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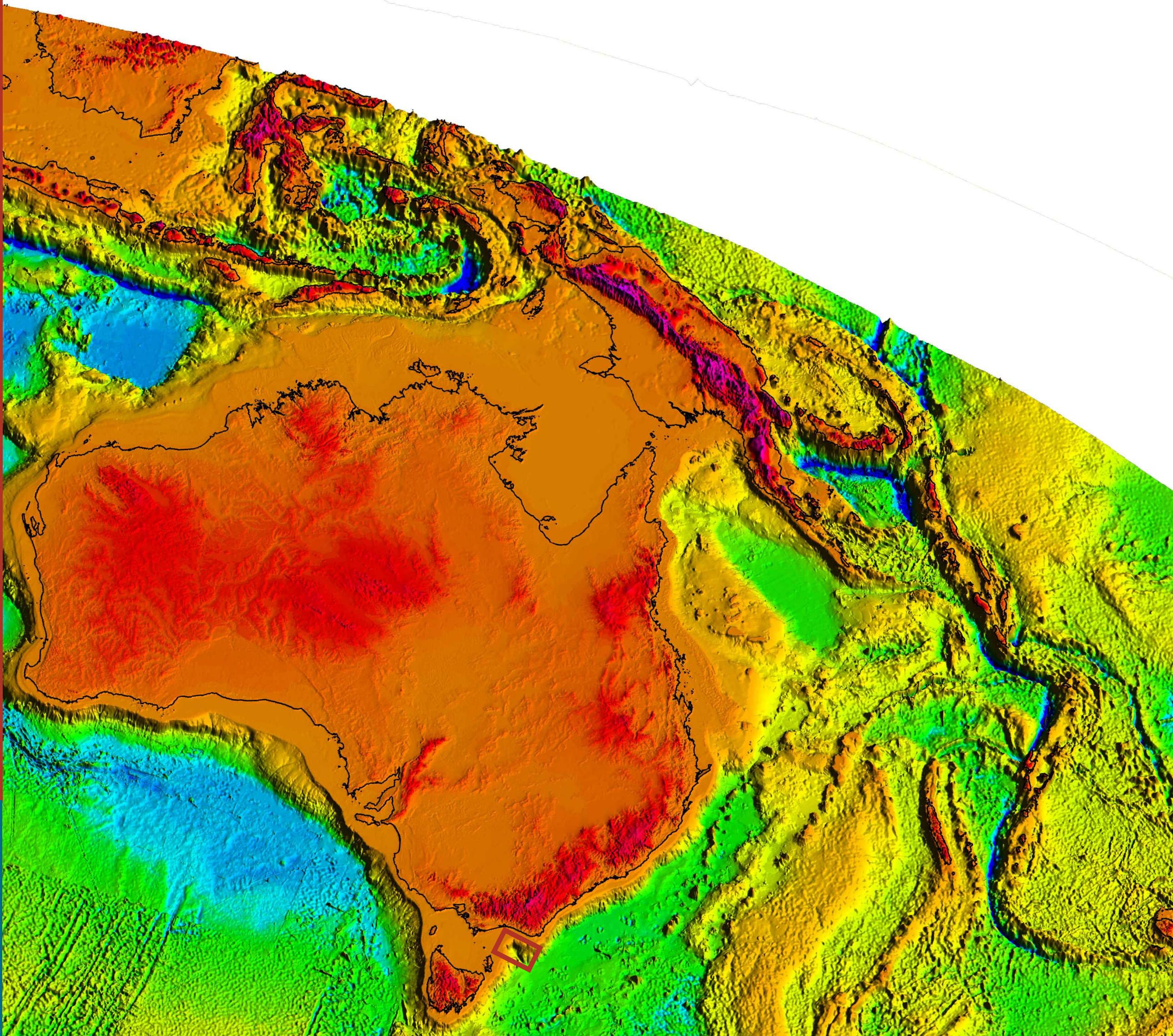

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Cretaceous volcanogenic and Miocene calcareous strata dredged from the deepwater Gippsland Basin on R/V *Franklin* Research Cruise FR 11/98

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1. ABSTRACT

In 1998, *Franklin* Cruise FR11/98 recovered 18 dredge hauls in deep water in the Gippsland Basin. The dredge hauls were sited on the basis of seismic reflection profiles and morphological features. The study provided information on the lithologies, ages and paleo-environments of the little-known deepwater Gippsland Basin. The rocks and sediments fall broadly into four categories: volcanics of probable Late Cretaceous age, volcaniclastics and labile sediments of Late Cretaceous age, Neogene marly calcareous sediments, and calcareous oozes of Quaternary to Holocene age. Minor ferromanganese nodules and crusts from several deepwater stations are of no economic potential, being high in SiO2 and remarkably low in copper and cobalt.

Volcanics were confined to the three easternmost dredges (present water depths 3300-3800 m) from a rifted block elongated west-northwest and just inboard of the continent-ocean boundary. They consist of basalt, hyaloclastite, breccia, scoria and volcaniclastic sandstone. Because, these volcanic rocks occur on an isolated ridge they cannot have derived pebbles and clasts from younger sequences. The rocks are not dated but may have been laid down during the Tasman Sea rifting phase in the Turonian to Coniacian. We hypothesise that lava flows and domes formed on a coastal plain and in shallow water. Normal vesicular flows formed on dry land, including scorias. In water they broke up to form volcaniclastic mass flow deposits such as hyaloclastites. Some of the volcaniclastics apparently became intermingled with soft clays and lime muds, because the interstices are now filled with zeolites, clay minerals and calcite.

No Early Cretaceous rocks (Strzelecki Group) age were recovered, suggesting that they might not have been deposited east of the Gippsland Rise (~149°30’E). Immature labile rocks of the Late Cretaceous (Emperor and Golden Beach Subgroups of the Latrobe Group) were recovered in eleven dredges on the outer continental margin (present water depths 800-2040m). Palynological ages are Turonian to Campanian (~90 Ma to ~74 Ma). Thin to medium bedded labile sandstone, siltstone and mudstone (and their weathered variants) are carbonaceous in part. Some beds are burrowed and mottled or contain cross-lamination, ferruginous nodules, trace fossils, load casts, ripple marks and plants. Marine macrofossils are generally absent. These rocks were apparently deposited rapidly in coastal and marine environments, in the rift involving eastern Australia, Lord Howe Rise, and the Gippsland Basin. Palynology documents the onset on marine conditions, and rapid subsidence between ~90 Ma and ~86 Ma, as the Tasman Sea entered. Silts and clays were deposited in a deep freshwater lake in the Early to mid Turonian, deep marine carbonates in the Santonian, and deep marine muds in the Campanian.

Marine calcareous rocks of the post-Eocene Seaspray Group were recovered in eight dredges (present water depths 680-2800 m): medium to very fine grained calcarenites, calcisiltites and calcareous mudstones, composed largely of molluscan debris, foraminifers and clay. They are often poorly bedded, with some thin to medium bedding. Quartz, feldspar, clay clasts and muscovite are common. Mottling shows that bioturbation was widespread, and organic debris includes wood and leaves, sponge spicules and echinoderm spines. Foraminifera date the older rocks as early to middle Miocene. Microplankton indicate deep-water deposition.

Key Words: Gippsland Basin, Late Cretaceous, Miocene, deep water, seabed samples, volcanics, volcaniclastic sediments, limestone

2. INTRODUCTION

This Record covers in detail the results of dredging of older strata on *Franklin* Cruise FR11/98 in the Gippsland Basin (**Figures 1** & **2**). Within Geoscience Australia, the cruise is known as AGSO Survey 211. Keene (1998) first reported on *Franklin* Cruise FR11/98 in the Gippsland Basin. As part of the expedition, 25 dredge stations were occupied in deeper water over a period of 5 days. The locations were determined on the basis of detailed seabed maps obtained during an earlier swath-mapping cruise of R.V. *Melville* (Hill et al., 1998; Exon et al., 1999), and of interpreted Geoscience Australia seismic reflection profiles.

Only here and in **Appendix 5** are the other activities on the cruise outlined briefly and their results summarised (after Keene, 1998). Keene led the cruise, and Exon and Hill were responsible for the deepwater dredging. Exon dealt with the dredge sedimentology, petrology and ferromanganese, Partridge with the palynology, Chaproniere with the palynology, and Hill with the geophysics.

2.1. General cruise objectives

The general objectives of *Franklin* Cruise FR11/98 were:

- To obtain sediment and sparker seismic transects across the shelf to enable the development of a sedimentological and environmental framework.
- To obtain sediment, bottom photographs and sparker seismic data from three canyon heads on the outer shelf and upper slope.
- To obtain sediment, bottom photographs and sparker seismic data from the slope and proximal basin floor to enable the correlation of this analogous modern sedimentary regime with that of the Tertiary Seaspray Group in order to develop a rigorous environmental framework for the shelf and slope.
- To obtain rock samples from the strata outcropping on the sides of canyons to assess the rate of propagation, erosion and origin of submarine canyon/channel development in slope sediments and to extend the boundaries of offshore Gippsland Basin sedimentary facies. These rock samples would also confirm the age of seismic reflectors obtained from previous surveys and constrain the tectonic evolution of the basin.

2.2. General activities

Overall *Franklin* Cruise FR 11/03 was successful in meeting all scientific objectives. The vessel sailed from Hobart at 1000 on Friday 18 September 1998, and arrived in Sydney at 0900 on Monday 5 October 1998. A total of 101 stations were occupied on the cruise of which 86 were successful or useful. We were particularly fortunate with the weather in this often stormy region, as only 31 hours were lost to bad weather. The cruise personnel are listed in **Appendix 1**. The study area is shown in **Figure 1** and an enlargement showing station locations is shown in **Figure 2**. Station numbers are compared to dredge, grab, or piston core numbers in **Appendix 2**.

Samples were sorted, briefly described and labelled on board. Un-edited merged one minute navigation and bathymetric data were provided on Exabyte tape. Geoscience Australia also received 5 second data on tape. Edited 5 minute navigation and PDR data were supplied by CSIRO post-cruise. All rock samples were shipped to Geoscience Australia for curation.

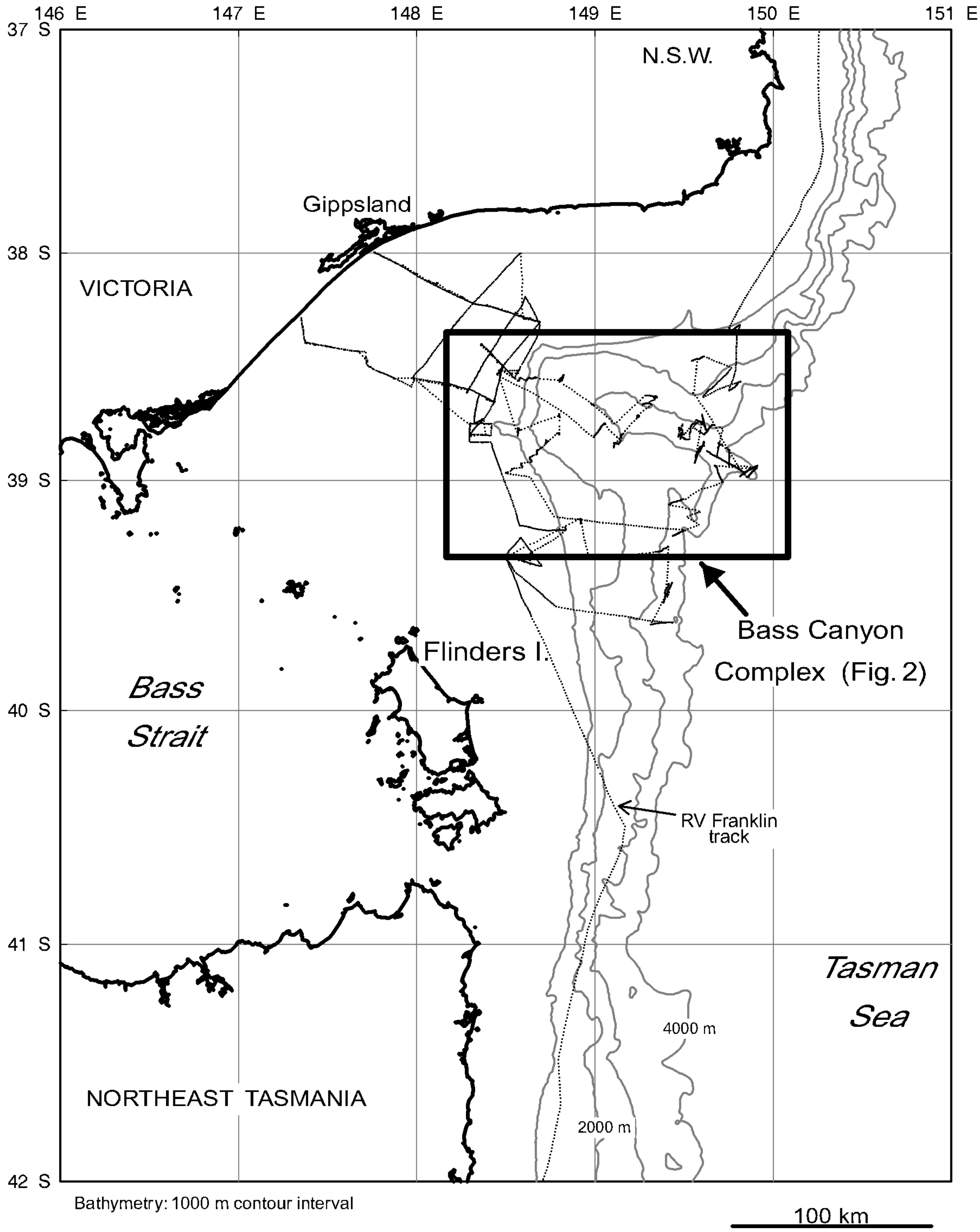

Figure 1. Regional setting.

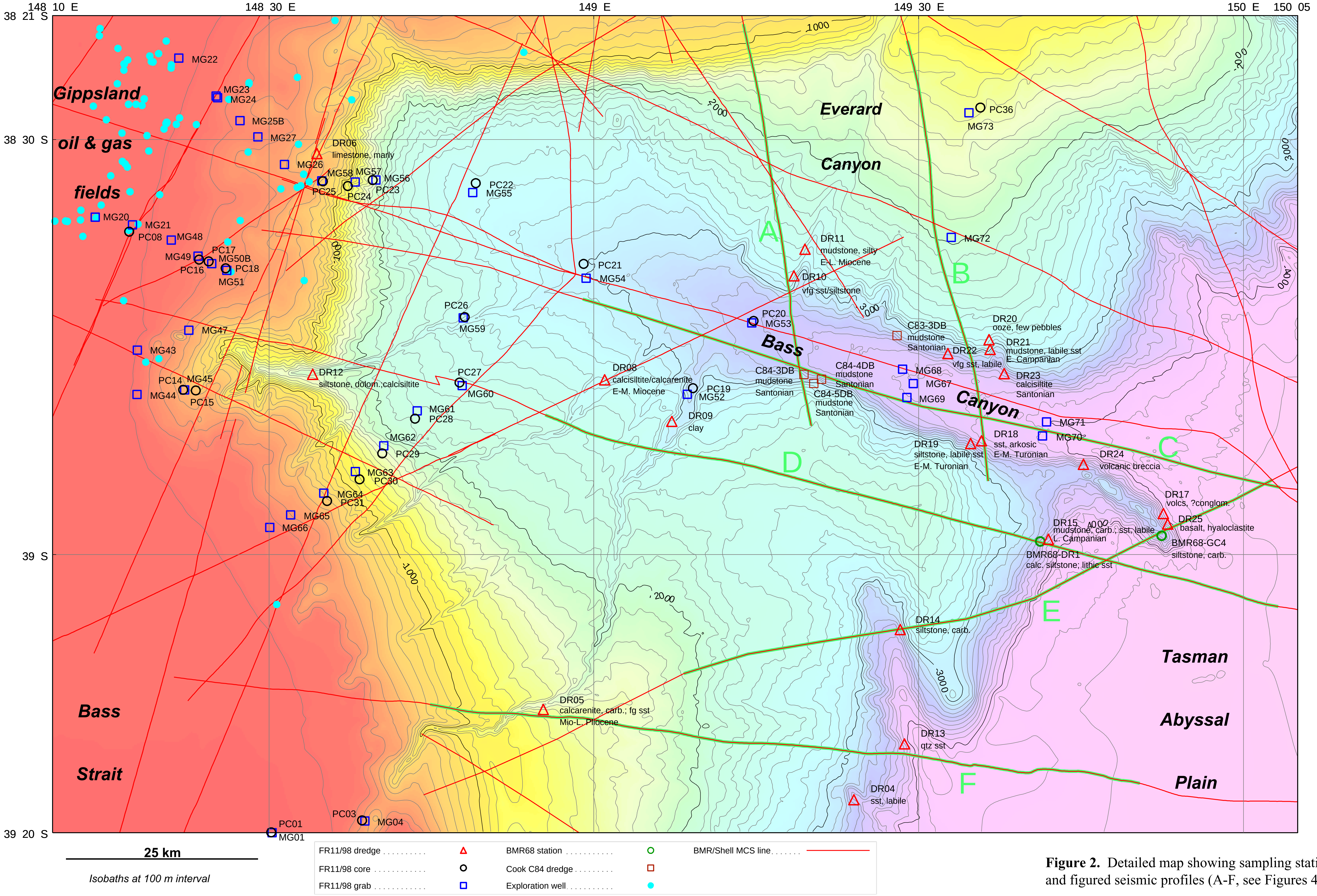

Figure 2. Detailed map showing sampling stations and figured seismic profiles (A-F, see Figures 4-9).

High-resolution sparker seismic profiles were shot on the continental shelf (**Appendix 3**) using a 0.5 second sweep (firing rate) and are curated at the University of Melbourne. Navigation data were recorded using Sydney University's GPS and a PC laptop computer. Copies of one minute fixes, course and speed are curated at Sydney University and Melbourne University. The single channel seismic data were recorded solely in analogue form until the start of Line 14, from whence they were also recorded digitally to the end of Line 24. Six Exabyte tapes in SEG-Y format were recorded and are curated at the University of Melbourne, with copies at the University of Sydney and Geoscience Australia.

When possible, and during weather delays, bathymetric surveys were carried out between stations. This was important on the upper slope where there was a data gap between the National Mapping 0-300 m data and the swath mapping below 2,000 m collected by RV *Melville* in 1997.

Some of the dredge results have been incorporated into a series of papers and reports representing broader, largely geophysical studies of the Gippsland Basin, including the deepwater Gippsland Basin, under VIMP, the Victorian Initiative for Minerals and Petroleum (Bernecker et al., 2001; Moore and Wong, 2001; Moore et al., 2001; Smith et al., 2000).

3. DREDGED ROCKS

3.1. Dredging activities

Sampling of the older, deeper-water rocks was targeted by using the maps produced by the 1997 swath-mapping cruise of R.V. *Melville* (Hill et al., 1998; Exon et al., 1999). A later swath-mapping cruise covered more of the northern slope of the Bass Canyon (Hill et al., 2000). The dredging had mixed success, partly due to the slope being sediment covered, partly due to the limitations of the ship in holding position and dredging in specific directions, partly due to lack of experience in dredging from *Franklin* in deep water, and partly due to failure of chain bag dredges. The lightness of the dredge wire (4 tonne safe working load) meant that a very weak link was inserted in deep water, and sheared with relatively light pulls.

Altogether, twenty-five dredge hauls were attempted (**Figure 2**) and they are described and related to seismic profiles in **Table 1**. Eighteen dredges were successful in obtaining some older rocks, although only eleven were large hauls. Most are related to seismic profiles in **Figures 4-9**. The hand-specimen descriptions, made aboard ship, were somewhat modified after 45 thin sections were examined (**Table 1**). The thin sections are described in **Table 2**. We use the stratigraphic nomenclature of Bernecker and Partridge (2001) as illustrated in **Figure 3**.

The dredge stations and the transits between them took about five days of ship time. Dredging was done from the main winch with a chain bag box dredge, a smaller solid box dredge and a pipe dredge. For the early stations we used conventional chain bag dredges, but experience showed that the dominantly soft sediments on the margin were being chewed up in the chain bag, giving very poor recovery. The bridles of the two new chain bag dredges proved to be poorly made, so that they both broke leading to zero or little recovery at two stations. Fortunately, the safety strap worked in each case, the dredge coming back on deck

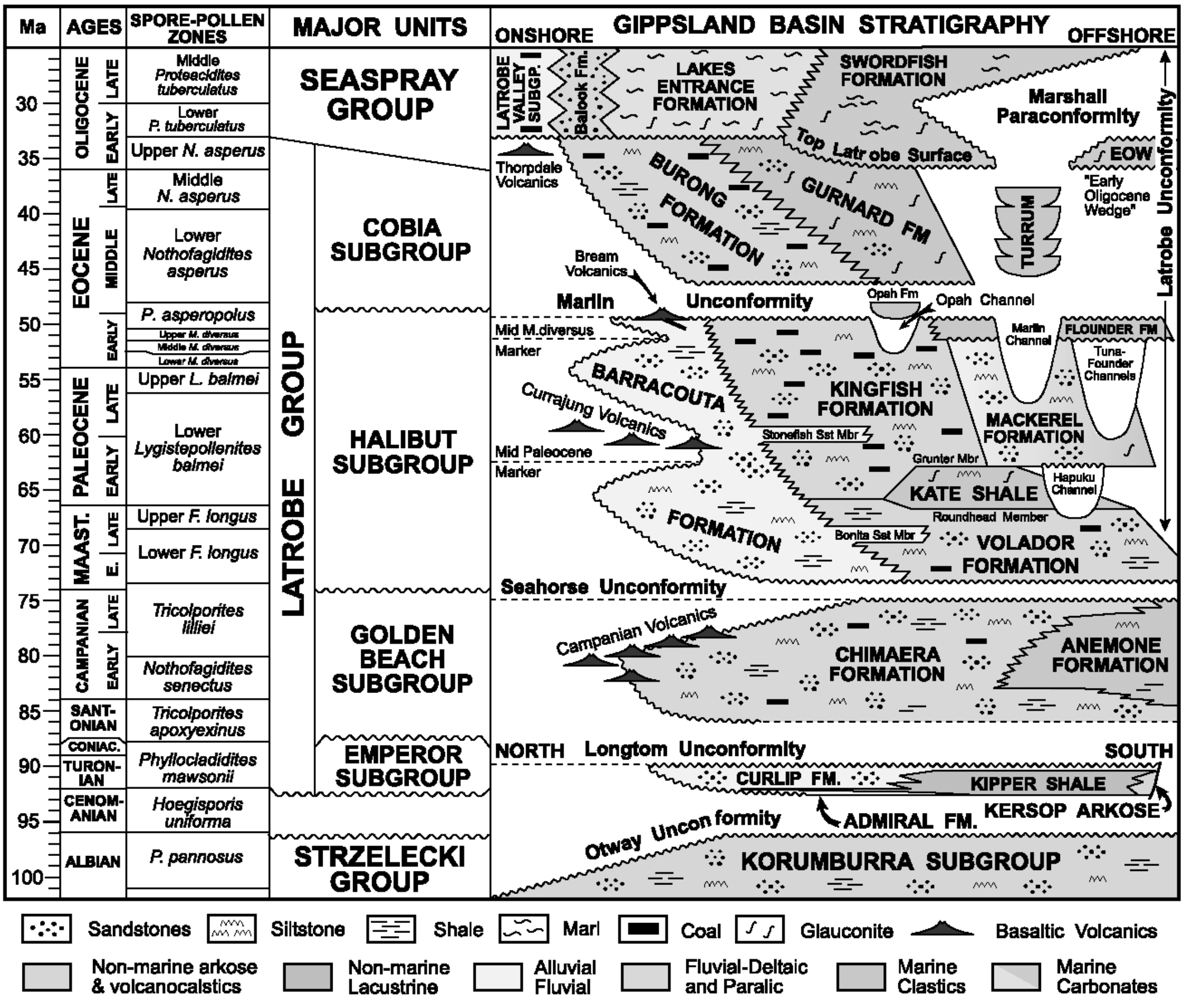

Figure 3. Stratigraphic nomenclature of the Latrobe Group after Bernecker & Partridge (2001).

tail first or sideways. The ship's engineering group re-welded the bridles successfully. The weak link broke at one station where the bridle also gave way (DR 14).

For later dredges (DR18 onwards) a simple box dredge was generally used, with better results. In all, we regard 15 dredge hauls as successful in that they recovered reasonable quantities of older rocks, three as moderately successful with some older rocks, and seven as unsuccessful with no recovery or only younger oozes.

The rocks and sediments that were recovered in deep water fall broadly into four categories: volcanics of uncertain but possibly early Late Cretaceous age, volcaniclastics and other labile sediments of Late Cretaceous age, marly Neogene calcareous sediments, and Quaternary to Holocene calcareous oozes. Nearly all dredges contained oozes, which will not be discussed further here. Most rocks are bored and manganese veneers are common. These rocks are discussed in more detail below, and a report on the chemistry of the ferromanganese material is given in **Appendix 4**.

Table 1: Successful Dredges

Sample Number Depth (metres)	Latitude (S) Longitude (E)	Comment*	Hand specimen description
DR04 3500-3100	39 17.63 149 24.02	Half dredge Golden Beach assemblage Figure 9	A: Abundant light olive grey (5Y6/1) ooze. B: Abundant white (N9) possibly calcareous clay. C: Yellowish grey (5Y8/1) possibly calcareous claystone. D: Olive grey, medium-coarse labile sandstone, abundant clay pellets and carbonaceous grains. Variably sized sorted, thin to medium bedded, bored and lightly manganese encrusted
DR05 1750-1520	39 11.15 148 55.33	Full dredge Seaspray assemblage A1: Late Pliocene forams B2: Late Pliocene-Miocene palynology C2: Late Pleistocene palynology Figure 9	A: Rare light olive grey (5Y6/1) lithified medium quartz sandstone with carbonaceous flecks and leaf impressions. Some calcareous organisms. B: Rare light olive grey (5Y6/1) weakly lithified siltstone to fine sandstone with carbonaceous flecks. Some calcareous organisms C: Common soft light olive grey (5Y6/1) silty to fine sandy calcarenite. Abundant black ?carbonaceous grains, rare white clay clasts, 1 scaphopod D: Common soft yellowish grey (5Y7/2) silty clay.
DR06 737-632	38 30.97 38 31.05 148 34.48 148 34.36	10 kg material in dredge. Bridle broken Seaspray assemblage	A: Cobbles of light brown marly limestone with shelly fossils. Coarse sand in *pipe dredge*, with quartz, lithics and shells
DR07 284-277	38 17.38 38 17.37 148 36.53 148 36.13	pipe dredge	Very coarse coarse quartz and shelly debris with whole shells including live squids, prawn like crustaceans, small turritellids, large gastropods, bivalves, worms. Quartz content ca. 40%, well rounded polished & coarse grained, with some brown stained lithics.
DR08 2800-2600	38 47.4 149 01.0	5 kg + pipe dredge Seaspray Assemblage A1: ?Early Miocene forams B1& B3: late Early Miocene forams B2: Early to Middle Miocene palynology	A: Minor cemented clayey medium grained calcarenite with lithic grains. Light olive grey (5Y 6/1) B: Abundant moderately lithified clayey, thin bedded calcisiltite to very fine calcarenite with carbonaceous flecks. Light olive grey (5Y 6/1). C: Soft light olive grey (5Y 6/1) silty clay
DR09 3030-2700	38 50.3 38 50.4 149 07.5 149 07.0	pipe dredge Figure 7	Soft silty and sandy clay. Light olive grey (5Y 6/1)
DR10 3100-2700	38 40.04 38 39.71 149 19 .08 149 17.88	1/3 dredge + pipe dredge Seaspray assemblage A1-3: Early Miocene and Late Pliocene forams Figure 4	A: Yellowish grey (5Y 7/2) heavily weathered quartz rich to clayey v.f. sandstone to siltstone. Thin to medium bedded with some cross-lamination; bedding picked out by changes in lithology content and cementation. Some calcareous organisms. Mottled in part. Probably lake, swamp and estuarine deposits
DR11 2700-2550	38 37.95 149 19.50	full dredge + pipe dredge Seaspray assemblage A1-3: late early Miocene, Middle Miocene, Pleistocene	A: Early and Middle Miocene greenish grey (5G 6/1) silty mudstone with a few thin carbonaceous layers. Some calcareous organisms B: Early to Middle Miocene light olive grey (5Y 6/1) mod. lithified mudstone with ferruginous veneer. Poorly med. bedded with some woody material. Some

		forams B1: late Early Miocene forams B2: Early to Middle Miocene palynology D1: Middle Miocene forams E1: Late Miocene palynology Figure 4	calcareous organisms. Marine characteristics include spreite and mottling. C: Dominant yellowish grey (5Y 7/2) mottled silty mudstone. Weakly lithified; weathered version of lithofacies B. D: Common Middle Miocene yellowish grey (5Y 7/2), lithified muddy siltstone to v.f. sandstone. Some calcareous organisms. Thin bedded, ferruginised, with some spreite. E: Common Late Miocene light olive grey (5Y 6/1) mod. lithified mudstone. Marine characteristics include spreite and mottling.
DR12 1725- 1600	38 47.0 148 34.03	1/4 dredge Seaspray assemblage B1: Quaternary forams B2: Pleistocene palynology	A: Common interbedded and lithified very light grey (N8) dolomitic siltstone and light olive grey (5Y 6/1) dolomitic m. calcarenite. Sand grains dominantly calcareous bioclasts and quartz with some dark lithics. Laminated to thinly bedded. B: Abundant greenish grey (5GY 6/1) soft silty calcisiltite and calcarenite with some weak colour banding. Very homogeneous & massive with bivalves. Abundant large *living* deepsea barnacle clumps with 4 main scutes and 2 subsidiary
DR13 3770- 3450	39 13.09 39 14.14 149 30.01 149 27.37	1/4 dredge full Golden Beach assemblage Figure 9	A: Minor yellow brown, soft clayey m. quartz sandstone with muscovite and carbonaceous flecks. Mn veneer, bored. B: Common grey brown, moderately lithified f.-c. quartz sandstone, with feldspar, muscovite, lithic and carbonaceous grains. Medium bedded, Mn crust to 3 mm thick, bored. Circular burrows 3 mm across with organic-rich walls. *Pipe dredge* contains grey brown muddy ooze, with patches of ferruginous m. muddy quartz sand.
DR14 3400- 2800	39 05.40 149 28.30	Minor rocks & plus sand and ooze in pipe dredge. Bridle and weak link broke Golden Beach assemblage Figure 8	A: Light olive grey (5Y 6/1) to brownish fissile siltstone to sandy siltsone with carbonaceous partings and a Mn veneer. Grains of quartz, feldspar and muscovite. *Pipe dredge* contains light olive grey ooze and sand weathered from lithotype A. It also contains several light brown clasts up to 2 cm across of brown coal.
DR15 3700- 3400	38 59.17 38 58.63 149 42.09 149 41.87	Minor rocks & ooze in pipe dredge Golden Beach assemblage C1: Late Campanian palynology Figure 7	A: Minor greenish grey (5GY 6/1) moderately lithified, thin labile sandstone. Well size sorted, with quartz, shaly clasts, feldspar, muscovite and carbonaceous flecks. Bored surface with Mn crust 2 mm thick. B: Trace greenish olive (10Y 4/2) mud to soft mudstone. C: well lithified greenish olive (10Y 4/2) carbonaceous mudstone. Light browny grey *ooze*, slightly silty
DR17 3800- 3700	38 57.05 149 52.6	Dredge broke Volcanic assemblage Figure 8	A: Minor Mn crusts 2-4 mm thick, plus one irregular nodule 3 cm thick B: Minor dark grey to dark brown subrounded to subangular pebbles, possibly from a Cretaceous conglomerate. Most are volcanics, aphitic, some vesicular. Probably acid to intermediate. Also some flattish fine grained metasediments.
DR18 3820- 3300	38 51.8 149 35.8	1/4 dredge Golden Beach assemblage B2: Early to mid	A: Common dark yellowish brown (10 YR 4/2) c-v.c. arkosic sandstone with feldspar, quartz, lithics. Thin to medium bedded, Mn veneer. B: Rare dark yellowish brown (10 YR 4/2) thin bedded

		Turonian palynology C2: Probably Turonian palynology D1: Early to mid Turonian palynology Figure 5	flaggy siltstone with obvious plant remains C: Abundant dark yellowish (10YR 4/2) sandy siltstone. Fissile to flaggy with load casts. Borings, Mn veneer D: Common dark yellowish brown (10YR 4/2) poorly consolidated silty mud or clay, with Mn veneer. E: Pale yellowish brown (10YR 6/2) sticky silty clay. F: Mn crusts to 4 mm thick. All these lithotypes are from the one interbedded sequence. Pale yellowish brown (10YR 6/2) clay from *pipe dredge*
DR19 3375-2900	38 52.00 38 52.00 149 34.96 149 34.63	Full dredge Golden Beach assemblage A1: Early to mid Turonian palynology Figure 5	A: Abundant blue grey (5B 5/1) laminated lithified sandy siltstone with thin Mn crust B: Dominant orange (5YR 5/6) clayey f-c. labile sandstone to sandy mudstone (greywacke). Thin bedded to massive, ripple marked in part. Thin Mn crust (2 mm). C: Abundant grey m-c. labile sandstone. Mn crust to 2 cm thick. Buff grey calcareous ooze in pipe dredge
DR20 3150-2610	38 45.2 38 43.7 149 36.8 149 36.2	Pipe dredge	Pale olive (10Y 6/2) ooze with some forams and a few small pebbles
DR21 3200-2800	38 45.4 38 45.0 149 36.8 149 36.4	Pipe dredge Golden Beach assemblage B1 & B2: Early Campanian palynology Figure 5	A: Minor pebbles of m-c. labile sandstone. Grey to orange or black when altered. Well size sorted, subangular grains. B: Common large pebbles of olive grey (5Y 4/1) lithified mudstone. Laminated to thin bedded, low density. Some mottling, boring, Mn veneer. C: Minor small pebbles of yellowish grey (5Y 7/2) foram-rich calcareous mudstone. Variably lithified Seaspray Group. Sticky pale to medium grey calcareous clay from *dredge teeth*. Yellowish grey (5Y 7/2) calcareous ooze in *pipe dredge*
DR22 3500-3160	38 45.9 38 45.1 149 32.3 149 33.1	Pipe dredge Golden Beach assemblage Figure 5	A: Few small pebbles of pale yellowish brown (10YR 6/2) to moderate brown (5Y 5/2) laminated to thin bedded v.f. labile sandstone to silty sandstone with minor muscovite. Bored with Mn veneer. Minor dark yellowish brown (10YR 4/2) sticky silty clay in box dredge. Light olive grey (5Y 5/2) calcareous ooze with some forams in *pipe dredge*.
DR23 3600-3100	38 47.40 38 46.50 149 37.50 149 38.30	1/2 dredge, pipe dredge. Golden Beach assemblage B1: Miocene or younger forams C1: Santonian palynology Figure 5	A: light grey yellow (5Y7/2) muddy calcarenite and calcisiltite. Only partly consolidated but fizzes in acid, foraminifera visible. B: light bluey grey (5B 7/1) partly consolidated, calcisiltite. C: dark grey lignitic (5Y 3/2) sticky clay - slightly calcareous and probably carbonaceous Ooze from *pipe dredge*, pale yellow brown (10YR 6/2).
DR24 3600-3300	38 53.2 38 53.9 149 45.15 149 45.3	1/4 dredge	A: Cobbles of yellowy green olive (10Y 6/2) hyaloclastite, breccia or tuff, with vesicles and veins. May be chloritic. Thin Mn cust, bored. B: Slabs of brownish grey green (10YR 5/4) gritty volcanic breccia, with clasts up to 1 cm. C: Cobbles of red brown orange (10 YR 6/6) fine

			grained rock, possibly volcanic scoria. Light brown ooze in *pipe dredge*, with starfish, sea spider and sponges
DR25 3600- 3300	38 57.3 38 58.3 149 53.7 149 52.4	2 kg Figure 8	A: Cobbles and pebbles of rounded black fine grained basalt and hyaloclastite, massive to highly vesicular. B: Light brown (5Y 6/4) f-c. volcaniclastic rocks, highly vesicular basalt clasts in part. Ooze in *pipe dredge*

*On the basis of the hand specimen descriptions, the thin-section descriptions below, and the palynological results, the rocks dredged were separated into three groups:

- Seaspray assemblage (Miocene-Pleistocene ages)
- Emperor and Golden Beach assemblage (Turonian to Campanian ages)
- Outer margin rift volcanics (assumed early Late Cretaceous age)

Table 2: Thin-section rock descriptions

Sample	Description and age
DR05-12	**Miocene-Pleistocene Seaspray Group (dredged from 630-2800 m water depth)**
DR05	A1: Sandy mudstone, with angular fine quartz and feldspar, clay clasts, muscovite, forams and other calcareous fragments, rare siliceous sponge spicules. Late Pliocene forams. B1: Silty calcareous mudstone, with very minor angular quartz and feldspar clasts, woody material, forams and other calcareous fragments. ?Middle Miocene forams. C1: Fine calcarenite, with abundant pyrite-filled forams, other calcareous clasts and sponge spicules. Some subangular quartz, feldspar and clay clasts, clay matrix. Late Pliocene forams. [B2: Late Pliocene-Miocene palynology]
DR08	A1: Medium calcarenite, with abundant forams and other calcareous clasts. Some subangular quartz, feldspar, lithic and clay clasts, abundant clay matrix. ?Early Miocene forams B1: Calcisiltite with some forams and minor carbonaceous wisps. Rare v.f. quartz clasts. Late Early Miocene forams. B3: Calcisiltite with common pyrite-filled forams and minor carbonaceous wisps. Rare v.f. quartz clasts, sponge spicules. More clayey than B1. Late Early Miocene forams. [B2: Early to Middle Miocene palynology]
DR10	A1: Carbonaceous mudstone with some forams and minor other calcareous clasts. Rare v.f. quartz clasts. Late Pliocene or younger forams. A2: Carbonaceous mudstone with rare forams and sponge spicules. Early to Middle Miocene forams. A3: Medium grained clayey sandstone, with abundant angular quartz and lesser feldspar, muscovite, chloritised lithic grains, carbonaceous grains and opaques. Intraclast of carbonaceous mudstone with some pyrite-filled forams. Late Pliocene or younger forams.
DR11	A1: Carbonaceous mudstone with rare quartz sand grains. Intraclasts of foram-bearing mudstone. Late Early Miocene forams. A2: Foram-rich calcisiltite with other calcareous clasts, and rare quartz, glauconite and carbonaceous wisps. Pleistocene forams. A3: Carbonaceous mudstone with common foraminifera, some sponge spicules, and rare quartz grains. Middle Miocene or younger forams. B1: Mottled carbonaceous calcareous mudstone with minor forams, sponge spicules and quartz. Late Early Miocene forams. C1: Mottled mudstone, with some carbonaceous and quartz clasts, rare forams and sponge spicules. D1: Ferruginous mudstone with common foraminifera and other calcareous fragments, and some quartz grains. Middle Miocene forams. [B2: Early to Middle Miocene palynology] [E1: Late Miocene palynology]
DR12	A1: Fine grained calcarenite consisting largely of molluscan debris, with rare quartz, muscovite and feldspar. B1: Mottled medium grained calcarenite with abundant molluscan clasts and some forams. Contains common subrounded quartz, feldspar and altered lithic

	grains, and minor muscovite, in a clayey groundmass. Some carbonaceous clasts. Quaternary forams.
DR04 & 13-23	**Late Cretaceous Emperor and Golden Beach Subgroups (dredged from 2040-3800 m water depth)**
DR04	D1: Medium to coarse grained labile sandstone, with angular quartz and chloritised lithic grains, and lesser feldspar, muscovite, biotite, carbonaceous grains and opaques. Some clayey groundmass. D2: Medium to coarse grained clayey sandstone, with angular quartz and chloritised lithic grains, and lesser feldspar, muscovite, and opaques.
DR13	A1: Fine grained clayey quartz sandstone with large clayey faecal pellets. Detrital clasts are subangular, with dominant quartz, with common muscovite and altered clay clasts, and minor biotite and feldspar. B1: Medium grained clayey quartz sandstone with large clayey burrows. Detrital clasts are subangular, with dominant quartz and chloritised clay clasts (some probably altered glauconite), with common feldspar, minor muscovite and biotite, and rare opaques and carbonaceous straps. Mn crust. B2: Bioturbated medium grained clayey quartz sandstone with large clayey burrows. Detrital clasts are subangular, with dominant quartz and chloritised or sericitised clay clasts (some probably altered glauconite), with minor feldspar and muscovite, and rare opaques. B3: Medium grained clayey quartz sandstone with subangular quartz and chloritised clay clasts (some probably altered glauconite), with minor feldspar, muscovite and biotite, and rare opaques and carbonaceous straps.
DR14	A1: Fissile mudstone with carbonaceous partings. Fine sandy layers contain quartz, feldspar, muscovite, and carbonaceous grains.
DR15	A1: Burrowed medium grained labile sandstone, with abundant subangular quartz, chloritised and sericitised shaly clasts, and feldspar, and common muscovite, biotite and opaques. [C1: Late Campanian palynology]
DR18	A1: Very coarse arkosic sandstone with abundant angular quartz and feldspar, and minor opaques, in a clayey groundmass. C1: Iron-stained sandy siltstone with abundant angular quartz grains and sericitised fine lithic clasts, and common feldspar and carbonaceous grains, set in a muddy matrix. [B2: Early to mid Turonian palynology] [C2: Probably Turonian palynology] [D1: Early to mid Turonian palynology]
DR19	A2: Mottled sandy siltstone with abundant angular quartz grains and sericitised fine lithic clasts, and common carbonaceous fragments and minor feldspar, set in a muddy matrix. Thin interbeds of fine sandstone with quartz dominant over lithic clasts. A3: Bimodal sandy siltstone with 20% coarse sand grains. Sand grains are largely angular or embayed quartz and presumed v.f. grained acid volcanics, plus some sericitised lithic clasts and carbonaceous grains, and minor muscovite. Siltstone matrix is finer grained equivalent. Mud flow? B1: Well-bedded v.f. to coarse labile sandstone with abundant subangular clasts of two feldspars, quartz, varied v.f. grained acid lithics, and carbonaceous grains, with minor muscovite. Extensive alteration to brownish yellow clay mineral. B2: Coarse iron-stained labile sandstone with abundant subangular feldspar, quartz, varied v.f. grained acid lithics, and carbonaceous grains, with minor

	muscovite. Extensive iron alteration. B3: Coarse labile sandstone with abundant angular feldspars, quartz, varied v.f. grained acid lithics, and carbonaceous grains, with minor muscovite. Some alteration to brownish yellow clay mineral. C1: Coarse labile sandstone with abundant angular quartz, feldspars, varied v.f. grained acid lithics, and carbonaceous straps, with some muscovite. Some alteration to brownish yellow clay mineral. C2: Coarse to very coarse labile sandstone with abundant angular quartz, feldspars, varied v.f. grained acid lithics, with some muscovite. Some strata with v.c. clasts of brown v.f. ?claystone. A few carbonaceous straps. C3: Coarse labile sandstone with abundant angular quartz, feldspars, varied v.f. grained acid lithics, and carbonaceous straps, with some muscovite. Extensive iron alteration. [A1: Early to mid Turonian palynology]
DR21	A1: Coarse labile sandstone with abundant angular quartz, feldspars, varied v.f. grained acid lithics, and carbonaceous straps. Extensive iron alteration. [B1 & B2: Early Campanian palynology]
DR22	A1: Fine iron-stained silty labile sandstone with carbonaceous partings and grains. Clasts dominantly v.f. grained acid lithics and quartz, with some feldspar and muscovite.
DR23	B1: Calcarenite, v.f. grained consisting largely of molluscan clasts, with abundant forams, and some echinoid spines, sponge spicules, quartz and lithic grains, carbonaceous grains and clay matrix. Miocene or younger forams. [C1: Santonian palynology]
DR24-25	**Outer margin rift volcanics (presumed early Late Cretaceous) dredged from 3300-3600 m water depth**
DR24	A1: Light and dark volcanics welded together, with light material filling pores in dark. Light material is a **hyaloclastite**, dominantly of angular glassy vesicular clasts (1-4 mm), with some darker vesicular clasts, and some large calcite bodies between clasts. It may have been a flow in which other material was caught up, before quenching and breakup. Calcite has filled the interstices, and entered pores later still. Dark material is vesicular **basalt**, with feldspar needles and brown altered olivine crystals in aphanitic groundmass. Vesicles largely 1mm across are filled with clay minerals and/or calcite. A2: Vesicular **basalt**, with feldspar needles and brown altered olivine crystals in aphanitic groundmass. Vesicles largely 1mm across, but some reach 4 mm, and are partly filled with clay minerals or calcite. Darker and lighter layers in the rock. The darker layers show slightly more advanced crystallisation, probably being further from the cooling front. B1: **Hyaloclastite**, dominantly of light coloured, angular glassy vesicular clasts (3-10 mm), probably pumice, with some darker similar clasts. Interstices not very abundant and filled with fine grained clay/zeolite with some calcite.
DR25	A1: Brown **hyaloclastite**, consisting of angular clasts (1-10 mm) of vesicular altered glassy material containing some altered olivine microphenocrysts and fresh titanian clinopyroxene ("titanaugite") (60%), floating in a matrix of radial zeolites and lesser clay minerals (40%), probably originally mud. B1: Brown vesicular **basaltic glass** (palagonite), containing feldspar [? check!] and altered olivine phenocrysts to 2 mm and euhedral titanian clinopyroxene cystals to 0.2 mm. The olivine is replaced by clays and red layered silicates ("iddingsite'). Vesicles are elongate (1-4 mm) and partially filled with zeolites.

3.2. Seaspray Group

Dredges 5-12 recovered marine calcareous rocks believed to be part of the post-Eocene Seaspray Group, in present-day water depths varying from 680 m to 2800 m. Palynology (**Section 4**) shows that DR8 and DR11 are Miocene in age, and DR5 and DR12 include Plio-Pleistocene strata (**Section 5**). Microplankton show that water depths were deep during deposition. Foraminifera (**Section 5**) show that the older rocks dredged in DR5, DR8, DR10 and DR11 are Early to Middle Miocene in age, and that the Quaternary DR12 consists of shallow-water material that was displaced downslope.

The rocks recovered include medium to very fine grained calcarenites, calcisiltites and calcareous mudstones, composed largely of molluscan debris, foraminifera (often filled with pyrite) and clay. Other organic debris includes wood and leaves, sponge spicules and echinoderm spines. Detrital clasts are largely quartz, feldspar, clay clasts and muscovite. The strata are often poorly bedded, with thin to medium bedding apparent in some cases. Mottling shows that bioturbation was widespread.

3.3. Emperor and Golden Beach Subgroups

Eleven dredges (DR4, DR13-16, DR18-23) recovered immature labile rocks believed to be part of the Late Cretaceous Emperor and Golden Beach Subgroups. Ages obtained thus far vary from Turonian to Campanian (**Section 4**). The dredges were taken on the outer continental margin in water depths ranging from 2040m to 3800 m (**Figure 2**). No rocks of Early Cretaceous (Strzelecki Group) age were recovered, perhaps supporting the view of Megallaa (1993) that they were not deposited on or east of the Gippsland Rise (a NNE-trending feature at ~149°30'E).

Common lithologies are labile sandstone, siltstone and mudstone (and the weathered variants, silt and clay). The sediments are carbonaceous in part and plant remains are apparent in some beds. They are often thin to medium bedded, and burrowed and mottled in part. Occasional beds contain other environmental indicators such as cross-lamination, ferruginous nodules and trace fossils. Load casts are present in DR18, and ripple marks in DR19. These rocks were deposited in the rift involving eastern Australia, Lord Howe Rise, and the Gippsland Basin, and are lithologically similar to those of the Strzelecki Group and the Emperor and Golden Beach Subgroups.

The rocks form a siliciclastic assemblage of lithologically immature, but well size-sorted, sandstones and mudstones, laid down rapidly in coastal plains, swamps and shallow-marine environments. Clasts are angular to subangular. Much of the debris consists of volcanic quartz, feldspar (dominantly plagioclase), and clasts of fine grained lithic rocks including acid volcanics. Carbonaceous straps and grains are very common. Minor but widespread components are muscovite, biotite and opaque minerals. Glauconite occurs in a few samples. The groundmass is clayey, and both it and some of the clasts are commonly chloritised and sericitised. Marine macrofossils are generally absent, despite the common presence of marine indicators such as burrows and mottling.

Santonian carbonaceous mudstone had earlier been dredged from the flanks of Bass Canyon by HMAS *Cook* (Marshall, 1988) in dredge hauls C84-3DB, C84-4DB and C84-5DB (**Figures 2** & **4-6**). Another earlier dredge haul, BMR 68-DR1 (**Figures 2** & **7**), consists of undated calcareous mudstone and lithic sandstone (Colwell, Coffin et al., 1987). This comes from the eastern continental slope, very close to our DR15 consisting of Late Campanian siliciclastic sediments.

The palynological results document the onset on marine conditions along the newly forming outer continental margin in the Late Cretaceous, as the developing Tasman Sea entered from the east. Algal cysts in Early to Middle Turonian sediments (DR18 & 19: ~90 Ma) show that silts and clays were deposited in a deep freshwater lake near the outer continental margin. Coniacian sediments were not recovered, but in the Santonian (DR23: ~86 Ma) microplankton indicate that considerable post–breakup subsidence of the outer continental margin had occurred, and that carbonates were being deposited in deep marine conditions. In the Early and Late Campanian (DR21 & DR15: ~82 Ma & ~75 Ma), deep marine muds continued to be deposited on the outer margin. Thus the results show that subsidence below sea level occurred between 90 Ma and 86 Ma.

3.4. Outer margin rift volcanics

The easternmost dredges were taken in water depths of 3300-3800 m (Figure 2) from a rifted block elongated west-northwest and just inboard of the continent-ocean boundary (DR17, DR24 & DR25). They contain basalt, hyaloclastite, breccia and volcaniclastic sandstone, none of which have been dated. The largest and most diverse dredge haul, DR24, contains cobbles of yellowy green olive hyaloclastite with highly vesicular clasts 1-4 mm in size, and containing dark vesicular basalt pebbles. The interstices, veins and vesicles are filled with calcite. It also contains slabs of brownish grey-green gritty hyaloclastite, with clasts up to 1 cm across. Interstices are filled with clay minerals and calcite. The third rock type occurs as cobbles of red brown orange fine grained vesicular volcanic scoria.

The small haul of DR25 is dominated by cobbles and pebbles of rounded, black, fine grained basalt and hyaloclastite, massive to highly vesicular. The interstices of the hyaloclastite are filled with zeolites and lesser clay minerals. Another common assemblage consists of light brown fine to coarse volcaniclastic rocks, containing highly vesicular basalt clasts. The very small haul of DR17 consists of dark grey to dark brown subrounded to subangular pebbles. Most are aphanitic volcanics, probably of acid to intermediate composition, some of which are vesicular. There are also some flattish pebbles of fine grained metasediments.

This assemblage of volcanic rocks occurs on an isolated ridge at the continent-ocean boundary and cannot have derived its pebbles and clasts from younger sequences. The assemblage is presumed to have been laid down sometime during the Tasman Sea rifting phase, in the Turonian to Coniacian. If this is correct, the labile non-marine sediments of the Emperor Subgroup (described in **Section 3.3**) were deposited synchronously further west. Bernecker and Partridge (2001) mention that basaltic volcanics of Campanian age occur in some wells near the Rosedale and Darriman fault systems, which bound the central deep of the Gippsland Basin, but they are probably unrelated.

We hypothesise that lava flows and domes formed on a coastal plain and in shallow water. In water, they were quenched and broken up to form volcaniclastic mass flow deposits such as hyaloclastites. Where the volcaniclastics formed by the combination of volcanic rock and muds, the interstices are now filled with zeolites and clay minerals, and any lime mud was replaced by diagenetic calcite. In the cases where the domes and flows formed on dry land, normal vesicular flows resulted, weathering to scorias in some cases.

4. RECONNAISSANCE PALYNOLOGICAL ANALYSIS OF FR11/98 DREDGE SAMPLES

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4.1. Introduction

Fourteen seafloor samples dredged from the sides of the Bass Canyon system in the Gippsland Basin in southeastern Australia were given a reconnaissance palynological analysis to determine age and possible stratigraphic assignment. The six shallower samples recovered from water depths between 1500 and 2800 metres gave Neogene ages (Early Miocene to Recent), while the eight deepest samples in water depths between 2800 and 3800 metres all gave Late Cretaceous ages (Turonian to Campanian). The results for each sample are discussed below with other information on the samples given in **Table 3**.

The material analysed consisted of an unfiltered kerogen slide and usually two unoxidised palynological slides sieved or filtered at 10µm and 20µm from each sample. The unfiltered kerogen slides generally displayed a very dense "felt" or suspension of very finely shredded, structured terrestrial, sapropelic, and opaque kerogen types and tiny pyrite crystal, in which floated very rare larger kerogen pieces and palynomorphs. The extreme density of the suspension on the unfiltered kerogen slides, combined with an average kerogen particle size of <5µm made these slides unusable for biostratigraphic purposes. The other two filtered but unoxidised slides were noticeably skewed, as the assemblages recorded from the different size fractions contained markedly different abundances of palynomorphs. It was therefore found necessary to examine both slides to achieve representative assemblages for the samples, but even when this was completed many of the assemblages recorded were considered to be skewed relative to assemblages previously recorded by the author in equivalent age samples from elsewhere in the basin. It is uncertain whether these problems are a consequence of the nature of the rocks or a result of the laboratory preparation methods.

4.2. Results from samples

SAMPLE: DR05-B2 (MFP12528)
Age: Late Pliocene to Pleistocene.
Zone: *Tubulifloridites pleistocenicus* Zone.
Stratigraphic unit: Seaspray Group.
Comments: The occurrence in the sample of abundant *Cyathidites paleospora* with common *Tubulifloridites pleistocenicus* and *Tubulifloridites simplis* is considered diagnostic of the largely Pleistocene *Tubulifloridites pleistocenicus* spore-pollen Zone. The *Spiniferites ramosus* dominated microplankton assemblage is probably no younger than the *Achomosphaera ramulifera* Zone of McMinn (1992), and the environment of deposition is open-marine consistent with the modern depositional setting of the dredge site.

SPECIES LIST:
Spore-pollen
Araucariacites australis
Banksieaeidites elongatus
Chenopodipollis chenopodiaceoides
Cyathidites paleospora
Foraminisporis bifurcatus
Gleicheniidites circinidites
Haloragacidites haloragoides
Haloragacidites harrisii
Laevigatosporites major
Laevigatosporites ovatus
Lygistepollenites florinii
Matonisporites ornamentalis
Milfordia incerta
Ophioglossisporites lacunosus
Podocarpidites spp.
Podocarpidites antarcticus
Polypodiaceoisporites ornatus
Pseudowinterapollis couperi
Ricciaesporites boxatus n.sp.
Tricolporites spp.
Tricolporopollenites pelargonioides
Tubulifloridites pleistocenicus
Tubulifloridites simplis
Microplankton & Algae
Achomosphaera alcicornu
Achomosphaera ramulifera
Botryococcus braunii
Impagidinium spp.
Lingulodinium machaerophorum
Spiniferites ramosus
Tasmanites punctatus
Tuberculodinium vancampoae

SAMPLE: **DR05-C2** (MFP12529)
Age: Late Pleistocene to Recent.
Zone: *Tubulifloridites pleistocenicus* Zone.
Stratigraphic unit: Seaspray Group.
Comments: Low yielding sample with a low concentration of palynomorphs on the slides. The microplankton *Protoperidinium* spp., *Impagidinium* spp. and the microforaminiferal liners appear to be most abundant forms, with *Tubulifloridites* spp. the commonest pollen. Abundance of other species is difficult to evaluate. Although recorded assemblage is of limited diversity the microplankton assemblage compares best with either the *Achomosphaera ramulifera* or *Protoperidinium leonis* Zones of McMinn (1992). Environment of deposition is open-marine consistent with the modern depositional setting of the dredge site.

SPECIES LIST:

Spore-pollen

Acaciapollenites myriosporites
Chenopodipollis chenopodiaceoides
Cyathidites paleospora
Diporites n.sp. aff. *G. nebulosus*
Haloragacidites haloragoides
Haloragacidites harrisii
Laevigatosporites ovatus
Matonisporites ornamentalis
Milfordia incerta
Monotocidites galeatus
Myrtaceidites parvus
Pseudowinterapollis couperi
Tricolporites spp.
Tubulifloridites pleistocenicus
Tubulifloridites simplis

Microplankton

Achomosphaera sp.
Impagidinium spp.
Lingulodinium machaerophorum
Protoperidinium conicum
Protoperidinium oblongum
Spiniferites membranaceus
Spiniferites ramosus

Other palynomorphs

Microforaminiferal liners
Scolecodonts

SAMPLE: **DR08-B2** (MFP12530)

Age: Early to Middle Miocene
Zone: Middle *P. tuberculatus* to *T. bellus* Zone.
Stratigraphic unit: Seaspray Group.

Comments: This low yielding sample gave a microplankton assemblage dominated by the dinoflagellate *Impagidinium* spp. and numerous undescribed dinoflagellate species that are can be assigned to the broad *Operculodinium* Superzone, which dominates the thick Miocene portion of the Seaspray Group. In the associated spore-pollen assemblage *Ophioglossisporites lacunosus* indicates an age no older than Late Oligocene, while *Cyatheacidites annulatus* indicates an age no younger than Pliocene. It is notable that *Nothofagidites* pollen, abundant in the more inshore Seaspray Group and equivalent aged coal measures in the Latrobe Valley, are extremely rare in the sample. It is suspected that their scarcity is more a consequence of sample preparation than removal by depositional processes. An open-marine, deep-water environment of deposition is most likely.

SPECIES LIST:

Spore-pollen

Araucariacites australis
Cyatheacidites annulatus

Cyathidites paleospora
Dilwynites granulatus
Foveotriletes balteus
Gleicheniidites circinidites
Haloragacidites harrisii
Ischyosporites gremius
Kuylisporites waterbolkii
Laevigatosporites major
Laevigatosporites ovatus
Lygistepollenites florinii
Nothofagidites emarcidus/heterus
Ophioglossisporites lacunosus
Podocarpidites spp.
Retitriletes sp.
Rugulatisporites mallatus
Stereisporites antiquisporites
Microplankton
Cymatisphaera spp.
Impagidinium spp.
Protoellipsodinium spp.
Pyxidinopsis sp.
Spiniferites ramosus
Tectatodinium sp.
Tectatodinium sp. cf. *T. pellitum*

SAMPLE: **DR11-B2** (MFP12531)
Age: Early to Middle Miocene
Zone: Middle *P. tuberculatus* to *T. bellus* Zone.
Stratigraphic unit: Seaspray Group.
Comments: A low yielding sample dominated by undescribed dinoflagellate species provisionally assigned to *Protoellipsodinium*. Although most or the assemblage is undescribed it has been widely recorded from the Early and Middle Miocene part of the Seaspray Group, and is part of the *Operculodinium* Superzone. The low diversity spore-pollen assemblage recorded is consistent with this age. An open-marine deep-water environment of deposition is most likely.

SPECIES LIST:
Spore-pollen
Araucariacites australis
Cyatheacidites annulatus
Cyathidites paleospora
Laevigatosporites major
Laevigatosporites ovatus
Latrobosporites sp.
Lygistepollenites florinii
Podocarpidites spp.
Retitriletes sp.
Microplankton
Impagidinium spp.

?Invertocysta sp.
Lingulodinium solarum
Operculodinium tabulatum n.sp.
Protoellipsodinium simplex n.sp.
Protoellipsodinium spp.
Pyxidinopsis sp.
Spiniferites ramosus
Tuberculodinium vancampoae

SAMPLE: **DR11-E1** (MFP12532)
Age: Late Miocene.
Zone: *Foraminisporis bifurcatus* Zone.
Stratigraphic unit: Seaspray Group.
Comments: Although also low yielding like the other sample from this locality, the assemblage recorded suggests a younger age based on the presence of the spore *Foraminisporis bifurcatus* n.comb., which is not known to range below the Late Miocene. The microplankton assemblage is also conspicuously different in lacking the *Protoellipsodinium* species and containing the distinctive dinoflagellate cyst *Melitasphaeridium choanophorum*. This latter species is recorded as ranging from Late Oligocene to Pliocene by Williams & Bujak (1985; fig.19), but has a later first appearance in the Gippsland Basin somewhere in the Miocene, and a older last occurrence in the early Pliocene (McMinn, 1992). Once the total range of this species is better established it may provide a more precise age for this sample. Environment of deposition is interpreted as deep-water open-marine.

SPECIES LIST:
Spore-pollen
Araucariacites australis
Cyatheacidites annulatus
Cyathidites paleospora
Dacrycarpites australiensis
Foraminisporis bifurcatus
Haloragacidites harrisii
Ischyosporites irregularis n.sp.
Lygistepollenites florinii
Matonisporites ornamentalis
Podocarpidites spp.
Polypodiaceoisporites ornatus
Polypodiidites perverrucatus
Pseudowinterapollis couperi
Retitriletes sp.
Microplankton & Algae
Achomosphaera alcicornu
Achomosphaera ramulifera
Cyclopsiella vieta
Impagidinium spp.
Lingulodinium machaerophorum
Melitasphaeridium choanophorum
Nematosphaeropsis rhizoma n.sp.

Operculodinium centrocarpum
Spiniferites ramosus
Tasmanites punctatus

SAMPLE: **DR12-B2** (MFP12533)
Age: Pleistocene.
Zone: *Tubulifloridites pleistocenicus* Zone.
Stratigraphic unit: Seaspray Group.
Comments: The sample is dominated by abundant large pieces of structure terrestrial kerogen associated with common *Cyathidites paleospora, Matonisporites ornamentalis* and *Tubulifloridites* spp., and in contrast to these terrestrial palynomorphs there are relatively few microplankton. Overall the assemblage has a nearshore character, but considering the young age and collection depth of >1600 metres it is concluded that the bulk of the organic material in the sample has been derived from the shelf and was probably delivered to the present site as turbidites.

SPECIES LIST:
Spore-pollen
Chenopodipollis chenopodiaceoides
Cyathidites paleospora
Foraminisporis bifurcatus
Haloragacidites harrisii
Haloragacidites trioratus
Matonisporites ornamentalis
Milfordia incerta
Monoporites media
Myrtaceidites eucalyptoides orthus
Myrtaceidites parvus
Myrtaceidites xanthomyrtoides
Pseudowinterapollis couperi
Tubulifloridites pleistocenicus
Tubulifloridites simplis
Microplankton & Algae
Achomosphaera sp.
Brigantedinium sp.
Operculodinium sp.
Tasmanites punctatus
Other palynomorphs
Microforaminiferal liners

SAMPLE: **DR15-C1** (MFP12534)
Age: Late Campanian.
Zone: *Isabelidinium korojonense* Zone
Stratigraphic unit: Anemone Formation of Golden Beach Subgroup.
Comments: The sample contains an abundant and diverse microplankton assemblage dominated by *Isabelidinium greenense*, which can be confidently assigned to the *I. korojonense* Zone on the presence of the eponymous species. Spore-pollen are rare in the

assemblage but can be considered consistent with a *T. lilliei* Zone assignment. Environment of deposition is distal marine and probably deep water.

SPECIES LIST:

Spore-pollen

Coronatispora perforata
Cyathidites minor
Dilwynites granulatus
Gambierina croccodilus n.sp.
Gambierina rudata
Gleicheniidites circinidites
Herkosporites proxistriatus
Laevigatosporites ovatus
Lygistepollenites florinii
Microcachryidites antarcticus
Nothofagidites senectus
Ornamentifera strumosus n.sp.
Phyllocladidites mawsonii
Podocarpidites spp.
Proteacidites spp.
Retitriletes sp.
Trichotomosulcites subgranulatus

Microplankton

Cribroperidinium sp., Marshall 1990
Exochosphaeridinium sp.
Isabelidinium cretaceum
Isabelidinium greenense
Isabelidinium korojonense
Isabelidinium variabile
Isabelidinium spp.
Microdinium cassiculum
Odontochitina sp. cf *O. echinatus* n.sp.
Odontochitina harrisii n.sp.
Odontochitina prolata n.sp.
Odontochitina spinosa
Samlandia mayi
Senoniasphaera edenensis
Spiniferites ramosus
Trithyrodinium vermiculata
Trithyrodinium sp. A, Marshall 1990

SAMPLE: **DR18-B2** (MFP12535)
Age: Early to mid Turonian.
Zone: *Rimosicysta* Superzone.
Stratigraphic unit: Kipper Shale of Emperor Subgroup.
Comments: The sample is poorly preserved and notwithstanding an abundance of palynomorphs on the slides there is only a limited diversity. This is entirely consistent with the character of assemblages recovered from the Kipper Shale. The dominance of *Dilwynites* pollen is characteristic of a Neves effect found in the distal and interpreted deepwater parts of

the Kipper Shale (e.g. Partridge, 1990). The endemic suite of algal cysts, originally described by Marshall (1989) and here considered to represent the *Rimosicysta* Superzone, are also characteristic of the formation, and are interpreted to indicate deposition in a fresh-water lacustrine environment.

SPECIES LIST:
Spore-pollen
Araucariacites australis
Baculatisporites spp.
Corollina torosa
Cyathidites minor
Dilwynites granulatus
Dilwynites pusillus n.sp.
Falcisporites grandis
Microcachryidites antarcticus
Perotrilites jubatus
Podocarpidites spp.

Microplankton & Algae
Rimosicysta asperatus
Rimosicysta eversa
Rimosicysta spp.
?Tetrachacysta keenei
Wuroia corrugata
Wuroia tubiformis

SAMPLE: **DR18–C2** (MFP12536)
Age: Probably Turonian.
Zone: Indeterminate.
Stratigraphic unit: Probably Kipper Shale.
Comments: The palynology residue is dominated by opaque and semi-opaque kerogen in which palynomorphs are rare. Although this low diversity assemblage is not age diagnostic its overall character and preservation is consistent with the assemblages from the three other dredge samples assigned to the Kipper Shale, and therefore a similar Turonian age is suggested.

SPECIES LIST:
Spore-pollen
Araucariacites australis
Ceratosporites equalis
Corollina torosa
Cyathidites minor
Dilwynites granulatus
Microcachryidites antarcticus
Podocarpidites spp.
Trichotomosulcites subgranulatus

SAMPLE: **DR18-D1** (MFP12537)
Age: Early to mid Turonian.
Zone: *Rimosicysta* Superzone.
Stratigraphic unit: Kipper Shale of Emperor Subgroup.
Comments: Assigned to the Kipper Shale based on the characteristic suite of algal cysts diagnostic of the *Rimosicysta* Superzone. The sample differs from DR18–B2 by containing common specimens of the colonial algae *Amosopollis cruciformis*. The spore-pollen are representative of the *P. mawsonii* Zone assemblages recorded from the formation in that there is a lack of most key species, but presence of a weak Neves effect. The sample is interpreted to have been deposited in a deep-water lacustrine environment.

SPECIES LIST:
Spore-pollen
Araucariacites australis
Baculatisporites spp.
Ceratosporites equalis
Cupressacites sp.
Cyathidites australis
Cyathidites minor
Dilwynites granulatus
Dilwynites pusillus n.sp.
Gleicheniidites circinidites
Interulobites intraverrucatus
Laevigatosporites ovatus
Microcachryidites antarcticus
Perotrilites jubatus
Podocarpidites spp.
Reticulosporis sp. cf. *R. albertonensis*
Rugulatisporites mesomallatus n.sp.
Trichotomosulcites subgranulatus
Microplankton & Algae
Amosopollis cruciformis
Luxadinium sp.
Rimosicysta cucullata
Rimosicysta eversa
Rimosicysta spp.
Wuroia sp. cf. *W. tubiformis*

SAMPLE: **DR19–A1** (MFP12538)
Age: Early to mid Turonian.
Zone: *Rimosicysta* Superzone.
Stratigraphic unit: Kipper Shale of Emperor Subgroup.
Comments: The low diversity microplankton are again diagnostic of the *Rimosicysta* Superzone, while the spore-pollen are considered to relate to the equivalent *P. mawsonii* Zone. The concentration of spore-pollen is too low to confidently demonstrate any Neves effect. Like the samples from locality 18, a distal and deep-water lacustrine environment of deposition is suggested.

SPECIES LIST:

Spore-pollen

Cyathidites minor
Dilwynites granulatus
Laevigatosporites ovatus
Microcachryidites antarcticus
Perotrilites jubatus
Podocarpidites spp.
Rugulatisporites mesomallatus n.sp.
Trichotomosulcites subgranulatus

Microplankton & Algae

Botryococcus braunii
Pediastrum sp.
Rimosicysta eversa
Rimosicysta kipperii
Rimosicysta spp.

SAMPLE: **DR21-B1** (MFP12539)
Age: Early Campanian.
Zone: *Nothofagidites senectus* Zone.
Stratigraphic unit: Anemone Formation of Golden Beach Subgroup.

Comments: The sample contains a high concentration of palynomorphs representing moderately diverse assemblages of both spore-pollen and microplankton. Although the eponymous species was not recorded the spore-pollen are confidently assigned to the *N. senectus* Zone based on the common occurrence of *Forcipites sabulosus*. The microplankton assemblage is dominated by *Isabelidinium variabile* and although the overall assemblage is consistent with the age assignment suggested by the spore-pollen it is difficult to confidently place this assemblage in relation to those described by Marshall (1988, 1990). The problem is that the sample lacks *Nelsoniella aceras* and *N. semireticulata* that are associated with the eponymous species of the *Satyrodinium haumuriense* Zone, but contains *Alterbidinium acutulum* which previously has not been recorded before the younger *I. korojonense* Zone (Marshall, 1990; fig.4), yet at the same time the presence of *Chatangiella arvensis* and spinose species of *Odontochitina* suggest affinities with the older Santonian assemblages described by Marshall (1988). Until the sequence of these assemblages is more adequately documented a microplankton zone assignment for this sample will remain uncertain. Environment of deposition is distal marine and probably deep water.

SPECIES LIST:

Spore-pollen

Australopollis obscurus
Clavifera triplex
Densoisporites velatus
Dictyophyllidites sp.
Dilwynites granulatus
Dilwynites pusillus n.sp.
Forcipites sabulosus
Gleicheniidites circinidites
Herkosporites proxistriatus
Lygistepollenites florinii

Microcachryidites antarcticus
Peninsulapollis gillii
Phyllocladidites mawsonii
Podocarpidites spp.
Proteacidites spp.
Retitriletes nodosus
Retitriletes spp.
Trichotomosulcites subgranulatus
Vitreisporites signatus

Microplankton & Algae
Alterbidinium acutulum
Amosopollis cruciformis
Chatangiella arvensis
Chatangiella victoriensis
Isabelidinium variabile
Isabelidinium spp.
Odontochitina costata
Odontochitina harrisii n.sp.
Odontochitina spinosa
Palambages sp.
Samlandia mayi
Spiniferites ramosus
Trithyrodinium vermiculata

SAMPLE: **DR21–B2** (MFP12540)
Age: Early Campanian.
Zone: *Nothofagidites senectus* Zone.
Stratigraphic unit: Anemone Formation of Golden Beach Subgroup.
Comments: The sample contains a nearly identical assemblage to that recorded from DR21–C1 and has same zone assignment problems for the microplankton. However, numerous specimens of *Nothofagidites senectus* were recorded from the slide filtered at 10µm, thereby confirming assignment to the *N. senectus* Zone. An equivalent deep-water marine environment of deposition is inferred.

SPECIES LIST:
Spore-pollen
Araucariacites australis
Cyathidites minor
Dilwynites granulatus
Dilwynites pusillus n.sp.
Forcipites sabulosus
Gleicheniidites circinidites
Lygistepollenites florinii
Microcachryidites antarcticus
Nothofagidites senectus
Peninsulapollis gillii
Perotrilites n.sp. (reticulate)
Podocarpidites spp.

Proteacidites spp.
Tricolpites confessus
Trichotomosulcites subgranulatus
Vitreisporites signatus
Microplankton & Algae
Alterbidinium acutulum
Amosopollis cruciformis
Chatangiella victoriensis
Exochosphaeridinium sp.
Isabelidinium sp. cf. *I. ponticum*
Isabelidinium variabile
Isabelidinium spp.
Microdinium cassiculum
Odontochitina harrisii n.sp.
Odontochitina spinosa
Palambages sp.
Spiniferites ramosus
Veryhachium sp. cf. *V. collectum*
Veryhachium sp.
Xiphophoridium alatum

SAMPLE: **DR23-C1** (MFP12541)
Age: Santonian
Zone: Equivalent to *Isabelidinium cretaceum* Zone.
Stratigraphic unit: Anemone Formation of Golden Beach Subgroup.
Comments: The sample contains moderately diverse assemblages of both spore-pollen and microplankton. The latter are very similar to the Santonian assemblages documented by Marshall (1988) and broadly conform to the interval of the *O. porifera* to *I. cretaceum* Zones although neither of the eponymous species were recorded. Assignment to the younger *I. cretaceum* Zones is preferred based on the occurrence of *Odontochitina indigena* which has not been recorded by the author from below the younger zone in the Otway Basin. The spore-pollen assemblage also lacks key index species, but is consistent with assignment to the *Tricolporites apoxyexinus* Zone. Once again an open-marine deep-water environment of deposition is suggested.

SPECIES LIST:
Spore-pollen
Araucariacites australis
Australopollis obscurus
Baculatisporites spp.
Cicatricosisporites sp.
Cyathidites australis
Cyathidites minor
Densoisporites velatus
Dictyophyllidites sp.
Dilwynites echinatus n.sp.
Dilwynites granulatus
Dilwynites tuberculatus
Gleicheniidites circinidites

Microcachryidites antarcticus
Perotrilites n.sp. (reticulate)
Phyllocladidites eunuchus ms
Phyllocladidites mawsonii
Podocarpidites spp.
Proteacidites spp.
Retitriletes spp.
Rugulatisporites mallatus
Trichotomosulcites subgranulatus
Microplankton
Amosopollis cruciformis
Chatangiella tripartita
Cyclonephelium compactum
Exochosphaeridium sp.
Isabelidinium variable
Odontochitina costata
Odontochitina indigena
Oligosphaeridium complex
Palambages spp.
Rimosicysta spp. (reworked?)
Spiniferites ramosus
Trithyrodinium sp.
Veryhachium sp.

Table 3: Palynological Summary

Sample	Latitude S Longitude E	Water Depth (metres)	Description
DR05	39 11.15 148 55.33	1750- 1520	B2: Late Pliocene-Miocene grey weakly lithified siltstone to fine sandstone. Open marine microplankton. C2: Late Pleistocene to Recent soft grey silt to fine sand. Open marine microplankton.
DR08	38 47.4 149 01.0	2800- 2600	B2: Early to Middle Miocene grey moderately lithified clayey, thin bedded very fine quartz sandstone with carbonaceous flecks. Open marine microplankton.
DR11	38 37.95 149 19.50	2700- 2550	B2: Early to Middle Miocene greenish grey silty mudstone with a few thin carbonaceous layers. Open marine microplankton E1: Late Miocene grey mudstone, with some woody material. Marine characteristics include spreite and mottling. Open marine microplankton.
DR12	38 47.0 148 34.03	1725- 1600	B2: Pleistocene grey soft silty mudstone. Very homogeneous & massive with rare bivalves. Nearshore palynomorphs believed re-deposited.
DR15	38 59.17 149 09.00 to 38 58.63 149 41.87	3700- 3400	C1: Late Campanian greenish olive carbonaceous mudstone. Open marine microplankton, probably deep water.
DR18	38 51.8 149 35.8	3820- 3300	B2: Early to mid Turonian yellowish brown thin bedded flaggy siltstone with obvious plant remains. Algal cysts indicate fresh-water lake. C2: Probably Turonian dark yellowish sandy siltstone. Fissile to flaggy with load casts. Environment non-marine. D1: Early to mid Turonian yellowish brown poorly consolidated silty mud or clay. Algal cysts indicate deep fresh-water lake.
DR19	38 52.00 149 34.96 to 38 52.00 149 34.63	3375- 2900	A1: Early to mid Turonian blue grey laminated lithified claystone. Deep fresh-water lake suggested.
DR21	38 45.4 149 36.8 to 38 45.0 149 36.4	3200- 2800	B1: Olive grey lithified mudstone. Laminated to thin bedded, low density. Some mottling, boring. B1 soft, B2 hard: both Early Campanian. Microplankton indicate deep marine for both.
DR23	38 47.40 149 37.50 to 38 46.50 149 38.30	3600- 3100	C1: Santonian grey lignitic sticky clay - slightly calcareous and probably carbonaceous. Microplankton indicate deep marine.

Samples identified in the form "FR11/98/DR05/B2"

4.3. Conclusions

The reconnaissance palynological analysis show that the seafloor dredge samples fall into the following three groups, (1) lacustrine sediments of Turonian age, (2) distal marine and probably deep-water sediments of Santonian to Late Campanian in age, and (3) deep-water marine sediments of Neogene age.

Not seen, and not even evidenced by reworked palynomorphs, are Early Cretaceous sediments of the Strzelecki Group and the Maastrichtian to Oligocene age sediments that account for the upper part of the Latrobe Group and basal part of the Seaspray Group. The Strzelecki Group is interpreted to have either not been deposited over the East Gippsland Rise east of longitude

149° (see Megallaa, 1993; p.47), or to have been removed by erosion during the Cenomanian Otway Unconformity. The upper Latrobe and basal Seaspray Groups are interpreted to be missing at an extended version of the "Latrobe Unconformity". Most of the missing time can be accounted by either non-deposition or extremely starved and condensed deposition. A third unconformity is also interpreted to be present located between the Turonian lacustrine sediments of the Kipper Shale and the Santonian marine sediments of the Anemone Formation. This last unconformity is correlated to the commencement of seafloor spreading in the Tasman Sea.

4.4. Recommendations

Additional palynological studies are only recommended at this time on the samples recovered from the Late Cretaceous Anemone Formation and Kipper Shale. Distribution of sediments belonging to two these formations is still poorly known in the Gippsland Basin and consequently any further study of the marine microplankton from these older samples may help future petroleum exploration. If this work is to be undertaken further palynological slides will need to be prepared for both abundance counts and more thorough documentation of the assemblages.

In contrast, no additional palynological study of the Neogene age samples can be justified at this time because of the lack of a suitable reference standard against which the recorded assemblages can be calibrated. A better approach would be to have the samples analysed for calcareous microfossils to test the ages proposed by the palynology. If the results of foraminiferal and nannofossil analyses are inconclusive, or provide encouragement for further palynological studies the latter should be conducted in conjunction with the investigation of a well dated long stratigraphic section through the Seaspray Group to establish the Neogene ranges of microplankton in the Gippsland Basin.

5. FORAMINIFERAL STUDIES OF FR11/98 DREDGE SAMPLES

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A brief scan of the foraminiferal assemblages from Cainozoic calcareous samples, carried out to provide evidence of age and palaeo-water depth, is summarised below. Table 4 is a species list for the samples, including foraminifers and other fossil groups. Planktonic forams greatly predominate over benthic forams, indicating that all sediments were deposited in depths of over 200 m. Echinoids, ostracodes, sponge spicules and bryozoans are present in some dredge hauls (**Table 4**).

The oldest samples in DR05-11 are all Early to Middle Miocene (14-16 Ma) in age and were deposited in upper bathyal depths (estimated at somewhere in the range 200-2000 m). They are now in somewhat deeper water (1600-2900 m), which suggests there has been some subsidence related to compaction and probably some tectonic subsidence of the margin.

Samples from DR12 contain Quaternary forams (and Quaternary palynomorphs) and shallow marine assemblages laid down in an outer shelf to upper slope regime (50-500 m). As the samples are now in water ~1650 m deep, they must have been carried there by downslope mass transport.

The forams from DR23 are of Miocene and younger age and were laid down in upper slope water depths (200-500 m). As the present water depth is ~3300 m these forams must have been transported down slope. It should be noted that the palynomorphs from this dredge haul are Santonian in age (~86 Ma).

FR11/98DR05 B1
Biostratigraphy: Zone ?N.9 to N.10; ?*O. suturalis* to *Gr. peripheroacuta* Zone; ?Middle Miocene.
Palaeodepth: Lower bathyal (500-2000 metres).
Lithology: Bioclastic mudstone.

FR11/98DR05 C1
Biostratigraphy: Zone N.21; *Gr. inflata* Zone; Late Pliocene.
Palaeodepth: 5.0 - Lower bathyal (500-2000 metres)
Lithology: Fine grained calcarenite

FR11/98DR05 A1
Biostratigraphy: Zone N.21; *Gr. inflata* Zone; Late Pliocene.
Palaeodepth: 5.0 - Lower bathyal (500-2000 metres)
Lithology: Sandy mudstone

FR11/98DR08 A1
Biostratigraphy:?Zone N.4 to N.8; *?Tu. euapertura* to *Pr. glomerosa* Zones; Early Miocene?
Palaeodepth: 5.0 - Lower bathyal (500-2000 metres)
Lithology: Medium grained calcarenite

FR11/98DR08 B1
Biostratigraphy: Zone N.7 to N.8?; *Gr. miozea* to *Pr. glomerosa?* Zones; late Early Miocene.
Palaeodepth: 5.0 - Lower bathyal (500-2000 metres)
Lithology: Calcisiltite

FR11/98DR08 B3
Biostratigraphy: Zone N.8; *Pr. glomerosa* Zone; late Early Miocene.
Palaeodepth: 5.0 - Lower bathyal (500-2000 metres)
Lithology: Calcisiltite

FR11/98DR10 A1
Biostratigraphy: Zone N.7 to N.8; *Gr. miozea* to *Pr. glomerosa* Zones; Early Miocene with N.21 to N.23; Late Pliocene of younger.
Palaeodepth: 5.0 - Lower bathyal (500-2000 metres)
Lithology: Calcareous mudstone

FR11/98DR10 A2
Biostratigraphy: N.7 to N.15; *Gr. miozea* to *Pa. mayeri* Zones; Early to Middle Miocene; with N.21 or younger in burrows.
Palaeodepth: 5.0 - Lower bathyal (500-2000 metres)
Lithology: Carbonaceous mudstone

FR11/98DR10 A3
Biostratigraphy: Zone N.21 or younger; *Gr inflata Zone*; Late Pliocene or younger.
Palaeodepth: 5.0 - Lower bathyal (500-2000 metres)
Lithology: Medium grained clayey sandstone

FR11/98DR11 A1
Zones N.7 to N.8; *Gr. miozea* to *Pr. glomerosa* Zones; late Early Miocene.
Palaeodepth: 5.0 - Lower bathyal (500-2000 metres)
Lithology: Carbonaceous mudstone

FR11/98DR11 A2
Biostratigraphy: Zone N.22 or younger; *Gr. truncatulinoides* Zone; Pleistocene.
Palaeodepth: 4.5 - Upper bathyal (200-500 metres)
Lithology: Foram-rich calcisiltite

FR11/98DR11 A3
Biostratigraphy: Zone N.9 or younger; *Orb. suturalis* Zone or younger; Middle Miocene or younger.
Palaeodepth: 5.0 - Lower bathyal (500-2000 metres)
Lithology: Carbonaceous mudstone

FR11/98DR11 B1
Biostratigraphy: Zones N.7 to N.8; *Gr. miozea* to *Pr. glomerosa* Zones; late Early Miocene.
Palaeodepth: 5.0 - Lower bathyal (500-2000 metres)
Lithology: Carbonaceous calcareous mudstone

FR11/98DR11 C1
Biostratigraphy: Not determinable
Palaeodepth: 5.0 - Lower bathyal (500-2000 metres)
Lithology: Mudstone

FR11/98DR11 D1
Biostratigraphy: Zone N.9 to N.15; *Orb. suturalis* to *Pr. mayeri* Zones; Middle Miocene
Palaeodepth: 5.0 - Lower bathyal (500-2000 metres)
Lithology: Ferruginous mudstone

FR11/98DR12 A1
Biostratigraphy: Not determinable
Palaeodepth: 3.5 - Deep middle neritic (50-100 metres)
Lithology: Fine grained calcarenite

FR11/98DR12 B1
Biostratigraphy: Zone N.22; *Gr. truncatulinoides* Zone; Quaternary
Palaeodepth: 4.5 - Upper bathyal (200-500 metres)
Lithology: Medium grained calcarenite

FR11/98DR23 B1
Biostratigraphy: Miocene or younger
Palaeodepth: 4.5 - Upper bathyal (200-500 metres)
Lithology: Very fine grained calcarenite

Table 4. Distribution of Neogene Foraminifera

Sample	*Dentoglobigerina altispira*	*Globigerina bulloides*	*Globigerina* sp.	*Globigerinoides triloba*	*Globorotalia cavernula*	*Globorotalia challengeri*	*Globorotalia crassaformis*	*Globorotalia inflata*	*Globorotalia miozea*	*Globorotalia praescitula*	*Globorotalia puncticulata*	*Globorotalia scitula*	*Globorotalia* sp.	*Globorotalia truncatulinoides*	*Globorotalia zealandica*	*Orbulina* sp.	*Paragloborotalia semivera*	*Praeorbulina glomerosa*	*Praeorbulina sicana*	*Sphaeroidinellopsis seminulina*	indeterminable planktics	indeterminable rotalines	indeterminable textularines	Bryozoa unident	Coralline algae unident	Echinoids unident	Ostracods unident	Pellets	Sponge spicules unident	Zone
FR11/98DR05 B1										?						?					X	X				X		X	X	Zone ?N.9 to N.10; *?Orb. suturalis* to *Gr. peripheroacuta* Zone
FR11/98DR05 C1			X					X			?										X	X							X	Zone N.21; *Gr. inflata* Zone
FR11/98DR05 A1	X							X													X	X				X	X		X	Zone N.21; *Gr. inflata* Zone
FR11/98DR08 A1		X	X	X																	X	X		X		X	X			?Zone N.4 to N.8; ?*Tu. euapertura* to *Pr. glomerosa* Zones
FR11/98DR08 B1			X						X	?											X	X								Zone N.7 to N.8?; *Gr. miozea* to *Pr. glomerosa?* Zones
FR11/98DR08 B3		X	X	X					X	X					?		X	X			X	X								Zone N.8; *Pr. glomerosa* Zone
FR11/98DR10 A1			X	X			X	X	X												X							?		Zone N.7 to N.8; *Gr. miozea* to *Pr. glomerosa* Zones with N.21 to N.23
FR11/98DR10 A2							X	X	X												X									N.7 to N.15; *Gr. miozea* to *Pa. mayeri* Zones with N.21 or younger
FR11/98DR10 A3			X	X				X			?					X					X	X								Zone N.21 or younger; *Gr inflata* Zone
FR11/98DR11 A1									?						?				?		X									Zone N.7 to N.8; *Gr. miozea* to *Pr. glomerosa* Zones
FR11/98DR11 A2		X	X	X	?		X	X			X											X					X		X	Zone N.22 or younger; *Gr. truncatulinoides* Zone
FR11/98DR11 A3		X	X	X								X								X	X	X					X		X	Zone N.9 or younger; *Orb. suturalis* Zone or younger
FR11/98DR11 B1		X		X						?											X									Zones N.7 to N.8; *Gr. miozea* to *Pr. glomerosa* Zones
FR11/98DR11 C1																					?									Not determinable
FR11/98DR11 D1				X		X							X			X					X	X	X							Zone N.9 to N.15; *Orb. suturalis* to *Pr. mayeri* Zones
FR11/98DR12 A1			?																		X	X			X		X			Not determinable
FR11/98DR12 B1			X					?						?							X	X		X		X	X		X	Zone N.22; *Gr. truncatulinoides* Zone
FR11/98DR23 B1				?									X				?				X	X								Miocene or younger

6. RELATIONSHIP TO SEISMIC PROFILES

The map of the Bass Canyon complex (**Figure 2**) shows sample station information and the locations of six key seismic profiles that portray the structural and stratigraphic environments of the dredge sites. These profiles, A-F, are presented in **Figures 4-9**. The detailed bathymetry in **Figure 2** was derived from recent AGSO swath (multibeam sonar) surveys (Exon et al. 1999; Hill et al. 2000).

As indicated in **Figure 2**, exploration wells in the Gippsland Basin are located mainly on the shelf and those off the shelf are in water depths of less than 800 m. The absence of well control over most of the deepwater Gippland Basin, including the Bass Canyon complex, indicates the importance of the new geological sampling data in making stratigraphic interpretations.

The multichannel seismic profiles (**Figures 4-9**) were shot during the 1972-73 Shell (*Petrel*) deep-water scientific survey and during BMR's Survey 68 in 1987 (Colwell, Coffin et al. 1987). They show as much as 2.5 s twt of sedimentary section of Gippsland Basin section on the margin, and 2 s twt of well-stratified post-breakup (Campanian and younger) Tasman Basin section beneath the adjacent rise and abyssal plain. The syn-rift section, comprising the Emperor (Turonian) and Golden Beach (Santonian-Campanian) Subgroups and possibly Strzelecki Group (Early Cretaceous), is faulted and folded and up to 2 s twt thick (as seen in the profiles). The overlying post-rift Latrobe siliciclastics (Halibut Subgroup, Maastrictian-Eocene) are gently folded and do not appear to be more than ~0.5 s twt thick. The post Eocene upper megasequence, the Seaspray Group, comprises mainly marine carbonates that are thick (~1 s twt) and strongly prograding on the upper continental slope but that rapidly wedge out downslope.

Fine-grained labile sandstones, siltstones and mudstones of the Golden Beach Subgroup are exposed in the steep middle and lower walls of Bass Canyon (**Figures 4-6**). In the deepest part of the canyon, on the lower southern wall, are outcropping siltstones and arkosic sandstones of the older (Turonian) Emperor Subgroup (**Figure 5**). The upper slopes of Bass Canyon are underlain by calcareous mudstones and other fine-grained sediments of the Seaspray Group (**Figure 4**). These deposits may partially mantle sediments of the Latrobe siliciclastics on the canyon walls. Dredging indicates that the 15-20 km long ridge at the mouth of Bass Canyon (**Figure 8**) is of volcanic origin. Its location at the continent-ocean boundary (COB) and the fact that it appears to be onlapped by the entire Tasman Basin succession, here ~1.5 s twt thick (**Figures 6** & **9**), suggests that it was emplaced close to breakup time (Campanian).

Several dredge sites were located on the steep and canyoned continental slope, southeast of the Bass Canyon complex (**Figures 7-9**). The seismic profiles at these sites show rugged basement relief and less than ~1 s twt of sedimentary section. Samples recovered comprised a variety of sedimentary lithologies, including labile sandstones. Though most could not be dated, they all appear to be of Golden Beach assemblage. Given the relatively thin sedimentary section on the margin in the vicinity of the sites, it is likely that any Strzelecki Group section in this area is very thin or absent.

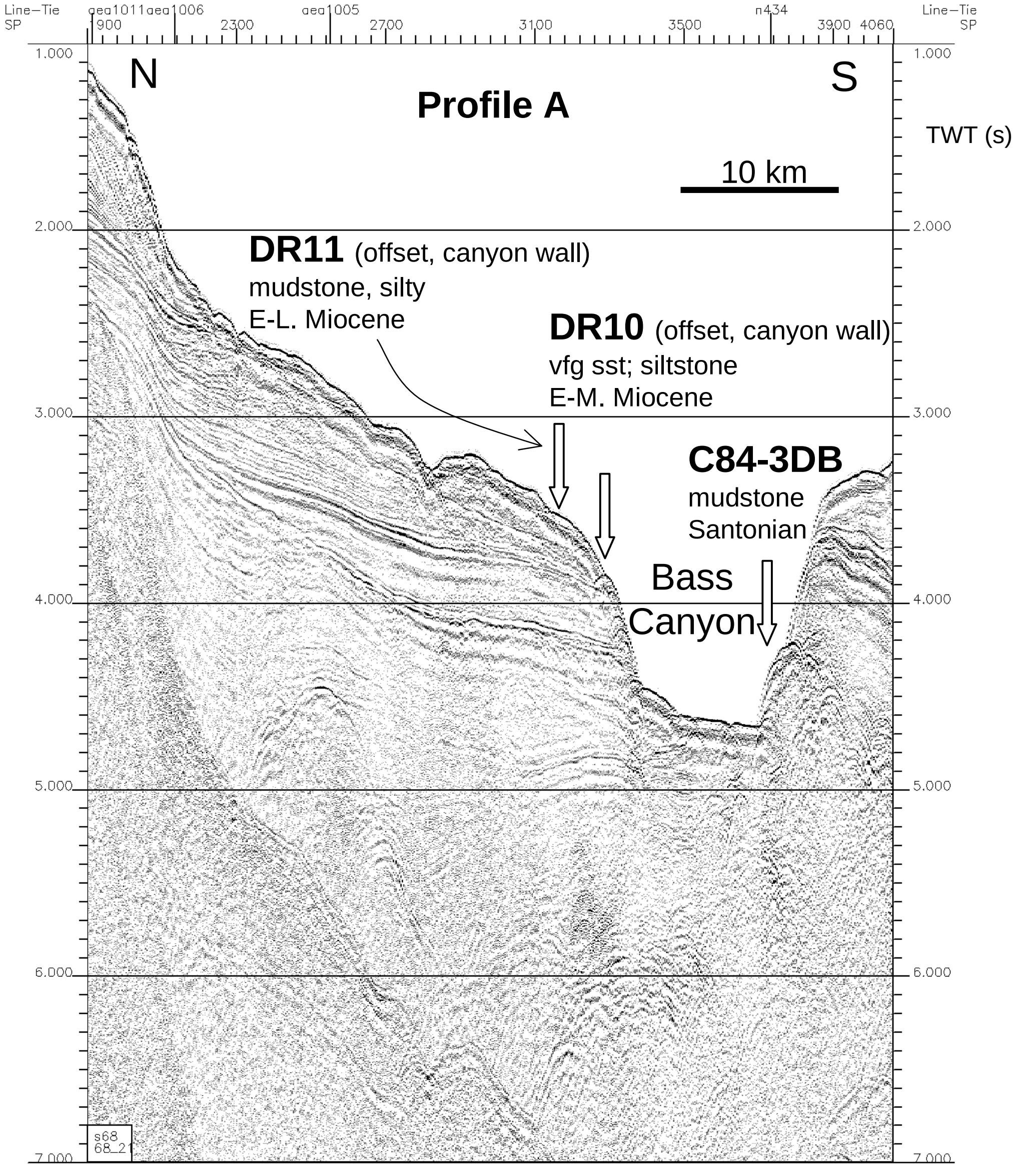

Figure 4. Seismic profile A (BMR line S68-21) showing dredge locations. Profile location in Figure 2.

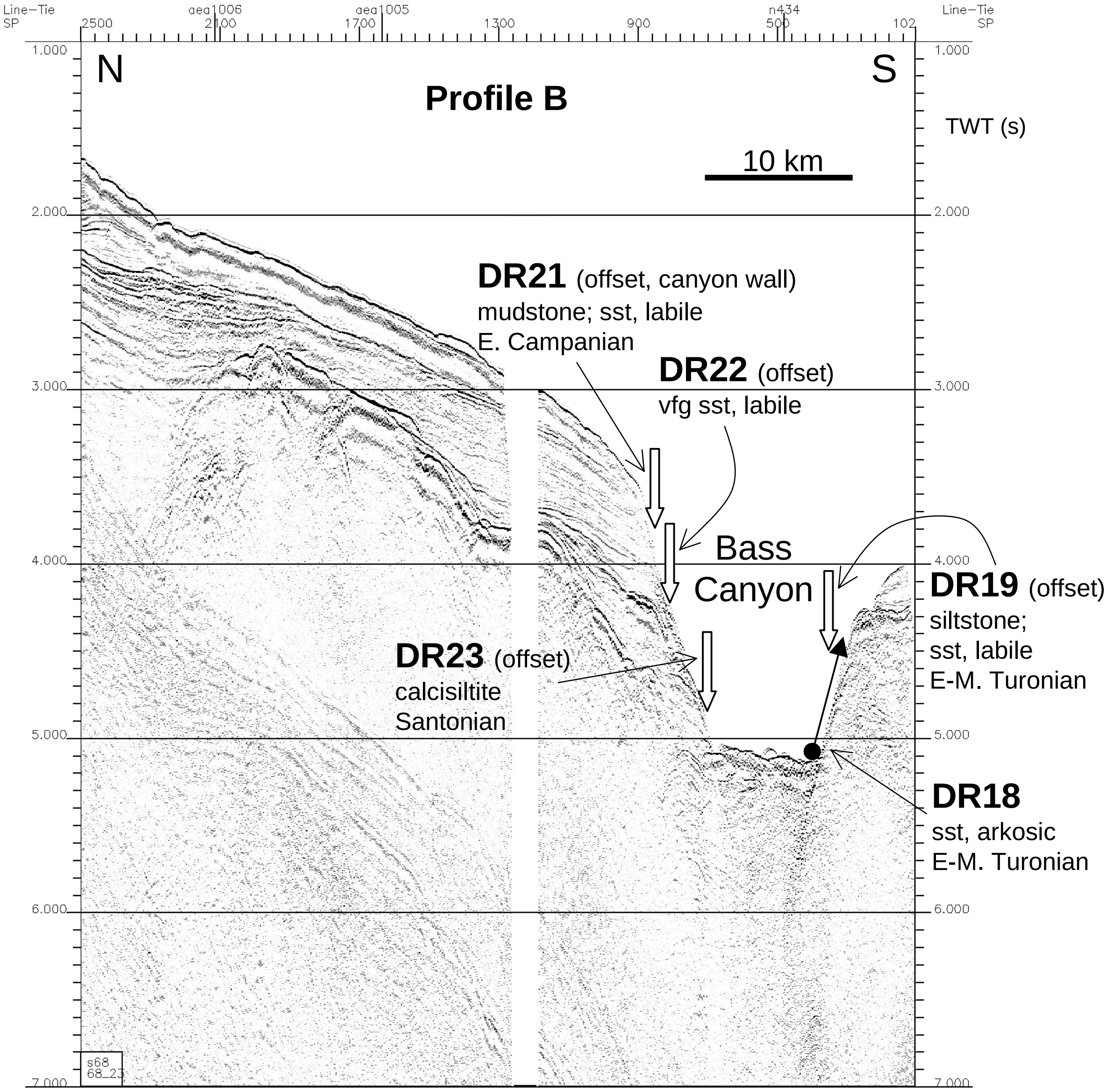

Figure 5. Seismic profile B (BMR line S68-23) showing dredge locations. Profile location in Figure 2.

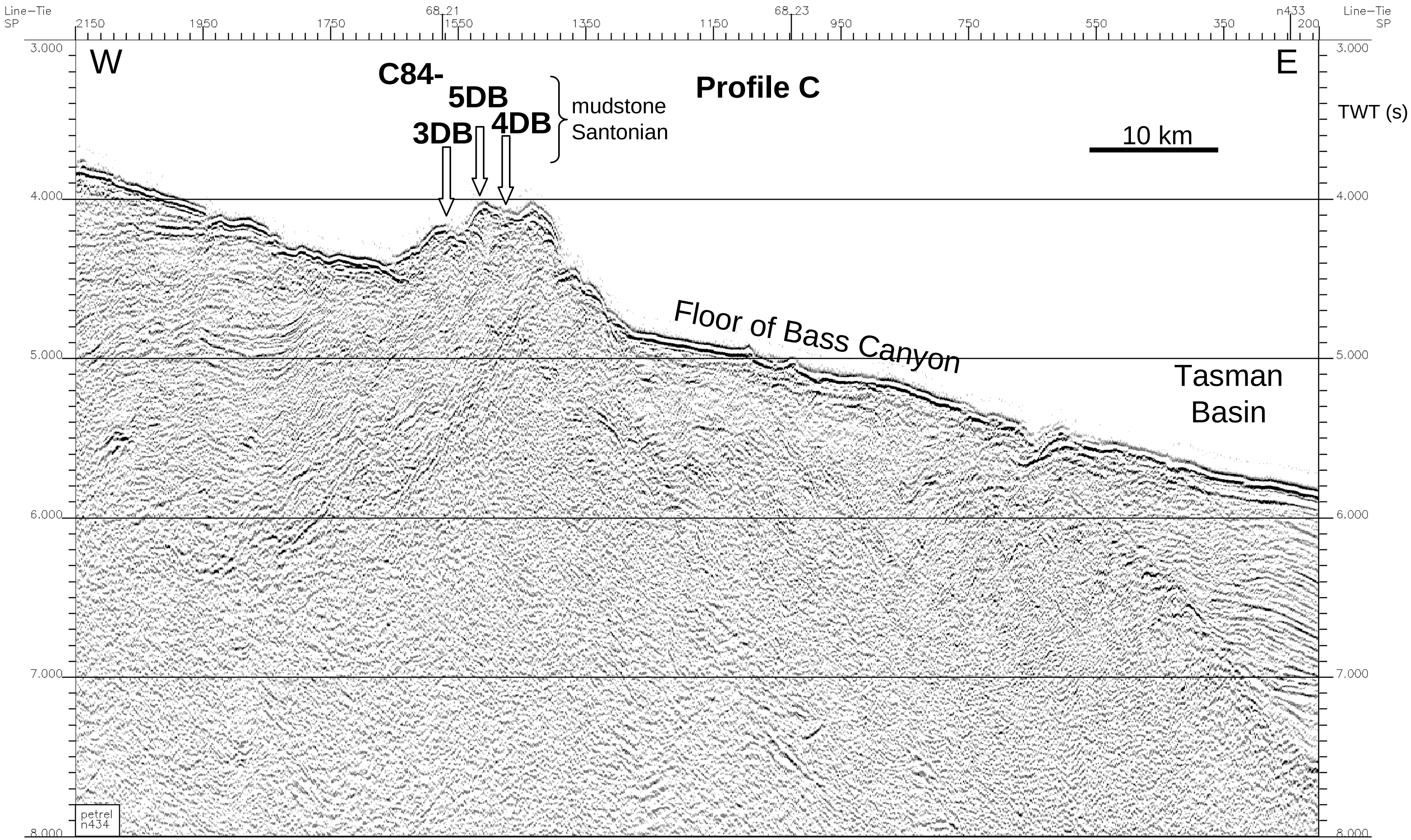

Figure 6. Seismic profile C (Shell Petrel line N434) showing dredge locations. Profile location in Figure 2. The C84 dredge samples were recovered by The University of Sydney and are described by Marshall (1988).

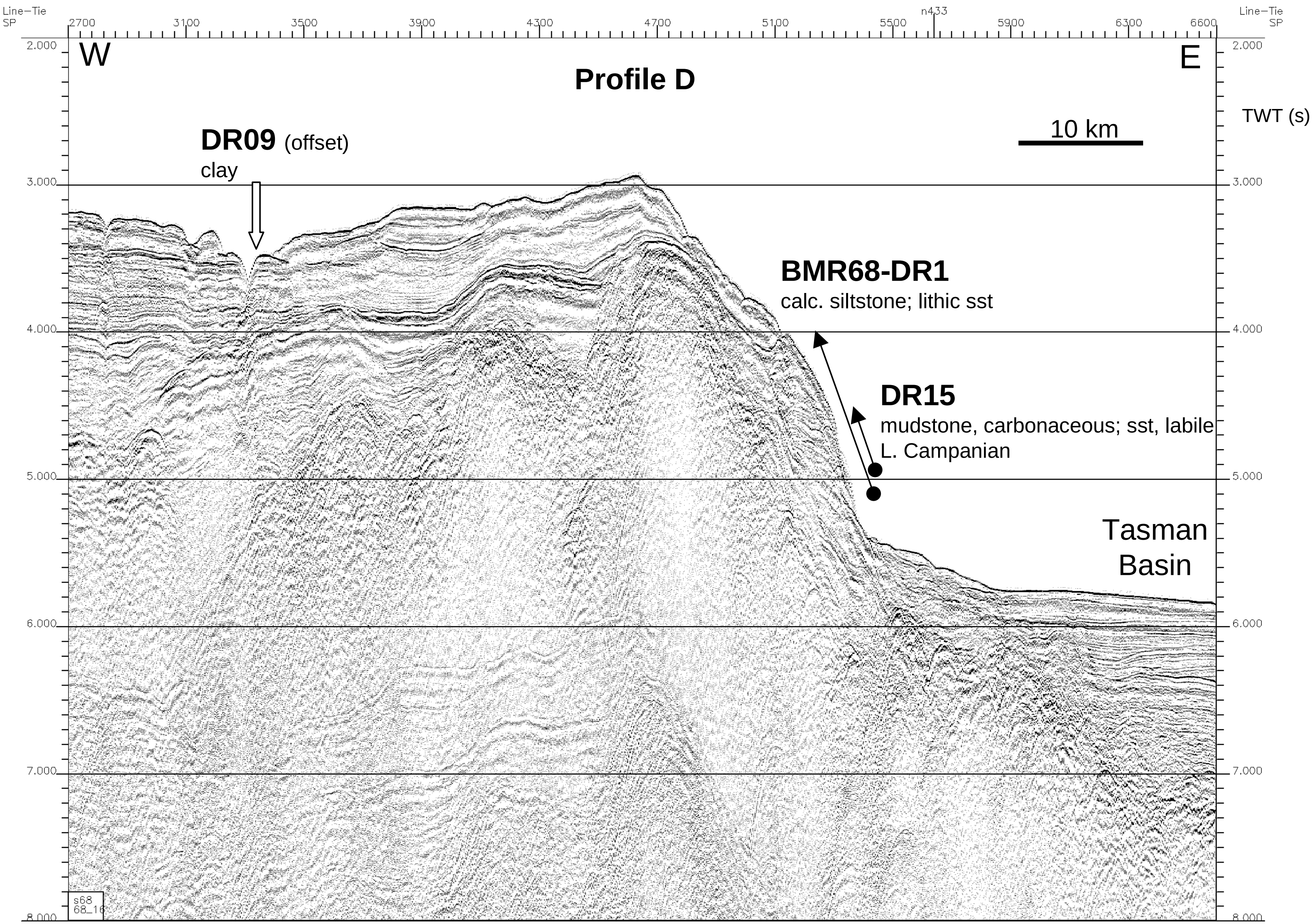

Figure 7. Seismic profile D (BMR line S68-16) showing dredge locations. Profile location in Figure 2.

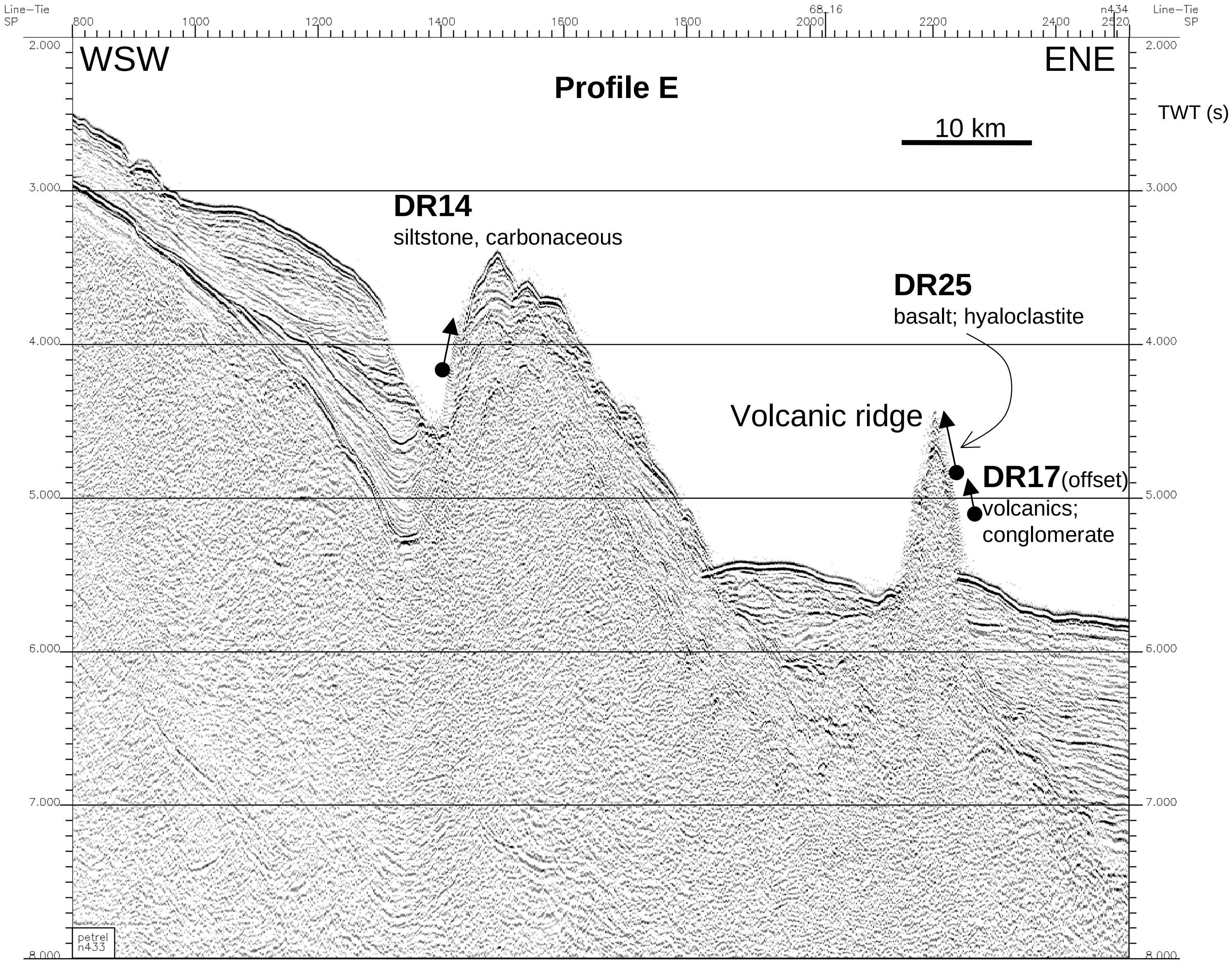

Figure 8. Seismic profile E (Shell Petrel line N433) showing dredge locations. Profile location in Figure 2.

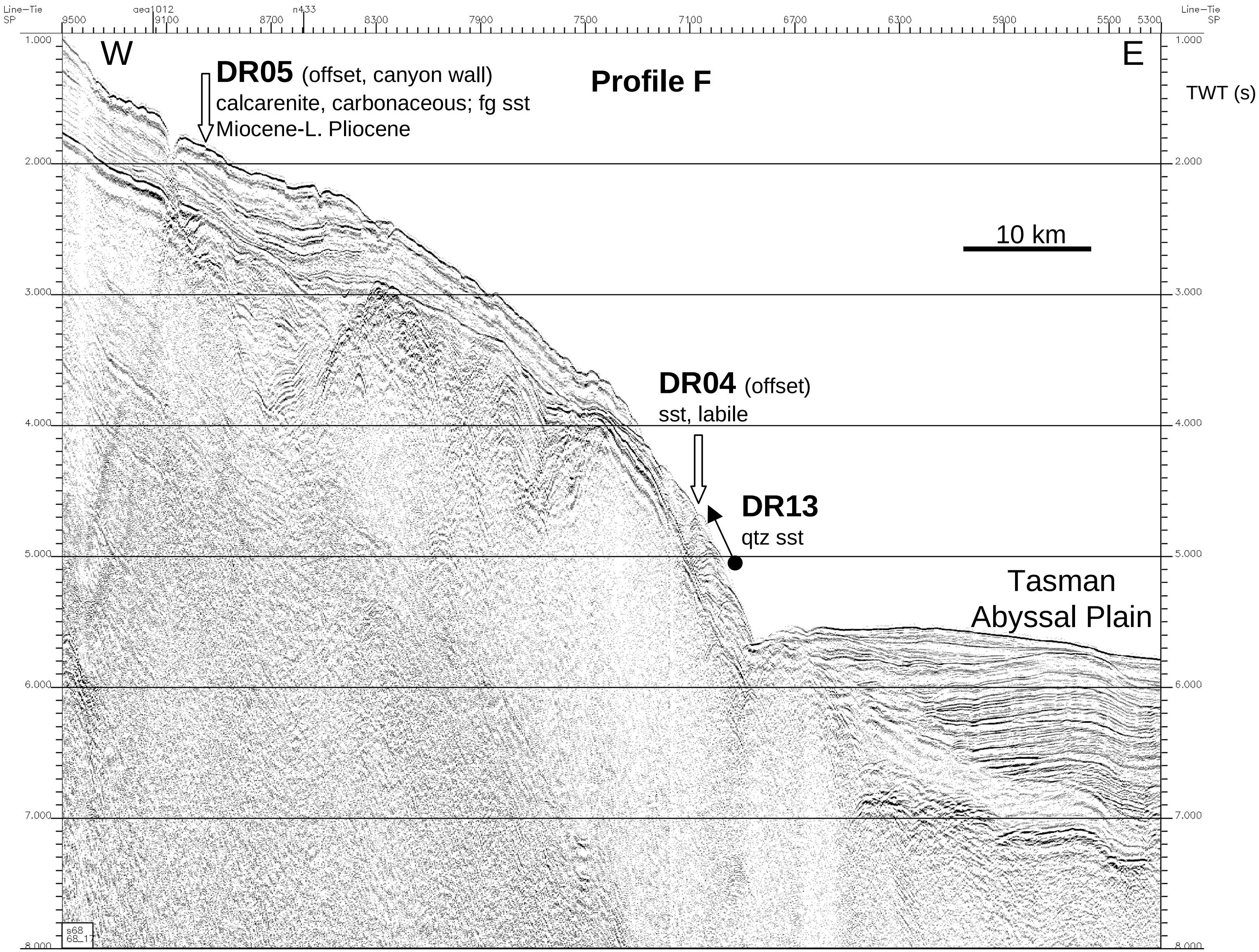

Figure 9. Seismic profile F (BMR line S68-17) showing dredge locations. Profile location in Figure 2.

7. CONCLUSIONS

As part of *Franklin* Cruise FR11/98 in the Gippsland Basin (Keene, 1998), 25 dredge stations were occupied in deeper water. The locations were determined on the basis of detailed seabed maps obtained during an earlier swath-mapping cruise of R.V. *Melville* (Hill et al., 1998; Exon et al., 1999), and of interpreted Geoscience Australia (BMR) seismic reflection profiles. The study was designed to provide information on the lithology, age and paleo-environment of the little-known deepwater Gippsland Basin. Fifteen dredge hauls were successful in recovering reasonable quantities of older rocks, three were moderately successful in recovering some older rocks, and seven were unsuccessful with no recovery of anything other than recent oozes. They are related to nearby seismic reflection profiles in **Figures 4-9**. Our results have been incorporated into recent reviews of the deepwater Gippsland Basin (Bernecker et al., 2001; Moore and Wong, 2001; Moore, Wong and Bernecker, 2001; Smith et al., 2000).

The rocks and sediments that were recovered in deep water fall broadly into four categories: volcanics of possible Turonian-Coniacian (Late Cretaceous) age, volcaniclastics and labile sediments of definite Turonian-Campanian age, Neogene marly calcareous sediments, and calcareous oozes of the Quaternary to Holocene. No rocks of Early Cretaceous (Strzelecki Group) age were recovered, supporting the view of Megallaa (1993) that they were not deposited on or east of the Gippsland Rise (a NNE-trending feature at ~149°30'E). Minor ferromanganese nodules and crusts from deepwater stations DR17 and DR18 (**Appendix 4**) are of no economic potential. They are high in SiO2 and remarkably low in copper and cobalt.

Volcanics were confined to the three easternmost dredges, taken in water depths of 3300-3800 m from a rifted block elongated west-northwest and just inboard of the continent-ocean boundary (DR17, DR24 & DR25). The larger hauls, DR 24 & DR25, consist of basalt, hyaloclastite, breccia, scoria and volcaniclastic sandstone. Dredge DR17 consists of a few pebbles of aphanitic volcanics, probably of acid to intermediate composition, and fine grained metasediments.

These basaltic volcanic rocks occur on an isolated ridge (**Figures 2** & **8**) and cannot have derived pebbles and clasts from younger sequences. The rocks are not fresh enough for radioactive dating, but are presumed to have been laid down during or immediately after the Tasman Sea rifting phase in Turonian to Coniacian times. We hypothesise that lava flows and domes formed on a coastal plain and in shallow water. Where the domes and flows formed on dry land, normal vesicular flows resulted, and these weathered to scorias in some cases. In water they were quenched and broke up to form volcaniclastic mass flow deposits such as hyaloclastites. Some of the volcaniclastics apparently became intermingled with soft clays and lime muds, because the interstices are now filled with zeolites, clay minerals and calcite.

Immature labile rocks of the Late Cretaceous Emperor and Golden Beach Subgroups were recovered in eleven dredges (DR4, DR13-16, DR18-23) on the outer continental margin in water depths of 2040m to 3800 m (**Figure 2**). Palynological ages obtained thus far are Turonian to Campanian (~90 Ma to ~74 Ma). Common lithologies are labile sandstone, siltstone and mudstone (and the weathered variants: silt and clay). The sediments are carbonaceous in part and plant remains are apparent in some beds. They are often thin to medium bedded, and burrowed and mottled in part. Occasional beds contain cross-lamination, ferruginous nodules, trace fossils, load casts and ripple marks. These rocks were deposited in the rift involving eastern Australia, Lord Howe Rise, and the Gippsland Basin, and are lithologically similar to those of the Strzelecki Group and Golden Beach Subgroup elsewhere in the Gippsland Basin.

The rocks are lithologically immature, but well size-sorted, sandstones and mudstones. Angular to subangular debris consists of volcanic quartz, feldspar (dominantly plagioclase), and clasts of fine grained lithic rocks including acid volcanics. The groundmass is clayey, and both it and labile clasts are commonly chloritised and sericitised. Carbonaceous straps and grains are very common. Minor but widespread components are muscovite, biotite and opaque minerals, and there is glauconite in a few samples. Marine macrofossils are generally absent, despite the common presence of marine indicators such as burrows and mottling. These sediments appear to have been rapidly deposited in coastal and marine environments.

The palynological results document the onset of marine conditions as the developing Tasman Sea entered from the east. Algal cysts in Early to mid Turonian silts and clays (DR18 & 19: ~90 Ma) indicate deposition in a deep freshwater lake near the outer continental margin. Microplankton in deep marine carbonates in the Santonian (DR23: ~86 Ma) indicate that considerable post–breakup subsidence of the outer continental margin had occurred by then. Thus there rapid subsidence between ~90 Ma and ~86 Ma. Microplankton in deep marine muds in the Campanian (DR21 & DR15: ~82 Ma & ~75 Ma) indicate continued deposition on the outer margin.

Marine calcareous rocks of the Neogene Seaspray Group were recovered in Dredges 5-12, in present-day water depths of 680 m to 2800 m. These rocks are medium to very fine grained calcarenites, calcisiltites and calcareous mudstones, composed largely of molluscan debris, foraminifers and clay. Common detrital clasts are quartz, feldspar, clay clasts and muscovite. They are often poorly bedded, with some thin to medium bedding. Organic debris includes wood and leaves, sponge spicules and echinoderm spines. Mottling shows that bioturbation was widespread.

Foraminifera date the older rocks dredged in DR5, DR8, DR10 and DR11 as early to middle Miocene, and show that the Quaternary dredge DR12 consists of shallow-water material displaced down slope. Palynology dates DR8 and DR11 as Miocene, and shows that DR5 and DR12 include Plio-Pleistocene strata (**Section 5**). Microplankton show that the water was deep during deposition.

8. ACKNOWLEDGEMENTS

This report covers a subset of the results of *Franklin* Cruise FR11/98, and as such involved the cooperation of all the scientific party (**Appendix 1**), whose excellent support we gratefully acknowledge. In particular, we would like to thank Guy Holdgate and Stephen Gallagher for their hand specimen descriptions of the dredge hauls, and David Mitchell for his help and advice with the dredging. We would also like to gratefully acknowledge the help given by the Master Dick Dougal, and the Mates, Arthur Staron and John Lynch, the ship's crew and the CSIRO support staff (all listed in **Appendix 1**), which enabled the cruise to be both enjoyable and a success. First Engineer Greg Pearce helped greatly by repairing the faulty AGSO (now Geoscience Australia) dredges.

Jon Stratton of the operations group of AGSO ensured that we had the necessary equipment aboard. Igneous petrologists Elizabeth Jagodzinski and Morrie Duggan of AGSO helped with the descriptions of the volcanic rocks. Jim Colwell and Phil O'Brien of Geoscience Australia kindly reviewed the text.

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APPENDIX 1. CRUISE FR 11/98 PERSONNEL

Scientific Party
Associate Professor Jock Keene, Dr Michael Hughes, Mr David Mitchell, Ms Karen Rae, School of Geosciences, The University of Sydney
Dr Stephen Gallagher, Dr Guy Holdgate, Mr Jim Daniels, Mr Andrew Smith, School of Earth Science, University of Melbourne
Dr Neville Exon, and Mr Peter Hill, AGSO, Canberra

ORV Support
Bob Beattie, CSIRO Marine Research, Cruise Manager and Computing
Alan Poole, CSIRO Marine Research, Electronics

Ship's Crew
Master: Dick Dougal
1st Mate: Arthur Staron
2nd Mate: John Lynch
Chief Engineer: John Morton
1st Engineer: Greg Pearce
Electrical Engineer: Andrew McLagan
Greaser: Wayne Browning
Bosun: Jannick Hansen
AB: Peter Genge
AB: Jerry O'Halloran
AB: Bill Hughes
Chief Cook: Gary Hall
2nd Cook: Tom Condon
Chief Steward: Ron Culliney

APPENDIX 2: ALL FR11/98 STATION DATA

Station Number	Sample Number	Latitude S	Longitude E	Water Depth(s) (metres)	Results
1	**DR01**	39 37.10	149 23.30	3900-3550	no recovery
2	**DR02**	39 27.02	149 25.82	3400-3200	no recovery
3	**DR03**	39 27.42	149 24.86	3400-3200	no recovery
3	**DR04**	39 17.63	149 24.02	3500-3100	successful, rocks
4	**DR05**	39 11.15	148 55.33	1750-1520	successful, rocks
5	**MG01**	39 20.00	148 30.28	46.5	shell hash, medium sand
5	**PC01**	39 19.97	148 30.20	47.5	sand, 0.8m
6	**MG02**	39 21.25	148 36.25	112	muddy, coarse shelly sand
7	**MG03**	39 21.70	148 38.43	308.5	coarse sand
7	**PC02**	39 21.83	148 38.16	224	limestone rock
8	**MG04**	39 19.15	148 38.85	324	sandy mud
8	**PC03**	39 19.11	148 38.59	240	sandy mud, 2.4m
9	**MG05**	39 12.79	148 50.16	1440	unsuccessful
10	**MG06**	38 17.19	147 21.11	19.5	medium bioclastic quartz sand
11	**MG07**	38 20.62	147 21.86	25	medium bioclastic quartz sand
12	**MG08**	38 23.65	147 22.47	34	medium bioclastic quartz sand
12	**PC04**	38 23.78	147 22.40	34.5	muddy sand-shell hash 1.63m
13	**MG09**	38 24.26	147 25.59	39	medium bioclastic sand
14	**MG10**	38 24.59	147 29.52	42.5	coarse bioclastic sand
15	**MG11**	38 24.83	147 30.93	44	coarse shelly quartz sand
15	**PC05**	38 24.88	147 30.97	44	muddy sand 2.7m
16	**MG12**	38 25.56	147 35.46	48.5	coarse shelly sand
17	**MG13**	38 25.92	147 40.15	51.5	muddy coarse sand
18	**MG14**	38 28.37	147 43.36	55	bioclastic sand
18	**PC06**	38 28.43	147 43.40	55	2.9m
19	**MG15**	38 31.41	147 47.35	62	muddy bioclastic sand
20	**MG16**	38 33.18	147 52.24	66	muddy coarse sand
21	**MG17**	38 33.11	147 59.28	70	medium shelly sand
21	**PC07**	38 33.11	147 59.28	70	coarse sand-rock 1.1m
22	**MG18**	38 33.98	148 04.02	76	med coarse bioclastic sand
23	**MG19**	38 34.81	148 08.70	78	med coarse bioclastic sand
24	**MG20**	38 35.63	148 13.94	79	med coarse bioclastic sand
25	**MG21**	38 36.18	148 17.39	84	med coarse bioclastic sand
25	**PC08**	38 36.68	148 17.08	86	shelly sand 1.25m
26	**MG22**	38 24.09	148 21.66	88	muddy coarse sand
27	**MG23**	38 26.84	148 25.11	134	coarse bioclastic quartz sand
28	**MG24**	38 26.97	148 25.25	145	coarse bioclastic sand
29	**MG25**	38 28.87	148 27.20	232	not successful
29	**MG25B**	38 28.63	148 27.31	242	med bioclastic sand
30	**DR06**	38 30.97	148 34.48	632-737	successful, rocks
31	**MG26**	38 31.81	148 31.43	471	sandy marl
32	**MG27**	38 29.80	148 28.96	210	calcareous mud
33	**MG28**	37 59.68	147 45.69	24.5	coarse shelly sand

34	**MG29**	38 01.67	147 50.75	43.5	muddy silt
35	**MG30**	38 03.48	147 55.02	48.5	fine sandy silt
35	**PC09**	38 03.33	147 55.32	48.5	unsuccessful
36	**MG31**	38 05.36	147 59.60	52.5	muddy shelly fine sand
37	**MG32**	38 07.34	148 03.85	55	muddy sand
38	**MG 33**	38 07.86	148 06.77	56.5	coarse shelly sand
39	**MG34**	38 10.23	148 10.86	58	muddy shell hash
39	**PC10**	38 10.05	148 10.97	58	successful, 1.5m
40	**MG35**	38 11.64	148 15.14	60	coarse shelly sand
41	**MG36**	38 13.43	148 19.00	63	coarse shelly sand
42	**MG37**	38 13.95	148 23.57	66.5	muddy coarse sand
42	**PC11**	38 13.85	148 23.59	66.5	successful, 1.7m
43	**MG38**	38 14.69	148 27.05	77	shelly sand
43	**PC12**	38 14.58	148 27.05	76.5	successful, 2.24m
44	**MG39**	38 15.59	148 30.61	97	coarse bioclastic sand
45	**MG40**	38 16.15	148 33.03	122	muddy coarse bio sand
45	**PC13A**	38 16.95	148 33.16	123	unsuccessful
45	**PC13B**	38 16.86	148 33.17	122	successful, 2.9m
46	**MG41**	38 17.22	148 38.13	263	bioclastic fine sand
47	**MG42**	38 18.24	148 41.46	170	muddy fine sand
48	**DRO7**	38 17.38	148 36.53	277-284	very coarse sand
49	**MG43**	38 45.25	148 17.83	95	fine shelly sand
50	**MG44**	38 48.45	148 17.80	130.5	v coarse shelly sand
51	**MG45**	38 48.13	148 22.20	467	calcareous silt
51	**PC14**	38 48.12	148 22.07	462.5	successful, 1.02m
52	**MG46A**	38 48.18	148 23.39	650	unsuccessful
52	**MG46B**	38 48.17	148 23.45	553	unsuccessful
52	**PC15**	38 48.17	148 23.23	513	successful, 1.0m
53	**MG47**	38 43.81	148 22.59	319	med fine shelly sand
53	**BP1**	38 44.34	148 21.32	204-287	successful
54	**MG48**	38 37.29	148 20.97	120.5	calcareous mud
55	**MG49**	38 38.45	148 23.44	190	bioclastic sand
55	**PC16**	38 38 70	148 23.54	196	successful, 1.85m
56	**MG50A**	38 38.81	148 24.54	173	unsuccessful
56	**MG50B**	38 39.00	148 24.70	209	shelly muddy sand
56	**PC17**	38 38.83	148 24.42	190	successful, 2.01m
57	**MG51**	38 39.48	148 26.09	276	muddy fine sand
57	**PC18**	38 39.33	148 25.99	255	successful, 1.88m
58	**BP2**	38 30.93	148 28.67	335-337	no photographs
59	**DR08**	38 47.40	149.01.00	2800-2600	successful, rocks
60	**DR09**	38 50.30	149 07.50	3030-2700	unsuccessful
61	**MG52**	38 48.44	149 08.63	3114	muddy silt
61	**PC19**	38 48.00	149 09.15	3137	successful 2.1m
62	**MG53**	38 43.28	149 14.59	3340	silty mud
62	**PC20**	38 43.14	149 14.75	3344	successful, 3.98m
63	**DR10**	38 40.04	149 19.08	3100-2700	successful, rocks
64	**DR11**	38 37.95	149 19.50	2700-2550	successful, rocks
65	**MG54**	38 40.05	148 59.28	2980	fine sandy mud

65	**PC21**	38 39.01	148 59.05	2975	0.9m disturbed core
66	**MG55**	38 33.84	148 48.81	2641	silty mud
66	**PC22**	38 33.16	148 49.09	2627	0.37m
66	**BP3**	38 32.29	148 47.50	2577-2609	successful
67	**MG56**	38 32.94	148 39.87	1802	calcareous mud
67	**PC23**	38 32.94	148 39.57	1814	successful, 2.47m
68	**MG57**	38 33.08	148 37.96	1137	sandy mud
68	**PC24**	38 33.37	148 37.27	1118	successful, 0.88m
69	**MG58**	38 33.00	148 34.87	603	calcareous silty mud
69	**PC25**	38 33.03	148 34.97	590	successful, 2.37m
70	**BP4**	38 31.76	148 28.04	346-260	successful
71	**DR12**	38 47.00	148 34.03	1725-1600	successful, rocks
72	**MG59**	38 42.91	148 47.93	2484	silty mud
72	**PC26**	38 42.86	148 48.07	2485	successful, 2.06m
73	**MG60**	38 47.81	148 47.84	2352	silty mud
73	**PC27**	38 47.59	148 47.59	2366	successful, 1.2m
74	**MG61**	38 49.64	148 43.68	2161	silty mud
74	**PC28**	38 50.20	148 43.48	2108	successful, 5.25m
75	**MG62**	38 52.16	148 40.60	1745	silty mud
75	**PC29**	38 52.71	148 40.45	1627	successful, 4.51m
76	**MG63**	38 54.02	148 37.97	1181	silty mud
76	**PC30**	38 54.58	148 38.36	1163	successful, 4.4m
77	**MG64**	38 55.58	148 35.06	577	muddy sand
77	**PC31**	38 56.14	148 35.36	548	successful, 0.65m
78	**MG65**	38 57.15	148 32.00	300	fine med sandy mud
79	**MG66**	38 58.05	148 30.06	132	muddy coarse sand
80	**DR13**	39 13.09	149 30.01	3450-3770	successful, rocks
81	**DR14**	39 05 .40	149 28.30	3400-2800	minor rocks
82	**DR15**	38 59.17	149 42.09	3700-3400	successful, minor rocks
83	**DR16**	38 57.10	149 52.40	3800-3220	unsuccessful
84	**DR17**	38 57.05	149 52.60	3800-3700	successful, rocks
85	**DR18**	38 51.80	149 35.80	3300-3820	successful, rocks
86	**DR19**	38 52.00	149 34.96	2900-3375	successful, rocks
87	**DR20**	38 45.20	149 36.80	2610-3150	unsuccessful
88	**DR21**	38 45.40	149 36.80	2800-3200	successful, rocks
89	**MG67**	38 47.67	149 29.51	3693	medium fine sand
89	**PC32**	38 48.08	149 28.55	3692	unsuccessful
90	**MG68**	38 46.63	149 28.52	3655	mud
91	**PC33**	38 46.18	149 28.42	3642	unsuccessful
91	**BP5**	38 47.58	149 29.36	3719-3702	successful
92	**MG69**	38 48.67	149 28.92	3692	mud with intraclasts
92	**PC34**	38 48.93	149 29.94	3695	unsuccessful
93	**DR22**	38 45.90	149 32.30	3160-3500	unsuccessful
94	**DR23**	38 47.40	149 37.50	3100-3600	successful, rocks
95	**MG70**	38 51.45	149 41.45	3910	mud with intraclasts
96	**PC35**	38 50.67	149 42.20	3921	unsuccessful
97	**MG71**	38 50.43	149 41.81	3931	mud with rock, intraclasts
98	**DR24**	38 53.20	149 45.15	3300-3600	successful, rocks

99	**DR25**	38 57.30	149 53.70	3300-3600	successful, rocks
100	**MG72**	38 37.09	149 33.01	1996	shelly mud
101	**MG73**	38 28.06	149 34.65	1469	muddy shelly sand
101	**PC36**	38 27.68	149 35.70	1446	successful, 1.5m

DR = dredge, **PC** = piston core, **MG** = Smith-McIntyre grab, **BP** = bottom photography

APPENDIX 3: FR11/98 SPARKER SEISMIC DATA

LINE No.	Julian Day	Latitude S	Longitude E	Distance km	Start Time	Finish Time	
1	262	148 35 09	39 30 97		start line @ 0530		
1	262	148 30 08	39 19 35	19.8km		finish line @ 0740	
2	262	148 30 08	39 19 35		start line @ 0740		
2	262	148 35 08	39 14 98	11.2		finish line @ 0857	
3	262	148 35 08	39 14 98		start line @ 0857		
3	262	148 41 48	39 22 43	16.4		finish line @ 1050	
4	262	148 41 48	39 22 43		start line @ 1050		
4	262	148 30 39	39 20 63	17.4		finish line @ 1320	
5	262	148 30 39	39 20 63		start line @ 1320		
5	262	148 45 99	39 32 45	33.2		finish line @ 1630	
6	264	148 41 86	39 12 95		start line @ 0440		
6	264	148 36 23	39 12 03	21.5		finish line @ 0540	
7	264	148 36 23	39 12 03		start line @ 0540		
7	264	148 24 88	39 49 78	55.6		finish line @ 0954	
8	264	148 24 88	39 49 78		start line @ 0954		
8	264	148 17 88	38 49 94	10		finish line @ 1055	
9	264	148 17 88	38 49 94		start line @ 1055		
9	264	148 17 89	38 45 31	9.2		finish line @ 1200	
10	264	148 17 89	38 45 31		start line @ 1200		
10	264	148 24 73	38 45 11	10		finish line @ 1320	
11	264	148 24 73	38 45 11		start line @ 1320		
11	264	148 25 00	38 48 04	5.6		finish line @ 1353	
12	264	148 25 00	38 48 04		start line @ 1353		
12	264	148 17 90	38 47 92	10.6		finish line @ 1456	
13	264	148 17 90	38 47 92		start line @ 1456		
13	264	148 26 02	38 39 24	20		finish line @ 1710	
14	264	148 26 02	38 39 24		start line @ 1710		
14	265	147 21 17	38 17 50	118.6		finish line @ 0332	
15	265	148 17 14	38 36 50		start line @ 1354		
15	265	148 36 62	38 11 56	54		finish line @ 2010	
16	265	148 36 62	38 11 56		start line @ 2010		
16	265	148 41 49	38 19 31	18.2		finish line @ 2146	
17	265	148 41 49	38 19 31		start line @ 2146		
17	265	148 40 33	38 22 66	7.5		finish line @ 2221	
18	265	148 40 33	38 22 66		start line @ 2221		
18	266	148 33 10	38 32 81	28.4		finish line @ 0035	
19	266	148 33 10	38 32 81		start line @ 0035		
19	266	148 21 79	38 24 07	23		finish line @ 0308	
20	266	148 29 40	38 29 57		start line @ 1027		
20	266	148 41 52	38 18 17	26.4		finish line @ 1314	
21	266	148 41 52	38 18 17		start line @ 1314		
21	267	147 46 37	38 00 04	90		finish line @ 2240	
22	267	148 34 45	38 00 25		start line @ 1110		
22	267	147 55 94	38 32 68	81		finish line @ 1904	
23	268	148 19 37	38 44 64		start line @ 0320		
23	268	148 20 97	38 37 29	14.2		finish line @ 0450	
24	268	148 26 02	38 39 33		start line @ 0831		
24	268	148 28 97	38 29 94	18.4		finish line @ 1020	

APPENDIX 4: CHEMICAL ANALYSES OF FERROMANGANESE MATERIAL

Minor ferromanganese nodules and crusts were found at several stations on *Franklin* Cruise FR11/98. Three bulk samples were analysed by Analabs in Adelaide. They came from deepwater dredge hauls DR17 and DR18, whose locations are shown in **Figure 2** and **Table 1** in the general text.

Two samples were analysed from DR17, taken in a water depth of 3800-3700 m. The only materials recovered from this dredge were minor ferromanganese crusts 2-4 mm thick, plus one irregular nodule 3 cm thick, and minor subrounded to subangular pebbles, possibly from a Cretaceous conglomerate. DR17/1 is a black microbotryoidal subspherical polygenetic nodule about 5 x 4 cm in size with a small core of ferromanganese crust and clay clasts. Most of it is a mottled mixture of ferromanganese and clay, and there is an outer dense layer of laminated ferromanganese 5 mm thick. DR17/2 is a smooth black crust, 2 x 1.5 cm in size, consisting of mixed clayey and ferromanganese material, overlain by dense ferromanganese up to 5 mm thick. The outermost dark layer is about 1 mm thick.

One sample was analysed from DR18, also taken in a water depth of 3800-3700 m. The dredge haul consisted of Turonian arkosic sandstone, flaggy siltstone with obvious plant remains, flaggy sandy siltstone with load casts, silty clay, and ferromanganese crusts up to 4 mm thick. The sample analysed, DR18/F1, was a black crust measuring 1 x 3.5 cm, and torn directly off the substrate.

Table. Chemical analyses in weight percent

Sample	**Type**	**Fe %**	**Mn %**	**Co %**	**Cu %**	**Ni %**	**SiO2%**	**LOI%**
DR17 A1	Nodule	12.95	10.79	0.0051	0.1110	0.369	31.71	15.80
DR17 A2	Crust	17.29	6.66	0.0029	0.0895	0.240	40.94	12.41
DR18 F1	Crust	5.38	0.39	0.0032	0.0072	0.017	62.00	6.09

The samples are all very high in SiO2 (clay content) and water (LOI = loss on ignition) and remarkably low in cobalt and copper. DR17A1 is more typical of nodules from the Australian region than the others, in that it has considerable manganese and iron and an Fe:Mn ratio around one. DR17A2 has a high Fe:Mn ratio. DR18F1 is so high in SiO2 that all the other values are perforce very low.

APPENDIX 5: PRELIMINARY RESULTS FOR NEOGENE SEDIMENTS

Many of the shipboard party had a primary interest in Neogene sediments. The team with particular interest in the Neogene carbonates came from the School of Earth Science, University of Melbourne: Stephen Gallagher, Guy Holdgate, Jim Daniels and Andrew Smith. The team with particular interest in turbidite sedimentation in the canyons came from the School of Geosciences, The University of Sydney: Jock Keene, Michael Hughes, David Mitchell and Karen Rae. Their final results will be published elsewhere (e.g., Gallagher et al., 2001) but this Appendix is drawn from their initial shipboard summary, drawn from Keene et al. (1998). Virtually all their sampling was by Smith-McIntye grab or piston core. Station numbers and locations are shown in **Appendix 2**, and the station numbers are different from the sample numbers which we use in the body of the report for the dredge stations.

A large wedge of sediments, which has accumulated in the last 30 million years in the Gippsland Basin, epitomises a large part of the geological history of Australia's southern margins. The sediment wedge contains an assemblage of sedimentary rocks including brown coals, coastal barrier sands, marine non-tropical limestones and deeper water calcareous mudstones and older rocks cut by submarine canyons. Together these sediments and rock types make up a unusual shelf and slope type by global standards. The aim of the Neogene sedimentation studies was to learn how this type of shelf and slope is formed.

The modern siliciclastic sediments of the Gippsland shelf are not analogous with the carbonate sediments in the underlying Seaspray Group. The abrupt change in depositional environments from the carbonates of the Seaspray Group to the more quartz-rich sediments of the present day is possibly associated with Pleistocene to Recent uplift of the Australian Highlands. However, this is only a tentative hypothesis based on preliminary results.

The Seaspray Group is composed of cool-water grainstones, packstones and wackestones with very little quartz sand present (<5%). These sediments appear to represent deep-water (outer shelf and slope) environments with little terrigenous input. Those Seaspray Group sediments that were dredged from the slopes of submarine canyons are dominated by carbonate-rich, bioclast-bearing wackestones and packstones, sometimes with intraclasts, and often in association with spiculites and dolomites.

In contrast, the modern submarine canyons in the Gippsland Basin are dominated by fine to medium terrigenous quartz sand with mud and fine bioclasts, like that on the shelf. Slope and canyon sampling transects show a diversity of environments including debris flow in the floor of Bass Canyon with angular dolomite and intraclasts along with clean channel floor sands. The canyon heads and deep canyon floor are dominated by siliciclastic sediment.

Samples recovered from seven stations in the upper continental slope, in upper bathyal to mid-bathyal environments (200-1000 m water depth) range from greenish grey to grey fine silty muds to fine sands (31, 32, 56, 57, 69, 77, 78 - **Appendix 2**). However, sediments from three stations associated with canyons range from yellow-brown bioclastic sands to grey bioclastic silt (46, 51, 53). Epifaunal organisms associated with the upper continental slope include abundant sponges, Crustacea, Bryozoa, Bivalvia, Gastropoda, barnacles, and worm tubes.

Sediments recovered from 18 stations on the lower continental slope and toe of slope, in lower bathyal to abyssal environments (1000-4000 m in water depth) were dominated by brown to green-grey foraminifera-bearing silty clays and muds with occasional sand and varying amounts of fine bioclasts (61, 62, 65-68, 72-76, 89, 90, 92, 95, 97, 100, 101). However, one locality, on the floor of a channel at 3,693 m in Bass Canyon, contained clean well-sorted medium to fine sand (89). Occasional intraclasts, probably associated with debris flows, were seen in two samples (95, 97). Bioturbation was common in many samples with abundant feeding traces (?*Thalissinoides*) and nearly complete homogenisation of surface sediments. Epifaunal organisms present in samples from the lower continental slope include sponges, worms, irregular echinoids, and brachiopods. Deposition in the lower continental slope and toe of slope represents largely hemipelagic deposition with turbidity current influence.

The sparker seismic records from the upper slope and canyon heads (**Appendix 3**) provided information as to how the modern and buried canyons erode and fill. Reflectors show unconformities, downlap and onlap of strata. These stratigraphic relationships for the near-surface layers (0.5 s two-way time: twt) should be further enhanced with shore-based processing of the digital data. Grab sampling in these canyons was relatively successful in water less than 500 m, but deeper than 500 m the canyons become very narrow (less than 200m wide) and difficult targets for sampling. Three runs were made by the Sydney University group with a deepsea camera, and bottom photographs should further characterise the sedimentary environments.