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Palynological age and environmental analyses of cuttings samples from Bridgewater Bay-1, offshore Otway Basin.

by

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TABLE OF CONTENTS

Summary

The results of palynological analysis of eighteen new cutting samples between 2230m and 4200mT.D. from the Sherbrook Group in Bridgewater Bay-1 are presented. The most significant observations are:

- The new analyses confirm the presence of the Skull Creek Mudstone, Nullawarre Greensand and a thick Belfast Mudstone in Bridgewater Bay–1.

- The palynology could not confirm whether Bridgewater Bay–1 penetrated either the Flaxman or Waarre Formations because extremely poor and unreliable samples below ~3500m.

- Both quantity and quality of cuttings samples below 3500m was poor. The palynological processing gave low yields and the recorded assemblages were very meagre and most likely caved. The age dating of the interval 3500 to 4200m is therefore of very low reliability and unlikely to be improved on unless the sidewall cores can be located and reprocessed.

- All productive samples are considered to have been deposited in offshore marine environments based on common marine microplankton. Counts of the assemblages give an average microplankton abundance of 32%.

- The particulate organic matter (kerogen) recovered from the samples between 3565 to 4200m has been effected by refined diesel added to the drilling mud to improve the operations of the turbo drill used below ~3500m. Unusual features observed in the palynological slides are interpreted to have resulted from contamination by the diesel which has modified, or "vulcanised" with, the *in situ* organic matter. Confusing the interpretation of the kerogen are the low sample yields and an apparent increase in the abundance of amorphous "oil-prone" kerogen whose near maturity has perhaps made it more susceptible to alteration. Overall the interpretation of these deeper samples needs to be treated with considerable caution.

Introduction

Eighteen cutting samples are analysed from the Sherbrook Group in Bridgewater Bay-1 between 2230m and T.D. at 4200m. Moderate diversity assemblages providing confident zone identification and ages were obtained from the nine samples between 2230 to 3385m. Unfortunately only poor, barren to low diversity assemblages were obtained in the nine deeper samples between 3565m to 4200m T.D. The latter provide only low confidence zone and age determinations which are of uncertain reliability because of the potential for masking by caved material. The zone and age subdivisions of the Sherbrook Group based on the new analyses integrated with the original palynological analyses of Martin (1984) are summarised in the following table:

Table 1: Palynological summary for Bridgewater Bay-1.

AGE	UNIT	SPORE-POLLEN ZONES	MICROPLANKTON ZONES (SUBZONES)
DANIAN to MAASTRICHTIAN	K/T Boundary Shale 1230-1236m	No data	No data
MAASTRICHTIAN	TIMBOON SAND 1236-1595m	*T. longus* 1244-1373*m *T. lilliei* 1522–1939*m	*I. korojonense* 1522*m
CAMPANIAN	PAARATTE FORMATION 1595-2395m	*N. senectus* 2015*-2360m	*X. australis* 2015*–2230m *N. aceras* 2360m
CAMPANIAN to SANTONIAN	SKULL CREEK MUDSTONE 2395-2630m	*T. apoxyexinus* 2515-2625m	*N. aceras* 2515-2590*m *I. rotundatum* 2625m
SANTONIAN	NULLAWARRE GREENSAND 2630-2715m	*T. apoxyexinus* 2630-2685m	*I. rotundatum* 2630-2685m
SANTONIAN to CONIACIAN	BELFAST MUDSTONE 2715-4100m	*T. apoxyexinus* 2730-3190m *P. mawsonii* 3380-4065+m	*I. cretaceum* 2730-2775*m *O. porifera* 2915-3190m *C. striatoconus* 3380-4065m+
TURONIAN ?	FLAXMAN FORMATION 4100-4202m	Indeterminate	Indeterminate

T.D. 4202m

NB: Depths marked with * are from SWCs in Martin (1984)

\+ Base of zones possibly based on caved material — use with caution.

Materials and Methods

Only very meagre amounts of sample were supplied from most of the cuttings. The weighed samples varied between 2 and 7 grams (average 3.7 g). The exception was the deepest cuttings from which 20 grams were supplied. The palynological processing was performed by Laola Pty Ltd in Perth with palynological slides on 15 samples received back from them on 15 August and provisional results on these samples provided on 21 August. Because of initial low quantities of cuttings supplied additional material was collected from the three deepest samples and these were received back from processing on the 9 September. As no significant new data was obtained no provisional report was prepared.

Interpretative data on all samples, including zone identification and Confidence Ratings, are recorded in Table 4. Basic data on lithologies, sample quantities, residue yields, preservation and diversity are recorded on Tables 5. Counts of selected assemblages are presented on Table 6 and distribution of all palynomorphs recorded in the samples are given on Table 7.

Moderate residue yields were recovered in the cuttings above 3500m but only very low residue yields were recovered from samples below 3500m to T.D. Palynomorph concentrations were mainly low and only rarely moderate on the slides. Palynomorph preservation was fair in the shallower samples but became increasingly poorer deeper in the well. Recorded spore-pollen diversity was moderate above 3500m averaging 22+ species per sample but very low below 3500m (Table 5). Microplankton were abundant above 3500m although diversity was low averaging 7+ species per sample. Recorded abundance and diversity below 3500m in not considered representative of the section because of low recoveries from the samples. Key zone index species for both spore-pollen and microplankton are relatively rare in all samples.

Stratigraphy

1. The new cuttings samples both confirm and improve on the original palynological analyses of the sidewall cores by Martin (1984). The data also supports the revised correlation between palynological zones and formations in the Otway Basin proposed in Partridge (1997). The revised stratigraphic table is reproduced as Figure 1.

2. The identification of the *X. australis* Zone at 2230-35m and the *N. aceras* Zone at 2360-65m suggest the interbedded sand-shale section down to ~2400m belongs to the basal Paaratte Formation.

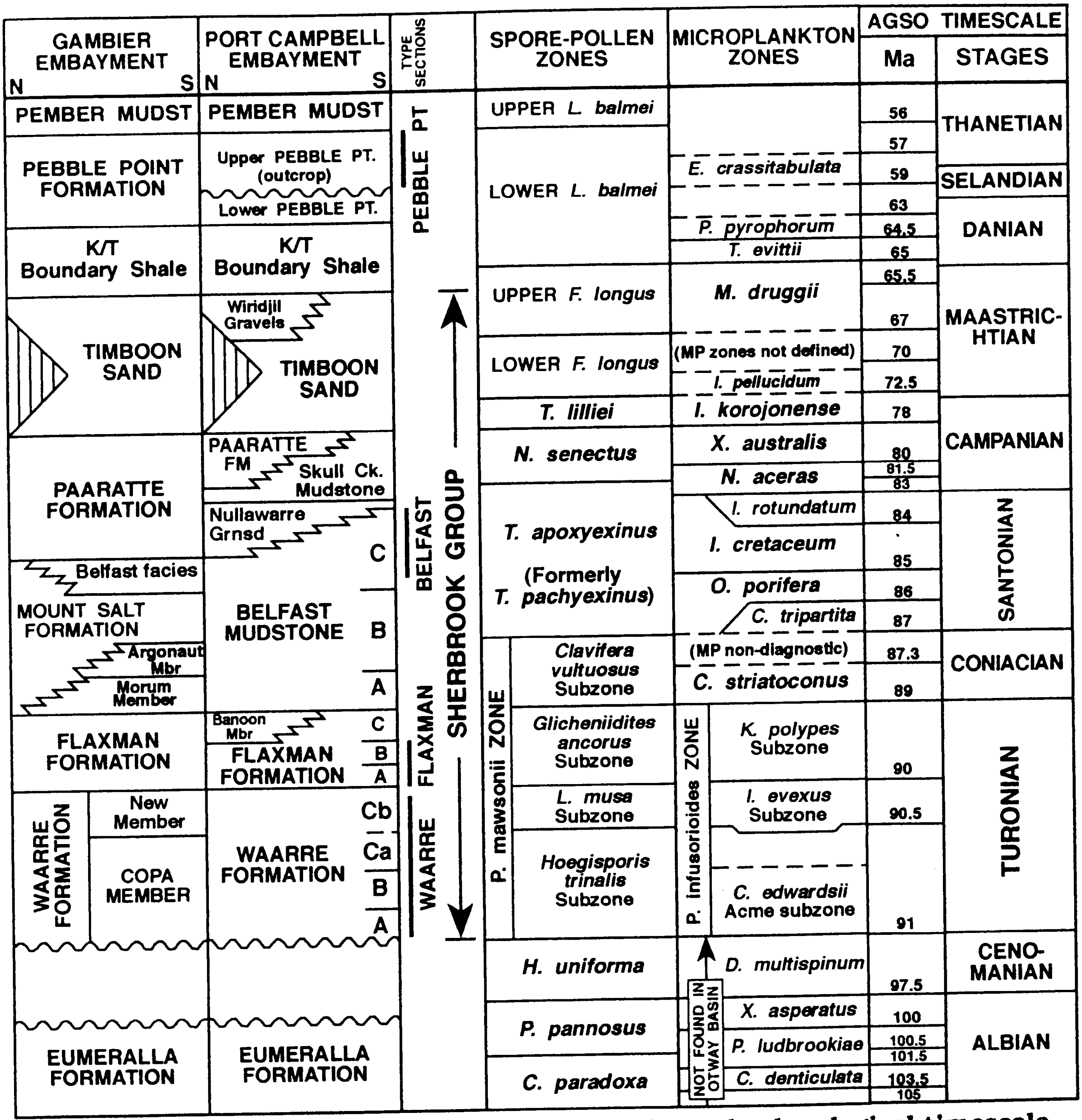

Figure 1: Revised Sherbrook Group stratigraphy and palynological timescale.

3. The *N. aceras* Zone at 2515–20m overlying the new *I. rotundatum* Subzone at 2625–30m correlates the largely shale unit between 2400m to 2630m to the Skull Creek Mudstone recognised in the Port Campbell Embayment (GSV = Geological Survey of Victoria, 1995). It should be noted however that in the Minerva wells in the Shipwreck Trough the Skull Creek Mudstone extends as an unbroken shale into the overlying *X. australis* Zone.

4. The presence of the newly recognised *I. rotundatum* Subzone in three samples between 2625–30m to 2730–35m provides confirmation that the characteristic "coarsening upwards" sand between ~2630m to ~2690m is a good correlative of the Nullawarre Greensand. The presence of the index species *Isabelidinium rotundatum* ms in the deepest of the three samples may be caved as this species is not usually recorded in the Belfast Mudstone.

5. Identification of the *O. porifera* Zone between 2915–3190m and the *C. striatoconus* Zone in samples at 3380–85m and 4065–70m (the latter based on one specimen) suggests that the thick shale interval between 2690m to 4100m all belongs to the Belfast Mudstone. It is further tentatively suggested the interval can be subdivided into Belfast Unit C (equivalent to the type section of the Belfast Mudstone in the Port Campbell Embayment) between 2690m to 2900m; Belfast Unit B between 2900m to 3300m?; and Belfast Unit A between 3300m? to 4100m. The last unit has informally been referred to as the Morum Member in offshore wells in the South Australian portion of the Otway Basin (Fig.1). The sandy Argonaut Member of the Mount Salt Formation found overlying the Morum Member in Copa-1, Morum-1 and Argonaut-1 does not appear to extend as far east as Bridgewater Bay-1. The time equivalent of these sands, if present in Bridgewater Bay-1 would lie between approximately 3200m to 3380m.

6. Correlating the ~1300 metre thick shale unit only with the Belfast Mudstone suggests the poor sands penetrated at the base of Bridgewater Bay-1 between 4100m to T.D. represent the upper part of the Flaxman Formation and **not** the Waarre Formation as suggested in the well completion report. It should be stressed however that the evidence for this is **extremely weak** as all samples below ~3500m are very poor. It needs to be emphasised that no key species were recorded in the new cuttings samples which would confirm that either formation has been penetrated!

An alternative correlation with a shallower pick for the top of the Flaxman Formation is possible however based on very weak data. In the original palynological report the species *Kiokansium polypes* was recorded in two sidewall cores at 3760m and 3800m (Martin, 1984; range chart). In my work in the Port Campbell Embayment over the past three years analysing new wells and preparing new samples on old wells the highest or youngest occurrence of *K. polypes* has proved to be a reliable marker for the top of the Flaxman Formation. This however needs to be contrasted with the work of other palynologists who have recorded *K. polypes* at a much higher stratigraphic levels in the Sherbrook Group. It is not clear whether their occurrences represent reworking or are the result of a much broader species concept. If the identification of *K. polypes* is indeed correct in Bridgewater Bay-1 the top for the Flaxman Formation should lie above 3740m within the relatively homogeneous shaly sequence assigned to the Belfast Mudstone. Unfortunately, because the original palynological slides or any remaining sidewall core material are unavailable these identifications cannot be checked. Counting against such a correlation is the failure to find any species diagnostic of either the Flaxman or Waarre Formations in the current study. Further, accepting the identification and range of *K. polypes* in Bridgewater Bay-1 would require that *Conosphaeridium striatoconus* is caved in the cuttings at 4065m and a cuttings sample at 3800m examined by Martin (1984).

Palaeoenvironment

All samples examined are marine based on the consistent and abundant occurrence of marine microplankton in the samples. The variation between the microplankton abundances and the kerogen types or "palynofacies" between the samples is consistent with the variations observed through the Sherbrook Group elsewhere in the basin. Most changes are interpreted to be due to variations in amount of sand and shale through the sequence or to the relative position of the wells on the shelf. The table below illustrates the changes in microplankton abundance (expressed as a percentage of microplankton in combined spore-pollen and microplankton count) for cuttings samples in three wells located at different distances from the depositional edge of the Sherbrook Group.

In all units tabulated there is a significant increase in microplankton abundance comparing Lindon-1 to Bridgewater Bay-1. The increase in interpreted to represent increasing distance from palaeoshoreline which is probably also associated with increasing water depths. In the three wells tabulated all samples analysed for palynology have proved to be marine, and all are interpreted to have been deposited seaward of the palaeoshoreline. Coastal plain environments landward of the palaeoshoreline which can be typified by coal deposition and/or palynological assemblages with characteristics indicative of fluviatile, marsh or lagoonal environments have not been found in the western part of the Otway Basin. Overall, such environments are extremely rare in the Sherbrook Group.

Table 2: Comparison of Microplankton Abundances

Formations and Zones	**Lindon-1** (Partridge, 1996a)	**Najaba-1A** (Partridge, 1996b)	**Bridgewater Bay-1** (this report)
Paaratte *X. australis* to *N. aceras*	<4%–6%	2%	6%–25%
Skull Creek *N. aceras*	<4%–6%	NR	22%–32%
Nullawarre *I. cretaceum*	7%	~2%	29%–40%
Belfast B/C *I. cretaceum* to *O. porifera*	3%–7%	17%–24%	32%–70%
Belfast A *C. striatoconus*	NR	17%	30%

NR: Equivalent zone or interval not recorded or not sampled

On the current sample spacing within Bridgewater Bay–1 any further subdivisions of marine environments using the palynology must be considered speculative. For example, it is not possible to distinguish whether the deposition is in Transgressive, Highstand or Lowstand System Tracts, or to demonstrate whether there are differences in the environment of deposition of individual sands. To achieve such detail would require access to the sidewall cores shot in the well which are not currently available, and/or analysis of cuttings samples at intervals of 10 to 20 metres.

Comments on Kerogen

In all cuttings samples analysed below 3500m the extracted solid organic matter or kerogen shows unusual features interpreted to be the result of contamination from diesel added to the drilling mud. The diesel has either altered or been "vulcanised" onto *in situ* kerogen. Examples of these problematic kerogen types are illustrated in Plate–1. The presence of diesel in the samples is believed to be a significant contributing factor to the low recoveries of palynomorphs from cuttings below 3500m.

The initial palynological processing of six cuttings between 3565-70m to 4065-70m gave low yields which contained very meagre assemblage. The second batch of three cuttings between 4110-15m to 4195-200m were first treated with a solvent in an attempt to extract any residual diesel in the cuttings. Although these samples gave better yields they still showed the same unusual modification of the kerogen and unfortunately did not contain any fossils.

The first hint that something out of the ordinary was effecting the samples was a brown staining to the solvent based Eukitt™ mounting medium used to attach the coverslips to the slides. As well as irregular staining to the mounting medium individual solid kerogen pieces were surrounded by brown halos (Pl. 1, fig. 1) or exhibited "microscopic extrusions" (Pl. 1, fig.2) and isolated "oily blebs" (Pl. 1, fig.5) were observed. The only similar features that I am aware of recorded in the palynological literature was a paper I attended at the 1979 American Association of Stratigraphic Palynologists Annual Meeting which has only ever been published in abstract (Groth, 1981). In his presentation Groth interpreted the "microscopic extrusions" and "blebs" as evidence of either hydrocarbon expulsion or primary migration.

Because diesel is recorded as a drilling mud additive for the section turbo-drilled below ~3500m it would seem to be the most likely source for these unusual features in the kerogen. I have never previously observed these features or anything similar from other palynological preparations in the Sherbrook Group which would justify the identification of these features as evidence for primary hydrocarbon expulsion.

In resolving the problems with the kerogen provisional estimates of the major organic matter types in selected cuttings is presented in Table 3.

Notwithstanding difficulties in separating "spongy amorphous organic matter" (Pl. 1, figs 1 & 7) which may be "vulcanised" diesel from "felted or clumped finely disseminated amorphous organic matter" (Pl. 1, fig. 2 & 6) the table indicates there is a marked increase in the proportion of organic matter types more favourable for the generation of oil below ~3300m. The deeper samples seem to show a corresponding decrease in structural terrestrial organic matter type typically derived from land plants. Some of these latter types may however be included in the Opaques category. Note that in light microscope analysis of kerogen it is not always possible to distinguish "Opaques" derived from reworking of organic matter or derived from natural charcoal from "Opaques" produced by thermal maturation. In the Bridgewater Bay-1 samples this problem is compounded by the poor quality and low yields from the deeper cuttings.

Overall the kerogen analysis suggests the Units A and B of the Belfast Mudstone contains higher proportion of oil prone organic matter. Unfortunately the low organic yields extracted from most of the cuttings suggests the volume or quantities of this favourable organic matter may be low.

Table 3: Bridgewater Bay-1 Kerogen Analysis

Depth (m)	Amorphous %	% Opaques &	Size range	Other features
2685-90	30% felted & finely disseminated	20%	<100μm	~50% very fine angular, opaque & semi opaque kerogen
3190-95	30% mostly 1-10μm	10%	>100μm	60% semi-opaque and structured terrestrial.
3380-85	80% finely disseminated	20%	50 to >100μm	No oil blebs or spongy amorphous kerogen observed.
3565-70	40% some felted	60%	50 to >300μm	~1% structural terrestrial + oil blebs present.
3660-65	85% felted & finely disseminated	15%	50 to 100μm	Kerogen still with spongy and oil blebs.
3845-50	65% brown coloured	30%	50 to >200μm	5% yellow-brown translucent homogeneous round pieces without structure.
3975-80	90% felted & clumped	10%	50 to >200μm	spongy & vulcanised kerogen & oil blebs present.
4045-50	80% dark brown	20%	100 to >200μm	spongy & vulcanised kerogen & oil blebs present.
4065-70	75% spongy & brown	25%	>100μm	spongy & vulcanised kerogen & oil blebs present.
4110-15	15%	80%	50 TO >200μm	~5% biodegraded terrestrial.
4135-40	20%	75%	up to 500μm	~5% structured and biodegraded terrestrial.
4195-200	20% spongy & felted	80%	up to 250μm	Spongy & vulcanised kerogen & oil blebs still present.

Biostratigraphy

The zone and age determinations are based on the Australia wide Mesozoic spore-pollen and microplankton zonation schemes described by Helby *et al.* (1987) with further resolution provided by the recently recognised subzones summarised in Partridge (1997). Author citations for most spore-pollen species can be sourced from Helby *et al.* (1987), Dettmann (1963), Dettmann & Jarzen (1988), Stover & Partridge (1973) or other references cited herein, whilst author citations for dinoflagellates can be found in the index of Lentin & Williams (1993). Species names followed by "ms" are unpublished manuscript names.

SPORE–POLLEN ZONES

***Nothofagidites senectus* spore–pollen Zone**
Sample at: 2230–2360 metres.
Age: Early Campanian.

These two cuttings are assigned to the *N. senectus* Zone on the common occurrence of *Proteacidites* pollen (9%-12%) and the presence of *Nothofagidites* *senectus* and *Forcipites sabulosus* in the higher sample. The deeper sample lacks the key pollen species but is assigned to this zone based on the associated dinoflagellates.

***Tricolporites apoxyexinus* spore-pollen Zone**
Interval: 2515–3190 metres.
Age: Santonian.
The six cuttings examined over this interval are assigned to this zone on the common occurrence of *Proteacidites* sp. (8%-30%) and the consistent but rare presence of specimens and fragments of the spore *Latrobosporites amplus.* The eponymous species *Tricolporites apoxyexinus* was not observed in any of the samples. The occurrence of the other key index species *Ornamentifera sentosa* at 3380-85m is interpreted as caved.

***Phyllocladidites mawsonii* spore-pollen Zone**
Interval: 3380–4065 metres.
Age: Coniacian–Turonian.
The samples below ~3300m are assigned to the *P. mawsonii* Zone on the absence of significant numbers of *Proteacidites* spp. Other index species indicative of the zone are not recorded in the poor assemblages.

MICROPLANKTON ZONES

***Xenikoon australis* microplankton Zone.**
Sample at: 2230–35 metres.
Age: Early Campanian.
The common to abundant occurrence (21% of MP count) of the eponymous species *X. australis* is considered diagnostic of this zone in cuttings. The rare occurrences of *X. australis* in the deeper cuttings between 2515m to 2685m are all considered to be caved.

***Nelsoniella aceras* microplankton Zone.**
Interval: 2360–2515 metres.
Age: Latest Santonian to Early Campanian.
The occurrence of the eponymous species *N. aceras* without *X. australis* in the higher sample and without *Isabelidinium rotundatum* ms in the lower sample justifies assigning the interval to the *N. aceras* Zone. In both samples the microplankton assemblages are dominated by *Heterosphaeridium* spp.

***Isabelidinium cretaceum* microplankton Zone and**
***Isabelidinium rotundatum* Subzone.**
Interval: 2625–2735 metres.
Age: Santonian.
All three cuttings clearly belong to the *I. cretaceum* Zone on the presence of *Isabelidinium rotundatum* ms in all samples, frequent *Amphidiadema denticulata* in the middle sample and the eponymous species *I. cretaceum* in the bottom sample. In this latter sample *I. rotundatum* ms may be caved as it is not usually found below the Nullawarre Greensand. All assemblages are dominated by *Heterosphaeridium* spp.

***Odontochitina porifera* microplankton Zone.**
Interval: 2915–3190 metres.
Age: Early Santonian.
This interval is assigned to the *O. porifera* Zone on the presence of the eponymous species although only with low confidence. The younger index species *Isabelidinium cretaceum* is recorded from the deeper sample, but is probably caved as *Amosopollis cruciformis* is still relatively common in this sample and this tends favour an older age. In contrast the common occurrence of *Trithyrodinium vermiculata* in the shallower sample tends to favour assignment to the younger *I. cretaceum* Zone even though the eponymous species and other related species were not recorded. The characteristic species *Chatangiella tripartita* which is recorded as a distinct subzone at the base of the *O. porifera* Zone in some wells in the Gambier Embayment was not recorded. It is unclear whether this time interval is missing or just unsampled below 3190m.

***Conosphaeridium striatoconus* microplankton Zone.**
Interval: 3380–4065 metres.
Age: Coniacian.
The youngest occurrence of the eponymous species at 3380–85m (Pl. 1, figs 3-4) is definitive evidence for the top of the *C. striatoconus* Zone in the cuttings within the thick Belfast Mudstone. Specimens of *C. striatoconus* were also recorded in cuttings at 3800m by Martin (1984) and at 4065m but as they were recorded in low diversity assemblages it is quite likely that they may be caved. The increase in abundance of *Amosopollis cruciformis* to 12% of the combined SP and MP count in the shallower sample is consistent with Coniacian to late Turonian age assemblages in other wells in the Otway Basin.

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Table 4: Interpretative Palynological Data for Bridgewater Bay-1.

Sample Type	Depth (m)	Spore-Pollen Zone (Microplankton Zone and Subzone)	CR	MP%	Comments and Key Species Present
Cuttings	2230-2235	*N. senectus* (*X. australis*)	D4 D3	25%	FADs of pollen *Nothofagidites senectus* and dinoflagellate *Xenikoon australis*.
Cuttings	2360-2365	*T. apoxyexinus* or younger (*N. aceras*)	D4 D3	6%	*Nelsoniella aceras* present without evidence of younger *Xenikoon australis*.
Cuttings	2515-2520	*T. apoxyexinus* (*N. aceras*)	D4 D3	32%	FAD *Nelsoniella aceras*.
Cuttings	2625-2630	*T. apoxyexinus* (*I. cretaceum* Zone and *I. rotundatum* Subzone)	D4 D3	22%	LAD *Isabelidinium rotundatum* ms.
Cuttings	2680-2685	*T. apoxyexinus* (*I. cretaceum* Zone and *I. rotundatum* Subzone)	D4 D3	40%	Both *I. rotundatum* and *Amphidiadema denticulata* present.
Cuttings	2730-2735	*T. apoxyexinus* (*I. cretaceum* Zone and probably also *I. rotundatum* Subzone)	D4 D3	29%	FAD *Isabelidinium rotundatum* associated with *Isabelidinium cretaceum*.
Cuttings	2915-2920	*T. apoxyexinus* (*I. cretaceum* to *O. porifera*)	D4 D3	70%	*Proteacidites* pollen and dinoflagellate *Trithyrodinium vermiculata* common.
Cuttings	3190-3195	*T. apoxyexinus* (*O. porifera*)	D4 D3	32%	FAD of *Odontochitina porifera* in assemblage with common *Proteacidites* spp. (14%) and *Amosopollis cruciformis* (~9%).
Cuttings	3380-3385	*P. mawsonii* (*C. striatoconus*)	D4 D3	30%	LAD for *Conosphaeridium striatoconus*. *Amosopollis cruciformis* common at 12%.
Cuttings	3565-3570	Indeterminate		NA	Low recovery sample — effectively barren.
Cuttings	3660-3665	Indeterminate		NA	Low recovery sample — effectively barren.
Cuttings	3845-3850	Indeterminate		NA	Low recovery sample — barren of fossils.
Cuttings	3975-3980	Indeterminate		NA	Low recovery sample — barren of fossils.
Cuttings	4045-4050	Indeterminate		NA	Low recovery sample — barren of fossils.
Cuttings	4065-4070	(*C. striatoconus*)	D3	NA	FAD for *C. striatoconus*. Poor spore-pollen assemblage not assignable to a zone.
Cuttings	4110-4115	Indeterminate		NA	High recovery but barren of fossils.
Cuttings	4135-4140	Indeterminate		NA	High recovery but barren of fossils.
Cuttings	4195-4200	Indeterminate		NA	High recovery but barren of fossils.

*CR = Confidence Ratings FAD = First Appearance Datum
MP% = Microplankton as % of total MP & SP. LAD = Last Appearance Datum
NA = Not Applicable - Fossils too rare to obtain meaningful count.

Confidence Ratings

The Confidence Ratings assigned to the zone identifications on Table 4 are quality codes used in the STRATDAT relational database 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.

Species Diversity

The use of relative diversity terms equate to the following number of species. Both spore-pollen and microplankton diversity excludes reworked or caved species in the samples

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

Table 5: Basic Sample and Palynomorph Data for Bridgewater Bay–1

Sample Type	Depth (m)	Lithological Description	Amount of Sample	Wt	Vom (cc)	O/Yield	Visual Yield	Palynomorph Concentration	Preservation	Number SP Species	Number MP Species
Cuttings	2230-2235	Medium grey mudstone	Moderate	4.7	0.3	0.063	High	Low	Fair	20	8
Cuttings	2360-2365	Medium grey mudstone		4.2	0.3	0.071	High	Moderate	Fair	33	3
Cuttings	2515-2520	Medium grey mudstone	Moderate	2.9	0.1	0.034	Low	Low	Poor-fair	17	8
Cuttings	2625-2630	Medium grey hard/massive mudstone	Moderate	4.8	0.8	0.166	High	Low	Poor-fair	28	10
Cuttings	2685-2690	Medium grey siltstone	Moderate	7.1	1.0	0.140	High	Low	Poor	24	10
Cuttings	2730-2735	Medium grey mudstone	Low	4.3	0.5	0.116	Moderate	Low	Poor	20	5
Cuttings	2915-2920	Grey mudstone	Moderate	3.1	0.4	0.129	High	Low	Poor	18	10
Cuttings	3190-3195	Medium grey mudstone–clumped	Moderate	6.4	0.6	0.093	High	Low	Poor	21	5
Cuttings	3380-3385	Medium grey mudstone–bluish tinge	Moderate	3.0	0.4	0.133	High	Low	Poor	25	8
Cuttings	3565-3570	Coal/Carbonaceous ~50%; grey mudstone ~50%.	Low	2.1	0.3	0.142	Very low	Extremely low	Poor	2	2
Cuttings	3660-3665	Medium grey mudstone	Low	2.6	0.40	0.153	Very low	Extremely low	Poor	1	2
Cuttings	3845-3850	Grey mudstone ~30%; coal ~70%	Low	2.2	0.40	0.181	Very low	Barren	Poor	NR	NR
Cuttings	3975-3980	Grey mudstone ~50%; coal/carbonaceous ~50%	Low	2.5	0.8	0.320	Very low	Barren	Poor	NR	NR
Cuttings	4045-4050	Dark grey mudstone to carbonaceous mudstone	Low	2.4	0.3	0.125	Very low	Barren	Poor	NR	NR
Cuttings	4065-4070	Medium grey mudstone	Low	2.1	0.2	0.095	Very low	Very low	Very poor	3	5
Cuttings	4100-4115	Mudstone & mica—poor sample	Low	4.0	0.5	0.125	High	Barren!	Very poor	NR	NR
Cuttings	4135-4140	Mudstone & mica—poor sample	Low	5.2	0.5	0.096	High	Barren!	Very poor	NR	NR
Cuttings	4195-4200	Brown/grey mudstone and carbonaceous flecks, some lost circulation mica	Low	20.4	0.8	0.039	High	Barren!	Very poor	NR	NR
		Averages:		**4.7**						**17.7**	**4.5**

Wt = Weight of samples in grams

Vom (cc) = Volume of aqueous suspension of kerogen residue recovered by Laola Pty Ltd

O/Yield = Volume (cc) divided by Weight (grams)

NR = None recorded

Table 6: Bridgewater Bay-1—Range and Abundance Chart for selected palynomorphs.

Sample Type	CTS	CTS	CTS	CTS	CTS	CTS	CTS	CTS	CTS
Depth (m)	2230-2235	2360-2365	2515-2520	2625-2630	2685-2690	2730-2735	2915-2920	3190-3195	3380-3385
SPORES									
Triletes undiff.	10.9%	6.5%	7.9%	7.5%	6.6%	5.6%	11.8%	6.3%	9.9%
Aequitriradites spp.	1.0%								1.4%
Baculatisporites spp.		5.6%		2.8%	0.9%		7.8%		4.2%
Biretisporites sp.									
Cicatricosisporites spp.		0.8%		0.9%				2.5%	
Clavifera spp.			1.6%					3.8%	2.8%
Coptospora pileolus ms		0.8%					2.0%		
Cyathidites (large) >40μm	4.0%	6.5%	11.1%	2.8%	3.8%	1.4%	7.8%	6.3%	7.0%
Cyathidites (small) <40μm	8.9%	12.1%	12.7%	17.0%	6.6%	9.9%	13.7%	11.4%	7.0%
Dictyophyllidites spp.	1.0%	2.4%		0.9%			2.0%	2.5%	2.8%
Gleicheniidites spp.	2.0%	0.8%		2.8%	4.7%	2.8%	2.0%	11.4%	9.9%
Herkosporites spp.			4.8%	2.8%	0.9%		2.0%	1.3%	5.6%
Laevigatosporites spp.	3.0%	0.8%	3.2%		3.8%	1.4%		2.5%	4.2%
Marratisporites scabratus	2.0%	1.6%		0.9%			2.0%		
Osmundacidites spp.		2.4%		0.9%	1.9%	1.4%			1.4%
Perotrilites spp.		0.8%		0.9%		1.4%		2.5%	1.4%
Retitriletes spp.	1.0%	0.8%	3.2%		0.9%	4.2%	5.9%	1.3%	1.4%
Rugulatisporites spp.		0.8%					2.0%		1.4%
Stereisporites spp.	1.0%	3.2%		1.9%	2.8%	2.8%	2.0%	2.5%	
Triporoletes reticulatus	1.0%		1.6%						
Total Spores	**36%**	**46%**	**46%**	**42%**	**33%**	**31%**	**61%**	**54%**	**61%**
GYMNOSPERMS									
Araucariacites australis	4.0%	6.5%	6.3%	0.9%	4.7%	4.2%		1.3%	11.3%
Corollina spp.									1.4%
Cupressacites sp.					0.9%				1.4%
Dilwynites pusillus	2.0%	0.8%		0.9%	1.9%				
Dilwynites spp.	3.0%	2.4%	4.8%	3.8%	3.8%	2.8%	3.9%	3.8%	1.4%
Lygistepollenites florinii	1.0%								
Microcachryidites antarcticus	2.0%	3.2%	1.6%	0.9%	2.8%	2.8%	2.0%	2.5%	4.2%
Phyllocladidites mawsonii	5.0%		6.3%	6.6%	3.8%	1.4%		5.1%	1.4%
Podocarpidites spp.	22.8%	15.3%	17.5%	11.3%	18.9%	16.9%		15.2%	9.9%
Podosporites microsaccatus	3.0%	4.0%		2.8%	0.9%	1.4%	17.6%	1.3%	2.8%
Vitreisporites signatus		0.8%							
Total Gymnosperms	**43%**	**33%**	**37%**	**27%**	**38%**	**30%**	**24%**	**29%**	**34%**
ANGIOSPERMS undiff.		1.6%	1.6%						
Asteropollis asteroides							2.0%	1.3%	1.4%
Australopollis obscurus	4.0%	3.2%	6.3%	3.8%	3.8%	1.4%	5.9%	1.3%	
Forcipites sabulosus	1.0%								
Nothofagidites senectus	2.0%					2.8%			
Peninsulapollis gillii	2.0%			0.9%	0.9%				
Proteacidites spp.	11.9%	8.9%	7.9%	22.6%	21.7%	29.6%	7.8%	13.9%	1.4%
Tricolpites/Tricolporites spp.	1.0%	7.3%	1.6%		1.9%	5.6%			2.8%
Triporopollenites spp.				2.8%	0.9%				
Total Angiosperms	**22%**	**21%**	**17%**	**30%**	**29%**	**39%**	**16%**	**16%**	**6%**
Total Spore-Pollen	**101**	**124**	**63**	**106**	**106**	**71**	**51**	**79**	**71**

Table 6: Bridgewater Bay-1—Range and Abundance Chart for selected palynomorphs.

Sample Type	CTS	CTS	CTS	CTS	CTS	CTS	CTS	CTS	CTS
Depth (m)	2230-2235	2360-2365	2515-2520	2625-2630	2685-2690	2730-2735	2915-2920	3190-3195	3380-3385
Fungal spores	0.7%	0.7%	2.0%	0.7%	0.6%				
Fungal hyphae				0.7%	0.6%	1.0%			
Total Fungii	**0.7%**	**0.7%**	**2.0%**	**1.4%**	**1.1%**	**1.0%**			
Reworked Fossils	2.9%	0.7%	5.0%		0.6%	1.0%	0.6%	1.7%	1.0%
DINOFLAGELLATES undiff.	9%	13%	20%	13%	3%	3%	2%	5%	10%
Amosopollis cruciformis			3%	7%	6%	10%	1%	26%	39%
Conosphaeridium striatoconus									6%
Exochosphaeridium spp.							2%		
Heterosphaeridium spp.	62%	88%	33%	57%	68%	67%	70%	47%	32%
Isabelidinium spp.					10%	10%	1%	18%	6%
Isabelidinium rotundatum				7%	4%	3%			
Micrhystridium spp.							1%		
Nelsoniella aceras	6%		3%				1%		
Odontochitina spp.			30%	13%	6%	7%	9%	3%	
Oligosphaeridium spp.	3%								
Sigmopollis carbonis					1%				
Spiniferites spp.							1%		3%
Trithyrodinium spp.			3%	3%	1%		13%		3%
Xenikoon australis	21%		7%		1%				
Total Microplankton	**34**	**8**	**30**	**30**	**72**	**30**	**118**	**38**	**31**
Microplankton as % of MP + SP count	**25%**	**6%**	**32%**	**22%**	**40%**	**30%**	**70%**	**32%**	**30%**
Amosopollis cruciformis as % of MP & SP count			1%	1%	2%	3%	1%	9%	12%
SP and MP COUNT	**135**	**132**	**93**	**136**	**178**	**101**	**169**	**117**	**102**
TOTAL COUNT	**140**	**134**	**100**	**138**	**181**	**103**	**170**	**119**	**103**

Table 7: Bridgewater Bay-1—Range Chart for selected palynomorphs

Sample Type	CTS	CTS	CTS	CTS	CTS	CTS	CTS	CTS	CTS	CTS	CTS	CTS	CTS	CTS	CTS	CTS	CTS	CTS
Depth (m)	2230-2235	2360-2365	2515-2520	2625-2630	2685-2690	2730-2735	2915-2920	3190-3195	3380-3385	3565-3570	3660-3665	3845-3850	3975-3980	4045-4050	4065-4070	4110-4115	4135-4140	4195-4200
SPORES																		
Aequitriradites spinulosus	X																	
Aequitriradites verrucosus									X									
Araucariacites australis		X	X	X	X	X		X	X						X			
Asteropollis asteroides							X	X	X									
Australopollis obscurus	X	X	X	X	X	X	X	X										
Baculatisporites spp.	X	X		X	X		X		X									
Camarozonosporites australiensis		X																
Camarozonosporites bullatus		X																
Camarozonosporites heskermensis					X													
Cicatricosisporites spp.		X		X				X										
Clavifera triplex			X					X	X									
Coptospora pileolus ms		X					X											
Corollina torosa									X									
Cupressacites sp.					X													
Cyatheacidites tectifera				X														
Cyathidites australis >40μ	X	X	X	X	X	X	X	X	X									
Cyathidites minor <40μ	X	X	X	X	X	X	X	X	X	X								
Densoisporites vellatus	X		X	X		X		X										
Dictyophyllidites spp.	X	X		X				X	X									
Dictyotosporites complex		X																
Dilwynites echinatus ms	X		X	X			X											
Dilwynites granulatus		X	X	X	X	X		X	X						X			
Dilwynites pusillus ms		X		X	X													
Foraminisporis asymmetricus				X			X											
Forcipites sabulosus	X																	
Foveogleicheniidites confossus					X		X											
Gambierina rudata	X																	
Gleicheniidites circinidites	X	X		X	X	X		X	X									
Herkosporites elliottii		X	X	X	X		X	X	X									
Laevigatosporites ovatus	X	X	X		X	X		X	X									
Latrobosporites amplus	X	X	X	X	X		X		X									
Latrobosporites ohaiensis	X	X																
Lygistepollenites florinii		X																
Marratisporites scabratus		X		X			X											
Microbaculispora spp. **RW**	X		X			X		X										
Microcachryidites antarcticus		X	X	X	X	X	X	X	X									
Neoraistrickia truncata				X		X												
Nothofagidites senectus	X					CV												
Ornamentifera sentosa									CV									
Ornamentifera wellmanii		X		X	X	X			X									
Peninsulapollis askiniae				X				X										
Peninsulapollis gillii	X				X													
Perotrilites majus				X		X		X										
Perotrilites oepikii		X							X									
Phyllocladidites mawsonii	X	X	X	X	X	X		X	X									
Pilosisporites notensis **RW**									X									
Plicatipollenites sp. **RW**	X	X	X				X	X										
Podocarpidites spp.	X	X	X	X	X	X	X	X	X	X								
Podosporites microsaccatus		X		X	X	X		X			X							

Table 7: Bridgewater Bay-1—Range Chart for selected palynomorphs

Sample Type	CTS	CTS	CTS	CTS	CTS	CTS	CTS	CTS	CTS	CTS	CTS	CTS	CTS	CTS	CTS	CTS	CTS	CTS
Depth (m)	2230-2235	2360-2365	2515-2520	2625-2630	2685-2690	2730-2735	2915-2920	3190-3195	3380-3385	3565-3570	3660-3665	3845-3850	3975-3980	4045-4050	4065-4070	4110-4115	4135-4140	4195-4200
Proteacidites spp.	X	X	X	X	X	X	X	X	X						X			
Pseudoret. pseudoreticulata **RW**	X	X			X													
Retitriletes spp.	X	X	X		X	X	X	X	X									
Rugulatisporites mallatus							X		X									
Senectotetradites varireticulatus			X															
Stereisporites antiquisporites	X	X		X	X	X	X	X										
Stereisporites pocockii	X																	
Stereisporites regium		X																
Tetracolporites araneosus ms		X																
Tricolpites spp.		X			X	X			X									
Triporoletes reticulatus			X															
Triporopollenites spp.				X	X													
Vitreisporites signatus		X																
MICROPLANKTON																		
Amosopollis cruciformis				X	X	X	X	X	X	X	X				X			
Amphidiadema denticulata					X													
Chatangiella victoriensis				X														
Cleistosphaeridium spp.	X																	
Conosphaeridium striatoconus									X						X			
Cribroperidinium sp.															X			
Cribroperidinium edwardsii			X															
Cyclonephelium distinctum									X									
Diconodinium cristatum				X														
Exochosphaeridium phragmites				X			X								X			
Heterosphaeridium spp.	X	X	X	X	X		X	X	X	X	X				X			
Heterosphaeridium evansii ms	X																	
Heterosphaeridium heteracanthum	X		X	X	X		X											
Isabelidinium spp.					X		X	X	X									
Isabelidinium belfastense									X									
Isabelidinium cretaceum								X										
Isabelidinium rotundatum ms				X	X	X												
Nelsoniella aceras	X	X	X				CV											
Nelsoniella tuberculata	X																	
Nummus sp.							X											
Odontochitina spp.							X											
Odontochitina costata			X	X	X		X											
Odontochitina porifera	X			X			X	X										
Palaeohystrichophora infusorioides					X													
Paralecaniella indentata	X																	
Sigmopollis carbonis					X													
Spiniferites ramosus									X									
Trithyrodinium spp.				X			X		X									
Trithyrodinium sp. A M90			X															
Trithyrodinium vermiculata					X		X											
Xenikoon australis	X		CV	CV	CV													
OTHER																		
Fungal hyphae		X		X		X	X								X			
Fungal spores		X		X														
Fruiting bodies										X								
ABBREVIATIONS																		
X = Present																		
CV = Caved																		

PLATE 1

Unusual features of particulate organic matter (kerogen) and palynomorphs in Bridgewater Bay-1 cuttings samples.

1. Spongy amorphous organic matter. Arrow points to margin which seems to dissolve into mounting medium and shows circular (spherical?) vesicles.

2. Mostly felted amorphous organic matter enclosing small (<1μm) pyrite crystals. Arrow A points to possible "fluid" impregnating kerogen. Arrow B points to possible semi-fluid "bleb" emerging from kerogen.

3-4. *Conosphaeridium striatoconus* (Deflandre & Cookson, 1955) Cookson & Eisenack 1969. It is unusual for palynomorphs to be as badly fractured as this specimen. The fracturing is thought to be due to mechanical breakage caused by the turbo drill.

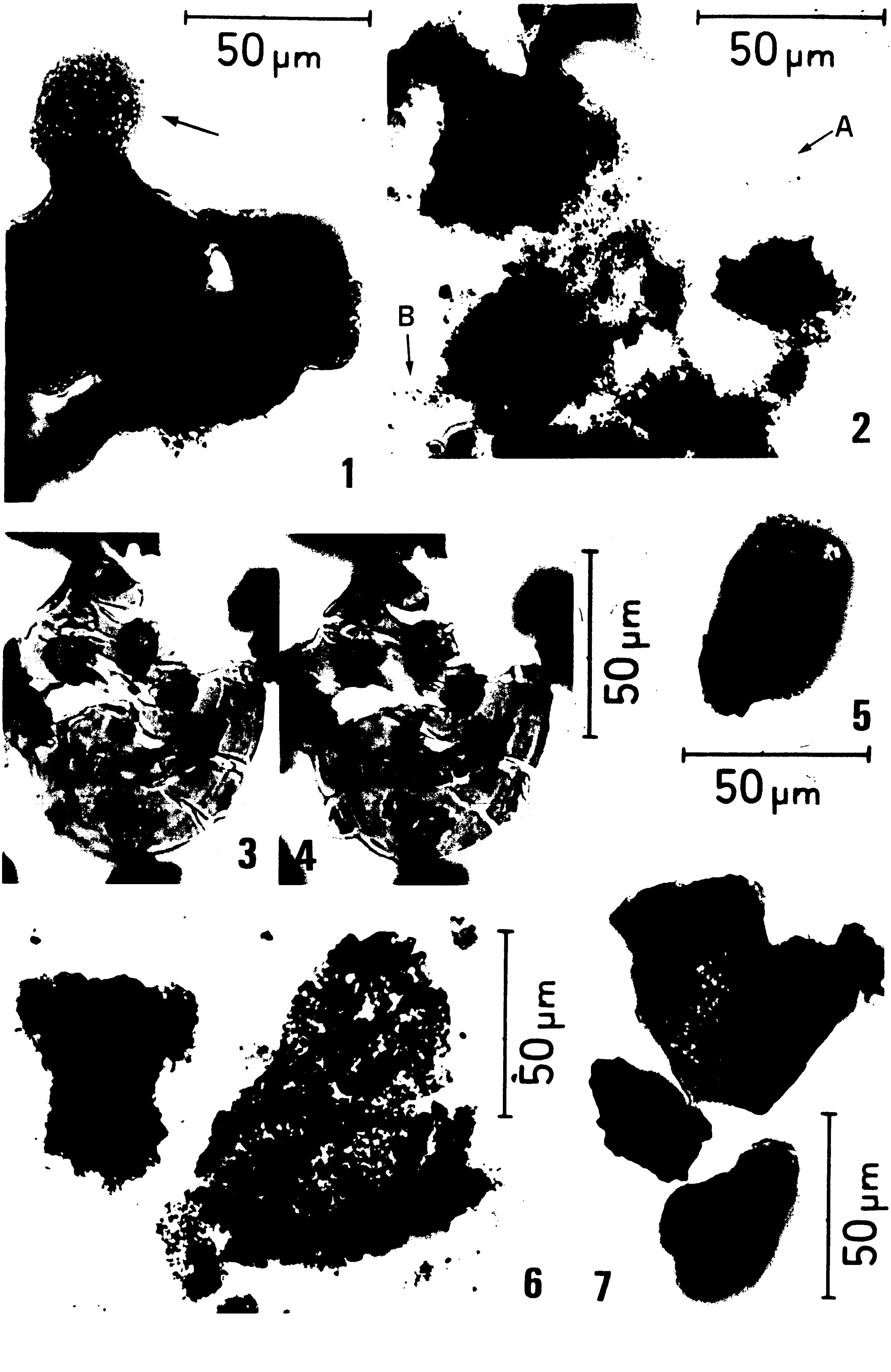
5. "Globule" of diesel additive or *in situ* asphalt found in a kerogen slide. Note edges dissolving into mounting medium and spherical vesicles within "globule" which do not show any apparent deformation associated with burial. The lack of deformation suggests this material is either secondary (ie. the diesel added to the drilling mud) or that the material was plastic or semi-fluid at depth. The material is "solid" but "reactive" as the palynological processing has extracted it as a solid particle but it is now reacting with or being "dissolved" by the mounting medium.

6. Felted or aggregated amorphous organic matter enclosing small (<1μm) pyrite crystals.

7. Amorphous organic matter with texture similar to a sponge. This material (also illustrated in figure 1 above) is common below 3500m in Bridgewater Bay-1. It may represent "vulcanised" diesel or some modification of *in situ* organic matter. It is not typical of solid particulate organic matter recorded in samples from Belfast Mudstone in other wells in the Otway Basin.

View location and coordinates in Bridgewater Bay-1

Fig.	Depth	Slide	Coordinates	Film	Frame
1	4065-70m	K	12.4, 89.2	97/30	27A
2	3565-70m	K	14.0, 109.3	97/30	30A
3-4	3380-85m	3	17.7, 87.3	97/30	22-23A
5	4065-70m	K	12.5, 90.7	97/30	26A
6	4065-70	K	22.2, 107.9	97/30	28A
7	4065-70m	K	12.8, 89.3	97/30	25A


50 μm
50 μm
A
B
1
2
50 μm
5
50 μm
3
4
50 μm
50 μm
6
7