttings	7800-10ft 2377.4-80.5m	Medium grey shale.	Moderate	Moderate	Poor	30+	Abundant 31%	22+
Core-5*	7885-97ft 2403.3-07.0m	Dark grey-black massive/heavy mudstone with ~10% brown glauconite.	Moderate	Low	Poor	19+	Abundant 42%	16+
Cuttings	7890-7900ft 2404.9-07.9m	Dark grey shale 95%; and siltstone 5%.	High	Moderate	Fair	25+	Abundant 31%	14+
Core-6*	7904-13ft 2409.1-11.9m	Medium-dark greenish grey, very fine to fine matrix supported sandstone. No obvious glauconite.	Moderate	Moderate	Poor	34+	Abundant 27%	24+
Core-7*	7913-30ft 2411.9-17.1m	Dark greenish-grey v.fine to fine grained hard sandstone (greywacke) with rare patches of glauconite.	High	Low	Poor	27+	Abundant 33%	17+

Cuttings	7960-70ft 2426.2-29.3m	Medium grey siltstone 70% and fine grained sandstone 30%.	High	Moderate	Fair	24+	Abundant 25%	13+
Cuttings	8050-60ft 2453.6-56.7m	Medium grey siltstone 80% and dark grey claystone 20%.	High	Low	Fair	12+	Abundant 45%	19+

Table–6: Basic Sample Data—Port Campbell-2.

Sample Type	Depths	Lithology	Residue Yield	Palynomorph Concentration	Palynomorph Preservation	Number S-P Species	Microplankton Abundnace	Number MP Species
Core-8*	8096-110ft 2467.7-71.9m	Medium grey siltstone with ~15% floatin quartz pebbles up to 15mm size.	High	Moderate	Poor	22+	Abundant 55%	16+
Cuttings	8155-60ft 2485.6-87.2m	Light grey finely laminated coally sandstone 50%; and dark grey siltstone to mudstone 50%.	High	Very low	Very poor	9+	Common ~10%	3+
Core-9*	8174-88ft 2491.4-95.7m	Mottled-bioturbated muddy carbonaceous siltstone to sandstone. No pebbles.	High	Very low	Very poor	7+	Common	7+
Core-11*	8339-46ft 2541.7-43.9m	Light grey carbonaceous siltstone.	Low	Moderate	Fair	29+	Common 15%	8+
Core-15	8409-18ft 2563.1-65.8m	Dark grey to brown carbonaceous mudstone.	High	Moderate	Poor	24+	Rare <1%	5+
Core-16	8556-70ft 2607.9-12.1m	Dark grey to greenish grey silty mudstone.	High	Low	Poor–fair	20+	Common 15%	9+

*Cores 4–11 from original hole; Cores 12–16 and cuttings from Sidetrack hole

Table–7: Basic Sample Data—Flaxmans-1.

Sample Type	Depths	Lithology	Residue Yield	Palynomorph Concentration	Palynomorph Preservation	Number S-P Species	Microplankton Abundance	Number MP Species
Core-17	6375-91ft 1944.6-46.1m	Dark grey mudstone with ~5% very fine to fine grained glauconite pellets.	Moderate	Low	Fair	28+	Abundant 38%	12+
Cuttings	6520-30ft 1987.3-90.3m	Dark grey shale 60%; and brown grey siltstone 40%.	High	Very low	Fair	10+	Very abundant 58%	13+
Cuttings	6590-600ft 2008.6-11.7m	Dark grey shale 90%; and grey siltstone 10%.	High	High	Fair	35+	Abundant 30%	27+
Cuttings	6600-10ft 2011.7-14.7m	Dark grey shale 60%; and dark grey siltstone 40%.	Moderate	Very low	Poor-fair	7+	Common	7+
Core-18	6606-16ft 2013.5-16.6m	Dark brown to green medium-coarse grained quartz sandstone.	Very low	Very low	Poor-good	19+	Abundant 25%	8+
Core-19	6616-26ft 2016.6-19.6ft	Dark greyish brown coarse grained sandstone with ~10% pebbles and limonitic matrix.	Very low	Very low	Poor-good	12+	Common <10%	3+
Core-20	6626-36ft 2019.6-22.7ft	Brown grey-green grey coarse sandstone with ~2% pebbles and limonitic matrix.	Very low	High	Good	19+	Abundant 39%	20+
Cuttings	6690-6700ft 2039.1-42.2m	Medium grey siltstone 50%; caved? dark grey shale 40%; and caved limestone 10%.	High	High	Fair-good	43+	Abundant 27%	32+
Cuttings	6740-50ft 2054.4-57.4m	Medium grey siltstone 60%; caved? dark grey shale 35%; and caved limestone 5%.	High	Moderate	Fair-good	30+	Common 19%	17+
Cuttings	6800-10ft 2072.6-75.7m	Medium grey siltstone 70%; fine-coarse quartz sandstone 15%; and caved? dark grey shale 15%.	High	High	Poor-fair	33+	Abundant 37%	27+

Core-21	6832-38ft 2082.4-84.2m	Dark grey mudstone–shale and rounded pebbles of hard mudstone. Core all broken into pieces <4cm.	Low	Moderate	Poor	22+	Abundant 26%	13+

Table–7: Basic Sample Data—Flaxmans-1.

Sample Type	Depths	Lithology	Residue Yield	Palynomorph Concentration	Palynomorph Preservation	Number S–P Species	Microplankton Abundance	Number MP Species
Cuttings	6360-70ft 2090.9-94.0m	Light grey very fine to fine cemented snadstone 40%; medium grey siltstone 10%; and caved dark grey shale 50%.	High	Moderate	Fair	22+	Abundant 43%	21+
Core-22A	6871-78ft 2994.3-96.4m	Medium grey micaceous siltstone with fine sandstone burrows.	High	High	Poor–good	24+	Abundant 44%	8+
Core-22B	6871-77ft 2094.3-96.1m	Mottled grey to red-brown fine grained sandstone with ~2% coarse sand up to 5mm and ~40% calcareous matrix.	High	Moderate	Poor	27+	Very abundant 53%	18+
Core-25	6902-13ft 2103.7-07.1m	Light–medium grey mottled/burrowed fine–medium sandstone with carbonaceous flecks and up to 10% pebbles.	Moderate	Low	Poor–fair	17+	Very abundant 54%	10+
Core-27	7200-20ft 2194.6-200.7m	Dark grey micaceous and carbonaceous siltstone.	Moderate	Low	Poor	27+	Common 12%	6+