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Palynological analysis of Langley-1, Port Campbell Embayment, Otway Basin.

by

Alan D. Partridge
Biostrata Pty Ltd
A.C.N. 053 800 945

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INTERPRETATIVE DATA

Introduction

Thirty-three sidewall cores and two core samples between 895-1989m were analysed in Langley-1. The author cleaned and split the samples then forwarded them to Laola Pty Ltd in Perth for processing to prepare the palynological slides.

Between 3.2 to 14.4 grams (average 9.8 g) of the sidewall cores and 13 grams of the conventional core samples were processed for palynological analysis. High residue yields were extracted from most samples, and kerogen slides were prepared with filtered and unfiltered fractions, and separate oxidised slides were prepared from fractions concentrated from the residues using 8 and 15 micron filters. Notwithstanding the use of the coarser filter palynomorphs concentrations on nearly all palynological slides was generally low to very low. Further, most palynomorphs in all but the shallowest four samples are poorly preserved. Because of the interaction of these two problems the palynological slides were particularly difficult and slow to examine. The assemblage abundance data presented in Table-2 were obtained from counts made on slides prepared using the 8 microns filter.

Spore-pollen diversity is moderate to occasionally high averaging 25+ species in the productive samples. Spore-pollen recorded as contaminants or as reworked are excluded from calculation of species diversity for individual samples and overall average. Microplankton diversity is low to moderate 3 to 27 species in the Sherbrook and Wangerrip Groups with an average of 10+ species, and very low in the Eumeralla Formation with only one or two non-marine microplankton recorded per sample.

Geological ages, formations and palynological zones for the interval sampled in Langley-1 are given in Table-1. Additional interpretative data with zone identification and Confidence Ratings are recorded in Table-3, whilst basic data on residue yields, preservation and diversity are recorded on Tables-4 and 5. All species which have been identified with binomial names are tabulated on the palynomorph range charts which present the recorded assemblages in order of lowest appearances.

Table-1: Palynological Summary Langley-1

AGE	UNIT	SPORE-POLLEN ZONES	MICROPLANKTON ZONES (SUBZONES)
PALEOCENE	K/T BOUNDARY SHALE 892-917m	*L. balmei* 895m	*P. pyrophorum* 895m
MAASTRICHTIAN	PAARATTE FORMATION 917-1348m	Upper *T. longus* 918m	(*A. acutulum*) 918m
CAMPANIAN TO SANTONIAN		*N. senectus* 1291-1325m	Indeterminate
	SKULL CREEK MUDSTONE 1348-1517m	*T. apoxyexinus* 1516-1692m	*I. cretaceum* 1516-1677m
	NULLAWARRE GREENSAND 1517-1555m		
	BELFAST MUDSTONE 1555-1716m		*O. porifera* 1712.5m
CONIACIAN		*P. mawsonii* 1701-1825.5m	*C. striatoconus* 1701m
TURONIAN	WAARRE D 1716-1731m		*P. infusorioides* (*I. glabrum*) 1712.5-1728m
	WAARRE C 1731-1768m		*P. infusorioides* (*A. parvum*) 1733.5m
	WAARRE B 1768-1803m		*P. infusorioides* (*C. edwardsii*) 1768.2-1825.5m
	WAARRE A 1803-1826m		
LATE ALBIAN	EUMERALLA FORMATION 1826-T.D.	*P. pannosus* 1855-1989m	

Geological Comments

1. The sequence sampled in Langley-1, with minor modifications, can be readily assigned to the Mesozoic spore-pollen and microplankton zones defined by Helby, Morgan & Partridge (1987). The time interval sampled is from the Late Albian to basal Paleocene.

2. A number of the spore-pollen zones used or discussed herein represent modifications or name changes by Helby *et al.* (1987) of zones originally erected by Dettmann & Playford (1969) in wells from the Port Campbell Embayment. As these latter zones are is still widely used in reports and publications on the Otway Basin it is appropriate to provide a summary of the equivalence between the two zonation schemes. Explanations of the reasons for the zone name changes can be found in Helby *et al.* (1987). The zones referred to in this report are:

Dettmann & Playford (1969)	**Helby *et al.* (1987)**
Nothofagidites Microflora (in part only)	*N. senectus* Zone
T. pachyexinus Zone	*T. apoxyexinus* Zone
C. triplex Zone	*P. mawsonii* Zone
A. distocarinatus Zone	*A. distocarinatus* Zone
P. pannosus Zone	*P. pannosus* Zone

3. The spore-pollen zones identified conform to the normal succession in the Otway Basin except that the *P. mawsonii* Zone was found to extend to the base of the Waarre Formation (as well as base of the Sherbrook Group) and the *A. distocarinatus* Zone as redefined by Helby *et al.* (1987) is considered to be absent at the unconformity between the Waarre and Eumeralla Formations.

   Above 1516m the samples analysed are too widely spaced to distinguish all spore-pollen known to occur in this part of the sequence.

4. Marine microplankton first appear in Langley-1 in the basal sample analysed from the Waarre Formation and thereafter are found in all samples analysed from the Sherbrook Group. The microplankton zones conform to the normal sequence between the basal Turonian to Santonian, but above 1516m the decreased sampling density and low microplankton diversity means not all zones known to occur in the succession could be identified. In contrast, the close sampling of the

Waarre Formation (21 samples at 5 metres spacing) has enabled the recognition of additional subzones within the *P. infusorioides* Zone.

5. Commencing from total depth the oldest unit penetrated in Langley-1 is the Eumeralla Formation, which based on the sidewall cores recovered is a characteristically blue-grey claystone to siltstone (Table-4). The Late Albian *P. pannosus* Zone identified from this section conforms to the youngest age known from this formation.

6. The base of the overlying Waarre Formation and hence base of Sherbrook Group is readily recognised on the palynology by the influx of marine microplankton representing the base of a marine transgression. This occurs in the shaly unit between 1820-1826m at the base of Unit A of the Waarre Formation (see Buffin 1989). The microplankton are of low abundance (<5% of assemblage) but have moderate diversity. The assemblage is considered no older than the *P. infusorioides* Zone and hence is of Turonian to very latest Cenomanian in age (Helby *et al.* 1987, fig.45). No samples were analysed from the sandy part of Unit A between 1803 and1820m.

7. It is noted that Evans (1966, p.33) has recorded marine dinoflagellates from the top of his Unit M (= Eumeralla) in Port Campbell-2 and other wells, and Dettmann & Playford (1969, p.193) consider that the uppermost horizons of their *C. paradoxa* Zone and hence Eumeralla Formation occasionally yield marine microplankton including *Odontochitina operculata* and *Cribroperidinium* (al. *Gonyaulacysta*) *edwardsii*. The detailed sampling and analysis in Langley-1 suggests these occurrences of marine dinoflagellates in the Eumeralla Formation are unlikely. Instead it is suggested that the assemblages recorded by both Evans (1966) and Dettmann & Playford (1989) are from equivalents of the Waarre Formation and the misassignment of both age and formation is a result of relying on the spore-pollen for age identification without recognising that there is reworking of palynomorphs from the underlying Eumeralla Formation.

8. In Unit B of the Waarre Formation between 1768-1803m all samples analysed contain marine microplankton and there is a overall increase in their abundance and diversity going up section. Other marine indicators include the identification of a scolecodont at 1789m and microforaminiferal inner liners at 1776.5m. The latter represent the chitinous inner layers of the earliest chambers of foraminifera. In this case they are very rare and it is unlikely that any foraminifera could be extracted from the small amount of sample remaining from the sidewall

core using the conventional techniques for extraction of calcareous microfossils.

9. From Unit C of the Waarre Formation between 1731-1768m only three samples have been analysed. Although the two samples from the conventional core contained both marine microplankton and foraminiferal inner liners these marine indicators were swamped by abundant terrestrially derived kerogen including spores and pollen and thus appear less marine than assemblages from the underlying Unit B. The shallowest of the three samples, the sidewall core at 1733.5m, represents a significant change in the microplankton assemblage with the first appearance of index or eponymous species of the *Ascodinium parvum* Zone recognised by Evans (1966). This zone is recognised as a separate subzone within the *P. infusorioides* Zone in Langley-1. In the adjacent Port Campbell-2 well the *A. parvum* Zone was recognised by Evans (1966) between 7906-8100ft (2410-2469m) in contrast to its occurrence in only the thin shale bed between 1733-1734m in Langley-1. Assuming the early palynological work in Port Campbell-2 can still be trusted it is suggested that a significant part of this zone could be missing in Langley-1 at a sequence boundary or minor unconformity at approximately 1731m. Support for this interpretation is provided by the sidewall core at 1732m which is a coarse sandstone of a brown colour and weathered character.

10. Above 1731m, the Unit D of the Waarre Formation and the overlying Belfast Mudstone are open marine shales based on the abundance and diversity of microplankton and consistent presence of foraminiferal inner liners. With the exception of low gamma spikes at 1702m and 1716.5m there is little change in the gamma log between these two units. There is however more character and potential lithological resolution on the combined bulk density/neutron porosity logs where there are distinct log breaks at 1696.5m (or 1698m) and 1716m. It is unclear, however, at which break to place the major formation boundary. Correlating from Iona-1 and Iona-2 on the position of the *C. striatoconus* and *O. porifera* Zones in the three wells the boundary between the Waarre Unit D and the Belfast Mudstone would be best placed at 1696.5m (see Partridge 1994). Correlating from Port Campbell-2 where *Conosphaeridium striatoconus* has been recorded by Cookson (1965) between 7403-7450ft (2256-2271m), from the basal part of the Belfast Mudstone, the base of this last unit would be best placed in Langley-1 at 1716m. To agree with geological analysis in the well completion report the deeper pick at 1716m is accepted as base of Belfast Mudstone.

Since the type section for the Flaxmans Formation is given by Glenie (1971) as the interval 7676-8184ft (2334-2494m) in Port Campbell-2 it seems likely that Unit D of the Waarre Formation in Langley-1 actually represents the Flaxmans Formation.

11. The Belfast Mudstone to basal Skull Creek Mudstone in Langley-1 contains the *O. porifera* and *I. cretaceum* microplankton Zone as was also found in Iona-2. The top of the *I. cretaceum* Zone in both wells is characterised by the species *Isabelidinium rotundatum* ms Marshall 1984 (recorded as *Isabelidinium* sp. cf *I. cretaceum* on the Iona-2 range charts). This species has considerable potential for defining a new zone or subzone which can be used to correlate the base of the Skull Creek Mudstone.

12. The distinctive shale unit between 892-917.5m in Langley-1 is remarkably similar to the Cretaceous/Tertiary (K/T) boundary shale which is widely found in the eastern part of the offshore Gippsland Basin. This correlation is supported by a basal Paleocene age at 895m based on identification of the *L. balmei/P. pyrophorum* Zones and a Maastrichtian Upper *T. longus* Zone age below the shale at 918m. In Iona-1, where the shale between 637-660m shows remarkably similar gamma log character, data in Morgan (1988) indicates the Maastrichtian Upper *T. longus* Zone extends as shallow as 652m and confirms that the K/T boundary actually lies within this shale package. The recent mapping and palynological study by Keating (1993) shows clearly that neither this shale nor these ages can be found in the type outcrop section of the Pebble Point Formation.

13. As discussed in more detail in the following zone descriptions the spore-pollen succession in Langley-1 lacks clear evidence for the presence of the *A. distocarinatus* Zone as redefined by Helby *et al.* (1987). Thus an obvious question is what was the zone concept that Dettmann & Playford (1969) were applying when they designated the type section for the *A. distocarinatus* Zone in the adjacent Port Campbell-2 well**?** From the detailed sampling and palynological analysis in Langley-1 it is suggested that their zone represented the consistent occurrence or partial acme zone for the zone species *A. distocarinatus*. In Langley-1 this approximates Unit B of the Waarre Formation because the spore *A. distocarinatus* was recorded in 7 of the 10 samples from this unit and although specimens are rare in individual samples they are still much more abundant than either *Phyllocladidites mawsonii* or *Clavifera triplex* which define the base of the *P. mawsonii* Zone. It is suspected that the identification of the *A. distocarinatus* Zone will need to be revised throughout the Otway Basin.

This conclusion has been derived from a more rigorous and detailed analysis of individual samples rather than more detailed sampling. For example in a preliminary review of the Port Campbell-2 well *Clavifera triplex* has been recorded from as deep as core-15 at 8409-8418ft (2563-2566m) which is given as the base of the type section for the *A. distocarinatus* Zone!

Table-2: Microplankton Abundance for Selected Samples.

Sample Type	Depth (m)	Microplankton Zone or Subzone	Microplankton Abundance as % Relative to total Spore-pollen and Microplankton	Most abundant microplankton species as % of total microplankton
SWC-46	1677	*I. cretaceum*	14%	*Isabelidinium cretaceum* ≥25%. *Amosopollis cruciformis* <10%.
SWC-45	1692	*O. porifera*	21%	*Heterosphaeridium* spp. >35%. *Amosopollis cruciformis* >15%.
SWC-44	1701	*C. striatoconus*	13%	*Heterosphaeridium* spp. >40% *Amosopollis cruciformis* >20%.
SWC-43	1712.5	*I. glabrum*	26%	*Amosopollis cruciformis* >70%.
SWC-42	1718	*I. glabrum*	36%	*Heterosphaeridium* spp. >25% *Amosopollis cruciformis* >25%.
SWC-40	1729.5	*P. infusorioides*	>75%	*Heterosphaeridium* spp. >20%. *Amosopollis cruciformis* >15%.
SWC-38	1733.5	*A. parvum*	>40%	*Amosopollis cruciformis* >35% *Ascodinium parvum* >10%.
SWC-37	1768.2	*C. edwardsii*	13%	Mixed *Cyclonephelium* & *Heterosphaeridium* spp. >50%.
SWC-34	1776.5	*C. edwardsii*	12%	*Oligosphaeridium* spp. >40%.
SWC-33	1778.5	*C. edwardsii*	25%	*Cribroperidinium edwardsii* >25%.
SWC-32	1781	*C. edwardsii*	13%	No species dominant in low count.
SWC-28	1795	*C. edwardsii*	3%	Microplankton count too low.
SWC-27	1798	*C. edwardsii*	6%	*Odontochitina operculata/costata*.
SWC-16	1824	*C. edwardsii*	4%	Microplankton count too low.
SWC-11	1855		5%	*Micrhystridium* sp. 100%.
SWC-2	1989		3%	*Sigmopollis carbonis* 75%.

14. All samples analysed from the Sherbrook Group are considered to be marine based on the abundance and diversity of their contained microplankton (Tables 2 & 5). Abundance of microplankton expressed as a percentage increases gradually through the Waarre Units A and B where it varies from 3% to 25% but averages <12%. Average diversity in these units is 8 species per sample and overall diversity in excess of 15 species. Data from Unit C is limited but in the interval from the shallowest sample at 1733.5m to the shallowest sample counted in the Belfast Mudstone at 1677m average microplankton abundance increases dramatically to >30%. The highest abundance occurs at the base of Unit D (at 1729.5m) and suggests that this is a significant marine flooding surface.

15. The few organic walled microplankton recorded from the Eumeralla Formation would generally be classed as acritarchs and are here all considered to be derived from non-marine lacustrine environments. The deposition of the Otway Group at high latitudes in the Early Cretaceous can be compared to modern deposition environments above the Arctic Circle where there are typically thousands of lakes of all sizes in the modern depositional basins as a consequence of low temperatures and low evaporation. It is easy to envisage algal cysts deposited in such lakes being reworked by fluvial processes throughout the depositional basin. These microplankton in the Otway Group have been recorded and discussed by other palynologists dating back to Evans (1966, p.31).

16. Reworked palynomorphs were recorded from virtually all samples analysed. Because of the considerable age difference the Permian and Triassic spores and pollen are the most obvious reworked palynomorphs. Reworked Early Cretaceous spores and pollen from the Otway Group are found throughout the Sherbrook Group but the full extent of this reworking is impossible to estimate as many Early Cretaceous species are considered to range into the Late Cretaceous. The detailed sampling of the Waarre Formation and detailed examination of samples where several slides were examined for each sample has enabled more confidence in identification of the portion of the assemblage reworked from the underlying Otway Group and these species are grouped together on the range chart. Of particular interest is the occurrence of *Coptospora paradoxa* only at 1781m where it is interpreted as reworked. As this species was relied on in many of the early palynological reports for picking the top of the Eumeralla Formation it suggests considerable caution should be applied when evaluating these early report.

Biostratigraphy

The zone and age determinations for the Cretaceous samples are based on the Australia wide Mesozoic spore-pollen and microplankton zonation schemes described by Helby, Morgan & Partridge (1987), with addition of a number of microplankton subzones which have the potential to provide a more detailed subdivision of the lower units in the Sherbrook Group. For the Tertiary, zone and age determinations are based on the spore-pollen zonation scheme of Stover & Partridge (1973) with subsequent unpublished modifications.

Author citations for most spore-pollen species can be sourced from Helby, Morgan & Partridge (1987), Dettmann (1963), Stover & Partridge (1973) or other references cited herein. Author citations for dinoflagellates can be found in the indexes of Lentin & Williams (1985, 1989) or other references cited herein. Species names followed by "ms" are unpublished manuscript names.

Spore-Pollen Zones

***Lygistepollenites balmei* Zone.**
Interval: 895.0 metres.
Age: Basal Paleocene.

This shallowest sample is assigned to this broad zone on the presence of the eponymous species *Lygistepollenites balmei* together with *Australopollis obscurus*, *Gambierina rudata* and *Tricolpites phillipsii*. No diagnostic species of either the Upper or Lower subzones of the *L. balmei* Zone were recorded but the associated microplankton would suggest assignment of the Lower subzone.

Upper *Tricolpites longus* Zone.
Interval: 918.0 metres.
Age: Maastrichtian.

The presence of rare *Stereisporites (Tripunctisporis)* sp. with common *Gambierina rudata* confirms the sample is no older than the Upper *Tricolpites longus* Zone, while the species *Proteacidites clinei* ms, *P. otwayensis* ms, *Tetradopollis securus* ms and *Battenipollis sectilis* (Stover) Jarzen & Dettmann 1992 confirm an age no younger than this zone. The index species *Forcipites* (al. *Tricolpites*) *longus* was not recorded.

***Nothofagidites senectus* Zone.**
Interval: 1291.0-1325.0 metres (34+ metres).
Age: Lower Campanian.

Two samples are assigned to this zone on the rare presence of the eponymous species *Nothofagidites senectus*. The shallower sample also contains frequent specimens of the accessory index species *Forcipites* (al. *Tricolpites*) *sabulosus* (Dettmann & Playford) Dettmann & Jarzen 1988. No other zone diagnostic species were recorded in these obviously high diversity samples which were difficult to work due to the low concentrations of the palynomorphs.

***Tricolporites apoxyexinus* Zone** (formerly the *Tricolpites pachyexinus* Zone).
Interval: 1541.0-1692.0 metres (151+ metres).
Age: Santonian.

Whilst moderate diversity assemblages of mainly long ranging species were recorded from the six samples over this interval, because of the overall poor preservation index species were extremely rare. In particular the eponymous species *T. apoxyexinus* was not recorded. Assignment to the zone is thus based on accessory species such as *Ornamentifera sentosa* (at 1516m & 1677m), *Forcipites stipulatus* Dettmann & Jarzen 1988 (at 1634m), *Latrobosporites amplus* (at 1516m & 1541m) and *L. ohaiensis* (at 1692m). Supporting the zone assignment are the more consistent presence, compared to their occurrences in the underlying zone, of the species *Australopollis obscurus, Clavifera triplex, Herkosporites elliottii* and *Phyllocladidites mawsonii.* This latter feature is similar to the observations made in Iona-2 (Partridge 1994).

Two specimens suggest the *T. apoxyexinus* Zone could extend lower. A single specimen of *Latrobosporites amplus* was recorded at 1701m and a poorly preserved specimen of *Tricolporites apoxyexinus* at 1712.5m. Both samples are also above the last rare occurrence of *Appendicisporties distocarinatus* (at 1718m) which is not considered to range above the underlying *P. mawsonii* Zone (Helby *et al.* 1987, fig.33; Partridge 1994). However, assigning the samples at 1701m and 1712.5m to the *T. apoxyexinus* Zone would break the preferred correlations between the spore-pollen and microplankton zones established by Helby *et al.* (1987) whereby the *T. apoxyexinus/P. mawsonii* Zone boundary is correlated to the *O. porifera/C. striatoconus* Zone boundary. Whilst the possible need for such a recalibration is here noted it is not considered that the spore-pollen succession in Langley-1 is either sufficiently well preserved or adequately documented to justify such a change in our standard correlations without further testing.

***Phyllocladidites mawsonii* Zone** (formerly the *Clavifera triplex* Zone).
Interval: 1701.0-1825.5 metres (124+ metres).
Age: Turonian-Coniacian.

All twenty-two samples over the interval of the *P. mawsonii* Zone are poor to very poorly preserved and this is compounded by the generally low to very low palynomorph concentrations. The eponymous species *Phyllocladidites mawsonii* was recorded in approximately one in four samples and has its FAD (First Appearance Datum) at 1802m. The former index species *Clavifera triplex* is recorded in just half the samples above its FAD at 1772m. Although neither of these species extend to the base of the Waarre Formation in Langley-1, in other aspects, both the spore-pollen and associated microplankton assemblages do not change markedly in character. Given the rarity of the key index species, a feature that has also been well documented in the Gippsland Basin, it is reasonable to say the base of the *P. mawsonii* Zone extends to the base of the Waarre Formation.

The lower part of the interval can be considered a separate subzone based on the occurrence of *Hoegisporis trinalis* ms which was recorded in all but one of the 14 samples between 1750.2-1824m. Other consistent species over this interval are *Rugulatisporites admirabilis* ms and *Appendicisporites distocarinatus*. The latter was recorded in all samples between 1772-1798m. Species recorded sporadically in the interval are *Interulobites intraverrucatus*, *Densoisporites muratus* ms, *Cicatricosisporites cuneiformis* and *C. pseudotripartitus*. Counts of selected samples show the assemblages can be characterised by common to abundant *Dilwynites* spp. (9%-25%; average 21%) and *Gleicheniidites* spp. (12%-24%; average 19%), with frequent to common *Podocarpidites* spp. (4%-13%; average 11%), *Microcachryidites antarticus* (<2%-8%; average <5%), and *Cupressacites* sp. (<1%-6%; average <4%). The abundances of these species or species groups clearly distinguish these samples from those assigned to the underlying *P. pannosus* Zone.

In the six samples between 1701-1733.5m the frequency of occurrence of the more diagnostic species markedly decreases. A possible exception is *Clavifera triplex* which both more consistent and more abundant (max. <2%). This difficulty in finding key species is partly a consequence of poor preservation of the palynomorphs in the more pyrite rich lithologies, but is also a consequence of the more distal marine character of the shaly lithologies between 1698-1731m. Nevertheless, key species found in this interval supporting the *P. mawsonii* Zone assignment include the LADs (Last Appearance Datums) for *Appendicisporites distocarinatus* at 1718m; *Cyatheacidites tectifera* at 1701m; and *Laevigatosporites musa* ms at 1733.4m. Counts of the assemblages were less reliable than the deeper interval because of poorer preservation and lower palynomorph concentrations. They show the same pattern of species abundances as given above except for the two shallowest samples at 1701m and 1712.5m. These display an increase in abundance of *Cupressacites* sp. to 14%-15% and compensating decrease in *Dilwynites* spp. to 8%-10%. The other categories are much the same. As discussed in the overlying zone there is other evidence to suggest these two shallowest samples may belong to the *T. apoxyexinus* Zone.

Of taxonomic interest is the identification of *Piriurella elongata* Cookson & Eisenack 1979 at 1798m. This species was considered by the original authors to be an algal species but has subsequently been shown to be a fungal spore by Smith & Chaloner (1979).

***Appendicisporites distocarinatus* Zone.**
Interval: Not recorded in Langley-1.
Age: Cenomanian.

Langley-1 is close to Port Campbell-2 wherein the original type section for the *Appendicisporites distocarinatus* Zone was designated by Dettmann & Playford (1969) as between 8096ft-8418ft (2468-2566m). Based on the extremely good sampling and detailed analysis in Langley-1 it is believed that the type section of the *A. distocarinatus* Zone needs to be reassigned to the *P. mawsonii* Zone. The justification for this reassignment is that the top of the *A. distocarinatus* Zone has been redefined by Helby *et al.* (1987) to place more emphasis on the first appearance of *Phyllocladidities mawsonii* compared to the first appearance of *Clavifera triplex*. The latter was given more weight by Dettmann & Playford (1969). Since the results in Langley-1 show that *P. mawsonii* can be found as a very rare component of the assemblages to near the base of the Waarre Formation it is hypothesised that a similar range would be found Port Campbell-2 with more detailed analysis.

Considering the detailed occurrence data from Langley-1 it would seem the designated type section of the *A. distocarinatus* Zone in Port Campbell-2 would approximated the interval in Langley-1 between 1776.5-1779m where the zone index *A. distocarinatus* occurs in every sample prior to first appearance of *C. triplex* at 1772m. A difficulty with this interpretation is that this represents only an 12+ metres interval in Langley-1 whereas the type section in Port Campbell-2 is much thicker at 98 metres. To resolve this difficulty requires new palynological work on Port Campbell-2.

***Phimopollenites pannosus* Zone.**
Interval: 1855.0-1989.0 metres (144+ metres).
Age: Late Albian.

Two samples are assigned to the *P. pannosus* Zone. The deeper sample contains *Phimopollenites pannosus* and is dominated by the pollen types *Podocarpidites/Falcisporites* spp. (19%) and spores of *Cyathidites* spp. (20%). The shallower sample lacks the eponymous species but it too can be confidently assigned to the Eumeralla Formation based on an assemblage dominated by *Podocarpidites/Falcisporites* spp. (42%) and *Corollina* spp (25%) and lack of younger index spore-pollen or marine dinoflagellates characteristic of the Waarre Formation. This confidence is derived from the slightly better sampling in Iona-2 where it was clearly shown that the Eumeralla Formation can be distinguished from the Waarre Formation based on abundances of the commonest species (Partridge 1994).

Microplankton Zones

***Palaeoperidinium pyrophorum* Zone**
Interval: 895.0 metres
Age: Basal Paleocene.

The *Palaeoperidinium pyrophorum* Zone is a recently recognised zone in the Gippsland Basin and lies between the *Trithyrodinium evittii* and *Eisenackia crassitabulata* Zones of Partridge (1975, 1976). It defines the interval from the last appearance of *T. evittii* to the last appearance of *P. pyrophorum* and is recognised in Langley-1 by the presence of the eponymous species. Lithologically the sample shows some similarity to the Pebble Point Formation but the gamma log character suggests it is still within the sedimentary package informally termed the K/T Boundary Shale (Table-1). Recent work by Keating (1993) has shown that the type outcrop section of this formation extends no older than the *E. crassitabulata* Zone and is of Late Paleocene age. Away from the type section precise limits for the Pebble Point Formation still need to be revised.

***Alterbidinium acutulum* Zone**
Interval: 918.0 metres
Age: Maastrichtian.

The *A. acutulum* Zone was defined by Wilson (1984) as the interval between the last appearance of *Odontochitina porifera* (and the genus *Odontochitina*) to the first appearance of *Manumiella druggii*. Based on the absence of both these species and related morphotypes this limited diversity assemblage can be assigned to this zone on the presence of *Alterbidinium acutulum*.

Undifferentiated *Isabelidinium* Superzone.
Interval: 1291.0-1325.0 metres (34+ metres).
Age: Senonian.

The two samples contain only rare dinoflagellates (7+ species). Their stratigraphic position, plus presence of *Heterosphaeridium evansii* ms Marshall 1984 (= *H. laterobrachius* ms) in the shallower sample and *Odontochitina porifera* in the deeper sample, confirm assignment to the broad superzone and a Senonian age.

***Isabelidinium cretaceum* Zone.**
Interval: 1516.0-1677.0 metres (161+ metres).
Age: Santonian.

Of the five samples over this interval the three deeper samples are assigned to the *I. cretaceum* Zone on the rare to common occurrence of the eponymous species and lack of the succeeding zone indicators. The two shallowest samples are assigned to the zone on the presence of *Isabelidinium rotundatum* ms Marshall 1984. This species is the variety of *I. cretaceum* recorded by Cookson & Eisenack (1961, p.11, figs 1,2) from the Belfast No. 4 bore. It is characteristically circumcavate rather than simply cavate at the apices like the holotype and most of the paratypes of *I. cretaceum*.

Other zone diagnostic species are *Isabelidinium thomasii* at 1541m and 1677m, *Heterosphaeridium evansii* ms at 1516m and 1579m while *Trithyrodinium vermiculata* occurs in all samples between 1516-1579m. The assemblages are mostly dominated by *Heterosphaeridium* spp. while *Odontochitina porifera* is a conspicuous accessory.

***Odontochitina porifera* Zone.**
Interval: 1692.0 metres (<25 metres).
Age: Santonian.

This poorly preserved, moderate diversity assemblage is assigned to the zone on the presence of *Odontochitina porifera* and *O. cribropoda* and lack of the succeeding zone indicators. The assemblage is dominated by *Heterosphaeridium heteracanthum*. A single specimen of *Isabelidinium rotundatum* ms recorded is interpreted as caved.

***Conosphaeridium striatoconus* Zone.**
Interval: 1701.0 metres.
Age: Coniacian.

The sample is confidently assigned to the zone based on the occurrence of frequent specimens of *C. striatoconus*. The only supporting species for this assignment is the FAD for *Dinogymnium acuminatum* in an assemblage dominated by *Heterosphaeridium heteracanthum*. *Odontochitina cribropoda* was represented by a single specimen.

***Palaeohystrichophora infusorioides* Zone.**
Interval: 1712.5-1825.5 metres (113+ metres).
Age: Turonian.

All samples over this interval contain marine dinoflagellates with diversity in individual samples varying from 5 species in the poorly preserved and terrestrial kerogen dominated core samples to greater than 27 species at 1718m. Average diversity was 10+ species whilst total diversity over the interval was 42+ species. Except for the occurrence of *Isabelidinium glabrum* between 1712.5-1728m all species recorded are known to range beyond the *P. infusorioides* Zone. The zone is therefore recognised on negative evidence identical to the way it was originally defined (Helby *et al.* 1987, p.62). The interval is no older than the *P. infusorioides* Zone based on the absence of index species *Pseudoceratium ludbrookiae* and significant accessory species *Litosphaeridium siphoniphorum* and *Canninginopsis denticulata*. Although conforming to the strict definition, the assemblages are less diverse than assemblages from the Northwest Shelf. Conspicuously absent are the variety of *Diconodinium* species. In contrast to the base the top of the zone is clearly defined by the FAD for *Conosphaeridium striatoconus* the key index species of the overlying zone.

Three subzone recognised within the *P. infusorioides* Zone in Langley-1 are discussed below:

***Isabelidinium glabrum* Subzone.**
Interval: 1712.5-1728.0 metres (15+ metres).
Age: Turonian.

The three samples contain a small *Isabelidinium* species tentatively referred to *I. glabrum* known to occur in upper part *P. infusorioides* Zone (Helby *et al.* 1987, fig.37). The assemblages may be equivalent to those containing *Isabelidinium* (al. *Deflandrea*) *acuminatum* recorded from Port Campbell-1 between 5660-5700ft

(1725-1737m) by Evans (1966, p.25). The Langley-1 specimens however cannot be referred to *I. acuminatum* as they lack the characteristic apical horn on the endophragm (Cookson & Eisenack 1958; pl.4, figs. 5-7). The specimen illustrated by Evans (1966, pl.1, fig.6) does seem to have this apical horn but still needs to be checked.

Other features of this zone are the very rare occurrences of *Odontochitina cribropoda* at 1781m and 1728m and possible occurrence of *Valensiella griphus* originally described from Cenomanian on Bathurst Island (Norvick, 1976). *Heterosphaeridium* spp. and *Amosopollis cruciformis* dominate the microplankton assemblages (Table-2).

***Ascodinium parvum* Subzone.**
Interval: 1733.5.
Age: Turonian.

The sample contains a similar assemblage to the underlying *Cribroperidinium edwardsii* Zone but differs by presence of *Ascodinium parvum* (approx. 10%) and absence of *C. edwardsii* which may have been replaced by introduction of related species *Cribroperidinium cooksonae*. Overall the microplankton assemblage is dominated by algal cyst *Amosopollis cruciformis* with an abundance of approximately 35%.

The *A. parvum* Zone was originally proposed by Evans (1966) but has not subsequently been widely documented. Evans did not specify a type section but gave prominence to its occurrence in Port Campbell-2 between 7906-8102ft (2410-2469m).

Ascodinium parvum was identified on overall shape as preservation of specimens were too poor to confidently identify acheopyle type. *Isabelidinium acuminatum* in same sample was identified by distinct apical horn on endophragm and clear **"I"** acheopyle.

***Cribroperidinium edwardsii* Subzone.**
Interval: 1768.2-1825.5 metres (57+ metres).
Age: Turonian.

This zone was originally defined in Iona-2 as an acme zone covering all of the Waarre Formation (Partridge 1994). In Langley-1 because the index species *Cribroperidinium edwardsii* is consistently present in all samples over the zone interval but is prominent in only two samples it is felt the designation as an acme zone is inappropriate. Further, the subzone interval only corresponds to

Units A and B of the Waarre (*sensus* Buffin 1989) in Langley-1, but was found in all four samples in the Waarre in Iona-2 extending up into Units C and D. The younger occurrences in Iona-2 are now suspect and believed caused by either sample contamination, reworking, mis-identification, or simply very rare occurrences. The preferred zone charactristic is the consistent occurrence of *C. edwardsii*.

Aside from the eponymous species the samples contain fairly consistent *Odontochitina costata/operculata* and *Oligosphaeridium complex/pulcherrimum* and inconsistent *P. infusorioides*. A further subdivision of this zone may be practical locally based on the prominence of *Cyclonephelium compactum, C. distinctum* and *Palaeoperidinium cretaceum* in the lower part and the incoming and rise to prominence of *Heterosphaeridium heteracanthum* and *Kiokansium polypes* in the upper part. This will need further testing as these changes could equally be a reflection of facies or environments.

Because of low palynomorph concentration the counts on the microplankton through this zone (Table-2) are only reliable to within 5%. The abundance of the algal cyst *Amosopollis cruciformis* is consistently less than 1% of total spore-pollen and microplankton count and estimated to be generally less than 10% of microplankton count.

Non-marine microplankton in Eumeralla Formation.
Interval: 1855.0-1989.0 metres (144+ metres).
Age: Late Albian.

The two samples from the Eumeralla Formation are characterised by a limited suite of microplankton comprising *Sigmopollis carbonis, Micrhystridium* sp. A of Marshall (1989) and *Veryhachium* sp. These have been previously recorded from this unit (Evans 1966, p.31-34; Partridge 1994) and are interpreted to indicate deposition in freshwater, most likely lacustrine environments. The form *Sigmopollis carbonis* has been compared to Holocene microfossil algae occurring in eutrophic and mesotrophic freshwater environments by Pals *et al.* (1980, p.407) and Srivastava (1984, p.528).

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Table-3: Interpretative Palynological Data for Langley-1, Otway Basin

Sample Type	Depth (m)	Spore-pollen Zone	CR*	Microplankton Zones	CR*	Comments
SWC-59	895.0	*L. balmei*	B2	*P. pyrophorum*	B3	
SWC-58	916.0	Upper *T. longus*	B1	*(A. acutulum)*	B3	FAD *Stereisporites* (*Tripunctisporis*) sp. with common *Gambierina rudata*.
SWC-56	1291.0	*N. senectus*	B1	Indeterminate		FAD *Forcipites sabulosus*.
SWC-55	1325.0	*N. senectus*	B2	Indeterminate		FAD *Nothofagidites senectus*.
SWC-52	1516.0	*T. apoxyexinus*	B1	*I. cretaceum*	B2	*Isabelidinium rotundatum* ms present.
SWC-49	1541.0	*T. apoxyexinus*	B4	*I. cretaceum*	B3	*Isabelidinium rotundatum* ms present.
SWC-48	1579.0	*T. apoxyexinus*	B5	*I. cretaceum*	B3	*Trithyrodinium vermiculata* present.
SWC-47	1634.0	*T. apoxyexinus*	B1	*I. cretaceum*	B3	FAD *Forcipites stippulatus*.
SWC-46	1677.0	*T. apoxyexinus*	B2	*I. cretaceum*	B3	FAD *Isabelidinium cretaceum* with spore *Ornamentifera sentosa*.
SWC-45	1692.0	*T. apoxyexinus*	B4	*O. porifera*	B3	FAD *Odontochitina porifera*.
SWC-44	1701.0	*P. mawsonii*	B1	*C. striatoconus*	B2	*Cyatheacidites tectifera* and *Clavifera vultuosus* ms present.
SWC-43	1712.5	*P. mawsonii*	B5	*P. infusorioides (I. glabrum)*	B4	Poorly preserved specimen of *Tricolporites apoxyexinus* present with *Clavifera vultuosus* ms.
SWC-42	1718.0	*P. mawsonii*	B2	*P. infusorioides (I. glabrum)*	B4	LAD of good *Appendicisporites distocarinatus*.
SWC-41	1728.0	*P. mawsonii*	B4	*P. infusorioides (I. glabrum)*	B2	FAD *Odontochitina cribropoda*.
SWC-40	1729.5	Indeterminate		*P. infusorioides*	B2	Spore-pollen assemblage non-diagnostic.
SWC-38	1733.5	*P. mawsonii*	B2	*P. infusorioides (A. parvum)*	B4	*Amosopollis cruciformis* abundant, with frequent *Ascodinium parvum* and rare *Isabelidinium acuminata*.
Core-1	1750.2	*P. mawsonii*	B2	*P. infusorioides*	B5	LAD *Hoegisporis trinalis* ms and local LAD *Densoisporites muratus* ms.
Core-1	1758.8	*P. mawsonii*	B4	Indeterminate		Palynomorphs sparse.
SWC-37	1768.2	*P. mawsonii*	B2	*P. infusorioides (C. edwardsii)*	B3	Megaspore *Balmeisporites glenelgensis* present.
SWC-35	1772.0	*P. mawsonii*	B1	*P. infusorioides (C. edwardsii)*	B3	Local FAD of *Clavifera triplex*, and LAD of consistent *A. distrocarinatus*.
SWC-34	1776.5	*P. mawsonii*	B4	*P. infusorioides (C. edwardsii)*	B3	*Densoisporites muratus* ms present. FAD for Microforaminiferal inner tests.
SWC-33	1778.5	*P. mawsonii*	B2	*P. infusorioides (C. edwardsii)*	B3	Local FAD of *Kiokansium polypes*.
SWC-32	1781.0	*P. mawsonii*	B4	*P. infusorioides (C. edwardsii)*	B2	Reworked? *Coptospora paradoxa*.
SWC-29	1789.0	*P. mawsonii*	B4	*P. infusorioides (C. edwardsii)*	B3	Marine scolecodont and *Phyllocladidites mawsonii* present.

Table-3: Interpretative Palynological Data for Langley-1, cont...

Sample Type	Depth (m)	Spore-pollen Zone	CR*	Microplankton Zones	CR*	Comments
SWC-28	1795.0	*P. mawsonii*	B4	*P. infusorioides* (*C. edwardsii*)	B3	*Appendicisporites distocarinatus* and *Interulobites intraverrucatus* present.
SWC-27	1798.0	*P. mawsonii*	B4	*P. infusorioides* (*C. edwardsii*)	B3	FAD of consistent *A. distocarinatus*
SWC-26	1799.5	*P. mawsonii*	B3	*P. infusorioides* (*C. edwardsii*)	B3	*Microdinium ornatum* present.
SWC-25	1802.0	*P. mawsonii*	B3	*P. infusorioides* (*C. edwardsii*)	B3	FAD *Phyllocladidites mawsonii.*
SWC-18	1821.0	*P. mawsonii*	B4	*P. infusorioides* (*C. edwardsii*)	B3	Frequent *Hoegisporis trinalis*.
SWC-17	1822.5	*P. mawsonii*	B4	*P. infusorioides* (*C. edwardsii*)	B3	Frequent *Palaeoperidinium cretaceum.*
SWC-16	1824.0	*P. mawsonii*	B4	*P. infusorioides* (*C. edwardsii*)	B3	FAD *Palaeohystrichophora infusorioides*.
SWC-15	1825.5	*P. mawsonii*	B4	*P. infusorioides* (*C. edwardsii*)	B3	FAD *Appendicisponites distocarinatus* and *Cribroperidinium edwardsii.*
SWC-14	1827.0	Indeterminate				Barren sample.
SWC-11	1855.0	*P. pannosus*	B4			Dominated by *Podocarpidites* spp. 42% and *Corollina torosa* 26%.
SWC- 2	1989.0	*P. pannosus*	B1			Several specimens of *Phimopollenites pannosus*.

*CR = Confidence Ratings
LAD = Last Appearance Datum
FAD = First Appearance Datum

Confidence Ratings

The Confidence Ratings assigned to the zone identifications on Table-4 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 4: Basic Sample Data - Langley-1, Otway Basin

Table-5: Basic Palynomorph Data for Langley-1, Otway Basin

Palynomorph Range Charts for Langley-1, Otway Basin

Range Chart 1: Spore-pollen by Lowest Appearance

Range Chart 2: Microplankton by Lowest Appearance

Table-4: Basic Sample Data for Langley-1, Otway Basin.

SAMPLE TYPE	DEPTH (metres)	REC (cm)	LITHOLOGY	SAMPLE WT (g)	RESIDUE YIELD
SWC-59	895.0	4.0	Black micaceous, pyritic' argillaceous sandstone =Pebble Pt Fm (clean sample).	11.4	High
SWC-58	916.0	5.0	Dk gry med. grn. sandstone with mud filled burrows up to 5mm diameter. Accessory mica & pyrite (sample well cleaned).	14.4	Low
SWC-56	1291.0	1.5	Interlaminated black siltstone & grey fine grn sandstone (laminae <1mm). Poorly cleaned.	7.0	Low
SWC-55	1325.0	4.5	Med tan-gry mottled sandstone. Sample cross cut by veins of drilling mud up to 1mm thick.	13.5	Low
SWC-52	1516.0	3.5	Dk gry homogeneous claystone (clean sample).	11.3	Moderate
SWC-51	1518.5	<1.0	Lt gry argillaceous sandstone with coarse quartz pebbles (badly mud penetrated - not selected for palynology).		
SWC-50	1522.0	2.5	Soft med. gry sandstone (badly mud penetrated - not selected for palynology).		
SWC-49	1541.0	3.0	Dk gry-blk homogeneous siltstone with trace mica. (Clean sample).	10.8	High
SWC-48	1579.0	5.0	Dk. gry-blk siltstone, fractured with some mud contamination	10.9	High
SWC-47	1634.0	3.0	Dk gry-blk homogeneous siltstone, with very fine glauconite. (Clean sample).	10.4	High
SWC-46	1677.0	3.5	Dk gry-blk grn glauconitic siltstone, firm not bedded (minor mud contamination).	10.8	High
SWC-45	1692.0	5.0	Dark grey homogeneous siltstone (badly mud penetrated).	11.2	Moderate
SWC-44	1701.0	4.7	Dk gry-blk firm siltstone with v.fine glauconite (<20%), negligible mud contamination.	11.9	High
SWC-43	1712.5	4.3	Dk gry-blk firm silty glauconitic mudstone (sample well cleaned).	10.3	Moderate
SWC-42	1718.0	3.5	Med. gry mudstone with 6mm laminae of lt gry f. grn sandstone (clean sample).	10.2	Moderate
SWC-41	1728.0	4.0	med gry silty mudstone with floating quartz pebbles up to 5mm, & trace mica and glauconite (clean sample).	9.9	High
SWC-40	1729.5	5.0	Med. gry, med. gry argillaceous sandstone with white clay matrix and common pyrite, tr. glauconite (clean sample).	10.2	Low
SWC-39	1732.0	<2.0	Unconsolidated or fracture sample of brown to white sandstone with pebbles up to 10mm. Sample appears mud contaminated - not suitable for palynology.		
SWC-38	1733.5	4.0	Interlaminated dk gry-blk mudstone with lt gry f. grn sandstone; laminae 1-4mm (clean sample).	7.4	High
Core-1	1750.2		Med-dk grey claystone with trace mica and pyrite.	12.8	High
Core-1	1758.5		Med-dk grey claystone with laminae of carbonaceous matter and pyrite <1mm thick.	13.0	High

Table-4: Basic Sample Data for Langley-1, Otway Basin.

SAMPLE TYPE	DEPTH (metres)	REC (cm)	LITHOLOGY	SAMPLE WT (g)	RESIDUE YIELD
SWC-37	1768.2	3.5	Interlaminated med gry pyritic sandstone & dk gry mudstone; laminae 1-5mm thick (clean sample).	10.4	Moderate
SWC-35	1772.0	3.0	Interlaminated dk gry mudstone (up to 18mm thick) with white f. grn sandstone (up to 6mm). Clean sample, but sandstone not processed.	7.1	High
SWC-34	1776.5	3.5	Finely laminated med. gry siltstone and lt gry f. grn sandstone; no obvious glauconite (clean sample).	8.9	Low
SWC-33	1778.5	3.8	Med grey faintly laminated muddy siltstone; no obvious glauconite (clean sample).	10.3	Moderate
SWC-32	1781.0	4.0	Med. gry homogeneous glauconitic (<20%) sandstone (clean sample).	9.4	Moderate
SWC-31	1783.0	3.5	Brown (oxidised?) sandstone mixed with hard med. gry siltstone. No glauconite observed (sample broken and poorly cleaned).		
SWC-29	1789.0	3.0	Interlaminate med. gry claystone (8mm) with lt gry f. grn sandstone (6-12mm). Sandstone not processed but clean sample.	6.4	High
SWC-28	1795.0	3.5	Med. grey homogeneous claystone with carbonaceous fragments (clean sample).	8.6	High
SWC-27	1798.0	2.7	Med. gry claystone with a few siltstone laminae <1mm thick (clean sample).	11.1	High
SWC-26	1799.5	3.3	Med. gry claystone with siltstone laminae <1mm thick (clean sample).	11.0	High
SWC-25	1802.0	2.5	Dk grey claystone with occasional thin (<1mm) wh. siltstone laminae (clean sample).	10.2	High
SWC-18	1821.0	3.0	Dk grey homogeneous claystone with white med. sandstone layer 5mm thick (clean sample but sandstone not processed).	9.7	High
SWC-17	1822.5	<2.0	Interlaminated med. grey claystone and white f. grn sandstone (<2mm). Sample badly mud penetrated poorly cleaned.	5.6	High
SWC-16	1824.0	4.0	Dk grey claystone with occasional thin (<1mm) white siltstone laminae (clean sample).	10.1	High
SWC-15	1825.5	1.5	Med. gry f-crs grn poorly sorted sandstone with carbonaceous laminae (fairly well cleaned).	3.2	High
SWC-14	1827.0	3.7	Lt blue gry argillaceous siltstone/sandstone =Eumeralla (clean sample).	10.1	Very low
SWC-11	1855.5	3.0	Lt blue gry homogeneous claystone (clean sample).	9.8	Low
SWC-10	1870.0	3.0	Med. blue grey claystone with micro laminae of carbonaceous material (clean sample).		
SWC- 8	1878.5	4.0	Med. blue grey homogeneous claystone. Sample hard with micro fractures which may be mud penetrated, otherwise well cleaned.		
SWC- 5	1924.5	4.0	Med. blue grey siltstone to silty mudstone (clean sample).		
SWC- 4	1957.0	3.0	Interlaminated med. grey siltstone and f. grn sandstone with laminae 0.1-2mm (clean sample).		
SWC- 2	1989.0	2.5	Med grey homogeneous brittle claystone (moderately clean sample).	9.0	Low

Table-5: Basic Palynomorph Data for Langley-1, Otway Basin.

Sample Type	Depth (m)	Palynomorph Concentration	Palynomorph Preservation	No. S-P spp*	Microplankton Abundance	No MP Species*
SWC-59	895.0	Moderate	Good	21+	Rare	5+
SWC-58	918.0	Low	Good	33+	Rare	6+
SWC-56	1291.0	Low	Fair-good	28+	Rare	3+
SWC-55	1325.0	Low	Fair	18+	Rare	4+
SWC-52	1516.0	Low	Fair	29+	Common	14+
SWC-49	1541.0	Low	Poor	18+	Common	9+
SWC-48	1579.0	Low	Very poor-poor	18+	Common	10+
SWC-47	1634.0	Moderate	Poor	23+	Common	10+
SWC-46	1677.0	Low	Poor	21+	Common	7+
SWC-45	1692.0	Low	Poor-fair	25+	Common	11+
SWC-44	1701.0	Low	Poor	39+	Common	22+
SWC-43	1712.5	Moderate	Poor	33+	Abundant	17+
SWC-42	1718.0	Moderate	Poor	27+	Abundant	27+
SWC-41	1728.0	Moderate	Poor	27+	Abundant	23+
SWC-40	1729.5	Very low	Poor	11+	Abundant	15+
SWC-38	1733.5	Very low	Very poor	25+	Abundant	12+
Core-1	1750.2	Low	Very poor	35+	Very rare	11+
Core-1	1758.8	Very low	Very poor	25+	Very rare	5+
SWC-37	1768.2	Low	Poor	26+	Common	9+
SWC-35	1772.0	Low	Poor	30+	Rare	7+
SWC-34	1776.5	Very low	Poor	25+	Frequent	7+
SWC-33	1778.5	Low	Poor	25+	Common	11+
SWC-32	1781.0	Low	Poor-fair	31+	Common	10+
SWC-29	1789.0	Low	Poor	24+	Rare	6+
SWC-28	1795.0	Very low	Very poor-poor	26+	Rare	4+
SWC-27	1798.0	Very low	very poor	21+	Rare	6+
SWC-26	1799.5	Low	Very poor	26+	Rare	11+
SWC-25	1802.0	Low	Poor	12+	Frequent	5+
SWC-18	1821.0	Very low	Poor	23+	Frequent	11+
SWC-17	1822.5	Low	Poor	31+	Rare	7+
SWC-16	1824.0	Low	Poor-fair	34+	Frequent	14+
SWC-15	1825.5	Low	Poor	24+	Rare	4+
SWC-14	1827.0	Barren				
SWC-11	1855.0	Moderate	Poor	18+	Very rare	1
SWC- 2	1989.0	Moderate	Poor	31+	Very rare	2

Diversity:

Very low	=	1-5	species
Low	=	6-10	species
Moderate	=	11-25	species
High	=	26-74	species
Very high	=	75+	species