New observations on the Cenozoic stratigraphy of the Bassian Rise derived from a palynological study of the Groper-1, Mullet-1 and Bluebone-1 wells, offshore Gippsland Basin, southeast Australia.

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Table of Contents

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Summary

Palynological analyses have been performed on forty new samples from the Latrobe and Seaspray groups and integrated with previous biostratigraphic studies and electric logs to develop a new age and correlation framework between the Groper-1, Mullet-1 and Bluebone-1 wells located in the southern Gippsland Basin.

This new study confirms the presence of Late Eocene age "coarse clastic" reservoir facies of the Latrobe Group in all three wells, with the 18 metre thick latest Eocene age Gurnard Formation present in Groper-1 thinning to ~8 metres in Mullet-1, and pinching-out before reaching Bluebone-1, where the time-equivalent section is a probable beach-shoreface sandstone.

The basal unit of the Seaspray Group which is referred to as the "Lakes Entrance Formation" in the three individual Well Completion Reports is interpreted from the new palynological data to be of Early Oligocene age and therefore older than the "micaceous marl" facies of the traditional Lakes Entrance Formation which is distributed across the northern and western margins of the Gippsland Basin. This basal unit is part of the hitherto enigmatic Early Oligocene Wedge (EOW) which is best developed along the southern portion of the Central Deep. The seismic event at the top of this wedge has incorrectly been picked as the Top of Latrobe in a number of exploration wells.

At the base of the EOW the distinctive *Phthanoperidinium comatum* dinocyst Acme (within the Upper *Nothofagidites asperus* spore-pollen Zone) previously reported in Groper-1, could not be identified from the palynological samples analysed in either Bluebone-1 or Mullet-1, but may be present in the latter well based on the presence on the sonic log of a subtle velocity spike at the base of the Seaspray Group.

At a younger level within the EOW a distinctive "yellow-stained quartz sandstone" mixed with coarse shelly calcarenite is identified in Bluebone-1 within the Lower *Proteacidites tuberculatus* spore-pollen Zone, but is interpreted to pinch-out before reaching Mullet-1, and is also not present in either of the two Groper wells. This sandstone is age equivalent to the Colquhoun Sandstone on the northern Lakes Entrance Platform where the latter is the artesian aquifer underlying the residual oil accumulation in the Cunninghame Greensand. The analogous sandstones on the Bassian Rise may be more viable exploration targets as the area has been less effected by the latest Pliocene to Pleistocene uplift, which on the northern margin has allowed the introduction of meteoric waters into the Colquhoun Sandstone and thereby destroyed the commerciality of the Lakes Entrance Oil Field.

The EOW represents the regional sealing unit for the potential sandstone reservoirs on the Bassian Rise, and the unit is distinctly thicker and more shaly than time equivalent units along the northern margin of the Gippsland Basin. The EOW also represents the marine transgression at the initial opening of the seaway or strait between the Gippsland and Bass basins across the Bassian Rise. Indeed, a significant portion of the finer-grained clastics deposited along the southern margin of the Gippsland Basin at the time of the EOW may have been sourced from out of the Bass Basin. The recognition that the EOW is potentially therefore a blanketing seal unit across the Bassian Rise can only improve the viability of any pinch-out traps.

The top of the EOW is marked by a prominent change on the electric logs (higher gamma ray and slow sonic) and this boundary is the time-line that represents the base of fine-grained carbonates or base of Seaspray Group over the northern portion of the Central Deep where the EOW is typically either missing or extremely thin (<16 metres in >60% of wells). Above this datum the remaining Seaspray Group in the three wells under review is divided into five local Bassian Rise units labelled BR5 to BR1 in ascending order. The oldest Unit BR5 is equivalent to the traditional "micaceous marl" portion of the Lakes Entrance Formation in the northern onshore portion of the basin. The next three younger units correlate with the broad concept of the Gippsland Limestone, while the youngest unit BR1 is wholly or partly equivalent to the Sale Subgroup.

Introduction

This study was undertaken for Mineral Resources Tasmania to help re-evaluate the pinch-out play concept on the Bassian Rise between the Gippsland and Bass basins by improving the age dating and correlation of the stratigraphic succession. The project involved the collection of new samples of the available conventional cores, sidewall cores, and cuttings samples from the Latrobe and Seaspray groups in the wells Groper-1, Mullet-1 and Bluebone-1 for quantitative palynological analysis. Thirty-nine new samples are analysed from these three wells. Integrated with this new data are an additional two samples from Groper-1 which were previously quantitatively analysed by Partridge (2003b). A single new sample was also analysed from Groper-2 (Appendix 1).

The results from the study are provided in this report. The details of the quantitative palynological analysis are graphically displayed on interpretative StrataBugs™ range charts (Attachments 2 to 4), and the proposed new stratigraphic subdivisions and correlations derived are presented on a new stratigraphic table (Attachment 1) and large cross-section (Attachment 5).

Historical Background: Groper-1, Mullet-1, Groper-2 and Bluebone-1 are respectively the 17th, 18th, 30th and 31st wildcat wells drilled in the Gippsland Basin by the Esso/BHP joint venture, and they were all drilled during a ten month period between December 1968 and November 1969. The wells were designed to test successively smaller pinch-out traps of the Latrobe Group onto the Bassian Rise. Unfortunately, no hydrocarbons were discovered in any of the wells, and the pinch-out play concept and the whole southern flank of the Gippsland Basin was dismissed as a high risk area and no serious exploration has subsequently occurred.

The four wells are all located on the Southern Platform[1], which lies south of the Foster Fault, and forms the northern flank of the Bassian Rise, which forms the shallow water sill separating the Gippsland and Bass basins, and runs NW to SE between Wilsons Promontory and Flinders Island (Figure-1). The wells all penetrate a moderate thickness of temperate carbonates belonging to the Seaspray Group (range 464 to 866 metres, average 661 metres thick), then a thin section of quartz-rich clastic sediments assigned to the Latrobe Group (range 32 to 85 metres, average 68 metres thick), before reaching TD in basement granitic rocks or Palaeozoic red beds (Table 1).

The key geological components needed for the original play concept to have worked are: **1)** the reservoir sands of the Latrobe Group pinchout onto the Bassian Rise, **2)** the "Lakes Entrance Formation" at the base of the Seaspray Group forms an effective top seal, **3)** the basement rocks form an effective bottom seal, **4)** the lateral dimensions of the traps are constrained within local "embayments" of the Latrobe Group against the Bassian Rise. The irregular pinchout of the Latrobe Group, and the "embayments" that were tested, are illustrated in Figure 1 (adapted from Plate 1a in the Bluebone-1 well completion report). The most likely reasons that the play was unsuccessful are: **1)** there was no effective top seal, **2)** there was no effective bottom seal, **3)** there was no lateral seal, and **4)** the traps are too remote from the source kitchen in the Central Deep of the Gippsland Basin, and therefore did not receive any migrated hydrocarbons. Or the reason for failure may have been a combination of more than one of these factors.

A consequence of the initial rapid drilling of four wells, and the great disappointment when the play concept failed, was that no thorough post-drill geological analysis of the stratigraphic succession encountered by the four wells was ever provided in any of the Well Completion Reports (WCRs). This is poignantly illustrated by the situation in Groper-1 (the first well drilled) where a continuous

[1] The terms Southern Platform and Bassian Rise are used interchangeably throughout this report as there is no structural feature that clearly defines where the Southern Platform ends and Bassian Rise begins.

suite of 15 conventional cores were cut over a ~155 metre interval between 853.4 and 1007.9m (2800 to 3307 feet), encompassing what is now recognised as the basal 76 metres of the Seaspray Group and the uppermost 78 metres of the Latrobe Group. Even though this represents the best and most complete suite of conventional cores across the top of Latrobe Group anywhere in the basin, there has never been any comprehensive studies made of these cores.

The four Bassian Rise wells have also been neglected in the following three and half decades of active exploration in the Gippsland Basin since they were drilled. The situation has therefore arisen where even though the broad subdivision of the succession into the Seaspray and Latrobe groups remains valid it has proved difficult to correlate the biostratigraphy and the electric logs in the four wells to other wells in the basin with any greater degree of precision. Particular problems are:

1) Planktonic foraminifera are reported as rare through the Seaspray Group in the four wells making biostratigraphic correlation to the thicker sections in the Central Deep of the Gippsland Basin both difficult and problematic.

2) Although good electric log correlations can be made between the four wells on the Southern Platform, these correlation have not been successfully carried to the wells on the Southern Strzelecki Terrace, or into the Central Deep.

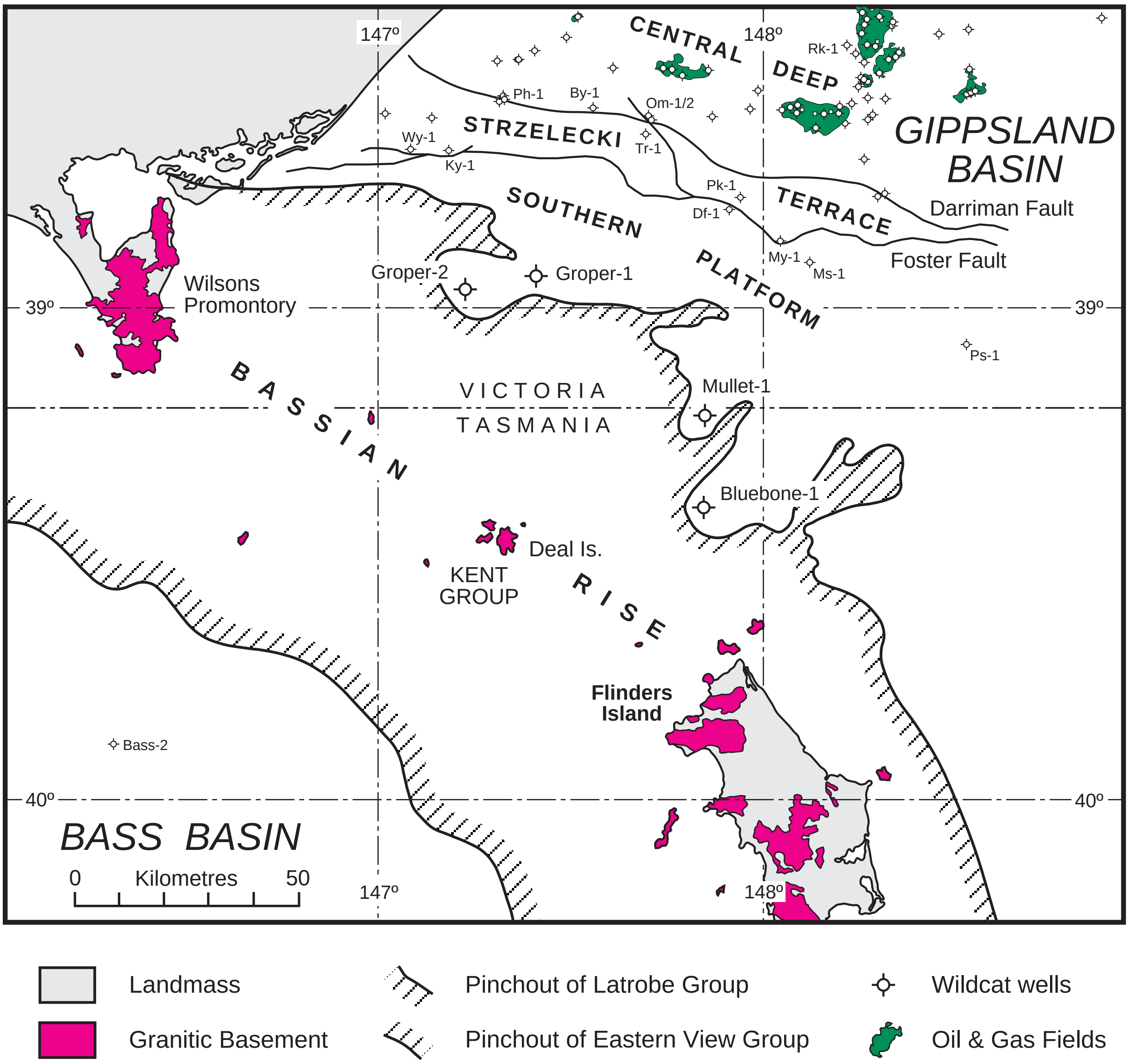
3) There is a conflict between the foraminiferal correlations provided in the Well Completion Reports and the most obvious electric log correlations, in that the foraminiferal data suggest marked diachronism of the oldest marine sediments, whereas the log correlations would favour almost "layer-cake" stratigraphy.

4) The available palynological data on the four wells is largely restricted to the Latrobe Group and is now considered to be out-of-date. Further, comprehensive palynological analysis has not been performed on the marine Seaspray Group where the planktonic foraminiferal assemblages are unreliable.

New understanding gained over the past decade of the stratigraphy throughout the rest of the basin, also has a bearing on the interpretation of the stratigraphic succession in the wells on the Bassian Rise. In particular, new palynological studies have confirmed that some sandstone reservoirs containing hydrocarbons along the northern margin of the Gippsland Basin are actually of Early Oligocene age (eg. Golden Beach gas field and Lakes Entrance oil field). This discovery provides a new perspective to the southern margin, where analogous age Early Oligocene sands could also occur and constitute untested targets. Such sandstones if they are present on the Bassian Rise may be more viable exploration targets as the area has been less affected by the latest Pliocene to Pleistocene uplift, which on the northern margin has allowed the introduction of meteoric waters into the reservoirs (eg. Lakes Entrance Oil Field).

The conceptualized models for the distribution of these Oligocene sands is either as isolated beach-barrier complexes landward of the existing wells and/or as channels oriented perpendicular to the pinch-out edge. Hypothetically such channels could originate as either subaerial rivers draining the Bassian Rise or as entrenchment valleys formed during Oligocene low sea levels. The latter type of channel could even potentially act as conduits between the shoreline sands and the Central Deep.

Although the development of such play concepts and identification of prospects will ultimately depend on detailed seismic studies a current constraint in understanding the area is the precise age dating of the stratigraphic successions encountered in the wells, and the improvement of that aspect is the goal of this report.



By-1 = Bullseye-1	My-1 = Moray-1	Ph-1 = Perch-1	Rk-1 = Rockling-1
Df-1 = Devilfish-1	Ms-1 = Mudskipper-1	Pk-1 = Pike-1	Tr-1 = Tarra-1
Ky-1 = Kyarra-1A	Om-1/2 = Omeo-1 & 2A	Ps-1 = Pisces-1	Wy-1 = Wyrallah-1

Figure 1. Locality map showing wells analysed and discussed and the pinchout edge of Latrobe Group, copied from Plate 1a in Bluebone-1 Well Completion Report.

Project Objectives: This new study of the four wells on the Bassian Rise was proposed to combine: **1)** the collection and analysis of new palynological samples with a focus on the base of the marine succession and the uppermost Latrobe Group; **2)** the construction of a geological cross-section incorporating the electric logs and the new biostratigraphic data, and **3)** the revision of stratigraphic correlations with the rest of the basin to aid the identification of possible Oligocene sands. This work was initiated in the lead up to the gazettal of acreage on the Bassian Rise in May 2006, and was to be completed in time for interested companies to use the results in their evaluation of the permits prior to the submission of bids.

Material and Methods: The conventional cores, sidewall cores and cuttings samples analysed from the Mullet-1 and Bluebone-1 wells were collected from Mineral Resources Tasmania (MRT) during a trip to Hobart from 8th to 10th February 2006. The sidewall cores were sampled from unprocessed rock material amongst the relinquished micropalaeontological materials. The conventional core and cuttings were sampled at the MRT core store. Brief hand-specimen descriptions of the cuttings are provided in Appendices 2 and 3 as no equivalent individual descriptions of the cuttings samples were provided in the respective Well Completion Reports. Unfortunately, the quantity of washed and dried cuttings in the individual sample bags was generally very low, and therefore to collect enough material for palynology without compromising the collections it was necessary to take composite samples over an interval of two or three cuttings bags. The conventional core samples analysed from Groper-1 and 2 were collected from the Victorian Department of Primary Industry (DPI) Werribee Core Library on 7th March 2006.

All analysed samples were processed by the palynological laboratory facilities at Core Laboratories Australia Pty Ltd in Perth. The processing procedure requested was a slight modification of their routine or standard method, whereby samples were oxidised prior to the application of zinc bromide density separation used to remove any undissolved mineral matter. This alternate procedure was considered necessary to remove finely disseminated pyrite within the samples and impregnating the palynomorphs. The revised methodology is believed to have improved both the amount of organic residue recovered and the concentration of the palynomorphs on the palynological slides.

The final palynological zones and ages assigned to the samples, zone confidence ratings, and zone identification criteria for each of the samples are summarised on Tables 3 to 5. The basic sample data comprising the lithologies, weights of sample processed, and the visual organic yields, and the basic palynological assemblage data comprising the palynomorph concentrations on the slides, their preservation, as well as the number of species of spore-pollen (SP) and microplankton (MP) recorded from individual samples are provided in Tables 6 to 8. Overall the visual yield from the samples varies from very low to high, with the concentration of palynomorphs on the slides was also highly variable from very low to high, while palynomorph preservation is mostly fair to good. The recorded spore-pollen diversity varies from very low to high and has an overall average of >30 species per sample, whereas the recorded microplankton diversity is typically low to moderate with an overall average of ~11 species per sample.

Description of Range Charts: The distribution of the palynomorphs identified in the samples are presented on range charts produced using the StrataBugs™ program. On these range charts the recorded palynomorph species are displayed in the samples proportional to their depth in the wells and in terms of their relative abundance (as a percentage). The palynomorphs recorded are also split between different categories. The terrestrial spore-pollen are divided between spores, gymnosperm pollen and angiosperm pollen, which are plotted in separate panels with their abundances expressed as a percentage of the total spore-pollen count. The next panel labelled Neves Effect represents the percentage sum of all species of the gymnosperm pollen *Araucariacites* and *Dilwynites* in the spore-pollen count. The following panel labelled MP% displays the total abundance of all marine microplankton species as a percentage relative to the combined spore-pollen and microplankton count. Next, the percentage abundance of individual species in the microplankton count are displayed in panel labelled Microplankton. Then plotted are Other palynomorphs, with abundances expressed as a percentage of the sum of the total spore-pollen plus other palynomorphs counted. Finally, reworked Permian, Triassic, Cretaceous and Paleocene species in the assemblages are plotted in panel labelled RW. Within each of the panels the species are plotted according to either their lowest/oldest occurrence or in alphabetical order.

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

Numbers	=	Percentage abundance
+	=	Species outside of count
C	=	Caved species
R	=	Reworked species
?	=	Questionable identification of species.

Author citations for most of the recorded spore-pollen species can be sourced from papers by Stover & Partridge (1973, 1982) and Macphail (1999), while the author citations for the microplankton species can be sourced from the indexes for dinocysts and other organic-walled microplankton prepared by Fensome *et al.* (1990) and Williams *et al.* (1998). Manuscript species names and combinations are indicated by “sp. nov.” or “comb. nov.” on the range chart, and “ms” after their binomials names in the text and tables.

Geological Discussion.

In the following section the results of the palynological analyses are integrated with the lithological descriptions and electric logs to subdivide the succession penetrated in the three wells analysed into the stratigraphic units shown on Tables 1 and 2. The relationship of these units on the Southern Platform to the stratigraphy in other parts of the Gippsland Basin is illustrated on Attachment 1. The new nomenclature is an extension of the stratigraphic revisions suggested in Partridge (1999), which has been published in outline by Bernecker & Partridge (2001; appendix).

BASEMENT: Crystalline granitic rocks were recovered in bottom hole conventional cores in Bluebone-1 and Mullet-1 and in the deepest recovered sidewall core at 1017.1m (3337 ft) in Groper-1. In Groper-2 the other well drilled on the Bassian Rise the basement was described as a dark red-brown siltstone and compared on lithology with the Late Devonian Avon River Group in south-east Victoria. The inspection of the cuttings samples during collection of palynological samples in Bluebone-1 and Mullet-1 revealed there was distinct change from well-rounded and predominantly clear quartz sands to very angular and milky-white quartz and feldspathic sands. The top of these angular sands are interpreted as weathered arkose, and occur at 551.7m (1810 ft) in Bluebone-1 and at 728.5m (2390 ft) in Mullet-1 (Appendices 2 & 3). The apparent discrepancy with the picks on the electric logs can be explained as incorrect depth lagging of the cuttings returns. In Groper-1, based on the sidewall core descriptions, the top of this weathered arkose extends as high as 1012m (3320 ft), with top of unweathered granite placed at the log break at 1013.8m (3326 ft).

LATROBE GROUP: Based on a combination of the observed lithologies, the character of the electric logs and available palynological age dating the Latrobe Group intersected in the three wells is assigned to the non-marine to paralic Burong Formation and the marine Gurnard Formation, which on the Southern Platform are both Late Eocene in age.

Table 1. Formation tops in three wells on Bassian Rise.

Stratigraphic Units		Suggest Age	Bluebone-1	Mullet-1	Groper-1
Bassian Rise Units	BR1	Pleistocene – Late Miocene	58m*	63m*	67m*
	BR2	Middle-Late Miocene	200m	260m	364m
	BR3	Early-Middle Miocene	282m	383m	508m
	BR4	Early Miocene	345m	474m	632m
	BR5	Early Miocene – Late Oligocene	416m	560m	744m
Upper **EOW**		Early Oligocene	461.8m	619.3m	807.7m
Lower **EOW** (Yellow Sandstone†)			495.3m	~672m	~893m
DT Spike		basal Oligocene		688.2m	929.6m
Gurnard Formation		Late Eocene		689.8m	932.1m
Burong Formation			522.7m	698.0m	949.8m
Crystalline Basement		Palaeozoic	594.4m	737.9m	1013.8m
Total Depth (T.D.)			605m	751m	1030m

EOW = Early Oligocene Wedge * Top of unit BR1 is Seafloor.

Table 2. Thickness of stratigraphic units in three wells on Bassian Rise.

Stratigraphic Unit		Suggest Age	Bluebone-1	Mullet-1	Groper-1
Bassian Rise Units	BR1	Pleistocene – Late Miocene	142m	197m	297m
	BR2	Middle-Late Miocene	82m	123m	144m
	BR3	Early-Middle Miocene	63m	91m	124m
	BR4	Early Miocene	71m	86m	112m
	BR5	Early Miocene – Late Oligocene	45.8m	59.3m	63.7m
Upper **EOW**		Early Oligocene	33.5m	52.7m	85.3m
Lower **EOW** (Yellow Sandstone†)			27.4m	16.2m	36.6m
DT Spike		basal Oligocene		1.6m	2.5m
Gurnard Formation		Late Eocene		8.2m	17.7m
Burong Formation			71.7m	39.9m	64.0m
Crystalline Basement		Palaeozoic	10m+	13m+	16m+

† Yellow Sandstone member is part of Lower EOW in Bluebone-1 where it is 14 meters thick

Burong Formation: The section containing quartz sands and thin carbonaceous shales at the base of the stratigraphic succession is currently best assigned to the Burong Formation defined in the Appendix to Bernecker & Partridge (2001). This formation is a non-marine and paralic[2] coastal plain facies which is laterally time equivalent to the glauconitic marine Gurnard Formation. The Burong Formation was erected by Partridge (1999) to replace the broad usage of the Traralgon Formation of Hocking (1976a-b; 1988), Thompson (1986) and Holdgate *et al.* (2000). Under the rules of the *Australian Code of Stratigraphic Nomenclature 1964*, the prior and continuing usage of the stratigraphic term Traralgon Seam in the Gippsland Basin, precludes the use of the same geographic name for another stratigraphic unit in the same area, even if it does have a different stratigraphic rank. The Traralgon Seam proper is restricted to the area around the Baragwanath Anticline in the onshore Gippsland Basin and is treated as a member within the Burong Formation. In the Central Deep the Burong Formation has an age range of Middle to Late Eocene, which extends into the Early Oligocene in the onshore Seaspray Depression. The lithological boundary between the Burong and Gurnard formations is diachronous younging to the west.

In Bluebone-1 and Mullet-1 all the cuttings through the Burong Formation were inspected in an attempt to find suitable material for palynological age dating. In both wells the top of the Latrobe "coarse clastic facies" was marked by the abrupt first downhole appearance in the cuttings of clear, well-rounded and coarse quartz sands (Appendices 2 & 3). In Bluebone-1 these sands are first recorded in the cuttings at 518-521m (1700-10 ft) and in Mullet-1 at 686-689m (2250-60 ft). The discrepancy with the deeper picks off the electric logs on Table 1 is explained as incorrect depth lagging of the cuttings returns. Disappointingly, material suitable for palynological age dating of the Latrobe Group was difficult to find in the cuttings. Although there are clear shale spikes on the gamma ray logs there is negligible shale in any of the cuttings which are mostly clean quartz sand. The palynological work was therefore restricted to the reprocessing of the sidewall core at 547.7m (1797m) in Bluebone-1, and the analysis of a extremely small amount (0.4 grams) of carbonaceous shaly material in Mullet-1. The latter sample was picked from all the cuttings bags over the broad interval 695-728.5m (2280-2390 ft). Both samples gave assemblages diagnostic of the Late Eocene Middle *N. asperus* Zone.

No new palynological analyses were performed in Groper-1 on the Burong Formation between 949.5 and 1013.8m[3] (3115 to 3326 ft), but the earlier studies by Evans (1969a) and this author confirmed that the Middle *N. asperus* Zone extends as deep as the dark brown micaceous shale recovered in SWC-4 at 1010.4m (3315 ft).

Gurnard Formation: Glauconitic sandstones assigned to the Gurnard Formation are identified in Groper-1 and Mullet-1 but apparently do not occur in Bluebone-1. In Groper-1 the formation is identified on the gamma ray log between 932.1[4] and 949.8m (3058 to 3116 ft) and is recovered in Cores 9 and 10 between 934.8 and 951.6m (3067 to 3122 ft). These cores need to be adjusted upwards by 1.8 to 2.7 metres against the electric logs to account for the discrepancies in the depths. Note also that in Core 10 only 17 feet was recovered out of 37 feet cut, and it would seem likely that the missing interval was the first reservoir sandstone which was probably unconsolidated sand that fell out of the core barrel.

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[2] Used according to the strict definition in the *Glossary of Geology* for sediments deposits by the sea, but non-marine; especially pertaining to inter-tongued marine and continental deposits laid down on the **landward side** of a coast, or in shallow water subject to marine invasion, and to the environments (such as lagoons or littoral) of marine borders [from Bates & Jackson, 1987; p.481].

[3] Base of Burong Formation taken at break on sonic and density logs.

[4] On the sonic log the top of the Gurnard Formation would be placed slightly deeper at 932.7m (3060ft).

In Mullet-1 the five sidewall cores recovered over the interval 690.4 to 699.2m (2265 to 2294 ft), which are described as siltstone and sandstones with abundant glauconite are also interpreted to represent the Gurnard Formation. Unfortunately these samples were amalgamated together with either younger and older sidewall cores in the original palynological study by Evans (1969b) and give confusing and unreliable results. It was hoped that this unit could be recognised and sampled in the cuttings, but sadly that proved not to be the case as there is an abrupt change from calcareous marl to unconsolidated quartz sands, without any obvious glauconitic sediment (see Appendix 2).

In Bluebone-1 there is no evidence on the recorded lithologies or the electric logs for the presence of any Gurnard Formation. The glauconitic sandstones recorded in Core-1 and in sidewall cores up to 477.9m (1568 ft) are assigned to the basal Seaspray Group as they are calcareous and contain younger ages. In contrast, the 11 metre thick blocky sand from 522.4 to 533.4m (1714 to 1750 ft) at the top of the Burong Formation could be interpreted as a time-equivalent beach-shoreface sand facies equivalent to the Gurnard Formation in the other two wells. However, complicating this possibility is the interpretation in the WRC that Bluebone-1 lies in a separate embayment from both Mullet-1 and Groper-1 (Figure 1). This model may explain the greater thickness of the Burong Formation in Bluebone-1 compared to Mullet-1 (Table 2).

The Gurnard Formation is only reliably dated in Groper-1 where it is has a Late Eocene age based on the presence of the Middle *N. asperus* spore-pollen Zone and the *Gippslandica extensa* and *Stoveracysta kakanuiensis* microplankton zones.

SEASPRAY GROUP: Overlying the Latrobe Group in the three wells is the cool-water carbonate succession of the Seaspray Group (Bernecker *et al*., 1997). This group is only 464 metres thick in Bluebone-1 but nearly doubles in thickness to 866 metres in Groper-1. It nearly doubles again in the wells on the northern edge of the Southern Platform where it is 1535 metres thick in Devilfish-1 and 1557 metres in Moray-1, then thickens further to 2072 metres in Tarra-1 on the northern margin of the southern Strzelecki Terrace. For comparison, the maximum drilled thickness is 2653 metres in Volador-1 at the eastern end of the Central Deep on the edge of the continental slope.

Early Oligocene Wedge: Based on the new palynological analyses and contrary to the previous foraminiferal age dating the basal unit of the Seaspray Group, which was referred to the "Lakes Entrance Formation" in the four original Well Completion Reports, is now interpreted to be Early Oligocene in age and therefore older than the "micaceous marl" facies of the traditional Lakes Entrance Formation distributed across the northern and western margins of the Gippsland Basin (see Attachment 1). This basal unit is best interpreted as part of the enigmatic Early Oligocene Wedge (EOW) which was defined by the author as:

> "*… an informal term used for the interval below the seismic pick for the top-of-Latrobe down to the best lithological and palaeo pick for the boundary between calcareous sediments of the Seaspray Group and the non-calcareous Gurnard Formation, or if the latter is not present the quartz sandstones of the older Kingfish Formation. The unit exists because the top-of-Latrobe seismic mapping surface actually corresponds to a position within the basal part of the Seaspray Group. This subtle discrepancy does not matter when mapping across the top of major structures where the EOW is typically missing, but becomes increasingly important on the flanks of structures where it is common to find extra interposed section. Unfortunately, the lack of consistent lithological and electric log character precludes the description of the EOW as a formal member of the Swordfish Formation.*" (extract from Appendix – Stratigraphic Nomenclature in Bernecker & Partridge, 2001)

The EOW has been referred to informally for over two decades but the author does not know who first proposed the term, nor precisely when it was first used. During the early years of exploration in the basin whenever there was a mis-tie between the predicted and actual top of Latrobe Group in exploration wells the explanation of the anomaly was always attributed to seismic "pull-up" due to higher seismic velocities in the younger Miocene channels. The possibility that the prediction error could partly be attributed to incorrectly picking the top of Latrobe on the seismic sections was never discussed. The early Bullseye-1 well drilled in 1974, and located 41 km NNE of Groper-1, provides a typical example. In the Well Completion Report the top of Latrobe post-drill is given as 2048mKB[5], which is 76m low to the pre-drill predicted depth of 1972mKB. The latter shallower pick actually lies at the boundary between the I1 and I2 foraminifera zones (Taylor, 1974), where it constitutes the top of the EOW (Attachment 1). Five years later in the Rockling-1 well, located on the western flank of the Halibut field, the WCR provides one of the earliest statements that there was a stratigraphic component and not only shallower seismic velocity problems affecting the pre-drill picking of the top of Latrobe. In the "Geophysical Analysis" section of the WCR it states:

> "*In Rockling-1, a thin wedge of Oligocene sediments (14 metres thick) was encountered above the Top of Latrobe Group. It is this unit which in fact gives rise to the event mapped as the Top of Latrobe, which was found 32 metres deeper than predicted.*"

The best way to conceptualise the EOW it to equate it to the patchy and irregular distribution, and limited thickness, of the foraminiferal zones I2 and J over most of the offshore Gippsland Basin, and especially in the Central Deep. Typically these zones are very thin or missing on the crests of the major structures (eg. Snapper, Marlin, Halibut and part of Kingfish), but are found, or increase in thickness, in wells on the flanks of the structures. Unfortunately, there does not appear to be any consistent lithological or log character that can be readily associated with these zones. There are also inconsistencies in the biostratigraphy between adjacent wells which are believed to be the result of a combination of stratigraphic leakage, reworking, and the type and density of available sampling. All these difficulties with mapping the EOW can ultimately be attributed to the fact that over most of the offshore basin the base of the Seaspray Group represents an interval of extremely slow deposition in a deep-water hemipelagic environment (Bernecker *et al*., 1997; fig.4). In the terminology of sequence stratigraphy the interval is represented by a stacked set of "condensed sections" equivalent to multiple eustatic or coastal onlap cycles (Loutit *et al*., 1988).

A thorough discussion of the distribution of the EOW throughout the Gippsland Basin is beyond the scope of this report. Instead the section attributed to the EOW in the wells on the Bassian Rise is compared to the distribution of equivalent age sediments in the closest wells immediately to the north. The wells are discussed from west to east as follows:

a) A recent study by Partridge (2003a), of the Wyrallah-1 and Kyarra-1A wells (located ~35 km to the NNW of Groper-1), found that there was an Early Oligocene interval of sand and coals at the top of the Latrobe Group in Wyrallah-1 that correlates with a condensed marine section at the base of the Seaspray Group in the Kyarra-1A well. The stratigraphic equivalent of the EOW in Wyrallah-1 is therefore made up of 38 metres (875 to 913m) of coastal plain facies (= Lower EOW), overlain by up to 35 metres (840 to 875m) of very glauconitic calcareous claystone[6] (= Upper EOW), which compares to <17 metres (>995.5 to <1013m) of marine glauconitic claystone in Kyarra-1A (representing both Lower and Upper parts of the EOW).

[5] The author would now favour a deeper pick of 2072.3mKB for the Top of Latrobe Group in the Bullseye-1 well, which only increases the discrepancy between the predicted and actual top of Latrobe.

[6] The author prefers pick of 825m for base of foram zone H1 in Wyrallah-1 compared to originally pick of 845m.

b) Across the Perch field (located ~41 km NNW of Groper-1), the best biostratigraphic data is from the Perch-2 well where the EOW is no more than 33 metres thick (1104 to 1137m).

c) In Bullseye-1, which has already been discussed above, the EOW is interpreted to be 34 metres thick (2048 to 2072m).

d) In the Tarra-1 and adjacent Omeo-1 and 2A wells (located 41 to 45 km NNE of Groper-1), the top of the Gurnard Formation and hence top of Latrobe Group has in the individual Well Completion Reports actually been incorrectly picked at the top of the EOW. Indeed, the break on the sonic log picked as the Top of Latrobe in Tarra-1 and Omeo-1[7] is very similar to the break on the sonic log in all the Bassian Rise wells (Attachment 5). Of the three wells Tarra-1 appears to have the most reliable biostratigraphy, in contrast to Omeo-1 and 2A where caved Miocene foraminiferal assemblages are recorded from within the EOW. Based on the author's revised interpretation of the biostratigraphy and electric log correlations the EOW is identified in Tarra-1 from 2110 to 2165m (= 55 metres thick), in Omeo-1 from 2188 to 2266 (= 78 metres thick) and in Omeo-2A from 2181 to 2260m (= 79 metres thick).

e) The Devilfish-1 and Pike-1 wells (located ~48 km NE of Groper-1 and due north of Mullet-1), the age of the base of the Seaspray Group is poorly controlled. Although Early Miocene faunas (zone H1) occur a short distance above the base of the Seaspray Group, there is still a distinct 7 to 9 metre thick undated interval at the base of the group that can be assigned to the EOW based on the character of the density log. This unit immediately overlies a 125 to 135 metre thick coarsening upwards sandstone at the top of the Latrobe Group which lacks palynological age dating.

f) In Moray-1 (located 43 km NNE of Mullet-1), the identification of zone J faunas in deeper cutting, and low confidence zone I faunas in sidewall cores are interpreted to indicate the presence a ~20 metre thick (1625 to 1644m) EOW based on the density/porosity logs.

g) In Mudskipper-1 (located ~42 km NNE of Mullet-1), there is unfortunately no age dating over the bottom 240 metre of the Seaspray Group, but based on the electric logs the basal 27 metres (1448 to 1475m) is tentatively identified as the EOW.

h) Finally, in Pisces-1, located 60 km ENE of Mullet-1 there is major unconformity across the top of Latrobe with Early Miocene (zone G) resting on probable Maastrichtian age sediments.

From the above review of the broad sweep of wells immediately north of the Bassian Rise the EOW varies from <20 to 35 metres thick to the northwest, from 50 to 80 metres thick directly to the north, and from 10 to 30 metres thick to the northeast, declining to zero towards the east. The EOW can also be shown to thin further north of this line of wells into the Central Deep. The thickest known development of the EOW unit is therefore found in the wells on the Southern Platform.

It therefore needs to be asked what is the provenance of the fine-grained clastics that make up this wedge of sediment on the Southern Platform? These sediments could not have come from directly north across the Central Deep as that area was clearly deeper water based on the abundance of planktonic foraminifera. They also could not have been derived from the onshore Seaspray Depression to the northwest because the orientation of palaeoshorelines throughout the Cenozoic is indicative of consistent longshore drift of sediments to the northeast (see discussions in Bernecker & Partridge, 2005). Instead, the most likely provenance for the fine-grained clastics is out of the

[7] In Omeo-2A the TOL in WCR is picked 65 metres too low compared to sonic log correlation to adjacent Omeo-1.

Bass Basin over an eroded down to base level Bassian Rise. The EOW identified in the Groper-1 and 2, Mullet-1 and Bluebone-1 wells therefore reflects the initial opening of the marine strait between Flinders Island and Wilsons Promontory connecting the Gippsland and Bass basins. Indeed, the EOW is potentially a blanketing seal across the Bassian Rise and this can only improve the viability of any pinch-out traps.

From the above discussion the EOW is clearly a mappable unit and therefore deserves a formal stratigraphic name. As nearly two-thirds of the thickest known section has been conventionally cored in Groper-1 the most appropriate name would clearly be Groper Formation. The formation is predominantly glauconitic calcareous mudstone to marl, with a top boundary marked by a sharp break on the sonic log from fast to slow velocities. At the base of the formation the boundary is marked down-hole change from carbonate-rich sediments with obvious shelly fossils above to the essentially non-calcareous glauconitic sediments of the Gurnard Formation below. The "DT spike" and "Yellow sandstone" discussed below represent local members within the formation.

DT Spike: At the base of the EOW in Groper-1 there is a distinctive 2.5 metre thick unit between 929.6 and 932.1m, which is characterised by fast sonic, high density and low gamma ray electric log responses, that is here informally designated as the DT Spike. These log parameter correlate to a hard cemented glauconitic sandstone which was recovered from the top of Core-9 from 931.8 to 934.5m[8] (3057 to 3066 ft). The palynological sample from Core-9 at 933.3-33.6m (3062-63 ft) contains microplankton diagnostic of the *Phthanoperidinium comatum* Acme zone, and spore-pollen diagnostic of the Upper *Nothofagidites asperus* Zone. In the previous study by Partridge (2003b) this unit was interpreted to lies just below the traditional "top of Latrobe" and constitute part of the Gurnard Formation, but for this report is considered to lie at the base of the Seaspray Group. The lack of suitable sidewall cores and poor quality of the cuttings does not allow either of these palynological zones to be recognised in Mullet-1 or Bluebone-1. However, the subdued sonic spike in Mullet-1 at 688.2 to 689.8m (2258 to 2263m) may be equivalent. Nothing similar is identified on the electric logs in Bluebone-1.

The *P. comatum* Acme and associated Upper *N. asperus* Zone are elsewhere found sporadically in a condensed marine section at the boundary between the Gurnard Formation and Seaspray Group in offshore wells in the main part of the Central Deep, to the east of Groper-1. The interval is typically no more than 5 or 10 metres thick and whether or not it is recorded relies on the density and recovery of sidewall cores across the top of Latrobe boundary, as both zones are extremely difficult to confidently identify using cuttings. In marked contrast, in wells to the west of Groper-1, in the nearshore Central Deep and onshore Seaspray Depression, the Upper *N. asperus* Zone is recorded from an expanded coal measures succession (eg. Burong-1, Wurruk Wurruk-1 and Wyrallah-1; Partridge, 1971, 2003a; Partridge & Macphail, 1996). Maximum thickness is >100 metres and these lower coastal plain facies are placed in the Early Oligocene portion of the Burong Formation (Partridge, 1999; Bernecker & Partridge, 2001; fig.2). Knowledge of the microplankton assemblages within these coastal plain facies is poor due to the limited number of cores and sidewall cores available, but the data available suggests that these are substantially an expanded non-marine equivalent of the *P. comatum* Acme.

Based on the distribution of the marine condensed sections and coal measures facies belonging to the Upper *N. asperus* Zone a palaeoshoreline can be mapped just east of an arcuate line extending through the wells Wyrallah-1, Tommyruff-1, Golden Beach-1A and the onshore Spermwhale Head-1 bore. The precise extension of this palaeoshoreline onto the Southern Platform is speculative, but it has to lie south of Groper-1 based on the identification of the marine condensed

[8] The depths of Cores 8 and 9 need to be adjusted upwards by 2 to 3 metre (6.5 to 10 feet) to match the electric logs.

section belonging to the *P. comatum* Acme, and the overlying younger part of the Upper *N. asperus* Zone in this well (see Attachment 1). This palaeoshoreline also needs to lie south of the nearby Groper-2 well, and probably both Mullet-1 and Bluebone-1, based on the electric log and biostratigraphic correlation of these well with Groper-1. The importance of this observation is that there may still be potential for shoreline facies further south on the Southern Platform which have not yet been fully explored.

Yellow Sandstone member: At a younger level within the EOW a distinctive "yellow-stained quartz sandstone" mixed with coarse shelly calcarenite is identified in cuttings between 493.8 and 509m (1620 to 1670 ft) in Bluebone-1 (Appendix 3). These are equivalent to the interval 495.3 and 509m (1625 to 1670 ft) on the gamma ray log (Attachment 4), and lie within the *Proteacidites tuberculatus* spore-pollen Zone based on the recovery of the key index species *Cyatheacidites annulatus* in the deeper Core-1 at 510.5m (1675 ft). This “Yellow Sandstone member” is therefore younger than the Upper *N. asperus* Zone age sandstones discussed above, that are assigned to the Burong Formation. Instead, the unit is age equivalent to the Colquhoun Sandstone on the northern Lakes Entrance Platform where the latter unit is the artesian aquifer underlying the residual oil accumulation in the Cunninghame Greensand (Attachment 1). The analogous sandstones on the Bassian Rise may be more viable exploration targets as the area has been less effected by the latest Pliocene to Pleistocene uplift, which on the northern margin has allowed the introduction of meteoric waters into the Colquhoun Sandstone and thereby destroyed the commerciality of the Lakes Entrance Oil Field. Based on the palynology and electric log correlations the “Yellow Sandstone member” is interpreted to pinch-out before reaching Mullet-1, and is also not present in either of the two Groper wells, however more extensive development of the unit may occur south of the existing wells (Attachment 5).

Bassian Rise Units: Above the EOW the remaining Seaspray Group in the three wells under review is divided into five local Bassian Rise units based primarily on the character of the electric logs (Attachments 1 and 5). The base of the oldest BR5 unit is marked by slow velocities and higher gamma ray and is interpreted to represent a major flooding surface (above the fabled mid-Oligocene sequence boundary?). The velocities increase and gamma ray declines as the section become more carbonate-rich up section. Unit BR5 is correlated with the traditional “micaceous marl” portion of the Lakes Entrance Formation in the northern onshore portion of the basin. The overlying Unit BR4 is characterised by the highest velocities and lowest gamma ray signature through the Seaspray Group, and is interpreted to represent the beginning of the broad concept of the Gippsland Limestone (= Longford Limestone and Longfordian Stage). Next, Unit BR3 is characterised by continuing high velocities in Groper-1, but a notable decline in velocities in the more inshore Mullet-1 and Bluebone-1. Based on the examination of the cuttings this is suggested to be due to less consolidated and higher porosity calcarenites, representative of higher energy more inshore environments. Unit BR3 is broadly late Early to early Middle Miocene in age equivalent to the Balcombian Stage. The base of Unit BR2, like the base of BR5, is marked by slow velocities and higher gamma ray signature, albeit more subtly, and is interpreted to represent another flooding surface overlying a major sequence boundary. This surface is correlated with the commencement of Mid-Miocene channelling in the Central Deep and therefore Unit BR2 is Middle Miocene and younger (= Bairnsdalian Stage and younger). Little is known of the youngest Unit BR1 as no cuttings were collected this shallow in any of the wells, and the only lithological information available is from the four shallowest sidewall cores in Bluebone-1 between 125 and 182.3m (410 to 598 ft). These are described as calcareous sandstones but they lack any meaningful foraminifera and have not been analysed for palynomorphs. Based solely on lithological similarities Unit B1 is wholly or partly equivalent to the Sale Subgroup.

Biostratigraphy.

The samples analysed are classified according to palynological zonation schemes erected in the Gippsland Basin and are discussed in ascending order. The spore-pollen zonation scheme was originally proposed by Stover & Evans (1974) and Stover & Partridge (1973, 1982), and has recently been updated and refined by Partridge (1999). The parallel microplankton zonation scheme was initially proposed in outline by Partridge (1975, 1976), and has subsequently been substantially refined and modified by Partridge (1999). A recent published summary of these schemes can also be found in the latest edition of the *Geology of Victoria* (Partridge & Dettmann, 2003).

Middle *Nothofagidites asperus* spore-pollen Zone
Age: Late Eocene

This zone is recorded from the Burong and Gurnard formations of the Latrobe Group in all three wells. In Bluebone-1 the SWC at 547.7m (1797 ft) from the middle of the Burong Formation yielded a non-marine assemblage dominated by *Nothofagidites* pollen (47% of SP count), which contains the overlap in ranges of *Santalumidites cainozoicus* and *Aglaoreidia qualumis* and this suggests a correlation with the upper part of the Middle *N. asperus* Zone. In Mullet-1 there was no rock material surviving from any of the sidewall cores, so the sample analysed was an extremely small amount (0.4 grams) of carbonaceous shale picked from eleven cuttings bags between 2280 and 2390 ft (~695 to 729m). Surprisingly, this meagre quantity of picked cuttings gave a good assemblage which was again dominated by *Nothofagidites* pollen (42%), with a secondary abundance of the gymnosperm pollen *Phyllocladidites mawsonii* (22%). An age not younger than the Middle *N. asperus* Zone is favoured by presence of *Dryptopollenites semilunatus*, although the occurrence of *Granodiporites nebulosus* and *Clavastephanocolporites meleosus* suggests a position at the very top of the zone, or some material caved from the younger Upper *N. asperus* or Lower *P. tuberculatus* zones. Some degree of ambiguity about the precise age is unavoidable given the nature of the sample.

The two samples analysed from the Gurnard Formation in Groper-1 are also assigned to this zone although the evidence is weak as they lack the principal index species. However, based on original study by Evans (1969a) and earlier undocumented studies by this author it is known that the Middle *N. asperus* Zone occurs over the broader interval 938.4 to 1010.4m encompassing all of the Gurnard as wells as the underlying Burong Formation. The relinquished palynological slides from these earlier studies were not re-examined for this report because of time and budget constraints.

Gippslandica extensa and *Stoveracysta kakanuiensis* microplankton Zones
Age: Late Eocene

Elsewhere in the Gippsland Basin it has been established that the *G. extensa* Zone, defined on the total range of the eponymous species, is equivalent to the entire Middle *N. asperus* spore-pollen Zone, while the *S. kakanuiensis* Zone, also defined on the total range of the eponymous species, is equivalent to the uppermost part of the Middle *N. asperus* Zone (Attachment 1). The latter zone is also considered to lie immediately below the Eocene/Oligocene boundary and is an important marker for the top of the Latrobe Group. *Gippslandica extensa* the species and the Zone in this study is recorded from the picked cuttings in Mullet-1 and the two core samples analysed from the Gurnard Formation in Groper-1 (Tables 3 & 4), while *Stoveracysta kakanuiensis* the species and the Zone is recorded from Core-9 at 939.1m in Groper-1.

In an earlier study by Stover (1970a) the dinocyst *Gippslandica* (al. *Deflandrea*) *extensa* was also recorded in Core-10 in Groper-1 between 953.1 and 957m (3127 to 3140 ft). These depths are now considered spurious as the 17 feet of core recovered from the 37 feet cut was originally incorrectly assigned to the bottom half of the interval cored. Once the depths of the samples examined by Stover are adjusted his deepest sample is found to be equivalent to the new sample analysed at 951.3m (3121 ft)[9]. As a consequence of this adjustment the *G. extensa* Zone is no longer known to extend into the Burong Formation in Groper-1. This absence may warrant further investigation because of the contrasting results from Mullet-1, where another study by Stover (1970b) reports *G. extensa* in sidewall cores between 718.1 and 727.3m (2356 to 2386 ft) from near the base of the Burong Formation. These latter occurrences most probably represent contamination as the sidewall cores from which they are reported were described as poorly sorted and unconsolidated sandstones, which are not the usual lithologies to yield marine dinocysts. The presence of *G. extensa* in the new sample analysed from Mullet-1 between 695 and 729m does not provide any clarification of this question as those composite picked cuttings also cover the interval of the Gurnard Formation.

Upper *Nothofagidites asperus* spore-pollen Zone
Age: Early Oligocene

This zone is only documented in Groper-1 where it is recorded from the samples in Core-8 over a 16 metre interval from 915.9 to 931.8m (3005 to 3057 ft). Based on the electric log character it is also possible that much thinner sections assignable to this zone could occur in Mullet-1 and Bluebone-1 but this can never be proved due to the lack of suitable samples. The zone is defined as the interval from the extinction of numerous Eocene index species (on the current range charts the significant species are *Santalumidites cainozoicus, Dryptopollenites semilunatus* and *Proteacidites adenanthoides*) to the FADs (First Appearance Datums) of the spore *Cyatheacidites annulatus* or *Proteacidites tuberculatus* (Stover & Partridge, 1973; Partridge & Dettmann, 2003).

The five samples assigned to the zone in Groper-1 are characterised by assemblages with abundant *Nothofagidites* pollen (range 32 to 52%, average 41%) and moderate ***Neves effects***[10] (~15%). Key species with oldest consistent occurrences in this zone are *Proteacidites rectomarginis* (at 933.3-933.6m), *Proteacidites stipplatus*, and *Forcipites crater* (both at 930.6-931.8m). Unusual first occurrences in this zone are the presence of *Chenopodipollis chenopodiaceoides* and *Graminidites media* at 928.4m, which might represent contamination.

The associated microplankton belong to the *P. comatum* Acme zone, which is discussed next and the *F. leos* Zone of the *Operculodinium* Superzone which is discussed after the *P. tuberculatus* and *T. bellus* zones.

***Phthanoperidinium comatum* microplankton Acme Zone**
Age: Basal Oligocene

The sample in Groper-1 at 933.3 to 933.6m (3062-63 ft) from the top of Core-9 was previously analysed and reported on by Partridge (2003b) whose comments are summarised here. The sample is assigned to the *P. comatum* Acme based exclusively on the abundant occurrence of the eponymous *Phthanoperidinium comatum* which represent 30% of the total MP count. The assemblage is however dominated by *Spiniferites* spp. (59%), and subdividing the specimens of this genus, and the closely related *Achomosphaera* into their component species would substantially increase the overall diversity of the sample. Unfortunately no species with distinctive morphology

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9 These samples from Core-10 also need to be adjusted upwards by 2 to 3 metres against the logs to place them above the top of the Burong Formation picked at 949.8m (Table 1).

10 ***Neves effects*** are the tendency for certain fossil gymnosperm pollen to occur in greater abundance in distal marine environments. In the Australian Late Cretaceous and Cenozoic palynological succession Neves effects have empirically been found to be displayed by the species *Araucariacites australis* and the various species of the genus *Dilwynites*. When the combined abundance of these two pollen types exceeds 20% of the total count of the terrestrial spores and pollen a strong Neves effect is indicated.

and biostratigraphic value can currently be distinguished within this group. The presence of the older index species *Corrudinium incompositum* and *Gippslandica extensa* in the sample is treated as reworking as both species are represented by only one specimen each in the three rich slides examined.

***Proteacidites tuberculatus* spore-pollen Zone**
Age: Early Oligocene to Early Miocene

The original definition by Stover & Partridge (1973, p.243) gave equal weight to a number of species, but since then the preferred zone concept has stabilised as the interval from the FAD of *Cyatheacidites annulatus* to the FADs of any of several species with first occurrences near the base of the *Triporopollenites bellus* Zone. The *P. tuberculatus* Zone was also subdivided by Stover & Partridge (1973) into Lower, Middle and Upper subzones, however, only the boundary between the Lower and Middle subzones, which is defined by the FADs of *Foveotriletes lacunosus* and *Cyathidites subtilis*, has been widely recognised. The younger boundary between the Middle and Upper subzones has proved unreliable as the specified index species *Acaciapollenites* (al. *Polyadopollenites*) *myriosporites* and *Psilastephanocolporites micus* are extremely rare and no additional marker species have yet been identified. Part of the problem is that most of the palynological work through the Early Miocene have been on either coals or marine carbonates, which tend to contain lower diversity assemblages.

The *P. tuberculatus* Zone has been identified in the majority of samples from the three wells under investigation and is also recorded from the single sample analysed in Groper-2 (Appendix 1). The core samples in Groper-1 are all confidently assigned to the Lower subzone, whereas the cuttings analysed from Mullet-1 and Bluebone-1 cannot be assigned to the subzones with any degree of confidence (Tables 3 to 5).

In Groper-1 more than 50 metres of the Lower *P. tuberculatus* Zone is recorded from Cores 1 to 7 between 854.4 and 907.1m (2803 to 2976 ft). The assemblages are dominated by *Nothofagidites* pollen (range 19 to 51%, average 36%) and displays moderate to strong *Neves effects* (~21%). The principal index species *Cyatheacidites annulatus* is recorded from 10 of the 14 samples analysed, whereas the eponymous species *Proteacidites tuberculatus* was only recorded in two samples. The following secondary index species are also rare through the section: *Foveotriletes palaequetrus* (4 samples), *Foveotriletes crater* (2 samples), *Proteacidites stipplatus* (3 samples), *Myrtaceidites eucalyptoides* (1 sample). The samples analysed can be no younger than the Lower subzone because they lack specimens of either *Foveotriletes lacunosus* and *Cyathidites subtilis*, and the shallowest sample still contains *Granodiporites nebulosus* which has its LAD within the Lower subzone.

In Mullet-1 the *P. tuberculatus* Zone is recorded from several composite cuttings samples between 426 and 658m (1540 to 2160 ft) but confidence in any further refinement is precluded by the low to moderate yields and palynomorph concentrations. *Cyatheacidites annulatus* is recorded from 4 out of the 5 productive samples, and *Cyathidites subtilis* in the shallowest sample where it is consistent with a Middle to Upper subzone assignment. The deeper samples by default are consistent with the Lower subzone based on weak negative evidence (ie. the absence of *Foveotriletes lacunosus* and *Cyathidites subtilis*). *Nothofagidites* pollen abundance through the zone is variable averaging 28% in the bottom three samples but declining to <20% in the two shallower quantitative assemblages, where there is an increase in gymnosperm pollen abundance and stronger *Neves effects* (>26%).

The six shallowest samples analysed in Bluebone-1 probably all belong to the *P. tuberculatus* Zone, but the mostly low to very low yields combined with very low concentrations of spores and pollen on the palynological slides makes confident zone assignments impossible. Importantly however, the spore *Cyatheacidites annulatus* was recorded from the glauconitic marly sandstone in Core-1 at

510.5m (1675 ft) and this confirms that the overlying "Yellow Sandstone member" belongs to the *P. tuberculatus* Zone. Further, based on negative evidence (the absence of the younger spores *Foveotriletes lacunosus* and *Cyathidites subtilis*) the slightly more diverse assemblages from the cuttings at 457-66m and the SWC at 477.9m are considered to belong to the Lower subzone.

***Triporopollenites bellus* spore-pollen Zone**
Age: Middle to Late Miocene

The *T. bellus* Zone is identified in four sidewall cores and the shallowest cuttings in Mullet-1 over the interval 317 to 436m (1040 to 1430 ft). The base of this zone was originally defined by Stover & Partridge (1973; p.244) by the mutual oldest occurrence of six species. Of these the most frequent in Mullet-1 is the spore *Rugulatisporites cowrensis* (= senior synonym of *Rugulatisporites micraulaxus*), which occurs in 4 of the 5 samples analysed. Other index species recorded are *Polypodiaceoisporites tumulatus* (at 350.5m and 365.2m) and *Tubulifloridites antipodica* (at 350.5m), while the presence of *Haloragacidites haloragoides* in the SWC at 335.3m is also important as this species has a FAD within the zone. Unfortunately, the eponymous species *Triporopollenites bellus* was not found in any of the samples. The assemblage counts display an overall decline in *Nothofagidites* pollen and a compensating increase in spores and gymnosperm pollen but they are not considered to be very reliable because of the low yields from the samples.

The *Operculodinium* microplankton Superzone
Age: Early Oligocene to Recent

The term *Operculodinium* Superzone has been used for over two decades in unpublished company reports to broadly categorise the organic-walled microplankton assemblages from the Seaspray Group which are typically dominated by chorate[11] dinocysts, most notably the species *Spiniferites* spp., *Operculodinium centrocarpum* and *Lingulodinium machaerophorum*. This long duration superzone has proved difficult to subdivide into shorter zones principally due to a lack of formal taxonomic documentation of the diverse assemblages. The necessity to undertake this applied research has been perceived to have low priority because there were already existing calcareous microfossil zonation schemes, that were suitable for the age dating and correlation of the carbonate-rich Seaspray Group. However, the author believes that further refinement of the palynological microplankton zonation can still make a significant contribution, especially in those parts of the marine succession where planktonic foraminifera are rare.

This current study identifies four zones within the *Operculodinium* Superzone in the three wells being analysed (Attachment 1). The two youngest zones shown on the chart were erected by McMinn (1992), and although not applicable to this study are included for sake of completeness. It needs to be stressed that the current positions shown for the boundaries, between the new *P. simplex*, *T. vancampoae* and *M. choanophorum* zones, against the planktonic foraminiferal zones and the geologic time scale is very imprecise. Note also that if a sample cannot be confidently assigned to the one of the zones it defaults to the broader *Operculodinium* Superzone. In addition to the formal zones a unique acme of the dinocyst *Svalbardella* is recorded in Groper-1. Although this potentially could be and important marker horizon it is not yet considered to be a formal zone.

[11] The term chorate cysts apply to those dinocysts which have numerous long processes or spines. The central body is typical 1/3 to 2/3rds the overall diameter of the cysts as defined by the distal tips of the processes. As an empirical rule the proportion of chorate cysts in microplankton assemblages increases in more open-marine environments.

***Fromea leos* microplankton Zone**
Age: Early Oligocene

This zone is defined as the range zone of the eponymous species *Fromea leos* sp. nov. and is recorded from Cores 1 to 8 in Groper-1. The eponymous species unfortunately was not recorded in the much poorer assemblages recovered from Mullet-1 and Bluebone-1. The microplankton assemblages are dominated by *Spiniferites* spp. (range 6 to 81%; average 41%) with secondary and more irregular abundances of *Operculodinium centrocarpum* (range <1% to 52%; average 15%) and *Lingulodinium machaerophorum* (range <1% to 39%; average 10%). Other species potentially diagnostic of the zone are *Glyphanodinium facetum* and fairly consistent *Selenophemphix* spp. The next younger zone index species *Protoellipsodinium simplex* sp. nov. first appears in the upper half of the *F. leos* Zone but is generally rare. Elsewhere in the basin this zone is usually associated with the foraminiferal zones J1 and J2. The original identification of foraminiferal zones I1 and I2 from the cores in Groper-1 is now considered suspect and needs to be re-examined.

In the shallowest sample analysed in Groper-1 from Core-1 at 854.4m (2803 ft) there is a unique abundance of the of the dinocyst *Svalbardella* sp. which could potentially represent an important Acme zone. The recent article by Van Simaeys *et al.* (2005) has identified a similar acme in the Arctic dinocyst succession and correlates it with an Oligocene glaciation episode. On current correlations to the international geologic time scale there is an age discrepancy between these two high latitude acmes, but it constitutes an interesting occurrence that warrants further investigation.

***Protoellipsodinium simplex* microplankton Zone**
Age: Early Oligocene to Early Miocene.

The zone is defined as the interval from the LAD of *Fromea leos* to the FAD of *Tuberculodinium vancampoae*. The zone also can be characterised by the consistent and often common occurrence of *Protoellipsodinium simplex* sp. nov. and related species. These are chorate dinocysts are typically characterised by smooth-walled ellipsoidal to spherical endocysts, with precingular archeopyles involving only a single paraplate, and a variety processes including spines, triangles, clavae and cones. Most forms appear to belong to as yet undescribed species.

***Tuberculodinium vancampoae* microplankton Zone**
Age: Early to Middle Miocene.

The zone is defined as the interval from the FAD of *Tuberculodinium vancampoae* to the FAD of *Melitasphaeridium choanophorum*. The zone is only recorded in the shallowest cuttings sample analysed in Mullet-1 based on the oldest occurrence of the eponymous species (Table 4). The assemblage is characterised by the very abundant occurrence of *Protoellipsodinium simplex* sp. nov.

***Melitasphaeridium choanophorum* microplankton Zone**
Age: Middle Miocene to Pliocene.

This zone was originally proposed by McMinn (1992) and is here used as a range zone defined by the total range of the eponymous species *Melitasphaeridium choanophorum.* The zone is only recorded in the four shallowest sidewall cores samples analysed in Mullet-1, and is identified by the oldest occurrence of the eponymous species (Table 4). The low diversity assemblages are characterised by the abundant occurrence of *Pyxidinopsis psilata*.

Conclusions

The palynological analysis of a new suite of samples from the wells Groper-1, Mullet-1 and Bluebone-1 has substantially improve the age dating and correlation between these Southern Platform wells located on the northern flank of the Bassian Rise. The study has also resolved anomalies that existed in the original Well Completion Reports and has provided an improved stratigraphy for the area. Listed in point form are the principal results:

1) The stratigraphic unit originally identified as the "Lakes Entrance Formation" in the four wells Groper-1, Mullet-1, Bluebone-1, and Groper-2 has been found to be older than the traditional and thickest "micaceous marl" portion of the Lakes Entrance Formation as was originally documented along the northern onshore portion of the Gippsland Basin.

2) This basal section of the Seaspray Group is instead correlated with the hitherto enigmatic Early Oligocene Wedge (EOW), which is revealed by this study to have its thickest development along the southern margin of the Gippsland Basin. The EOW is 60 to 125 metres thick in the wells on the Southern Platform, compared to <20 metres thick in most wells in Central Deep.

3) The thicker development of the EOW in the wells examined is interpreted to be a consequence of the initial opening of the marine strait between the Gippsland and Bass basins across the Bassian Rise. A substantial portion of fine-grained clastics within the EOW are also believed to have been sourced out of the Bass Basin, and therefore the unit potentially represents a regional seal for all older sandstone reservoirs on the Bassian Rise.

4) The study confirms a Late Eocene age (Middle *Nothofagidites asperus* Zone) for the "coarse clastic" reservoir facies of the Latrobe Group in the Bluebone-1, Mullet-1 and Groper-1 wells.

5) A 17 metre thick latest Eocene age portion of the Gurnard Formation is identified in Groper-1. The same electric log character in Mullet-1 is thinner at ~8 metres, but the age dating cannot be confirmed due to lack of suitable rock samples. The formation however, clearly pinches-out before reaching Bluebone-1, where the time-equivalent section is interpreted to be a beach-shoreface sandstone facies.

6) A younger Early Oligocene "Yellow Sandstone member" comprising well rounded yellow-stained quartz sand mixed with coarse shelly calcarenite is identified in Bluebone-1 within the lower part of the EOW, and this member could constitute a potential hydrocarbon reservoir in areas south of the current wells. Equivalent "yellow sands" were not identified in the cuttings inspected from Mullet-1 nor in the conventional cores over the equivalent interval in Groper-1, and therefore the unit clearly pinches-out before reaching these more northern wells.

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Table 3. Interpretative palynological data for Groper–1

No.	Depth Feet	Depth Metres	Sample Type	Spore-Pollen Zone	CR	Microplankton Zone	CR	Comments & Key Species	Age/Stage	MP%
1	2803	854.4	Core 1	Lower *P. tuberculatus*	A1	*Svalbardella* Acme	A3	LAD of *Granodiporites nebulosus*	Early Oligocene	42%
2	2818	858.9	Core 1	Lower *P. tuberculatus*	A4	*Operculodinium* Superzone	A5	LAD of *Glyphanodinium facetum*	Early Oligocene	7%
3	2826.5	861.5	Core 1	Lower *P. tuberculatus*	A1	*Operculodinium* Superzone	A5	*Proteacidites stipplatus* present	Early Oligocene	3%
4	2839	865.3	Core 1	Lower *P. tuberculatus*	A1	*Fromea leos*	A1	LAD of *Fromea leos*	Early Oligocene	44%
5	2854	869.9	Core 1	Lower *P. tuberculatus*	A1	*Fromea leos*	A1	*Proteacidites tuberculatus* present	Early Oligocene	30%
6	2866	873.6	Core 4	Lower *P. tuberculatus*	A1	*Fromea leos*	A1	*Fromea leos* present	Early Oligocene	49%
7	2876	876.6	Core 5	Indeterminate		*Operculodinium* Superzone	A5	<50 palynomorphs recovered	Indeterminate	25%
8	2885	879.3	Core 5	Lower *P. tuberculatus*	A4	*Operculodinium* Superzone	A4	Low yield lacking key species	Early Oligocene	54%
9	2903	884.8	Core 6	Lower *P. tuberculatus*	A4	Indeterminate		Low yield lacking key species	Early Oligocene	7%
10	2914	888.2	Core 6	Lower *P. tuberculatus*	A2	Indeterminate		*Cyatheacidites annulatus* present	Early Oligocene	2%
11	2927.5	892.3	Core 6	Lower *P. tuberculatus*	A2	Indeterminate		*Cyatheacidites annulatus* present	Early Oligocene	5%
12	2939	895.8	Core 6	Lower *P. tuberculatus*	A5	*Fromea leos*	A4	*Glyphanodinium facetum* present	Early Oligocene	73%
13	2952	899.8	Core 7	Lower *P. tuberculatus*	A1	*Fromea leos*	A4	FAD of *Proteacidites tuberculatus*	Early Oligocene	55%
14	2976	907.1	Core 7	Lower *P. tuberculatus*	A1	*Fromea leos*	A4	FAD of *Cyatheacidites annulatus*	Early Oligocene	48%
15	3005	915.9	Core 8	Upper *N. asperus*	A4	*Fromea leos*	A4	Common *Impletosphaeridium* sp.	Early Oligocene	37%
16	3035	925.1	Core 8	Upper *N. asperus*	A4	*Fromea leos*	A4	FAD of *Fromea* sp. cf. *F. leos*	Early Oligocene	23%
17	3046	928.4	Core 8	Upper *N. asperus*	A4	*Operculodinium* Superzone	A1	*Aglaoreidia qualumis* present	Early Oligocene	10%
18	3053-57	930.6-31.8	Core 8	Upper *N. asperus*	A1	*Operculodinium* Superzone	A1	FAD of *Foveotriletes crater*	Early Oligocene	13%
19	3062-63	933.3-33.6	Core 9	Upper *N. asperus*	A1	*P. comatum* Acme	A1	*Phthanoperidinium comatum* 30%	basal Oligocene	43%
20	3081	939.1	Core 9	Middle *N. asperus*	A4	*S. kakanuiensis*	A1	FAD of *Stoveracysta kakanuiensis*	Late Eocene	41%
21	3121	951.3	Core 10	Middle *N. asperus*	A4	*G. extensa*	A3	FAD of *Gippslandica extensa*	Late Eocene	6%

SP & MP = Spore-Pollen and Microplankton
FAD & LAD = First & Last Appearance Datums
CR = Confidence Ratings
MP% = Abundance of microplankton in SP + MP count.

Table 4. Interpretative palynological data for Mullet–1

No.	Depth Feet	Depth Metres	Sample Type	Spore-Pollen Zone	CR	Microplankton Zone	CR	Comments & Key Species	Age/Stage	MP%
1	1040	317.0	SWC	*T. bellus*	B3	*M. choanophorum*	B5	*Rugulatisporites cowrensis*present.	Mid-late Miocene	69%
2	1100	335.3	SWC	*T. bellus*	B2	*M. choanophorum*	B5	*Rugulatisporites cowrensis*present.	Mid-late Miocene	45%
3	1150	350.5	SWC	*T. bellus*	B2	*M. choanophorum*	B3	FAD of *Tubulifloridites antipodica*	Mid-late Miocene	14%
4	1198	365.2	SWC	*T. bellus*	B2	*M. choanophorum*	B3	FAD of *Melitasphaeridium choanophorum*	Mid-late Miocene	37%
5	1400-30	426.7-435.9	Composite Cuttings	*T. bellus*	D2	*T. vancampoae*	D3	FAD of *Rugulatisporites cowrensis* and FAD of *Tuberculodinium*	Early-mid Miocene	45%
6	1540-80	469.4-481.6	Composite Cuttings	*P. tuberculatus*	D1	*Operculodinium* Superzone	D2	*Cyathidites subtilis* present.	Early Miocene	29%
7	1710-40	521.2-530.4	Composite Cuttings	Indeterminate		*Operculodinium* Superzone	D5	Low yield <50 palynomorphs.	Indeterminate	32%
8	1860-90	566.9-576.1	Composite Cuttings	*P. tuberculatus*	D1	*Operculodinium* Superzone	D2	Abundant *Operculodinium janduchenei*	Early Miocene	43%
9	1970-2000	600.5-609.6	Composite Cuttings	*P. tuberculatus*	D1	*Operculodinium* Superzone	D2	*Cyatheacidites annuylatus* present.	Early Miocene	18%
10	2040-60	621.8-627.9	Composite Cuttings	*P. tuberculatus*	D1	*Operculodinium* Superzone	D2	*Cyatheacidites annuylatus* present.	Oligocene	13%
11	2130-60	649.2-658.4	Composite Cuttings	*P. tuberculatus*	D1	*Operculodinium* Superzone	D2	FAD of *Cyatheacidites annulatus*	Oligocene	32%
12	2220-50	676.7-685.8	Composite Cuttings	Indeterminate		*Operculodinium* Superzone	D5	Low yielding mixed assemblage	Oligocene	23%
13	2280-2390	694.9-728.5	Picked Cuttings	Middle *N. asperus*	D4	*G. extensa*	D3	LAD of *Gippslandica extensa* FAD of *Granodiporites rebulosus*	Late Eocene	7%

Table 5. Interpretative palynological data for Bluebone–1

No.	Depth Feet	Depth Metres	Sample Type	Spore-Pollen Zone	CR	Microplankton Zone	CR	Comments & Key Species	Age/Stage	MP%
1	1260-90	384.0-393.2	Composite Cuttings	Indeterminate		*Operculodinium* Superzone	D5	Low yield <50 palynomorphs.	Miocene	13%
2	1400-40	426.7-438.9	Composite Cuttings	Indeterminate		*P. simplex*	D3	*Protoellipsodinium simplex* present.	Miocene	47%
3	1500-30	457.2-466.3	Composite Cuttings	Lower *P. tuberculatus*	D4	*Operculodinium* Superzone	D2	LAD of *Cooksonidium* spp.	Early Oligocene	65%
4	1568	477.9	SWC	Lower *P. tuberculatus*	D4	Indeterminate		SP dominated by *Nothofagidites* pollen.	Early Oligocene	3%
5	1640-70	499.9-509.0	Composite Cuttings	Indeterminate		Indeterminate		Low yield <20 palynomorphs.	Indeterminate	20%
6	1675	510.5	Core-1 TOP	*P. tuberculatus*	A3	*Operculodinium* Superzone	A5	FAD of *Cyatheacidites annulatus*	Early Oligocene	5%
7	1797	547.7	SWC	Middle *N. asperus*	B1	Indeterminate		FAD of *Aglaoreidia qualumis* and LAD of *Santalumidites cainozoicus*	Late Eocene	NR

CONFIDENCE RATINGS (CR)

Alpha Code Linked to Sample
A = Core
B = Sidewall core
C = Coal cuttings
D = Ditch cuttings
J = Junk basket

Numeric Code Linked to Palynomorph Assemblage
1 = Excellent confidence: High diversity assemblage **plus** key zone species.
2 = Good confidence: Moderately diverse assemblage **plus** key zone species.
3 = Fair confidence: Low diversity assemblage **plus** key zone species.
4 = Poor confidence: Moderate to high diversity **minus** key zone species.
5 = Very low confidence: Low diversity assemblage **minus** key zone species.

Table 6. Basic sample and palynological assemblage data for Groper–1

No.	Depth Feet	Depth Metres	Sample Type	Lithology (Hand-specimen description)	Weight grams	Visual Yield	Palynomorph Concentration	Palynomorph Preservation	No. SP Species	No. MP Species
1	2803	854.4	Core 1	Pale greenish-grey glauconitic marl	15.5	High	High	Fair-good	47+ (2+)	12+
2	2818	858.9	Core 1	Hard greenish-grey glauconitic marl with shells	17.1	Low	Moderate	Fair	29+	7+
3	2826.5	861.5	Core 1	Medium greenish-grey glauconitic marl	16.2	Low	High	Fair-good	46+	5+ (1+)
4	2839	865.3	Core 1	Medium greenish-grey glauconitic marl	15.2	Moderate	High	Poor-fair	43+	14+
5	2854	869.9	Core 1	Med green-grey marl with shells & crs glaucony	15.0	Moderate	High	Poor-fair	45+ ((2+)	15+
6	2866	873.6	Core 4	Pale tan-grey marl (top of core)	15.2	High	High	Poor-fair	33+	12+
7	2876	876.6	Core 5	Pale greenish-grey mudstone to marl	16.0	Very low	Very low	Fair	9+	15+
8	2885	879.3	Core 5	Pale grnish-grey fossiliferous mudstone to marl	16.9	Low	Moderate	Poor-fair	25+	17+
9	2903	884.8	Core 6	Light-medium greenish-grey mudstone to marl	15.4	Low	Moderate	Fair	29+	7+
10	2914	888.2	Core 6	Light-medium greenish-grey mudstone to marl	15.2	Low	Moderate	Fair-good	34+	4+
11	2927.5	892.3	Core 6	Light-medium greenish-grey mudstone to marl	15.3	Very low	Moderate	Fair	29+ (1+)	5+
12	2939	895.8	Core 6	Light-medium grey mudstone to marl	16.0	Low	Moderate	Poor-fair	19+	14+
13	2952	899.8	Core 7	Medium grey mudstone to marl, trace glaucony	15.4	Moderate	High	Poor	37+ (1+)	13+
14	2976	907.1	Core 7	Pale tan grey marl (top of decline in fossils)	16.4	Moderate	High	Poor-fair	19+ (1+)	15+
15	3005	915.9	Core 8	Med brown-grey calc. mudstone, tr. glaucony	15.8	Low	Moderate	Poor-fair	24+ (1+)	11+
16	3035	925.1	Core 8	Medium brownish-grey calc. mudstone to marl	15.3	Moderate	High	Poor	44+	17+ (2+)
17	3046	928.4	Core 8	Medium brn-grey calc. mudstone to marl	15.8	High	High	Poor	40+	9+
18	3053-57	930.6-31.8	Core 8	Marl	30.0	High	Very high	Good	61+	18+ (2+)
19	3062	933.3-33.6	Core 9	Hard greensand	30.0	High	High	Good	41+	12+
20	3081	939.1	Core 9	Dark grey glauconitic mudstone	16.1	High	High	Poor	24+ (1+)	21+
21	3121	951.3	Core 10	Mottled grey-green & dk grey muddy sandstone	16.8	High	Low	Poor	27+	5+

SP = Spore-Pollen
MP = Microplankton
Numbers in brackets in two right-hand columns refer to species which are reworked.

Table 7. Basic sample and palynological assemblage data for Mullet–1

No.	Depth Feet	Depth Metres	Sample Type	Lithology (Hand-specimen description)	Weight grams	Visual Yield	Palynomorph Concentration	Palynomorph Preservation	No. SP Species	No. MP Species
1	1040	317.0	SWC	Light tan-grey marl or calcilutite	7.2	Low	Low	Fair	14+	10+
2	1100	335.3	SWC	Light grey homogeneous marl or calcilutite	10.9	Moderate	Moderate	Fair	34+	6+
3	1150	350.5	SWC	Light tan-grey marl or calcilutite with shells	14.9	Moderate	Moderate	Fair	33+ (1+)	6+
4	1198	365.2	SWC	Light grey homogeneous marl or calcilutite	9.4	Moderate	Moderate	Fair	31+	13+
5	1400-30	426.7-435.9	Composite Cuttings	Light grey unconsolidated calcarenite with bryozoa and forams	11.4	Low	Moderate	Fair	27+	13+
6	1540-80	469.4-481.6	Composite Cuttings	Light grey unconsolidated calcarenite >80%	15.1	Low	Low	Poor-fair	21+	15+
7	1710-40	521.2-530.4	Composite Cuttings	Light grey unconsolidated calcarenite 80-100%	14.2	Very low	Very low	Fair	6+	9+
8	1860-90	566.9-576.1	Composite Cuttings	Light grey calcisiltite to calcarenite (clumped and powdery)	14.9	Moderate	High	Fair	29+	11+
9	1970-2000	600.5-609.6	Composite Cuttings	Light grey muddy calcilutite to marl (clumped)	14.9	Moderate	Moderate	Fair	36+ (1+)	17+
10	2040-60	621.8-627.9	Composite Cuttings	Light grey marl (calcilutite)	14.6	Low	Moderate	Fair	35+ (1+)	13+
11	2130-60	649.2-658.4	Composite Cuttings	Light grey marl (calcilutite)	17.8	Moderate	High	Fair	30+ (2+)	16+ (1+)
12	2220-50	676.7-685.8	Composite Cuttings	Light grey marl (80%), calcarenite (~20%), trace quartz (sand to powder texture).	17.9	Low	Low	Fair	22+	12+
13	2280-2390	694.9-728.5	Picked Cuttings	Dark grey to black carbonaceous mudstone	0.4	Moderate	High	Good	44+	5+

Table 8. Basic sample and palynological assemblage data for Bluebone–1

No.	Depth Feet	Depth Metres	Sample Type	Lithology	Weight grams	Visual Yield	Palynomorph Concentration	Palynomorph Preservation	No. SP Species	No. MP Species
1	1260-90	384.0-393.2	Composite Cuttings	Cream-white coarse calcarenite >90%; with medium to dark grey siltstone/shale <10%	9.3	Moderate	Very low	Poor	15+ (2+)	3+
2	1400-40	426.7-438.9	Composite Cuttings	Light cream to tan coarse calcarenite; trace of quartz sand and dark grey siltstone/shale	8.1	Low	Low	Fair	14+ (5+)	11+
3	1500-30	457.2-466.3	Composite Cuttings	Very light grey calcarenite to calcisiltite with minor coarse shelly fragments	5.6	Low	Moderate	Poor-fair	27+ (3+)	15+
4	1568	477.9	SWC	Grey marl speckled green with very fine grained glauconite (est. <20% by volume)	11.9	Very low	Low	Fair	25+	3+
5	1640-70	499.9-509.0	Composite Cuttings	~40% well-rounded crs qtz sand (1/4 yellow stained) and 60% off-white calcarenite	10.6	Very low	Very Low	Poor-fair	5+	2+
6	1675	510.5	Core-1 TOP	Greenish off-white marl with fine-grained glauconite and shelly fossil fragments	21.5	Very low	Very low	Good	12+	1+
7	1797	547.7	SWC	Light brownish-grey silty mudstone	11.9	High	High	Good	44+	NR

Appendix 1. Palynological analysis of Core-3 at 749.2 metres in Groper-2.

The sample from Core-3 at 749.2 metres (2458 feet) in Groper-2 was collected by the author from the Victorian DPI Werribee Core Library at the same time as the cores from Groper-1 were sampled. Sixteen grams of rock were processed to give a high organic residue yield, containing a moderate to high concentration of palynomorphs, whose preservation was mostly fair to good. A moderate to high diversity assemblage of more than 40 spore-pollen species and 17 microplankton species was were recorded on the palynological slides, and these species are tabulated below.

The assemblage recorded is assigned to the *P. tuberculatus* Zone based on the presence of the eponymous species *Proteacidites tuberculatus* in association with *Proteacidites stipplatus*. A position near the base of the zone is suggested by the absence of the principal index species *Cyatheacidites annulatus*. The sample also probably belongs to the Lower subzone based on the absence of the spores *Foveotriletes lacunosus* and *Cyathidites subtilis* which characterise the overlying Middle subzone (Stover & Partridge, 1973; fig.2). Overall the spore-pollen assemblage is characterised by abundant angiosperm pollen (74%), with common gymnosperm pollen (19%) and frequent spores (7%). The commonest forms in the assemblage are the angiosperm pollen belonging to *Nothofagidites* (54%) and *Haloragacidites harrisii* (14.5%), and the gymnosperm pollen *Phyllocladidites mawsonii* (5.2%). All other species categories have abundances of less than 5%.

The associated microplankton assemblage is dominated by the dinocysts *Spiniferites* spp. (47%), *Operculodinium centrocarpum* (22%) and *Lingulodinium machaerophorum* (22%). The high abundances of these species is characteristic of the *Operculodinium* Superzone. The presence of the small acritarch species *Fromea leos* sp. nov. in the sample is diagnostic of the *F. leos* Zone at the base of the Superzone. A position not far above the next older *P. comatum* Acme zone is suggested by the rare presence of the eponymous species *Phthanoperidinium comatum*.

Core-3 was cut between 744 and 749.2 metres (2441 to 2458 ft) in Groper-2 and is located just 12 metres above the designated top of the Latrobe Group at 762.3m (2501 ft) in the Well Completion Report (Curnow, 1969). The confident Early Oligocene age obtained on the palynology from both the spore-pollen and microplankton assemblages contrast markedly with Early Miocene age for the base of the marine succession suggested in the original study of the foraminifera by Taylor (1969), and later reaffirmed in a review of the original data by Taylor & Martin (1983). Although in the discussion under section *IV. Geology* in the Well Completion Report the young “Early Miocene” age was disputed the preferred interpretation in was still for a substantial section (66 metres or 219 ft thick) to be missing at the base of the marine succession in Groper-2 relative to Groper-1 due to the effect of onlap to the south (see Curnow, 1969; plate 1).

Appendix 1. Palynological analysis of Core-3 at 749.2 metres in Groper-2 (cont.).

Spores	
Baculatisporites disconformis Stover *in* Stover & Partridge 1973	0.5%
Cyathidites spp. (small)	1.0%
Gleicheniidites circinidites (Cookson) Dettmann 1963	1.0%
Herkosporites elliottii Stover *in* Stover & Partridge 1973	0.5%
Ischyosporites gremius Stover *in* Stover & Partridge 1973	0.5%
Ischyosporites irregularis sp. nov.	X
Laevigatosporites major (Cookson) Krutzsch 1959	X
Laevigatosporites ovatus Wilson & Webster 1946	0.5%
Latrobosporites marginatus Mildenhall & Pocknall 1989	X
Matonisporites ornamentalis (Cookson) Partridge *in* Stover & Partridge 1973	0.5%
Retitriletes spp.	0.5%
Stereisporites australis (Cookson) Krutzsch 1959	0.5%
Trilete spores indet.	1.6%
Verrucosisporites kopukuensis (Couper) Stover & Partridge 1973	X
Total Spores:	**7.3%**
Gymnosperm Pollen	
Araucariacites australis Cookson 1947	3.1%
Cupressacites sp.	2.1%
Dilwynites granulatus Harris 1965	2.6%
Dilwynites tuberculatus Harris 1965	0.5%
Lygistepollenites florinii (Cookson & Pike) Stover & Evans 1974	1.6%
Phyllocladidites mawsonii Cookson 1947	5.2%
Podocarpidites spp.	4.1%
Total Gymnosperm pollen:	**19.2%**
Angiosperm Pollen	
Haloragacidites harrisii (Couper) Harris *in* Mildenhall & Harris 1971	14.5%
Ilexpollenites spp.	1.0%
Malvacipollis robustus sp. nov.	X
Malvacipollis subtilis Stover *in* Stover & Partridge 1973	X
Milfordia incertus (Thomson & Pflug) Krutzsch 1962	0.5%
Nothofagidites brachyspinulosus (Cookson) Harris 1965	0.5%
Nothofagidites deminutus (Cookson) Stover & Evans 1974	1.0%
Nothofagidites emarcidus/heterus (Cookson)	46.6%
Nothofagidites falcatus (Cookson) Hekel 1972	2.6%
Nothofagidites flemingii (Couper) Potonié 1960	0.5%
Nothofagidites vansteenisii (Cookson) Stover & Evans 1974	3.1%
Periporopollenites demarcatus Stover *in* Stover & Partridge 1973	X
Proteacidites spp.	1.5%
Proteacidites stipplatus Partridge *in* Stover & Partridge 1975	0.5%
Proteacidites tuberculatus Cookson 1950	X
Quintinia psilatispora Martin 1973	0.5%
Tricolporate pollen undiff.	0.5%
Tricolporites adelaidensis Stover & Partridge 1982	0.5%
Triporopollenites ambiguus Stover *in* Stover & Partridge 1973	X
Total Angiosperm Pollen:	**73.6%**
Total Spore-Pollen Count:	**193**

Appendix 1. Palynological analysis of Core-3 at 749.2 metres in Groper-2 (cont.).

Microplankton (as % of microplankton count)	
Microplankton undiff. (marine)	7%
Batiacasphaera spp.	X
Crassosphaera concinna Cookson & Manum 1960	X
Cyclopsiella spp.	X
Dapsilidinium pseudocolligerum (Stover) Bujak *et al.* 1980	X
Fromea leos sp. nov.	2%
Hystrichokolpoma rigaudiae Deflandre & Cookson 1955	X
Impletosphaeridium sp.	22%
Lecaniella sp. 8 of Head 1992	X
Lingulodinium machaerophorum (Deflandre & Cookson) Wall 1967	X
Micrhystridium spp. (marine)	X
Operculodinium centrocarpum (Deflandre & Cookson) Wall 1967	22%
Phthanoperidinium comatum (Morgenroth) Eisenack & Kjellström 1972	X
Protoellipsodinium simplex sp. nov.	X
Spiniferites spp.	47%
Systematophora placacanthum (Deflandre & Cookson) Davey *et al.* 1969	X
Tectatodinium pellitum Wall 1967	X
Total Microplankton Count:	**55**
Total Count Microplankton & Spore-Pollen:	**248**
Microplankton abundance as % of SP + MP Count:	
Other Palynomorphs (as % of SP + Other Palynomorphs)	
Fungal spores & hyphae	1%
Insect setae	X
Microforaminiferal liners	0.5%
Reworked palynomorphs	0.5%
Indeterminate palynomorphs	3%
Total count of Other Palynomorphs:	**11**
Total Count :	**259**

Appendix 2. Hand-specimen description of cuttings in Mullet-1.

Cuttings were only collected from below the 13-3/8 inch casing in Mullet-1, between 1338 and 2463 feet TD (407.8 to 751m). As the **only** lithological descriptions in the WCR are the brief summary in the text and the description of composite cuttings intervals on the Core Lab *Grapholog* brief "hand-specimen" descriptions were made of **selected** cuttings as they were inspected and collected for the palynological analysis. These descriptions are included here to supplement the limited information in the WCR.

Sample Type	Depth feet	Depth metres	Hand-specimen Lithological Descriptions
Cuttings	1350-60	411.5-414.5	Casing cement
Cuttings	1370-80	417.6-420.6	Casing cement
Cuttings	1380-90	420.6-423.7	Bryozoan calcarenite, light grey, loose >70% & calcisiltite
Cuttings	1390-1400	423.7-426.7	Calcarenite, light grey, loose >80%.
Cuttings	1400-10	426.7-429.8	Calcarenite — clumped but apparently more muddy
Cuttings	1410-20	429.8-432.8	Calcarenite, light grey, loose, with bryozoa and forams
Cuttings	1420-30	432.8-435.9	Calcarenite, light grey loose >90%
Cuttings	1460-70	445-448.1	Calcarenite, light grey loose >90%
Cuttings	1500-10	457.2-460.2	Calcarenite — clumped, as above but more muddy
Cuttings	1530-40	466.3-469.4	Calcarenite, light grey loose >80%
Cuttings	1540-50	469.4-472.4	Calcarenite, light grey loose >80%
Cuttings	1560-70	475.5-478.5	Calcarenite, light grey <75%, calcisiltite 25% (clumped)
Cuttings	1700-10	518.2-521.2	Calcarenite, light grey loose >90%.
Cuttings	1710-20	521.2-524.3	Calcarenite, light grey loose >90%
Cuttings	1720-30	524.3-527.3	Calcarenite, light grey loose 100%
Cuttings	1730-40	527.3-530.4	Calcarenite, light grey loose 100%
Cuttings	1790-1800	545.6-548.6	Calcarenite, light grey loose ~50%; calcisiltite ~50%
Cuttings	1860-70	566.9-570	Calcarenite/Calcisiltite (clumped)
Cuttings	1870-80	570-573	Calcarenite/Calcisiltite, dirty light grey
Cuttings	1960-70	597.4-600.5	Calcisiltite light grey muddy and clumped
Cuttings	1970-80	600.5-603.5	Calcisiltite light grey muddy and clumped
Cuttings	1980-90	603.5-606.6	Marl, in large pieces.
Cuttings	1990-2000	606.6-609.6	Marl, light grey
Cuttings	2040-50	621.8-624.8	Light grey marl (calcilutite)
Cuttings	2050-60	624.8-627.9	Light grey marl (calcilutite)
Cuttings	2130-40	649.2-652.3	Light grey marl (calcilutite)
Cuttings	2140-50	652.3-655.3	Light grey marl (calcilutite)

Appendix 2. Hand-specimen description of cuttings in Mullet-1 (continued).

Sample Type	Depth feet	Depth metres	Hand-specimen Lithological Descriptions
Cuttings	2150-60	655.3-658.4	calcarenite, light grey, unconsolidated sand-size >40% and light grey marl <60%
Cuttings	2240-50	682.8-685.8	Marl, light grey marl ~80%, calcarenite ~20%, trace quartz
Cuttings	2250-60	685.8-688.8	Quartz Sandstone, clear to milky white, coarse, very well-rounded ~80%, caved light grey marl/calcarenite ~20%.
Cuttings	2260-70	688.8-691.9	Quartz Sandstone, clear to milky white, coarse, very well-rounded, >90%, caved light grey marl/calcarenite <10%.
Cuttings	2270-80	691.9-694.9	Quartz Sandstone, as above >95%, with trace of dark lithics (carbonaceous shale?) <1%
Cuttings	2280-90	694.9-698	Quartz Sandstone, as above, increase of carbonaceous shale to >2%
Cuttings	2290-2300	698-701	Quartz Sandstone, as above >95% sand.
Cuttings	2300-10	701-704.1	Quartz Sandstone, as above >95%, dark lithics and carbonaceous shale <5%.
Cuttings	2310-20	704.1-707.1	Quartz Sandstone, as above >85%, caved calcarenite ~10%, dark lithics and carbonaceous shale <5%.
Cuttings	2330-40	710.2-713.2	Quartz Sandstone 98%, very coarse, very well-sorted and well-rounded, clear rather than milky white in colour.
Cuttings	2340-50	713.2-716.3	Quartz Sandstone, as above 98%, with trace dark lithics.
Cuttings	2350-60	716.3-719.3	Quartz Sandstone, as above >95%.
Cuttings	2360-70	719.3-722.4	Quartz Sandstone, as above >98%
Cuttings	2370-80	722.4-725.4	Quartz Sandstone, as above
Cuttings	2380-90	725.4-728.5	Quartz Sandstone, as above
Cuttings	2390-2400	728.5-731.5	Angular quartz Sandstone, milky-white ~90%; rounded quartz sand and calcarenite ~10%, probably caved.

Appendix 3. Hand-specimen description of cuttings from Bluebone-1.

Cuttings were only collected from below the 9-5/8 inch casing in Bluebone-1, between 1250 and 1984 feet TD (381 to 605m). As the **only** lithological descriptions in the WCR are the brief summary in the text and the description of composite cuttings intervals on the Core Lab *Grapholog* brief "hand-specimen" descriptions were made of **selected** cuttings as they were inspected and collected for palynological analysis. These descriptions are included here to supplement the limited information in the WCR.

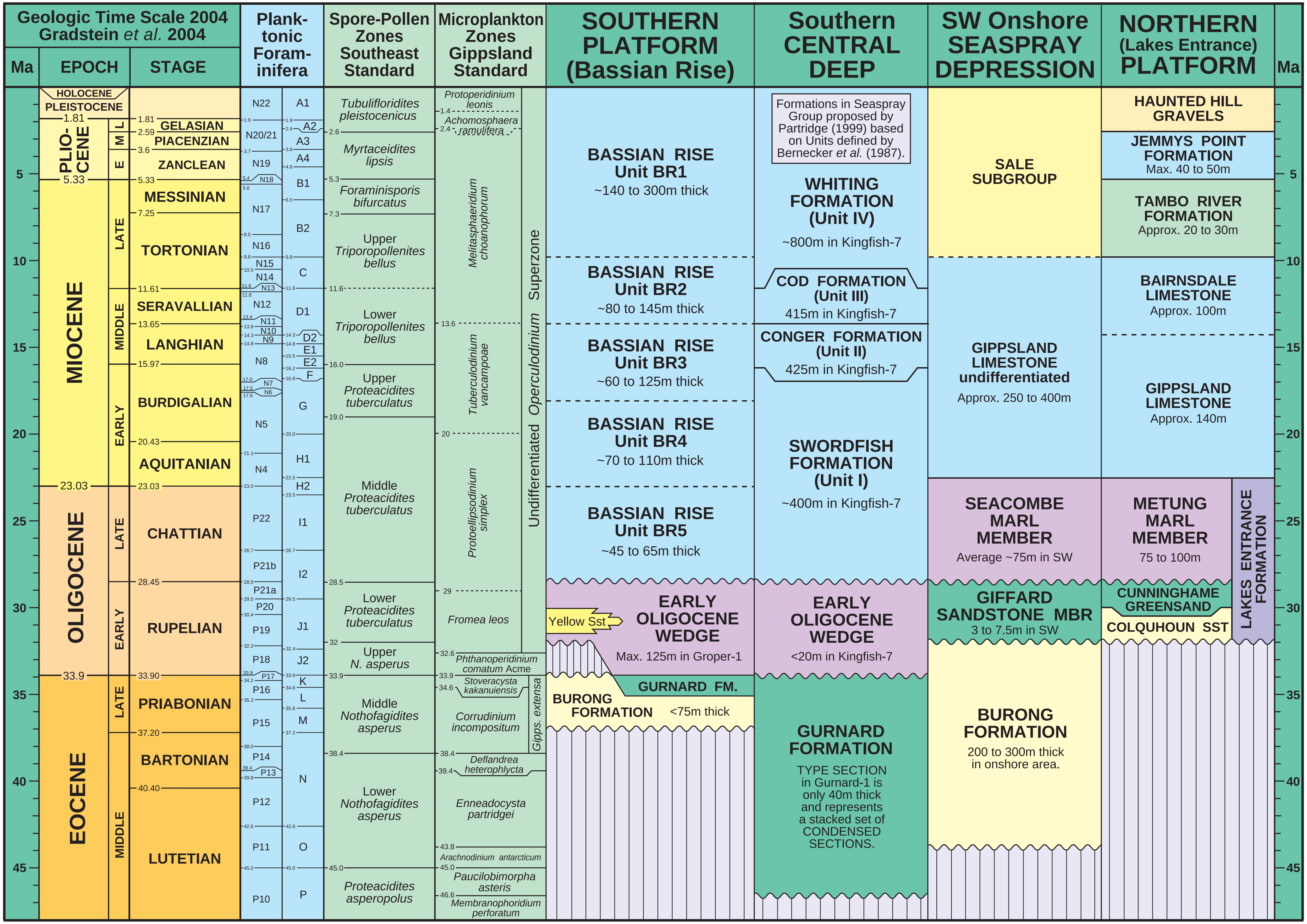
Sample Type	Depth feet	Depth metres	Hand-specimen Lithological Descriptions
Composite Cuttings	1260-90	384-393.2	Calcarenite, cream-white coarse-grained >90%; with medium to dark grey siltstone/shale <10% (composite of 3 cuttings bags)
Composite Cuttings	1400-40	426.7-438.9	Calcarenite, light cream to tan coarse-grained; trace of quartz sand and dark grey siltstone/shale (from 3 cuttings bags)
Composite Cuttings	1500-30	457.2-466.3	Calcarenite, very light grey, to calcisiltite with minor coarse shelly fragments (from 3 cuttings bags)
Composite Cuttings	1560-90	475.5-484.6	Calcarenite, cream and light grey coarse-grained, unconsolidated (composite of 3 cuttings bags)
Cuttings	1600-10	487.7-490.7	Calcarenite, coarse-grained, mainly shell fragments, bryozoa, benthic forams >98%; rare yellow-stained quartz sand <2%.
Cuttings	1610-20	490.7-493.8	Calcarenite and trace of yellow-stained quartz sand as above
Cuttings	1620-30	493.8-496.8	Calcarenite, coarse-grained, mainly shell fragments >80%; and yellow-brown stained, coarse quartz sand ~20%.
Cuttings	1630-40	496.8-499.9	Calcarenite, coarse-grained, mainly shell fragments >70%; and yellow-brown stained, well rounded, coarse quartz sand ~30%.
Composite Cuttings	1640-70	499.9-509	Quartz Sandstone, well-rounded coarse-grained, 1/4 yellow stained, >40%; calcarenite, off-white <60% (3 cuttings bags).
Cuttings	1660-70	506-509	Quartz Sandstone, 1/5th yellow-brown stained, remainder clear >50%; calcarenite, mainly bryozoa and shelly fragments <50%.
Cuttings	1687-1700	514.2-518.2	Sample contaminated with caved junk after cutting of Core-1 from 1675-87m. Predominantly mixed quartz sands clear to milky-white to grey, ~50%, calcarenite, mostly comprised of loose shelly fragments, bryozoa and echinoid spines.
Cuttings	1700-10	518.2-521.2	Quartz Sandstone, clear, coarse-grained, well-rounded, 85%, calcarenite and lithics 15%.
Cuttings	1710-20	521.2-524.3	Quartz Sandstone, clear, well-rounded, 95%, black lithics 5%.
Cuttings	1720-30	524.3-527.3	Quartz Sandstone, clear, coarse-grained >90%; dark lithics or chert, bryozoa fragments and limestone ~10%.
Cuttings	1730-40	527.3-530.4	Quartz Sandstone, clear, coarse-grained, well-rounded >90%; dark lithic grains ~10%.
Cuttings	1740-50	530.4-533.4	Quartz Sandstone, clear, coarse-grained, well-rounded >90%; dark lithic grains ~10%.
Cuttings	1750-60	533.4-536.4	Quartz Sandstone, clear, coarse-grained, well-rounded >90%; dark lithic or chert grains, well-rounded and hard ~10%.

Appendix 4. Hand-specimen description of cuttings in Bluebone-1 (continued).

Sample Type	Depth feet	Depth metres	Hand-specimen Lithological Descriptions
Cuttings	1760-70	536.4-539.5	Quartz Sandstone, clear, coarse-grained, well-rounded >90%; dark lithic or chert grains, well-rounded and hard ~10%.
Cuttings	1770-80	539.5-542.5	Angular Quartz Sandstone, milky-white and coarse 95%.
Cuttings	1780-90	542.5-545.6	Angular Quartz Sandstone, milky-white and coarse-grained >95%; dark lithic grains, etc ~5%.
Cuttings	1790-1800	545.6-548.6	As above.
Cuttings	1800-10	548.6-551.7	As above.
Cuttings	1810-20	551.7-554.7	Angular Quartz Sandstone, milky-white and coarse-grained >98%; dark lithic grains <2%.
Cuttings	1820-30	554.7-557.8	As above.
Cuttings	1830-40	557.8-560.8	As above.
Cuttings	1840-50	560.8-563.9	As above.
Cuttings	1850-60	563.9-566.9	As above.
Cuttings	1870-80	570-573	As above. (no trace of shale spike present on GR log).
Cuttings	1880-90	573-576.1	Angular Quartz Sandstone, milky-white and coarse-grained ~95%, dark lithic grains ~5%; BUT no obvious feldspar.
Cuttings	1890-1900	576.1-579.1	Quartz sand, milky-white, angular, coarse-grained <80%, light grey feldspar <20%, coarse black mafic grains <5%.
Cuttings	1900-10	579.1-582.2	Quartz sand, milky-white, angular >90%, feldspar <10%, black mafic grains <1%
Cuttings	1910-20	582.2-585.2	Quartz sand, milky-white, angular to subrounded, coarse to very coarse-grained >90%, feldspar <10%, black grains <2%.
Cuttings	1920-30	585.2-588.3	Quartz sand, milky-white, angular (less subrounded) >95%, feldspar black mafic grains <5%.
Cuttings	1930-40	588.3-591.3	As above.
Cuttings	1940-50	591.3-594.4	As above with rare <2% yellow-stained quartz, and without any obvious biotite grains.
Cuttings	1950-60	594.4-597.4	Angular quartz and feldspar sand with first occurrence of biotite flakes up to 2mm, with some limestone/bryozoa coming down hole and rusty iron <5%.
Cuttings	1960-66	597.4-599.2	Angular quartz ~80% and feldspar <30% grains, with ~2% biotite flacks and some other medium grey grains.

STRATIGRAPHY OF BASSIAN RISE and COMPARISON to broader GIPPSLAND BASIN.

by Alan D. Partridge — © Biostrata Pty Ltd 2006



Attachment-1 to Biostrata Report 2006/07

Version 2 — 15 June 2006

Groper-1

Well Name : Groper-1

Operator : Esso Australia Ltd
Well Code : GROPER-1
Lat/Long : 38°56' 20.00"S 147°24' 56.00"E
Interval : 350m - 1050m
Scale : 1:1200
Chart date: 15 June 2006

Spudded : 18 December 1968
Completed : 08 January 1969

Palynological Range Chart
Sample interval 854.4 to 951.3 metres
Microscope analysis by Alan D. Partridge

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AUSTRALIA

Attachment-2 to Biostrata Report 2006/07

Well Name : Mullet-1

Operator : Esso Australia Ltd — Spudded : 09 January 1969
Well Code : MULLET-1 — Completed : 17 January 1969
Lat/Long : 39°13' 2.00"S 147°51' 22.00"E
Interval : 210m - 760m — Palynological Range Chart
Scale : 1:1200 — Sample interval 317 to 728.5 metres
Chart date: 15 June 2006 — Microscope analysis by Alan D. Partridge

Mullet-1

Biostrata Pty Ltd
AUSTRALIA

Attachment-3 to Biostrata Report 2006/07

Well Name : Bluebone-1

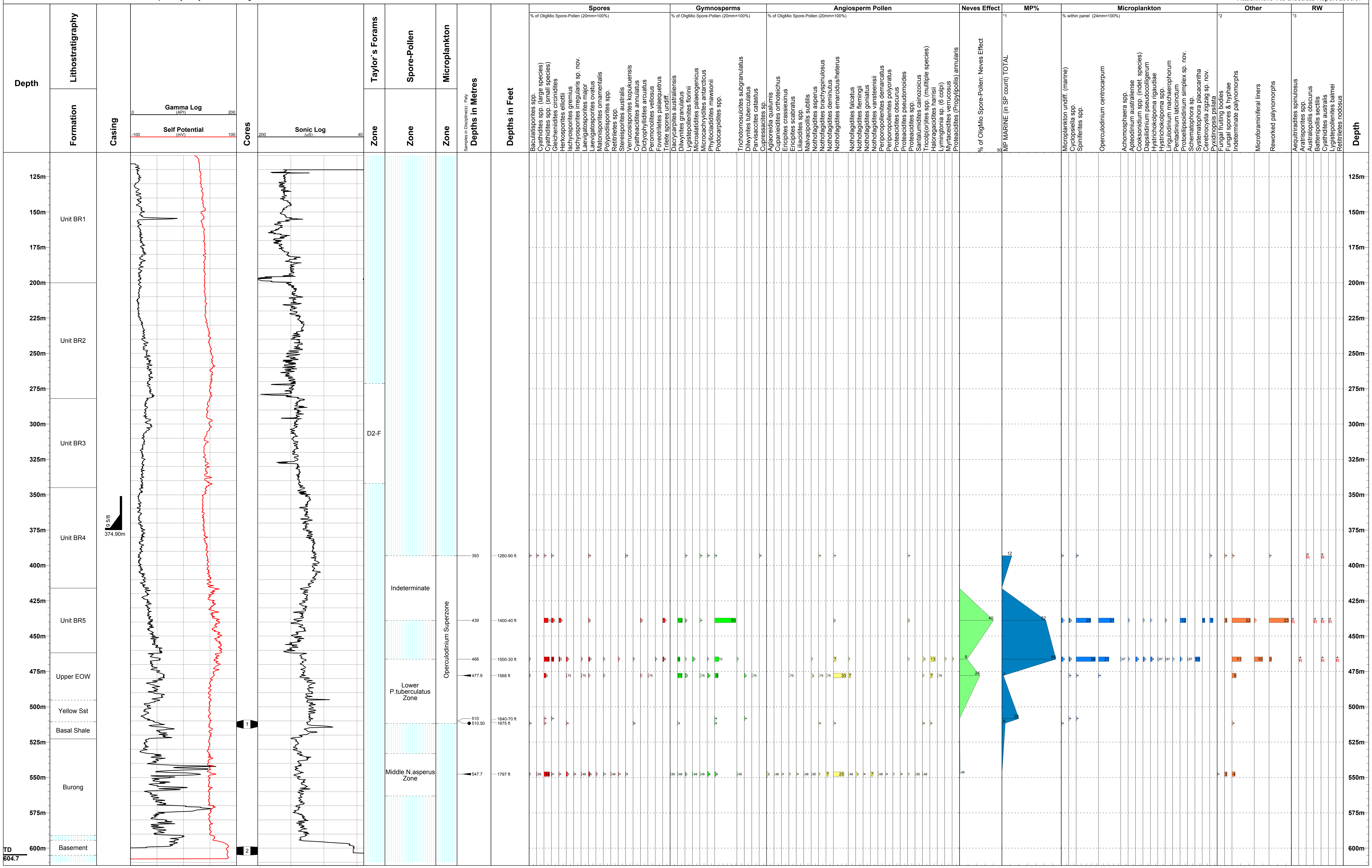
Operator : Esso Australia Ltd
Well Code : BLUEBONE-1
Lat/Long : 39°24' 24.29"S 147°50' 52.74"E
Interval : 110m - 610m
Scale : 1:1500
Chart date: 15 June 2006

Spudded : 26 September 1969
Completed : 01 October 1969
Palynological Range Chart
Sample interval 384 to 547.7 metres
Microscope analysis by Alan D. Partridge

Bluebone-1

Biostrata Pty Ltd
AUSTRALIA

Attachment-4 to Biostrata Report 2006/07



Attachment-5 to Biostrata Report 2006/07

Chart date: 15 June 2006

Biostrata Pty Ltd
AUSTRALIA