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Southern Surveyor Cruise SS02/2005

Neville Exon, George Bernardel, Julie Brown, Andrea Cortese, Claire Findlay, Kinta Hoffmann, Richard Howe & Pat Quilty

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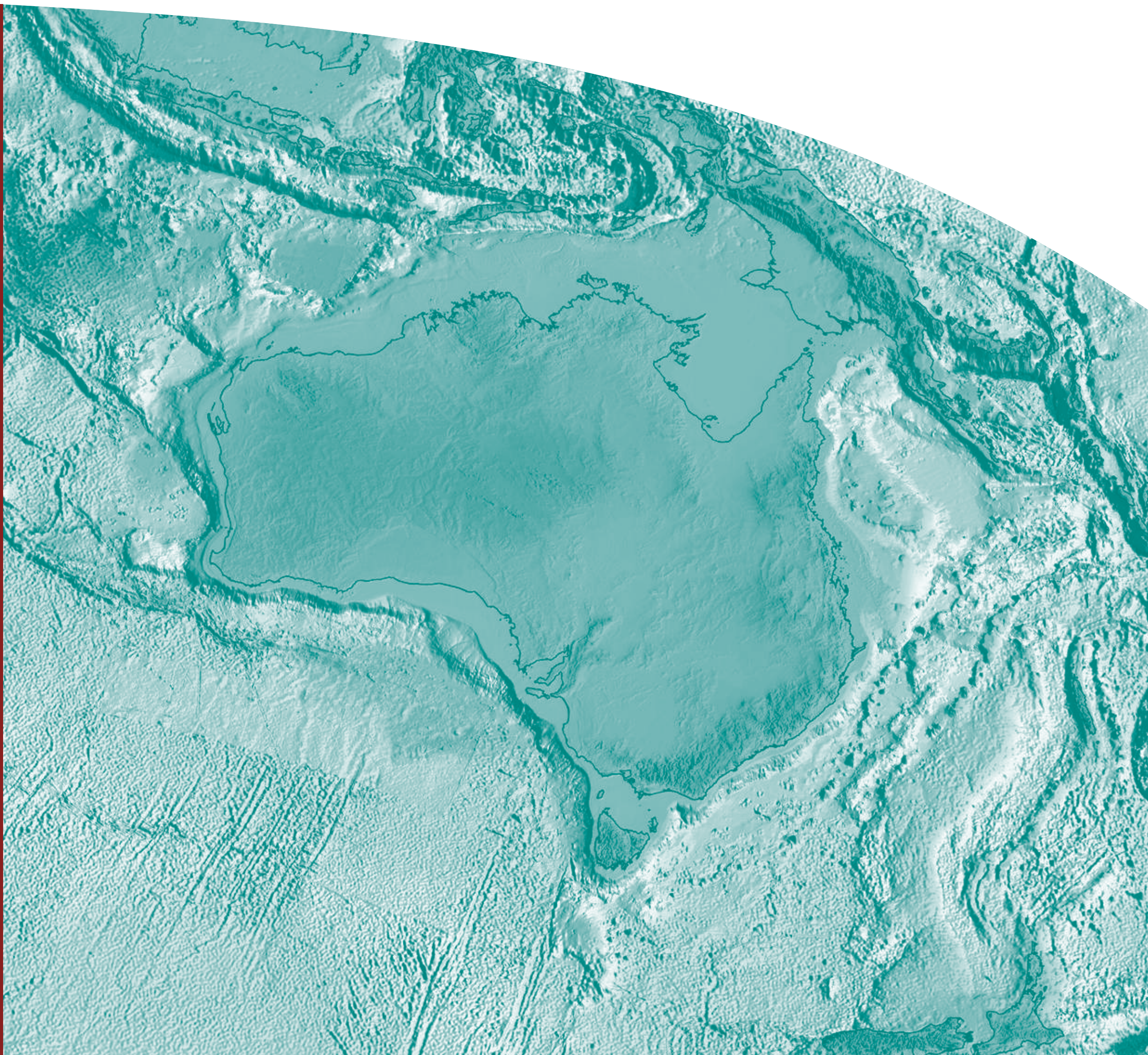

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The geology of the Mellish Rise region off northeast Australia: a key piece in a tectonic puzzle - *Southern Surveyor* Cruise SS02/2005 - - Geoscience Australia Survey 274 -

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ABSTRACT

The Mellish Rise lies off northeast Australia, to the north of another fragment of continental crust, the Kenn Plateau. It trends northeast overall, is about 700 km long and 300 km wide, and lies mostly in Australian territory. In the southwest, near Mellish Reef, a large area of the rise is shallower than 2500 m, but further northeast there are only occasional shallow highs. To the northwest, the Coral Sea Basin and the Louisiade Trough, and to the southeast, the narrow South Rennell Trough and the west D'Entrecasteaux Basin are all deeper than 3500 m, and are probably entirely underlain by oceanic crust.

The Mellish Rise and Kenn Plateau have been the subject of recent geoscience surveys of R.V. *Southern Surveyor*, undertaken by Geoscience Australia, to determine their composition and geological histories. The emphasis in this report is on the Mellish Rise survey (SS02/2005 – GA 274), during which 1189 km of multichannel seismic data were acquired using a 24-channel, 600 m streamer and two GI airguns. In addition, multibeam and single beam bathymetry, and magnetic data were recorded. Forty-four dredge sites and five core stations were occupied to investigate the geology, and the great bulk of these deployments were successful. Dredge sites were concentrated on the Mellish Rise and Kenn Plateau, but also included the Louisiade Plateau. Foraminiferal, nannofossil and petrological studies have been carried out on suitable rocks and sediments.

The seismic and other data have shown that rifting of pre-existing continental basement rocks, Mesozoic sediments and other rock types formed generally northeast-trending Late Cretaceous and Cainozoic rift basins. The older rocks form major plateaus and escarpments. The rift basins contain up to four distinct seismic sequences.

Dredging recovered continental basement rocks and siliceous sedimentary rocks from the northern Kenn Plateau, but no continental basement from Mellish Rise. The Mellish Rise dredging of steep plateau scarps has recovered basalts, a few dolerites and associated volcanics. Dolerites, quartz-rich fragments in volcanic conglomerates, and quartz-bearing Paleocene calcarenites suggest that continental basement rocks occur in the Mellish Rise plateaus, along with the apparently dominant basalts. The basaltic rocks from the plateaus consist of flow basalts that may well be Early Cretaceous rift volcanics. Hyaloclastites dominate the Eocene hotspot volcanoes of the Tasmantid seamount chain.

Both shallow-marine and deeper-marine carbonates are common. Their ages are generally Late Paleocene, late Middle to Late Miocene, or younger. The ages of the shallow-marine carbonates (often reefal) correspond with periods of reef growth (warm conditions) in the Great Barrier Reef region. Carbonate deposition in deeper water is well documented by DSDP and ODP sites in the general region - siliceous chalks in the latest Cretaceous to Middle Eocene and pure chalks thereafter - and our samples fit this picture. Within the deepwater carbonate sequences, the usual regional unconformities (Paleocene-Eocene and Eocene-Oligocene boundaries) appear to be present.

Eocene-Oligocene bentonitic claystone occurs in a single occurrence on northeastern Mellish Rise. Fine-grained 'redbeds' are widespread, and some of these have been shown to be altered fine-grained volcanics (probably ferruginised tuffs) 'lateritised' on dry land. They could be of Eocene age and associated with hotspot volcanism. An undated discovery of travertine (sinter) near Mellish Reef, associated with Upper Eocene to Lower Oligocene marine carbonates, suggests the existence of Eocene or older hydrothermal springs on dry land.

The Mellish Rise is the last marginal plateau in Australian jurisdiction to have been geologically explored by Geoscience Australia. As expected, it shows little resource potential, but we have shown that much of it is continental, validating tectonic models that have made that assumption. Coherent geological histories have been built up for the Kenn Plateau and Mellish Rise, and they bear on the regional understanding of what was all part of eastern Australia in the Early Cretaceous.

1. INTRODUCTION

The Mellish Rise, a large (700 by 300 km), northeast-elongated, and poorly known submerged block off northeast Australia (Figure 1), lies adjacent to a fossil tectonic triple junction between the fossil Australian, Lord Howe Rise and Louisiade Plateau spreading centres. *Southern Surveyor* Cruise SS02/2005 (Geoscience Australia Survey 274) aimed to investigate fundamental questions about the geological evolution and environmental significance of the rise (Exon et al., 2005b). The methods employed included swath-mapping, seismic, bathymetric and magnetic profiling to establish the framework and setting, and dredging and coring to obtain rocks and sediments. This research aimed to improve the understanding of the geology and palaeogeography of the Mellish Rise region, and, thus, to help constrain the tectonic model of the region.

1.1 Scientific objectives

The main aims of this survey were to establish:

- the nature and tectonic style of the margins of the Mellish Rise to help constrain plate tectonic hypotheses and the tectonic relationships to the nearby Louisiade, Queensland, Marion and Kenn plateaus; and

- the nature and distribution of acoustic basement: is it continental and/or oceanic?

Other questions to be addressed included:

- the nature and age of volcanic intrusions and extrusions, and their relationship to the Tasmantid volcanic chain;

- the nature of Mesozoic and Cainozoic sedimentary rocks, with emphasis on climatic and oceanographic evolution;

- the controls on the initiation and development of east Australian carbonate platforms since the middle Oligocene;

- the nature of the modern surficial sediments on this remote marginal rise and their influence on benthic habitats, as an aid to environmental management; and

- the geological background bearing on the long-term resource potential and environmental management of the Mellish Rise and adjacent deepwater basins.

In addition, sampling was carried out on the northern Kenn Plateau, as a substitute for sampling not done on the *Southern Surveyor* Cruise SS05/2004 (Exon et al., 2005a) because of equipment failure. The new Kenn Plateau sampling is addressed through this text as appropriate.

1.2 Scientific background

The tectonic model of Gaina et al. (1999) predicts the existence of a triple junction between the Australian, Lord Howe Rise, and Louisiade Plateau continental blocks between 62 and 52 Ma. The Mellish Rise is near the proposed triple junction, yet the junction has never been studied in detail. Consequently, the acquisition of high resolution seismic and magnetic data during Cruise SS02/2005 was predicted to significantly improve the understanding of the regional tectonic elements. Dredging of basement rocks would provide further constraints on the Mellish Rise's tectonic history, allowing the composition and nature of the crust to be determined. Dredging would also target the volcanic intrusions to establish their age and relationship to other volcanic provinces in the region, and the older sedimentary rocks to build up an understanding of the Cretaceous and younger history of the Mellish Rise.

The sedimentary material across the surrounding plateaus and the Mellish Rise is believed to be predominantly pelagic sediments. Short cores through the sediments could provide insights into the Quaternary climatic evolution of the Mellish Rise and its sensitivity to change.

The research cruise reported here builds on the geophysical and sampling results from the Kenn Plateau survey of May 2004 (Exon et al., 2005a), providing additional data to further refine the tectonic and sedimentary history of offshore northeastern Australia. Further understanding of this region is aided by the acquisition of seismic reflection data in conjunction with sampling of the basement and sedimentary material. Previous sampling had focussed on the Cainozoic sequences of the Coral Sea Basin, and the Queensland and Marion Plateaus, providing a good indication of sedimentary, climatic and sea level history there, and providing a pertinent comparison to sedimentary samples obtained from the Mellish Rise. Much of the most valuable information comes from Deep Sea Drilling Project Leg 21 in the region (Burns, Andrews et al., 1973), Ocean Drilling Program (ODP) Leg 133 on the Queensland and Marion Plateaus (McKenzie, Davies, Palmer-Julson et al., 1993), and ODP Leg 194 on the Marion Plateau (Isern, Anselmetti, Blum et al., 2002).

1.2.1 Regional setting

This report largely follows the bathymetric nomenclature of the CCOP/SOPAC bathymetric map of the Southwest Pacific (Kroenke et al., 1983). It also uses the bathymetric and structural nomenclature set out for the Kenn Plateau by Exon et al. (2005a), with the exception that it abandons the name *Chesterfield Rise* for the northernmost structural high of the Kenn Plateau, lying between the Bampton Trough to the north and the Chesterfield Trough to the south. Exon et al. (2005a) described this high as an "ENE-trending rise 100 km long, west of Chesterfield Reef and forming the northernmost block of Kenn Plateau, with ~5000 km² shallower than 2000 m". There already exist the names *Chesterfield Reef* and *Chesterfield Bank* on the Bellona Plateau to the east, and Gaina et al. (1999) used the name *Chesterfield Plateau* for what this report regards as the southern part of the Kenn Plateau. To reduce confusion, this report re-names this structural high *Selfridge Rise* after *Selfridge Bank* (located at 20º56'S, 157º05'E; rising to 44 m depth and covered with coral, coarse sand and shell), which lies on the southwest part of the rise.

The main structural and bathymetric features of the region are illustrated in Figure 1. Large submarine plateaus occur on the northeastern margin of Australia: the Queensland, Kenn, and Louisiade Plateaus and Mellish Rise. They lie in water depths of 500 to 3000 m, adjacent to basins about 4500 m deep. Current understanding of the formation and character of these plateaus is limited, with much key work dating back to the 1970s, when acquisition technology was less advanced than at present and satellite gravity maps did not exist. Nevertheless, interpretation of the 1970s surveys suggested that the area is tectonically very unusual for Australia's margin, with the Mellish Rise located at the fossil junction of three presumed palaeo-plate boundaries between Australia, Lord Howe Rise and Louisiade Plateau (Weissel and Watts, 1979; Gaina et al., 1999).

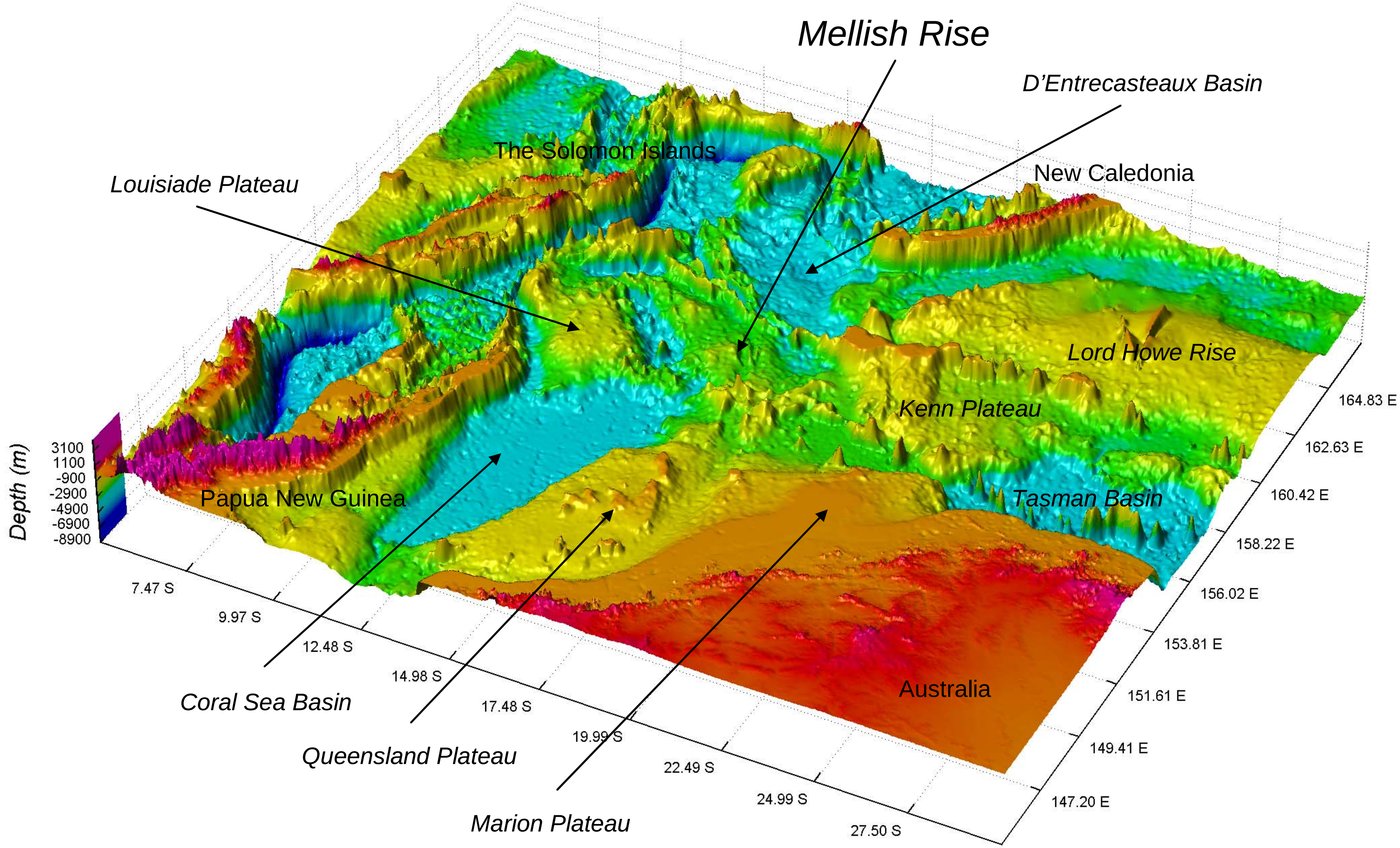

Figure 1. Southwest Pacific 3D topographic setting highlighting the Mellish Rise and surrounding major tectonic elements.

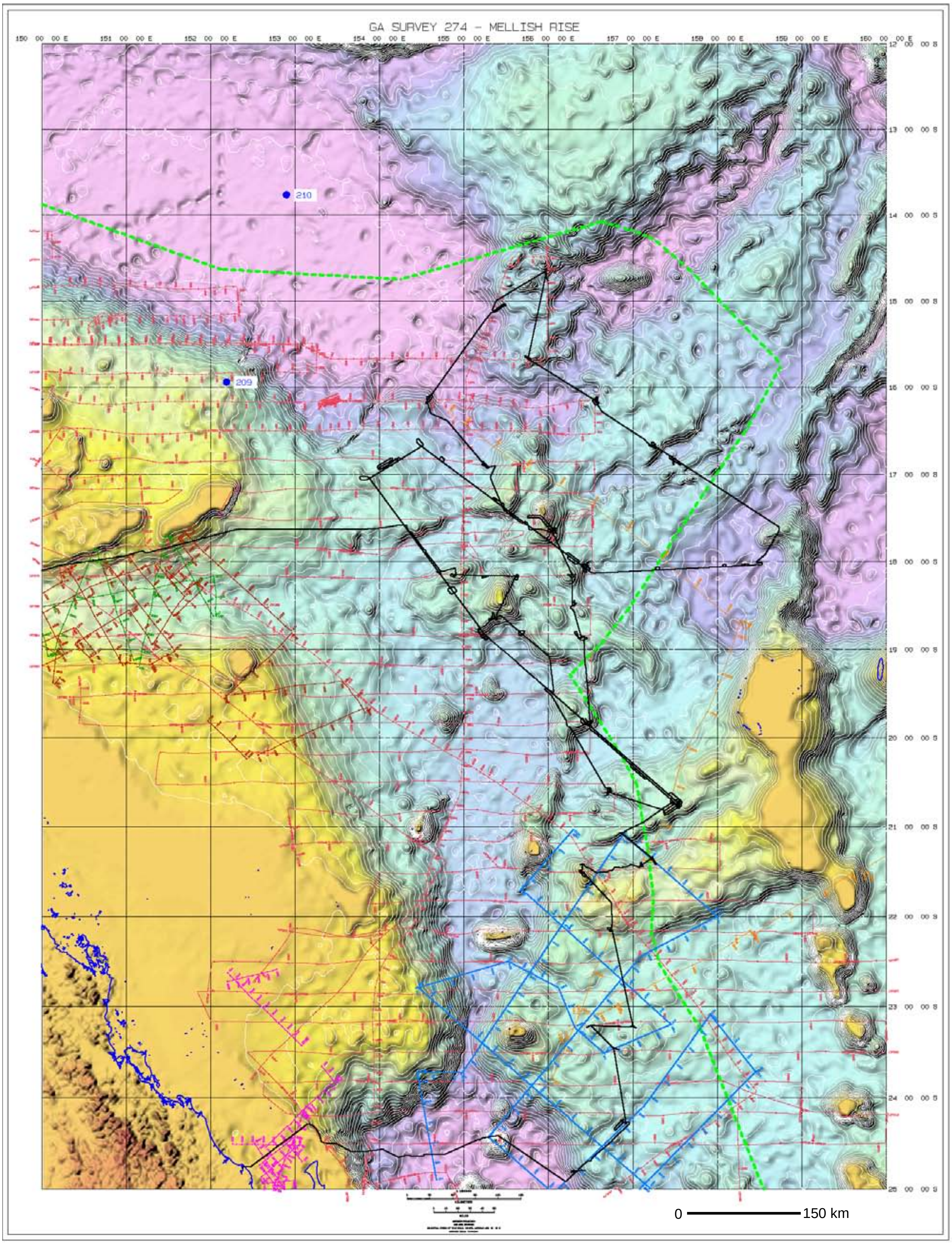

Figure 2. Mellish Rise survey area showing some of the pre-existing seismic coverage: BMR Continental Margins Survey (red), BMR Survey 50 (green), BMR Survey 76 (brown), BMR Survey 91 (magenta), GA Survey 270 (blue; includes swath coverage) and Shell ‘Petrel’ roving survey (orange). Outer limit of the Australian EEZ shown as dashed green line while GA Survey 274 tracks shown as black line.

The Mellish Rise lies largely between latitudes 15° and 19°S to the southeast of the Coral Sea Basin. It covers an area of about 700 x 300 km and its depth is in the range 500-3000 m. It is separated from the eastern margins of the Queensland Plateau and Townsville Trough, and the northeastern margin of the Marion Plateau, by the Cato Basin (used here in the sense of a bathymetric low extending southward between the Coral Sea Basin and the Tasman Basin). Gaina et al. (1999) characterised the Mellish Rise as a tectonic feature with high gravity anomaly values, surrounded by troughs with negative gravity anomaly values. Several steep-sided intrusions and extrusions are present, and the Mellish Reef has grown on a volcano (Terrill, 1975b). Volcanic seamounts also form the foundations of the Kenn Plateau reefs and guyots to the south (Exon et al., 2005a). None of the volcanics or sedimentary rocks in the Mellish Rise had been sampled prior to the present survey.

To the northwest of the Mellish Rise, the Coral Sea Basin developed by NE-SW spreading in the late Paleocene (~60-55 Ma) (e.g. Kroenke, 1984). The Mellish Rise is separated from the Louisiade Plateau to the north by the 190 km wide and 4000 m deep NE-SW trending Louisiade Trough (e.g. Gaina et al., 1999). The Louisiade Trough may be an eastern prolongation of the Townsville Trough, which was separated from it by the formation of the Cato Trough. Kroenke (1984) suggested that it formed in the mid Eocene (~55-45 Ma). The NW-trending Rennell Trench to the northeast of Mellish Rise is thought to be an easterly dipping fossil trench, also active in the Eocene (~55-40 Ma) (Landmesser, 1974; Daniel et al., 1978; Yan and Kroenke, 1993). The South Rennell Trough east and southeast of the Mellish Rise may be a former fracture zone (Rennell Fracture Zone, Landmesser, 1974; Shaw, 1979), which acted as a strike-slip fault during the opening of the Tasman and Coral Seas (Gaina et al., 1999). It almost certainly became a spreading ridge in the late Oligocene (Larue et al., 1977; Daniel et al., 1978). It is part of an arcuate feature that extends from the Bellona Plateau in the south to the West Torres Plateau (near Santo in Vanuatu) in the east.

The Mellish Rise is highly fractured and has a varied topography (Terrill, 1975a). Faulting has formed several grabens and half-grabens that are infilled with young sediments and appear unconsolidated (transparent) on seismic sections. Terrill (1975b) suggested that there are two main fault trends: a NNW-SSE trend and a NE-SW trend. The NNW-trending faults are apparently most pronounced along the flanks of the Cato Trough and are considered to be associated with rifting along this margin. Terrill (1975b) considered that the Tasman and Middleton basins, which also show NNW-trending spreading ridges, may have formed as part of the same system. Gravity anomalies within the Louisiade Trough indicate several NNW-oriented fracture zones (Gaina et al., 1999), which most likely developed during formation of the Tasman Sea and Cato Trough, and were associated with the separation of the Mellish Rise and the Louisiade Plateau in the mid Eocene. NE-SW trending faults are most common along the South Rennell and Louisiade Troughs, and are observed on seismic profiles (Terrill, 1975b) and gravity anomalies (Gaina et al., 1999). Terrill (1975a) suggested that the faults extend across the Mellish Rise area, and most likely formed during formation of the surrounding ocean basins and rifting between the plateaus.

The block-faulted nature of the basement over plateau areas, such as the Mellish Rise, has been interpreted as indicating continental basement (Symonds and Willcox, 1988). However, the considerable disruption caused by intrusions, normal faulting, and movement along the Louisiade and South Rennell Troughs makes it difficult to determine the original crustal structure (Terrill, 1975b). A continental crustal composition for the Mellish Rise and Louisiade Plateau would infer that they were rifted from the Queensland Plateau and each other during the formation of the Coral Sea (Landmesser et al., 1975). Alternatively, if the Mellish Rise and Queensland Plateau were underlain by oceanic crust, their basement would probably be of comparable age to the Coral Sea (Late Paleocene) and represent spreading ridges formed along the perimeter of the Coral Sea Basin (Landmesser et al., 1975). Thus, Gaina et al. (1999) concluded that determining the nature of the crust underlying the Mellish Rise and Louisiade Plateau is crucial to our understanding of the tectonic history of this area, requiring additional gravity, bathymetry, magnetic, and seismic data.

Davies et al. (1989) and Feary et al. (1991) used a variety of geological information, including Australia's movement northward, to outline climatic evolution and its control on carbonate deposition off northeast Australia. They postulated that sea surface temperatures for the Cainozoic were warm enough to support reef growth before 45 Ma and after 25 Ma. Later studies have generally corroborated their views.

1.2.2 Plate tectonics

Table 1 lists the basinal features around the Mellish Rise, with ages from selected workers. Ages in the North Tasman Basin, the Coral Sea Basin and the South Rennell Trough come largely from magnetic anomalies, whereas those in other depressions come from less direct seismic interpretation and plate tectonic reconstructions. The table suggests that the Townsville Trough started to form in the Early Cretaceous, the North Tasman Basin and D'Entrecasteaux Basin both started to form in the Late Cretaceous, but the evidence for the age of the D'Entrecasteaux Basin is extremely tenuous. Gaina et al. (1999) argue, on plate tectonic grounds, that the North Tasman Basin, the Coral Sea Basin and the Louisiade Trough formed a triple junction in the Paleocene. The eastward dipping subduction zone of the Rennell Trench was first described by Récy et al. (1975) and, building on earlier workers, Kroenke (1984) concluded that subduction was in the Eocene, in part synchronous with Late Eocene obduction on New Caledonia. The South Rennell Trough appears to be an Early Oligocene spreading centre that propagated southwest with time (Larue et al., 1977).

Table 1. Basinal features around the Mellish Rise.

Feature	**Age**	**References**
Townsville Trough	?L. Jurassic - E. Cretaceous	Struckmeyer and Symonds (1997)
North Tasman Basin	L. Cretaceous - E. Eocene (74-52 Ma)	Hayes and Ringis (1973); Gaina et al. (1998)
Coral Sea Basin	Paleocene - E. Eocene (62-52 Ma)	Weissel and Watts (1979), 62-56 Ma; Gaina et al. (1998), 62-52 Ma
Louisiade Trough	Paleocene - E. Eocene (62-52 Ma)	Kroenke (1984), 53-44 Ma; Gaina et al. (1998, 1999), 62-52 Ma
Rennell Trench	Eocene (53-39 Ma)	Kroenke (1984)
South Rennell Trough	E. Oligocene (30 Ma)	Larue et al. (1977)
D'Entrecasteaux Basin	L. Campanian (76-73 Ma)	CPCEMR (1991)

A tectonic model developed by Weissel and Watts (1979) predicted that the Mellish Rise was displaced relative to the Louisiade Plateau in a NNE-SSW direction in the late Paleocene (~60-56 Ma) during the opening of the Coral and Tasman Sea Basins. This direction of

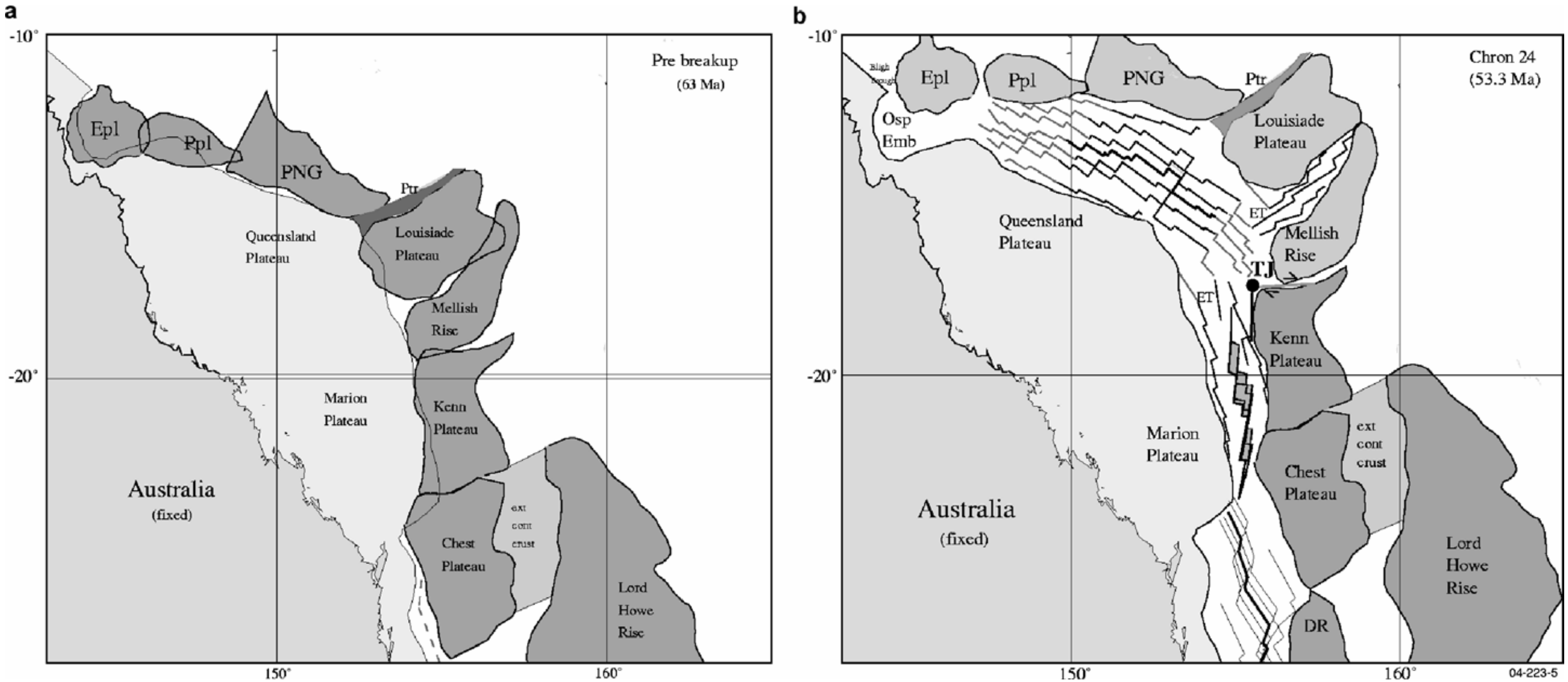

Figure 3. Reconstructions for the evolution of the Louisiade Triple Junction (TJ) after Gaina et al. (1999). 3a shows the pre-breakup reconstruction at 63 Ma (Early Paleocene). Dark grey areas are tectonic blocks involved in the Coral Sea opening: Papuan Plateau (Ppl), Eastern Plateau (Epl), southern Papua New Guinea (PNG), Louisiade Plateau, Mellish Rise, Kenn Plateau, Chesterfield Plateau and Lord Howe Rise. 3b shows reconstructions at chron 24 at 53.3 Ma (Early Eocene). The active spreading ridges in the Coral Sea, Cato and Louisiade Troughs, and northern Tasman Sea are thick black lines. The segments of isochrons in the Coral Sea that are unconstrained by magnetic anomalies are drawn in light gray. Gray areas between the Kenn and Marion Plateaus highlight oceanic crust in the Cato Trough formed after chron 26, during approximate N-S oriented transtension between the Kenn and Marion Plateaus. ET is an extinct transform fault. The direction of strike-slip motion between the Mellish Rise and the Kenn Plateau is indicated with arrows. The spreading system became extinct at 52 Ma (Early Eocene).

separation corresponds with the trend of faults through the Louisiade Trough as observed on bathymetric maps, but the direction of extension is not yet tightly controlled.

Rifting and seafloor spreading along the eastern Australian margin between 95 and 52 Ma created two major oceanic basins, the Tasman and Coral Sea Basins, along with a series of isolated slivers of continental crust that detached from the Australian continent (Figure 1). The following discussion is drawn from Gaina et al. (1999) and is based on reconstructions using seafloor magnetic lineaments, GEOSAT gravity data, and bathymetric images. The opening of the Tasman and Coral Sea Basins occurred in several stages and included a number of failed rifting events. Between 95 and 64 Ma, rifting in the Tasman Sea propagated from south to north. A change in the nature of rifting and the orientation of seafloor spreading occurred around 63 Ma, and the spreading ridge propagated northward from the northern Tasman Sea into the Cato Basin. At approximately the same time, seafloor spreading began in the Coral Sea, and presumably in the Louisiade Trough, resulting in the development of the Louisiade Triple Junction just west of the Mellish Rise. Beginning with a major plate reorganisation at around 60 Ma, and ending with the cessation of spreading at 52 Ma, the marginal plateaus off northeastern Australia were subjected to a complex regime of transpressional, transtensional and strike-slip movements controlled by the propagation and eventual abandonment of the triple junction in the Coral Sea Basin (Figure 3).

The history of oceanic crust adjacent to the Mellish Rise is poorly understood. While the crust that underlies the Cato Trough, southwest of the Mellish Rise, has been interpreted as Paleocene oceanic crust (Gaina et al., 1999), the evolution of the eastern region is somewhat speculative. Lapouille (1982) interpreted magnetic anomalies in the D'Entrecasteaux Basin (east of Mellish Rise) as Late Cretaceous, and Daniel et al. (1978) suggested a late Oligocene age for the spreading centre of the South Rennell Trough. Until now, there has been no comprehensive study explaining the tectonic evolution of the D'Entrecasteaux area (immediately east of Kenn Plateau and Mellish Rise), and therefore no complete tectonic framework for the evolution of the presumed continental blocks of the Kenn Plateau and Mellish Rise after they were detached from the Australian continent.

It is postulated that the plate boundary between the Australian and Pacific Plates during Late Cretaceous to Eocene times consisted mainly of transform faults formed as the Pacific Plate moved northward, and the Australian Plate moved very slowly in the same direction (Yan and Kroenke, 1993). Sdrolias et al. (2001) showed that east-dipping subduction is required for the time period 90-45 million years ago (Ma), in order to explain the development of the North Loyalty and Norfolk Basins in the southwest Pacific. This scenario would favour the existence of a large oceanic basin east and northeast of Australia that was slowly consumed under the Pacific Plate. In this case, the D'Entrecasteaux Basin and the Rennell Trench might be the only oceanic crust and fossil trench to be preserved of this tectonic system.

As the Pacific Plate changed its absolute motion around 43 Ma, and the Australian Plate was pushed northward by a rapid spreading pulse at the Southeast Indian Ridge, the tectonic regime east and northeast of Australia changed, with the Pacific Plate being subducted under the Australian Plate. Within this tectonic framework, a back-arc basin might have been formed east of the Mellish Rise and Kenn Plateau, with the South Rennell Trough acting as a spreading centre.

1.2.3 Interpretation of previous geophysical profiles

The northeastern Australian region has seen only one systematic regional geophysical survey, BMR's Continental Margin (CMP) Survey (Figure 2), which was reported on in Mutter

(1973) and Symonds (1973). Unfortunately, neither author focussed on the Mellish Rise as such. In addition, data quality is variable across the Mellish Rise, but the lines are potentially useful when tied to later surveys across the area.

Before the Mellish Rise survey, Geoscience Australia interpreted a high quality re-processed Shell 'Petrel' seismic line, N700, which crosses the northern part of the Mellish Rise (Figure 2). Its seismic characteristics, coupled with extrapolation from seismic megasequences within the nearby Lord Howe Rise region, were used to provisionally date the seismic sequences. The pre-rift section was interpreted as Palaeozoic to Early Mesozoic basement. The highly fractured and faulted nature of the Mellish Rise make it very difficult to infer the nature of the basement material and the subsequent evolution of the rise. However, the uniformity of basement reflectance across the rise and adjacent troughs suggested that much of the basement might be metamorphic. Highly reflective units that overlie basement on parts of the rise were interpreted as possibly Late Jurassic volcanics, while the sequences overlying basement elsewhere were interpreted as Early Cretaceous sediments. The Early Cretaceous sequence on the eastern Mellish Rise appeared to be overlain by a possible volcanic debris unit, as indicated by its fractured appearance and association with intrusions. Alternatively, this unit may be a facies change within the Late Cretaceous to Eocene sequences or caused by disruption of these sediments. The interpreted Late Cretaceous to Eocene sequence onlaps the underlying units and is mostly restricted to grabens on the rise and adjacent troughs. The uppermost sequence extends the length of the seismic line and is interpreted as Miocene to Recent pelagic oozes, lying above an unconformity interpreted to be the Eocene-Oligocene regional unconformity.

1.2.4 Ocean drilling results

Drilling on the Queensland Plateau and Coral Sea Basin during Deep Sea Drilling Program (DSDP) Leg 21 at Sites 209 and 210 (Burns, Andrews et al., 1973), and more recently during Ocean Drilling Program (ODP) Leg 133 at ODP sites 824 and 825 on the Queensland and Marion Plateaus (McKenzie, Davies, Palmer-Julson et al., 1993; Feary et al., 1991; Brachert et al., 1993), indicated that middle Oligocene cool-water carbonates formed the initial carbonate platforms in the region. This was followed by a gradual warming and the deposition of tropical carbonates in the latter part of the early Miocene. Warming across the region is associated with the northward drift of the Australian plate (Feary et al., 1991) as well as incursions of warmer water and/or long-term global climatic cycles (Brachert et al., 1993). Latitudinal thermal gradients have gradually increased as the Australian plate has moved northward (Feary et al., 1991).

Important comparative sedimentological information for the Neogene comes from ODP Leg 133 cores on the Queensland and Marion Plateaus, and in the Great Barrier Reef (McKenzie, Davies, Palmer-Julson et al., 1993). ODP Leg 194 on the Marion Plateau (Isern, Anselmetti, Blum et al., 2002) drilled Neogene sequences to test the amplitude of the major middle Miocene sea level fall (Pigram et al., 1992), and studied many other aspects of carbonate and siliciclastic sedimentation on drowned reefs, reef slopes and in the basin. Carbonate platforms first formed in the early Miocene on the Marion Plateau (18-25 Ma) from cool subtropical calcareous faunas. There was extensive reef growth by the middle Miocene. Acoustic basement was cored at five sites and highly altered lava flows and volcaniclastics were recovered. They have not been dated but are immediately overlain by early Miocene carbonates. The lack of deformation suggests that they may have been emplaced during the Late Cretaceous to Paleocene rifting in the region.

DSDP Leg 21 provided a great deal of information about the stratigraphic sequences in areas near the Mellish Rise (Burns, Andrews et al., 1973). Representative sites from the abyssal Coral Sea Basin (Site 210), Queensland Plateau (Site 209) and northern Lord Howe Rise (Site 208) are summarised in Table 2. Basement was not reached at these sites. At Site 210, the lowermost 190 m consists of Eocene and Oligocene pelagic nannofossil chalk, which gives way in the Miocene to graded beds, which represent turbidite sedimentation through into the Pleistocene. Sites 209 and 208 were drilled in bathyal depths, and the Eocene and younger sequences tend to be similar in both. The Oligocene and younger sequences are calcareous ooze, and the Eocene sequences are chalk grading to radiolarite (with some chert). At Site 208 the Eocene is underlain by Paleocene radiolarian nannofossil chalk, and Maastrichtian nannofossil chalk. Thus, in these pelagic sites, deposition of radiolarians and other biosiliceous organisms is concentrated in the Paleocene and Eocene.

A very important discovery of DSDP drilling is that there are two very widespread regional unconformities in the region (Edwards, 1973). The younger is the regional Eocene-Oligocene unconformity, which spans at least the late Late Eocene and the early Early Oligocene. The older is the Paleocene-Eocene unconformity, which was recognised in DSDP Sites 206, 207 and 208, and spans at least all of the Late Paleocene and the early Early Eocene. This is the best dating of the regional unconformities that are present in our seismic profiles.

1.2.5 The Townsville, Maryborough and Capricorn Basins

The Townsville Basin (Townsville Trough) was described by Struckmeyer and Symonds (1997), largely on the basis of AGSO multichannel reflection seismic surveys carried out in 1985 and 1987, but has not been drilled. It probably developed in the latest Jurassic to Early Cretaceous as part of a complex rift system extending through the Queensland Trough, Townsville Trough, east of the Marion Plateau and into the Capricorn Basin. It contains up to 6.5 km of sedimentary rocks on seismic evidence.

A detailed study of the offshore Maryborough and Capricorn Basins was carried out by Hill (1994) following a multichannel reflection seismic survey (AGSO Survey 91). The Maryborough Basin developed in the earliest Triassic to mid Jurassic, probably as a foreland depression, and Neocomian volcanism and rifting led to a second phase of deposition. Total

Table 2. Representative DSDP and ODP drill sites in the region.

Character	**DSDP Site 210 Coral Sea Basin**	**DSDP Site 209 Queensland Plateau**	**ODP Site 1198 Marion Plateau**	**DSDP Site 208 North Lord Howe Rise**
Location	13º45.99’S 152º53.78’E	15º56.19’S 152º11.27’E	20º57.93’S 152º44.00’E	26º06.61’S 161º13.27’E
Water depth	4643 m	1428 m	319.4 m	1545 m
Pleistocene	130 m graded beds with nannofossil ooze	20 m calcareous ooze	110 m outer neritic limestone with clay	40 m calcareous ooze
Pliocene	230 m graded beds with nannofossil ooze	20 m middle to late Pliocene calcareous ooze	90 m outer neritic limestone with clay	60 m calcareous ooze
Miocene	165 m total: 115 m late Miocene graded beds with	65 m foraminiferal ooze	315 m total proximal slope limestone: 200 m middle and	330 m calcareous ooze: 130 m late Miocene;

	nannofossil ooze; 50 m early and middle Miocene silty clay.		late Miocene; 108 m early and middle Miocene; over basalt	85 m middle Miocene; 115 m early Miocene
Oligocene	20 m early to middle Oligocene clayey nannofossil chalk	40 m late Oligocene foraminiferal ooze		50 m late Oligocene calcareous ooze
Eocene	>170 m nannofossil chalk to nannofossil clay: 15 m late Eocene; 130 m middle Eocene; >25 m early Eocene	>200 m calcareous ooze with terrigenous detritus: 135 m late Eocene sandy foraminiferal ooze and chert; > 60 m middle Eocene outer neritic sandy foraminiferal limestone		50 m middle Eocene foraminiferal radiolarian nannofossil chalk to nannofossil bearing radiolarite
Paleocene				35 m early to middle Paleocene radiolarian nannofossil chalk
Maastrichtian				>20 m foraminiferal nannofossil chalk, variably cherty, with rare radiolarians
Total thickness	711 m	344 m	522.6 m	594 m

sediment thickness may be as much as 8-9 km. The Capricorn Basin is a north-northwest trending failed rift, related to that in the Tasman Sea, which formed in the Late Cretaceous to Paleocene. It contains as much as 6 km of sediment.

Two commercial wells were drilled in the Capricorn Basin on the Marion Plateau in 1967 and 1968 (e.g. Ericson, 1976): Capricorn 1A (total depth 1710 m) and Aquarius 1 (total depth 2650 m). The results were interpreted by Chaproniere et al. (1990) in terms of age and palaeo-water depths, after new foraminiferal studies, and are summarised in Figure 4. The wells indicate that the basin contains:

- Miocene and younger marls;
- Upper Oligocene limestone, bentonitic claystone, and claystone with glauconite;
- Eocene quartz sandstone with lignite and anhydrite, overlying either quartz sandstone with bentonitic claystone or shelly limestone;
- Upper Cretaceous to Paleocene conglomerate and arkosic sandstone in both wells. A redbed section about 600 m thick – reddish-brown claystones with some interbedded conglomerate and sandstone – was recovered in Aquarius 1; and
- Cretaceous volcanics formed basement in Capricorn 1A, and probably Palaeozoic metasediments formed basement in Aquarius 1.

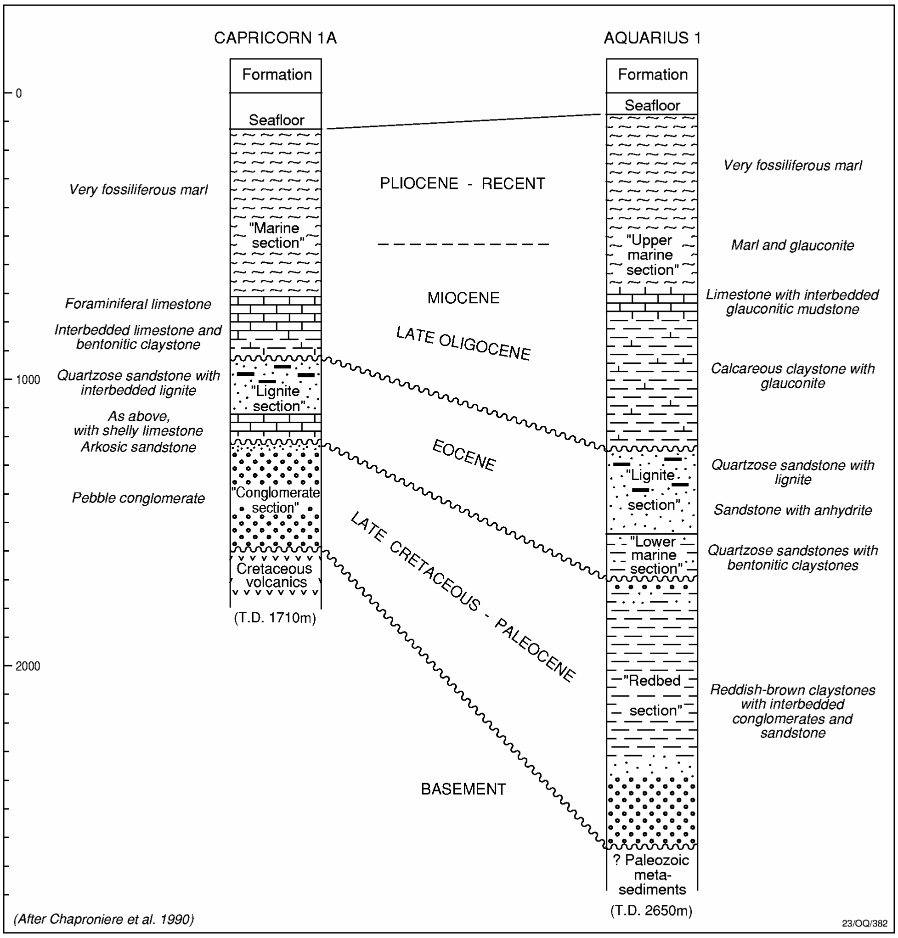

Figure 4. Capricorn 1A and Aquarius 1 petroleum exploration wells (after Hill, 1994).

The structuring that formed the Townsville Trough and the Maryborough and Capricorn Basins may have affected the Mellish Rise region. Therefore, the west-trending Townsville Trough may correlate with the apparently younger northeast trending depressions further east, like the Louisiade Trough or the rifts within the Mellish Rise itself.

1.2.6 Volcanism

There are four major known periods of younger volcanism in the region:

- The Early Cretaceous (~120-105 Ma) explosive rift-related volcanism of the Graham’s Creek Formation in the Maryborough Basin: tuffs, agglomerates and volcanic breccias, overlain by trachyte and rhyolite flows, overlain by basaltic andesite and dacite (Sutherland, 1995; Bryan et al., 1997).

- The Early Cretaceous (~120-105 Ma) volcanism of the Whitsunday and Cumberland Islands (Whitsunday Volcanic Province): dacite, rhyolite, and andesitic ignimbrite (Sutherland, 1995; Bryan et al., 1997).

- The assumed Late Cretaceous to Paleocene rift-related volcanism of the Marion Plateau (drilled in ODP Leg 194): altered basalt flows and volcaniclastic breccias and conglomerate (Isern, Anselmetti, Blum et al., 2002).

- The Late Eocene to Early Oligocene hotspot volcanism of the Tasmantid and Lord Howe chains: basalts and hyaloclastites (McDougall and Duncan, 1988). The western part of the region was affected by the Tasmantid seamount trail, which trends north-south, continuing the trail of seamounts in the northern Tasman Sea. CPCEMR (1991) predicted an age of 38 million years for a seamount southeast of the Mellish Reef seamount, based on a hotspot track model for the Tasmantid seamounts. The Lord Howe seamount trail parallels the Tasmantid trail further east, and CPCEMR (1991) predicted an age of 25 Ma for the northern end of Bellona Plateau, the most northerly part of that chain.

1.3 The present expedition: data acquired

Work undertaken during *Southern Surveyor* Cruise SS02/2005 (GA Survey 274) included the recording of approximately 1189 km of multi-channel seismic, plus multibeam and single beam sonar, magnetic data, the dredging of steep slopes and canyons to recover basement, volcanics and outcropping sediments, and coring of the modern and shallow sub-surface succession. A map depicting the survey track is shown in Figures 2 and 5. Water depths ranged from 500 - 4000 m.

Table 3. *Southern Surveyor* Cruise SS02/2005 (GA Survey 274) dredge samples.

No.	Position (S, E)	Depths (m)	Description
DR01	24°49.00’, 156°19.80’	3200	Calcareous ooze
DR02	23º27.70’, 156º46.80’	1700	Thick manganese crust; Late Eocene - Mid Miocene micritic limestone with bivalves; fine grained ?metasediment
DR03	23º12.70’, 156º30.40’		No recovery.
DR04	23º13.60’, 157º00.80’	1700	Thin manganese crust; calcareous ooze
DR05	22°08.00’, 156º44.60’	1600	Late Miocene chalk; calcareous ooze; foram sand
DR06	21º30.85’, 156º24.65’	700-400	Mid Miocene micritic limestone; Pleistocene pebbly calcarenite; shell hash; pebbles; manganese crust
DR07	21º25.50’, 156º24.45’	1600-1500	Silicic tuff; ?Eocene calcarenite; shell hash; calcareous ooze; manganese crust
DR08	21º25.85’, 157º06.80’	1500-1400	Volcanic agglomerate with calcareous matrix; welded agglomerate; fine felsic volcanics; volcaniclastic sandstone; lapilli sandstone; thick manganese crust; calcareous ooze
DR09	21º21.50’, 157º14.60’	1800	Miocene friable calcirudite; water worn volcanic pebbles; thick manganese crust; calcareous ooze
DR10	21º21.90’, 157º14.80’	1600	Calcarenite; thin manganese crust
DR11	21º04.50’, 156º52.60’	1800-1700	Metamorphic quartzite; volcanogenic greywacke; welded tuff; pebbles; shell hash; thick manganese crust; calcareous ooze
DR12	16º49.90’, 157º30.90’	2600	Quaternary porcellanite; thick manganese crust
DR13	16º51.10’, 157º29.20’	2900-2750	Dolerite; vesicular basalt; chert; Late Paleocene bored chalk; Eocene – Early Oligocene pebbly chalk; Early Eocene porcellanite in manganese nodule; large manganese nodules; coral
DR14	16º40.60’, 157º15.80’	2900-2400	Quartz gabbro (dolerite); vesicular basalt; hyaloclastite; Late Eocene – Early Miocene bentonitic siliceous claystone; Late Paleocene muddy glauconitic chalk; latest Mid Miocene bored chalk; serpentinite breccia; Paleocene – Holocene calcareous ooze; manganese crust
DR15	16º10.10’, 156º34.80’	2630	Basalt; Late Paleocene muddy glauconitic chalk; manganese crust and nodules
DR16	15º39.50’, 155º45.30’	2600-2500	Fine tuff; thick manganese nodules; calcareous ooze
DR17	14º41.60’, 155º52.20’	3250-3000	Basalt; agglomerate; sideritic red mudstone; ?grey

			bioturbated mudstone; ?Paleocene porcellanite; well sorted calcarenites; olivine-rich sandstone; manganese crust
DR18	15º05.30’, 155º26.00’	3300-3100	Basalt; hyaloclastite in carbonate cement; manganese crust
DR19	16º10.90’, 154º34.10’	3750-3650	Hyaloclastite; manganese crust and nodules; Late Paleocene – Early Eocene consolidated ooze
DR20	16º54.60’, 155º15.80’		No recovery.
DR21	17º24.40’, 155º29.30’	1950-1500	Basalt; minor basaltic conglomerate and agglomerate; dark red claystone; laminated glauconitic carbonates; Paleocene – Early Oligocene pebbly chalk; manganese crust
DR22	17º35.70’, 155º45.70’	1700-1300	Basalt; vesicular basalt; ?Oligocene reef limestones (algal boundstone, calcareous conglomerate, calcarenite); manganese crust
DR23	17º38.50’, 156º03.90’	2300-2000	Hyaloclastite; manganese nodules
DR24	17º40.20’, 156º03.20’	2200-2000	Late Eocene quartzose calcarenite; Oligocene – Miocene calacarenites; Eocene – Pliocene micritic foram limestone; sinter; basalt; volcanogenic conglomerate; crystal lithic tuff; muddy calcareous lithic sandstone; hyaloclastite
DR25	18º09.00’, 156º17.30’	2650-2350	Eocene quartzose calcarenite; Late Eocene – Early Oligocene foram chalk; hyaloclastite; thick manganese crust
DR26	18º29.90’, 156º18.00’	2100-1950	Rounded basalt boulder; Late Pliocene conglomerate; calcareous pebbly litharenite; thick manganese crusts
DR27	18º51.70’, 156º23.10’	1800-1650	Conglomerate; manganese crust; deepwater corals (*Corallium*, bamboo, black)
DR28	18º51.50’, 156º23.20’		No recovery
DR29	19º49.80’, 156º27.70’		No recovery
DR30	19º49.80’, 156º26.30’	2300-2000	Volcaniclastic conglomerate; calcareous ooze
DR31	19º49.90’, 156º27.60’	2600-2450	Calcareous tuff; Late Eocene brown and green foram marls; calcareous ooze; thick manganese crust
DR32	20º45.70’, 157º32.10’	1550	Thick manganese crust; pumice stones; calcareous ooze
DR33	20º45.70’, 157º32.10’	1800-1700	Ferruginised quartz sandstone; Early – Mid Miocene chalk; calcareous ooze; manganese crust
DR34	20º50.60’, 157º22.20’	1700	Quartz-rich metadolerite; thick manganese crust
DR35	20º36.70’, 156º43.50’	2200-1950	Hard quartzose litharentie; glauconitic and muddy litharenties; ?Pliocene foram chalk; carbonaceous cross-laminated litharenite; carbonaceous mudstone; ?bentonitic mudstone; pebbly micritic limestone; calcareous concretion; Late Eocene – Early Miocene foram chalks; calcareous ooze
DR36	19º27.60’, 156º00.40’	2500-2150	Basalt; foram-rich calcarenite; Late Pliocene foram chalk; bentonitic clay; thick manganese crust
DR37	18º49.50’, 155º41.70’	2200	Late Pliocene foram-rich chalk; thick manganese crust; greywacke; foram nanno oozes
DR38	18º38.60’, 155º19.60’	2600	Basalt; pumice
DR39	18º37.90’, 155º23.60’	2400	Basaltic hyaloclastic agglomerate; minor calcareous ?tuff; manganese crust
DR40	18º10.80’, 155º37.60’	2100-1850	Pliocene – Holocene calcareous conglomerate; algal boundstone; weathered calcarenite; vesicular basalt; brecciated vesicular basalt; red mudstone; weathered red mudstone; hard grey mudstone; greenish grey mudstone; weathered mudstone; manganese crust
DR41	18º10.40’, 155º15.80’	1900-1450	Felsic igneous (dacite, rhyolite, quartz diorite, dolerite); basalt; volcanics weathered to multicoloured claystone; red mudstone; volcanogenic sandstone; Mid – Late Miocene chalk; Pliocene – Holocene weathered algal boundstone; coral hash; manganese crust
DR42	18º09.20’, 154º53.40’	1600	Basalt; lateritised basalt; Early – Mid Miocene foram chalk; grey mudstone; mudstone conglomerate; manganese crust
DR43	18º07.90’, 154º42.00’	2000-1850	Hard cemented calcarenite; Late Pliocene friable glauconitic calcarenite; hard quartz-rich calcareous sandstone; thick manganese crust and nodules
DR44	17º38.00’, 154º20.30’	2500-2350	Mid – Late Paleocene calcarenite; Paleocene bentonitic mudstone; calcareous conglomerate within manganese nodules; manganese crust and nodules

Table 4. *Southern Surveyor* Cruise SS02/2005 (GA Survey 274) core samples.

No	Position (S, E)	Depth (m)	Description
GC01	24°17.03’, 156°55.38’	2695	320 cm calcareous ooze
GC02	21º31.02’, 156º34.70’	1222	Two attempts at Palaeogene sediments failed; minor ooze
GC03	21º26.71’, 157º04.84’	1306	Few cm calcareous ooze over Miocene foram chalk
GC04	17º33.25’, 155º42.74’	2295	160 cm foram nanno ooze
GC05	17º53.98’, 154º32.99’	2860	Few cm foram nanno ooze

Table 5. *Southern Surveyor* Cruise SS02/2005 (GA Survey 274) seismic lines.

Line	Direction shot	Start	End	Length
274/01	northwest	20 44.00S, 157 32.36E	18 49.80S, 155 14.84E	335 km
274/01	northwest	18 49.80S, 155 14.84E	17 02.76S, 153 52.80E	262 km
274/02	northeast	17 03.14S, 153 52.77E	16 40.11S, 154 31.04E	86 km
274/03	southeast	16 40.41S, 154 29.18E	08 07.98S, 156 31.31E	283 km
274/03	east	18 07.98S, 156 31.31E	18 02.37S, 158 30.95E	223 km

Note: lines 274/01 and 274/03 include a dogleg (see Figure 5).

The seismic data were acquired at 7.5 knots using a 24 channel, high-resolution, 600 m long streamer, and two GI (generator/injector) airguns. In good weather conditions this system can achieve penetration of up to 2.5 seconds (>3 kilometres). The seismic lines were laid out NW-SE and SW-NE, normal to the transform and rifted margins of the Mellish Rise and complementary to the existing east-west Continental Margin Program seismic lines.

Five soft-sediment gravity core sites were chosen to provide environmental information, and data on sedimentation processes during the Quaternary (Table 4). In conjunction with on-board data, seismic lines from previous surveys were used to determine the optimal locations for 44 dredge sites (Table 3). The location of the dredge samples was critical, as they provide the only direct samples of deep sub-surface rocks from the Kenn Plateau, Mellish Rise and south Louisiade Plateau.

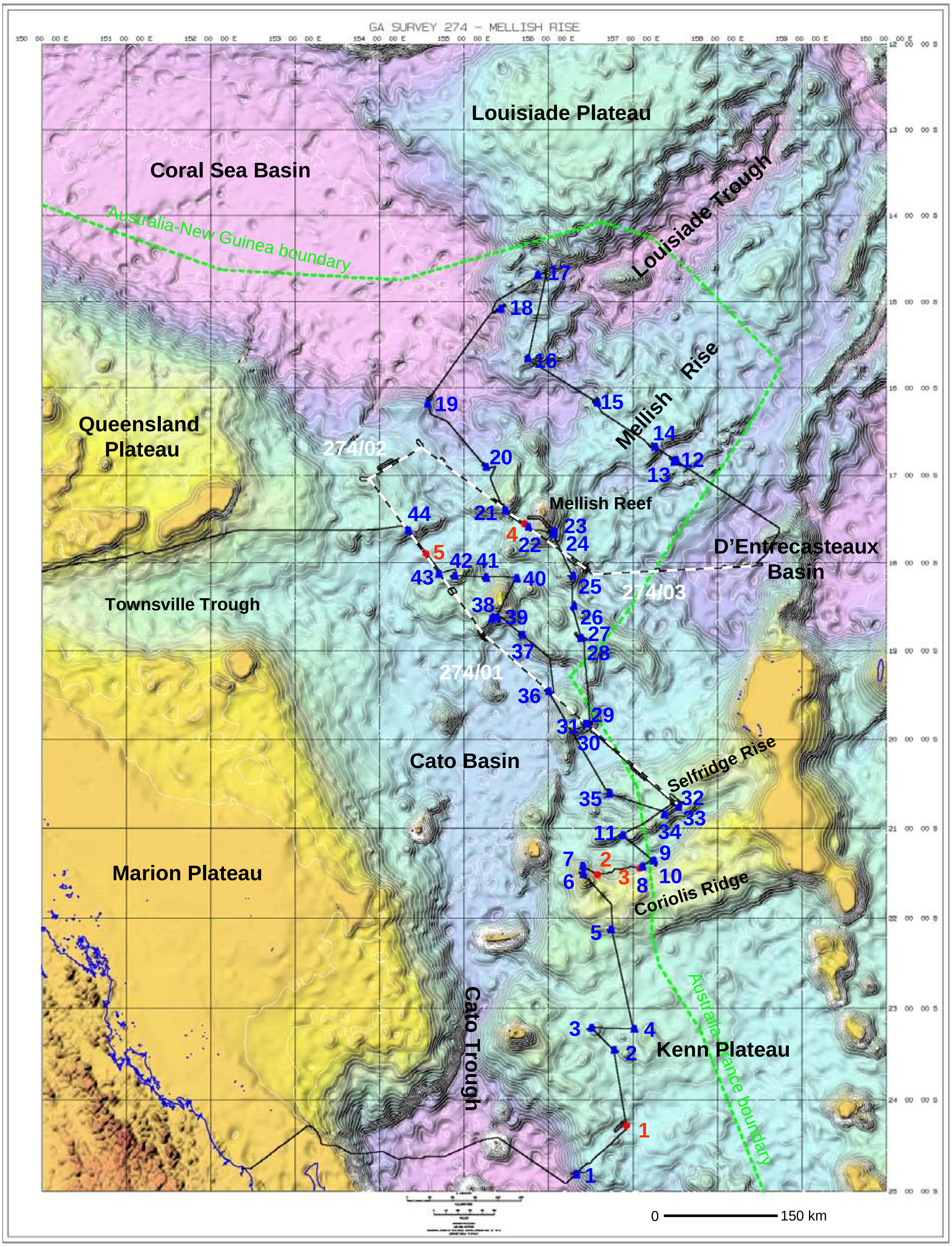

Figure 5. Mellish Rise survey area showing GA Survey 274 track (black line), seismic profiles (overlying dashed white line), dredge sites (labelled blue triangles) and gravity core sites (labelled red circles). Dashed green line is the outer limit of the Australian EEZ.

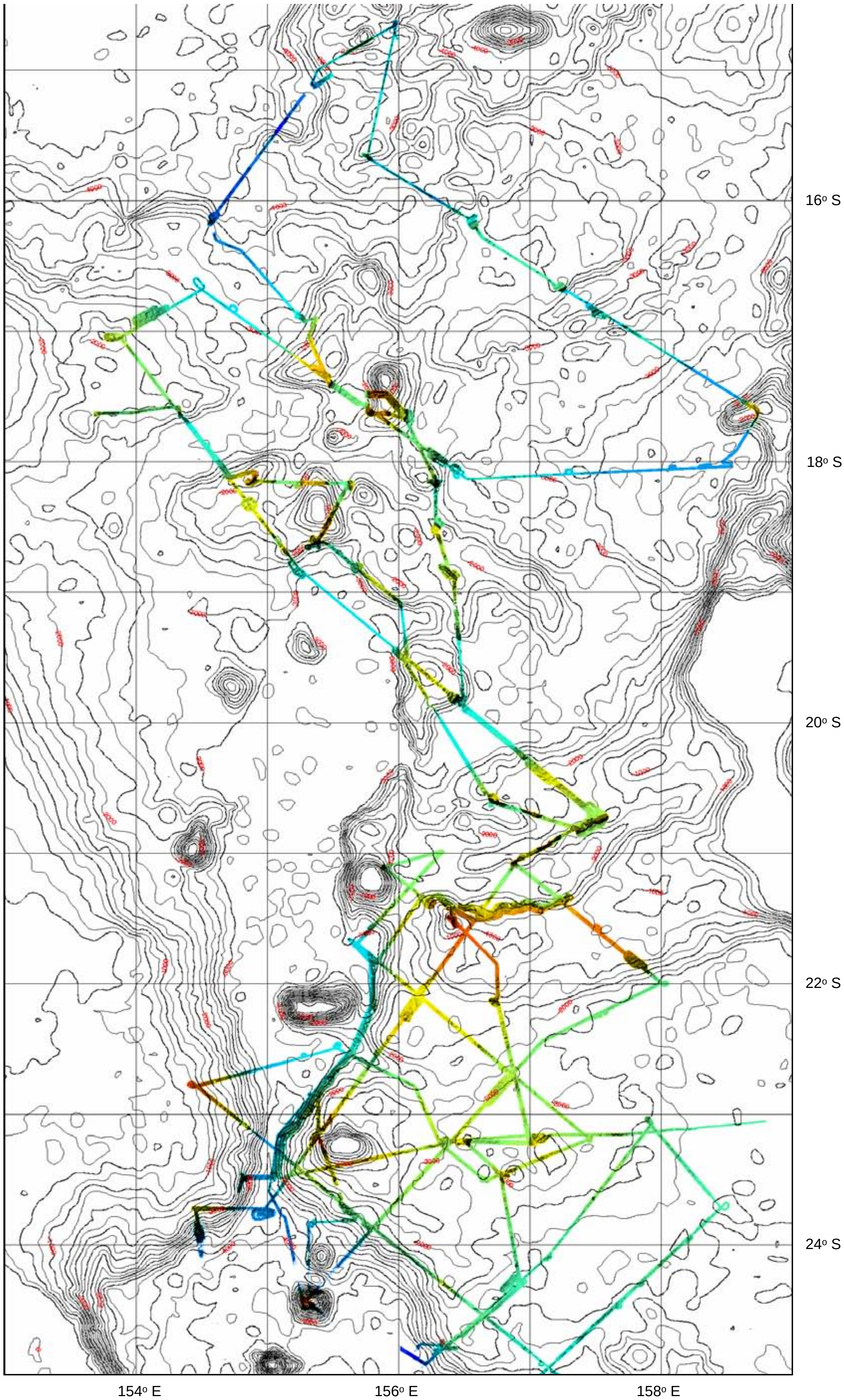

Figure 6. Mellish Rise area showing extents of swath coverage for GA Survey 274 (Mellish Rise) and GA Survey 270 (Kenn Plateau) – see Figure 2 for respective tracks. ETOPO2 contours shown to present overall seafloor morphology (contour interval 200 m).

1.4 Acknowledgements

Geoscience Australia has had a series of major ongoing cooperative studies with French scientists in the Tasman Sea. Part of the Mellish Rise survey was in French/New Caledonian waters, and we are grateful for the permission to enter their waters. We gratefully acknowledge the input of Geoscience Australia scientists Georgina Burch, Alix King and Peter Hill to the successful proposal to carry out this survey on the *Southern Surveyor* (Exon et al., 2003). We are grateful to the National Facility Science Advisory Committee and Steering Committee for making ship time available for this expedition. We are grateful to the Master, Les Morrow, the Mates, Bob McManamon and Brent Middleton, and all the maritime crew for their support during the cruise. The deck crew, led by bosun Tony Hearne, were efficient and helpful at all times. Especial thanks are due to engineer Bob Cave for his efforts to try to help fix the diesel engine of the compressor. The excellent food helped keep spirits up. We thank the CSIRO Marine Division staff of Don McKenzie, Bernadette Heaney and Peter Dunn for ensuring that all the necessary scientific support was provided. The Geoscience Australia technical group of Jon Stratton, Ian Atkinson, Craig Wintle, Andrew Hislop and Franz Villagran did an excellent job aboard ship.

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The prime responsibilities for the different parts of this report are as follows:

- Chapter 1 (Introduction): Neville Exon
- Chapter 2 (Morphology and Structure of Mellish Rise): George Bernardel
- Chapter 3 (Swath-mapping Results): Andrea Cortese
- Chapter 4 (Preliminary Interpretation of Seismic Profiles): George Bernardel
- Chapter 5 (Kenn Plateau Dredging Results): Kinta Hoffmann
- Chapter 6 (Mellish Rise and Louisiade Plateau Dredging Results): Kinta Hoffmann
- Chapter 7 (Igneous Petrology): Julie Brown
- Chapter 8 (Micropaleontological Summary): Neville Exon drawing upon the work of Claire Findlay and Richard Howe (Appendix 3) and Pat Quilty (Appendix 4)
- Chapter 9 (Structural and Basinal Geology): George Bernardel
- Chapter 10 (Discussion and Conclusions): Neville Exon

Jim Colwell is thanked for comments on the draft report.

2. MORPHOLOGY AND STRUCTURE OF MELLISH RISE

The Mellish Rise (Figure 1) lies some 1000 km due east of northern Queensland. It is a submerged plateau of highly variable morphology with a somewhat elongate triangular form that is slightly arcuate. The elongation trends northeast-southwest and extends over about 700 km while the triangle-base trends northwest-southeast and extends over about 300 km. The triangular form of the rise is bounded:

- to the northwest by the wide Coral Sea Basin, the elongate Louisiade Trough (which separates the rise from the large Louisiade Plateau) and a, as-yet unnamed, deep-plateau like feature abutting the Louisiade Plateau between the Basin and Trough;
- to the southeast by the elongate South Rennel Trough, West d'Entrecasteaux Basin and, newly named, Bampton Trough; and
- to the southwest and west by the, newly named, Cato Basin and eastwards submerged extension of the Queensland Plateau.

As defined above, the total area of the Mellish Rise is about 105,000 km^2, of which about 5%, or 5,000 km^2, lies in French territory, about 15%, or 16,000 km^2, in the territory of The Solomon Islands and the remaining 80%, or 84,000 km^2, in Australian territory. Generally, the plateau is deepest in its northeastern two-thirds while shallower, but more complex in form, in its southwestern extent.

For the following discussion on the morphology and structure of the Mellish Rise reference is made to the topographic grid presented as a hill-shaded coloured image in Figure 7. This is a merged grid (Webster and Petkovic, 2005) of swath data (including the swath acquired on GA Survey 274 – see Figure 6), individual track data and predicted bathymetry (Smith and Sandwell, 1997). Therefore, because of the gridding process used, artefacts are present within the image. Also, the dominance of satellite-derived data over the area means that only those features generally larger than 15 km across with substantial vertical relief show up readily in the image.

Based on Figure 7, the Mellish Rise can be divided into:

- a northern section ranging over 3400-1950 m depth and of moderate topographical relief;
- a central section ranging over 3400-2200 m depth characterised by a central broad high flanking a trough; and
- a southern section ranging over, mostly, 3000-1000 m depth of a highly dissected form comprising rectangular-like highs, some crowned by seamounts, separated by intervening troughs.

The northern section of the Mellish Rise is about 250 x 100 km in size. It forms the northern elongate extension of the rise as it becomes wedged between the arcuate to-the-west

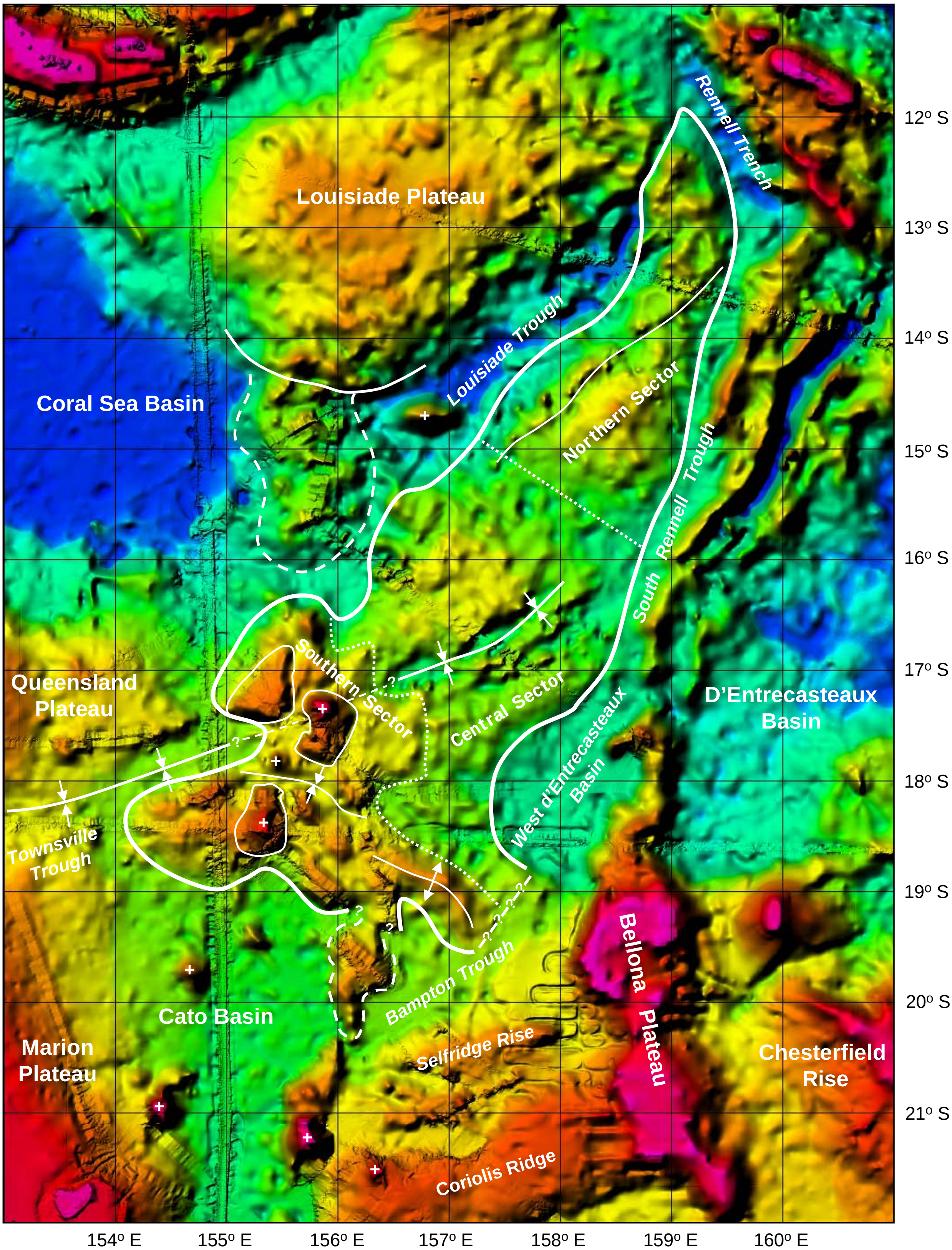

Figure 7. Hill-shaded coulour image of terrain over the Mellish Rise and surrounds. Major morphological features are highlighted while the general outline of the Mellish Rise is shown (thick white line). Various internal features are also highlighted. The background terrain grid is a merge of, largely, predicted bathymetry data (Smith and Sandwell, 1997) and other swath (includes GA Survey 274 swath tracks) and track data held by Geoscience Australia (Webster and Petkovic, 2005).

Louisiade and South Rennell Troughs. To its south, a broad high, centred at 158^o 28.82'E, 14^o 39.74'S, averages 2200 m depth and culminates at 1950 m according to predicted bathymetry. The predicted bathymetry data set also reveals a slightly arcuate northeast lineament cross-cutting this elongate section, which may be a trough or fault-related boundary. The sub-parallel form of this lineament to the rise's flanking depressions suggests some fault-related (possible strike-slip) origin related to regional breakup and subsequent plate movements.

The central section of the Mellish Rise is about 400 x 200 km in size. It forms a central broad area of the rise of largely subdued morphology. The predicted bathymetry data set indicates average depths of 2700-2900 m encircling a central sub-circular high area averaging 2500-2300 m. This is confirmed by depths on the GA Survey 274 swath track which traverses it (Figure 6). The southeastern flank of this central high is bounded by a narrow depression trending east-northeast. Although not continuous through the southern section, this trough aligns with the Townsville Trough extending eastwards from the Queensland margin and may be related to its development.

The southern section of the Mellish Rise is about 200 x 300 km in size. Both the predicted bathymetry and sparse GA Survey 274 swath tracks show that it is a strongly dissected plateau characterised by a complex hill and valley morphology overprinted by several seamounts. The detailed swath tracks reveal that the edge of many of the high-standing blocks are escarpments (Figure 6). These blocks culminate at average depths of 1900-1200 m. A major high, centred at about 155^o 51.87'E, 17^o 33.17'S, is the pedestal for a large seamount on its northern flank, which hosts the Mellish Reef.

GA seismic lines 274/01 and 274/03 (Figures 13 and 14), which traverse the southern section of the Mellish Rise, show that the seafloor highs overlie basement elevated above the intervening seafloor valleys. This suggests that the mosaic of dissected high-standing blocks may have formed by the rifting and partial breakup of a large seafloor plateau.

To the south of the southern section of the Mellish Rise, centred at about 156^o 10.70'E, 19^o 39.52'S, lies a high-standing block between the Cato Basin to the west and Bampton Trough to the east. It has an average depth of 1850 m. It is traversed by swath tracks and GA seismic line 274/01, which show it to be very similar in form to the Selfridge Rise to the east and the southern extension of the Mellish Rise to the west. It is sub-rectangular in shape, crowned by small volcanos (see Figure 13 for traversing seismic line) and bounded by steep escarpment-like flanks. Although the predicted bathymetry shows that it is separated from the southern section of the Mellish Rise by a narrow trough, its internal form is characteristic of the high-standing blocks comprising the southern end of the Rise. This, then, suggests that it may be linked to the formation of the southern part of the Mellish Rise.

Apart from the Mellish Reef seamount, centred at 155^o 51.87'E, 17^o 23.76'S, other possible seamounts, as suggested by the predicted bathymetry, are centred at 155^o 26.75'E, 17^o 49.66'S and 155^o 20.48'E, 18^o 25.76'S. These seamounts, along with those to the south in the Cato Basin, may represent the northern extension to the Tasmantid seamount chain. This chain extends over 1800 km from the southern Tasman Basin north into the Kenn Plateau area. The seamounts increase in age northwards with the oldest dated so far being the Queensland Seamount (at about 26^o 30.00' S) at 24 Ma (McDougall and Duncan, 1988). Dating of samples taken on GA Survey 274 may indicate whether the southern Mellish Rise seamounts form part of this hotspot chain.

3. SWATH-MAPPING RESULTS

The Mellish Rise survey was originally designed as a regional seismic survey, therefore swath coverage for the survey consisted primarily of single lines criss-crossing an area spanning approximately 6˚ of latitude and 4˚ of longitude (Figures 2 and 6 give an overview of swath coverage obtained). The multibeam data was used successfully to image potential dredge and coring sites (see Appendix 6).

The following sections of this chapter describe representative and interesting bathymetric features imaged on swath data during the survey.

3.1 Sand waves and erosional features

On the northwestern end of Coriolis Ridge (Figure 5), on approach to dredge site 274/DR06, some interesting sand wave features were imaged (Figure 8). The sand waves have amplitudes of 5 to 8 m and an approximate wavelength of 300 m. The direction and cross-section view of the waves suggest a bottom-current moving in a north-northeast direction. Another set of sand waves appears further to the south. Here, they are smaller in amplitude and in wavelength, but, more significantly, appear to be moving in roughly the opposite direction to the larger set (ie. from north to south).

Moat development, due to current scour around hard material on the seafloor, also suggest bottom currents, although with a direction more from the west.

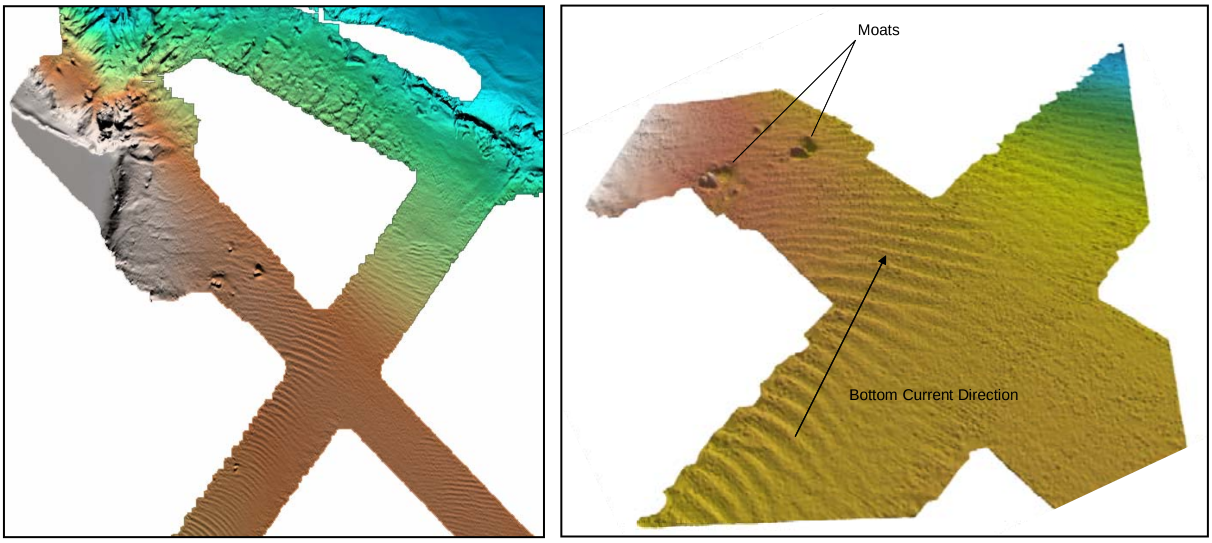

Figure 8. Swath coverage from GA surveys 274 and 270 combined to image (left) sand waves to the southeast of DR06 with detailed view (right) of the sand waves and current-generated moats.

3.2 Cone-like features

Cone-like features (Figure 9A) were imaged on a bathymetric high between DR30 and DR36 (Figure 5). The shape of these cone features and the recovery from dredges at both ends of the swath line suggests that they are of volcanic origin.

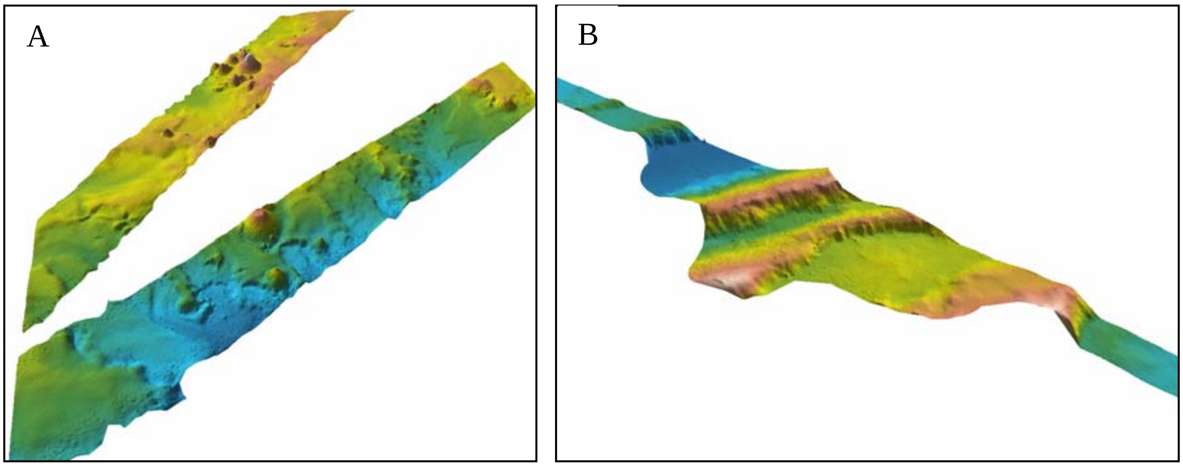

Figure 9. **A:** Volcanic cones on a topographic high between dredge sites DR30 and DR36. **B:** En echelon tilted seafloor highs over sites DR12-DR14.

3.3 Tilted blocks

A section of the swath line between dredge sites DR12 to DR14 (Figure 5) shows large rotated ?basement-controlled tilt-blocks (Figure 9B), which are similar in morphology to parts of the Selfridge Rise.

3.4 Selfridge Rise

Good swath coverage of Selfridge Rise (Figure 5) was obtained producing an excellent image of its morphology (Figure 10). Selfridge Rise is an elongated rise striking east-northeast with an elevation of approximately 700 m from the surrounding seafloor. The north-facing and south-facing slopes differ in character. To the north, the slope is much gentler and uniform in texture, while to the south it is steeply dipping with canyons and gullies. The imaged part of the rise is interpreted to be a large tilted basement block dipping approximately 15˚ to the north-northwest.

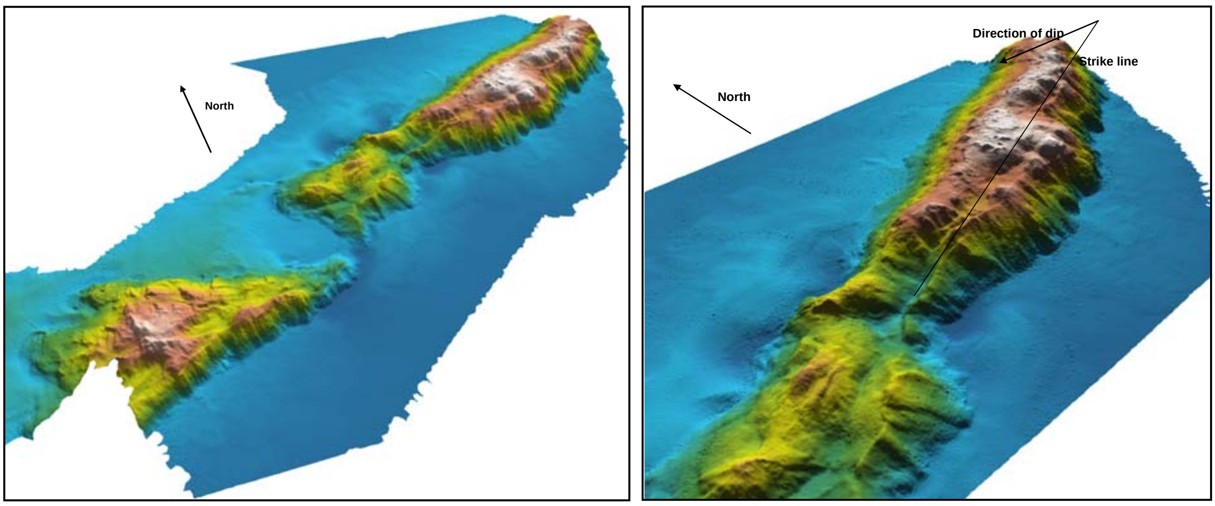

Figure 10. 3D view (left) with close-up (right) of Selfridge Rise.

3.5 Mellish Reef volcanos

The eastern slope of the Mellish Reef seamount (Figures 5 and 11) was imaged along with a number of relatively small (200 m in height with approximately an 800 m footprint) cone-like features arranged in an arc around the southern foot of the seamount. These features are most likely small vents or volcanos. A much larger and flatter dome like feature is also prominent to the south of the seamount, which is probably the remnant of a southwards expansive lava flow.

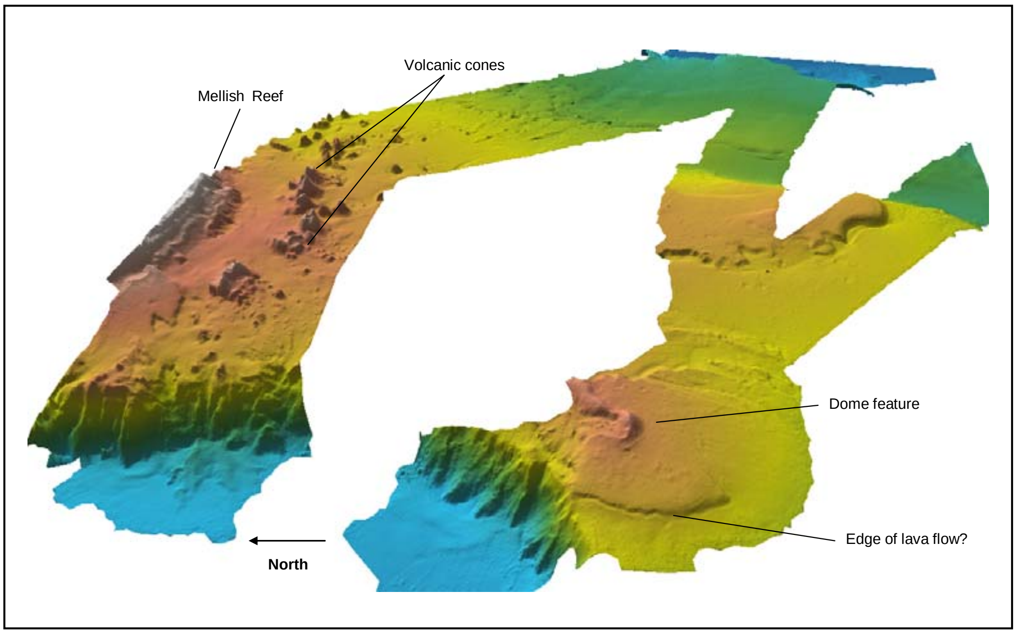

Figure 11. 3D view from the southwest of the platform supporting the Mellish Reef seamount.

4. PRELIMINARY INTERPRETATION OF SEISMIC PROFILES

Figure 12 depicts the three seismic profiles acquired on GA Survey 274, along with pre-existing seismic coverage over the Mellish Rise and surrounds. The western half of the rise is covered by the largely east-west directed lines of the BMR Continental Margins Survey. In the eastern half, Shell Petrel Survey line p700 runs northwest to southeast across the rise into the D'Entrecasteaux Basin.

The seismic lines acquired on Survey 274 are listed in Table 5. They were recorded at an average ship speed of 7-7.5 knts (ie. shot spacing of 50 m) with a 550 m streamer (ie. 300 m active section of 24 channels) producing a 3-fold seismic coverage. The profiles were processed onboard and are of good quality with penetration down to 2 s TWT in a sediment-filled graben. As a result of failure of the seismic acquisition system (see Appendix 8), only a third of the planned seismic coverage was acquired. Nevertheless, the lines shot provide some appraisal of the structural framework and sedimentary regime of the southern third of the Rise.

The initial onboard analysis of the seismic profiles confirms the impression provided by the predicted bathymetry data set (Figure 5) that the Mellish Rise comprises several large-scale basement controlled horst-and-graben blocks. Several small grabens and half-grabens within the Mellish Rise appear to have been created by faulting, and have subsequently been infilled with sedimentary packages < 1 s TWT thick (<1000 m) (Figures 13 and 14). Their deposition in post-deformational settings and their low seismic reflectance suggests that they are relatively young and unconsolidated. Interpretation of seismic profiles obtained during DSDP Leg 30 suggests that the younger sedimentary deposits across the rise are moderately stratified and probably dominated by pelagic biogenic components (Landmesser et al., 1975).

Troughs adjacent to the Mellish Rise contain moderately thick sedimentary sequences of up to 2-3 s TWT, which pinch out towards the Mellish Rise. These sequences contain reflectors that may correspond to the regional Eocene-Oligocene unconformity that occurs in most seismic sections west of the Lord Howe Rise. In these areas the reflector has been correlated with the highly reflective chert and siliceous limestone which lie directly below the unconformity (Terrill, 1975b). The widespread occurrence of this reflector allows dating and correlation of sequences across much of the region, but it is not clearly identifiable across the Mellish Rise, where the sedimentary history of the smaller basins remains speculative.

A recent reflection seismic and sampling survey of the Kenn Plateau to the south (Exon et al., 2005a) shows very considerable structural complexity there. The extensional tectonic regime in the Paleocene separated the plateau from continental Australia and rotated it 45º anticlockwise.

The Mellish Rise defines a complex setting for eastern Gondwana breakup in the Late Cretaceous to Early Tertiary. The high-relief structuring and widespread presence of volcanics, evident on the regional-scale profiles 274/01 and 274/03, mean that the seismic sequence descriptions that follow are preliminary in scope. A future, more detailed analysis encompassing additional seismic coverage from the BMR Continental Margins Survey, GA Survey 270 (ie Kenn Plateau) and regional Shell Petrel reconnaissance survey will more adequately address the depositional and structural styles across the area.

4.1 Seismic profile 274/01

Seismic profile 274/01 (Figure 13) is characterised by four elevated basement blocks, which are separated by basins. The blocks rise about 1000 m above the intervening basins and vary between 50 and 100 km in width. Although separated by the basement blocks, four seismic sequences can be correlated across the basins. These are from youngest to oldest:

- Seismic Unit I_01: The topmost seismic sequence averages 300 ms TWT (~250 m) in thickness. It is characterised by generally highly-continuous reflectors with the lowermost units having stronger amplitudes.

- Seismic Unit II_01: This sequence averages 500 ms TWT (~350 m) in thickness. Its reflectors are weak to moderate in amplitude strength and are somewhat chaotic in form. A series of strong amplitude basal reflectors in the central basin suggests volcanic flows derived from the flanking basement highs.

- Seismic Unit III_01: This sequence appears to be present only in the two easternmost basins, flanking a large basement block/seamount. It thickens to a maximum of 400 ms TWT (~500 m) and is characterised by low continuity reflectors of weak amplitude. Its basal section comprises strong amplitude reflectors of moderate continuity leading away from the central horst/seamount into the adjacent depocentres consistent with lava flows sourced from the central horst/seamount feature.

- Seismic Unit IV_01: This lowermost sequence is present in all three basins. A series of strong amplitude reflectors about 2 s TWT below seafloor in the central basin may image basement or lava flows within the sequence. At its thickest, the sequence is 800 ms TWT (~ 1200 m) in the central basin, with seismic penetration too poor to image its base in the other basins. Although dispersed throughout, strong amplitude reflectors suggest lava flows and/or volcanic sills. Reflectors in both the eastern and western basin are sinuous in form, and are truncated at the boundary with sequence III_01. This geometry suggests that compression occurred prior to the deposition of sequence III_01.

Seismic sequence I_01 caps a volcanic substrate across all the elevated basement features. However, a complex horst-and-graben rotated morphology on the Selfridge Rise hosts several other underlying thin seismic packages of strong amplitude and high continuity.

4.2 Seismic profile 274/03

Seismic profile 274/03 (Figure 14) displays a thin cover of sediment over the Mellish Rise proper and complex structuring. The structuring is dominantly horst-and-graben with evidence for inversion along the rise’s eastern margin with the D’Entrecasteaux Basin. Although seismic sequence identification is more difficult than for profile 274/01, at least three sequences are present. From youngest to oldest these are:

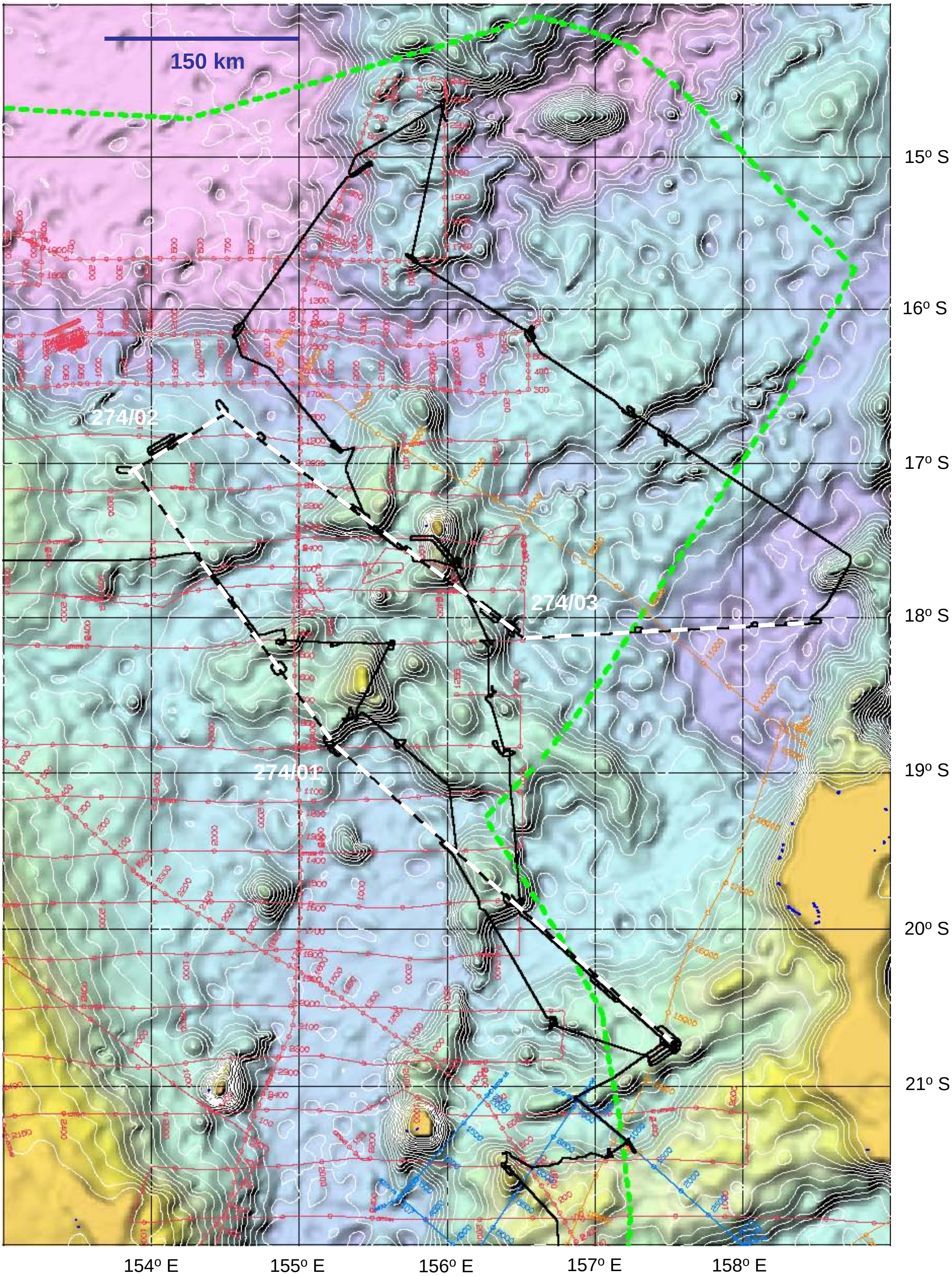

Figure 12. Seismic coverage over southern Mellish Rise. GA Survey 274 seismic profiles highlighted (dashed black and white line) along with GA Survey 270 (blue lines), Shell 'Petrel' roving survey (orange lines) and BMR Continental Margins Survey (red lines). Dashed green line is the outer limit of the Australian EEZ

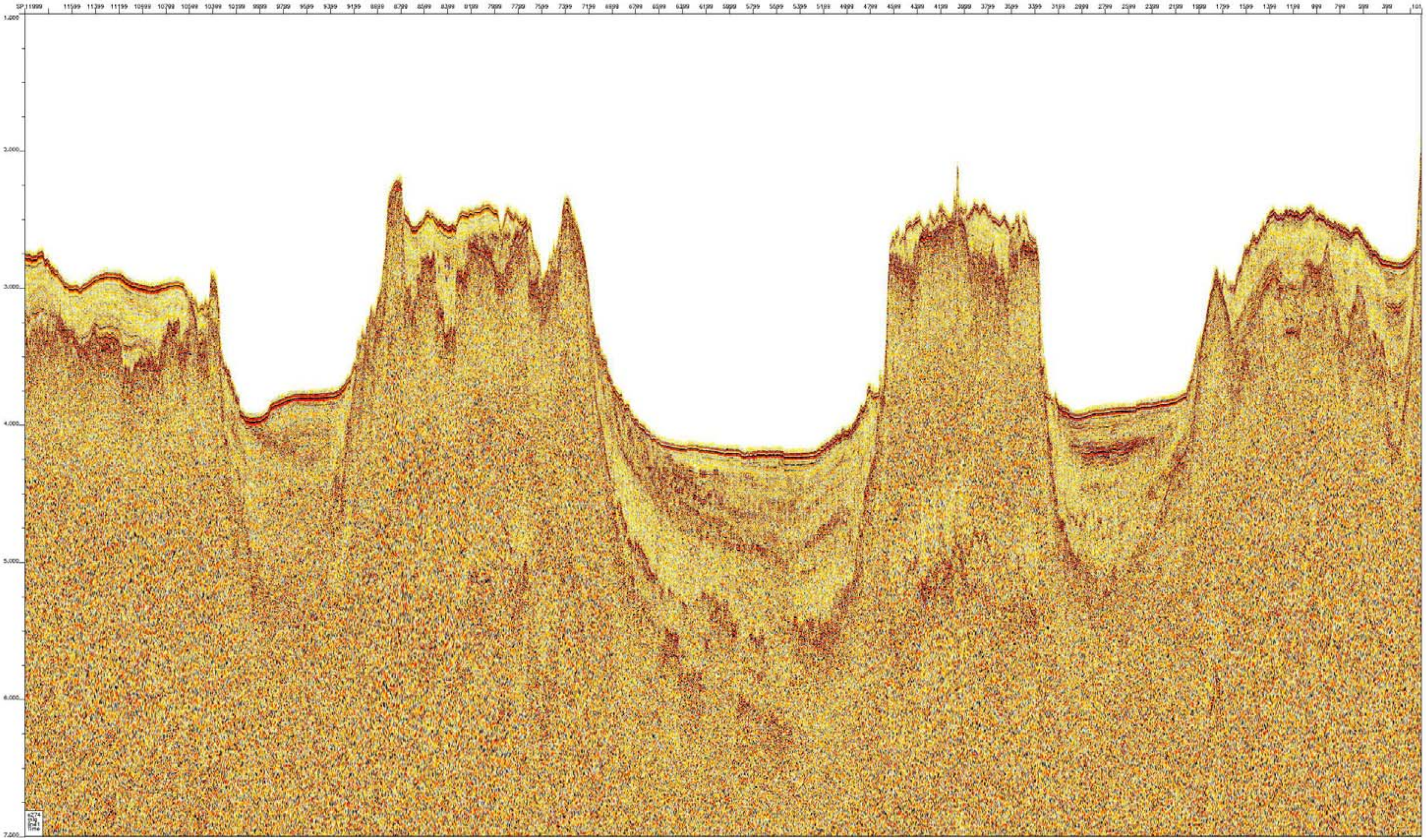

Figure 13. Seismic line GA 274/01 (see Figure 12 for location). Note scale: 1-7s TWT depth and approximately 595 km line length.

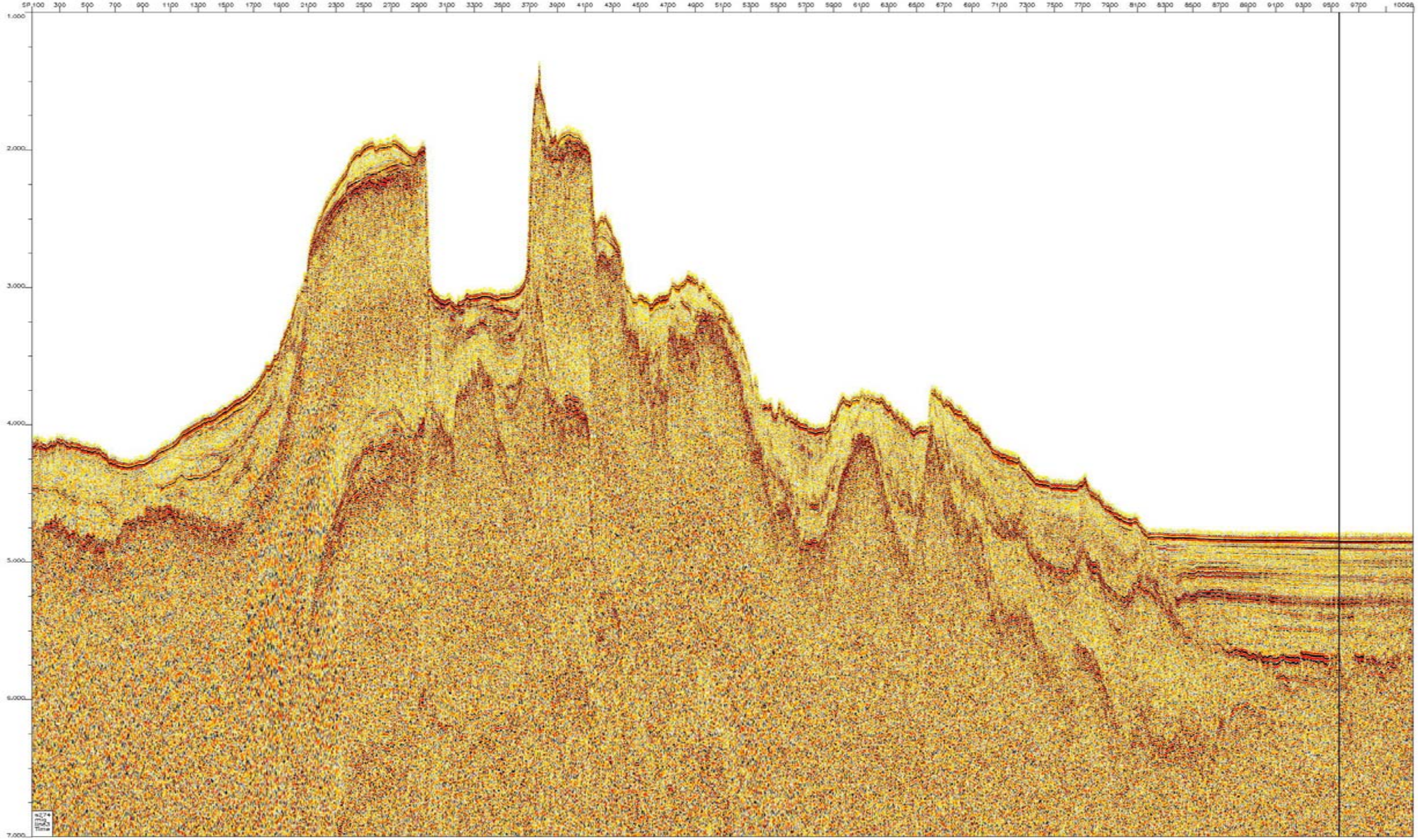

Figure 14. Seismic line GA 274/03 (see Figure 12 for location). Note scale: 1-7s TWT depth and approximately 502 km line length.

- Seismic Unit I_03: This sequence occurs in the D'Entrecasteaux Basin, where it is about 1 s TWT thick and comprises moderate amplitude and highly continuous horizontal reflectors. It appears to extend up and over the ?inverted eastern flank of the Mellish Rise where it varies from 200 to 500 ms TWT thick. Over the eastern flank the reflectors are of weaker amplitude and lower continuity. A buckled seafloor and chaotic appearance to the reflectors midway down the flank are suggestive of former and continuing compression. Although much thinner, this package extends across the rise summit (including within the central collapsed graben) and down its western flank.

- Seismic Unit II_03: Within the D'Entrecasteaux Basin this sequence averages 400 ms TWT thick. Up the eastern flank of the rise, however, it thins and thickens over inverted half-graben basement morphology, reaching 800 ms TWT within the easternmost half-graben. The reflectors are of mostly weak amplitude, but are largely continuous. This sequence is not present across the rise summit, but probably rests on volcanic basement or substrate within the central rise graben. It may also be present as the lowermost 200 – 400 ms TWT thick sequence extending down the western flank of the rise.

- Seismic Unit III_03: This is the lowermost sequence identifiable and is only discernible beneath the D'Entrecasteaux Basin and the bordering eastern flank of the Mellish Rise. It may continue further up the rise flank towards the central summit masked beneath volcanics. It is characterised by moderate – high amplitude and strongly continuous reflectors. It reaches a maximum of 500 ms TWT thickness.

In addition, a more restricted syn-rift styled sequence is sandwiched between sequences I_03 and II_03 down the eastern flank of the Rise.

4.3 Conclusions

Without further analysis employing the widely spaced grid of BMR Continental Margins Survey lines over the western Mellish Rise, the following correlations of seismic sequences on profiles 274/01 and 274/03 are possible:

sequence I_01 = sequence I_03
sequence II_01 = sequence II_03
sequence IV_01 = sequence III_03

where sequence III_01 is possibly correlative to the restricted syn-rift packages identified down the eastern flank of the Mellish Rise on profile 274/03.

Exon et al. (2005a) identify two prominent regional seismic horizons on the Kenn Plateau, which they interpret as late Eocene – early Oligocene and mid Eocene unconformities. The mid Eocene unconformity is related to compressional tectonics associated with collision of the Loyalty Arc with New Caledonia to the east. The Late Eocene – Early Oligocene event is attributable to the establishment of the Antarctic Circumpolar Current (ACC).

Because of the relatively undisturbed nature of the sediments in seismic sequences I_01 and I_03, the sequence boundary at their base is interpreted as the mid Eocene unconformity related to the New Caledonia compression. These sequences are thin over the elevated

Mellish Rise summit and associated basement/seamount blocks, suggesting that the upper part of the sequences may post-date the erosive action of the Late Eocene - Early Oligocene ACC.

Sequence II – IV on profile 274/01 and sequences II-III on profile 274/03 appear to post-date the rifting and separation of the Louisiade Plateau, Mellish Rise and Kenn Plateau in the Late Cretaceous to Paleocene. The sequence boundaries and interbedded volcanics are thought to be related to the complex intra-plate re-adjustments resulting from the establishment and later migration of the Louisiade Triple Junction in the Early Paleocene.

5. KENN PLATEAU DREDGING RESULTS

Eleven dredges and three cores were attempted during *Southern Surveyor* Cruise SS02/2005 (GA Survey 274) on the voyage northward across the Kenn Plateau, and another four dredges on the Selfridge Rise after the period of seismic acquisition (Figure 5). These operations were designed to sample in areas that had not previously been sampled because of the failure of the winches on the Kenn Plateau Survey SS05/2004 (Exon et al., 2005a). It was hoped that older rocks could be sampled than on the earlier survey - the oldest dated rock being Eocene chalk.

The dredge equipment used consisted of a large oblong chain bag dredge behind which two small pipe dredges (one closed, one with a grid at the outer end) were hung. This equipment ensured that both rocks and ooze could be recovered. Coring was done with a one tonne gravity corer with a six metre long core barrel. The dredge results are summarised in Table 3 (repeated in Tables 6 and 8 for Kenn Plateau and Mellish Rise/Louisiade Plateau, respectively) and the gravity core results in Table 4. Nine dredges succeeded in recovering rocks, and two cores were successful. Thick manganese crusts were almost ubiquitous on the rocks. The results were disappointing on the central and southern plateau, where slopes are low, but much better in the north, where higher and steeper (up to 30º) scarps occur on both margins of the Chesterfield Trough, which trends northeasterly. Bedrock samples were collected from the northern flank of Coriolis Ridge and the southern flank of Selfridge Rise (Figure 5).

Table 6. *Southern Surveyor* Cruise SS02/2005 (GA Survey 274) dredge sites on the Kenn Plateau.

No.	Seismic line: Shotpoint	Latitude (S) Longitude (E)	Depth (m) Haul (kg)[2]	Description of recovered material
DR01	270/07: 915	24°49.0’, 156°19.8’	3200	Calcareous ooze
DR02	270/14 swath	23º27.7’, 156º46.8’	1700 15 kg	Thick manganese crust; Early Oligocene and early Late Miocene micritic limestone with bivalves; fine grained ?metasediment
DR03	13/31 swath	23º12.7’, 156º30.4’	1770-1620	No recovery. Probably did not reach bottom in rough conditions
DR04	13/31 swath	23º13.6’, 157º00.8’	1700 10 kg	Thin manganese crust; calcareous ooze
DR05	N701	22°08.0’, 156°44.6’	1600 30 kg	Late Miocene chalk; calcareous ooze; foram sand
DR06	13/44:45.0807[1]	21º30.85’,156º24.65’	700-400 10 kg	Mid Miocene micritic limestone; Pleistocene pebbly calcarenite; shell hash; pebbles; manganese crust
DR07	14/02:9.0455[1]	21º25.5’, 156º24.45’	1600-1500 60 kg	Silicic tuff; late Middle Eocene calcarenite; shell hash; calcareous ooze; manganese crust
DR08	701: 12820[1]	21º25.85’, 157º06.8’	1500-1400 200 kg	Volcanic agglomerate with calcareous matrix; welded agglomerate; fine felsic volcanics; volcaniclastic sandstone; lapilli sandstone; thick manganese crust; calcareous ooze
DR09	270/04:1000[1]	21º21.5’, 157º14.6’	1800 300 kg	Late Oligocene – Early Miocene friable calcirudite; water worn volcanic pebbles; thick manganese crust; calcareous ooze
DR10	270/04:1000[1]	21º21.9’, 157º14.8’	1600 100 g	Undated calcarenite; thin manganese crust
DR11	270/03-04 intersection	21º04.5’, 156º52.6’	1800-1700 50 kg	Metamorphic quartzite; volcanogenic greywacke; welded tuff; pebbles; shell hash; calcareous ooze; thick manganese crust

DR32	274/01:1000	20º45.7'S,157º32.1'E	1550 0.5 kg	Thick manganese crust; pumice stones; calcareous ooze
DR33	274/01:1000	20º45.7'S,157º32.1'E	1800-1700 0.5 kg	Ferruginised quartz sandstone; Early - Middle Miocene chalk; calcareous ooze; manganese crust
DR34	N701:14250	20º50.6'S,157º22.2'E	1700 4 kg	Quartz-rich metadolerite; thick manganese crust
DR35	13/49:0448	20º36.7'S,156º43.5'E	2200-1950 150 kg	Hard quartzose litharenite; glauconitic and muddy litharenites; ?Pliocene foram chalk; carbonaceous cross-laminated litharenite; carbonaceous mudstone; ?bentonitic mudstone; pebbly micritic limestone; calcareous concretion; Late Eocene – Late Oligocene foram chalks; calcareous ooze

[1] Shotpoint is approximate closest shot point on seismic profile passing near dredge location.
[2] Recovery weight of dredge haul excludes ooze and shell hash.

5.1 Basement rocks

The only continental basement rocks came from the Selfridge Rise. A single cobble of light to medium grey, hard metamorphic quartzite, collected from dredge DR11, is dominantly quartz. It is medium to coarse-grained, with rounded crystals up to 4 mm across. The remainder of the rock is made up of epidote-green fragmental clasts and grey rounded clasts, up to 5 mm across. Other interstitial material includes rare plagioclase. Thin section examination (see Chapter 7) shows this rock to contain substantial quantities of plagioclase and altered volcanic rock (?basalt). Varied angularity suggests brecciation of some fragments. A dark vein (~5 mm wide) cross-cutting the specimen shows associated alteration and disseminated sulphide and iron oxide crystals. Reflection petrography identified these as pyrite, chalcopyrite, covellite and magnetite.

5.2 Volcanic rocks

These are the most abundant hard rocks recovered from the dredging. Fragmental volcanic rock types, consisting of lithic tuffs, agglomerate and basaltic volcanics, were recovered from both the Coriolis Ridge and the Selfridge Rise. Thin section examination shows that these volcaniclastic rocks are often pyroclastic (tuffs and agglomerates). None are hyaloclastic (dominantly glassy), although some contain altered glass. They are all associated with steep slopes and escarpments.

Tuffs and related minor greywacke (DR07, DR08, DR11 - described below) contain numerous lithic fragments of various compositions. The clasts are of various colours, including dark green, dark red, orange, grey, brown, white and black, and probably consist of various rock types including basalt and mudstone or shale. Most fragments are smaller than ~1 cm, with few larger than 1.5 cm. Rare calcium carbonate fragments up to 1.5 cm long were noted as well (possibly coral?). Welded textures are developed locally and have occasionally been observed as banding and stretching of clasts defining a heterogenous layering. The commonly observed rounding of several fragments may also be attributed to welding or perhaps reworking. For most of the lithologies, the matrix is very fine-grained to aphanitic (possibly glassy – to be determined by thin section study). Matrix colour varies between samples from red-purple to various shades of green – almost exclusively siliceous in composition with the exception of an agglomerate sampled from the Coriolis Ridge (DR08). The green shades may reflect varying degrees of epidote (and probably chlorite) alteration and/or metasomatism/metamorphism on compositionally heterogeneous layering. Thin section examination (see Chapter 7) shows that basalt dominates the volcaniclastic fragments, but that plagioclase feldspar is also common in the generally sand-sized pyroclastic rocks. Strong alteration is common, especially in the matrix. Secondary minerals include calcite, zeolites and clays.

An agglomerate from the Coriolis Ridge (DR08) contains fewer clasts and has a very fine-grained calcareous matrix. Phenocrysts are rare, and when present plagioclase is sometimes recrystallized to quartz. Small, ~1 mm sized, dark green crystals, possibly pyroxene, are also rare. A soft (hardness <3), pale, opaque, bright green mineral forms 1-3 mm euhedral grains in the matrix. Very altered, non-calcareous, mottled brown welded agglomerate from the same dredge contains cobble sized basaltic clasts with indistinct contacts.

5.3 Sedimentary assemblages

A diverse range of sedimentary rocks have been recovered from dredging and gravity coring on the Kenn Plateau. The assemblage includes siliciclastics, reefal limestones, chalks, Quaternary calcareous ooze and other unconsolidated accumulations. A selection of siliciclastics was sampled for thin-sectioning and the six petrographic descriptions are summarised in Table 7, with detailed microscopic observations, scanned slide images and photographs provided in the attached Report CD-ROM. Appendix 7 presents a summary table of data at each dredge site on the Kenn Plateau, which contains references to figures, photos, petrographic descriptions and slide numbers.

Table 7. *Southern Surveyor* Cruise SS02/2005 (GA Survey 274) thin section rock descriptions from Kenn Plateau.

Sample number/ GA lab number	Description and age
274/10DR08F1.1 1603232	Graded volcaniclastic sandstone with accretionary lapilli (<11 mm wide). Tuffaceous matrix with quartz, felspar, opaques, and mixed source rock fragments (basalt, rhyolite, sandstone, tuff). Scour surfaces.
274/39DR35A1.1 1603486	Fine-grained litharenite (70% quartz grains) contains lithic fragments, felspar, and muscovite. Foraminiferal chalk adheres to the litharenite consisting of foram tests, micritic matrix, mineral grains, and lithics (tuff, siltstone, basalt, ?quartzite, rhyolite). Chalk dated tentatively as Pliocene.
274/39DR35A2.1 1603488	Fine-grained litharenite (60% quartz) with flaser-like stringers of heavy minerals depicting troughs. Consists of felspar, muscovite, biotite, and lithics (quartzite, pumice, chalcedonic quartz fragments).
274/39DR35A4 1603490	Fining-upwards(?) sequence of glauconitic litharenite, iron-stained siltstone, and iron-rich mudstone. Dominant component is lithics (40%). Amorphous aggregates of glauconite but non-calcareous. Transitional contacts between beds.
274/39DR35B1.1 1603492	Carbonaceous very fine-grained litharenite with planar cross-lamination. Quartz, opaques, muscovite, biotite, brown organic material, clay-altered felspar and lithics. Concentration of carbonaceous fragments in one bed. Iron oxide cement.

274/39DR35B3.1 1603496	Interlaminated carbonaceous mudstone and fine-grained muddy litharenite with calcareous fragments. Components include quartz, felspar, muscovite, and lithics (quartzite, schistose fragment). Dull brown pods, fibrous and amorphous material are probably organics.

5.3.1 Siliciclastic sediments

On the Kenn Plateau, continental-derived siliciclastic rocks are confined to the Selfridge Rise on the northern reaches of the plateau. The assemblage consists of quartzose and mixed composition (labile) sandstones, siltstones, and mudstones. Well-sorted, non-calcareous sandstones from dredge sites DR33 and DR35 range from quartzose to litharenites and are composed of detrital quartz, felspar, muscovite, biotite, carbonaceous fragments, lithic fragments (chalcedonic quartz fragments, basalt, pumice, quartzite, schist, siltstone, mudstone), and dispersed opaque minerals. These quartz grains commonly display undulose extinction and contain inclusions, whereas the polycrystalline quartz grains have sutured boundaries (ie. slides #1603486, #1603488, #1603490 and #1603492). These features are all characteristic of quartz derived from plutonic, gneissic or schistose crystalline rocks (Blatt et al., 1980). Volcanic quartz lacks inclusions and is non-undulatory under cross-nicols. One red-brown sandstone from DR33 is ferruginised suggesting it was most likely exposed for a considerable period prior to being submerged (Figure 15A).

Bedding features observed in the assemblage include thin beds, laminae, planar cross-bedding, and flaser-like bifurcated stringers of heavy minerals depicting ripple troughs. The latter two types were present in sandstones at DR35 and imply shallow variable current activity prevailed (Figure 15B; slides #1603488 and #1603492). One specimen from DR35 (Figure 15C; slide #1603490) displays either a fining-upwards or coarsening-upwards sequence of glauconitic sandstone, siltstone and mudstone with gradational contacts (way up is not clear). The presence of authigenic glauconite indicates that the sand accumulated in slightly reducing conditions in shallow-marine waters where the rate of sedimentation was low (Blatt et al., 1980; Reineck and Singh, 1980).

There is a single cobble-sized calcareous concretion from site DR35 which shows paler circular structures up to 5 cm wide; these are believed to be burrows. The late stage manganese oxides have been precipitated through the concretion but avoided the centre of the burrows.

Carbonaceous material was identified in a mudstone and a litharenite from DR35 (slides #1603492 and #1603496). The organics range from dull brown amorphous material to fibrous pods and concentrated stringers. The mixed source lithic fragments associated with these sediments are continental in origin (quartzite, schistose fragment, clay altered lithics, polycrystalline quartz) and hence these carbonaceous rocks were probably deposited in a fluvio-lacustrine to neritic environment to account for the terrigenous input (Figure 15D). The dredge site was in water depths over 1950 m suggesting there has been considerable subsidence of the Selfridge Rise and surrounding region since deposition.

The fine grain-sizes and the implied current activity preserved in these siliciclastic deposits in the Selfridge Rise area suggest accumulation occurred in shallow waters in a fluvio-lacustrine to shallow-marine setting. The predominance of quartz grains and the presence of organic matter, micas, quartzite, and schistose fragments indicate an exposed vegetated continental source was nearby. Furthermore, there is a paucity of volcaniclastic lithologies which appear to be common in other rock assemblages to the south. The microscopic properties of the quartz grains confirm a non-volcanic provenance. Associated rock types on this structure include metadolerite and quartzite.

There is a subset of siliciclastic rocks, the volcanogenic lithofacies, which include a volcaniclastic greywacke, volcaniclastic sandstones, and bentonitic claystone. The greywacke (DR11) contains abundant angular and poorly sorted granule to pebble sized altered clasts in a grey-green matrix. Clasts, including basalt and probable mudstone, are very similar in appearance to the clasts within the pyroclastic volcanics at this site. The range of grain sizes, the angularity of particles, and the disturbed nature of the greywacke suggest it may be a debris flow deposit within a volcanic terrain.

Volcaniclastic sandstones from the Coriolis Ridge (DR08) consist of fine to medium-sized lithic fragments; one specimen has unidentified emerald green cement. Interestingly, one of the felsic volcanic samples from this site also has the emerald green mineral but as a concentrically layered infill to amygdales. Spectacular lapilli sandstone from dredge DR08 on the northern edge of the Coriolis Ridge shows fining-upwards graded bedding and scour surfaces (Figure 15E). This non-calcareous sandstone is light grey, very fine to coarse-grained, and quartzofeldspathic. The spherical lapilli form during pyroclastic events through the accretion of ash onto a nucleus (Cas and Wright, 1988). The lapilli cores, which are composed of coarse tuff, are enclosed by concentric layers of finer tuff. The entrained lapilli range between 3–11 mm in diameter. Thin-section observations of this lapilli sandstone are summarised in slide #1603232. Deposition is believed to be by resedimentation of an unconsolidated lapilli tuff as there is no evidence of welding of the volcaniclastic particles.

Light olive brown bentonitic mudstone from DR35 has a prominent network of haematitic veins and dendritic manganese oxides across it (Figure 15F). The presence of bentonite (montmorillonite) records the input of volcanic ash. Rare nannofossils were present in the examined calcareous residue. The incorporation of some coccoliths in this mudstone is suggestive of a marine shelf depositional setting.

5.3.2 Shallow-marine limestones

Shallow-marine limestones, mostly calcarenites, are present in dredges from the northern margin of the Coriolis Ridge: DR06 from a guyot, DR07 from a steep slope, and DR09 and DR10 from a terraced region on the northern margin of eastern Coriolis Ridge. Calcarenites, with coarser fragments up to 1 cm in maximum dimension, were present in all these sites and are variably cemented, but often poorly consolidated. They consist of variable proportions of bryozoans, bivalves and echinoid spines, with lesser serpulid worm tubes, solitary corals and larger benthic foraminifera. In the shallow water dredge DR06 (400-700 m water depth), Mid Miocene calcarenite was deposited in the photic zone during tropical-subtropical climatic conditions (Quilty, 2005, this report). Two Quaternary nanno oozes accumulated on the calcarenite outcrop signifying a hiatus of some 10 million years. The calcarenite have subsequently broken down, either in outcrop or in the dredge, to form a shell hash with the above constituents mixed in with modern debris, consisting of fossil and living bryozoans and corals, echinoids, gastropods, pteropods, heteropods, forams, serpulids, siliceous sponge spicules, shark teeth, and small solitary corals.

These semi-consolidated and consolidated bioclastic limestones are believed to constitute intertidal and lagoonal deposits associated with palaeo-reefs and carbonate platforms fringing the northern Kenn Plateau. Present water depths vary from 400 to 1800 m, indicating considerable subsidence since their original deposition within the photic zone in less than

Figure 15. Shipboard photos of freshly cut dredge samples. **A:** ferruginised coarse-grained quartz arenite (Kenn Plateau DR33, Lithology A). **B:** cross-laminated fine-grained litharenite with carbonaceous flecks (Kenn Plateau DR35, Lithology B1; slide #1603492). **C:** bedding contacts between glaucontitic litharenite, iron-rich siltstone and mudstone (Kenn Plateau DR35, Lithology A4; slide #1603490). **D:** interlaminated carbonaceous mudstone and muddy litharenite with calcareous fragments (Kenn Plateau DR35, Lithology B3; slide #1603496). **E:** graded lapilli sandstone with scour surfaces (Kenn Plateau DR08, Lithology F; slide #1603232). **F:** bentonitic mudstone with haematitic veins (Kenn Plateau DR35, Lithology C).

200 m water. Foraminiferal identification (Quilty, 2005, this report) has dated the calcarenite dredged at DR07 as Eocene or Early Tertiary and indicated that deposition occurred in a seagrass bed below wave base. A very shallow-water environment with a terrigenous influx has also been determined from the foraminiferal assemblage in the calcirudite at DR09 (Figure 16A), which is dated at the Oligocene-Miocene boundary. In summary, the carbonates dredged from DR06, DR07, DR09 and DR10 on the northwest of the Coriolis Ridge have foraminifera assemblages characteristic of shallow to very shallow water. The associated igneous rocks collected at these sites are a volcanic suite. Thus, this ridge is inferred to have been an exposed volcanic terrain with a fringing or barrier reef from at least the Eocene. This does not preclude it from being underlain by continental basement.

Subsequent diagenesis has resulted in the cementation or recrystallisation of these carbonate rocks to a micritic limestone. In dredge DR06, hard micritic limestone contains shell fragments and other bioclastic debris in several generations of calcareous cement. Anastomosing brown stringers are evident in the pebbly micritic limestones retrieved from DR35 (Figure 16B), which are suggestive of sediment or tuff influx during deposition. The pebbles consist of angular to rounded sandstone and mudstone clasts indicating a depositional site proximal to the coast. To explain the lithological relationship, either a coastal lagoon open to sediment influx is required or a submerged carbonate platform abutting a cliff of older non-carbonate rocks.

Preliminary stratigraphic determinations suggest these shallow-water limestones would have developed along the Tertiary continental shelf as well as on submerged plateaus, guyots, and seamounts which allowed the reefal fauna and flora to colonise suitable elevated substrates within the photic zone.

5.3.3 Cainozoic chalks

Preserved calcareous pelagic sediments deposited on the Kenn Plateau during the Tertiary consist of foraminiferal nannofossil chalks and micritic limestones. The pelagic deposits were retrieved from dredge sites DR02, DR05, DR33 and DR35 and gravity core GC03. Microfossil examination of the calcareous residues has determined that all these chalks are similarly aged at Early Eocene to Late Miocene.

Although homogeneous white chalk was dredged from DR05, DR33 and DR35, other chalks and limestones from DR02 and DR35 have been shown from thin-section to contain a variety of sand to pebble sized lithic fragments (quartzite, rhyolite, basalt, siltstone, tuff, sandstone, mudstone) and mineral grains (quartz, felspar, pyroxene) (slide #1603486). To explain such a terrigenous influx, the depositional settings would have been proximal to exposed land, such as on the continental shelf or on a submerged platform adjacent to older rocks. The white chalks (DR05, DR33, DR35 and GC03) have been extensively bored by a number of different marine invertebrates after lithification (Figure 16C). One of the trace fossils consists of 10-15 mm wide branching burrows and voids, whereas another burrow type are only 1-2 mm wide. Both burrow systems have been lined with manganese oxides while exposed on the sea floor. Burrows are commonly infilled with light grey unconsolidated nanno ooze, presumably of Pleistocene-Holocene age.

A thin-section of a fresh foram chalk adhering to a litharenite was taken from DR35 (slide #1603486). The chalk consists of 50% foraminifera (including Globigerinids and uniserial types) supported in a micritic matrix with 5% lithic and mineral grains as well as rare bryozoan and bivalve bioclasts. Nannofossil assemblage has tentatively dated the chalk as Pliocene. This sample warrants further investigation to unravel the relationship between the litharenite abutting against the chalk. One proposal is that there is a hiatus between the lithologies however the contact is fresh without any evidence of exposure. The alternate scenario is that the chalk represents an accumulation on a steep-sided structure rather than a deep-water setting.

Hard micritic limestone, containing nannofossils, foraminifera, and one species of large bivalve, was recovered from dredge DR02 in the south. Its general fine grain size and microfossil content suggest that this may be a deep water deposit. This concurs with the foraminiferal assemblage that is specific to the continental slope and deeper environments.

Although calcareous ooze was common in dredge hauls, there was no siliceous ooze recovered from the Kenn Plateau. Dredge sites were generally in water depths of less than 2200 m (except for DR01 which provided samples from 3200 m) which would largely explain the lack of siliceous deposits.

5.3.4 Quaternary sediments

These are a diverse group of lithologies including the ubiquitous calcareous nannofossil ooze, manganese oxide precipitation, water worn pebbles, unconsolidated bioclast accumulations and migrating foram sand waves.

Calcareous nanno ooze and manganese oxides were recovered from most dredges (DR01-DR02, DR04-DR11 and DR32-DR35). Core GC01 on the southern Kenn Plateau recovered 320 cm of pale brown, pale grey, and white calcareous ooze of varying foram content from a water depth of 2695 m (Figure 16D). The nannofossil assemblage dates all the dredged calcareous oozes as Pleistocene to Holocene (Findlay and Howe, 2005, this report). Dredge site DR05 and gravity core GC03 sampled light brown unconsolidated foram sand which is well sorted and contains some thin shelled fragile bivalve fragments. That the foram sand is a current-washed version of the ooze is suggested by the presence on the plateau of sand waves in some relatively shallow areas (water depth ~950 m) in the vicinity of these sampling sites. Swath-mapping and echosounder profiles show that individual sand waves can be traced for kilometres (Figure 8). They have asymmetrical sinuous crests which are 4-5 m high with a wavelength of 250-350 m. The direction of asymmetry indicates these megaripples are migrating northeast across the plateau.

A possible hiatus is indicated from the foraminiferal assemblage at DR06 where two Quaternary nannofossil oozes have accumulated on a Mid Miocene shallow-water micritic limestone (Quilty, 2005, this report). This period of non-deposition does not correspond to the two regional unconformities identified by Edwards (1973) for the western South Pacific Ocean (L.Paleocene-E.Eocene and L.Eocene-E.Oligocene) hence it may have been a more localised event. According to Vail et al. (1977), there was a relative fall in global sea level from Mid Miocene until the Pliocene; this may have been the main influence on deposition in the region during this time.

Unconsolidated shell hash or bioclast accumulations are believed to be disaggregated Tertiary aged calcarenites and calcirudites. Their occurrence is confined to DR06, DR07 and DR11 on the northwestern part of the Kenn Plateau. Constituents of the shell hash include bryozoans, bivalves, echinoid spines, gastropods, pteropods, shark teeth, fish bones, sponge spicules, serpulids, heteropods, crinoid, corals, coralline algae, and a variety of foraminifera tests. This mix of fossil and modern biota alludes to the environmental conditions for this part of the seafloor and water column since the Tertiary.

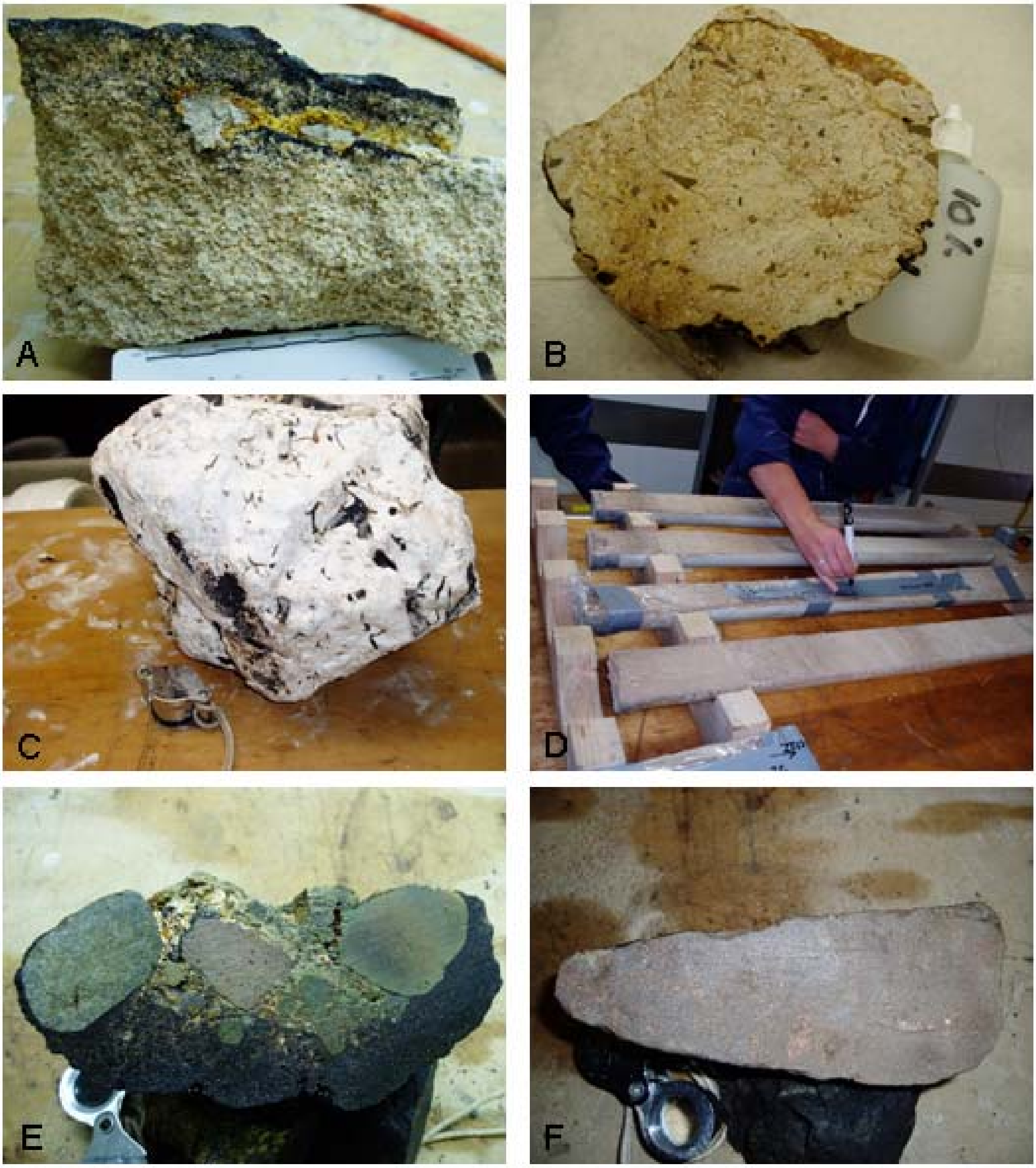

Figure 16. Ship-board photos of freshly cut dredge samples. **A:** calcirudite with manganese crust and voids infilled with light grey calcareous ooze (Kenn Plateau DR09, Lithology A). **B:** pebbly micritic limestone (Kenn Plateau DR35, Lithology D1). **C:** chalk with hardground borings infilled with black manganese oxides and light grey calcareous ooze (Kenn Plateau DR05, Lithology A). **D:** calcareous ooze recovered from gravity core 1 (Kenn Plateau, GC01). **E:** conglomerate with pebbles of tonalite (left), quartzofeldspathic greywacke (centre) and altered basalt (right) encrusted with black manganese oxides (Mellish Rise DR24, Lithology F). **F:** fine-grained, calcareous litharenite containing bioclastic fragments and glauconite (Mellish Rise DR24, Lithology C1).

Manganese oxides, in the form of manganite, pyrolusite, and psilomelane, have precipitated out of solution onto exposed rocks on the seafloor. Crystal growth for these oxides includes botryoidal and microbotryoidal crusts enveloping outcropping rocks, a fine dendritic habit which generally grows on the edge of specimens, the linings of hardground burrows, nodules accreted on to a nucleus, and individual grains dispersed through the matrix of most facies. Nanno ooze has settled on the developing crust and has subsequently been bound within voids, fractures, and interstitially between crystals as observed in DR02 and DR34 where crusts have grown up to 9 cm thick. Precipitation rates for manganese oxides appear to vary depending on the availability of manganese and iron as well as water depths, seawater oxygenation, and the properties of the surface it is accreting onto (Mero, 1969; Kennett, 1982).

A variety of loose pebbles and cobbles were collected in the dredge buckets at sites DR06, DR09, and DR11. These rounded pebbles are composed of igneous and metamorphic rocks (basalt, ?quartzite, pumice and ?granitoid) and are up to 8 cm in length. Their water-worn shape suggests they have been subject to considerable reworking or have been transported a long way. They are likely to have formed through disaggregation of existing conglomerates and are being redeposited as scree or drowned littoral zones. The composition of the pebbles indicates both continental and volcanic terrain provenances.

5.4 Conclusions

The diverse sedimentary rock assemblage recovered from the Kenn Plateau dredge sites includes both continental and volcanogenic derived lithic fragments and mineral grains. Evidence of continental basement comes only from the Selfridge Rise. The quartz-rich and metamorphosed lithologies sampled from the Selfridge Rise (quartzite, quartz sandstones, dolerite and metasediment) suggest this ridge is a remnant of continental crust which has been rifted from continental Australia. This agrees with the findings of earlier scientific work on the plateau (Exon et al., 2005a). The carbonaceous material observed in some of the siliciclastics implies the provenance involved an exposed vegetated landscape. This is further supported by the ferruginised siliciclastics and haematitic veins sampled at DR33 and DR35 which suggest a period of subaerial exposure to oxidise the iron-rich minerals. Lending further evidence is the microscopic examination of quartz grains which reveals undulose extinction and inclusions which are indicative of continental igneous and metamorphic rocks. Unfortunately, no age dates are available for the siliciclastics, but these are presumably Cretaceous and Paleogene in age.

The occurrence of authigenic glauconite is important as it indicates slight reducing conditions prevailed in a shallow-marine environment with a low sediment supply. Glauconite can precipitate directly from seawater, resulting from the alteration of faecal pellets and phyllosilicates, or be introduced as reworked detrital grains (Blatt et al., 1980). Only authigenic glauconite was observed in the siliciclastics on the Kenn Plateau.

The quartzite from dredge DR11 is most likely the metamorphosed equivalent of quartz-rich sandstone. It shows evidence of substantial metamorphism and, as such, it must be older than the siliciclastic sedimentary and volcanic rocks, which structurally and stratigraphically underlie all carbonate units subsequently described. The sulphide-bearing vein within the quartzite is probably post-metamorphic and formed during subsequent fluid infiltration along fractures. The quartz-rich metadolerite, recovered from dredge DR34, is cut by fine quartz veins and is deformed indicating metamorphism of a continental rock, probably prior to rifting.

Although the Tertiary rock assemblage for the Coriolis Ridge to the south of the Selfridge Rise contains only volcanic, volcaniclastic, and shallow-water carbonates, this does not exclude the ridge from having a continental basement. Interpretation of seismic profiles for the region may assist in understanding the development of the ridge.

The rift-related volcanics and some of the siliciclastic sediments are intimately related as shown by the similarities between clastic fragments, as well as colour. The siliceous rift volcanics may be related to the widespread Early Cretaceous silicic pyroclastic volcanism (e.g. the Whitsunday Volcanic province) described by Bryan et al. (1997) and the Peninsula Range and Double Mountain Volcanics at Port Clinton which include lapilli tuff (Day et al., 1983). However, the generally basaltic composition of the flows and volcaniclastic rocks recovered by dredging suggests that this correlation is unlikely. More probably, these volcanics were intimately associated with the Late Cretaceous rifting, and coeval with the pre-Miocene rift volcanics drilled in several of the ODP sites on Marion Plateau to the west (Isern, Anselmetti, Blum et al., 2002). The Marion Plateau volcanics consist of highly altered lava flows and volcaniclastics. The hard ferruginous bedded sandstone and the hard quartz-rich sandstone from the Selfridge Rise are of possible Palaeozoic age.

Vertical accretion of landmasses due to volcanic activity coupled with probable subsidence of other structures during rifting and sea level rise may have assisted in creating elevated platforms close to or above sea level. Suitable submerged substrates within the photic zone were then colonised by reefal fauna and flora to produce fringing or barrier reefs. Only detrital limestones have been recovered; no framework reefal material was collected. The oldest calcarenites dredged on this survey are Eocene in age (DR07) and presumably the result of the initial transgression accompanying the rifting. These deposits also correlate with a global sea level high (Vail et al., 1977). Reef development in the region occurred between the Eocene and Holocene however it is unclear how pervasive the growth was through time at the sites. On the northeastern Coriolis Ridge, at the location of dredges DR09 and DR10, the calcarenites are associated with three large terraces. Whether they formed the terraces as the sea rose, or the terraces were formed by basalt flows as evidenced by water-worn pebbles, is uncertain. However, given the morphology that suggests that the terraces are formed of hard resistant rocks, and because the calcarenites are friable, we favour a basaltic origin. If this is the case, the calcarenites formed from calcareous organisms that colonised the terraces as the region sank and the sea rose.

Micritic foraminiferal limestones contain pebble-sized clasts and brown stringers indicating a significant terrigenous input; further investigation is required to fully understand their depositional setting. Homogenous white chalks have accumulated in bathyal water depths but have been subject to post-lithification burrowing by marine invertebrates while exposed on the seafloor. The chalks also show a significant terrigenous content of sand to pebble-sized metamorphic, volcanic and sedimentary lithic fragments indicating a nearby landmass.

6. MELLISH RISE AND LOUISIADE PLATEAU DREDGING RESULTS

Twenty-nine dredges and two cores were attempted during *Southern Surveyor* Cruise SS02/2005 (GA Survey 274) over the Mellish Rise and southern Louisiade Plateau (Figure 5). This represented the first known sampling survey over the Mellish Rise. Both gravity cores succeeded in recovering some ooze and twenty-six of the twenty-nine dredge attempts recovered rocks (Table 8). The dredged material comprises a diverse suite of sedimentary and volcanic rocks.

Table 8. *Southern Surveyor* Cruise SS02/2005 (GA Survey 274) dredge sites on the Mellish Rise and Louisiade Plateau.

No.	Line: SP	Latitude (S) Longitude (E)	Depths (m) Recovery	Description of recovered material
DR12	Swath	16º49.9'S, 157º30.9'E	2600 30 kg	Quaternary porcellanite; thick manganese crust
DR13	Swath	16º51.1'S, 157º29.2'E	2900-2750 100 kg	Dolerite; vesicular basalt; chert; Late Paleocene bored chalk; Eocene-Early Oligocene pebbly chalk; Early Eocene porcellanite in manganese nodule; large manganese nodules; coral
DR14	Swath	16º40.6'S, 157º15.8'E	2900-2400 500 kg	Quartz gabbro (dolerite); vesicular basalt; hyaloclastite; Late Eocene-Early Miocene bentonitic siliceous claystone; Late Paleocene muddy glauconitic chalk; latest Mid Miocene bored chalk; serpentinite breccia; ?Holocene calcareous ooze; manganese crust
DR15	14/35:32.0555	16º10.1'S, 156º34.8'E	2630 60 kg	Basalt; Late Paleocene muddy glauconitic chalk; manganese crust and nodules
DR16	14/56:55.1455	15º39.5'S, 155º45.3'E	2600-2500 15 kg	Fine tuff; thick manganese crust; calcareous ooze
DR17	14/57:52.2245	14º41.6'S, 155º52.2'E	3250-3000 500 kg	Basalt; agglomerate; sideritic red mudstone; ?grey bioturbated mudstone; ?Paleocene porcellanite; well sorted calcarenites; olivine-rich sandstone; manganese crust
DR18	14/59:56.0640	15º05.3'S, 155º26.0'E	3300-3100 20 kg	Basalt; hyaloclastite in carbonate cement; manganese crust
DR19	14/36:32.1820	16º10.9'S, 154º34.1'E	3750-3650 400 kg	Hyaloclastite; manganese crust and nodules; Late Paleocene-Early Eocene consolidated ooze
DR20	14/78:92.0240	16º54.6'S, 155º15.8'E	2850-2650	No recovery. Probably did not reach bottom.
DR21	274/03:2300	17º24.4'S, 155º29.3'E	1950-1500 200 kg	Basalt; minor basaltic conglomerate and agglomerate; dark red claystone; laminated glauconitic carbonates; Paleocene-Early Oligocene pebbly chalk; manganese crust
DR22	274/03:8200	17º35.7'S, 155º45.7'E	1700-1300 350 kg	Basalt; vesicular basalt; ?Oligocene reef limestones (algal boundstone, calcareous conglomerate, calcarenite); manganese crust
DR23	13/72:88.2007	17º38.5'S, 156º03.9'E	2300-2000 0.2 kg	Hyaloclastite; manganese nodules
DR24	13/72:88.2007	17º40.2'S, 156º03.2'E	2200-2000 200 kg	Late Eocene quartzose calcarenite; Oligocene-Miocene calcarenites; Eocene-

				Pliocene micritic foram limestone; sinter; basalt; volcanogenic conglomerate; crystal lithic tuff; muddy calcareous lithic sandstone; hyaloclastite
DR25	13/64:72.1640	18º09.0’S, 156º17.3’E	2650-2350 200 kg	Eocene quartzose calcarenite; Late Eocene-Early Oligocene foram chalk; hyaloclastite; thick manganese crust
DR26	13/62:66.1120	18º29.9’S, 156º18.0’E	2100-1950	Rounded basalt boulder; Late Pliocene conglomerate; calcareous pebbly litharenite; thick manganese crusts
DR27	13/60:66.0723	18º51.7’S, 156º23.1’E	1800-1650 0.5 kg	Conglomerate; manganese crust; deepwater corals (*Corallium*, bamboo, black)
DR28	13/60:66.0723	18º51.5’S, 156º23.2’E	No recovery	Not on bottom
DR29	274/01:3340	19º49.8’S, 156º27.7’E	No recovery	Not on bottom
DR30	274/01:3340	19º49.8’S, 156º26.3’E	2300-2000 0.5 kg	Volcaniclastic conglomerate; calcareous ooze
DR31	274/01:3340	19º49.9’S, 156º27.6’E	2600-2450 7 kg	Calcareous tuff; Late Eocene brown and green foram marls; calcareous ooze; thick manganese crust
DR36	274/01:4660	19º27.6’S, 156º00.4’E	2500-2150 8 kg	Basalt; foram-rich calcarenite; Late Pliocene foram chalk; bentonitic clay; thick manganese crust
DR37	13/60:66.0321	18º49.5’S, 155º41.7’E	2200 25 kg	Late Pliocene foram-rich chalk; thick manganese crust; greywacke; foram nanno oozes
DR38	274/01:7160	18º38.6’S, 155º19.6’E	2600 0.1 kg	Basalt; pumice
DR39	274/01:7160	18º37.9’S, 155º23.6’E	2400 12 kg	Basaltic hyaloclastic agglomerate; minor calcareous ?tuff; manganese crust
DR40	13/64:72.1233	18º10.8’S, 155º37.6’E	2100-1850 200 kg	Pliocene-Holocene calcareous conglomerate; algal boundstone; weathered calcarenite; vesicular basalt; brecciated vesicular basalt; red mudstone; weathered red mudstone; hard grey mudstone; greenish grey mudstone; weathered mudstone; manganese crust
DR41	13/64:72.1020	18º10.4’S, 155º15.8’E	1900-1450 450 kg	Felsic igneous (dacite, rhyolite, quartz diorite, dolerite); basalt; volcanics weathered to multicoloured claystone; red mudstone; volcanogenic sandstone; Mid-Late Miocene chalk; Pliocene-Holocene weathered algal boundstone; manganese crust; coral hash
DR42	13/64:72.0808	18º09.2’S, 154º53.4’E	1600 20 kg	Basalt; lateritised basalt; Early-Mid Miocene foram chalk; grey mudstone; mudstone conglomerate; manganese crust
DR43	274/01:8932	18º07.9’S, 154º42.0’E	2000-1850 130 kg	Hard cemented calcarenite; Late Pliocene friable glauconitic calcarenite; hard quartz-rich calcareous sandstone; thick manganese crust and nodules
DR44	**274/01:xxx**	17º38.0’S, 154º20.3’E	2500-2350 10 kg	Mid-Late Paleocene calcarenite; Paleocene bentonitic mudstone; calcareous conglomerate within manganese nodule; manganese crust and nodules

6.1 Volcanic rocks

The petrology of the heavily-altered volcanic rocks dredged are described in detail in Chapter 7. They are different from those of the northern Kenn Plateau in that they do not include volcaniclastic and pyroclastic rocks (other than hyaloclastites), and they do include hyaloclastite and dolerite. As on the Kenn Plateau, a variety of basalts was recovered. The basalts contain crystals of olivine, plagioclase and clinopyroxene in a fine groundmass. Glassy clasts are present occasionally. The hyaloclastites occur as basaltic hyaloclastite, hyaloclastite basalt, and palagonitised glass, and are genetically related to the basalts.

6.2 Sedimentary assemblages

The Mellish Rise and Louisiade Plateau have a similar diversity of sedimentary rocks to the Kenn Plateau (Table 8). The assemblage consists of common siliciclastics, calcarenites, foraminiferal chalks, and Quaternary calcareous ooze and unconsolidated accumulations. However, a few unusual lithologies were collected including a sinter deposit, porcellanites, and a laminated glauconitic carbonate; all three lithologies are significant indicators of certain palaeo-environments. Thin-sections were prepared for a mix of siliciclastics, carbonates, and chalk samples and are summarised in Table 9. Detailed petrographic descriptions, scanned slide images and photographs are provided in the attached Report CD-ROM. Appendix 7 presents a summary table of data at each dredge site on the Mellish Rise and Louisiade Plateau, which contains references to figures, photographs, petrographic descriptions and slide numbers.

Table 9. *Southern Surveyor* Cruise SS02/2005 (GA Survey 274) thin section rock descriptions from the Mellish Rise and Louisiade Plateau.

Sample number/ GA lab number	Description
274/20DR17D1.1 1603331	Haematitic sandy mudstone with sideritic veins. Components include quartz, felspar, opaques, and lithics (basalt). Massive bed with dark red brown spherical-elliptical bodies (?bioturbation). Authigenic felspar infills voids.
274/24DR21F1.1 1603383	Prismatic calcite interlaminated with glauconite laminae, micrite, glauconitic coquinite, and dismicrite. Prismatic calcite believed to be pelecypod valves and source for the coquinite. Iron and manganese oxide deposits present as bands and aggregates.
274/44DR40D1.1 1603552	Haematitic bioturbated mudstone has basalt fragments and dispersed opaques. Faecal nests and spreiten structure indicating bioturbation. Blocky quartz cement as coronas around mudstone aggregates and infilling pore space.
274/44DR40I1.1 1603564	Bentonitic mudstone with abundant euhedral-suhedral opaques and some lithics (volcanics, mudstone). Pervasive mineral has silky appearance in XPL, possibly montmorillonite. Extensive arcuate open fracturing lined with ?haematite.
274/45DR41A1.1 1603570	Haematitic sandy mudstone with quartz grains, opaques, and basalt fragments. Massive bed however has a clumped appearance (?clay flocculation).

274/45DR41B1.1 1603573	Volcanogenic pebbly mudstone consists of volcanogenic lithic fragments (mixed basalt types, mudstone), felspar, olivine, ?devitrified glass, and opaques supported in a haematitic mud matrix.
274/46DR42A1.1 1603617	Homogeneous foram chalk displays diverse range in foram type and size. Other bioclasts present include ostracods, shell debris, echinoid fragment and ?bryozoan. Elongate burrows evident which are lined with manganese and iron oxides. Unconsolidated foram sand infills burrows. Dated as Early to Mid Miocene from nannofossils.
274/47DR43B1.1 1603635	Glauconitic calcarenite consists of bioclastic fragments (<2mm) and medium-grained quartz, felspar, and detrital glauconite grains. Bioclasts include forams, calcareous algae, bryozoan, shells, and calcispheres. Endolithic borings on bioclasts. Nannofossil assemblage dates as Late Pliocene.
274/47DR43C1.1 1603638	Glauconitic calcarenite composed of 70% bioclastic fragments with quartz, felspar, olivine, detrital glauconite, and lithics. Bioclasts include bryozoan, calcareous algae, forams, echinoid spines, calcispheres, coral, and shells. Drusy and sparry calcite cement. Endolithic borings.

6.2.1 Siliciclastic sediments

Diverse terrigenous lithologies found on the Louisiade Plateau and southern Mellish Rise include conglomerates, sandstones, mudstones, and a greywacke. The multi-coloured conglomerates from DR24, DR26, DR27, DR30 and DR42 show pebbles from a mixed sedimentary and igneous source. Pebbles are sub-angular to well rounded, gravel to cobble sized particles composed of quartzose calcarenite, tonalite, quartzofeldspathic greywacke, volcanic breccia, basalt, mudstone, and obsidian. The components in most samples show considerable weathering and generally reflect other lithologies at or near the dredge sites. The specimen from dredge DR24 contains quartz-rich pebbles of tonalite and greywacke implying the provenance to be continental crust which has tectonic and sea level implications for this deep ocean site (>2000 m water depths) (Figure 16E). The sand-sized matrix of the conglomerates is commonly ferruginous and/or calcareous. Bioclastic fragments (bryozoan, shell fragments) have also been incorporated in the specimen from DR26. The poor sorting, the range in grain size and sphericity of particles suggests there was considerable reworking or transport before reaching their final resting place on either a fluvial plain in a river bed or accumulating in a coastal environment. Strongly ferruginised particles in DR26 and DR30 indicate subaerial exposure of the source rocks or while the particles were in transit. Conglomerates are variably cemented by iron oxides, calcite and yellow-red chert. An enigmatic sample from DR42 appears to be a conglomerate composed wholly of light grey subangular mudstone clasts cemented by iron oxides which is feasible as the site also dredged a similar mudstone.

The provenance for the limited number of sandstones dredged on the Mellish Rise and Louisiade Plateau is a mix of siliciclastic, carbonate, and volcanogenic. The litharenite sampled at DR24 is a muddy, fine-grained calcareous sandstone consisting of quartz and felspar grains, lithics, glauconite, and white-orange bioclastic fragments (Figure 16F). A hard quartz-rich calcareous sandstone was also recovered from DR43 which appears to have inclusions of minor bioclastics. The sediments are likely to have accumulated in shelfal setting. An unusual waxy, deeply altered litharenite (DR41) appears to be composed of quartz grains and lithic fragments with iron and manganese oxides deposited as dispersed grains, veins, and dendrites. The waxiness may be due to the presence of montmorillonite derived from the alteration of volcanic ash. Another unusual resinous, labile sandstone from DR17 on the Louisiade Plateau consists largely of one grain type, a yellow-olive green mineral believed to be olivine. Possible quartz or volcanic glass fragments may also be entrained. At this stage of the investigation, the environment of deposition for the variety of sandstones is determined broadly as a fluvial-neritic setting.

A small fragment of highly ferruginised, siliceous greywacke is bound within a 12 cm thick manganese oxide crust from DR37. Quartz grains are evident in the greywacke but there is insufficient specimen to determine much more about its origins.

The most abundant siliciclastics are the mudstones which have been subdivided based on either a terrigenous or a marine source. The pale olive-grey brown mudstones and marls are distinctly marine hemipelagic deposits containing microfossils, terrigenous material, and sometimes bentonite (montmorillonite). These are described with the Cainozoic chalks and siliceous oozes below. The other group of mudstones probably owe their origins to the lateritisation of basalt and other iron-rich rocks. They are invariably brick red in colour, haematitic, and show no obvious bedding development. Thin section observations for samples dredged from DR17, DR21, DR40 and DR41 show the entrainment of sand to pebble-sized particles of muscovite, quartz, felspar, olivine, opaques, lithic grains (basalt, mudstone) as well as unidentified white grains (slides #1603331, #1603552, #1603570 and #1603573). The quartz, muscovite, felspar, and basalt fragments included in the haematitic sandy mudstone at site DR17 suggest the sediment was being sourced from an exposed landmass located nearby, which was most probably composed of both continental and volcanic rocks (Figure 17A). Deep weathering of outcrops rich in ferromagnesian minerals involves lateritisation resulting in clay residues enriched with ferric hydroxides (Blatt et al., 1980; Eggleton, 2001). The haematitic mudstones collected here are believed to be distal deposits of this laterite detritus. The fact that deeply weathered red brown basalts and agglomerate were also retrieved from DR17, DR40 and DR41 lends support to this theory of a lateritised landscape.

Some of the mudstones have preserved trace fossil activity such as the faecal nests and spreiten which are present in the DR40 sample (slide #1603552) and brown spherical structures (up to 1.6 mm wide) which are commonly infilled with mud marginally darker than the matrix (specimen from DR17, slide #1603331).

A pervasive network of fine veins cross-cuts the DR17 mudstone which has been infilled with a light brown cryptocrystalline mineral believed to be siderite due to the high birefringence (Figure 17A). Subsequent blocky cementation occurred with the influx of felspar closing some of the remaining voids.

The mixing of fresh and saline waters results in the rapid deposition of massive muds due to the flocculation of clay particles (Blatt et al., 1980). Hence, the depositional environment for the massive red mudstones is likely to be fluvio-deltaic. The pebbly and sandy mudstones from DR17 and DR41 are believed to have formed as the result of a mud flow due to their diverse range of particle sizes, the lack of bedding, the fact that they are matrix-supported accumulations, and their low degree of sorting.

One light grey mudstone was recovered from DR42 which is relatively homogenous, iron-stained, and contains dispersed coarse white grains believed to be quartz. Generally mudstones that are grey-black in colour indicate a probable carbonaceous material or pyrite content though these small samples are insufficient to ascertain their full composition. This

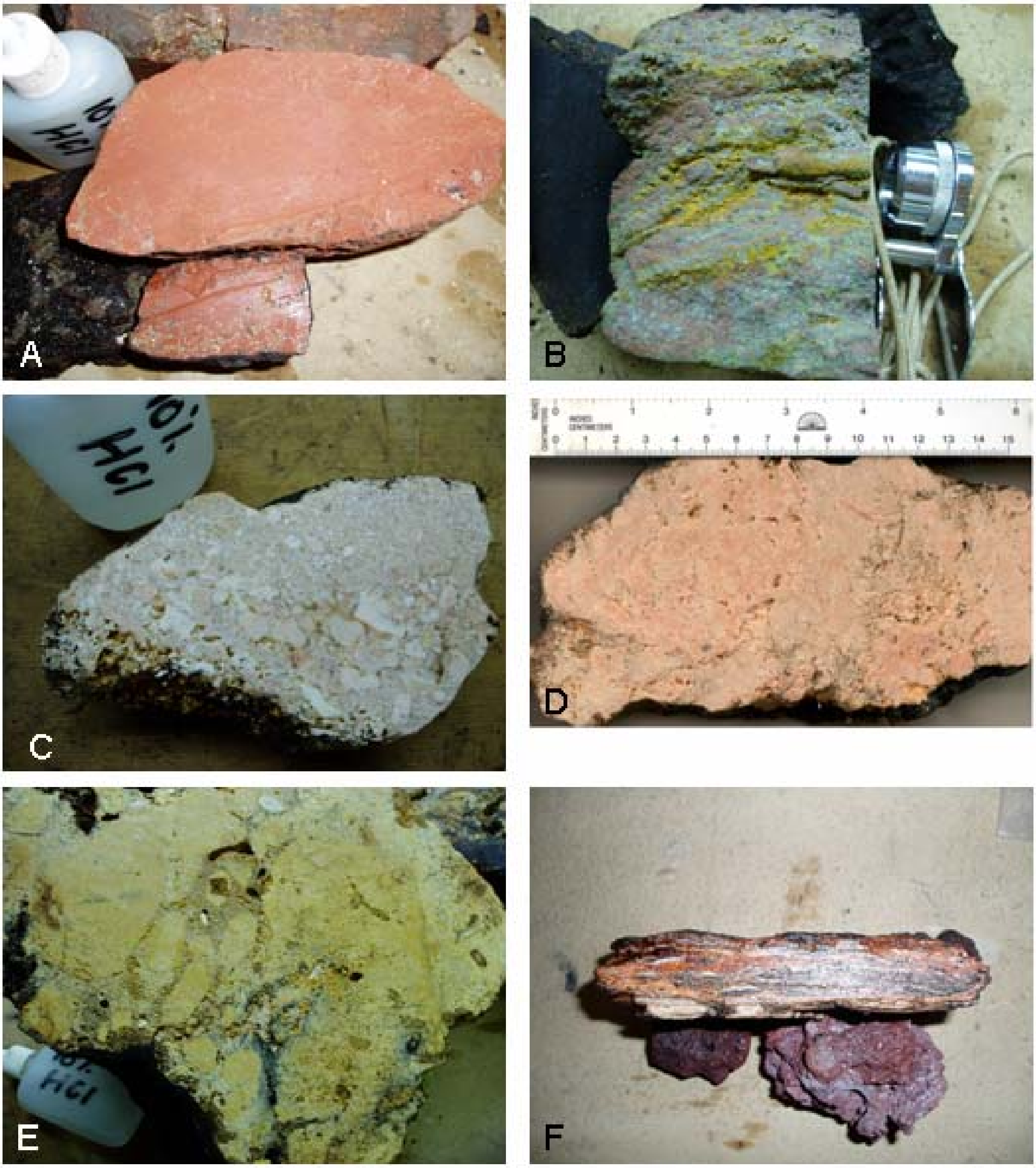

Figure 17. Shipboard photos of freshly cut dredge samples. **A:** massive red sandy mudstone with siderite veins (Louisiade Plateau DR17, Lithology D1; slide #1603331). **B:** multi-coloured sinter deposit from freshwater geothermal pools (Mellish Rise DR24, Lithology D). **C:** high-energy calcarenite (Mellish Rise DR22, Lithology G). **D:** pink algal boundstone detailing the hemispherical oncolites (left) (Mellish Rise DR22, Lithology D). **E:** calcareous conglomerate with black interstitial manganese oxide precipitation (Mellish Ride DR40, Lithology A). **F:** laminated glauconitic carbonates including flat pelecypod valves, orange brown glaucontitic laminae and coquinite (Mellish Rise DR21, Lithology F; slide #1603383). Specimen is 10 cm across.

lithology may have provided the source for the mudstone conglomerate retrieved from the same dredge site.

Observations of the greenish grey bentonitic mudstone at DR40 in thin-section reveals precipitation of a mineral through the mudstone which is silky in crossed nicols and shows patches of optical continuity (slide #1603564). Without the aid of a microprobe or XRD analysis, this mineral is presumed to be montmorillonite which is imparting the green colour to the specimen. No bioclastics were identified so it is likely to have formed in a non-marine to deltaic setting.

6.2.2 Travertine

A single accumulation of travertine (sinter) was recovered from dredge site DR24. Sinter represents a freshwater hydrothermal deposit of carbonate and/or silica which forms by encrusting vegetal remains, porous volcanic rocks or is associated with bacterial growth (Julia, 1983; Chafetz and Folk, 1984). Workers are unclear whether the bacteria are actively involved in precipitating the sinter or whether it is by purely geochemical methods. The specimens are non-calcareous, dense and exhibit some faint layering (Figure 17B). They are mottled pink, blue, purple, white, and yellow. The yellow mineralisation is associated with elongate vughs. According to geomicrobiologist Dr Susan Childers (University of Idaho website[1]), multi-coloured sinter results from the presence of a diversity of bacteria within the matrix. These non-calcareous samples are most likely to be amorphous silica. This sinter is an important find as it confirms the existence of an exposed landmass with an active geothermal environment.

6.2.3 Shallow-marine limestones

Calcarenites are the predominant shallow-water carbonate with subordinate algal boundstone, calcirudite, calcilutite, calcareous conglomerate and an unusual laminated carbonate. Calcarenites were recovered from DR17, DR22, DR24, DR25, DR36, DR40 and DR43 and microfossil examination has returned ages for the samples as Late Paleocene, Late Eocene-Early Oligocene, Late Pliocene and Quaternary. The calcarenites can be divided into very shallow water and deeper shelfal accumulations within the photic zone. The high-energy deposits in shallow water generally contain a variety of well-sorted bioclastic fragments including calcareous algae, bryozoan, echinoid debris, molluscs, coral, calcispheres, encrusting and benthic forams with minor quartz, felspar, olivine and lithic grains (DR17, DR22, DR24, DR36 and DR43). Some of the finer grained calcarenites at DR43 have up to 5% detrital glauconite entrained which gives the sample a grey speckled appearance (slides #1603635 and #1603638). Figure 17C shows a well cemented, high-energy calcarenite from DR22.

The calcarenites that accumulated in deeper shelfal waters as determined by the foram assemblage (sampled at sites DR24 and DR25) have an abundance of benthic foram species but are devoid of planktonic types. The Eocene benthic foraminifera at site DR25 are characteristic of tropical to warm temperate conditions. Other components include bivalves, echinoid debris, gastropods, coralline algae and bryozoan, as well as angular terrigenous material.

The similarity in bioclastic and mineral constituents between the shallow- and deep-water calcarenites emphasises the importance of foraminiferal determinations to provide the palaeo-environment and palaeo-climatic details as well as age dating. Those lithologies with a

[1] See http://www.webpages.uidaho.edu/~childers/.

terrigenous input indicate the carbonate platform was adjacent to a landmass (terrigenous material present at DR24, DR25, DR36, DR43 and DR44).

Only one calcilutite was retrieved (site DR44) which has been dated as Mid-Late Paleocene from the limited nannofossil content. There are mineral grains and probable glauconite though both are hard to distinguish in this fine-grained carbonate. Veins infilled with calcite traverse the specimen.

Other shallow-water carbonates include algal boundstones and calcareous conglomerates. Algal boundstone, recovered from DR22, DR40 and DR41, consists largely of hemispherical growths of coralline algae known as oncolites (Figure 17D). The algal growths help bind the carbonate debris on the reef crest or reef front which are subject to agitatation by waves and currents (James, 1983). These pink coloured oncolites are up to 10 cm wide and are surrounded by buff interstitial bioclastics consisting of bivalves, forams, bryozoan, and echinoid debris. One sample from DR22 has been tentatively dated as Oligocene from its foraminiferal content whereas the weathered and iron-stained specimen from DR41 has a mixture of Pliocene and Pleistocene-Holocene species.

The calcareous conglomerates or rudstones are composed of coarse reef rubble with finer bioclastics forming the matrix (DR22, DR40 and DR44). Wave action has broken up lithified calcarenite into pebble-cobble sized talus and redeposited them on the fore-reef slope with unconsolidated detritus (including pteropods, forams, bryozoan, coralline algae, and bivalves). Figure 17E illustrates the rounded cobbles of calcarenite supported in a finer bioclastic matrix (DR40). The sample from DR44 is a fragment encased within a manganese nodule. Age dating derived from foraminifera and nannofossil assemblages range from ?Oligocene for the specimen at DR22 to mixed Pliocene and Pleistocene- Holocene in DR40 sample. Correspondingly, the older DR22 sample is well cemented compared to those from the other two sites.

All the shallow-water carbonate accumulations tend to be recrystallised or at least well-cemented with sparry calcite. Some well-cemented calcarenites (DR24) and rudstones from DR40 display mouldic porosity (secondary) due to dissolution of some coarser bioclastic material. Very weathered, iron-oxide cemented calcarenite and algal boundstone were collected from sites DR40 and DR41 which have been dated as Pliocene-Holocene by their nannofossil assemblages. The presence of oxidation minerals would suggest these carbonate horizons spent a period subaerially exposed.

A small but fascinating specimen was recovered from dredge DR21 on the southern Mellish Rise (Figure 17F). Thin-section observations of this laminated glauconitic carbonate reveal it to consist of prismatic calcite interlaminated with glauconite layers, micrite, dismicrite, and glauconitic coquinite (slide #1603383). The prismatic calcite is believed to be the valves of a species of flat pelecypod. These small shells and shell fragments are up to 2.5 cm in length. The coquinite is composed of individual calcite prisms derived from the breakdown of the bivalves which has been cemented with glauconite. Further investigation is required to obtain an accurate assessment of the molluscan fossils. The glauconite laminae range in colour from yellow brown to olive green, displaying a mix of cryptocrystalline, radiating and fibrous crystal habits within a single layer. Some micrite and coquinite laminae have entrained angular intraclasts of glauconite signifying consolidated glauconite was a nearby facies. Endolithic borings exist within the glauconite laminae which is evidence for the direct precipitation of glauconite from seawater within the photic zone. The fine-grained components suggest it was a quiet depositional setting with mildly-reducing conditions and low sedimentation rates allowing glauconite to precipitate onto the seafloor.

6.2.4 Cainozoic chalks and siliceous ooze

Both calcareous and siliceous pelagic and hemipelagic rocks have been dredged on the southern Mellish Rise and Louisiade Plateau. The calcareous lithologies include foram nanno chalks and light olive-grey brown marls. Samples of marls were recovered from sites DR31, DR36 and DR44. These hemipelagic deposits have an abundance of foraminifera, both planktonic and benthic, in a terrigenous clay matrix and may also contain nannofossils and radiolaria which has allowed them to be dated (DR31 and DR44 are aged as Late Eocene and Paleocene, respectively). Bioclastic debris identified in the samples include ostracods, echinoid spines, bryozoan, bivalves, gastropods, brachiopods, and siliceous sponge spicules. The depositional setting for all sites is believed to be middle to outer shelf with a terrigenous input from a nearby exposed landmass (Quilty, 2005, this report). The light olive colour of the marl may be due to the presence of glauconite or green phyllosilicates such as montmorillonite after volcanic glass.

Concentrated accumulations of mainly foraminifera with variable contents of nannofossils and radiolaria are known as chalks; these are the most common pelagic lithology recovered from the Mellish Rise. Samples were retrieved from the following dredges: DR13, DR14, DR15, DR19, DR24, DR25, DR36, DR37, DR41 and DR42. Age determinations from microfossil assemblages have dated the range of specimens broadly as Late Paleocene-Early Oligocene, Miocene-Early Pliocene and Pliocene-Holocene. Some Miocene forams have been reworked and incorporated in younger deposits at DR36 and DR37. The oldest chalk beds are from dredges DR13, DR15 and DR19 implying deep water sediments were accumulating here during the Paleocene. However, it must be remembered that seafloor spreading will have relocated the ocean-floor sediments from the original site of deposition. Chalks are commonly white to buff in colour though some deposits are pale olive and speckled partly due to the inclusion of dark green glauconite grains (DR14 and DR15). Other bioclastic material observed includes ostracods, teeth, bryozoan, echinoid debris, sponge spicules, molluscs, and pteropods. There are no bedding features developed in the chalks as the particles tend to be a similar size and have settled through the water column to depths well below regular current activity.

Pebbly chalk adhering to a dolerite sample at DR13 (dated as Eocene-Lower Oligocene) has incorporated angular clasts of chert, chalk, and dolerite ranging from sand sized to 20 mm in length. A similar pebbly chalk with subangular basalt clasts was collected from DR21 adhering to a basalt boulder. It has been dated as Paleocene-Early Oligocene which implies the basalt flow must be at least Early Oligocene in age. Such pebbly pelagic deposits would involve turbulence and possibly the injection of a debris flow.

One chalk fragment removed from a manganese nodule (DR19) appears to be totally altered to an unidentifiable mineral (low birefringence) leaving only pseudomorphed planktonic foram tests (Quilty, 2005, this report). The sample was dredged from a site on the southern margins of the Coral Sea Basin and has been dated as Late Paleocene-Early Eocene from its foraminifera content. This basin developed by rifting which commenced during the latest Cretaceous to Early Eocene (Gaina et al., 1999).

There is evidence of invertebrate burrowing and hardground borings in some samples. A system of elongate horizontal burrows with cylindrical cross-sections was developed in chalks from DR42 which appear to have been constructed prior to lithification (Figure 18A; slide #1603617). The burrows are infilled with unconsolidated foram sand with no sign of an agglutinated wall or diagenetic lining. Post-lithification borings in rocks exposed at the

Figure 18. Shipboard photos of freshly cut dredge samples. **A:** burrowed chalk with foram sand infilling the elongate burrows (Mellish Rise DR42, Lithology A; slide #1603617). **B:** porcellanite (clay-rich siliceous ooze) with dendritic manganese oxide developed along fractures (Mellish Rise DR17, Lithology G). **C:** multi-coloured banded chert showing microfaulting (top layer) (Mellish Rise DR13, Lithology E). **D:** manganese nodule encasing a hyaloclastite fragment. Both botryoidal and laminar MnO growth present with interstitial ooze (Mellih Rise DR19, Lithology C). **E:** manganese nodules (Mellish Rise DR19, Lithology B). **F:** foram nanno ooze recovered from dredge bucket (Mellish Rise DR39, Lithology C). **G:** water-worn basalt boulder (Mellish Rise DR13, Lithology A). **H:** coral hash consisting of a variety of branching corals (Mellish Rise DR27, Lithology C).

seafloor are common and were recovered from sites DR13, DR14, DR24, DR25 and DR42. The recent borings in these hardground surfaces are usually lined with manganese oxides and infilled with unconsolidated foram nanno ooze.

Siliceous claystones or oozes were collected from DR12, DR13, DR14 and DR17 (Figure 18B). Their colours vary from buff to olive brown as well as one reddish yellow specimen. Microfossil examination of the siliceous residue has detected abundant radiolaria in most samples although some are not easily recognisable due to alteration. There is a sparsity of foraminifera except for rare ones in DR12 and only rare nannofossils present in samples from DR12, DR13 and DR14. The nannofossil assemblage has yielded an Early Eocene age for the DR13 sample, a mix of Late Eocene to Early Miocene for DR14 and a Quaternary age for the DR12 specimen. Abundant radiolarians were identified in the DR13 and DR17 specimens and pseudomorphs of radiolaria are present at DR12 and DR14. According to the micropalaeontological observations, the matrix for all these oozes (except DR14) is fine white clay particles believed to be smectite, therefore colour variations between samples may be due to mineral impurities. This clay-rich siliceous ooze is known as porcellanite.

To accumulate these siliceous oozes, upwelling of nutrient and silica rich waters is required to replenish the silica content in the undersaturated surficial waters, resulting in increased plankton productivity (Kennett, 1982). Additionally, water depths for the depositional sites needed to be below the Calcium Compensation Depth (CCD) to allow preservation of the siliceous tests. Takahashi et al. (1979) have calculated the present day CCD in the southern Pacific Ocean to be at approximately 3500 m (Findlay and Howe, 2005, this report). Current depths for the DR12, DR13 and DR14 dredged sites are 2600 m, 2750-2900 m, and 2400-2900 m, respectively, indicating possible uplift or crustal rebound for this part of the Mellish Rise to explain their occurrence in shallower waters. Alternately, the CCD during the Tertiary may have been at a different level which is feasible since its present day level fluctuates between ocean basins due to differences in sea water properties and bathymetry (Kennett, 1982). One sample from DR17 has echinoid spines and bone fragments which are not generally transported to the bathyal water depths. Some siliceous claystones have a waxy feel which is characteristic of the mineral montmorillonite (eg. sample from DR14). Further sampling may assist in understanding the development and distribution of these porcellanites across the ocean floor.

One cobble-sized fragment of multi-coloured banded chert was retrieved from DR13 on the Mellish Rise (Figure 18C). Individual beds and laminae are evident due to contrasting colours of brown, green, pinkish brown, white, and yellow. It is non-calcareous and exhibits conchoidal fracturing. The uppermost green laminae, displays micro-fracturing and displacement. The development of chert is not clearly understood and several theories exist to explain these hard siliceous deposits: volcanogenic, diagenetic smectite-illite alteration, or a biogenic silica origin (Kennett, 1982). The latter is the most accepted theory based on Deep-Sea Drilling Program (DSDP) results. With further analysis, this specimen may provide valuable information to assist in understanding their formation.

6.2.5 Quaternary sediments

The Quaternary accumulations are a diverse mix. Foram nanno ooze, the ubiquitous manganese crusts and nodules, pumice stones, water worn cobbles-boulders and coral hash were collected from dredges across the Mellish Rise and Louisiade Plateau.

Manganese crusts have encrusted rocks and bioclasts exposed at the seafloor at nearly every dredge site (DR12-DR19, DR21-DR27, DR31, DR36-DR37 and DR39-DR44). Massive black crusts up to 20 cm thick have been described at DR12 though most crusts are less than 10 cm thick. Precipitation of these crusts occurs as very fine laminae or botryoidal and micro-botryoidal growth forms which appear to incorporate small amounts of ooze interstitially and surficially into their framework during growth (Figure 18D). Manganese nodules consist of concentric laminae which completely envelop a central nucleus of variable composition (Kennett, 1982). Nodules ranging in width between 0.5 cm and 50 cm were recovered though most average less than 4 cm across. Slabbed larger nodules are shown to encase angular to sub-rounded lithic fragments of calcarenite, chalk, porcellanite, basalt, lithic tuff or hyaloclastite. Two kilos of small nodules were recovered from DR15 suggesting a nodule field exists at this site (Figure 18E).

Many lithologies are recorded as having dendritic and fine-grained manganese oxides disseminated through the matrix such as, for example, the grey speckled calcarenites at DR43. Calcareous conglomerate at DR40 displays preferential precipitation of the manganese oxide grains around the margins of the cobbles.

There is still debate amongst experts regarding aspects of the mode of formation of manganese nodules. All are in agreement that precipitation occurs slowly in a setting with very low sedimentation rates or even non-deposition (Kennett, 1982). Growth rates for deep water have been determined using radiometric dating and are generally between 1 and 4 mm per 1,000,000 years. Nodule fields, as present at DR15, are believed to indicate agitation by either strong bottom currents or rolling by benthic organisms.

Pleistocene-Holocene-aged foram nanno oozes were sampled at many sites and consist of very pale brown unconsolidated sediment (DR14, DR16, DR18, DR21, DR22, DR25, DR30, DR31, DR37, DR39 and DR41). Nannofossil assemblages observed at some sites were mixes of Tertiary and Quaternary species: DR14 incorporates Paleocene to Holocene species and DR37 has Miocene-Holocene species (Findlay and Howe, 2005, this report). The mixed assemblages indicate that either there were pelagic deposits accumulating over a long period of time at these sites or that dredging and/or current activity have combined unconsolidated sediments. Figure 18F is an example of the calcareous ooze taken from the DR39 dredge bucket.

The shape of several rock samples collected from DR13 and DR23 are distinctly water worn cobbles and boulders. The basalt boulders from DR13 are coated in a manganese veneer or thin crust and the largest has a maximum dimension of 35 cm (Figure 18G). The boulders form an uncemented accumulation of subangular to well-rounded fragments which would have been reworked by river currents or wave action when this was once the location of a shallow coastal environment (i.e. fluvial to littoral zone). The samples were dredged from over 2750 m of water which implies there has been a lot of subsidence and/or relative sea level rise at the site since the boulders were emplaced. Dredge DR23 has retrieved a single well-rounded cobble approximately 5 cm long which is composed of hyaloclastite.

Coral hash or uncemented bioclastic accumulations have been recovered from DR13, DR27 and DR41 and consist of a variety of coral species in a light brown sand. Nannofossils have been extracted from the calcareous residue in DR27 giving a Pleistocene-Holocene date for the sample (Findlay and Howe, 2005, this report). The coral fragments are individual branched varieties including black coral, bamboo coral, and *Corallium* sp (Figure 18H). The coral is coated with a manganese veneer however broken pieces reveal a white-pink interior and display evidence of fine burrowing. The largest fragments are 25 cm in length.

Pumice stones were sampled at DR12, DR13, DR15, DR30, DR36, DR40 and DR43, however, it is difficult to determine whether they are associated with these sites or have merely floated in from other recent volcanic eruptions. The fragments ranged up to 12 cm in length and they are greyish white to light grey in colour.

6.3 Conclusions

Detailed examination of the sedimentary rocks and microfossil assemblages for the Mellish Rise and Louisiade Plateau has resulted in the identification of several exposed land surfaces. The fact that sinter deposits recovered at DR24 require freshwater as well as vegetal or bacterial growth for their precipitation is good evidence for an exposed landmass, possibly with active geothermal pools. Microfossil examinations have also identified deposition of both shallow- and deeper-water quartzose calcarenites at this site. The shallow quartzose calcarenites (tentatively dated as ?Late Eocene) are likely to have been part of a reef complex on the inner shelf fringing this landmass. Furthermore, the quartz-rich lithologies (tonalite, quartzofeldspathic greywacke) which are present in conglomerates also indicate a continental provenance. Hence, it is postulated that this exposed landmass was part of a microcontinent that has rifted from continental Australia during the opening of the adjacent ocean basins.

Similarly, site DR17 on the Louisiade Plateau was part of a volcanic terrain which probably emerged above sea level during the Late Cretaceous or Tertiary. Subaerial exposure of the landscape resulted in the laterisation of basalts and other iron-rich lithologies. The deep weathering and soil development of the volcanic rocks would have been the source for the haematitic particles that accumulated as iron-stained mudstones in fluvial and coastal areas. The mudstones have entrained very coarse sand-sized quartz and muscovite grains implying there may have been a continental source as well. If this interpretation of the site is correct, then there is a great difference between the current water depth at over 3 km and the original depositional site close to sea level. Other haematitic bioturbated and sandy mudstones have been collected at sites DR40 and DR41 implying their formation may have also been associated with nearby exposed land. Deeply weathered red brown-blue grey volcanics were recovered from both sites which could well be the precursor of these haematitic mudstones. The fact that this segment of ocean floor (now located at the DR40 site) was once elevated above sea level is supported by the sampling of calcareous conglomerate, a shallow reef facies, at the site. The shallow depths required for reef development contrast with its present day depth of approximately 2000 m.

Elevated or exposed landmasses are also evident at DR22, DR36 and DR43 where very shallow calcarenites with a terrigenous content and calcareous conglomerates have been deposited. The calcarenite sample from DR43 has been dated as Late Pliocene. Although it is not known whether these carbonates developed during different time periods, they nevertheless reveal an association with barrier or fringing reef complexes, inferring shallow water environments once prevailed at these sites.

The ages of reef lithologies vary from probable Paleocene at DR17 and DR44, to Eocene-?Oligocene at DR22, DR24 and DR25, and then Pliocene to Holocene at sites DR40, DR41 and DR43. The age dates are controlled by dredging locations and reefs may have existed at other times. However, the ages of known reefal development in the region agree broadly with the conclusions of Davies et al. (1989) work on carbonate platforms and sea water temperatures through the Tertiary.

Chalks have accumulated on the seafloor in this region from as early as the Late Paleocene at DR13, DR15 and DR19. Deposition continued during the Eocene to Early Oligocene as evidenced from chalks collected from DR13 and DR25. Other chalks from sites DR41 and DR42 have been dated as Early to Middle Miocene. A Late Pliocene foram assemblage was identified in the chalk samples from DR36 and DR37. Hence, it appears bathyal water depths have prevailed throughout the Tertiary at the various dredge sites.

The siliceous oozes or porcellanites are the deepest-water facies recovered from the Mellish Rise. The predominantly radiolarian microfossil content indicates deposition occurred below the CCD (currently at approximately 3500 m) where preservation of calcareous planktonic microfossils is negligible. The siliceous rocks were retrieved from sites DR12, DR13 and DR14 and included a single specimen of chert. The ages of the porcellanites are Quaternary, Early Eocene, and Early Miocene, respectively. Deposition during the Early Eocene would correspond with the global sea level high (Vail et al., 1977). Curiously, this siliceous facies was recovered with some waterworn boulders of basalt at DR13 implying the site became a shallow-water environment during its geological history. These high energy conditions may have developed during the Late Oligocene when there was a major drop in global sea level. The littoral accumulations have since been drowned by the progressive rise in relative sea level to its current depth at over 2750 m.

A condensed deposit of glauconitic laminated carbonates was dredged from site DR21 and contains glauconite laminae which appear to have precipitated directly from seawater as there are clasts of the layer incorporated in the overlying laminae. Glauconite is also present cementing the calcite prisms in the adjacent coquinite layers. This is the only example of such a deposit on this voyage. The prismatic calcite laminae in this specimen are believed to be valves of a flat pelecypod.

The identification of exposed volcanic terrains on the southern Mellish Rise and Louisiade Plateau does not exclude the existence of continental crust forming the base to these landmasses at DR17, DR22, DR36, DR40, DR41 and DR43. The occurrence of quartz-rich calcareous sandstone at DR43 lends support to this idea. Extensive lateritic horizons have been mapped along the entire east coast of Queensland from the southeast to Aurukun (Day et al., 1983). Their development extended from the Oligocene to at least the Pliocene in some regions, and partly correlates with an Oligocene hiatus identifiable both on land and offshore in the marine sequences.

It is also important to realise that most dredge sites are not in their original depositional site due to the rifting of microcontinents from continental Australia and the creation of new oceanic crust in between. Hence, the unravelling of the stratigraphic sequence in this region has been complicated by not only by seafloor spreading but also by major fluctuations in sea level during the Cainozoic. However, examination of foraminiferal assemblages has been invaluable in providing further lithological details, palaeo-water depths and the prevailing climate during deposition.

7. IGNEOUS PETROLOGY

As detailed in Chapters 5 and 6, quartzofeldspathic breccia, volcaniclastic[2] and pyroclastic rocks were dredged from the Kenn Plateau; hyaloclasite and dolerite were dredged on the Mellish Rise; while basalt was dredged in both terranes. This chapter describes the petrology of these igneous rocks, which are frequently altered.

7.1 Hydrothermal alteration

Igneous rocks from the Mellish Rise have pervasively been affected by seawater infiltration and low temperature alteration (Figure 19). The most pristine samples have only been marginally affected by alteration, with original textures preserved. In cases of extensive alteration, primary fabrics are almost never entirely obscured, even when primary minerals have been completely replaced. The publications of Schramm (2004) and Walton and Schiffman (2003) were valuable references with respect to indentifying alteration textures and minerals. General patterns of alteration are described here, and will be referred to in the text for individual lithological units below. The result is in keeping with Cann (1979) who recognized five different mineral assemblage facies (two of which are recognized in the Mellish Rise) in oceanic igneous rocks recovered by dredging and drilling.

The mineral assemblages of the igneous rocks are the result of brownstone and zeolite facies alteration. Brownstone facies alteration is the result of low temperature ocean floor weathering or hydrothermal alteration (cool), while zeolite facies minerals occur when temperatures get to about 50-100°C. In the case of brownstone minerals in the study area, palagonite alteration of glass is common. It is often associated with the zeolite mineral phillipsite, and less commonly the zeolite chabazite, as well as calcite. The mineral iddingsite is a mixture of various hydrous iron and magnesium silicates, and is a common alteration product of olivine. Though not a conventionally classified mineral, iddingsite is widely referred to as such in the literature on seafloor alteration of basalt. Iddingsite pseudomorphs of olivine are common, but is sometimes eventually replaced by fine-grained celadonite, and the zeolite mineral – saponite, a common progression with respect to vesicle mineral infilling on the seafloor (Schramm, 2004).

In many of the most heavily-altered samples, plagioclase and clinopyroxene may still be present. Clinopyroxene is unaffected by zeolite facies alteration, while plagioclase at times is at least partially altered to saponite.

The extent of alteration is variable, and may be expressed as a continuum between extremely altered, and a few fresh samples. The alteration has been assessed on a scale from 1 to 10, where 1 is a fresh sample (see Appendix 5 - Table 1: alteration index).

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[2] The term 'volcaniclastic' refers broadly to any clastic rock that contains volcanic material, in any percentage. Pyroclastic and hyaloclastic rock types are grouped beneath volcaniclastic. Pyroclastic is a more specific term, referring to a rock that is formed by the accumulation of fragments of volcanic rock scattered by a volcanic eruption. Hyaloclastite is a specific type of pyroclastic deposit, which forms when magma flows into water, consequently shattering into angular fragments.

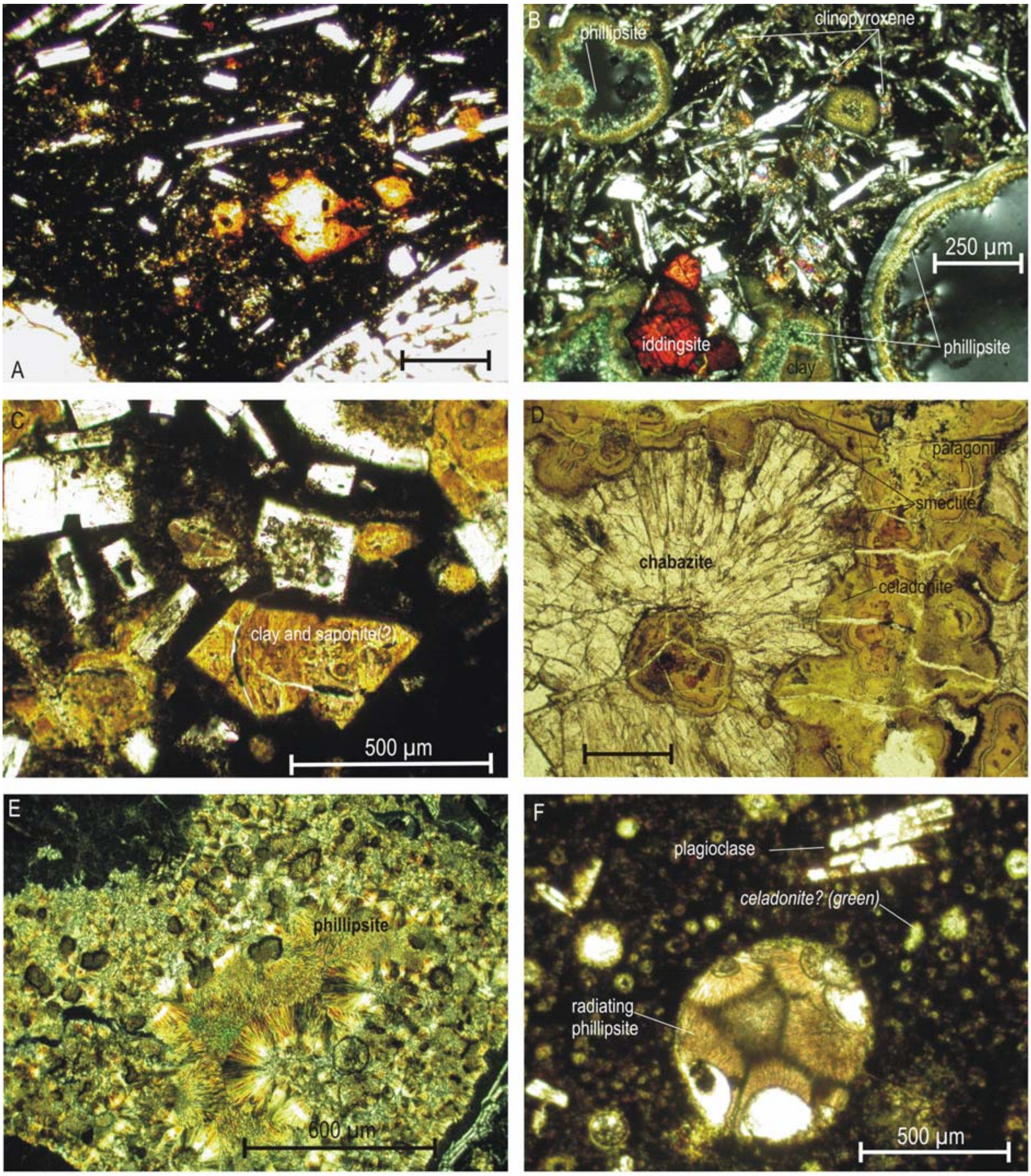


Figure 19. **A:** DR08-B1.1 iddingsite pseudomorphing olivine in basalt (PPL). **B:** DR17-B2.2 zeolites infilling vesicles in relatively fresh basalt (XPL). **C:** DR08-B1.1 fine-grained alteration of olivine (PPL). Fine-grained minerals may be celadonite and saponite (Schramm, 2004) (PPL). **D:** DR39-A1.1 chabazite filling space in hyaloclastite, with smectite and celadonite (PPL). **E:** DR14-D1.1 radiating phillipsite alteration of volcanic glass (XPL). **F:** DR14-D1.1 high-altered basalt. Vesicle filled with radiating phillipsite (PPL).

Table 10. Summary of alterations illustrated in Figure 19.

Original mineral	Brownstone facies	Zeolite facies	Comment
Glass	Celadonite, phillipsite, smectite	Saponite, occasionally chabazite	Palagonite is a term used to denote the alteration of basaltic glass (devitrification)
Olivine	Iddingsite (common)	Saponite	Iddingsite is not recognized as an official mineral
Plagioclase	not seen	Minor saponite, possibly orthoclase	
Clinopyroxene (augite)	-	-	Not recognized to have undergone alteration.

7.2 Quartzofeldspathic breccia with volcanic clasts

Dredged from the Selfridge Rise at Site 11 (Figure 5), this sample (DR11-A1.1, Figure 20) is an unusual specimen. Part of the thin section is brecciated quartzite (with quartz clasts up to 1 cm) though grains of plagioclase indicate that it is impure[3]. The matrix varies from quartz-rich to altered fine-grained green and grey, and there are several rounded highly-altered basalt fragments. Figure 20 shows a portion of the rock, with angular quartz fragments in finer-grained crystalline quartz (that appear almost interlocking), and a rounded clast of altered volcanic rock (basalt?). One of the unusual features of this specimen is the presence of sub-rounded quartz and plagioclase, rounded volcanic clasts and broken up and angular quartz (and a few clasts of unknown rock type). Quartz and sulfide-oxide veins cut all previously described features.

7.3 Volcaniclastics

The term 'volcaniclastic' (see Appendix 5 - Table 1) is used with reference to fragmental rocks that contain volcanic clasts. A more narrow classification for those samples is precluded

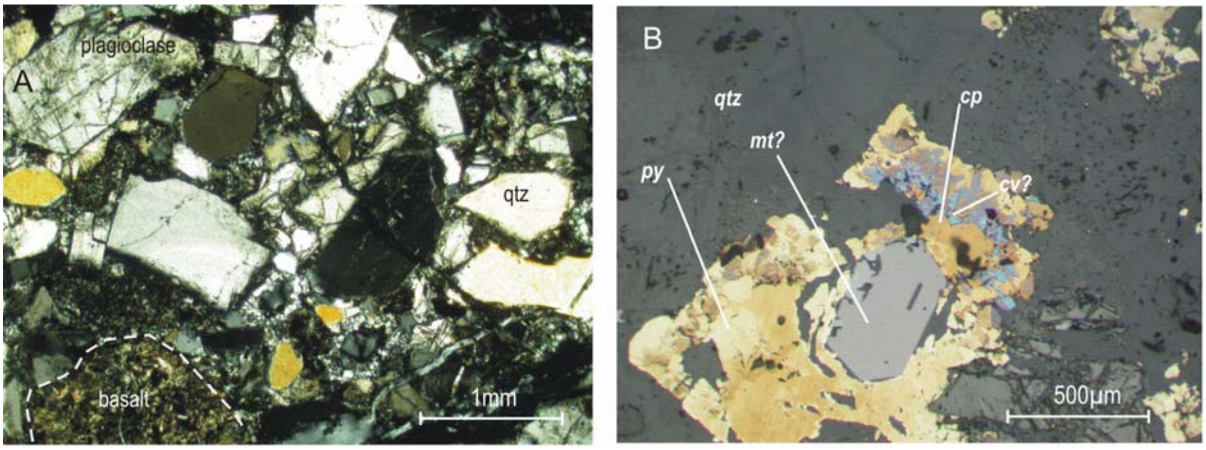


Figure 20. Sample DR11-A1.1 quartzofeldspathic breccia from the Selfridge Rise. **A**: large angular quartz fragments with interstitial granular fine-grained quartz, and other material. Note rounded volcanic fragment and quartz veining (cross-polarised light). Lower left-hand corner shows rounded and highly-altered clast of basalt. **B:** sulphide and oxide minerals cutting breccia; qtz=quartz, py=pyrite, cp=chalcopyrite, cv=covellite, mt=magnetite.

[3] Thin section analysis was made difficult because of the anomalous thickness of the slide.

in this study by a combination of reworking and alteration.

Figures 21 and 22 are handsample and photomicrographs, respectively, of volcaniclastic and pyroclastic rocks. The four volcaniclastic specimens identified were dredged from the Kenn Plateau (the Selfridge Rise and the Coriolis Ridge). All of them have been affected by intense zeolite mineral alteration, to the point where many of the original textures within two of the samples from the Selfridge Rise have been significantly obscured.

This collection of rocks consists almost entirely of basalt fragments in a fine-grained matrix. On the whole, the matrix shows indications of post-eruptive disturbance. Rounded calcite (Figure 22) and, less commonly, quartz, comprising part to all of the matrix of several samples, means that basalt fragments have at some point been subjected to sedimentary reworking. The grey-green, fine-grained altered matrix in three samples is potentially volcanic. However, in one case, the matrix is not uniformly alterated and contains quartz and calcite. In the remaining two samples, the high degree of alteration precludes confirmation of the nature of the original unaltered rock type (pyroclastic?).

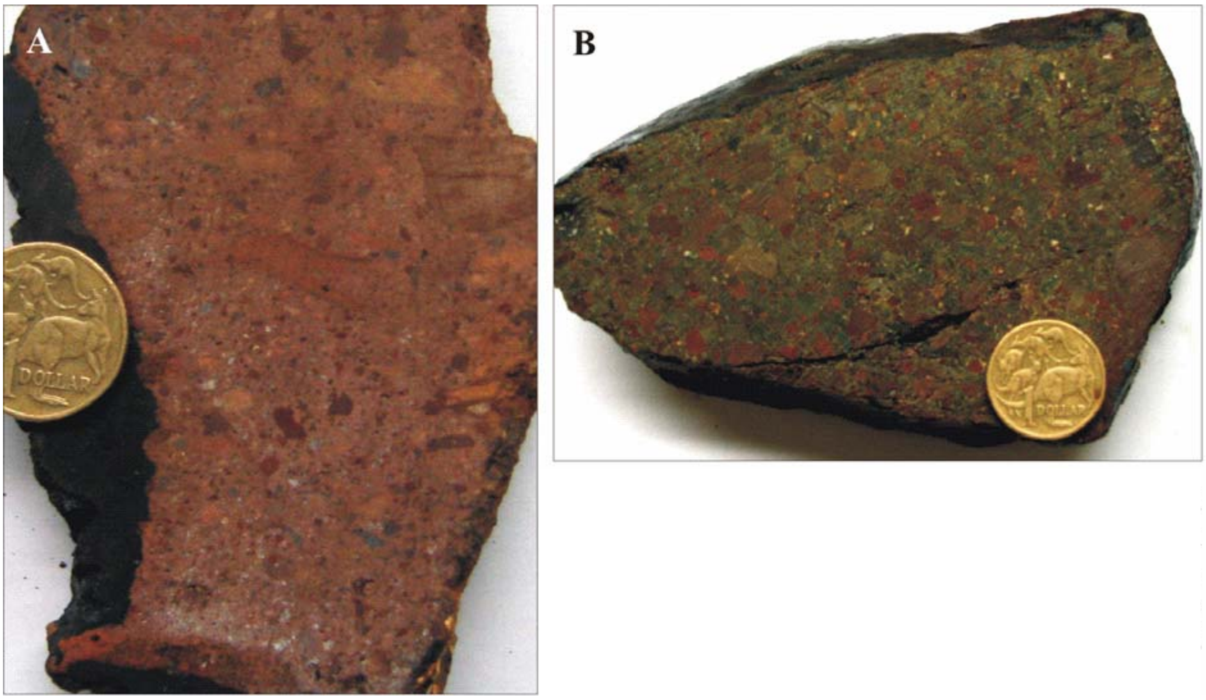


Figure 21. **A:** DR08-G1.1 matrix-supported pyroclastic from the Coriolis Ridge (Kenn Plateau) with a homogeneous even-grained matrix. **B:** DR11-B1.1 clast-supported volcaniclastic from the Selfridge Rise (Kenn Plateau) where matrix is heterogeneous in composition and alteration.

With respect to matrix-to-clast proportion, these volcaniclastics are similar to the pyroclastic lithology described below (with one exception – DR11-B1.1). Sample DR11-B1.1 is clast-supported and interstitial material consists variably of granular quartz grains and fine-grained grey-green alteration.

7.4 Pyroclastics

Five pyroclastic samples were identified, all from the Kenn Plateau. Pyroclastic units are characterized by fragments of volcanic rock (basalt) and plagioclase megacrysts within a relatively homogeneous, finer-grained matrix normally comprising more than half of the lithology in thin section. Most clasts are well smoothed; the extent of basalt clast weathering is variable, but always moderately high. Plagioclase grains show disequilibrium textures and mottled and corroded edges (Figure 22). Palagonite was found in sample DR08-C3.1 forming a minor (but significant) portion of the clast population. One clast of 0.8 cm coral was noticed in hand specimen (sample DR08-G1.1). The matrix in all samples is devitrified, though of normally constant composition.

Several fragments within pyroclastic units exhibit evidence of welding (Figure 22). Rounded and mottled edges of large (0.5 mm) plagioclase grains may also indicate welding. However, the degree of matrix alteration within all pyroclastic samples makes it difficult to accurately

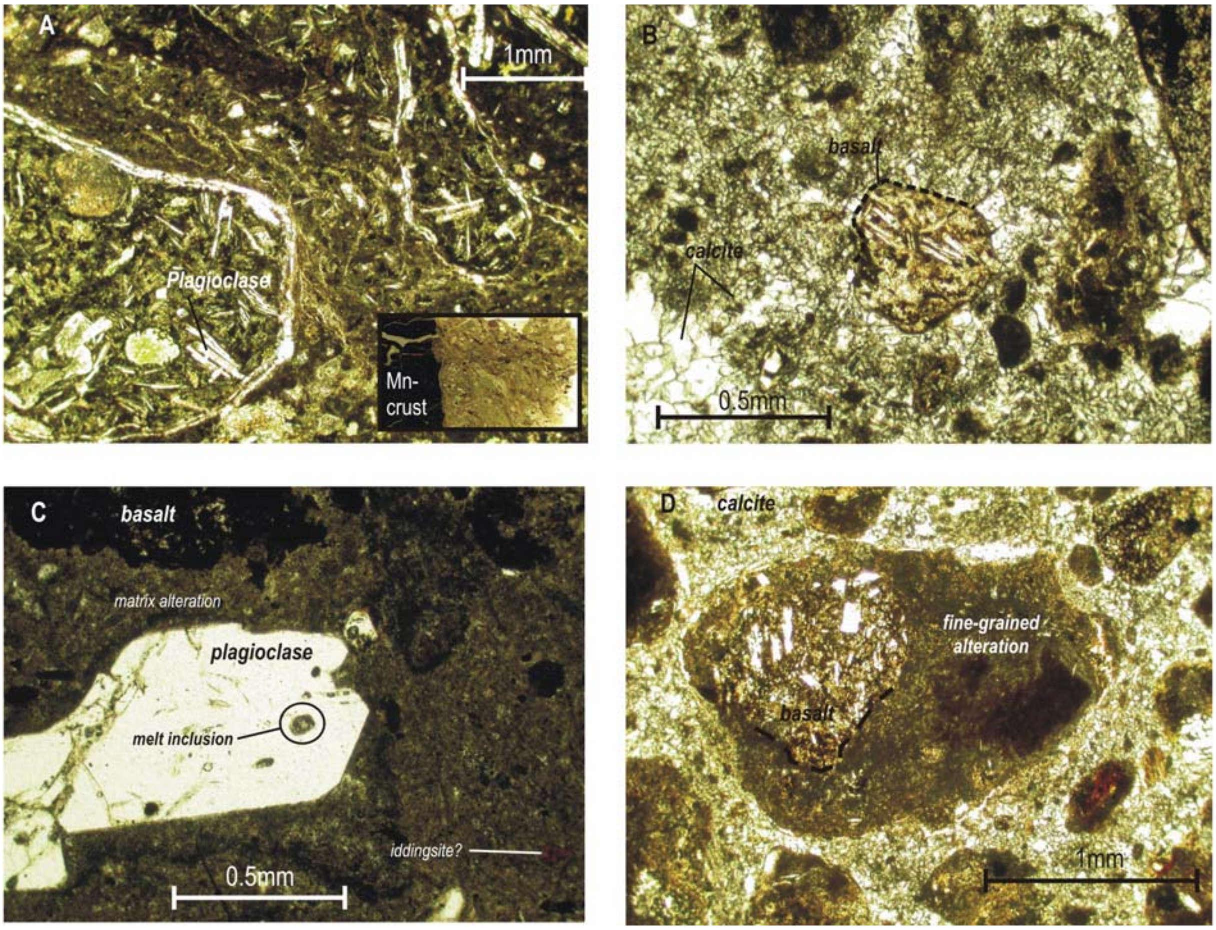


Figure 22. Volcaniclastic and pyroclastic photomicrographs (PPL). **A:** DR11-C1.1 pyroclastic. Heavily altered specimen of welded basalt clasts with basalt matrix. Inset photo is thin section to show pyroclastic flow textures remnant from deposition despite alteration. **B:** DR07-A1.1 volcaniclastic. Matrix dominated by rounded calcite grains (calcareous sandstone) indicating unit was reworked (subsequent to ?pyroclastic event). **C:** DR08-G1.1 pyroclastic. Melt inclusion in plagioclase. **D:** DR08-A1.1 volcaniclastic. Central clast within heterogeneous matrix. Matrix is mainly calcite with a few quartz grains. Central clast comprises a basalt (upper left) and fine-grained alteration, suggesting that originally the clast formed part of a pyroclastic rock similar to DR08-G1.1.

infer what the matrix once was – i.e., whether certain units are tuffs, with an altered ash matrix. In addition, some of the corroded grains also contain melt inclusions (Figure 22).

The fragmental units (volcaniclastic and pyroclastic) on the Kenn Plateau have been strongly altered. In the least altered sample, glass has been palagonatized. Basalt and andesite, though less common lithologies, were more resistant to alteration, probably reflecting that pyroclastic and volcanic units are more susceptible to fluid infiltration and alteration.

7.5 Hyaloclastites

There are three hyaloclastite samples (including rock types listed as basaltic hyaloclastite, hyaloclastic basalt, palagonatized glass) from the Mellish Rise. They are genetically related to Mellish Rise basalt.

Glass in the hyalocastite is altered to palagonite. Celadonite, often located within voids, can also be identified in the groundmass of several samples, along with fine-grained smectite. Chabazite, another pore-filling a zeolite mineral, is found along with radiating blades of phillipsite, along zones of palagonitic alteration in hyaloclastite (Figure 19D). Figure 23 shows basalt from DR17-C1.1 with hyaloclastic fragmentation. Basalt clasts are broken up within devitrified glass.

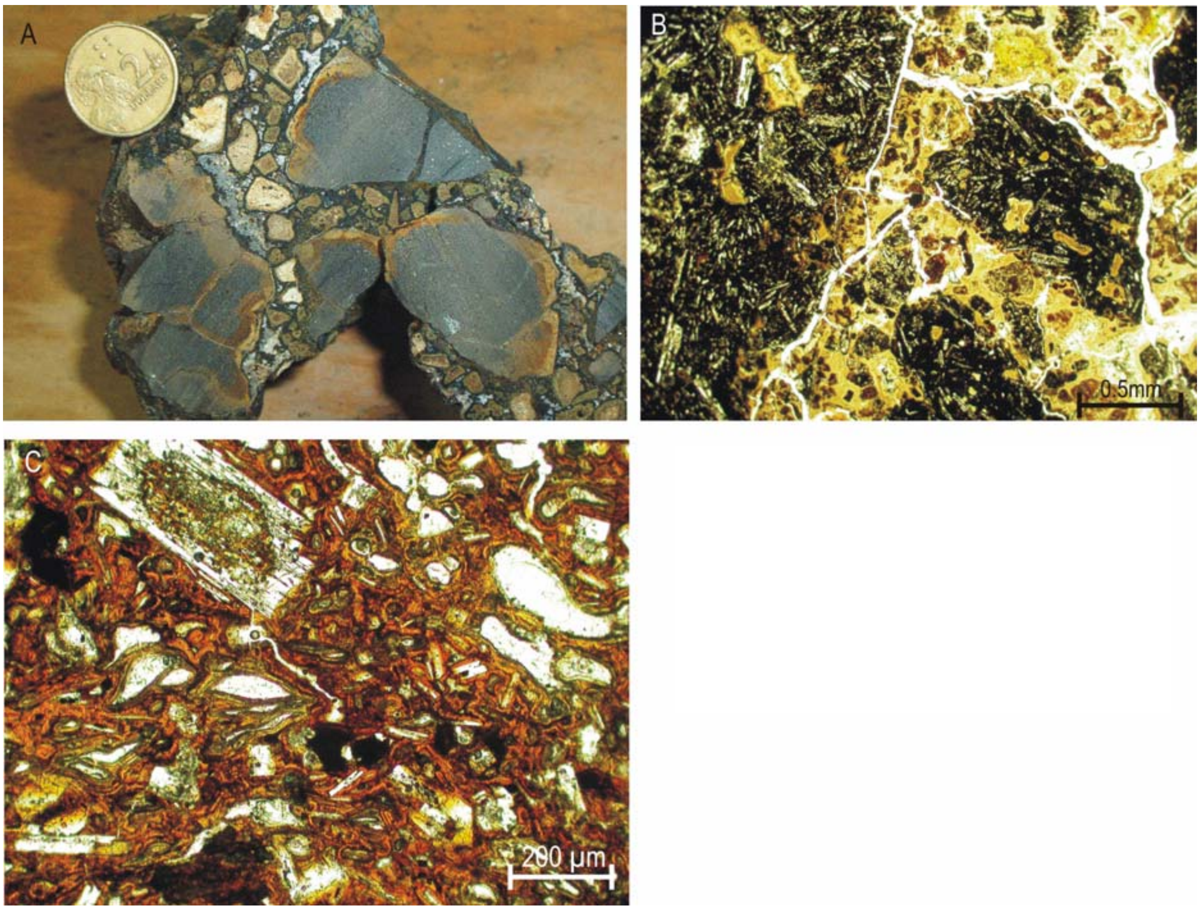


Figure 23. Basaltic hyaloclastite. A: handsample. B: DR17-A1.1 fragments of basalt in palagonitized glass. C: DR25-A1.1 deformed vesicles (and plagioclase) in palagonite.

7.6 Basalts

Basaltic rock types are the most abundant igneous unit recovered from the dredging, and they also dominate the clast-types within all of the above fragmental samples. Both the Kenn Plateau and the Mellish Rise dredging recovered basaltic lithological units.

Olivine is generally altered to iddingsite. In many cases, skeletal olivine has been completely pseudomorphed by iddingsite. The basaltic matrix is rarely pristine: in almost all samples (with one exception), the matrix has been altered to fine-grained brown, grey and green minerals, that were identified in some cases as smectite, celadonite, and a zeolite mineral (likely saponite). Celadonite and phillipsite were identified within several vesicles (Figure 19F).

Plagioclase is always present. Typically, it forms lath-shaped crystals in devitrified basaltic matrices. Alteration of plagioclase does occur when suitably intense. However, even when alteration has been intense, plagioclase generally preserves basaltic texture. Sometimes, it forms large subophitic structures with iddingsite or clinopyroxene (Figure 24). Plagioclase megacrysts can be up to ~1 cm in length.

Clinopyroxene is the third common crystalline component of basalts. Like plagioclase it can form large phenocrysts on its own and subophitic with plagioclase. Less commonly, it can be

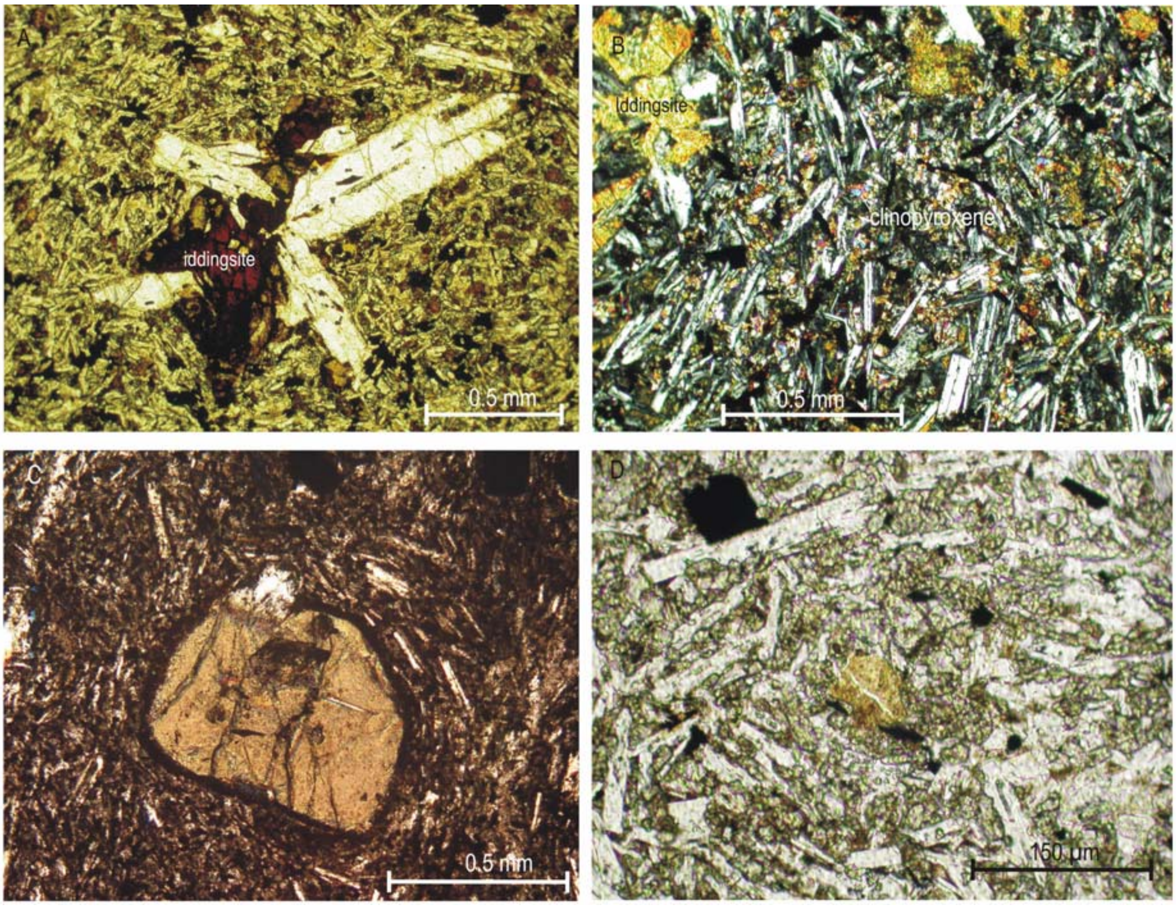


Figure 24. **A:** DR14-E1.1 subophitic plagioclase and iddingsite (PPL). **B:** DR41-E2.1 clinopyroxene-rich basalt (XPL). **C:** DR08-D1.1 clinopyrozene megacryst in basalt (XPL). **D:** DR15-A1.1 clinopyroxene-rich basalt with palagonite fragment.

found as a disseminated component of certain samples. In three samples (from the Mellish Rise) clinopyroxene dominates the matrix with plagioclase. These are quite fresh samples because clinopyroxene is immune to the low temperature hydrothermal alteration prevalent in this suite of rocks.

Opaque minerals are always present. Dominantly, they have the morphology of magnetite, though ilmenite was found in one thin section.

Pristine basaltic glass was found in sample DR30-A1.1 (Figure 25), along a seamount chain (Tasmantid?) on the southern Mellish Rise. It contains numerous lath-shaped plagioclase crystals, as well as fresh olivine. The remainder of the thin section has been subject to some alteration: glass has been palagonatized, and olivine present throughout shows characteristic skeletal textures, and is beginning to be pseudomorphed by iddingsite.

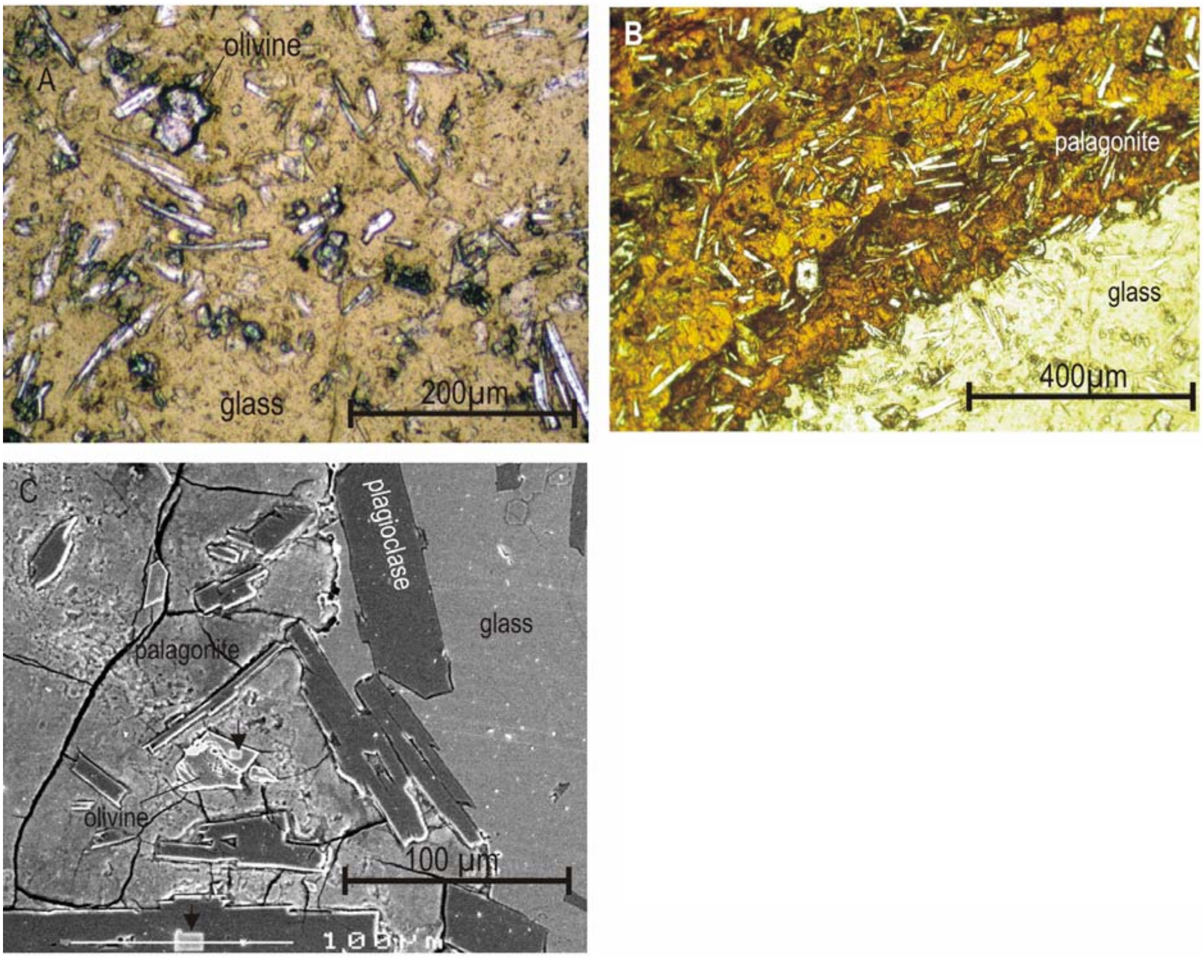


Figure 25. Sample DR30-A1.1. **A+B:** Glass analyses plotted in Figure 26 were taken from this area (PPL). **C:** Secondary electron image (by SEM). The arrow shows the location of two spectra collected in plagioclase and in olivine. Analyses were made over a rectangular area, in between glass analyses, and can be seen in this photo. Glass is smooth while palagonite is fractured and has a mottled appearance.

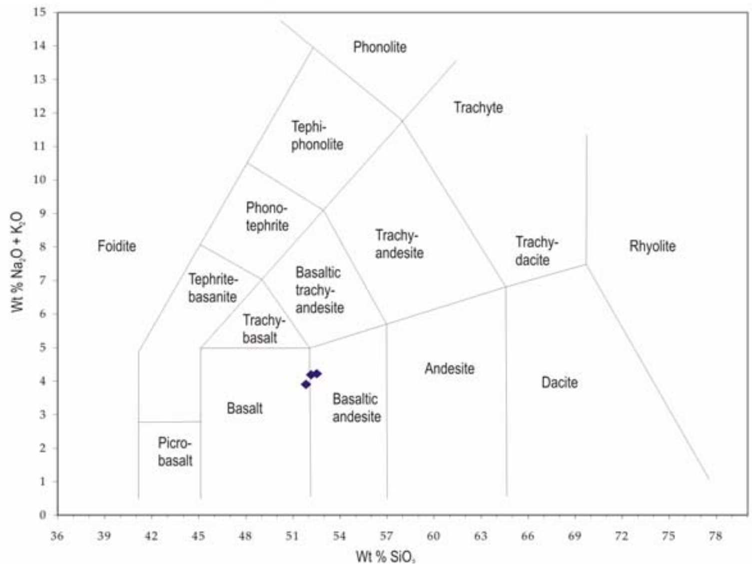


Figure 26. Classification of analysed basalt glass from sample DR30-A1.1 (following the classification scheme of Lebas et al., 1986). Analyses plot along the basalt-basalt andesite. However, the high Ti content (Appendix 5 - Table 3) is consistent with an interpretation for alkaline basalt.

Glass and palagonite analyses are listed in Appendix 5 - Table 2. Glasses plotted on Figure 26 lie along the boundary between alkali basalt and basaltic andesite. However, the high Ti content of the basalts supports the interpretation of these as alkali basalts.

7.7 Andesite

Only dredge sample DR08 was found to be andesitic in composition, with subophitic plagioclase-clinopyroxene. It may be closely related to basalt, as two separate pieces from the same lithological classification (DR08-D1 and D2) were classified differently. Lithology D2 (the andesite) was separated out owing to the dominance of plagioclase.

7.8 Dolerites

Three dolerites were recovered from the Mellish Rise. Commonly associated with basaltic units, much coarser-grained dolerites are often more well-preserved. Dolerites are characterized by subophitic textured plagioclase and clinopyroxene (Figure 27). The remaining groundmass in the dolerite samples has undergone weathering. Fresh olivine has not been found, though iddingsite is present in some samples. The apparent preferential freshness of dolerite units (alteration index normally of 3) is due to the fact that coarse, interlocking, plagioclase and clinopyroxene (augite) modally dominate specimens and are resistant to low temperature alteration so prevalent in the basalts.

7.9 Discussion

In the samples studied to date, volcaniclastic and pyroclastic lithological units are restricted to the Kenn Plateau, hyaloclastite and dolerite are found only on the Mellish Rise, while basalt is common to both terranes, though only a few basalt or andesite samples were recovered from dredging along the Kenn Plateau.

The fragmental units on the Kenn Plateau are evidence of a rift-related volcanic event. Regionally, correlation may be possible with an Early Cretaceous pyroclastic event as seen in the Whitsunday Volcanic Province (WVP; Bryan et al., 1997). However, the WVP pyroclastic volcanics are reportedly siliceous, unlike those of the Kenn Plateau, where one felsic volcanic studied in thin section is andesitic, varying to basalt. At this stage, we believe it is more likely that Kenn Plateau rift volcanics may be coeval Late Cretaceous rifting as seen in the Marion Plateau volcanics, which consist of highly altered lava flows and volcaniclastics (Isern et al., 2002).

Of the Mellish Rise volcanics (altered basalt flows, dolerite, and hyaloclastite), basalt and hyaloclastite from the seamounts (DR30, DR36 and DR39) are less altered on average (including the sample of fresh basaltic glass).

Possible future work on the igneous rock samples includes:

1. Major and trace element bulk rock geochemistry of that would help to differentiate further between the basaltic rocks.

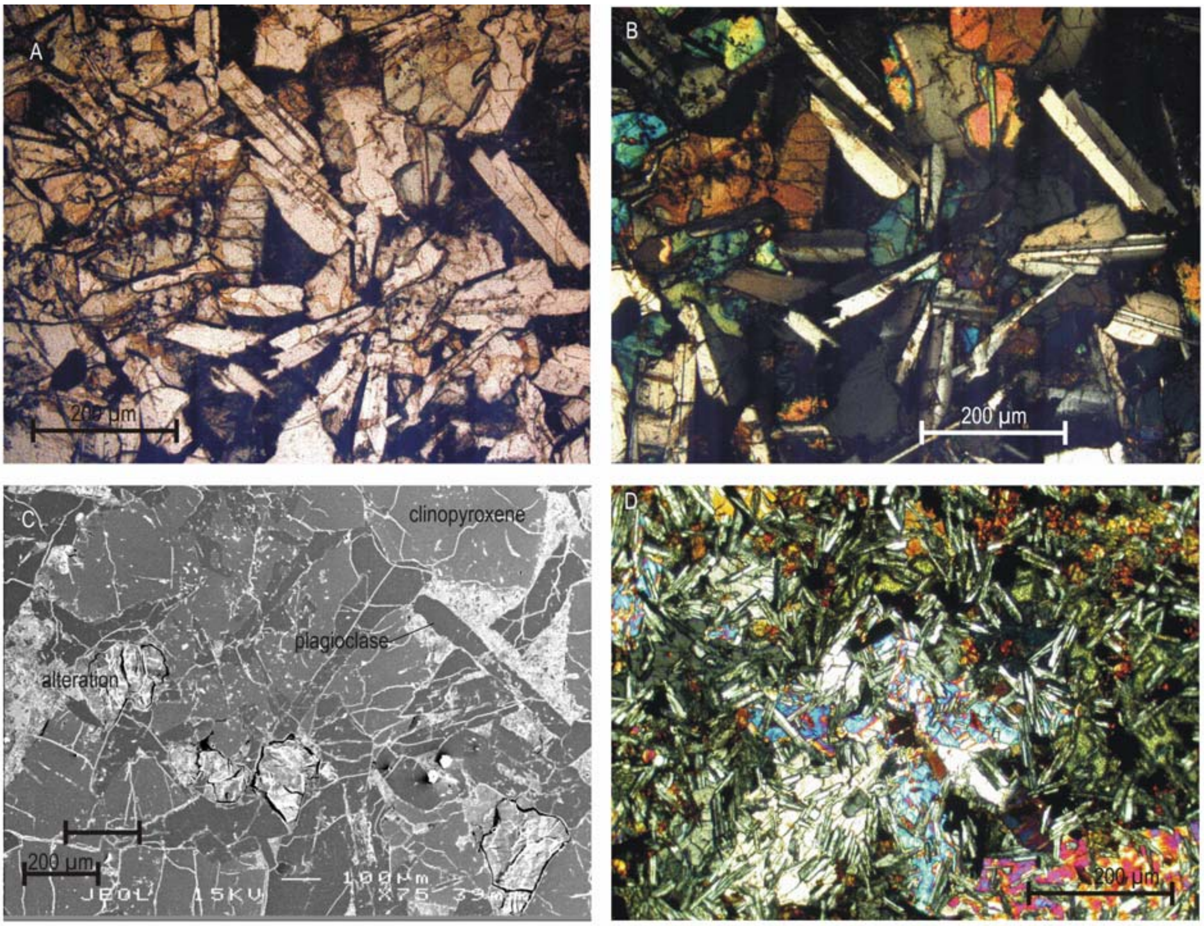


Figure 27. Subophitic clinopyroxene-plagioclase texture typical of dolerite. **A:** clinopyrxene is pale green next to plagioclase (PPL). **B:** clinopyroxene shows up with colourful birefringence (XPL). **C** (secondary electron image)**:** DR13-B1.1 plagioclase and pyrozene are unaffected by alteration. Also, interstitial material, which has been altered, shows up as bright patches in the secondary electron image. **D:** DR41-H1.1 (XPL) different type of dolerite – this sample has iddingsite disseminated throughout. Plagioclase laths overprint interlocking subophitic plagioclase and clinopyroxene.

2. Systematic mineral chemistry by microprobe.

3. Basalt sample DR30-A1.1 may be dateable.

4. Studies of fluid melt inclusions in plagioclase grains.

8. MICROPALAEONTOLOGICAL SUMMARY

The two micropalaeontological studies, in Appendices 3 and 4, have provided invaluable information on the age and depositional environments of the dredged and cored sediments and sedimentary rocks recovered during *Southern Surveyor* Cruise SS02/2005 (GA Survey 274). A brief overview is provided here while a summary of the biostratigraphic dating is found in Table 11.

8.1 Kenn Plateau

The micropalaeontology of the Kenn Plateau samples from this survey, along with those from the earlier Kenn Plateau survey (Southern Surveyor Cruise SS5/2004; Geoscience Australia Survey 270) was briefly outlined by Exon et al. (2005a, 2006). Their results and the present more detailed studies show that bentonitic claystone and calcarenite/calcilutite are the oldest dateable rocks recovered. Bentonitic claystone, dated by nannofossils as Late Eocene to Early Oligocene, occurs on the Selfridge Rise (274/DR35). Aquarius 1 well (see Figure 4) in the Capricorn Basin also contains Eocene-Oligocene bentonitic claystone associated with quartzose sandstone (Chaproniere et al., 1990).

Shallow-marine limestones, mostly calcarenites, were present in dredges from the northern margin of the Coriolis Ridge: 270/DR12 from the eastern slope of Kenn Reef seamount (Early Oligocene foraminifera), 274/DR06 from a seamount (Middle Miocene forams), 274/DR07 from a steep slope (late Middle Eocene foraminifera), and 274/DR09 (Eocene/Oligocene boundary foraminifera) and 274/DR10 (undated) from a terraced region further east. Excluding 274/DR06, present water depths are 1600-1900 m, indicating comparable subsidence since sediment deposition, from the Middle Eocene (274/DR07) to the Early Oligocene (274/DR09). The calcarenites are variably cemented, but often poorly consolidated. They consist of variable proportions of bryozoans, bivalves and echinoid spines, with lesser serpulid worm tubes, solitary corals and larger benthic foraminifera. Upper Eocene to Lower Oligocene micritic calcarenite occurs on the Selfridge Rise (274/DR35). One calcilutite (274/DR02) from the western margin of the plateau contains Early Oligocene and early Late Miocene foraminifera.

Pelagic oozes from the Coriolis Ridge are as old as Late Miocene. Core 274/GC03 contains Middle Miocene foraminifera and nannofossils, and dredge 274/DR05 contains Late Miocene foraminifera and nannofossils.

8.2 Mellish Rise

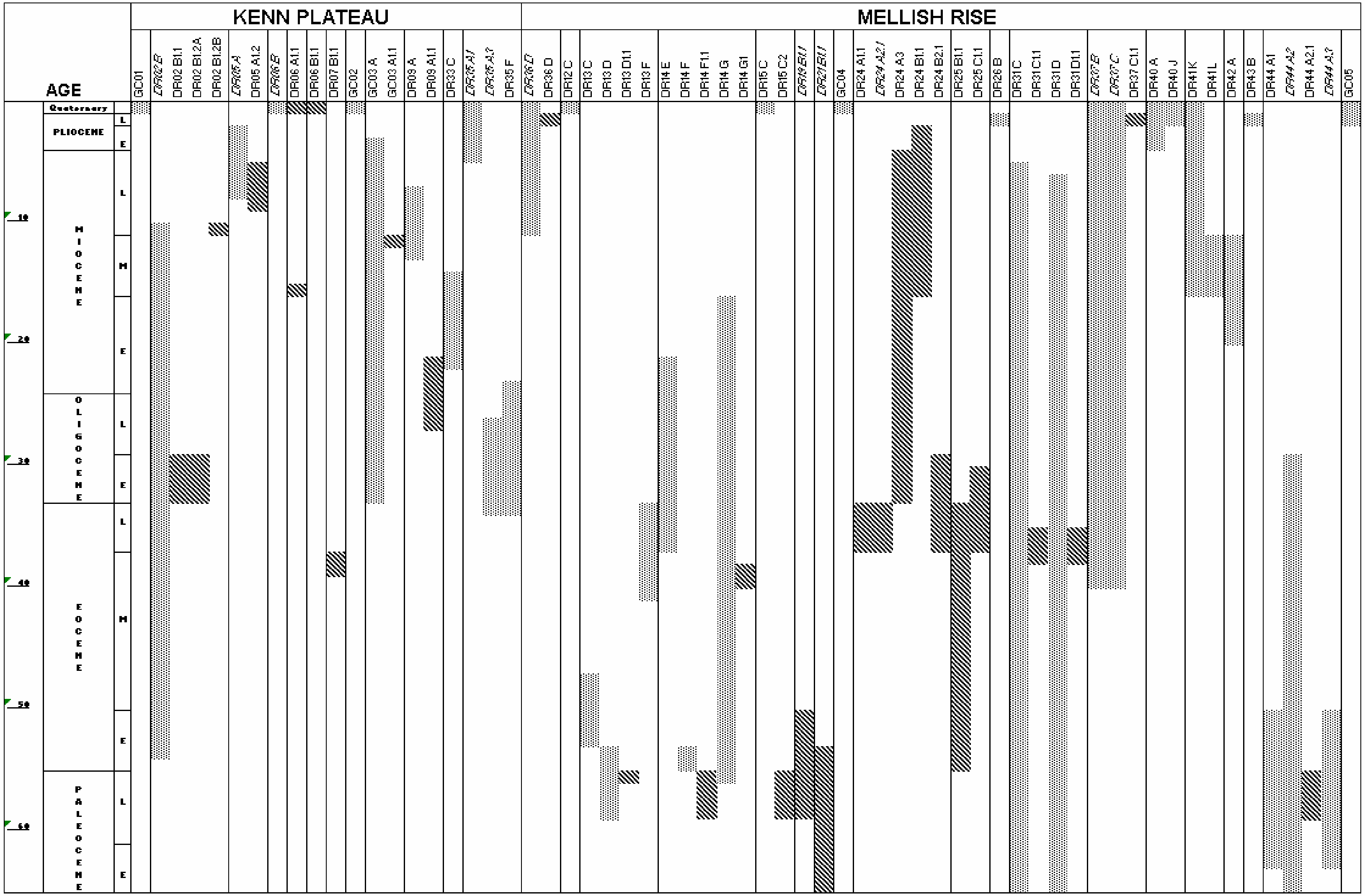
Micropalaeontological studies were made of twenty dredge hauls and sediment cores, obtained during *Southern Surveyor* Cruise SS02/2005 (GA Survey 274) in the Mellish Rise area (Appendices 3 and 4). Most of the fossiliferous samples are shallow-water coarse-grained carbonates, deeper-water calcilutite or chalk, and calcareous ooze. There are also two claystone samples, which appear to be bentonitic.

The carbonates include calcarenite, algal boundstone, calcareous conglomerate, calcilutite and related rocks from reefs and carbonate shelves (see Chapter 6). Table 11 shows that most of the reliable ages are Late Paleocene (mostly calcilutite, but including coarser grained rocks) and late Middle to Late Eocene (calcilutite and coarser grained rocks. Upper Paleocene calcilutites are present in dredges 274/DR13, 14, 15, 19 and 44, and coarser Upper Paleocene carbonates occur in dredges 274/DR13 and 14. Dredge 274/DR44 appears to also contain

Cretaceous foraminifera. Upper Middle to Upper Eocene calcilutites are present in 274/DR13, 14, 24 and 31, and coarser coeval carbonates occur in 274/DR24 and 25. Coarse-grained carbonates, calcilutites and chalks of Oligocene, Miocene and younger ages also occur; calcareous ooze is of Middle Miocene and younger age.

One bentonitic claystone (274/DR14 Lithology E) has been dated as of Late Eocene to Early Miocene age on the basis on nannofossils. This may equate with the Eocene-Oligocene bentonitic claystone associated with quartzose sandstone in the Aquarius 1 well (see Figure 4) in the Capricorn Basin (Chaproniere et al., 1990).

Table 11. Generalized biostratigraphic summary of *Southern Surveyor* Cruise SS02/2005 (GA Survey 274) dredges and cores compiled from the nannofossil and foraminiferal work detailed in Appendices 3 and 4, respectively (stippled pattern for nannofossils and hatching pattern for forams).



9. STRUCTURAL AND BASINAL GEOLOGY

The structure map of the Mellish Rise (Figure 28) was compiled from the following data sources:

- GA Survey 274 airgun seismic;
- BMR Continental Margins Survey sparker seismic surveys 13 and 14;
- Shell Petrel airgun seismic survey 1972-73 (line p700); and
- GA 250 m bathymetry grid (Webster and Petkovic, 2005).

As can be seen from the figure (see Figure 2 for data in the wider region) seismic data coverage is concentrated in the southern-most section of the rise and, so, provides better control on the structural and basinal interpretation than to the north, where gross structure is largely inferred from the bathymetric architecture based on satellite-derived gravity (Smith and Sandwell, 1997). In addition to the seismic lines examined, the GA Survey 274 swath coverage, which forms part of the background image to Figure 28 (ie. Webster and Petkovic, 2005), provides some evidence for seafloor expression of the underlying structure (see also Figure 7 for morphology, but with a different colour palette applied).

9.1. Main structural features

The Mellish Rise is a highly fractured mosaic of high-standing continental and/or transitional/oceanic crustal blocks that have been rifted, re-rifted and separated by possible incipient oceanic crust spreading. This dissected structure is characterised in the satellite-derived gravity field as a series of anomalous highs and lows (Gaina et al., 1999). It is encircled by a complex collection of ocean basins, troughs, ridges and oceanic/continental/volcanic plateaus. To the northwest the Coral Sea Basin is floored by oceanic crust while to the southwest and east the Cato and D'Entrecasteaux basins, respectively, are interpreted, via plate reconstructions and gravity data, to be oceanic in origin. The nature of the Bampton Trough, which separates the southern Mellish Rise from the Selfridge Rise of the northern Kenn Plateau, is unknown. To the north the Louisiade Trough, which separates the Mellish Rise from the Louisiade Plateau, is inferred to be a mid Eocene extension to the Townsville Trough (Kroenke, 1984) and is of unknown basement origin. Along the northeastern flank of the Mellish Rise, the South Rennell Ridge/Trough system, which also bisects the D'Entrecasteaux Basin, may be a former fracture zone (Landmesser, 1974; Shaw 1979) related to strike-slip movements resulting from the Tasman Sea and Coral Sea openings (Gaina et al., 1999) with a probable Late Oligocene transition into a spreading ridge (Larue et al., 1977; Daniel et al., 1978). This complex arrangement is believed to have been largely driven by the development of a Late Paleocene triple junction somewhere between the Mellish Rise and Marion Plateau (Gaina et al., 1999).

The basement and probable capping sedimentary structure of the high-standing blocks have been masked by widespread mid Tertiary hotspot volcanics. Also, basement in the intervening troughs is generally not imaged by the low-power seismic source used to date in the region because of the thick sediment cover and interbedded volcanics.

Figure 28 represents a first-pass structural analysis of that part of the southern Mellish Rise covered (to a sparse extent) by seismic. The following features are highlighted:

- most of the high-standing blocks are characterised by edges that are steep scarps (swath) and/or are fault-bounded (seismic);

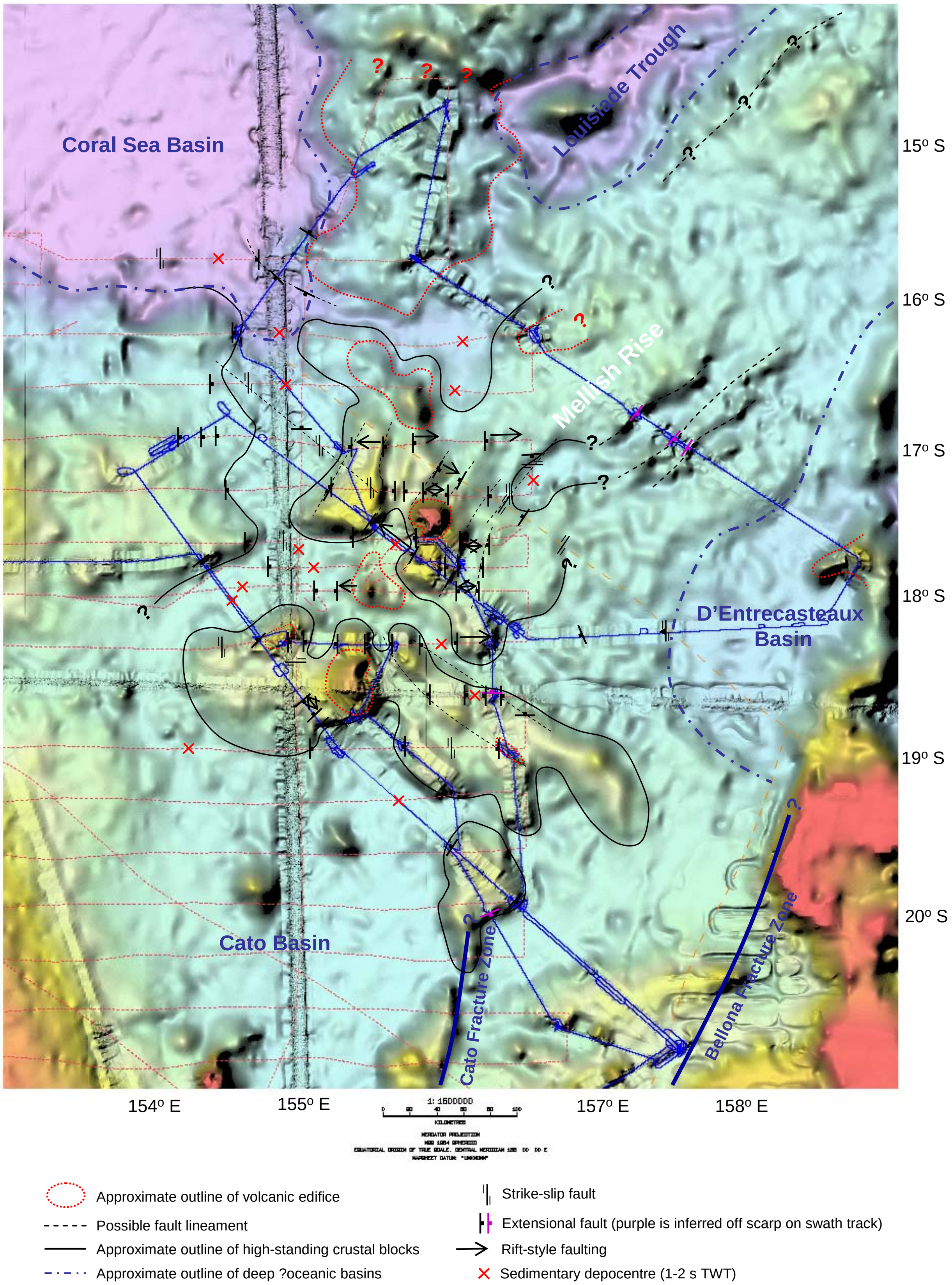


Figure 28. Structural sketch map of the Mellish Rise and surrounds. Data used in the interpretation is highlighted (see Figure 2 for all data in the wider region): GA Survey 274 seismic and swath (solid blue line); BMR Continental Margins Survey 13 and 14 (dotted red line) and Shell Petrel line p700 (dashed orange). Backround image derived from merge of various bathymetric grids (Webster and Petkovic, 2005). The Cook Fracture Zone and Bellona Fracture Zone lineaments are northwards extensions of the mapping in Exon et al. (2005a).

- the southern extension of the Louisiade Trough is a volcanic terrain;
- volcanic edifices are present throughout the Mellish Rise and generally surmount the high-standing blocks;
- zones of rifted faulting indicate that the region has been under extension;
- bathymetric lineaments and line-to-line faulting correlations suggest a dominant northeast structural grain;
- some fault correlation and volcanic ridge development indicates a strong northwest structural grain as well;
- seismic line 274/03 (see Figure 14) reveals that the western edge of the D'Entrecasteaux Basin is characterised by a reverse fault of probable strike-slip origins; and
- the deeper troughs separating the high-standing blocks are thickly sedimented with up to 2s TWT, with basement not clearly imaged.

The interpretation made suggests that the Mellish Rise is most likely a dissected plateau cored by either continental material or an older high-standing oceanic plateau. The widespread presence of extensional faulting indicates that the dissection into disparate high-standing blocks was effected by one or more phases of rifting. Reverse faulting along the western D'Entrecasteaux Basin margin indicates a period of eastern compression. Widespread strike-slip faulting marks the area as having undergone periods of readjustments due to tectonics in the wider region, and may represent the transformation of pre-existing extensional faults.

The volcanic edifices developed, including the large central Mellish Reef seamount, are probably related to late-stage volcanic overprinting of the northern extent of the Tasmantid hot-spot seamount chain. This chain is progressively younger to the south with the larger seamounts typically spaced by 80 km and capped by considerable carbonate platforms such as those on the western flank of the Kenn Plateau (Exon et al., 2005a).

9.2. Basin development

The major oceanic basins encircling the Mellish Rise are, in a clockwise sense, the Coral Sea Basin, the Louisiade Trough, the D'Entrecasteaux Basin and the Cato Basin. Ages for these are Paleocene – Early Eocene for the Coral Sea Basin (Gaina et al., 1998), Paleocene – Early Eocene for the Louisiade Trough (Gaina et al., 1998 and 1999), Late Campanian for the D'Entrecasteaux Basin (CPCEMR, 1991) and Paleocene for the Cato Basin/Trough (Gaina et al., 1999). Seismic data from GA Survey 274 traverses the D'Entrecasteaux and Cato Basins.

Very little stratigraphic information is available to control the seismic stratigraphy on the Mellish Rise and the Kenn Plateau to its south (Table 2). DSDP Site 210, in the Coral Sea Basin, is distant and samples largely deep ocean floor sediments. DSDP Site 208, on the northern Lord Howe Rise, is valuable in controlling the Maastrichtian – Recent sedimentation history for the Kenn Plateau, but is far from the Mellish Rise. However, DSDP Site 209 on the northern Queensland Plateau is nearby and samples strata of equivalent depth to those overlying the high blocks of the Rise. However, it did not reach basement and sampled sediments only as old as the Eocene (Table 2). In addition, an important discovery of the DSDP drilling is that there are two regional unconformities across the region (Edwards, 1973). The younger is the Eocene-Oligocene unconformity while the older is the Paleocene-Eocene unconformity. This represents the best dating of the post-Paleocene regional unconformities present in the Mellish Rise area.

Although seismic line 274/03 (Figure 14) does not image basement, it shows that the D'Entrecasteaux Basin comprises a 1s TWT thick sequence onlapping a 1s TWT thick lower sequence showing some minor structuring (Figure 14). The intervening reflector may represent the Late Eocene - Early Oligocene regional unconformity related to compression resulting from collision along the Loyalty Arc with New Caledonia (Sdrolias et al., 2003) further to the east.

Seismic line 274/01 (Figure 13) traverses the northern extremity of the Cato Basin where it abuts the southernmost high-standing blocks of the Mellish Rise. The section is at least 2s TWT thick with evidence of lava flows sourced from the flanking highs. Several sequences are identified and are discussed above. Except for a weak reflector at 3s TWT depth below seafloor basement is not imaged.

Many of the troughs separating the high-standing blocks are shown by the seismic to be deeply-sedimented fault-bounded grabens. Only seismic line GA 274/03 clearly images the sequences contained (Figure 14). Rotated fault blocks and a deep syn-rift package along the southeastern margin of the graben provide clear evidence for rifting across the rise.

10. DISCUSSION AND CONCLUSIONS

Recent plate tectonic reconstructions have suggested that the Mellish Rise and Louisiade Plateau are stretched and thinned continental fragments (e.g. Gaina et al., 1998, 1999). The present study aimed to build an improved understanding of the tectonic evolution of Mellish Rise, thus testing the model of Gaina et al. (1999), and, accordingly, leading to a better understanding of the evolution of the area off northeastern Australia. This would be a good starting point for unravelling the nature of plate boundaries between the Australian and Pacific Plates since the Late Cretaceous, and to better understand the mechanism of microcontinent detachment east and northeast of Australia. Although we managed to gather a great deal of geophysical and geological information of great value in deciphering the history of the area, we unfortunately did not obtain absolutely definitive seismic or geological evidence to prove whether or not the Mellish Rise is continental or an oceanic build-up, and hence did not meet one major aim. However, some of our dredge information favours a continental origin for the Mellish Rise, and shows that the northern Kenn Plateau is continental.

10.1 Mellish Rise morphology and structure

Bathymetric maps (Figures 1, 5 and 7) show that the Mellish Rise and Louisiade Plateau lie in deeper water than the Queensland Plateau, Marion Plateau and northern Kenn Plateau (Coriolis Ridge and Selfridge Rise), suggesting that the crust is thinner and may have some oceanic components. However, we assume from lithological information that much of the Mellish Rise is highly extended continental crust. There is a marked morphologic grain in the Mellish Plateau region, trending northeast overall. In the southwest, near Mellish Reef, a large area is shallower than 2500 m, but further northeast there are only occasional highs as shallow as that. To the northwest the Coral Sea Basin and the Louisiade Trough, and to the southeast the narrow South Rennell Trough and the west D'Entrecasteaux Basin are all deeper than 3500 m. All these features probably consist of Cretaceous or Palaeogene oceanic crust.

On seismic and bathymetric profiles it is clear that there are large slopes, up to 1000 m high, which correspond to deep-seated faults and flank high blocks. The swath mapping (Chapter 3) has revealed the details of many slopes, some of which are elongated and related to fault blocks, like the northeast-trending scarps of dipping blocks making up the Selfridge Rise. Others are the roughly conical slopes of volcanic build-ups probably caused by the movement of the region over a volcanic hot spot. The Tasmantid volcanic chain in the west is reasonably constrained in age, and its volcanic build-ups are likely to be Eocene in age. The Lord Howe hotspot chain may perhaps have affected the easternmost part of the Mellish Rise and, if so, any build-ups there are probably of Oligocene age.

The interpretation of two seismic profiles across the Mellish Rise and its bounding basins (Figures 13 and 14) shows that there are large blocks of acoustic basement (which other data suggest are trending northeast, and which sampling suggests are probably capped with thick basalt flows) separated by grabens containing several sedimentary sequences that total more than 2500 m thick in places. Our seismic system was not adequate to image the underlying basement in some areas, and we can only surmise what the maximum sediment thickness is. Basement in the graben is presumably also basalt, but whether it is oceanic or continental rift basalt is unknown. Tectonic modelling suggests that the rifting of the Louisiade Plateau, Mellish Rise and Kenn Plateau took place in the Late Cretaceous to Paleocene, and it is probable that rift sediments in the graben are no older than Late Cretaceous, although blocks of older sediments could be present within acoustic basement.

10.2 General geology of Mellish Rise

Continental basement rocks and siliceous sedimentary rocks have been dredged on the northern Kenn Plateau (Chapter 5), but no continental basement has been dredged on the Mellish Rise. On the Mellish Rise (Chapter 6) the dredging has been on steep scarps that are high on the basement highs, and has recovered basalts, a few dolerites and associated volcanics. The presence of dolerites, quartz-rich fragments in volcanic conglomerates, and quartz-bearing Paleocene calcarenites suggests that continental basement rocks may occur below and as highs between the basalt flows that dominate the upper parts of the basement highs. There appear to be two generations of basaltic rocks on Mellish Rise: the flow basalts may well be Early Cretaceous rift volcanics; the hyaloclastites are associated with the younger hotspot volcanoes and are almost certainly Eocene in age.

Both shallow-marine calcarenites and related reefal rocks, and deeper-marine calcarenites and chalk, are reasonably common (Chapter 6). Their ages tend to be Late Paleocene, late Middle to Late Miocene, or younger (Chapter 8). As regards the shallow-marine carbonates, these ages fit well with the periods of reef growth (warm conditions) that were postulated by Davies et al. (1989) and Feary et al. (1991) for the Great Barrier Reef region: older than 45 Ma and younger than 25 Ma. One can anticipate that carbonate deposition in deeper water would have been much like the sequences drilled in DSDP and ODP sites in the general region (Table 2): siliceous chalks in the latest Cretaceous to Eocene, and pure chalks thereafter. The evidence we have fits that hypothesis. Within the deep-water carbonate sequences, the regional unconformities (Paleocene-Eocene and Eocene-Oligocene boundaries) should be present.

Bentonitic claystone of Eocene-Oligocene age is present on the northeastern culmination of Mellish Rise (DR14). Fine-grained ‘redbeds’, some of which at least are altered fine-grained volcanics (almost certainly ferruginised tuffs), are widespread. They give the impression that they were ‘lateritised’ on dry land, and may be associated with Eocene ‘hot spot’ volcanism. An undated discovery of travertine (sinter) at a single location near Mellish Reef (DR24), associated with Upper Eocene to Lower Oligocene marine carbonates, suggests the existence of Eocene or older hydrothermal springs on dry land.

10.3 Geological history

During most of the Mesozoic, both the Kenn Plateau and the Mellish Rise are believed to have been integral parts of eastern Australia, lying south and east of what is now Marion Plateau (e.g. Gaina et al., 1998, 1999). They would have been formed of Palaeozoic basement rocks and Mesozoic basins containing largely non-marine sediments. Early Cretaceous felsic rift volcanics, like the Graham’s Creek Volcanics of the Maryborough Basin (mostly 120-105 Ma: Bryan et al., 1997), probably provided some of the basement rocks on Kenn Plateau (Exon et al., 2006). We postulate that the flow basalts and the dolerites in the Mellish Rise region are of similar age.

Late Cretaceous uplift, folding and erosion in the Maryborough Basin (85-80 Ma) would have provided siliceous detritus to parts of the Kenn Plateau region, and related tectonism in the Marion Plateau region might have provided detritus to the Mellish Rise region. Rifting probably occurred in both Kenn and Mellish regions in the later Cretaceous, setting up the present-day horst and graben structures. These presumably consist of continental basement rocks, Mesozoic sediments cut by dolerite, and overlying Lower Cretaceous (or perhaps Upper Cretaceous) flood basalts laid down during the early stages of rifting. At the end of the Cretaceous (~65 Ma), drifting started with both the Kenn Plateau and Mellish Rise moving away to the northeast (Gaina et al., 1999; Exon et al., 2006). Some oceanic crust was generated around these continental fragments, especially in the large and deep Coral Sea Basin (~62-52 Ma: e.g. Gaina et al., 1999) and the D'Entrecasteaux Basin (poorly constrained but probably Late Cretaceous).

It is postulated that the grabens, in both the Kenn and Mellish regions, were filled with siliciclastic detrital sediments in proximal settings, and siliceous chalks in distal marine settings, from the Late Cretaceous until the Middle Eocene, although there was a break in sedimentation (a regional unconformity) at the Paleocene-Eocene boundary. In a warm period in the Late Paleocene, reefal carbonates and calcareous sands (sometimes quartz-bearing) were deposited on the shelves around emergent land masses. A regional compressive event, related to the Middle Eocene obduction of ophiolites over New Caledonia (45-38 Ma; Sdrolias et al., 2003), may have tilted many of the basement highs in the Mellish Rise and northern Kenn Plateau (e.g. Chapter 3.3). The Eocene emplacement of onshore volcanoes, islands and seamounts of basaltic hyaloclastites and basalts, related to the Tasmantid hotspot, also probably gave rise to bentonitic clays, and the highly weathered 'redbeds' (ferruginised tuffs) that are common on Mellish Rise.

The regional Eocene-Oligocene boundary unconformity represents another break in sedimentation of pelagic carbonates. Thereafter the region subsided thousands of metres from near sea-level to its present depths, and pure pelagic carbonates (foram-nanno oozes, later altered to chalk) were laid down slowly and steadily. Calcareous organisms, forming reefs on volcanic seamounts, kept pace with subsidence for some time or, in the case of Mellish, Kenn and Wreck Reefs, until the present day.

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APPENDIX 1. SEISMIC PROCESSING

Introduction

The overall aim of the seismic acquisition program on *Southern Surveyor* Cruise SS02/2005 (Geoscience Australia Survey 274) was to collect new data to help study the structural and stratigraphic framework of the Mellish Rise. Similar equipment had been used on recently conducted surveys of the *Southern Surveyor*: GA Survey 265 over the Bremer and Denmark Sub-basins in early 2004 (Blevin, 2005) and GA Survey 270 over the Kenn Plateau in mid 2004 (Exon et al., 2005a). As with these other surveys, Survey 274 used a dual GI-gun source with expected penetration of 2-3 s two-way time (TWT) in basinal areas.

Onboard processing was required so that potential dredge and coring targets could be identified as an aid to the site selection based on swath mapping.

Computer Hardware

The main computing platform for onboard seismic processing was a Sun system *SunFire V240R*, attached to a 20" LCD monitor. The V240R has a single 1GHz Ultrasparc CPU, 2GB of RAM, a 76 GB SCSI disk, DVD/CD reader drive, and was configured with a single DLT8000 tape drive. The operating system is *Solaris OE 9.0*. A second complete system was available as a backup in case of the primary's failure.

With the reading of the first seismic acquisition tape it became apparent that the primary system's DLT8000 tape drive was faulty. Analysis of the shot file being written to disk and the Disco/Focus script job log file indicated that the drive was backtracking and rereading shots as a result of encountered end-of-record errors. In response, the secondary system's DLT8000 drive was connected to the second SCSI interface on the primary. This drive was subsequently used to read all field tapes without further problem.

Software

The seismic processing software loaded was *Paradigm Geophysical's Disco/Focus v5.1*. Mapping of ship tracks, seismic lines and shot point locations was performed via *Petrosys Mapping v12.4*. The generation of seismic plots required both Disco/Focus and *Larson Software Technology's PlotLite* plotting system (Plite). Disco/Focus generates CGM+ plot files which are then converted to HP RTL format by Plite. The RTL files are then submitted to the *HP Designjet 1055* A0 plotter for full-scale reproductions of the seismic profiles.

Networking

Using the Southern Surveyor's network the V240R was successfully connected to all of CSIRO's onboard plotters and printers as well as to the file-sharing server *Neptune*. No problems were encountered when plotting and file sharing was easily implemented through the /net subdirectory.

Acquisition Parameters

Syntron Stealtharray solid streamer: 24-channel, 300 m active section of 12.5 m group length.
Mean towing depth: 10 m
Centre of group 1(ie channel 1) behind stern: 250 m

Source: two 45/105 inch^3 GI guns suspended beneath a torpedo float at 6 m depth
Shot interval: 50 m (~13 seconds at 7 knts), giving 3-fold coverage

Record length: 9000 ms
Sampling interval: 2 ms
Bandpass filters: 10-250 Hz

Magnetometer fish (sensor) towed 225 m astern, deployed while shooting seismic and on long transits.

The DGPS navigation reference point on the ship is the EM300 MRU (motion reference unit), located 38.13 m forwards of the stern. The NMEA navigation data stream into the *Navipac*, as well as being recorded by the *Stratavisor* seismic acquisition system, is referenced to this unit.

Data Quality

Apart from the transit to the initial dredging station on the Kenn Plateau, the weather conditions were generally good and very good for the seismic program undertaken. No storms were experienced.

All 24 channels were recorded. However, channels 6 and 13 were seriously affected by very high noise levels for the entire survey and were edited in processing. Channels 7, 8, 11, 23 and 24 were affected for much of the survey and were also edited. Channel 1 was affected by ship-induced noise, but was largely used to compensate for the reduced fold redundancy.

Breaks in the seismic acquisition program were frequent, 3 lines being recorded over 20 line parts. The initial failures on line 274/01 were due to crashes with the *Stratavisor* acquisition system. Once this was rectified the remaining acquisition suspensions were due to various problems with the compressor, until its final failure resulted in the premature end to the seismic component of the survey. All acquisition halts required the ship to loop back onto the line for re-commencement to ensure there was 100% seismic coverage. This was not executed correctly towards the end of line 274/03, so that a data gap is evident in the final profile.

Seismic Processing Sequence

- Read in Stratavisor-recorded SEG-D (8058) data from DLT tape and write to disk in internal Disco format.
- Display neartrace gather (channel 1) and shot gathers for QC, water bottom digitising and shot/channel edits.
- Define geometry and write to seismic trace headers.
- Apply shot and channel edits.
- Apply a time-variant gain function keyed on water depth and then apply a F-K filter in the shot domain to reduce ship/streamer noise.
- Sort shot/channels into CDP gathers.
- Apply NMO correction using time-variant stacking velocity function keyed to water depth to create brute stack.
- Join brute stacks for the various line parts (as a result of acquisition halts) to make complete lines, resequencing shots where required.
- Apply 9-trace running mix to merge traces, then decimate to every 8th CDP, thereby taking CDP spacing from 6.25 m to 50 m.
- Digitise water bottom for cosmetic mute.

- Apply time-variant filter, cosmetic mute and AGC to create final stack.
- Apply finite difference migration to produce final migrated brute stack.
- Apply 9-trace running mix to merge traces, then decimate to every 8^{th} CDP, thereby taking CDP spacing from 6.25 m to 50 m (ie as for brute stack).
- Apply time-variant filter, cosmetic mute and AGC to create final migrated stack.
- Produce full-scale plots for onboard analysis.
- Create SEG-Y format files of final decimated migrated lines.

Navigation Processing

Shot, date, time and navigation information was determined and correlated via the acquired shot header information and the CSIRO-supplied 10-second navigation file. The DGPS-derived navigation data were generally of excellent quality and was continually available during the survey. However, the navigation data was not recorded over two periods on line 274/01.

Seismic line parts were displayed in *Petrosys* and join points (ie CDPs) determined for input to the seismic processing stream. These parts were merged to produce final reformatted shot-point files, corrected for navigational reference point offset (from source) and mid-point reflection offset.

Seismic Processing Summary

A total of three seismic lines (lines 274/01 – 274/03) were acquired and processed. Processing was done to the full 9 s record length and at the acquired 2 ms sampling rate. Maximum visible seismic signal penetration is 2.2 s TWT, in the central basin of line 274/01. The total final line length was 1189 km.

Recommendations

Apart from the problems reading data with the primary system's DLT8000 drive the seismic processing system, plotting software and hardware and vessel network performed very well. Problems still exist in interfacing a USB drive to the system. When plugged in the mouse is disabled making use of the operating system's file manager impossible. As quick data transfer is a clear advantage with USB drives this problem needs to be further examined.

APPENDIX 2. MULTIBEAM SONAR DATA ACQUISITION AND PROCESSING

Simrad EM300 Performance

The Simrad EM300 on the R/V *Southern Surveyor* is a 30 kHz multibeam system with 135 1° beams.

The survey area spanned approximately 6° of latitude and 4° of longitude. The topography varied from flat seafloor to seamounts and plateaus. Water depths ranged between 500 and 4300 m.

The survey was primarily designed as a regional seismic survey. Swath data was acquired throughout the voyage and it was used to image dredge sites. The extents of the survey area and the design of the survey did not allow for an overall bathymetric model of the survey area to be acquired. Only small patches were adequately imaged, mostly for the purpose of locating suitable dredge targets.

Weather conditions during the survey were generally very good with only a few days of seas around 2 m. Survey speed during the seismic operations was 7 knots, otherwise the remainder of the survey was conducted at speeds between 9 and 10.5 knots.

Generally noise levels in the data were more noticeable at depths approaching 3000 m; however, this was also greatly affected by the high survey speeds.

Across track coverage for the survey was reasonable given the water depths with the best coverage as a function of water depth being achieved over areas of outcrop and generally in water depths ~500 to 2000 m.

Unix platform performance

During the voyage the multibeam system had to be re-booted on a number of occasions. In the first instance a 'freeze' of the computer screens occurred. Although data were still being collected and being written to file, a restart was necessary. This situation has occurred on just about every voyage so far and appears due to a lack of RAM in the Sun system, software instability, and the fact that the system is generally running continuously for several weeks.

A number of more serious system crashes occurred in the second half of the survey which resulted in having to swap to the backup Sun workstation on which the rest of the survey was logged. The problem would manifest it self as a sudden memory dump and automatic re-booting of the system. The re-boot would then come to a halt reporting a malfunction with on of the external disks (data2 on em300). On a number of occasions the em300 workstation would then be shut down correctly (using the init 0 command as super user) and brought back up. This worked at first and the em300 would then run for several days before crashing again. On the last occasion it only lasted an hour or so. The decision was then made to switch IP addresses from em300 to em300-2 and run the swath mapper from the backup unit.

Sound Velocity

Sound Velocity (SV) profiles for the transits to and from the survey area were generated using the SVP Builder utility on board, which uses global oceanography data to derive a SV Profile for a given set of coordinates. This method has again provided an effective way of generating SVP's to be used during deep-water transits.

For the survey area a first SV cast was made to 2000 m water depth at the southern end of the area, using CSIRO's CTD equipment. A second cast was done towards the northern end of the survey area. Using the CDT as a means of producing a sound velocity profile also allows for the generation of an absorption coefficient profile. The use of the correct coefficient (as opposed to a Simrad default) does considerably improve on the backscatter returns by setting the correct gains at the transducer.

Swath Data Processing

Post-processing of the raw data was done using the CARIS HIPS & SIPS 5.4 software. Data quality was reasonable with most noise in the data due the high survey speeds. On board processing was carried for the majority of the data acquired with the transit leg into Cairns to be processed at a later date. Furthermore, a final pass over some of the lines between dredge sites was needed to be done to ensure that the data was cleaned of noise. The production of final displays for the dredge sites was completed onshore.

A total of approximately 7000 km of swath data was acquired on the voyage. Transits from Bundaberg to the survey area and from the survey area to Cairns accounted for about 1450 km, with about 5550 km for the survey area.

The acquired swath was presented as a 30 m resolution grid. This resolution was chosen as it is close to the beam footprint (at nadir) for the areas of interest. The on-screen bathymetric displays produced in CARIS, along with its associated tools for measuring distances and giving depth and position readouts, were invaluable for the selection of dredge sites.

APPENDIX 3. PRELIMINARY CALCAREOUS NANNOFOSSIL BIOSTRATIGRAPHY OF DREDGE AND CORE SAMPLES

Claire S. Findlay and Richard W. Howe

Smear slides were prepared from: dredge samples DR01 to DR11 and DR32 to DR35 from Kenn Plateau (DR11 and DR32 to DR35 from Selfridge Rise on Kenn Plateau); DR12 to DR31 and DR36 to DR44 from Mellish Rise; gravity cores GC01, GC02 and GC03 from Kenn Plateau; and, GC04 and GC05 from Mellish Rise. Samples were collected from water depths between 700 m and 3650 m, between latitudes 14˚41.6'S to 24˚49.0'S and longitudes 154˚20.3'E and 157˚30.9'E. A total of 78 samples were examined for calcareous fossil content with a Zeiss Axioplan 2 at a magnification of x1000 under cross-polarized light and phase contrast. Species identification and ages are taken from Bown (1998) and Perch-Nielsen (1985) and follows the calcareous fossil biostratigraphic zones CP and CN of Okada and Bukry (1980). Graphic representation of samples and associated species is provided in the CD-ROM attached to this report (ie. as JPEG images referred to as nannoX.jpg, where X is a number).

Samples of surface ooze are not considered to be stratigraphically important with the majority predictably the typical calcareous ooze of the Pleistocene-Holocene assemblage dominated by *Emiliania huxleyi* and *Florisphaera profunda* (nanno1.jpg). The exceptions are DR14, Lithology H which is a mix of Paleocene through to Holocene; DR30, Lithology B and DR33, Lithology B contain a few older re-worked species; and, DR37, Lithology E is a mix of Miocene to Pleistocene-Holocene species.

The calcium compensation depth in the South Pacific has been estimated at 3500 m and the lysocline at 1200 m (Takahashi et al., 1979). This is supported by DR01 sampled at a depth of 3200m, returning a well preserved Pleistocene-Holocene assemblage including species susceptible to dissolution, for example, *Umbellosphaera tenuis*, *Discophaera tubifera*, *Oolithus fragilis*, *Umbellosphaera irregularis* (McIntyre and McIntyre, 1971; Berger, 1973). Most samples are well persevered and dissolution is not considered to be a factor in preservation with one or two exceptions, for example, DR12 Lithology C.

Gravity core GC03, at core depth 310 cm, is dominated by *Gephyrocapsa carribeanica*. Hine (1990) identified two intervals within the Pleistocene dominated by *Gephyrocapsa caribbeanica*, that is, QAZ6 (CN13b) with *Reticulofenstra asanoi*, upper isotope stage 28 (930ky) to lower isotope stage 25 (847ky), and QAZ4 without *Reticulofenstra asanoi*, upper isotope stage 15 (589ky) to lower isotope stage 8 (258ky). Based on the absence of *Reticulofenestra asanoi*, this sample is from QAZ4. Isotope stratigraphy is based on Williams et al. (1987).

Dredge Samples

274/01 DR01 (nanno1.jpg and nanno29.jpg)
Southwest facing sloping flank of southwestern Kenn Plateau (156˚19.80′ E, 24˚49.00′ S) in 3200m water depth.

Calcareous ooze
Pleistocene-Holocene
A well preserved, typical Pleistocene-Holocene assemblage dominated by *Emiliania huxleyi* with abundant *Florisphaera profunda.*
Marker species:

Emiliania huxleyi CN15 Pleistocene-Holocene
Florisphaera profunda CN4 Mid Miocene Langhian-Serravalian to CN15 Pleistocene-Holocene
Calcidiscus leptoporus CN1c Early Miocene Aquitanian to CN15 Pleistocene-Holocene
Gephyrocapsa oceanica CN14a Pleistocene to CN15 Pleistocene-Holocene
Gephyrocapsa muellerae CN13a Late Pliocene Piacenzian to CN15 Pleistocene-Holocene
Umbilicosphaera sibogae CN12a Early Pliocene Zanclian to CN15 Pleistocene-Holocene
Umbellosphaera tenuis CN11a Early Pliocene Zanclian to CN15 Pleistocene-Holocene
Calciosolenia murrayi ?Palaeogene to CN15 Pleistocene-Holocene
Ceratolithus cristatus CN10c Early Pliocene Zanclian to CN15 Pleistocene-Holocene
Rhabdosphaera clavigera Palaeogene to CN15 Pleistocene-Holocene
Oolithus fragilis CN11a Early Pliocene Zanclian to CN15 Pleistocene-Holocene
Helicosphaera carteri CN7a Late Miocene Tortonian to CN15 Pleistocene-Holocene
Syracosphaera pulchra Palaeogene to CN15 Pleistocene-Holocene
Pontosphaera japonica Palaeogene to CN15 Pleistocene-Holocene

274/03 DR02
West facing slope on central Kenn Plateau (156˚46.80′ E, 23˚27.70′ S) in 1700m water depth.

Lithology B - foraminiferal chalk with bivalves (nanno3.jpg)
Late Eocene to Oligocene (?)
The age of this sample is tentative as nannofossils are rare.
Marker species:
Sphenolithus moriformis CP10 Early Eocene Ypresian to CN6 Late Miocene Tortonian
Cyclicargolithus floridanus CP15b Late Eocene Priabonian to CN5a Mid Miocene Serravalian
Reticulofenstra sp.

274/04 DR03
North facing slope on central Kenn Plateau (156˚30.40′ E, 23˚12.70′ S) in 2070m water depth.

No recovery.

274/05 DR04
West facing slope on central Kenn Plateau (157˚00.80′ E, 23˚13.60′ S) in 1700m water depth.

Calcareous ooze
Pleistocene-Holocene
Pleistocene-Holocene as per 274/01 DR01.

274/06 DR05
Southern slope of Coriolis Ridge on northern Kenn Plateau: south facing scarp related to east-west faulting (156˚44.60′ E, 22˚08.00′ S) in 1600m water depth.

Lithology A - bored chalk (nanno4.jpg, nanno5.jpg and nanno6.jpg)
Late Miocene
This sample is well preserved and is dominated by small *Reticulofenstra* species (mostly 3µm). The absence of large reticulofenestrids suggests an age no younger than CN9b.
Marker species:
Reticulofenestra haqii 3-5µm Early Miocene Aquitanian to Pliocene Zanclian
Sphenolithus abies CN5b Mid Miocene Serravalian to CN10d Pliocene Zanclian
Florisphaera profunda CN4 Mid Miocene Langhian-Serravalian to CN15 Pleistocene-Holocene
Coronocyclus nitescens Mid to Late Eocene to CN5a Mid Miocene Serravalian
Calcidiscus rotula CN1c Early Miocene Aquitanian- Burdigalian to CN12a Pliocene Zanclian-Piacenzian
Amaurolithus delicatus CN9b Late Miocene Tortonain-Messinian to CN10d Pliocene Zanclian
Discoaster pentaradiatus CN8a Late Miocene Tortonian to CN12c Pliocene Piacenzian
Discoaster exilis CN4 Mid Miocene Langhian to CN12a Pliocene Piacenzian
Calcidiscus tropicus CN3 Early-Mid Miocene Burdigalian-Langhian to CN8 Late Miocene Tortonian
Discoaster braarudii CN5a Mid Miocene Serravalian to CN8a Late Miocene Tortonian Pliocene Piacenzian

Lithology B - nanno/foram calcareous ooze

Pleistocene-Holocene
Pleistocene-Holocene as per 274/01 DR01.

274/07 DR06
Guyot on northwest Kenn Plateau – steep slope up to southwest (156˚24.65′ E, 21˚30.85′ S) in 700-400m water depth.

Lithology B - calcarenite (nanno7.jpg)
Pleistocene-Holocene
This sample is dominated by shell shards – pteropods. Nannofossils are not common.
Few Pleistocene-Holocene species including *Emiliania huxleyi*, *Gephyrocapsa oceanica.*

274/08 DR07
West facing steep slope on northern flank of Coriolis Ridge, Kenn Plateau (156˚24.45′ E, 21˚25.50′ S) in 1600-1500m water depth.

Calcareous ooze
Pleistocene-Holocene
Pleistocene-Holocene as per 274/01 DR01.

Lithology B - calcarenite
?age
Nannofossils very rare - mostly calcite debris with a few *Reticulofenstra* sp.

274/10 DR08
Northern margin of Coriolis Ridge, north facing slope above Selfridge Trough, Kenn Plateau (157˚06.80′ E, 21˚25.85′ S) in 1500-1400m water depth.

Calcareous ooze
Pleistocene-Holocene
Pleistocene-Holocene as per 274/01 DR01.

Lithology A - agglomerate
?age
Nannofossils rare – mostly mineral fragments, silica and some calcite debris.

274/12 DR09
Northern flank of Coriolis Ridge, Kenn Plateau; terraces and scarp facing north (157˚14.60′ E, 21˚21.50′ S) in 1800m water depth.

Calcareous ooze
Pleistocene-Holocene
Pleistocene-Holocene as per 274/01 DR01.

Lithology A – calcarenite-calcirudite (nanno8.jpg and nanno9.jpg)
Middle to Late Miocene
Reworked Miocene (CN5b to CN8b) with a few Pleistocene-Holocene species
Marker species:
Sphenolithus abies CN5b Mid Miocene Serravalian to CN10d Pliocene Zanclian
Florisphaera profunda Mid Miocene Langhian-Serravalian to CN15 Pleistocene-Holocene
Calcidiscus tropicus CN3 Early-Mid Miocene Burdigalian-Langhian to CN8 Late Miocene Tortonian
Discoaster brouweri CN7 Late Miocene Tortonian to CN12d Late Pliocene Piacenzian
Discoaster pentaradiatus CN6 Late Miocene Tortonian to CN12 Pliocene Zanclian-Piacenzian
Catinatus coalitus CN6-CN8 Late Miocene Tortonian
Discoaster variabilis CN7 Late Miocene Tortonian to CN12 Pliocene Zanclian-Piacenzian
Cyclicargolithus floridanus CP15b Late Eocene Priabonian to CN5a Mid Miocene Serravalian
Emiliania huxleyi CN15 Pleistocene-Holocene
Gephyrocapsa muellerae CN15 Pleistocene-Holocene
Discoaster deflandrei CP16c Early Oligocene Latdorfian to CN3 Mid Miocene Langhian

274/13 DR10
Upper terrace on northern Coriolis Ridge, Kenn Plateau; above lower terrace dredged by 274/12 DR09 (157˚14.80′ E, 21˚21.90′ S) in 1600m water depth.

Negligible recovery - shell hash and small piece of manganese crust only.

274/14 DR11
Southern side of Selfridge Rise, northern Kenn Plateau (156˚52.60′ E, 21˚04.50′ S) in 1800-1700m water depth.

Calcareous ooze
Pleistocene-Holocene
Pleistocene-Holocene as per 274/01 DR01.

274/15 DR12
Northwest facing scarp of graben in central Mellish Rise (157˚30.90′ E, 16˚49.90′ S) in 2600m water depth.

Lithology B - claystone with manganese veins
?age
No nannofossils. Very fine calcite remnant.

Lithology C - brown clay
Pleistocene-Holocene
Nannofossils are rare and indicate considerable dissolution.
Marker species:
Emiliania huxleyi CN15 Pleistocene-Holocene
Calcidiscus leptoporus CN1c Early Miocene Aquitanian to CN15 Pleistocene-Holocene
Gephyrocapsa ocenaica CN14a Pleistocene to CN15 Pleistocene-Holocene
Ceratolithus cristatus CN10c Early Pliocene Zanclian to CN15 Pleistocene-Holocene

274/16 DR13
Northwest facing scarp of graben in central Mellish Rise (157˚29.20′ E, 16˚51.10′ S) in 2900-2750m water depth.

Lithology C - chalk inclusion in manganese nodule
Lower Eocene
Mainly very fine calcite remnant with a few nannofossils.
Marker species:
Tribrachiatus orthostylus (common) CP9 Early Eocene Ypresian
Discoaster kuepperi CP10 Early Eocene Ypresian to CP12b Mid Eocene Lutetian
Discoaster barbadensis CP10 Early Eocene Ypresian to CP15b Late Eocene Priabonian
Chiasmolithus solitus CP9a Lower Eocene Ypresian to CP14a Mid Eocene Bartonian

Lithology D - bioturbated chalk (nanno10.jpg, nanno11.jpg, nanno12.jpg and nanno13.jpg)
Middle Paleocene to Middle Eocene
Marker Species:
Chiasmolithus solitus CP9a Early Eocene Ypresian to CP14a Middle Eocene Bartonian
Hornibrookina australis CP5 Late Paleocene Thanetian to CP9b Early Eocene Ypresian
Toweius eminens CP8a Late Paleocene Thanetian to CP9a Early Eocene Ypresian
Toweius selendanis CP4 Middle Paleocene Selandian
Transversipontis sp.CP9b Early Eocene Ypresian
Neochiastozygus perfectus CP4 Middle Paleocene Selandian to CP5 Late Paleocene Thanetian
Discoaster multiradiatus CP8a Late Paleocene Thanetian to CP9a Early Eocene Ypresian
Fasiculithus involutus CP8b Late Paleocene Thanetian to CP9 Early Eocene Ypresian

Lithology F - chalky breccia (nanno14.jpg)
Eocene to Early Oligocene
Sample is dominated by small species, mostly reticulofenestrids.
Marker species:

Sphenolithus moriformis CP10 Early Eocene Ypresian to CN6 Late Miocene Tortonian
Reticulofenestra (Dictyococcites) *bisectus* CP14a Eocene Lutetian to CP19b Oligocene Chattian
Coccolithus formosus last occurrence CP16 Early Oligocene Latdorfian
Cyclicargolithus floridanus CP15b Late Eocene Priabonian to CN5a Mid Miocene Serravalian

274/17 DR14
Southeast facing scarp of graben in central Mellish Rise (157˚15.80′ E, 16˚40.60′ S) in 2900-2400m water depth.

Lithology E - bentonitic mudstone (nanno17.jpg)
Mixed Late Eocene to Early Miocene
Nannofossils rare – very fine calcite remnant.
Marker species*:*
Sphenolithus belemnos CN2 Early Miocene Burdigalian
Coccolithus formosus LO CP16a Early Oligocene Latdorfian
?Cruciplacolithus oamaruensis CP15a Late Eocene Priabonian to CP16C Early Oligocene Latdorfian
Zygrhablithus bijugatus CN1 Early Miocene Aquitanian to Burdigalian

Lithology F - glauconite calcareous lithic sandstone (nanno15.jpg and nanno16.jpg)
Paleocene to Early Eocene
Marker species:
Chiasmolithus solitus CP9a Early Eocene Ypresian to CP14a Mid Eocene Bartonian
Hornibrookina australis CP5 Late Paleocene Thanetian to CP9b Early Eocene Ypresian
Toweius eminens CP8a Late Paleocene Thanetian to CP9a Early Eocene Ypresian
Toweius selendanis CP4 Mid Paleocene Selandian
Transverspontis sp. CP9b Early Eocene Ypresian
Neochiastozygus perfectus CP4 Middle Paleocene Selandian to CP5 Late Paleocene Thanetian
Ellipsolithus marcellus CP3 Early Paleocene Danian to CP9 Early Eocene Ypresian
Discoaster multiradiatus CP8a Late Paleocene Thanetian to CP9a Early Eocene Ypresian
Fasiculithus involutus CP8b Late Paleocene Thanetian to CP9 Early Eocene Ypresian
Coccolithus pelagicus CP1b Early Paleocene Danian to CN15 Pleistocene-Holocene
Cruciplacolithus tenuis CP2 Early Paleocene Danian to CP8a Late Paleocene Thanetian

Lithology G - chalk (nanno18.jpg and nanno19.jpg)
Early Eocene to Early Miocene
Marker species:
Hornibrookina australis CP5 Late Paleocene Thanetian to CP9b Early Eocene Ypresian
Sphenolithus belemnos CN1a Late Oligocene Chattian to CN3 Early Miocene Burdigalian
Discoaster kuepperi CP10 Early Eocene Ypresian to CP12b Middle Eocene Lutetian
Discoaster deflandrei CP16c Early Oligocene Latdorfian to CN3 Mid Miocene Langhian
Zygrhablithus bijugatus CN1 Early Miocene Aquitanian to Burdigalian
Reticulofestra umbilica CP14a Mid Eocene Bartonian to CP16c Lower Oligocene Latdorfian

Lithology H - calcareous ooze (nanno20.jpg and nanno21.jpg)
Mix of Paleocene through to Pleistocene-Holocene
Marker species:
Emiliania huxleyi CN15 Pleistocene-Holocene
Florisphaera profunda CN4 Mid Miocene Langhian-Serravalian to CN15 Pleistocene-Holocene
Neochiastozygus perfectus CP4 Mid Paleocene Selandian to CP5 Late Paleocene
Coccolithus formosus LO CP16 Early Oligocene Latdorfian
Calcidiscus tropicus CN3 Early-Mid Miocene Burdigalian-Langhian to CN8 Late Miocene Tortonian

274/18 DR15
Northern facing scarp along northern Mellish Rise (156˚34.80′ E, 16˚10.10′ S) in 2630m water depth.

Lithology C - muddy foram chalk
Pleistocene-Holocene
Pleistocene-Holocene as per 274/01 DR01.

274/19 DR16
South facing scarp on high south of Louisiade Plateau (155˚45.30′ E, 15˚39.50′ S) in 2600-2500m water depth.

Lithology C - calcareous ooze
Pleistocene-Holocene
Pleistocene-Holocene as per 274/01 DR01.

274/20 DR17
North facing scarp on high south of Louisiade Plateau (155˚52.20′ E, 14˚41.60′ S) in 3200-3000m water depth.

Lithology E - fine grained calcarenite
?age
Well preserved calcite fragments of various size and some minerals. No nannofossils.

Lithology G - bentonitic claystone
?age
Very fine calcite remnant. No nannofossils.

274/21 DR18
Southwest facing scarp on high south of Louisiade Plateau (155˚26.00′ E, 15˚05.30′ S) in 3300-3100m water depth.

Lithology D - calcareous ooze
Pleistocene-Holocene
Pleistocene-Holocene as per 274/01 DR01.

274/22 DR19
North facing scarp along northern Mellish Rise (154˚34.10′ E, 16˚10.90′ S) in 3750-3650m water depth.

Lithology A - hyaloclastite
?age
Very fine calcite remnant. No nannofossils.

Lithology B - claystone
?age
Very fine calcite remnant. No nannofossils.

274/23 DR20
West facing scarp along northern Mellish Rise (155˚15.80′ E, 16˚54.60′ S).

No recovery.

274/24 DR21
Southeast facing scarp of graben in central Mellish Rise (155˚29.30′ E, 17˚24.40′ S) in 1950-1500m water depth.

Lithology G - calcareous ooze
Pleistocene-Holocene
Pleistocene-Holocene as per 274/01 DR01.

274/26 DR22
Northwest facing scarp of graben in central Mellish Rise (155º45.70’ E, 17º35.70’ S) in 1700-1300m water depth.

Lithology E - calcareous ooze
Pleistocene-Holocene
Pleistocene-Holocene as per 274/01 DR01.

274/27 DR23

East facing scarp in central Mellish Rise (156º03.90’ E, 17º38.50’ S) in 2300-2000m water depth.

Lithology A - hyaloclastite
?age
Not possible to take sample for nannofossils – surface too hard.

274/28 DR24
East facing scarp in central Mellish Rise (156º03.20’ E, 17º40.20’ S) in 2200-2000m water depth.

Lithology A1.2 - calcarenite to litharenite
?age
Nannofossils absent – abundant calcite debris of varying size.

274/29 DR25
East facing scarp in central Mellish Rise (156º17.30’ E, 18º09.00’ S) in 2650-2350m water depth.

Lithology C2.3 - calcareous ooze from cavity in micritic calcarenite
Pleistocene-Holocene
Pleistocene-Holocene as per 274/01 DR01.

274/30 DR26
Northeast facing scarp in southern Mellish Rise (156º18.00’ E, 18º29.90’ S) in 2100-1950m water depth.

Lithology B - calcareous basaltic conglomerate (nanno22.jpg and nanno23.jpg)
Late Pliocene
Typical Pliocene assemblage. *Pseudoemiliania lacunosa* abundant; *Florisphaera profunda* abundant.
Mineral fragments common. A few older reworked species.
Marker species:
Discoaster triradiatus CN12d-c Pliocene Piacenzian
Discoaster asymmetricus CN10d Miocene Zanclian to CN12c Pliocene Piacenzian
Discoaster pentaradiatusts CN8a Late Miocene to CN12c Pliocene Piacenzian
Pseudoemiliania lacunosa CN12a Pliocene Piacenzian to CN14a Pleistocene
Gephyrocapsa muellerae CN12a Pliocene Piacenzian to CN15 Pleistocene-Holocene

274/31 DR27
South facing scarp of spur on southern Mellish Rise (156º23.10’ E, 18º51.70’ S) in 1800-1650m water depth.

Lithology C - shell hash
Pleistocene-Holocene
Typical Pleistocene-Holocene assemblage as per 274/01 DR01. *Florisphaera profunda* abundant. Re-worked *Sphenolithus belemnos* rare (Late Oligocene to Early Miocene).

274/32 DR28
South facing scarp of spur on southern Mellish Rise (156º23.20’ E, 18º51.50’ S).

No recovery.

274/33 DR29
Southeast facing scarp of seafloor high off southern Mellish Rise (156º27.70’ E, 19º49.80’ S).

No recovery.

274/34 DR30
Southeast facing scarp of seafloor high off southern Mellish Rise (156º26.30’ E, 19º49.80’ S) in 2300-2000m water depth.

Lithology B - calcareous ooze
Pleistocene-Holocene
Pleistocene-Holocene as per 274/01 DR01. *Emiliania huxleyi* abundant. *Florisphaera profunda* dominates.
Re-worked species:
Discoaster brouweri Late Miocene Tortonain to CN12d Pliocene Piacenzian
Pseudoemiliania lacunosa CN12a Pliocene Piacenzian to CN14a Pleistocene

274/35 DR31
South facing scarp of seafloor high off southern Mellish Rise (156º27.60' E, 19º49.90' S) in 2600-2450m water depth.

Lithology C - foraminiferal mudstone (nanno24.jpg and nanno25.jpg)
Paleocene-Miocene
Marker species:
Coccolithus formosus LO CP16 Lower Oligocene Latdorfian
Reticulofenstra rotaria CN9b Late Miocene Messinian
Reticulofenestra (Dictyococcites) *bisectus* CP14a Eocene Lutetian to CP19b Oligocene Chattian
Discoaster kuepperi CP10 Lower Eocene Ypresian to CP12b Mid Eocene Lutetian
Discoaster saipanensis CP14b Mid Eocene Bartonian to CP15b Late Eocene Priabonian
Bianolithus sparsus CP1a Early Paleocene Danian to CP3 Mid Miocene Selandian
Cruciplacolithus primus CP1 to CP3 Early Paleocene Danian
Toweius eminens CP8a Upper Paleocene Thanetian to CP9a Lower Eocene Ypresian
Zygrhablithus bijugatus CN1 Early Miocene Aquitanian to Burdigalian

Lithology D - foraminiferal calcareous sandstone (nanno26.jpg, nanno27.jpg and nanno28.jpg)
Paleocene-Miocene
Marker species:
Calcidiscus tropicus CN3 Early-Mid Miocene Burdigalian-Langhian to CN8 Late Miocene Tortonian
Cyclicargolithus floridanus CP15b Late Eocene Priabonian to CN5a Mid Miocene Serravalian
Bianolithus sparsus CP1a early Paleocene Danian to CP3 Mid Miocene Selandian
Discoaster saipanensis CP14b Mid Eocene Bartonian to CP15b Late Eocene Priabonian
Zygrhablithus bijugatus CN1 Early Miocene Aquitanian to Burdigalian
Discoaster kuepperi CP10 Lower Eocene Ypresian to CP12b Mid Eocene Lutetian
Reticulofenestra umbilicus CP14a Mid Eocene Bartonian to CP16c Lower Oligocene Latdorfian

Lithology E - calcareous ooze
Pleistocene-Holocene
Pleistocene-Holocene as per 274/01 DR01. *Emiliania huxleyi* and *Florisphaera profunda* abundant.

274/36 DR32
Southeast facing scarp of Selfridge Rise, northern Kenn Plateau (157˚32.10′ E, 20˚45.70′ S) in 1550m water depth.

Lithology C - calcareous ooze
Pleistocene-Holocene
Pleistocene-Holocene as per 274/01 DR01. *Emiliania huxleyi* and *Florisphaera profunda* abundant.

274/37 DR33
Southeast facing scarp of Selfridge Rise, northern Kenn Plateau (157˚32.10′ E, 20˚45.70′ S) in 1800-1700m water depth.

Lithology B - calcareous ooze (?)
Pleistocene-Holocene
Pleistocene-Holocene as per 274/01 DR01. *Florisphaera profunda* abundant.
Reworked species:
Sphenolithus abies CN5b Mid Miocene Serravalian to CN10d Pliocene Zanclian
Discoaster druggii CN1c Early Miocene Aquitanian to CN4 Mid Miocene Serravalian
Discoaster deflandrei CP16c Early Oligocene Latdorfian to CN3 Mid Miocene Langhian

Lithology C - bored chalk (nanno30.jpg and nanno31.jpg)

Early to Middle Miocene
Matrix of medium to large pieces of calcite fragments. Mineral fragments rare.
Marker species:
Discoaster deflandrei CP16c Lower Oligocene Latdorfian to CN3 Mid Miocene Langhian
Cyclicargolithus floridanus CP15b Late Eocene Priabonian to CN5a Mid Miocene Serravalian
Sphenolithus moriformis CP10 Early Eocene Ypresian to CN6 Late Miocene Tortonian
Sphenolithus heteromorphus CN3 Early Miocene Burdigalian to CN4 Mid Miocene Serravalian
Sphenolithus belemnos CN2 Early Miocene Burdigalian
Calcidiscus tropicus CN3 Early-Mid Miocene Burdigalian-Langhian to CN8 Late Miocene Tortonian
Discoaster druggii CN1c Early Miocene Aquitanian to CN4 Mid Miocene Serravalian

274/38 DR34
Southeast facing scarp of Selfridge Rise, northern Kenn Plateau (157˚22.20′ E, 20˚50.60′ S) in 1700m water depth.

Small piece of metadolerite and manganese crust.

274/39 DR35
Southwest facing scarp of Selfridge Rise, northern Kenn Plateau (156˚43.50′ E, 20˚36.70′ S) in 2200-1950m water depth.

Lithology A1 - chalk containing lithic clasts (nanno32.jpg)
?Pliocene
Few large calcite fragments. Mostly mineral fragments common. Nannofossils rare – too few to provide accurate date.
Marker species:
Pseudoemiliana lacunosa CN12a Pliocene Piacenzian to CN14a Pleistocene

Lithology A3 - chalk attached to fine grained sandstone
?Late Eocene to Early Oligocene
Matrix of small to large calcite fragments and minerals. Nannofossils rare – too few to provide accurate date.
Marker species:
Reticulofenestra (Dictyococcites) *bisectus* CP14a Eocene Lutetian to CP19b Oligocene Chattian
Cyclicargolithus floridanus CP15b Late Eocene Priabonian to CN5a Mid Miocene Serravalian

Lithology C - calcareous mudstone
?age
Dominated by very fine brown mineral particles and fine calcite remnants. Nannofossils very rare – not possible to date sample.
Gephyrocapsa muellerae

Lithology D - pebbly foraminiferal calcarenite
?age
Matrix of small to large angular calcite fragments and minerals. Nannofossils absent – not possible to date sediment.

Lithology F - micritic calcarenite (nanno33.jpg)
Late Eocene to Early Miocene
Matrix of fine angular calcite fragments, some minerals.
Marker species:
Cyclicargolithus floridanus CP15b Late Eocene Priabonian to CN5a Mid Miocene Serravalian
Sphenolithus moriformis CP10 Early Eocene Ypresian to CN6 Late Miocene Tortonian
Reticulofenestra abisectus CP18 Mid Oligocene Rupelian to CN1a Early Miocene Aquitanian

Lithology G - calcareous ooze
Pleistocene-Holocene
Pleistocene-Holocene as per 274/01 DR01. *Florisphaera profunda* dominates.

274/40 DR36

Northwest facing scarp of seafloor high off southern Mellish Rise (156º00.40’ E, 19º27.60’ S) in 2500-2150m water depth.

Lithology B - interstitial calcareous ooze in basalt
Pleistocene-Holocene
Pleistocene-Holocene as per 274/01 DR01. *Florisphaera profunda* dominates.

Lithology C - calcarenite
?age
Matrix of large calcite fragments and minerals. No nannofossils.

Lithology D - consolidated foraminiferal sand (nanno34.jpg)
Late Miocene with re-worked Pleistocene-Holocene
Matrix of large calcite fragments and minerals. Nannofossils not common. Dominated by small to medium reticulofenestrids suggesting Late Miocene.
Marker species:
Emiliania huxleyi CN15 Pleistocene-Holocene
Pseudoemiliania lacunosa CN12a Pliocene Piacenzian to CN14a Pleistocene
Gephyrocapsa muellerae ?CN12a Pliocene Piacenzian to CN15 Pleistocene-Holocene
Florisphaera profunda CN4 Mid Miocene Langhian-Serravalian to CN15 Pleistocene-Holocene
Reticulofenestra spp (small to medium dominate)

274/41 DR37
Southwest facing scarp of southern Mellish Rise (155º41.70’ E, 18º49.50’ S) in 2200m water depth.

Lithology B - foraminiferal calcarenite
Pleistocene-Holocene (with reworked Miocene)
Matrix of small angular calcite debris. Nannofossils common.
Pleistocene-Holocene as per 274/01 DR01. *Emiliania huxleyi* and *Florisphaera profunda* dominate.
Marker species:
Emiliania huxleyi CN15 Pleistocene-Holocene
Florisphaera profunda CN4 Mid Miocene Langhian-Serravalian to CN15 Pleistocene-Holocene
Re-worked species:
Discoaster druggii CN1c to CN4 Early Miocene Aquitanian to Mid Miocene Serravalian
Discoaster deflandrei CP16c Early Oligocene Latdorfian to CN3 Mid Miocene Langhian

Lithology C - foraminiferal calcarenite
Re-worked Miocene
Matrix of small calcite fragments. *Reticulofenstra* spp (small) dominate suggesting a Miocene age.
Marker species:
Discoaster druggii CN1c Early Miocene Aquitanian to CN4 Mid Miocene Serravalian
Discoaster deflandrei CP16c Early Oligocene Latdorfian to CN3 Mid Miocene Langhian
Calcidiscus tropicus CN3 Early-Mid Miocene Burdigalian-Langhian to CN8 Late Miocene Tortonian
Florisphaera profunda CN4 Mid Miocene Langhian-Serravalian to CN15 Pleistocene-Holocene

Lithology E - calcareous ooze
Mixed Miocene to Pleistocene-Holocene
Pleistocene-Holocene as per 274/01 DR01. *Emiliania huxleyi* abundant. *Florisphaera profunda* dominate.
Marker species:
Discoaster druggii CN1c Early Miocene Aquitanian to CN4 Mid Miocene Serravalian
Discoaster deflandrei CP16c Early Oligocene Latdorfian to CN3 Mid Miocene Langhian
Sphenolithus abies CN5b Mid Miocene Serravalian to CN10d Pliocene Zanclian
Reticulofenestra spp
Sphenolithus moriformis CP10 Early Eocene Ypresian to CN6 Late Miocene Tortonian

Lithology F - interstitial calcareous ooze in greywacke (Lithology A)
Pleistocene-Holocene
Pleistocene-Holocene as per 274/01 DR01. *Emiliania huxleyi* and *Florisphaera profunda* dominate.

274/42 DR38
South facing scarp of southern Mellish Rise (155º19.60’ E, 18º38.60’ S) in 2600m water depth.

Small piece of basalt only.

274/43 DR39
South facing scarp of southern Mellish Rise (155º23.60’ E, 18º37.90’ S) in 2400m water depth.

Lithology B - tuffaceous calcarenite
?age
Matrix of large calcite fragments and minerals. Nannofossils not common.

Lithology C - calcareous ooze
Pleistocene-Holocene
Pleistocene-Holocene as per 274/01 DR01.
Reworked species:
Pseudoemiliania lacunosa CN12a Pliocene Piacenzian to CN14a Pleistocene

274/44 DR40
West facing scarp of southern Mellish Rise (155º37.60’ E, 18º10.80’ S) in 2100-1850m water depth.

Lithology A - calcareous conglomerate (weathered reef talus)
Mixed Pliocene to Pleistocene-Holocene
Marker species:
Pseudoemiliania lacunosa (common) CN12a Pliocene Piacenzian to CN14a Pleistocene
Emiliania huxleyi CN15 Pleistocene-Holocene
Florisphaera profunda CN4 Mid Miocene Langhian-Serravalian to CN15 Pleistocene-Holocene

Lithology D - red mudstone
?age
Matrix of brown mineral particles. No calcite.

Lithology I - greenish-grey mudstone
?age
Matrix of calcite remnants and brown spherical mineral fragments. No nannofossils.

Lithology J - weathered calcarenite
Pleistocene-Holocene
Matrix of large calcite and some mineral fragments. Dominated by *Emiliania huxleyi*. *Florisphaera profunda* common.
Marker species:
Emiliania huxleyi CN15 Pleistocene-Holocene
Florisphaera profunda CN4 Mid Miocene Langhian-Serravalian to CN15 Pleistocene-Holocene

274/45 DR41
West facing scarp of western Mellish Rise (155º15.80’ E, 18º10.40’ S) in 1900-1450m water depth.

Lithology K - calcareous algal boundstone (nanno35.jpg)
Pliocene to Pleistocene-Holocene
Matrix of large angular calcite pieces and some minerals. Pleistocene-Holocene assemblage as per 274/01 DR01.
Marker species:
Pseudoemiliania lacunosa (common) CN12a Pliocene Piacenzian to CN14a Pleistocene
Emiliania huxleyi CN15 Pleistocene-Holocene
Florisphaera profunda CN4 Mid Miocene Langhian-Serravalian to CN15 Pleistocene-Holocene
Discoaster brouweri CN7 Late Miocene Tortonian to CN12d Late Pliocene Piacenzian

Lithology L - chalk (nanno36.jpg and nanno37.jpg)
Middle to Late Miocene
Matrix dominated by small sub-angular calcite pieces (?broken reticulofenestrids). Nannofossils not abundant. *Discoaster* spp common.
Marker species:

Discoaster braaudii CN5b Mid Miocene Serravallian to CN9b Late Miocene Messinian
Discoaster druggii CN1c Early Miocene Aquitanian to CN4 Mid Miocene Serravalian
Sphenolithus moriformis CP10 Early Eocene Ypresian to CN6 Late Miocene Tortonian
Sphenolithus abies CN5b Mid Miocene Serravalian to CN10d Pliocene Zanclian
Reticulofenestra spp
Cyclicargolithus floridanus CP15b Late Eocene Priabonian to CN5a Mid Miocene Serravalian
Discoaster deflandrei CP16c Lower Oligocene Latdorfian to CN3 Mid Miocene Langhian

274/46 DR42
Southeast facing scarp of western Mellish Rise (154º53.40’ E, 18º09.20’ S) in 1600m water depth.

Lithology A - foraminiferal chalk (nanno38.jpg and nanno39.jpg)
Early to Middle Miocene
Matrix dominated by *Reticulofenestra* spp (medium) and *Sphenolithus* spp. Small to medium angular calcite debris common, nannos abundant. *Discoaster* spp common.
Marker species:
Discoaster druggii CN1c Early Miocene Aquitanian to CN4 Mid Miocene Serravalian
Discoaster braaudii CN5b Mid Miocene Serravalian to CN9b Late Miocene Messinian
Sphenolithus moriformis CP10 Early Eocene Ypresian to CN6 Late Miocene Tortonian
Sphenolithus abies CN5b Mid Miocene Serravalian to CN10d Pliocene Zanclian
Reticulofenestra spp
Sphenolithus belemnos CN2 Early Miocene Burdigalian
Discoaster deflandrei CP16c Early Oligocene Latdorfian to CN3 Mid Miocene Langhian

274/47 DR43
North facing scarp of western Mellish Rise (154º42.00’ E, 18º07.90’ S) in 2000-1850m water depth.

Lithology B - calcarenite (nanno40.jpg and nanno41.jpg)
Late Pliocene
Pseudoemiliania lacunosa and *Florisphaera profunda* dominant. Matrix fine calcite pieces, mostly *Florisphaera profunda* with a few large calcite pieces. Abundant brown spherical mineral fragments.
Marker species:
Pseudoemiliania lacunosa CN12a Pliocene Piacenzian to CN14a Pleistocene
Gephyrocapsa muellerae ?CN12a Pliocene Piacenzian to CN15 Pleistocene-Holocene
Gephyrocapsa caribbeanica CN13b Pliocene Piacenzian to CN15 Pleistocene
Gephyrocapsa aperta (*>3μm*) ?CN11b Pliocene Zanclian to CN15 Pleistocene-Holocene
Discoaster triradiatus CN12d-c Pliocene Piacenzian
Discoaster brouweri CN7a to CN12d Pliocene Piacenzian
Discoaster variabilis CN4 Mid Miocene Langhian to CN12a Pliocene Piacenzian

274/49 DR44
South facing scarp of western Mellish Rise (154º20.30’ E, 17º38.00’ S) in 2500-2350m water depth.

Lithology A1 - calcarenite (nanno42.jpg and nanno43.jpg)
Middle to Late Paleocene
Matrix of large calcite pieces and minerals with very little fine fraction. Nannofossils not common. No *Biantholithus hughesii* thus younger than CP1a. No *Hornibrookina edwardsii* thus younger than CP2.
Marker species:
Toweius eminens CP8a Late Paleocene Thanetian to CP9a Early Eocene Ypresian
Cruciplacolithus tenuis CP2 Early Paleocene Danian to CP8a Late Paleocene Thanetian
Prinsius martinii CP2 Early Paleocene Danian to CP4 Mid Paleocene Selandian
Neococclithes protenus CP4 Early Paleocene Danian to CP10 Early Eocene Ypresian
Lanternithus duocavus LO top CP3 to top CP3 Early Paleocene Danian
Cruciplacolithus asymmetricus Paleocene

Lithology A2 - calcarenite (nanno44.jpg)
?reworked Paleocene
Matrix different to Lithology A1, mainly dissolved calcite with some large calcite and mineral fragments. Nannos not common and show marked dissolution.
Marker species:

Fasiculithus bobii CP7 to CP8a Late Paleocene Thanetian
Reticulofenestra umbilica CP14a Mid Eocene Lutetian to CP17 Mid Oligocene Rupelian
Toweius eminens CP8a Late Paleocene Thanetian to CP9a Early Eocene Ypresian
Lanternithus duocavus LO top CP3 to top CP3 Early Paleocene Danian
Cruciplacolithus tenuis CP2 Early Paleocene Danian to CP8a Late Paleocene Thanetian
?Chiasmolithus consuetus CP4 Mid Paleocene Selandian to CP15b Late Eocene Priobonian
Fasiculithus involutus CP8b Late Paleocene Thanetian to CP9 Early Eocene Ypresian
Chiasmolithus solitus CP9a Early Eocene Ypresian to CP14a Mid Eocene Bartonian

Lithology A3 - calcarenite (nanno45.jpg, nanno46.jpg and nanno47.jpg)
Middle to Late Paleocene
Matrix identical to Lithology A1 – large calcite and mineral pieces with very little dissolved calcite or fine fragment. Nannofossils not common.
Marker species:
Toweius eminens CP8a Late Paleocene Thanetian to CP9a Early Eocene Ypresian
Cruciplacolithus tenuis CP2 Early Paleocene Danian to CP8a Late Paleocene Thanetian
Lanternithus duocavus LO top CP3 to top CP3 Early Paleocene Danian
?Chiasmolithus consuetus CP4 Mid Paleocene Selandian to CP15b Late Eocene Priobonian

Lithology B1 - calcarenite inclusion in manganese nodule
?Age
Matrix of small calcite fragments and minerals. Abundant small brown spherical and needle-shaped particles (ash?). No nannofossils.

Core Samples

274/02 GC01
Located at (155˚50.19′ E, 17˚13.19′ S) in 2658m water depth.

Coretop (nanno48.jpg)
Pleistocene-Holocene
Pleistocene-Holocene as per 274/01 DR01.

10 cm
Pleistocene-Holocene
Pleistocene-Holocene as per 274/01 DR01.

310cm (nanno49.jpg)
Pleistocene
QAZ4 (isotope stage 15 (589ky) to lower isotope stage 8 (258ky)).
Dominated by *Gephyrocapsa caribbeanica* CN13b to CN15.

Corecatcher (nanno50.jpg)
Pleistocene
QAZ4 (isotope stage 15 (589ky) to lower isotope stage 8 (258ky)).
Dominated by *Gephyrocapsa caribbeanica* CN13b to CN15.

274/09 GC02
Located at (156˚34.02′ E, 21˚31.03′ S) in 1223m water depth.

Corecatcher
Calcareous ooze
Pleistocene-Holocene
Pleistocene-Holocene as per 274/01 DR01. *Emiliania huxleyi* dominates. *Florisphaera profunda* present, but not abundant.

274/11 GC03
Located at (157˚04.83′ E, 21˚26.71′ S) in 1300m water depth.

Corecather
Lithology A - foraminferal sand and chalk (nanno51.jpg, nanno52.jpg, nanno53.jpg and nanno54.jpg)
Middle Miocene
Matrix of coarse medium to large calcite pieces. Dominated by medium to large *Reticulofencestra* species. Foraminifera pieces common. A few *Emiliania huxleyi* – possible contamination rather than re-working as there is an absence of any other typical Pleistocene-Holocene species.
Marker species:
Reticulofenestra pseudoumbilica CN10a Late Miocene Messinian to CN11b Pliocene Zanclian
Cyclicargolithus floridanus CP15b Late Eocene Priabonian to CN5a Mid Miocene Serravalian
Calcidiscus tropicus CN3 Early-Mid Miocene Burdigalian-Langhian to CN8 Late Miocene Tortonian
Sphenolithus abies CN5b Mid Miocene Serravalian to CN10d Pliocene Zanclian
Solidopons petrae CN2 Early Miocene Burdigalian to CN7a-b Late Miocene Tortonian
Discoaster druggii CN1c to CN4 Early Miocene Aquitanian to CN4 Mid Miocene Serravalian
Discoaster braarudii CN5a Mid Miocene Serravalian to CN8a Late Miocene Tortonian
Discoaster deflandrei (?CP9b) CP16c Early Oligocene Latdorfian to (?CN5b) CN3 Mid Miocene Langhian

274/25 GC04
Located at (155º42.74’ E, 17º33.25’ S) in 2295m water depth.

Core base 160cm (bsf)
Pleistocene-Holocene
Pleistocene-Holocene as per 274/01 DR01. *Florisphaera profunda* abundant.

274/48 GC05
Located at (154º32.99’ E, 17º53.98’ S) in 2860m water depth.

Corecatcher - calcareous ooze
Pleistocene-Holocene
Pleistocene-Holocene as per 274/01 DR01. *Emiliania huxleyi* dominates. *Florisphaera profunda* abundant.

Table 1. Biostratigraphic summary of *Southern Surveyor* Cruise SS02/2005 (GA Survey 274) dredged and cored nannofossil samples.

Sample	**Estimated Age of Sample**	**Nannofossil Zones** (range of all species listed)	**Epoch** (range of all species listed)	**Stage** (range of all species listed)	**Age (Ma)** (range of all species listed)	**Marker Species**
Kenn Plateau dredge samples						
274/03/DR02 B foraminiferal chalk with bivalves	*Late Eocene to Oligocene (CP10 to CN6) Nannos rare*	*CP10 to CN6*	*Early Eocene to Late Miocene*	*Ypresian to Tortonian*	*7 to 54*	*Sphenolithus moriformis* *Cyclicargolithus floridanus*
274/06/DR05 A bored chalk	*Mixed Late Miocene to Early Pliocene (CN8b-CN10c) Nannos rare*	*CN1c-CN12c*	*Early Miocene to Early Pliocene*	*Burdigalian to Piacenzian*	*20.6 to 1.8*	*Sphenolithus abies* *Coronocyclus nitescens* *Calcidiscus rotula* *Amaurolithus delicatus* *Discoaster pentaradiatus* *Discoaster exilis* *Calcidiscus tropicus* *Discoaster braarudii*
274/07/DR06 B calcarenite	*Pleistocene-Holocene Nannos rare*	*CN15*	*Pleistocene to Holocene*		*0 to 0.3*	*Emiliania huxleyi* *Gephyrocapsa oceanica*
274/08/DR07 B calcarenite	*Nannos rare*					*Calcidiscus leptoporus*
274/12/DR09 A calcarenite-calcirudite	Re-worked Middle to Late Miocene (CN5b-CN8b)	CP16a-CN15	Late Eocene to Pliocene	Priabonian to Piacenzian	1.8 to 39.4	Emiliania huxleyi Gephyrocapsa muellerae Sphenolithus abies Florisphaera profunda Calcidiscus tropicus Discoaster brouweri Discoaster pentaradiatus Catinatus coalitus Discoaster variabilis Cyclicargolithus floridanus Discoaster deflandrei Reworked species:

						Emiliania huxleyi Gephyrocapsa muellerae
274/37/DR33 C bored chalk	Early to Middle Miocene (CN2-CN4)	CP10 to CN8b	Early Eocene to Late Miocene	Ypresian to Tortonian	5.4 to 54	Discoaster deflandrei Cyclicargolithus floridanus Sphenolithus moriformis Sphenolithus heteromorphus Sphenolithus belemnos Calcidiscus tropicus Discoaster druggii
274/39/DR35 A1 chalk containing lithic clasts	*Pliocene to Pleistocene Nannos rare*	*CN12a to CN14a*	*Pliocene to Pleistocene*		*0 to 5.4*	*Reticulofenestra sp Gephyrocapsa mullerae Pseudoemiliania lacunosa*
274/39/DR35 A3 chalk	*Late Eocene to Late Oligocene (CP15b-CP19b) Nannos rare*	*CP14a to CN15a*	*Middle Eocene to Middle Miocene*	*Bartonian to Serravalian*	*11.2 to 42*	*Reticulofenestra bisectus Cyclicargolithus floridanus*
274/39/DR35 C calcareous mudstone	*Pliocene to Pleistocene Nannos very rare*					*x1 Gephyrocapsa muellerae*
274/39/DR35 F micritic calcarenite	Late Eocene to Early Miocene (CP15b-CN1c)	CP10 to CN6	Early Eocene to Late Miocene	Ypresian to Tortonian	7 to 54	Cyclicargolithus floridanus Sphenolithus moriformis Reticulofenestra abisectus
274/39/DR36 D consolidated foraminiferal sand	*Pliocene to Pleistocene (CN12a-CN14a) (?reworked)*	*CN4 to CN15*	*Middle Miocene to Pleistocene to Holocene*	*Serravalian to Pleistocene*	*0 to 15*	*Emiliania huxleyi Florisphaera profunda Reticulofenestra sp.(small to medium dominate)*
Kenn Plateau core samples						
274/02/GC01 calcareous ooze coretop	Pleistocene-Holocene	CN15	Pleistocene to Holocene		0 to 0.3	Emiliania huxleyi
274/02/GC01 calcareous ooze 10cm (bsf)	Pleistocene-Holocene	CN15	Pleistocene to Holocene		0 to 0.3	Emiliania huxleyi
274/02/GC01 calcareous ooze core base 310cm bsf	Pleistocene Isotopic stage 15 to lower isotope stage 8	CN13b	Pleistocene		(589ky to 258ky)	Gephyrocapsa caribbeanica

274/02/GC01 calcareous ooze core catcher	Pleistocene isotopic stage 15 to lower isotope stage 8	CN13b	Pleistocene		(589ky to 258ky)	Gephyrocapsa caribbeanica
274/09/GC02 core catcher (only recovery)	Pleistocene- Holocene	CN15	Pleistocene to Holocene		0 to 0.3	Emiliania huxleyi
274/11/GC03 A corecatcher	Middle Miocene	CP16 to CN11b	Early Oligocene to Pliocene	Latdorfian to Zanclian	3.6 to 39.4	Reticulofenestra pseudoumbilica Cyclicargolithus floridanus Calcidiscus tropicus Sphenolithus abies Solidopons petrae Discoaster druggii Discoaster deflandrei Discoaster braarudii
Mellish Rise dredge samples						
274/15/DR12 C brown clay	Pleistocene- Holocene	CN15	Pleistocene to Holocene		0 to 0.3	Emiliania huxleyi
274/16/DR13 C chalk within manganese nodule	Early Eocene (CP9b-CP12b)	CP9a to CP15b	Early to Late Eocene	Ypresian to Priabonian	36 to 49	Tribrachiatus orthostylus Discoaster kuepperi Discoaster barbadensis Chiasmolithus solitus
274/16/DR13 D bioturbated chalk	Middle Paleocene to Middle Eocene (CP4-CP9b)	CP4 to CP14a	Middle Paleocene to Middle Eocene	Selandian to Bartonian	39.4 to 60.2	Chiasmolithus solitus Hornibrookina australis Toweius eminens Toweius selendanis Transverspontis sp. Neochiastozygus perfectus Discoaster multiradiatus Fasiculithus involutus
274/16/DR13 F chalky breccia	Eocene to Early Oligocene (CP14b-CP16a)	CP10 to CN6	Early Eocene to Late Miocene	Ypresian to Tortonian	7 to 54	Sphenolithus moriformis Reticulofenestra (Dictyococcites) bisectus Coccolithus formosus Cyclicargolithus floridanus
274/17/DR14 E bentonitic mudstone	Mixed Late Eocene to Early	CP13b to CN3	Middle Eocene to Middle Miocene	Lutetian to Langhian	15 to 49	Sphenolithus belemnos Zygrhablithus bijugatus

	Miocene (CP15a-CN1c)					Coccolithus formosus ?Cruciplacolithus oamaruensis
274/17/DR14 F glauconite calcareous lithic sandstone	Late Paleocene to Early Eocene (CP8a-CP9b)	CP2 to CP14a	Early Paleocene to Middle Eocene	Danian to Bartonian	39.4 to ?66.5	Chiasmolithus solitus Hornibrookina australis Toweius eminens Toweius selendanis Transversepontis sp Neochiastozygus perfectus Ellipsolithus marcellus Discoaster multiradiatus Fasiculithus involutus Cruciplacolithus tenuis
274/17/DR14 G chalk	Mixed Early Eocene to Middle Miocene (CP9a-CN3)	CP5 to CN3	Middle Paleocene to Middle Miocene	Thaneian to Langhian	15 to 60.2	Hornibrookina australis Sphenolithus belemnos Discoaster kuepperi Discoaster deflandrei Zygrhablithus bijugatus Reticulofestra umbilica
274/18/DR15 C muddy foraminiferal chalk	Pleistocene-Holocene	CN15	Pleistocene to Holocene		0 to 0.3	Emiliania huxleyi
274/30/DR26 B calcareous basaltic conglomerate	Pliocene (CN12a-CN12d)	CN8a to CN15	Late Miocene to Pleistocene-Holocene	Tortonian to Pleistocene-Holocene	0 to 11.2	Discoaster asymmetricus Discoaster pentaradiatus Pseudoemiliania lacunosa Gephyrocapsa muellerae
274/35/DR31 C foraminiferal mudstone	Mixed Paleocene-Miocene	CP1 to CN9	Early Paleocene to Late Miocene	Danian to Messinian	5.4 to 66.5	Coccolithus formosus Reticulofenstra rotaria Reticulofenestra (Dictyococcites) bisectus Discoaster kuepperi Bianolithus sparsus Cruciplacolithus primus Toweius eminens Zygrhablithus bijugatus Discoaster saipanensis
274/35/DR31 D foraminiferal calcareous sandstone	Paleocene-Miocene	CP1a to CN8	Paleocene to Late Miocene	Danian to Tortonian	7 to 66.5	Calcidiscus tropicus Cyclicargolithus floridanus Bianolithus sparsus Discoaster saipanensis

						Zygrhablithus bijugatus Discoaster kuepperi Reticulofestra umbilica
274/39/DR37 B foraminiferal calcarenite	*Re-worked Pleistocene-Holocene (CN14-CN15)*	*CP16a to CN15*	*Late Eocene to Pleistocene-Holocene*	*Priabonian to Pleistocene-Holocene*	*0 to 39.4*	*Emiliania huxleyi* *Florisphaera profunda* *Discoaster druggii* *Discoaster deflandrei* *Calcidiscus tropicus* *Reticulofenstra spp small(dominates)*
274/39/DR37 C foraminiferal calcarenite	*Re-worked Miocene (CN1c-CN5b)*	*CP16a to CN15*	*Late Eocene to Pleistocene-Holocene*	*Priabonian to Pleistocene-Holocene*	*0 to 39.4*	*Reticulofenstra spp small* *Discoaster druggii* *Discoaster deflandrei* *Calcidiscus tropicus*
274/39/DR40 A calcareous conglomerate (weathered reef talus)	Pliocene to Pleistocene-Holocene	CN12a to CN15	Pliocene to Pleistocene-Holocene	Serravalian to Holocene	0 to 3.6	Emiliania huxleyi Florisphaera profunda
274/39/DR40 J weathered calcarenite	Pleistocene-Holocene	CN4 to CN15	Pleistocene-Holocene		0 to 1.8	Emiliania huxleyi Florisphaera profunda
274/39/DR41 K calcareous algal boundstone	Pliocene to Pleistocene-Holocene	CN4 to CN15	Late Miocene to Pleistocene-Holocene	Langhian to Holocene	0 to 16.4	Pseudoemiliania lacunosa Emiliania huxleyi Florisphaera profunda Discoaster brouweri
274/45/DR41 L chalk	Middle to Late Miocene (CN3-CN5b)	CP10 to CN10c	Early Eocene to Pliocene	Ypresian to Zanclian	3.6 to 54	Discoaster braarudii Discoaster druggii Sphenolithus moriformis Sphenolithus abies Reticulofenestra spp Cyclicargolithus floridanus
274/46/DR42 A foraminiferal chalk	Early to Late Miocene (CN2 to CN6)	CP10 to CN10c	Early Eocene to Pliocene	Ypresian to Zanclian	3.6 to 54	Discoaster druggii Discoaster braarudii Sphenolithus abies Reticulofenestra spp Sphenolithus belemnos Discoaster deflandrei
274/47/DR43 B calcarenite	Pliocene (CN12a-CN12d)	CN4 to CN15	Middle Miocene to Pleistocene-Holocene	Langhian to Pleistocene-Holocene	0 to 16.4	Pseudoemiliania lacunosa Gephyrocapsa muellerae Gephyrocapsa caribbeanica

						Discoaster triradiatus Discoaster brouweri Discoaster variabilis
274/47/DR44 A1 calcarenite	Paleocene (CP2-CP8a)	CP2 to CP9a	Early Paleocene to Early Eocene	Danian to Ypresian	49 to 66.5	Toweius eminens Cruciplacolithus tenuis Prinsius martinii Neococcolithes protenus Lanternithus duocavus
274/47/DR44 A2 calcarenite	*Late Paleocene to Late Eocene*	*CP1a to CP17*	*Early Paleocene to Middle Oligocene*	*Danian to Rupelian*	*30 to 66.5*	*Fasiculithus bobii Reticulofenestra umbilica Toweius eminens Lanternithus duocavus Cruciplacolithus tenuis ?Chiasmolithus consuetus*
274/47/DR44 A3 calcarenite	*Paleocene (CP2 to CP8a)*	*CP1a to CP15b*	*Early Paleocene to Late Eocene*	*Danian to Priobonian*	*36 to 66.5*	*Toweius eminens Cruciplacolithus tenuis Lanternithus duocavus ?Chiasmolithus consuetus*
Mellish Rise core samples						
274/25/GC04 core base 160cm bsf	Pleistocene- Holocene	CN15	Pleistocene-Holocene		0 to 0.3	Emiliania huxleyi
274/48/GC05 small amount of calcareous ooze in corecatcher only	Pleistocene- Holocene	CN4 to CN15	Pleistocene-Holocene		0 to 1.8	Emiliania huxleyi Florisphaera profunda

Dredge samples of surface calcareous ooze with a Pleistocene-Holocene age are not included as they are not biostratigraphically significant.
Dredge samples without calcareous fossils are excluded. All core samples are included.
Ages of all species identified are given for mixed and reworked samples.
Entries in italics indicate age of sample is uncertain due to paucity of calcareous nannofossils and/or reworking.
bsf = below sea floor.

APPENDIX 4. FORAMINIFERAL BIOSTRATIGRAPHY OF DREDGE AND CORE SAMPLES

Pat Quilty

Abstract

Sixty-eight samples from Kenn Plateau (9) and Mellish Rise (59) have been examined either in processed residues or in thin section. Most contain workable foraminiferid faunas that yield ages from all epochs of the Cenozoic and possibly one from the Cretaceous. Samples are from many depths of deposition including those from shallow-water sediments, commonly now several thousand metres below original depth, allowing rough indications of amount and rate of subsidence. A few samples are barren of foraminiferids. Several require further examination of larger foraminiferid to obtain more refined ages; these will be reported on later. Comments include reference to non-foraminiferid component, environment of deposition and age. A feature is the quality of preservation of some Palaeogene faunas that merit formal documentation.

The material provides significant additions to our understanding of the Palaeogene faunas and environments of the region, especially the occurrence of a wide range of previously unrecorded large foraminiferids which allows correlation with the Indo-Pacific Letter classification of the Tertiary. Records such as that of *Biplanispira* are particularly significant. Neogene faunas are generally similar to those recorded from nearby and which have been documented reasonably well.

Mellish Rise contains samples (DR12, 13 and 14) that yielded no foraminiferid faunas and are carbonate-poor but radiolarian-rich. They are accompanied by Paleocene and Eocene carbonate samples with good foraminiferid faunas, and thus the radiolarian-rich samples deserve further study as current water depths are above the CCD and it is unlikely that their features are a result of simple CCD-related dissolution.

Paleocene and Eocene records appear to mirror sedimentation cycle patterns well known along southern Australia (and more widely) but the Neogene ages need more refinement before a good comparison can be made.

Introduction

This report summarises analysis of foraminiferids (and also makes reference to other constituents) in residues from 68 samples from Geoscience Australia's *Southern Surveyor* cruise SS02/2005 (GA Survey 274) off northeastern Australia. All but one are dredge samples, the other from a gravity core.

Material and methods

Most samples had been processed by Geoscience Australia and sieved at 63, 125 and 500 microns. For most samples, there is also a lithology sample but many consist only of the residues. Several highly lithified dredged lithologies were studied only in thin section provide by Geoscience Australia. All were subject to routine examination under stereomicroscope or petrological microscope and, where necessary, specimens of larger species were thin sectioned to aid identification. A few samples were reprocessed in Hobart after initial examination.

Sample numbers quoted are those supplied with the samples. They are treated in increasing order of GA number. Locality and depth data and sample numbers are included with individual sample results.

Discussion

Two regional localities have been studied – Kenn Plateau and Mellish Rise and they are taken separately.

The samples have yielded ages throughout the Tertiary, including Paleocene, Eocene, Oligocene, Miocene, Pliocene and Quaternary. Several include noteworthy species that have not been recorded from this area before, although many are known from elsewhere in the Indo-Pacific region and provide a means of reconstructing biogeography. As noted elsewhere (for example in Quilty & Packham, in press) knowledge of the evolution of palaeoenvironments and biogeographic affinities along the east coast of Australia throughout the late Cretaceous and younger, is poor. These samples provide a significant basis for improving the record. The planktonic species have been well recorded globally and in various ocean drilling records but the discovery of a diverse range of species of *Hantkenina* is interesting in the Australasian context.

The faunas include those from a variety of depositional environments, many with large foraminiferid such as *Nummulites, Biplanispira, Operculina, Discocyclina, Asterocyclina, Heterostegina* and possibly others as yet not identified, and others that, while sometimes classified as small, are studied using the same techniques as traditional ‘large’ foraminiferid. The latter include such genera as *Fabiania*, *Sherbornina* and *Crespinina*. With some marked exceptions, the large species are generally small (mostly some 4.5 mm) by the standards of ‘large’ foraminiferid. The significance of this small size is unclear but it may depend on some environmental factor such as deeper water deposition than required for the larger specimens, or not fully tropical conditions.

Many of the shallow water benthic forms represent new records, and this is especially significant for the Palaeogene larger species such as *Asterocyclina/Discocyclina*, *Nummulites, Biplanispira, Operculina, Fabiania, Crespinina*. Only Chaproniere (1983) has made any record of Palaeogene larger foraminiferid from the region (western margin of the Queensland Plateau), from >1000 km north of those in the 163 000 catalogue number range but it was from a single sample and the material was poor; only *Asterocyclina incisuricamerata* Cole and *Operculina pacifica* Whipple were major records. This study expands the range of those occurrences quite considerably and allows the sections to be compared with the Indo-Pacific Letter classification of the Tertiary to a degree previously impossible in Australasia.

There seem to be several new species and possibly a new genus among the material.

KENN PLATEAU SAMPLES

Sample No.: 1603176
Core details: 274/11GC03 A1.1
Locality: 21° 26.71’S; 157°04.84’E – 1306 m.
Material: Residue only
Lithology: Planktonic foram ooze. Residue very dominantly (>>99%) planktonic foraminiferids. *Orbulina universa* shows signs of dissolution but other species do not.
Fauna: Full diversity tropical fauna.
Planktonic species
Orbulina universa
Orbulina suturalis
Biorbulina bilobata

Globigerina nepenthes
Globigerinoides bollii
Sphaeroidinella seminulina kochi
Globoquadrina dehiscens dehiscens
Globoquadrina dehiscens advena
Globoquadrina altispira altispira
Globorotalia lenguaensis
Globorotalia menardii
Globorotalia conoidea
Hastigerina pelagica
Notable benthic species
Carpenteria monticularis
Benthic species include nodosariids, agglutinated forms and two species of conical attached forms, one agglutinated.
Age: Latter part of the Middle Miocene, N14.
Environment of deposition: Continental slope to deep sea floor depths.
Comment: A difficult sample to date even though planktonic forms are abundant and well preserved.

Sample No.: 1603181
Dredge details: 274/03DR02 B1.1
Locality: 23° 12.7'S; 156°30.4'E – 1770-1620 m.
Material: Thin section only
Lithology: Lithified nanno/foram ooze with echinoid spines and plates and a 1 cm rounded basalt clast. Mn staining around open cavities.
Fauna:
Lacks keeled globorotalids, convincing *Globoquadrina* or *Orbulina*, and is dominated by diverse thin walled globigerinids, both large and small.
Chiloguembelina ?*cubensis* (very rare)
Globigerina gortanii
Globigerina venezuelana
Globigerina praebulloides group.
Age: Probably Early Oligocene.
Environment of deposition: Continental slope or deeper but above CCD.
Comment: Nannoplankton may give a better result**.**

Sample No.: 1603182
Dredge details: 274/03DR02 B1.2A
Locality: 23° 12.7'S; 156°30.4'E – 1770-1620 m.
Material: Thin section only
Lithology: As for 1603181 but lacking clasts**.**
Fauna:
Essentially the same as 1603181 but with more *Chiloguembelina*
Age: Oligocene, probably Early
Environment of deposition: Continental slope or deeper but above CCD.
Comment: Nannoplankton may give a more refined result.

Sample No.: 1603183
Dredge details: 274/03DR02 B1.2B
Locality: 23° 12.7'S; 156°30.4'E – 1770-1620 m.
Material: Broken sample specimens plus residue**.** Mn oxide coated ooze**.**
Lithology: Lithified calcareous ooze. Residue consists of mixture of well-preserved modern fauna (not recorded below) and very poorly preserved older material from which good foraminiferids are hard to extract and identify.
Fauna:
Orbulina suturalis
Globigerina nepenthes
Globoqudrina altispira altispira
Globoquadrina dehiscens
Globorotalia lenguaensis
Globorotalia miozea
Age: Latter part Middle Miocene, N14/15
Environment of deposition: Continental slope to deep sea floor depths.

Sample No.: 1603191

Dredge details: 274/06DR05 A1.2
Locality: 22° 08'S; 156°44.6'E – 1600 m.
Material: Sample plus residues.
Lithology: Probably white nanno/foram ooze with minor pteropods and echinoid spines. Residue not clean and foraminiferids covered with dust. Minor Mn staining. Preservation satisfactory but not good. No evidence of dissolution.
Fauna:
Orbulina suturalis
Orbulina universa
Globigerina nepenthes
Globoquadrina altispira altispira
Globigerinoides quadrilobatus complex
Hastigerina aequilateralis
Hastigerina pelagica
Sphaeroidinella seminulina seminulina
Pulleniatina primalis
Neogloboquadrina acostaensis
Globorotalia merotumida
Globorotalia internec *limbata/multicamerata*
Age: Late Miocene, N17.
Environment of deposition: Continental slope to deep seafloor depths.
Comment: Some infauna indicating locality as having good nutrient supply.

Sample No.: 1603196
Dredge details: 274/07 DR06 Lithology A1.1
Locality: 21° 30.85'S; 156° 24.65'E – 700-400 m
Material: A single thin section.
Lithology: A difficult sample but with a real oddity. There are three phases in the sample - the primary biocalcarenite with abundant calcareous algae, bryozoans, echinoid debris. There are then two phases of micrite. One, probably the older, has abundant planktonic foraminiferids and pteropods, with a Quaternary appearance. The other micrite is nanno ooze with few planktonic foraminiferids but with dozens of the benthic *Patellina corrugata*.
Fauna:
Primary calcarenite
Orbulina universa,
Lepidocyclina sp.
'*Heterostegina*'
Sphaerogypsina globulus
Globigerinoides
Praeorbulina sp.
Micrite.
Globorotalia inflata
Globorotalia truncatulinoides (tentative because of so few specimens).
Age: Calcarenite: Middle Miocene N9.
Micrite: Quaternary.
Environment of deposition: Primary biocalcarenite is shallow, tropical/subtropical marine deposited in the photic zone and thus with few planktonic foraminiferids. Micrite represents two phases of ooze deposition. The presence of so many *Patellina corrugata* is very interesting. This is an odd species and usually very rare. There is some real environmental signal here but communication with colleagues around the world has not helped identify that signal.
Comment: Nannoplankton may give better results for the cavity filling micrite.
A slightly odd feature is the lack of expected species accompanying the Quaternary fauna.

Sample No.: 1603200
Dredge details: 274/07 DR06, lithology B1.1
Locality: 21° 30.85'S; 156° 24.65'E – 700-400 m
Material: Single thin section.
Lithology: The main body of the sediment consists of foram/pteropod biocalcarenite with dense micrite matrix and low porosity. This primary rock has an outer highly porous overlay. They may be the same sediment from which the nanno micrite has been preferentially sifted away from the outer part but I doubt this because there are differences. This outer layer has corals, mollusc debris, encrusting foraminiferids, *Amphistegina* etc. No calcareous algae or large forams.
Fauna:

Globorotalia truncatulinoides
Globorotalia tosaensis
Globorotalia menardii
Globorotalia tumida
Globorotalia inflata
One section through *Patellina corrugata*.
Age: very early Quaternary, earliest N22.
Environment of deposition: The outer overlay of the sediment seems to be a shallower sediment which is odd because the normal progression is to greater depth with time.

Sample No.: 1603213
Dredge details: 274/08DR07 B1.1
Locality: 21° 25.5'S; 156°24.45'E – 1600-1500m
Material: Sample plus residues.
Lithology: White calcarenite with abundant large foraminiferids, bryozoans, echinoid fragments, crinoid ossicles, trace small gastropods, trace calcareous algae, a few *Amphistegina*. No planktonic foraminiferids in the >500 micron fraction. Abundant very well preserved planktonic foraminiferids in the 63-125 micron fraction, but very likely to be contaminants. No evidence of significant abrasion to grains in depositional environment. Preservation rather poor with significant surface recrystallisation.
Fauna:
Globigerinatheka index tropicalis
Globigerinatheka index s.l.
Globigerinatheka mexicana barri
Globigerina yeguaensis
Catapsydrax unicavus
Catapsydrax dissimilis
Heterostegina equatoria
Sphaerogypsina globulus
Asterocyclina incisuricamerata
Age: Eocene, Late P14/EarlyP15 Tertiary *a*.
Environment of deposition: Seagrass beds (within photic zone) below wave base.

Sample No.: 1603239
Dredge details: 274/12DR09 A1.1
Locality: 21° 21.5'S; 157°14.6'E – 1800 m
Material: Sample plus residues.
Lithology: Slightly off-white bryozoal calcarenite with molluscs (mainly bivalve) fragments, ostracods, echinoid and crinoid remains. Preservation poor due to recrystallisation. No foraminiferids in >500 micron fraction. Foraminiferids very rare in 125-500 micron fraction but common and very well-preserved in the 63-125 micron fraction suggesting contamination.
Abundant, very well sorted, clean, angular-rounded quartz in 125-500 micron fraction. Entire 125-500 micron fraction picked.
Contains a few doubly terminated quartz crystals.
Fauna:
Very low diversity planktonic foraminiferid fauna; benthic fauna quite diverse.
Globigerina woodi
Globorotalia kugleri
Age: Oligo-Miocene boundary, N3/4.
Environment of deposition: Very shallow water with influx of well sorted terrigenous sand.
Comment: More work needed. The locality has subsided some 1700 m since deposition at 22 Ma.

MELLISH RISE SAMPLES

Sample No.: 1603260
Dredge details: 274/15DR12 B1.1
Locality: 16° 49.9'S; 157°30.9'E – 2600 m
Material: Sample plus residue
Lithology: Sample is of fine, white sediment, with minor Mn oxide coating on fragments to about 1 cm that did not disaggregate.
Residue consists of fragments of the fine sediment with apparent foraminiferid fauna but it is young and does not come from the sediment which was re-processed. Very minor reaction with acid. A few spherical and discoidal shapes appear to be radiolarians.

Fauna:
No foraminiferids
Age: Indeterminate but high siliceous content raises the question of Eocene.
Environment of deposition: Deep marine or below CCD to concentrate siliceous microfossils. Or at a time of different oceanography.

Sample No.: 1603262
Dredge details: 274/15DR12 C1.1
Locality: 16° 49.9'S; 157°30.9'E – 2600 m
Material: Residue only.
Lithology: Fine white host sediment. Minor reaction with acid and rock breaks down to fine sediment. 125-500 micron fraction contains some contaminant modern foraminiferids. Pale green 'blebs' suggest chert formation active. Odd shapes probably represent radiolarians.
Fauna:
No foraminiferids
Age: Indeterminate, but high siliceous content may suggest Eocene.
Environment of deposition: Deep marine or below CCD to concentrate siliceous microfossils. Or at a time of different oceanography.

Sample No.: 1603275
Dredge details: 274/16DR13 C2.1
Locality: 16° 51.1'S; 157°29.2'E – 2900-2750 m
Material: Residue
Lithology: Fine white with appearance of chalk. Abundant spherical radiolarians. No reaction with acid. Would be a radiolarite when lithified.
Fauna:
No foraminiferids. Abundant radiolarians.
Age: Indeterminate but high siliceous content may suggest Eocene.
Environment of deposition: Deep marine or below CCD to concentrate siliceous microfossils. Or at a time of different oceanography.
Comment: Might pay to have radiolarian expert look at Radiolaria, if you can find such an expert.

Sample No.: 1603279
Dredge details: 274/16DR13 D1.1
Locality: 16° 51.1'S; 157°29.2'E – 2900-2750 m
Material: Sample plus residue.
Lithology: Foram/nanno ooze; residue of planktonic foraminiferids. Small forms common and older than the common large modern contaminant. Minor benthic foraminiferids, dermal ossicles, ostracods (modern or Paleocene?). Preservation very good.
Fauna:
Chiloguembelina crinita
Planorotalites chapmani
Planorotalites pseudomenardii
Igorina tadjikistanensis
Morozovella acuta
Age: Late Paleocene, P4c.
Environment of deposition: Deep sea ooze.
Comment: An excellent sample that warrants re-processing and documentation.

Sample No.: 1603302
Dredge details: 274/17DR14 E1.2
Locality: 16° 40.6'S; 157°15.8'E – 2900-2400 m
Material: Residue only**.**
Lithology: Brown, solid, chert(?). No reaction with acid. Brown spheres probably after altered radiolarians. Strong foliation due to one or more of dissolution, compaction or shearing.
Fauna: No foraminiferids.
Age: Indeterminate.
Environment of deposition: Deep sea clay?
Comment: May get a result with radiolarians.

Sample No.: 1603304
Dredge details: 274/17DR14 F1.1
Locality: 16° 40.6'S; 157°15.8'E – 2900-2400 m

Material: Residue only.
Lithology: Dominantly planktonic foraminiferids and glauconite. Very diverse benthic foraminiferid fauna plus fish teeth, ostracods (good fauna), echinoid spines, sponge spicules (uncommon), bryozoans (uncommon). Some of the glauconite is in the form of spheres that may be after radiolarians. Foraminiferids filled with fine sediment (nanno ooze?) and some show signs of dissolution or defoliation of test, probably diagenetic rather than a deep sea artefact.
Fauna:
Chiloguembelina crinita
Subbotina triloculinoides
Acarinina mckannai
Morozovella acutispira
Age: Late Paleocene, P4a/b.
Environment of deposition: Probably outer shelf or upper slope.
Comment: Another excellent Paleocene fauna deserving full study**.**

Sample No.: 1603306
Dredge details: 274/17DR14 G1
Locality: 16° 40.6'S; 157°15.8'E – 2900-2400 m
Material: Residue only
Lithology: White nanno ooze with foraminiferids. Sample re-processed carefully to avoid young fauna.
Fauna:
Catapsydrax cf. *dissimilis (sensu* Bolli, 1957)
Hantkenina liebusi
Hantkenina sp.
Globanomalina micra
Globigerinatheka mexicana mexicana
Globigerinatheka index
Globorotalia bullbrooki
Globorotalia lehneri
Globigerina venezuelana
Truncorotaloides topilensis
Age: Latter part of Middle Eocene, P14.
Environment of deposition: Appears to be deep sea ooze but could be a continental slope deposit.
Comment: A beautiful fauna that deserves to be documented properly. *G. bullbrooki* seems to be too young and may be misidentification.

Sample No.: 1603313
Dredge details: 274/18DR15 C2
Locality: 16° 10.1'S; 156°34.8'E – 2630 m
Material: Residue
Lithology: Partly recrystallised calcarenite. Re-processed with cleaner result. Planktonic foraminiferids abundant plus sponge spicules, ostracods (a very good fauna), teeth. Includes some terrigenous material and glauconite.
Fauna:
Planorotalites pseudomenardii (single specimen)
Acarinina mckannai
Morozovella apanthesma
Subbotina triangularis
Subbotina cancellata
A high spired *Subbotina* (similar to *S. spiralis*)
Large *Elphidium* (very compressed flat species), *Astrononion*
Age: Late Paleocene, P4, probably 4a/b
Environment of deposition: Mid shelf
Comment: A magnificent benthic and planktonic fauna that deserves to be documented fully. The large *Elphidium* is *in situ*, common and also occurs elsewhere in the study in 1603333.

Sample No.: 1603333
Dredge details: 274/20DR17 E1.1
Locality: 14° 04.6'S; 155°52.2'E – 3250-3000 m
Material: Sample plus residue
Lithology: Pale bryozoan/echinoid calcarenite with few ostracods, trace glauconite, rhynchonellid brachiopod, bivalve fragments. Diverse benthic foraminiferid fauna, as in 1603313. Planktonic foraminiferid very rare and small.

Fauna:
Large flat *Elphidium/Astrononion* as in 1603313
Fabiania gigantea (Todd)
Gypsina sp.
Age: Probably very similar to that of 1603313 and thus Paleocene (although there is no real basis for this judgement as it is 2 degrees south of 1603313 but contains the same *Elphidium*).
Environment of deposition: Inner to mid shelf depths. Clear water off a coast with little or no terrigenous input.
Comment: Not readily datable on internal evidence. The region has subsided some 3000 m since deposition and thus the fauna is likely to be Palaeogene.

Sample No.: 1603335
Dredge details: 274/20DR17 F1.1
Locality: 14° 04.6'S; 155°52.2'E – 3250-3000 m
Material: Thin section only
Lithology: High porosity, clean, well-sorted bryozoal/echinoid calcarenite with heavily overgrown echinoid debris and poorly preserved calcareous algae. Traces of bivalve fragments.
Fauna:
Foraminiferids rare and non age-diagnostic. No planktonic species and few agglutinated forms (large textulariid), nodosariid (akin to *Glandulina*), possible *Stomatorbina*, *Cibicides*.
Age: Indeterminate
Environment of deposition: Very shallow water, high energy, well-washed.
Comment: Nannoplankton will not improve this poor result**.** This sample seems odd for the depth recorded.

Sample No.: 1603337
Dredge details: 274/20DR17 G1.1
Locality: 14° 04.6'S; 155°52.2'E – 3250-3000 m
Material: Residue
Lithology: Yellowish/green flakey, radiolarian rich residue with common altered echinoid spines, traces of bone, dermal ossicles. Radiolaria well preserved but filled.
Fauna: No foraminiferid fauna
Age: Indeterminate
Environment of deposition: Indeterminate marine, but echinoid content suggests not very deep, probably shelf, although is in conflict with the evidence from the radiolaria.
Comment: Must have had a higher carbonate content and volume reduced by dissolution/alteration.

Sample No.: 1603367
Dredge details: 274/22DR19 A4.2
Locality: 16° 10.9'S; 154° 34.1'E – 3750-3650 m
Material: Thin section and residue following request.
Lithology: Yellowish, volcanic agglomerate with very poorly preserved diatomaceous material between clasts. Processed sample yielded very highly recrystallised carbonate residue with nothing identifiable. Residue contains a few well-preserved spheres that are radiolarians.
Fauna: Sponge spicules, radiolarians (not easily recognised) and centric and pennate diatoms abundant in interstices.
Some shapes may represent very poorly preserved and unidentifiable silicified foraminiferids.
Age: Indeterminate
Environment of deposition: Marine
Comment: Diatomist (e.g. A. McMinn) may be able to work with sample (not thin section). Sample may be part of same unit as 1603337 to judge from siliceous nature and may represent a facies totally distinct from Cenozoic carbonates.

Sample No.: 1603371
Dredge details: 274/22DR19 B1.1
Locality: 16° 10.9'S; 154° 34.1'E – 3750-3650 m
Material: Thin section only
Lithology: Initially, the sediment was nanno/foram ooze but has been altered drastically to an unidentifiable low birefringence material from which carbonate has been removed but shapes of planktonic foraminiferids remain. Whole specimen with thick Mn crust.
Fauna: Material is extremely poorly preserved and identifications must be tentative
One vertical section is through a thin walled *Globorotalia* with approximately equally biconvex, low spire height test with low exposed dorsal early spire. Initially with gently angled margins but acutely angled in the adult with spinose margins and central dorsal spire. It belongs to the group of *G. acuta/formosa/marginodentata*
Other species bear similarities to *G. aequa*, *Globanomalina wilcoxensis*.

Chiloguembelina sp.
Catapsydrax sp.
Age: Late Paleocene – Early Eocene.
Environment of deposition: Marine, depths at which calcareous ooze accumulates.
Comment: I think it unlikely that better age can be determined unless fresh, friable material can be found. This sample may go some way to providing an age estimate for others in this dredge haul.

Sample No.: 1603377
Dredge details: 274/24DR21 B1.1
Locality: 17° 24.4'S; 155° 29.3'E – 1950-1500 m
Material: Short, thin section only
Lithology: Large 'basalt' clast with lithified nanno/foram ooze but unclear which is older**.**
Fauna:
Very difficult to study. Fauna consists of small, thin-walled globigerinids and appears to be very low diversity. *Chiloguembelina* is identified tentatively but based on very few specimens. There are no keeled globorotalids but there is a simple five-chambered turborotalid. There are no hints of anything that would suggest an Eocene, or Miocene or younger, age.
Age: My estimate is that it is Paleocene and if so, pre-dates the evolution of the Late Paleocene keeled diverse globorotalids. It could also be Early Oligocene but lacks any evidence of the *Globigerina tripartita* lineage that would be expected in tropical faunas of that age.
Environment of deposition: Marine, ooze environment but near a source of 'basalt'.
Comment: Nannoplankton should work on this sample. If any is friable, planktonic foraminiferids may be released and also contribute.

Sample No.: 1603391
Dredge details: 274/26DR22 B1.2
Locality: 17° 35.7'S; 155° 47.7'E – 1700-1300 m
Material: Thin section only
Lithology: Volcanic particles to almost 1 cm with fine to coarse sparry calcite between 'clasts'. No fossils seen.
Fauna: None.
Age: Indeterminate
Environment of deposition:
Comment: No fossils and to be studied by vulcanologist.

Sample No.: 1603400
Dredge details: 274/26DR22 D1.1
Locality: 17° 35.7'S; 155° 47.7'E – 1700-1300 m
Material: Thin section only
Lithology: Porous, biocalcarenite dominated by calcareous algae, bryozoans and a single layered, encrusting foraminiferid of the *Acervulina/Miniacina* type with simple, domed chambers and coarse radial wall structure. Minor bivalve and echinoid debris. Initial framework infilled commonly with micritic calcite and later some cavities filled with sparry calcite. Preservation not perfect. Section cut perpendicular to flat foram tests renders detailed identification difficult.
Fauna:
Operculina complanata (common)
Possible *Spiroclypeus/Heterostegina*
Sphaerogypsina globulus
Cibicides, *Amphistegina*, a large *Elphidium*
Lacks *Lepidocyclina/Miogypsina*
Age: See 1603410 below. Oligocene?
Environment of deposition: Shallow, fully marine in the lower photic zone and in quiet conditions.

Sample No.: 1603402
Dredge details: 274/26DR22 D2.1
Locality: 17° 35.7'S; 155° 47.7'E – 1700-1300 m
Material: Thin section only
Lithology: As for 1603400 but lower porosity, higher micritic infill content and more diverse range of components including echinoid and bivalve fragments.
Fauna:
As for 1603400 but more diverse and with *Gypsina howchini*
Possible *Chiloguembelina* but unclear because only cross sections were seen.
Age: Probably as 1603400 (?Oligocene)
Environment of deposition: Slightly deeper water than 1603400 but still within photic zone.

Comment: Nannoplankton from the micritic portion may help but are likely to be recrystallised.

Sample No.: 1603404
Dredge details: 274/26DR22 D3.1
Locality: 17° 35.7'S; 155° 47.7'E – 1700-1300 m
Material: Thin section only
Lithology: Part of same suite as 1603400 and 1603402 but darker in colour and with even more diverse, but non-diagnostic benthic foraminiferids. Abundant sparry calcite as cement.
Fauna: As for 1603400 and 1603402 but lacking *Sphaerogypsina* and containing *Rupertia/Carpenteria.* Possible *Chiloguembelina*.
Age: Probably as for 1603400, 1603402 (?Oligocene)
Environment of deposition: As for 1603402.

Sample No.: 1603408
Dredge details: 274/26DR22 G1.1
Locality: 17° 35.7'S; 155° 47.7'E – 1700-1300 m
Material: Thin section only
Lithology: Sparry calcite cemented, clean, well washed carbonate sand with calcareous algae, encrusting foraminiferids, broken large foraminiferids, bryozoans, echinoid and mollusc fragments.
Fauna:
An *Amphistegina/Operculina* fauna as in other specimens from this dredge haul.
No planktonic foraminiferids.
Age: Indeterminate
Environment of deposition: Shallow, high-energy environment, fully marine.

Sample No.: 1603410
Dredge details: 274/26DR22 H1.1
Locality: 17° 35.7'S; 155° 47.7'E – 1700-1300 m
Material: Thin section only
Lithology: Almost identical to 1603402 but with pteropods and higher planktonic foraminiferid content.
Fauna:
Amphistegina/Operculina
Patellina corrugata (single specimen)
Sphaerogypsina globulus
Planktonic species are thin-walled globigerinids and lack *Orbulina, Globoquadrina,* keeled globorotalids or any evidence of post-Oligocene forms which I would expect with the number and diversity of the planktonic species present.
Age: Oligocene?
Environment of deposition: As with others (1603400-1603408) of this suite but slightly deeper.
Comment: It is likely that this entire suite is essentially of one age but that is exceedingly difficult to identify. They seem to represent deposition in shallow-water, photic zone but several sub-environments, even though the large foraminiferid fauna is dominated always by the same genera – *Amphistegina/Operulina* and commonly with *Sphaerogypsina*.

Sample No.: 1603413
Dredge details: 274/28DR24 A1.1
Locality: 17° 40.2’S; 156°03.2’E – 2200-2000 m
Material: Thin section plus residue supplied later.
Lithology: High porosity, biocalcarenite, not well sorted, with abundant and diverse benthic foraminiferids (including large forms), calcareous algae, echinoid debris.
Fauna:
Slide is cut perpendicular to bedding and the larger species lie parallel to bedding so only vertical sections of the larger forms are present, making specific identification difficult. Later disaggregation of a sample allowed thin sectioning of individual specimens and somewhat more refined identification.
Nummulites sp.
Fragments of *Asterocyclina/Discocyclina*
Operculina sp. (thick form with only about 13 chambers in the final whorl).
Sherbornina carteri
Gypsina disca
Planorbulinella sp.
An odd chapmaninid genus that appears to be new
Age: Probably Late Eocene but this is not well based. *Sherbornina carteri* would appear to limit the maximum age to Late Eocene and *Nummulites* and a discocyclinid limit the younger age.

Environment of deposition: Deeper part of the photic zone after a time in a high-energy environment to account for breakages.
Comment: The chapmaninid deserves serious study.

Sample No.: 1603415
Dredge details: 274/28DR24 A2.1
Locality: 17° 40.2'S; 156°03.2'E – 2200-2000 m
Material: One thin section supplemented by a later sample for disaggregation
Lithology: Biocalcarenite with fragmental calcareous algae, echinoid, mollusc and bryozoans. Moderate rounding and sorting of grains. Thin section is cut perpendicular to bedding and thus sections through large species do not show equatorial details. Orientation of discoid forms parallel to bedding is unusually well developed. Later sample allowed slightly better access to details.
Fauna:
Large foraminiferid abundant; diverse smaller foraminiferids but few and unidentifiable planktonic species.
Operculina complanata
orbitoid species abundant but small
Gypsina disca
Sphaerogypsina globulus
Elphidium sp.
A form very similar to *Maslinella* a genus well known from the Late Eocene across southern Australia
Age: Indeterminate but possibly Late Eocene.
Environment of deposition: Fully marine in the photic zone but probably deep in the photic zone to account for the small orbitoids. Quite high energy to account for the breakages and sorting.
Comment: Almost incredibly, dozens of sections through the orbitoid foraminiferid are vertical sections and only one gives a poor hint of rectangular equatorial chambers suggesting that it is a discocyclinid rather than a lepidocyclinid and thus that the age may be Eocene.

Sample No.: 1603416
Dredge details: 274/28DR24 A3
Locality: 17° 40.2'S; 156°03.2'E – 2200-2000 m
Material: Sample plus residue
Lithology: Off white, partly recrystallised biogenic calcarenite but elements difficult to identify. Large specimens to be thin sectioned. Rhynchonellid brachiopod.
Fauna:
Operculina complanata??? (thin, flat, ribbed, low rate of increase of chamber height)
Operculina venosa ????? (thick, lenticular, high rate of increase of chamber height, some irregularity in addition of chambers)
Gypsina or *Planorbulinella* sp.
Age: Oligo-Miocene?
Environment of deposition: Inner shelf, fully marine, no terrigenous input.
Comment: More comment after thin sectioning of large species.

Sample No.: 1603418
Dredge details: 274/28DR24 B1.1
Locality: 17° 40.2'S; 156°03.2'E – 2200-2000 m
Material: Heavily stained thin section only.
Lithology: Moderately porous dirty foraminiferid ooze with minor bryozoans, radiolaria, echinoid spines, pteropods. Few geopetal structures.
Fauna:
Orbulina suturalis
Orbulina universa
Biorbulina bilobata
Globoquadrina altispira globosa
Globorotalia menardii group (rare)
Globigerinoides trilobus group
Streptochilus sp.
Sphaeroidinella sp.
Large species (rare) (*Heterostegina/Operculina*) and others that are unidentifiable.
Age: Despite the apparent diversity of planktonic species, it is difficult to tie the age down well. Mid-Late Miocene, possibly even early Pliocene, N13-N19.
Environment of deposition: Outer shelf at the outer limit of growth of large foraminiferid species. Appears to be below the photic zone.

Comment: Needs study of the large species and that requires a specimen for disaggregation. This would help differentiate Mid- from Late Miocene or younger.

Sample No.: 1603419
Dredge details: 274/28DR24 B2.1
Locality: 17° 40.2'S; 156°03.2'E – 2200-2000 m
Material: Thin section only
Lithology: Well-sorted biocalcarenite with sparry calcite cement, abundant and diverse calcareous algae, echinoid fragments, minor bryozoan, and abundant and diverse smaller foraminiferids but lacking planktonic species. Thin section cut perpendicular to bedding so that diagnostic features of large species are not visible.
Fauna:
Nummulites sp.
Gypsina howchini
Amphistegina sp.
Fabiania sp.
Crespinina sp.
small orbitoid
common agglutinated species,
common and diverse small miliolids
Age: A difficult sample to tie down as it needs thin sectioning of larger species. Probably Late Eocene-Early Oligocene.
Environment of deposition: Very shallow, fully marine in the photic zone in a high energy environment.
Comment: Needs disaggregation of sample to release specimens of several large species *(Fabiania, Nummulites, Crespinina*). Nannoplankton unlikely to be of assistance. The location has subsided some 2000 m since deposition, unless it can be shown that this is a slump accumulation.
This sample deserves serious study.

Sample No.: 1603437
Dredge details: 274/28DR24 I.5
Locality: 17° 40.2'S; 156°03.2'E – 2200-2000 m
Material: Thin section only
Lithology: Vesicular volcanic with flow texture.
Fauna: None

Sample No.: 1603442
Dredge details: 274/29DR25 B1.1
Locality: 18° 09.0'S; 156° 17.3'E – 2650-2350 m
Material: Thin section only
Lithology: 'Dirty' biocalcarenite, perhaps lightly ferruginised, with significant content of angular terrigenous debris in a grade finer than the biotic component. Abundant sparry calcite and significant recrystallisation is evident. Calcareous algae common and diverse. Gastropods, bryozoans and echinoid debris.
No planktonic foraminiferids but abundant small benthics.
Fauna:
Asterocyclina sp. (four rayed)
Crespinina sp.
Gypsina cf. *disca*.
Age: Eocene but undifferentiated.
Environment of deposition: Within the photic zone but probably near the lower range. Tropical or warm temperate, fully marine.
Comment: In this and some other samples, there is a very characteristic calcareous alga *Distichoplax*.

Sample No.: 1603444
Dredge details: 274/29DR25 C1.1
Locality: 18° 09.0'S; 156° 17.3'E – 2650-2350 m
Material: Thin section only
Lithology: Matrix-supported, lithified foraminiferid marl with common echinoid fragments and traces of bryozoans, molluscs etc. Planktonic foraminiferids dominate in two markedly different size ranges – large probably dominantly *G. tripartita* group) and small (*Chiloguembelina/Pseudohastigerina*). Many fragments broken. Details somewhat obscured by heavy staining of slide.
Fauna:
Chiloguembelina sp.
Globanomalina micra (common)
Globigerinatheka index

Globigerina tripartita group
Catapsydrax sp.
Small orbitoid
Operculina cf. *complanata*
Fusiform miliolid (one may be *Borelis pygmaea*)
Age: Late Eocene-Early Oligocene, more likely the latter due to apparent absence of any of the *Globorotalia cerro-azulensis* lineage.
Environment of deposition: Shelf below photic zone. Environment was high enough energy to allow fragmentation of coarse material while not affecting smaller foraminiferids as much.
Comment: Needs sample to disaggregate for orbitoids and details of planktonic species. Nannoplankton may help.

Sample No.: 1603445
Dredge details: 274/29DR25 C2.1
Locality: 18° 09.0'S; 156° 17.3'E – 2650-2350 m
Material: Thin section
Lithology: Calcareous ooze but difficult to see detail through deep blue staining. Matrix supported with abundant 'floating' planktonic foraminiferids. Minor cavity development. Echinoderm, bryozoan and mollusc fragments, highly broken. Fauna dominated by large globigerinid species.
Fauna:
Chiloguembelina cubensis
Globigerina sellii
Globigerina tripartita
Globigerina venezuelana
Catapsydrax sp.
Cassigerinella chipolensis.
Age: Latter part of Early Oligocene, P19.
Environment of deposition: Difficult to ascertain but probably outer shelf depths or possibly a slump deposit to account for fragmented macrofauna.

Sample No.: 1603455
Dredge details: 274/30DR26 C1.1
Locality: 18°29.9'S; 156°18.0'E; 2100-1950 m
Material: Thin section
Lithology: Very poorly sorted matrix-supported calcareous sandstone with common angular-rounded volcanic fragments, some vesicular, and sporadically with an encrusting foraminiferid. Mn oxide crust at one end of the slide. Highly fragmented bryozoans, pteropods, molluscs, minor calcareous algae, including *Distichoplax biserialis*. Cavities filled with coarse sparry calcite. Fossil preservation poor.
Fauna:
Common small sparry calcite spheres, one of which may be siliceous suggesting that they are after roughly spherical sponge spicules (sterrasters). Possible elongate spicules but only one seen with central cavity.
Very difficult to work with but probably *Spiroclypeus*.
Possibly a sphaeroidinellid foraminiferid.
Two very tentative identifications based on one cross section each – *Globigerinoides obliquus extremus* and *Pulleniatina spectabilis.*
Age: If tentative identifications are correct, age should be Pliocene, about N18/19.
Environment of deposition: Original material from the inner continental shelf in a dynamic environment to explain the fragmentation. Within the photic zone.

Sample No.: 1603463
Dredge details: 274/35DR31 A1.1
Locality: 19°49.9'S; 156°27.6'E – 2600-2450 m
Material: Thin section
Lithology: Dirty, Fe oxide stained, matrix (micrite)-supported sandstone with diverse, poorly sorted clasts including highly vesicular volcanic fragments. Minor echinoderm, bryozoa. No algae. Minor micritic ooze filled vein.
Fauna:
Main rock:
Globigerinatheka index
Catapsydrax sp. (or another species of *Globigerinatheka*
Globanomalina (compressed form and thus likely to be *G. micra*)
Chiloguembelina sp.
Mid shelf benthics quite common.

Vein material:
Chiloguembelina sp. (common)
Compressed *Globanomalina*
Age: main rock – Late Eocene (no reason to suggest an age different from Lithology C1.1 - see below)
Vein material: Probably Early Oligocene but could be Eocene
Environment of deposition: Probably continental shelf depths but below photic zone because of lack of large benthic species and of calcareous algae.

Sample No.: 1603466
Dredge details: 274/35DR31 C1.1
Locality: 19°49.9'S; 156°27.6'E – 2600-2450 m
Material: Residue
Lithology: Grey marl with abundant foraminiferids, especially planktonic species. Preservation satisfactory but not perfect. Good ostracod fauna, bryozoans common.
Fauna:
Globigerinatheka index index
Globigerinatheka semiinvoluta
Globanomalina micra (transitional with *G. wilcoxensis*)
Hantkenina alabamensis
Age: Late Eocene, P15.
Environment of deposition: Mid shelf off coast where there is river input.
Comment: Evidence of exposed land nearby.

Sample No.: 1603468
Dredge details: 274/35DR31 D1.1
Locality: 19°49.9'S; 156°27.6'E – 2600-2450 m
Material: Residue only
Lithology: Mn oxide coated, slightly recrystallised calcarenite with abundant large foraminiferids (*Discocyclina/Asterocyclina* and many others including conical and discoid uniserial forms), large planktonic foraminiferids, bryozoans, bivalves, gastropods, echinoid spines, small brachiopods, ostracods, crab claw, trace sponge spicules, a few vesicular volcanic glass particles. Minor terrigenous (volcanic?) other material. Very diverse foraminiferid fauna in the small benthics.
Fauna:
Hantkenina alabamensis
Globanomalina micra
Globigerinatheka index
Globigerinatheka semiinvoluta
Globorotalia cerroazulensis cerroazulensis
Abundant and diverse benthic foraminiferids
Asterocyclina incisuricamerata
Discocyclina sp.
Sphaerogypsina globulus
Heterostegina equatoria
Fabiania sp.
Crespinina sp.
Age: Earliest Late Eocene, P15
Environment of deposition: Mid to outer shelf depths
Comment: A magnificent fauna deserving of documentation. Awaits plenty thin sections. The locality has subsided some 2500 m at an average rate of approximately 60 m per million years.

Sample No.: 1603501
Dredge details: 274/39DR35 C3
Locality: 20°36.7'S; 156°43.5'E – 2200-1950 m
Material: Thin section
Lithology: Highly fragmented, highly Fe/Mn oxide stained, uniform very fine grained sediment lacking any identifiable fossil groups. Spherical shapes could be after radiolarians. Fragments a few mm across (generally elongate) have concentric weathering pattern.
Fauna: None identified
Age: Indeterminate but older than 1603503 (Lithology D1.1)
Environment of deposition:
Comment: Very different from other lithologies in this dredge.

Sample No.: 1603503

Dredge details: 274/39DR35 D1.1
Locality: 20°36.7'S; 156°43.5'E – 2200-1950 m
Material: Thin section
Lithology: Foraminiferid-rich, matrix (micrite)-supported, limestone/marl with fragments of Lithology C which are therefore older. Echinoderms and bryozoa. Possible hint of oncolite development around a foraminiferid.
Fauna: Identified by random sections through individual specimens.
Globanomalina wilcoxensis
Globanomalina sp. (compressed in the final chambers and thus akin to *G. micra*)
Globorotalia cf. *acuta*
Globorotalia cf *aequa*
Globorotalia cf. *imitatus*
Globorotalia chapmani
Globorotalia cf. *bullbrooki/wilcoxensis*
Low trochospiral form with about 7 chambers in the final whorl, akin to *Globorotalia praecursoria*
Form that seems to be *Globigerinatheka*.
Age: Hard to date accurately but probably Early Eocene.
Environment of deposition: Outer shelf or deeper.
Comment: Nannoplankton may refine this date.

Sample No.: 1603504
Dredge details: 274/39DR35 D1.2
Locality: 20°36.7'S; 156°43.5'E – 2200-1950 m
Material: Thin section
Lithology: As for 1603503 but with one major difference. It contains variants of Lithology C with common angular grains of quartz, feldspar and chert, and also contains common well rounded grains of quartz and quartz sandstone.
Fauna: As D1.1
Age: As D1.1
Environment of deposition: As D1.1
Comment:

Sample No.: 1603507
Dredge details: 274/39DR35 E1.1
Locality: 20°36.7'S; 156°43.5'E – 2200-1950 m
Material: Thin section
Lithology: Highly Mn oxide impregnated fine sediment, perhaps related to lithology C. Abundant fine shapes that are likely to be shards but some may be highly altered and unidentifiable fragments of fossils.
Fauna: None
Age: Indeterminate but if Lithology C, older than Early Eocene.
Environment of deposition: Indeterminate.

Sample No.: 1603510
Dredge details: 274/39DR35 F1.1
Locality: 20°36.7'S; 156°43.5'E – 2200-1950 m
Material: Thin section
Lithology: Grain supported foram/nanno ooze but details hard to examine because of heavy blue stain. Many foraminiferid lumina filled or partially filled with opaque material, either pyrite or Mn oxides.
Fauna:
Marked by lack of index forms of any sort. Lacks indices of Eocene age or Early Miocene or younger (lacks keeled *Globorotalia, Globoquadrina,* advanced members of the *Globigerina tripartita* lineage
Globigerina tripartite
Very rare *Chiloguemeblina.*
Age: Oligocene, probably Early.
Environment of deposition: Mid-shelf or deeper.
Comment: Oligocene faunas such as this are very difficult to date in thin section; they are marked by lack of species of any other age.

Sample No.: 1603516
Dredge details: 274/40DR36 C1.1
Locality: 19°27.6'S; 156°00.4'E – 2500-2150 m
Material: Thin section
Lithology: Calcarenite with abundant large foraminiferids (*Lepidocyclina/Spiroclypeus* but unidentifiable; could be *Discocyclina*), calcareous algae (including *Distichoplax biserialis*), bryozoans, fragmented molluscs; cavities

filled with sparry calcite. Planktonic foraminiferids rare and thick walled globigerinids; no *Globorotalia* evident. Must be well-bedded and thin section cut perpendicular to bedding making it impossible to see equatorial sections and thus identify large foraminiferids.
Fauna:
Chiloguembelina . sp. (two seen)
Large foraminiferids (abundant, probably *Lepidocyclina* but needs equatorial section)
Amphistegina sp.
Sphaerogypsina globulus
Spiroclypeus/Cycloclypeus/Operculina (need equatorial sections)
Age: Unclear but either Early Oligocene or Late Eocene.
Environment of deposition: Tropical/subtropical, clear water, high energy, shallow water.
Comment: Needs thin section cut parallel to bedding.

Sample No.: 1603517
Dredge details: 274/40DR36 D
Locality: 19°27.6'S; 156°00.4'E – 2500-2150 m
Material: Sample plus residue
Lithology: Foram/nanno ooze. Residues almost entirely of planktonic foraminiferids. Slight surface recrystallisation. *Orbulina universa* shows some signs of decortication.
Fauna:
Orbulina universa
Globorotalia tumida tumida
Globorotalia tosaensis
Globorotalia multicamerata
Pulleniatina praecursor
Globigerinoides quadrilobatus fistulosus
Globigerinoides conglobatus
Sphaeroidinella dehiscens dehiscens
Globoquadrina altipsira altispira
Hastigerina aequilateralis
Age: Late Pliocene, N21.
Environment of deposition: Probably current position; deep sea ooze
Comment: A good fauna**.**

Sample No.: 1603520
Dredge details: 274/41DR37 A1.1
Locality: 18°49.5'S; 155°41.7'E – 2200 m
Material: Thin section
Lithology: Thick, well-bedded Fe/Mn oxide crust incorporating angular quartz/feldspar grains.
Fauna: none visible
Age: Modern
Environment of deposition: Sea floor

Sample No.: 1603523
Dredge details: 274/41DR37 B1.1
Locality: 18°49.5'S; 155°41.7'E – 2200 m
Material: Thin section
Lithology: Heavily blue-stained foram/nanno ooze with abundant and diverse planktonic foraminiferid fauna
Fauna:
Orbulina universa
Sphaeroidinella dehiscens
Sphaeroidinellopsis seminulina
Globorotalia tosaensis (close to *truncatulinoides* but no *truncatulinoides* seen)
Age: Late Pliocene, N21
Environment of deposition: As now

Sample No.: 1603526
Dredge details: 274/41DR37 C1.1
Locality: 18°49.5'S; 155°41.7'E – 2200 m
Material: Sample plus residue
Lithology: Foram/nanno ooze. Residue virtually entirely planktonic foraminiferids. Full diversity. Preservation excellent.
Fauna:

Orbulina universa
Globorotalia tumida tumida
Globorotalia tosaensis
Globorotalia multicamerata
Globigerinoides quadrilobatus fistulosus
Globigerinoides conglobatus
Sphaeroidinella dehiscens dehiscens
Age: Late Pliocene, N21
Environment of deposition: As current position; deep sea ooze.
Comment: Excellent fauna.

Sample No.: 1603538
Dredge details: 274/43DR39 B1.1
Locality: 18°37.9'S; 155°23.6'E – 2400 m
Material: Thin section
Lithology: Highly overgrown, dirty, medium biocalcarenite with very diverse components including abundant calcareous algae (including *Distichoplax biserialis*), highly fragmented echinoid and foraminiferid debris (both small and smaller specimens of larger foraminiferids) and a few coarser fragments of what are probably volcanic glass. Also gastropods and bryozoans. Much micritic cement.
Fauna:
Chiloguembelina sp.
Miogypsina sp. cf. *thecidaeformis*
Gypsina disca
Lepidocyclina sp.
The benthic foraminiferid fauna contains some infaunal forms suggesting a significant nutrient supply.
Age: Probably Early Oligocene (rather tentative).
Environment of deposition: Deeper range of the photic zone near a source of a few volcanic glass fragments.
Comment: This is a very difficult sample to study from a single slide and needs material to yield free specimens of *Lepidocyclina* and *Miogypsina*. The *Miogypsina* is clear in two vertical sections only and appears to be the earlier form of *M. thecidaeformis* recorded by Chaproniere (1984) from the older parts of the Mandu Calcarenite of northwestern Australia.

<u>Dredge 274/44DR40</u>
Lithology A.
Several samples were examined in thin section from this dredge haul. They are all calcarenites but vary quite a lot in detail. Two slides are from Lithology A (GA1603541 and 1603542) and consist of well-sorted calcareous fragments with little matrix and significant overgrowths. They have abundant large foraminiferids and a few planktonic species. There is abundant echinoid debris and calcareous algae (including *Distichoplax biserialis*) and minor bryozoans, molluscs fragments and a fish tooth. They are highly fragmented attesting to high energy, shallow water and within the photic zone. There may be evidence of some autobrecciation. Preservation generally is poor because of the overgrowths but there is enough to gain some idea of age.

Sample No.: 1603541
Dredge details: 274/44DR40 A1.1
Locality: 18°10.8'S; 155°37.6'E – 2100-1850 m
Fauna:
Halkyardia sp.
Asterocyclina sp. (probably *A. incisuricamerata*)
Cycloclypeus sp.
Spiroclypeus/Operculina sp. indeterminate
Truncorotaloides sp.
Globigerinatheka index
Age: Middle Eocene, probably in the upper part, P14/15.
Environment of deposition: Inner shelf, fully marine, tropical, clear water**.**
Comment: Identification made more difficult because the thin section is cut almost normal to bedding and thus not allowing access to the details of the equatorial chambers; however, enough is visible to allow generic identification of some of the larger species which, together with some of the planktonic forms helps provide some age control.

Sample No.: 1603542
Dredge details: 274/44DR40 A1.2
Fauna: 18°10.8'S; 155°37.6'E – 2100-1850 m
Globorotalia cerroazulensis (*cocaensis*?)

Truncorotaloides cf. *topilensis*
Large foraminiferids are abundant but not as clearly identifiable generically as in 1603541.
Age: As 1603541, latter part of the Middle Eocene.
Environment of deposition: As 1603541.
Comment: As 1603541.

Lithology B
Represented by three slides (B1.1 – 1603544; B1.2 – 1603545; B2.1 - 1603547). All have a framework of calcareous algae that seems to be in place with cavities filled by calcareous sand composed dominantly of well-sorted foraminiferid/echinoid fragment sand with abundant fragmented large foraminiferids and a significant component of finer micritic material. Algae sporadically coated with encrusting foraminiferids but wall structure not well enough preserved to allow identification. Bryozoans, molluscs and other groups, minor. 1603547 is distinguished by containing a well-preserved thin section through a specimen of *Nummulites* almost 20 mm across. Planktonic species are few and scattered throughout but a few are roughly identifiable.

Age information is not as specific for Lithology B as for Lithology A but an association similar to the large foraminiferid fauna noted for Lithology B was recorded by Chaproniere (1983) as being early Middle Eocene (Tertiary *a3* or P10/11) but the original description of *A. incisuricamerata* was from Tertiary *b* (Late Eocene). If Lithology A is the same age as Lithology B, the better age control, for Lithology A would suggest a Middle Eocene age for Lithology B.

Sample No.: 1603544
Dredge details: 274/44DR40 B1.1
Locality: 18°10.8'S; 155°37.6'E – 2100-1850 m
Lithology: Differs from others in having no very large species. The group of 'larger' foraminiferids is represented by small versions.
Fauna:
Operculina/Spiroclypeus indet.
Discocyclina/Asterocyclina/Lepidocyclina indet.
Sherbornina sp.
Chiloguembelina sp.
Age: Indeterminate from this slide other than Eocene/Early Oligocene, but from the association with dated material of this lithology, probably Middle or Late Eocene.
Environment of deposition: In the photic zone but a robust reefal environment.
Comment: Difficulty in identifying large foraminiferids due to section perpendicular to bedding.

Sample No.: 1603545
Dredge details: 274/44DR40 B1.2
Fauna: 18°10.8'S; 155°37.6'E – 2100-1850 m
Asterocyclina sp
Discocyclina/Lepidocyclina indet..
Age: Eocene, probably as 1603544.
Environment of deposition: As 1603544
Comment: As 1603544 but one specimen of *Asterocyclina* was cut obliquely to allow generic identification.

Sample No.: 1603547
Dredge details: 274/44DR40 B2.1
Locality: 18°10.8'S; 155°37.6'E – 2100-1850 m
Material: Thin section
Lithology: As others in this association but more poorly sorted and with very large forms plus coral.
Fauna:
Asterocyclina sp. (to 6-7 mm diameter)
Nummulites sp. (to approximately 20 mm diameter).
Age: Middle-Late Eocene
Environment of deposition: Shallow water in photic zone, reefal environment.
Comment: The species of *Asterocyclina* is probably *A. incisuricamerata* (Cole) as recorded by Chaproniere (1983). He did not record a large *Nummulites* but this may be part o the association recorded by Cole (1957A) from Saipan when *N. djojdjokarta* (Martin) occurs with *A. incisuricamerata*,

Lithology J
This was originally well-sorted calcareous sand with abundant fragmented debris including large foraminiferids and interstitial material with common planktonic forms. It is now a high porosity, weakly cemented biocalcarenite but heavily overgrown grains making identification of species difficult. Planktonic species are

quite common but low diversity and lacking forms (e.g. keeled globorotalids) that are diagnostic and readily-identifiable forms. The deep blue staining of the slide has exacerbated that problem. Calcareous algae and echinoid material common.

Sample No.: 1603567
Dredge details: 274/44DR40 J1.1
Locality: 18°10.8'S; 155°37.6'E – 2100-1850 m
Material: Thin section
Lithology: (see above)
Fauna:
Discocyclina/Asterocyclina (identifiable generically by oblique sections)
Lepidocyclina
Operculina/Spiroclypeus
Gypsina disca
Common shallow water benthics.
Age: Mid-Late Eocene
Environment of deposition: Shallow water, high energy carbonate sand with no terrigenous input.
Comment:

Sample No.: 1603610
Dredge details: 274/45DR41 K1.1
Locality: 18°10.4'S; 155°15.8'E – 1900-1450 m
Material: Thin section
Lithology: Two phases, a younger nanno/foram ooze with well-preserved and abundant planktonic foraminiferids filling large cavity in the older lithology which is a highly porous, well-sorted, somewhat recrystallised, clean biocalcarenite. The older phase contains calcareous algae, bryozoans, echinoid debris, mollusc material and smaller versions of large foraminiferids. Some fragmentation, but not major.
Fauna:
Young ooze;
Sphaeroidinella dehiscens
Pulleniatina sp.
Globorotalia tumida
Globorotalia tosaensis transitional to *G. truncatulinoides*
Globorotalia menardii
Older fauna
Chiloguembelina sp. (one specimen)
Operculina/Spiroclypeus (more than one species)
Possibly a form of *Pellatispira* or *Biplanispira* (thick walled, high thickness/diameter ratio, large equatorial chambers that are large and seem similar size throughout – seen only in vertical section)
Age: Younger ooze**;** Late Pliocene-Early Pleistocene transition, about late N21/early N22.
Older material; Late Eocene Tertiary *b* (very poorly controlled) or possibly Early Oligocene.
Environment of deposition: Shallow water (in photic zone), well washed environment but not high energy enough to cause major fragmentation of material.
Comment: Again, it would be nice to have a section cut parallel to bedding or to have a friable specimen to obtain free specimens. A poor result.

Sample No.: 1603618
Dredge details: 274/46DR42 A1.2
Locality: 18°09.2'S; 154°53.4'E – 1600 m
Material: Thin section
Lithology: Nanno/foram ooze with a trace of calcareous algae. Foraminiferid content high. High diversity fauna, well preserved.
Fauna:
Orbulina universa
Globorotalia tumida tumida
Globorotalia menardii group
Globorotalia scitula
Globoquadrina altispira altispira
Sphaeroidinella paenedehiscens
Sphaeroidinella seminulina
Pulleniatina sp.
Age: Very Late Miocene (N18) to Early Pliocene (N20).
Environment of deposition: Deep water but the presence of a little calcareous algae is puzzling.

DREDGE 43

Rocks of this dredge are all shallow water, high energy, clean, well washed biocalcarenites lacking calcareous algae. Echinoderm debris is the dominant biogenic component and the foraminiferid content varies greatly. This dredge has yielded *Biplanispira*, a key genus in the Indo-Pacific Letter classification of the Tertiary (P14-P17 in planktonic foraminiferid zonal scheme). This is the first record of this genus in Australasia. Establishing the environment of deposition is difficult. The absence of calcareous algae is puzzling unless it implies that conditions were too robust for sessile forms to develop.

Sample No.: 1603632
Dredge details: 274/DR43 A1.1
Locality: 18°07.9'S; 154°42.0'E – 2000-1850 m
Material: Thin section
Lithology: Echinoderm-rich, well-sorted, clean biocalcarenite with bryozoans, molluscs, large and small foraminiferids. Calcareous algae not obvious. Considerable overgrowths of sparry calcite. Trace glauconite. Cut by veins of micritic nanno/foram ooze with common but not very diagnostic planktonic forms. They are thin-walled, globigerinid species lacking any evidence of Miocene (or younger) or Early Oligocene (or older).
Fauna:
Planktonic foraminiferids rare, large globigerinid species, lacking keeled forms of any sort, of low diversity.
Biplanispira cf. *mirabilis* (seen only in several vertical sections)
Lepidocyclina sp. (possibly *Discocyclina* but no equatorial sections seen)
Fabiania sp. (large and flat – not like any well-known species).
Age: *Biplanispira* suggests Late Eocene (Tertiary *b* in the Indo-Pacific Letter classification, or P14-P17), and *Fabiania* is consistent. This is the first record of this important genus in Australasia.
The veins of ooze probably are Late Oligocene, suggesting a significant increase in water depth over a relatively short time scale.
Environment of deposition: Initially, shallow, well washed environment but the lack of calcareous algae is a little puzzling. Later, in deeper water, probably continental slope or deeper.
Comment: A fascinating sample; difficult to work with but rewarding in recording *Biplanispira* in the region. Needs sample to allow oriented sectioning of *Biplanispira*.

Sample No.: 1603633
Dredge details: 274/47DR43 A1.2
Locality: 18°07.9'S; 154°42.0'E – 2000-1850 m
Material: Thin section
Lithology: As for 1603632 but lacking identifiable *Biplanispira*. Perhaps more fragmented than 1603632 but there seem to be fewer foraminiferids, including planktonic species and the diversity may be less.
Fauna:
Same globigerinid foraminiferids but fewer. No identifiable large species but there are few fragments that could be of *Biplanispira.*
Age: No reason to suspect an age different from that of 1603632.
Environment of deposition: Shallow water, fully marine, with no input of terrestrial debris. A well washed environment.

Sample No.: 1603639
Dredge details: 274/47DR43 C1.2
Locality: 18°07.9'S; 154°42.0'E – 2000-1850 m
Material: Thin section
Lithology: Extremely well sorted biocalcarenite with minor angular terrestrial debris very uniform in grain size. Trace glauconite. No calcareous algae. Contents mainly echinoid, bryozoan and bivalve fragments, heavily overgrown to provide the sparry calcite cement. Small benthic foraminiferids common; only two large specimens seen; planktonic species absent.
Fauna:
Very little identifiable but one of the large specimens is either *Biplanispira* or *Pellatispira.* Also large, flat *Elphidium*.
Age: Late Eocene, Tertiary *b* in the Indo-Pacific Letter classification (P14-P17)
Environment of deposition: Tropical marine, shallow water, perhaps in an embayment that gave no site for calcareous algae to grow.

Sample No.: 1603642
Dredge details: 274/49DR44 A1.1
Locality: 17° 38.0'S; 154°20.3'E – 2500-2350 m
Material: Thin section

Lithology: Very highly altered. Mineralogy indeterminate. Cut by veins lined with quartz and filed with carbonate (possibly zeolite). Highly altered echinoderm remains a high proportion of the rock. One vague form may be a high-turreted gastropod. One cross section through a foraminiferid 1.6 mm in diameter that looks like *Orbitolina* (but could also be a variant of *Fabiania*). Post-alteration cavities filled with nanno/foram ooze. Cavities very small and foraminiferids thin walled, few and difficult to identify. Entire rock then covered with Mn oxide coating.
Fauna:
Nothing specifically identifiable.
Possible *Orbitolina* a flat form with three generations of septa near the dorsal surface. The chamber lumina on the ventral surface are open rather than covered by a wall. This is not normally true of *Orbitolina* and more consistent with the early Tertiary (Late Paleocene-Eocene) *Fabiania*.
Age: Is it possible that there is a Cretaceous phase of history in the region?
Ooze appears Palaeogene but all very tentative. If the cavity fill is the same age as Lithology A2.1 (see 1603644), a Paleocene age is likely for the cavity fill, and thus the Cretaceous age of the "*Orbitolina*" becomes less unlikely. If correct, the age is likely to be approximately Aptian. Alternatively, if the form is *Fabiania* an early Tertiary age is more likely, consistent with other samples from this cruise.
Environment of deposition: Shallow marine, warm water.
Comment: An interesting sample that needs further study through many thin sections at right angle to this one.

Sample No.: 1603644
Dredge details: 274/49DR44 A2.1
Locality: 17° 38.0'S; 154°20.3'E – 2500-2350 m
Material: Residue only
Lithology: Unusual material. Coarse fraction dominated by large white flakey fragments of unidentified material. Fine fractions of partly recrystallised white calcarenite with echinoid spines, ostracods and few scattered white small globigerinid foraminiferid and a good benthic fauna of small species. Foraminiferid much more abundant in the 63-125 micron fraction. Small spheres probably represent radiolarians.
Fauna:
Planorotalites pseudomenardii (one small specimen)
Chiloguembelina midwayensis(few in fine fraction only)
Acarinina spp.
Subbotina triloculinoides
Age: Paleocene, probably P4a/b
Environment of deposition: Shelf depths
Comment: A very difficult sample and the results are tentative. Fauna seems to be low diversity in planktonic species. The sample seems to pre-date the evolution of the large Late Paleocene globorotalids. All species recovered are very small. Where are the larger specimens?
Nannoplankton may help.

Sample No.: 1603647
Dredge details: 274/49DR44 B1.1
Locality: 17° 38.0'S; 154°20.3'E – 2500-2350 m
Material: Thin section
Lithology: Highly calcareous sandstone, dominated by recrystallised sparry calcite which pervades everything. Considerable, well-sorted, angular quartz/plagioclase detritus. Trace glauconite. Scattered planktonic and small benthic foraminiferids. Common spheres are now filled with sparry calcite but with original wall or radial structure preserved in a few suggesting that they were originally sterraster sponge spicules or radiolarians.Simple sponge spicules also occur.
Fauna:
Planktonic foraminiferids are all very thin walled globigerinids and tell little. No other planktonics seen.
Age: Indeterminate from what is here but similarity with 1603644 would suggest Paleocene and the foraminiferids seen are consistent with this.
Environment of deposition: Continental shelf depths but probably below photic zone.

TAXONOMIC NOTES

Asterocyclina incisuricamerata Cole
Asterocyclina incisuricamerata Cole, 1957A, p. 349, pl. 117, figs. 1-5; Chaproniere 1983, p. 40, pl. 3, figs. 8,9; pl. 5, figs. 1-4.
This is the species recorded by Chaproniere (1983) and his comments are highly apposite. Both four- and five-rayed forms are present details of the periembryonic chambers are unclear. Equatorial chambers are roughly square.

The specimen examined from 1603213 is five rayed, as was the material figured by Chaproniere (op. cit.). Cole's original description emphasised the four-ray form but he later referred to five-rayed forms. From the little known in this region, it may be that a five-rayed form is more common. It then seems that a question of the identity arises. The occurrence in both samples is consistent with the age of Tertiary a_3 ascribed to the species.
Occurrence: 1603213, 1603468.

Discocyclina sp.
The test lacks rays. Embryonic chambers are large but the deuteroconch is much larger than the protoconch and almost envelopes it. There are no obvious periembryonic chambers and completely annular equatorial chambers commence immediately after the deuteroconch. A feature of the first annulus of equatorial chambers is that they chamberlets differ markedly from those in later annuli. Those in the first annulus are about 28 in number, almost square but expanding radially. Later equatorial chambers are very elongate radially.

The species is very similar to *D. omphala* (Fritsch) but seems to differ in the characteristics of the first annulus of 'square' chamberlets. It may be similar to *Asterocycline speighti* (Chapman) described from New Zealand, but the details of the first few chambers are not well described for that species.
Occurrence: 1603468.

Heterostegina equatoria Cole
Heterostegina equatoria Cole, 1957B, p. 756, pl. 234, figs. 1-12.
Samples 1603213 and 1603468 contains specimens of *Heterostegina* in which there are approximately 12-15 operculine chambers following the protoconch. They are very similar to Cole's original description of *H. equatoria.* Cole gave a Tertiary b age but here they occur in slightly older (Tertiary a_3). No specimens with the well-developed heterostegine stage as illustrated by Cole (1957) were encountered.

Heterostegina cf. saipanensis Cole, 1953
Heterostegina saipanensis Cole, 1957A, p. 331, pl. 102, figs. 17-19.
The species is characterised by possessing several (7-8) operculine chambers before chamberlets appear, and when they do, they are confined for many chambers to the outer part of the chambers.
Occurrence: 1603468.

Fabiania sp.
The species is uncommon. It is a regular cone, with only few early ventral chambers that are entire across the ventral surface. The margin is sharply angled. It seems not to be *F. gigantea, F. saipanensis, F. cassis* or *F. cubensis*.

It is not clear that this species differs from *F. cubensis* (Cushman & Bermudez) as illustrated by Cole (1952) from the Panama Canal Zone. That species is stated to have a deep umbilicus (as is the case in *F. gigantea*) but the vertical section shown by Cole has thicker latero-dorsal walls.

The relationship with *F. saipanensis* Cole is unclear but that species seems far more irregular in growth form and considerably larger (to approximately 4 mm diameter). *F. saipanensis* and *F. gigantea* have in common a thin latero-dorsal wall and very few chambers that are entire across the ventral surface.

Several authors have recorded *F. cassis* (Oppenheim) from the Indo-Pacific region but only Hanzawa (1959) seems to have documented the identification fully.

Occurrence: 1603468.

"Fabiania" gigantea (Todd) 1970
Patellina gigantea Todd, 1970, p. A10, pl. 3, figs. 1, 4.
Todd (1970) described *Patellina gigantea* from the Late Eocene of Tonga, noting that, at 1.6 mm diameter, it was much larger than other species of genuine *Patellina*. Todd's species is not attributable to *Patellina* as it lacks the biserial growth habit and its test is not built of calcite in optical continuity. It is a noteworthy species in sample 1603176 and several specimens were thin sectioned in the vertical plane. The species recorded here has in common with "*Patellina*" *gigantea* size, a conical form, regular circular outline, rough dorsal surface, uniserial growth habit, open umbilicus and appearance in vertical thin section. Todd referred to radial structures visible in the chambers indicating that it is am genuine *Fabiania.* These have not been seen in the form recorded here. It differs from other species of *Fabiania* in having a deep open umbilicus with very few chambers that are entire across the ventral surface.

Specimens from 1603333 are genuine *Fabiania* as the chamberlets are visible clearly.

“Crespinina” sp.

Cycloloculina sp. Todd & Low, 1970, p. E41, pl. 8, fig. 2

Description: Test discoid, thin, but irregular with clearly differentiated gently convex dorsal and gently concave ventral surfaces. Initial chambers obvious at apex of dorsal surface, consisting of small protoconch, almost surrounded by much larger deuteroconch and both enveloped by an undivided annular third chamber. No obvious attachment scars. Protoconch roughly spherical, approximately 35-40 microns in diameter. Protoconch reniform, approximately 65-70 microns in maximum. Normal diameter approximately 1.0 mm. Test one layer thick, without lateral chamber development. One specimen consists of plastogamic pair.

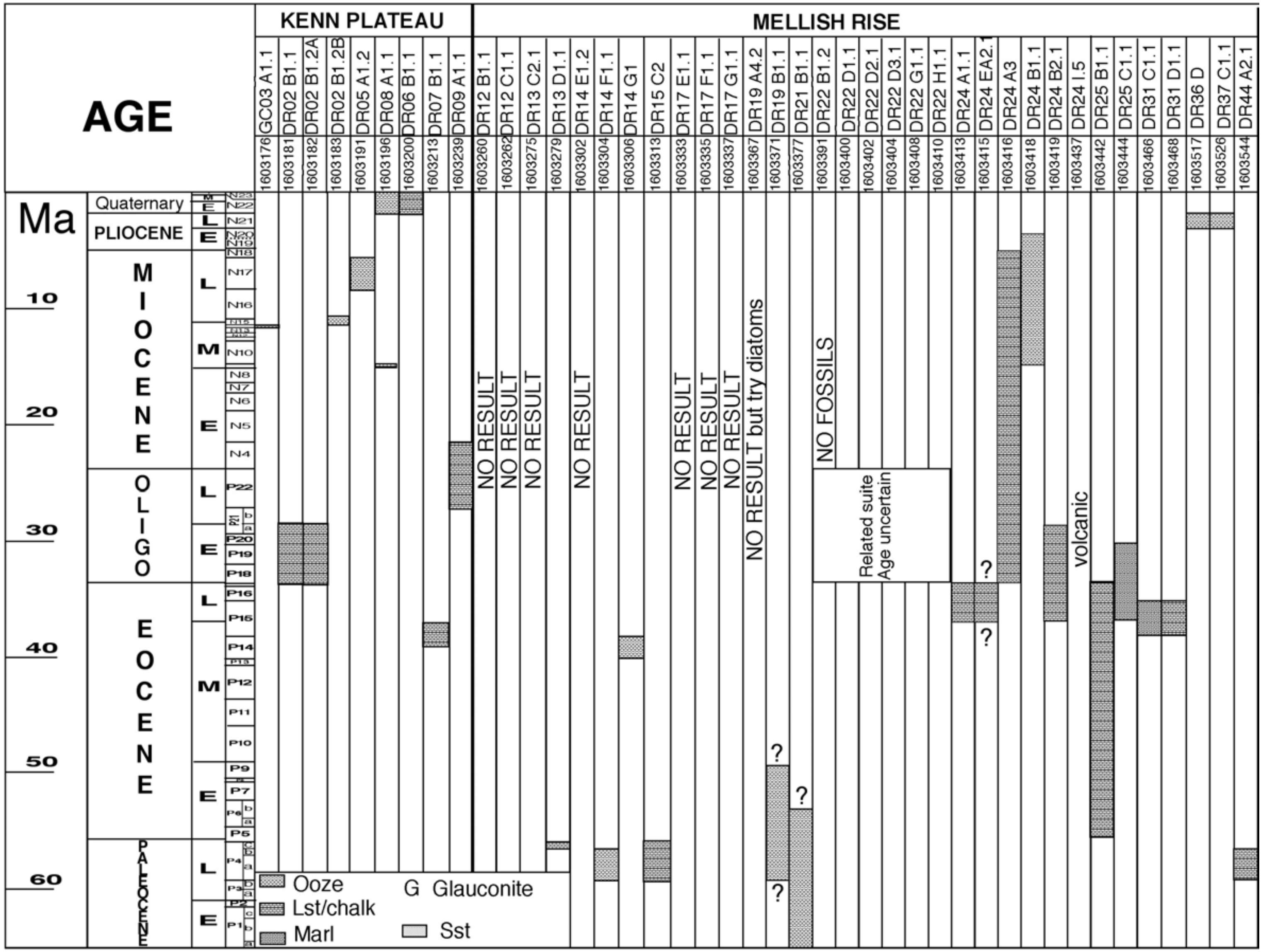
Following initial chambers, growth is annular with about 7 chambers. Chambers divided into up to 60 chamberlets by invaginations of the chamber wall, more obvious on the ventral surface. Chamberlet walls vertical and alternate between chambers. Dorsal surface coarsely perforate; ventral surface imperforate or very finely perforate. Chambers of constant height. As new chamber is added, it overlaps the previous chamber considerably on the dorsal side. Margin varies from rounded (normal) to angular. Ventral surface marked by large number of raised, radially-arranged, oval lobes which are the convex walls between invaginations.

Comment. This species is difficult to identify generically and probably is a new genus. It has much in common with *Crespinina* Wade, including the characteristic three-chambered embryonic apparatus, but lacks the addition of chambers across the ventral surface. The difference in the nature of perforaions on dorsal and ventral surfaces also is a *Crespinina* feature. It has much in common with *Sherbornina* but lacks simple annular chambers.

Todd & Low (1970) illustrated as *Cycloloculin*a an immature specimen of a species said to be rare, and this seems identical with some of the small specimens thin sectioned. She also (Todd 1957) recorded it in open nomenclature from Saipan but the illustration is not adequate for detailed comparison and there were no remarks in the text of the paper.

Occurrence: 1603468

Table 1. Biostratigraphic summary of GA Survey 274 dredged and cored foraminiferal samples.



APPENDIX 5. PRELIMINARY PETROLOGY AND MINERAL CHEMISTRY TABULATION OF DREDGE SAMPLES

Julie Brown

Optical microcopy of polished thin sections was undertaken at the Department of Earth and Marine Sciences, Australian National University; a summary of petrographic observations is presented in Table 1. Subsequent spot analyses for mineral compositions of selected samples were performed by scanning electron microscope (SEM) housed at the Electron Microscopy unit, Research School of Biological Sciences, Australian National University. Counting time, beam current, and accelerating voltage were set at 100 seconds, 1nA, and 15kV respectively. Glass analyses (Table 3) were conducted over a broad area (rather than the minimum spot size of ~3µm) in order to minimize damage to the glass and sodium loss, during the collection of a spectrum. To ensure the accuracy of glass data collected, glass spots were alternated with plagioclase or olivine grains – minerals that are easily checked for stoichiometry (Table 2).

Table 1. Summary of *Southern Surveyor* Cruise SS02/2005 (GA Survey 274) thin sections made for petrological analysis.

Slide #	*Dredge-lithology*	*Location*	*Shipboard description*	*Rock type*	*Alteration Index*	*Description*
28	DR08-D2.1	Coriolis Ridge	felsic volcanic	Andesite-basalt	5	Dominantly plagioclase rock. Phillipsite infilling of vesicles, with smectite. Appears to be an alteration halo across the thin section. Subophitic plagioclase-clinopyroxene, minor iddingsite.
24	DR08-B1.1	Coriolis Ridge	welded volcanic	Basalt	8	Large plagioclase pehoncrysts are form interlocking textures in black to green altered matrix. Even appears as though iddingsite (pseudomorphs after olivine) has been altered to fine-grained brown clay mineral. Zeolite infilling of vesicles.
27	DR08-D1.1	Coriolis Ridge	felsic volcanic	Basalt	3	Fine-grained plagioclase-rich (laths) in mildy altered matrix with large augite phenocrysts. Relic olivine is mostly altered to iddingsite, remaining matrix is fine-grained alteration. Large opaques - magnetite(?).
16	DR34-A1.1	SelfRidge Rise	quartz diorite	Basalt	10	(as in DR34-A2.1) Cut by numerous veins of carbonate, quartz, and zeolites. Matrix has smectite and phillipsite alteration, with numerous isometric magnetite crystals.
25	DR08-C2.1	Coriolis Ridge	volcaniclastic sst	Pyroclastic	8 - 9	0.5mm relic basalt, plagioclase, and altered glass fragments in fine-grained pale brown altered matrix. Glass is altered to palagonite. Corroded margins of clasts = welding. Thin layer along altered section margin contains gastropods - age would yield maxium age for pyroclastic volcanism?
26	DR08-C3.1	Coriolis Ridge	volcaniclastic sst	Pyroclastic	7 - 8	Basaltic clast dominated, with minor palagonite (altered glass) and plagioclase clasts. Clasts have welded edges. Plagioclase megacrysts (1mm) likewise show evidence of welding. Matrix is fine-grained green alteration mineral. C:M = 55-45%
2	DR07-A1.1	Northern Coriolis Ridge	altered tuff	Pyroclastic	9 - 10	Heavily altered fragmental rock, matrix is all altered to fine-grained (clay?) brown-gray minerals. Altered basalt clasts and remnant plag megacrysts in fibrous alteration matrix. Plagioclase comprises 90% of clasts, basalt the remaining 10%. Ratio of Clasts to Matrix (C:M) = 45:55
30	DR11-C1.1	SelfRidge Rise	welded tuff	Pyroclastic	9 - 10	Heavily altered, welded basaltic fragments in basalt matrix. Relic olivine pseudomorphs (now fine-grained alteration product). Narrow rim along edges of some basaltic inclusions is now fine-grained bright alteration (variably carbonate or zeolite)
3	DR08-G1.1	Northern Coriolis Ridge	siliceous tuff	Pyroclastic	8 - 9	Pyroclastic unit has devitrified matrix of consistent composition, with numerous entrained fragments, most notably - altered basalt (50% of clasts) and plagioclase megacrysts (50%). One possible 500 µm fine-grained sedimentary clast. C:M = 35-45:65-60, Feldspar phenocrysts have corroded edges indicative of welding, and exhibit zoning and mottling (owing to partial resorption). Also, plagiclase crystals contain melt inclusions.
4	DR11-A1.1	SelfRidge Rise	quartzite	Quartzite-quartzofeldspathic schist	n/a	Grain size variable with some large and blocky quartz (up to 1cm) and feldspar crystals, surrounded in some areas by much finer-grained quartz. Large grains vary in appearance from rounded to distinctively angular and fractured looking. 5 - 10% of the section consists of altered clasts, rounded

						and of uncertain affinity. Within this subgroup are certain well-rounded clasts that are volcanic in origin. Cut by sulfide and oxide bearing veins, and quartz veins. Anomalously thick section yields unusual birefringence in quartz and plagioclase.
17	DR34-A2.1	SelfRidge Rise	quartz diorite	Volcaniclastic	9.5	Patchy remains of basaltic texture. Matrix is now dominated by zeolite minerals.
29	DR11-B1.1	SelfRidge Rise	hyaloclastitic greywacke grit	Volcaniclastic	8 - 9	Fragmental rock dominated by fragments with basaltic lithology. Some calcite and rounded quartz (as well as one rounded clinopyroxene grain) in the matrix indicative of reworking. Most of the matrix is heavily altered, though patches are perhaps basaltic in composition. Clast dominant rock, C:M = 65:35.
31	DR11-C2.1	SelfRidge Rise	welded tuff	Volcaniclastic	10	Heavily altered. Remnant basalt in zeolite and clay dominated matrix.
23	DR08-A1.1	Coriolis Ridge	tuff?	Volcaniclastic	9	Matrix (~65% of slide) consists of granular, subrounded calcite. Grain size is predominantly quite fine, but coarsens to some angular grains. Clasts are almost all basalt, up to 1.1cm in length. Plagioclase form less than 5% of clasts.
41	DR14-D1.1	Eastern Mellish Rise	serpentinite breccia	Altered basalt	9	Numerous late, radiating crystals with fan like undulose extinction (phillipsite?) within fractures and vesicles. Altered green basaltic matrix.
40	DR14-C1	Eastern Mellish Rise	hyaloclastite	Altered, devitrified glass	2	Glass (faintly?) altered to fine grained clay(?) and zeolite facies minerals. Aphanitic varying from pale yellow-green to pale brown. Incipient formation of (micro crystals?). Some iddingsite alteration of lone Ol? Very few plagioclase phenocrysts.
32	DR13-A1.1	Eastern Mellish Rise	basalt	Basalt	8	2.5mm subophitic plagioclase-clinopyroxene, with iddingsite in fine-grained grey-green homogeneous altered matrix.
33	DR13-A2.1	Eastern Mellish Rise	vesicular basalt	Basalt	6	Much coarser grained than DR13-A1.1, but also has subophitic plagioclase-clinopyroxene. Related to gabbro, yet called basalt because of prominence of 2mm vesicles.
37	DR14-B1.1	Eastern Mellish Rise	basalt	Basalt	3 - 4	Similar to DR14-A1.1, except more fine-grained and lacking large subophitic cpx-plag. Contains ilmenite.
39	DR14-B4.1	Eastern Mellish Rise	plag-poor basalt	Basalt	7 - 8	Altered matrix contains some calcite. Few small vesicles are infilled by zeolites.
18	DR36-B1.1	North end of seamount	basalt	Basalt	3-4	Relatively fresh basalt with disequlibrium textured plagioclase megacrysts. Also contains some clinopyroxene (likely augite) megacrysts. Olivine still remains, has been partially altered to iddingsite. Glass matrix has been palagonatized. Phillipsite alteration of amygdales. Finely disseminated oxide - likely magnetite.
10	DR24-I3.1	Near Mellish Rise reef	basalt	Basalt	6-7	Coarser grained than most other basalts, with lath-shaped plagioclase up to 2.5mm long, with mottled edges. 1cm vesicles contain extremely fine-grained brown, then green and fibrous alteration. Olivine altered to iddingsite. Zeolite infilling of vesicles.
20	DR41-E1.1	North of seamount	basalt	Basalt	3	Similar to DR15-A1.1. Fine to medium grained clinopyroxene - plagioclase with iddingsite (after olivine - minor remnant). Iddingsite up to 1mm. Subophitic iddingsite/plagioclase ~3mm. Plagioclase megacrysts up to

						0.9cm. Red alteration front along edge of section. Opaque mineral = magnetite. Some fine-grained brown alteration.
21	DR41-E2.1	North of seamount	basalt	Basalt	2	Similar to DR41-E1.1.
5	DR15-A1.1	Northern Mellish Rise	altered basalt	Basalt	2-4	Subophitic 3mm plagioclase-clinopryxene in fine basalt matrix of fine-grained clinopyroxene and lath shaped plagioclase. 1.5cm patch of fractured palagonite (altered glass). Corroded plagioclase - indicative of disequilibrium. Ragged edges reflect some welding. Yellow zeolite alteration within vesicles up to 1mm across. + disseminated magnetite. Black alteration front progresses across slide.
7	DR17-A2.1	Northern Mellish Rise (edge of Louisiade Plateau)	basalt	Basalt	5	Minor olivine altered to iddingsite. Plagioclase phyric matrix, with crystals up to 0.8cm, crystals are zoned, with corroded rims. Clinopyroxene megacrysts present as well, up to 1mm. Contains ilmenite + magnetite.
6	DR16-A1.1	Northern Mellish Rise, north of DR15	tuff	Basalt	4-5	Black alteration predominant (manganite?). Iddingsite alteration of olivine (5%). Plagioclase-clinopyroxene matrix phaneritic as in DR15-A1.1. Large plagioclase megacrysts ~0.5mm. Elongate vugs (>1cm) with fine-grained mineral fill. More circular vesicles exhibit radiating phillipsite.
35	DR13-E1.1	Eastern Mellish Rise, near D'Entrecasteaux Basin	chert	Basalt + altered sedimentary rock	6 - 9	Basalt in contact with altered sedimentary unit. Pink horizon is an alteration halo, and not chert.
19	DR39-A1.1	Seamount	basaltic hyaloclastite	Basaltic hyaloclastite	2 - 4	Spectacular palagonatized hyaloclastite. Extensive zeolite facies mineral growth - perhaps chabazite. Skeletal olivine being replaced by iddingsite.
22	DR41-H1.1	North of seamount	quartz diorite	Dolerite	2	Subophitic plagioclase-cpx, with matrix olivine being altered to iddingsite. Fairly even-grained with clinopyroxene normally ~0.5mm.
34	DR13-B1.1	Eastern Mellish Rise, near D'Entrecasteaux Basin	dolerite	Dolerite-gabbro	3	Subophitic clinopyroxene-plagioclase - up to around 2mm. Fine-grained brown interstitial alteration.
36	DR14-A1.1	Eastern Mellish Rise	qtz gabbro-diorite	Gabbro	3	Subophitic clinopyroxene-plagioclase - up to around 2mm. Fine-grained brown interstitial alteration.
46	DR17-C1.1	Northernmost Mellish Rise	agglomerate	Hyaloclastic basalt	7	Zones of hyaloclastite have rounded fragments of <1mm to 1cm basalt in devitrified (brown) glass. Iddingsite alteration of basalt evident in basalt. Relic suphophitic olivine (now iddingsite) with plagioclase in basalt.
11	DR25-A1.1	South of Mellish Rise reef	hyaloclastite	Palagonatized glass	4-10	Altered glass (to palagonite) adjacent to completely altered volcanic. Palagonite contains deformed vesicles and plagioclase phenocrysts.
38	DR14-B2.1	Eastern Mellish Rise	vesicular basalt	Vesicular basalt	7	Similar to DR14-A1.2. More altered.
42	DR15-B1.1	Northern Mellish Rise	vesicular basalt	Vesicular basalt	7	Coarser grained with less plag than DR15-A1.1. Minor clinopyroxene, subophitic with plagioclase. Olivine completely altered to iddingsite.
43	DR17-A1.1	Northernmost Mellish Rise	basalt	Vesicular basalt	9	Relic plagioclase laths.
44	DR17-B1.1	Northernmost Mellish Rise	vesicular basalt	Vesicular basalt	5	Olivine altered to iddingsite, minor fresh Ol. Subophitic plagioclase and clinopyroxene.
45	DR17-B2.1	Northernmost Mellish Rise	vesicular basalt	Vesicular basalt	6	Similar to DR17-B1.1
12	DR26-A1.1	Southern Mellish Rise	vesicular basalt	Vesicular basalt	6	Lath-shaped plagioclase more aligned than other samples. Iddingsite pseudomorphs of olivine comprise ~ 10% of section. Black alteration prevalent. Corroded plagioclase phenocrysts - indicative of disequilibrium. Zeolite mineral (radiating phillipsite and unknown) fill within 2-3mm vesicles. Abundant disseminated opaque mineral (magnetite).

13	DR26-A1.2	Southern Mellish Rise	vesicular basalt	Vesicular basalt	6.5	Reddish alteration prevalent - iddingsite pseudomorphing olivine. Vesicles show radial infilling by celadonite or phillipsite. Plagioclase phyric (up to 1cm) - some with albite twins. Also contains augite.
14	DR30-A1.1	Southern Mellish Rise	basaltic conglomerate	Vesicular glassy basalt	1	Contains fresh patch of glassy basalt (<1cm across), with unaltered olivine crystals amongst plagioclase laths. Otherwise, glass is palagonatized with interstitial smectite (?) and phillipsite. Vesicles and veins infilled with zeolite minerals (phillipsite/celadonite).

Table 2. Selected mineral compositions.

SAMPLE	**DR30-A1.1**	**DR30-A1.1**	**DR30-A1.1**	**DR08-D1.1**	**DR08-D1.1**	**DR30-A1.1**	**DR30-A1.1**	**DR08-D1.1**	**DR08-D1.1**
	M-glassy basalt	M-glassy basalt	M-glassy basalt	K - basalt	K - basalt	M-glassy basalt	M-glassy basalt	K - basalt	K - basalt
Mineral	plagioclase 1	plagioclase 2	plagioclase 3	plagioclase	K-feldspar	olivine1	olivine2	Augite1	Augite2
Elemental weight %									
Si	24.17	24.51	25.23	25.29	30.14	18.71	19.06	24.39	23.98
Al	15.78	15.82	15.40	14.87	9.59	0.00	0.00	1.18	1.54
Ti	0.00	0.14	0.00	0.00	0.14	0.00	0.00	0.24	0.54
Mn	0.00	0.00	0.00	0.00	0.00	0.26	0.00	0.29	0.24
Mg	0.11	0.11	0.24	0.00	0.09	24.91	25.11	9.21	8.84
Fe	0.71	0.50	0.44	0.54	0.00	15.58	15.42	7.13	7.33
Ca	9.28	9.27	3.17	3.82	0.14	0.16	0.00	0.33	0.33
Na	2.83	2.97	9.14	7.95	0.00	0.16	0.22	14.22	14.87
K	0.18	0.17	0.16	0.00	13.84	0.00	0.00	0.00	0.00
O	46.64	47.09	47.57	46.69	45.94	42.37	42.75	42.97	43.09
Total	99.70	100.58	101.35	99.16	99.88	102.15	102.56	99.96	100.76
Atomic proportion									
Si	18.16	18.24	18.59	18.98	22.98	14.38	14.55	19.36	18.97
Al	12.34	12.25	11.81	11.62	7.61	0.00	0.00	0.97	1.26
Ti	0.00	0.06	0.00	0.00	0.06	0.00	0.00	0.11	0.25
Mn	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.12	0.10
Mg	0.09	0.09	0.20	0.00	0.08	22.12	22.14	8.45	8.08
Fe	0.27	0.19	0.16	0.20	0.00	6.02	5.92	2.85	2.92
Ca	4.89	4.83	4.72	4.18	0.00	0.08	0.12	7.91	8.25
Na	2.60	2.70	2.85	3.50	0.13	0.15	0.00	0.32	0.32
K	0.09	0.09	0.08	0.00	7.58	0.00	0.00	0.00	0.00
O	61.50	61.51	61.54	61.52	61.50	57.17	57.27	59.90	59.85
Total	100	100	100	100	100	100	100	100	100
Compound %									

SiO_2	51.72	52.43	53.97	54.10	64.48	40.03	40.77	52.17	51.30
Al_2O_3	29.81	29.88	29.10	28.09	18.12	0.00	0.00	2.23	2.90
TiO_2	0.00	0.23	0.00	0.00	0.23	0.00	0.00	0.40	0.91
MnO	0.00	0.00	0.00	0.00	0.00	0.34	0.00	0.38	0.32
MgO	0.18	0.17	0.40	0.00	0.14	41.31	41.64	15.27	14.65
FeO	0.92	0.65	0.57	0.69	0.00	20.05	19.84	9.17	9.43
CaO	12.99	12.97	12.78	11.13	0.00	0.22	0.31	19.90	20.81
Na_2O	3.82	4.01	4.27	5.15	0.19	0.22	0.00	0.45	0.45
K_2O	0.21	0.20	0.19	0.00	16.67	0.00	0.00	0.00	0.00
Total	99.65	100.54	101.28	99.16	99.83	102.17	102.56	99.97	100.77
Oxygen for calculation	8	8	8	8	8	4	4	6	6
# IONS									
Si	2.36	2.37	2.42	2.47	2.99	1.01	1.02	1.94	1.90
Al	1.60	1.59	1.54	1.51	0.99	0.00	0.00	0.10	0.13
Ti	0.00	0.01	0.61	0.54	0.00	0.01	0.01	0.79	0.83
Mn	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.03
Mg	0.01	0.01	0.00	0.00	0.00	0.01	0.00	0.01	0.01
Fe	0.04	0.02	0.03	0.00	0.01	1.55	1.55	0.85	0.81
Ca	0.64	0.63	0.02	0.03	0.00	0.42	0.41	0.29	0.29
Na	0.34	0.35	0.37	0.46	0.02	0.01	0.00	0.03	0.03
K	0.01	0.01	0.01	0.00	0.99	0.00	0.00	0.00	0.00
Cation sum	5.00	4.99	5.00	5.01	5.01	3.01	2.99	4.02	4.03

Table 3. Glass analyses from sample DR30-A1.1. Analyses 1-3 are plotted on Figure 22**.**

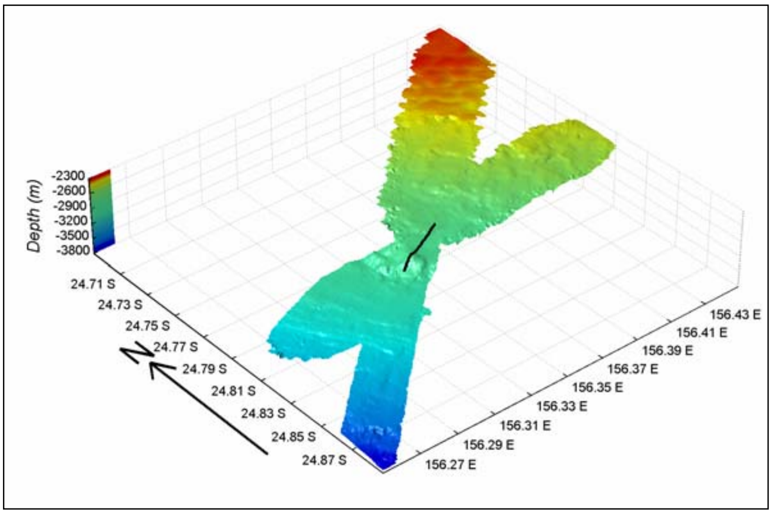
Elemental weight %	Glass 1	Glass 2	Glass 3	Glass 4 - palagonite	Glass 5 - palagonite
Si	24.23	24.39	24.55	18.76	20.38
Al	7.35	7.50	7.47	7.73	6.30
Ti	1.44	1.58	1.51	2.42	2.43
Mn	0.07	0.02	0.26	0.19	0.01
Mg	3.53	3.54	3.60	1.23	1.86
Fe	8.04	7.87	8.32	13.35	15.17
Ca	6.69	6.91	6.99	0.51	0.36
Na	2.28	2.50	2.44	1.63	1.15
K	0.69	0.68	0.77	2.96	3.61
Cl	0.04	0.00	-0.01	0.59	0.23
O	43.35	43.87	44.25	35.94	37.30
Total	97.71	98.86	100.15	85.31	88.80
Atomic proportion					
Si	19.39	19.27	19.21	17.96	18.86
Al	6.12	6.17	6.08	7.70	6.07
Ti	0.67	0.73	0.69	1.36	1.32
Mn	0.03	0.01	0.10	0.09	0.00
Mg	3.27	3.23	3.26	1.36	1.99
Fe	3.23	3.13	3.27	6.43	7.06
Ca	3.75	3.83	3.84	0.34	0.24
Na	2.23	2.41	2.33	1.90	1.30
K	0.40	0.38	0.43	2.04	2.40
Cl	0.02	0.00	-0.01	0.44	0.17
O	60.89	60.84	60.78	60.38	60.60
Total	100.00	100.00	100.00	100.00	100.00
Compound % Calculated on basis of 8 oxygen					
SiO_2	51.83	52.17	52.52	40.14	43.60
Al_2O_3	13.88	14.17	14.11	14.61	11.91
TiO_2	2.39	2.64	2.51	4.04	4.06
MnO	0.08	0.03	0.33	0.25	0.01
MgO	5.86	5.87	5.98	2.04	3.08
FeO	10.34	10.13	10.70	17.18	19.51
CaO	9.36	9.67	9.79	0.71	0.51
Na_2O	3.07	3.37	3.29	2.19	1.55
K_2O	0.83	0.82	0.93	3.57	4.34
Total	97.64	98.87	100.16	84.73	88.57

APPENDIX 6. SITE DETAILS OF INDIVIDUAL DREDGE STATIONS

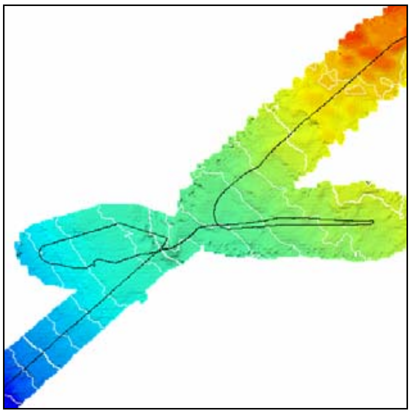
The following is a pictorial analysis of all successful dredge sites. Colour-coded 2-dimensional and 3-dimensional topographic images are rendered, using the swath bathymetry collected, to highlight the morphology of the dredge site. For the 3-dimensional images, both depth and slope values of the seafloor are colour-coded and draped over the modelled terrain. Where located near a seismic line, a portion of that seismic line is presented to highlight the underlying geology as imaged by seismic.

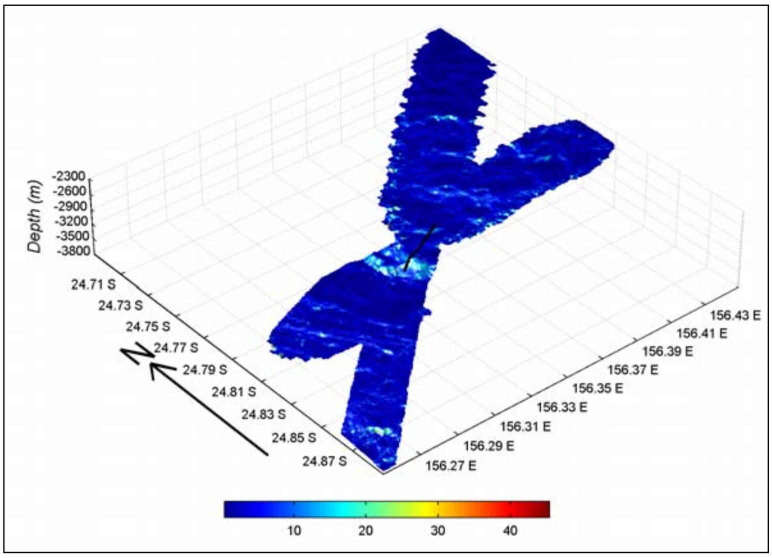
Dredge Site 274/DR01
(Kenn Plateau)

Location:	156° 19.72'E, 24° 48.65'S
Date:	Jan. 26, 2005
Depths:	3200-2800 m
Haulage:	in dredge pipe
Recovery:	calcareous ooze

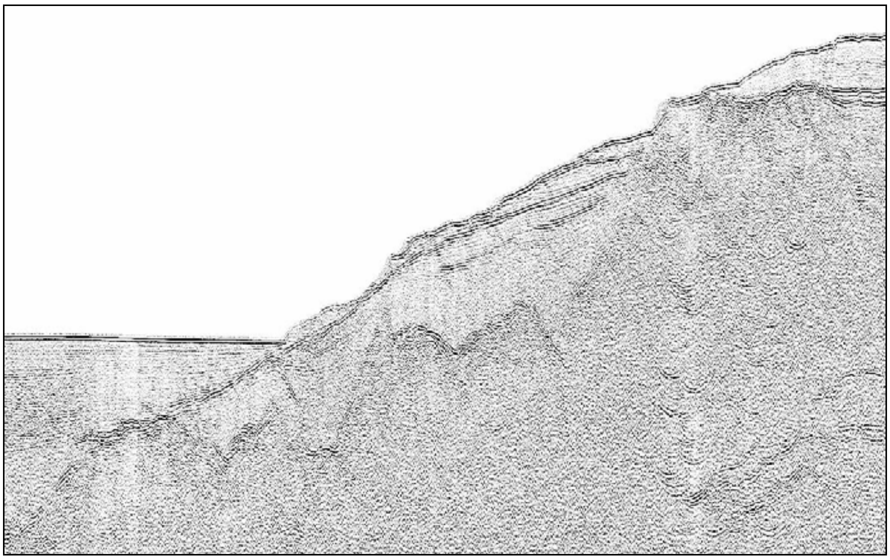


Colour-coded topographic model. Black line is approximate dredge trajectory upslope.



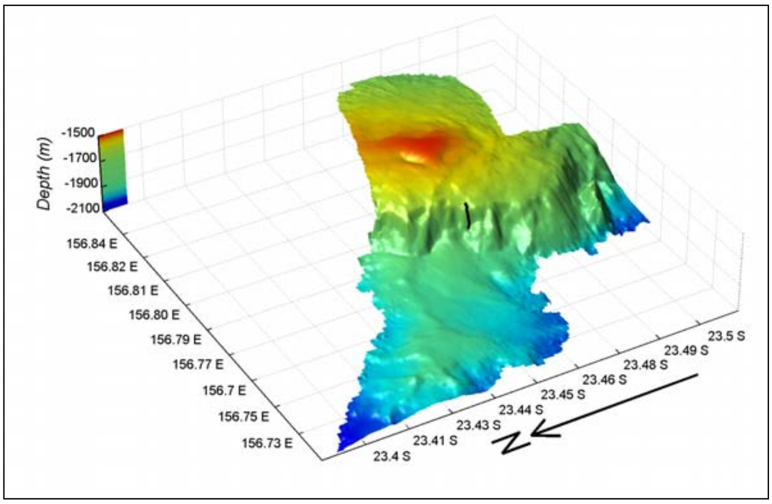


Topographic model superposed by terrain slope (degrees).



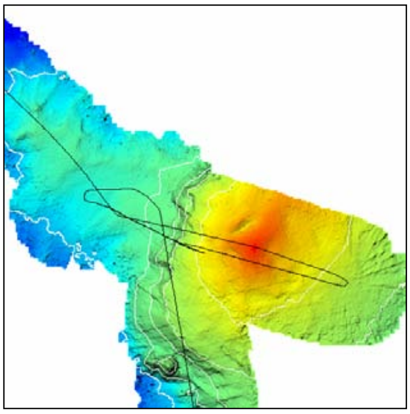
Southwest-northeast seismic line GA 270/07 over dredge site.

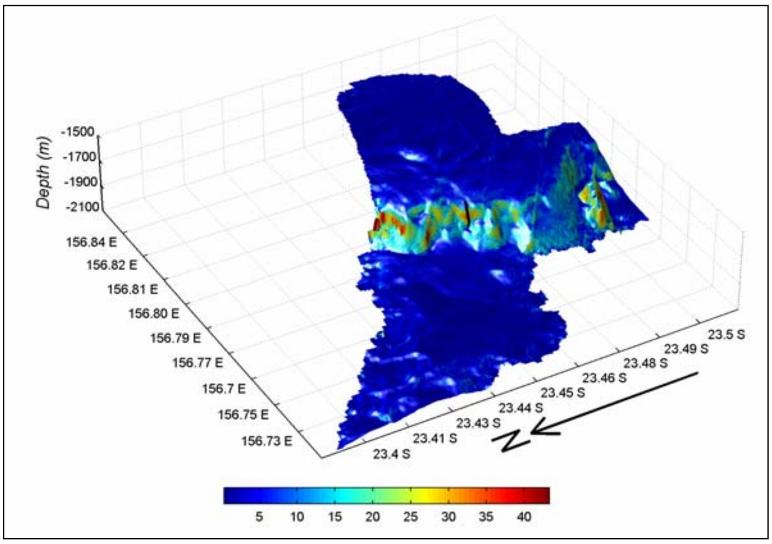
Dredge Site 274/DR02
(Kenn Plateau)



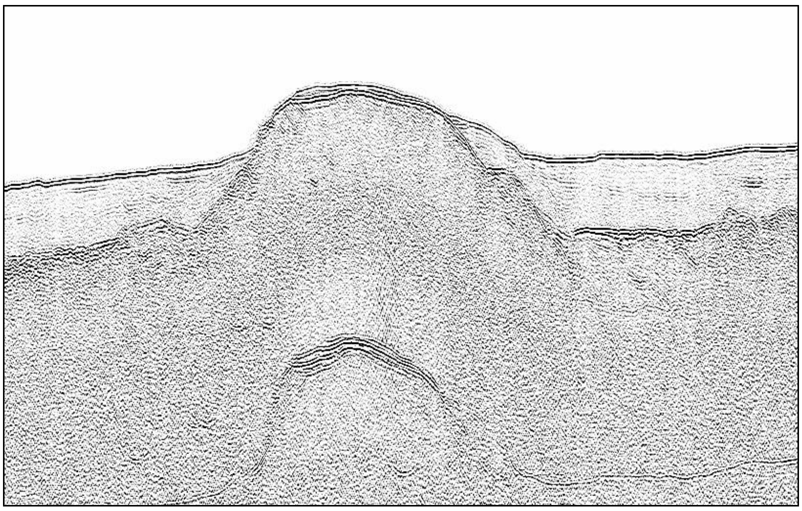
Location:	156° 45.50'E, 23° 27.00'S
Date:	Jan. 27, 2005
Depths:	1850-1650 m
Haulage:	15 kg
Recovery:	limestone, ?metasediment, manganese crust

Colour-coded topographic model. Black line is approximate dredge trajectory upslope.





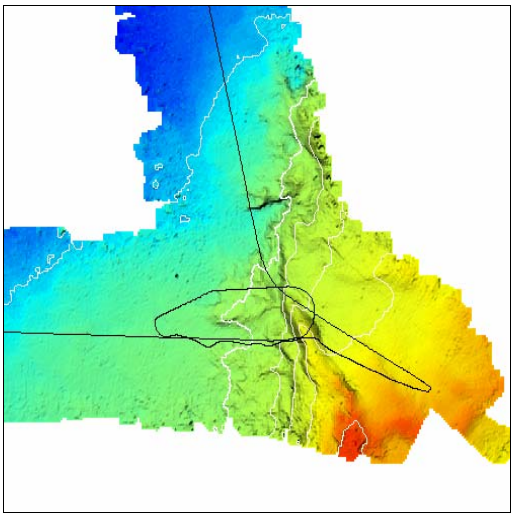
Topographic model superposed by terrain slope (degrees).

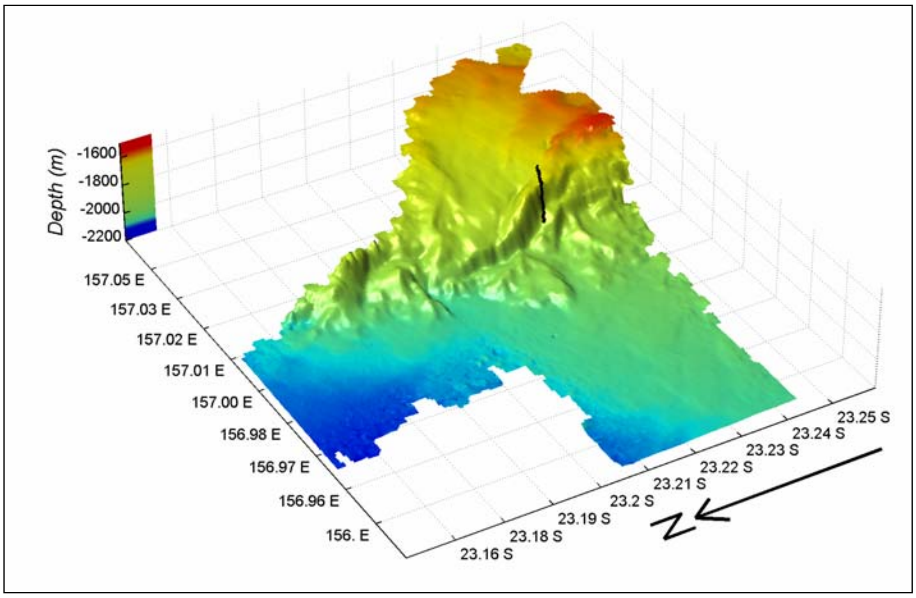


West-east seismic line GA 270/14 near dredge site.

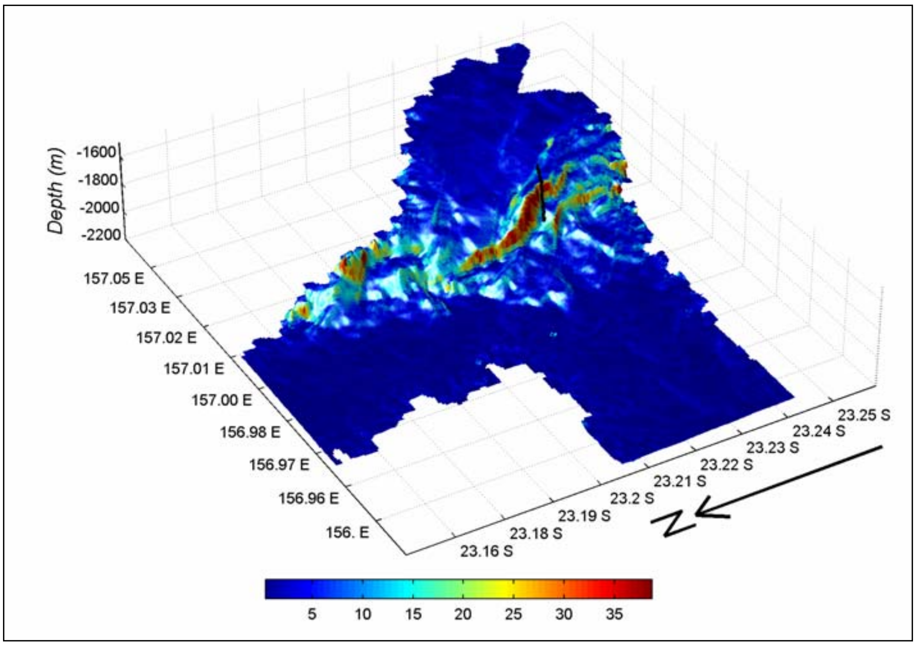
Dredge Site 274/DR04
(Kenn Plateau)

Location:	156° 59.01'E, 23° 13.57'S
Date:	Jan. 28, 2005
Depths:	1900-1650 m
Haulage:	10 kg
Recovery:	calcareous ooze and manganese crust





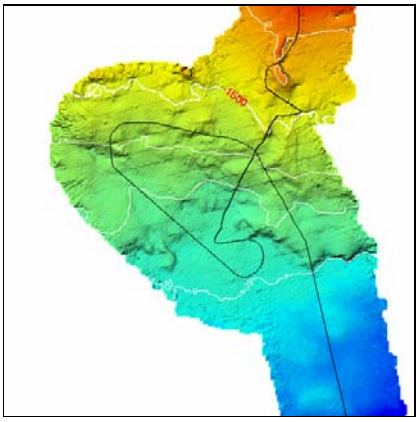
Colour-coded topographic model. Black line is approximate dredge trajectory upslope.

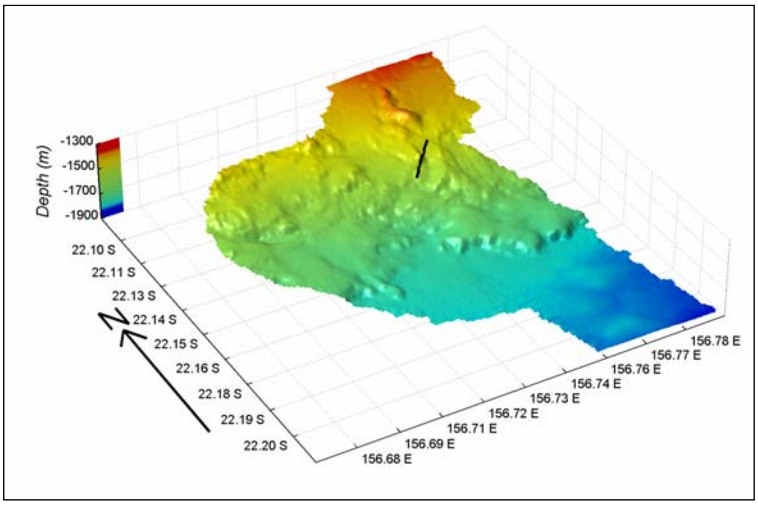


Topographic model superposed by terrain slope (degrees).

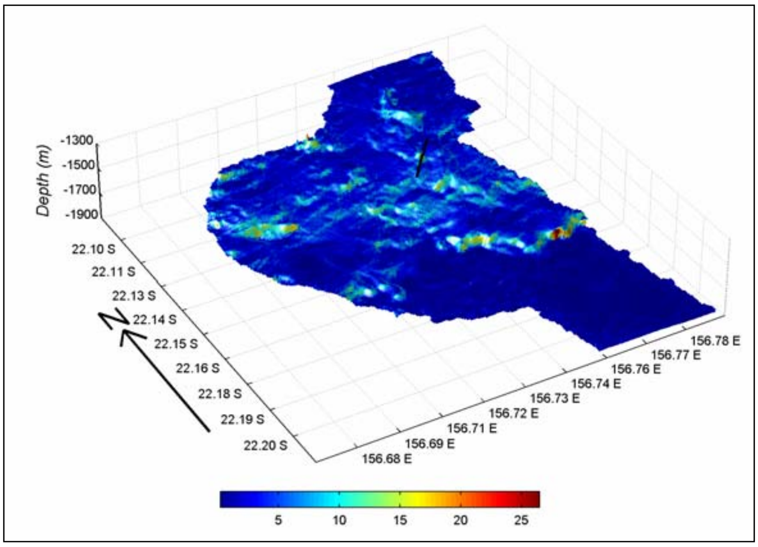
Dredge Site 274/DR05
(Kenn Plateau)

Location:	156° 44.54'E, 22° 08.16'S
Date:	Jan. 28, 2005
Depths:	1650-1500 m
Haulage:	30 kg
Recovery:	calcareous ooze, chalk and foram sand

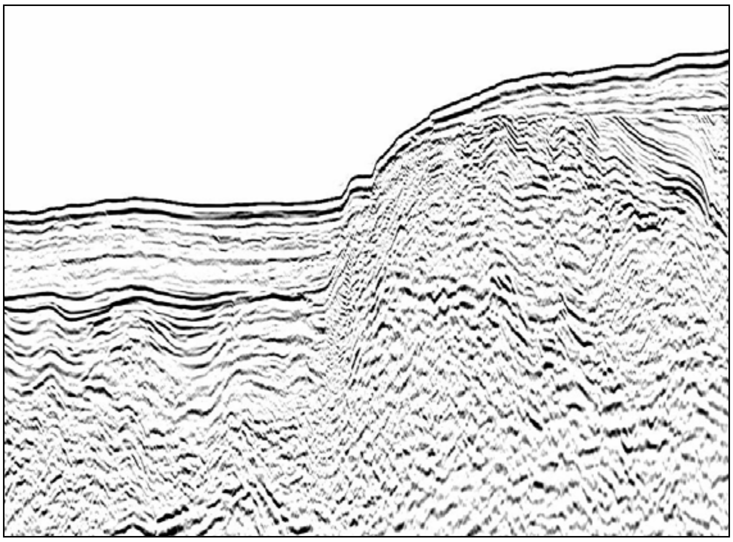




Colour-coded topographic model. Black line is approximate dredge trajectory upslope.

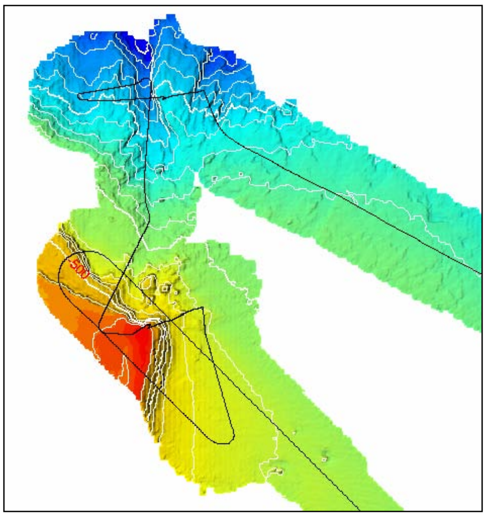


Topographic model superposed by terrain slope (degrees).

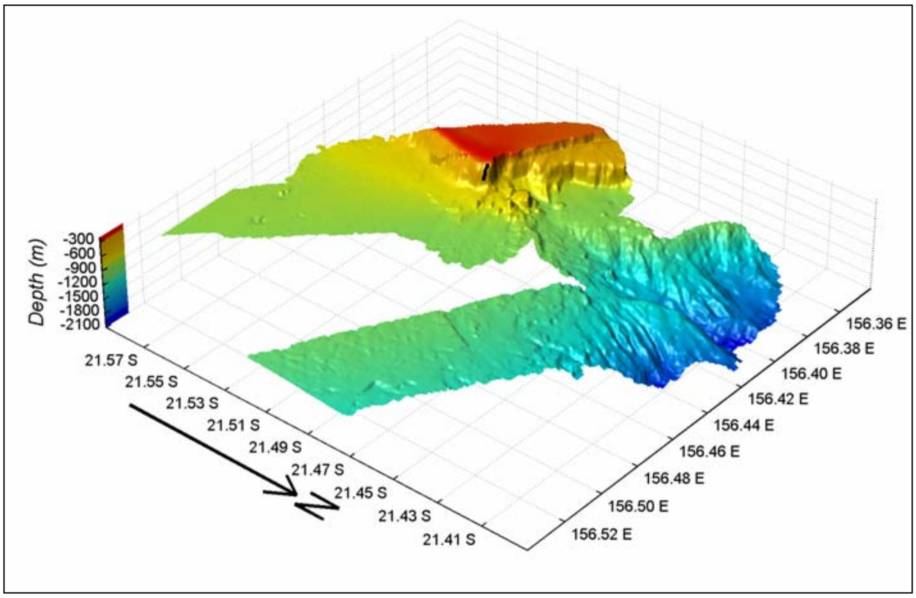


South-southwest to north-northeast seismic line Shell Petrel p701 near dredge site.

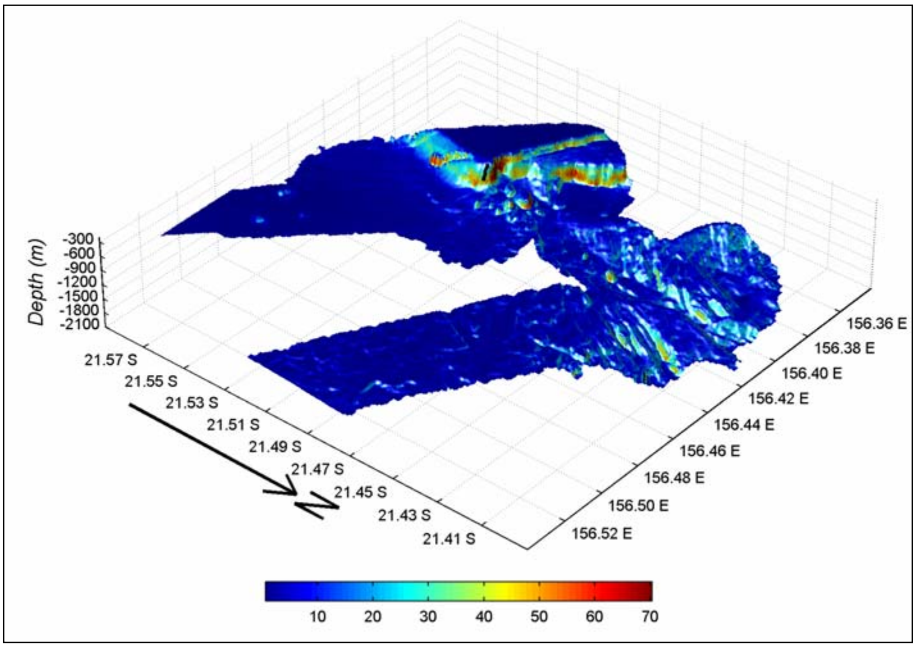
Dredge Site 274/DR06
(Kenn Plateau)



Location:	156° 24.82'E, 21° 30.81'S
Date:	Jan. 28, 2005
Depths:	700-300 m
Haulage:	10 kg
Recovery:	limestone, calcarenite and shell hash



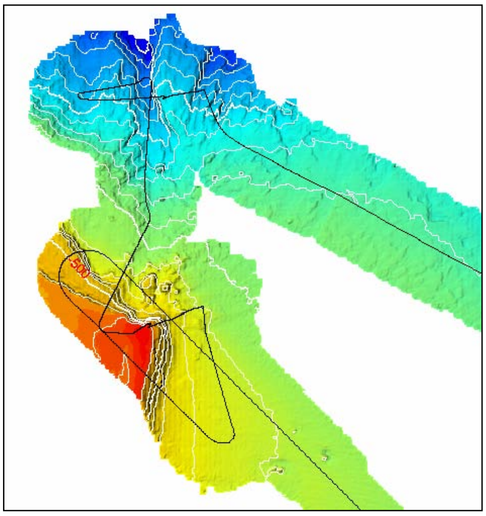
Colour-coded topographic model. Black line is approximate dredge trajectory upslope.

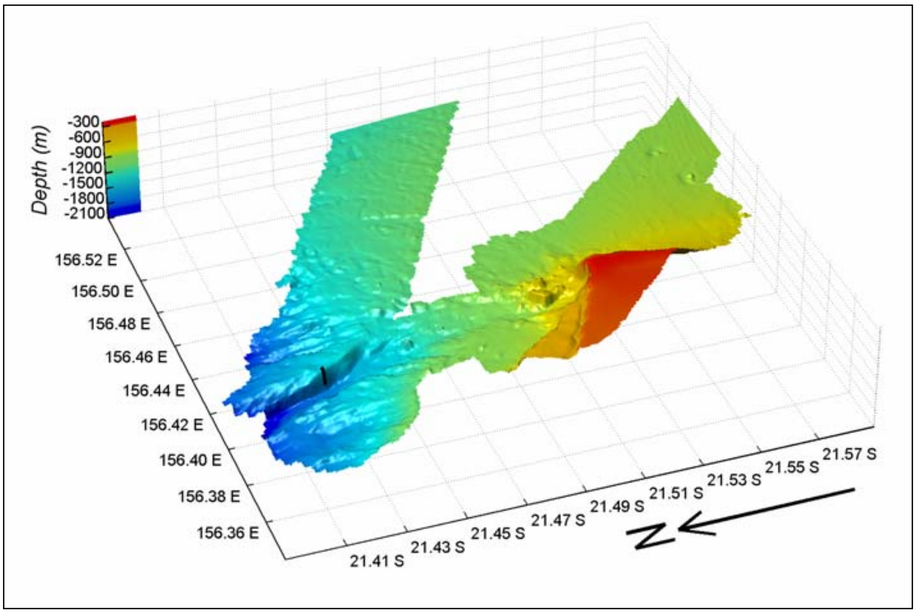


Topographic model superposed by terrain slope (degrees).

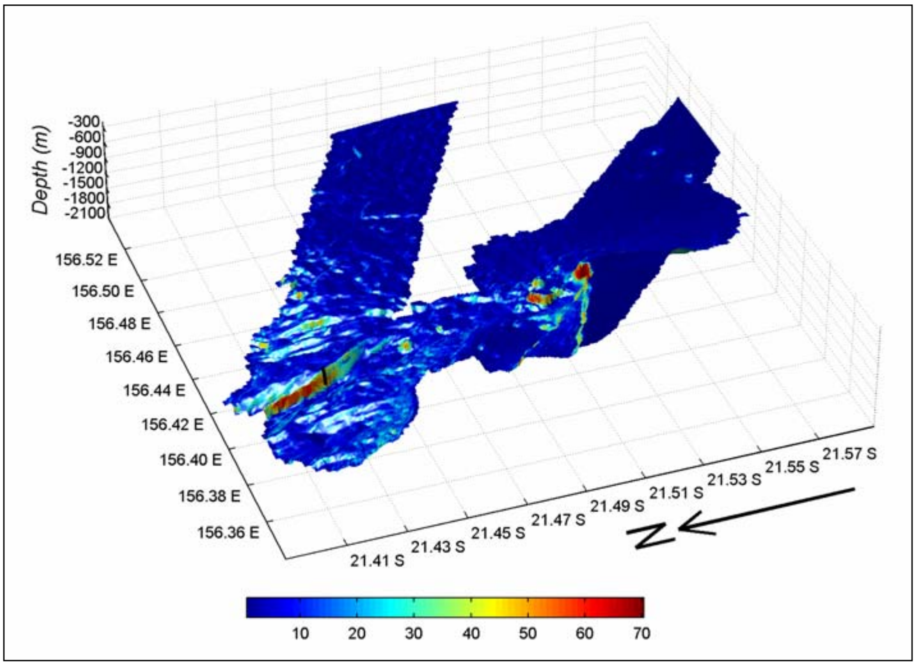
Dredge Site 274/DR07
(Kenn Plateau)

Location:	156° 24.36'E, 21° 25.51'S
Date:	Jan. 29, 2005
Depths:	1700-1400 m
Haulage:	60 kg
Recovery:	calcarenite, tuff and shell hash





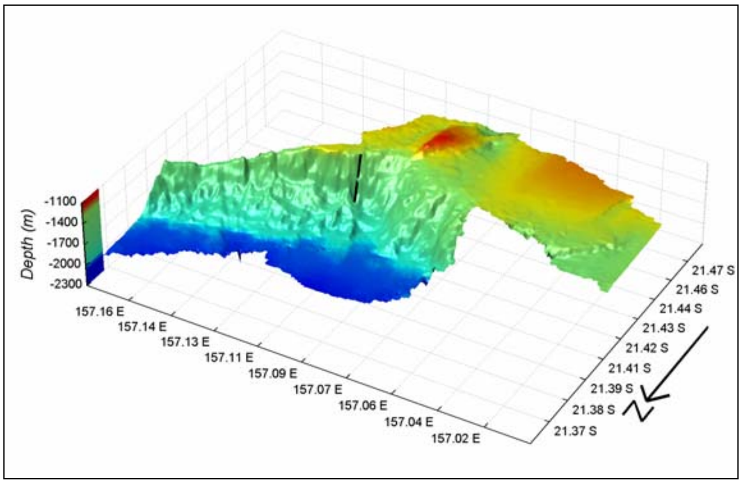
Colour-coded topographic model. Black line is approximate dredge trajectory upslope.



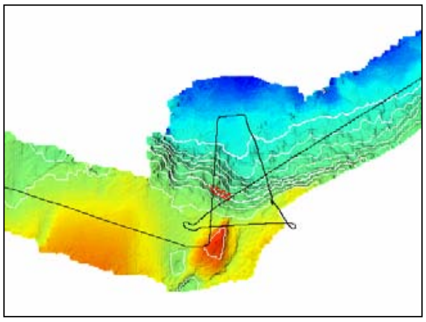
Topographic model superposed by terrain slope (degrees).

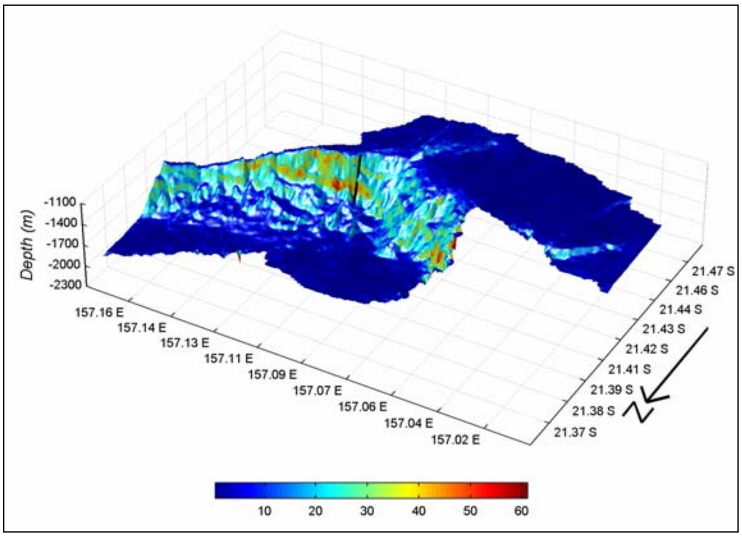
Dredge Site 274/DR08
(Kenn Plateau)

Location:	157° 06.78'E, 21° 25.69'S
Date:	Jan. 29, 2005
Depths:	1700-1300 m
Haulage:	200 kg
Recovery:	agglomerate, felsic, volcanics, sandstone and manganese crust

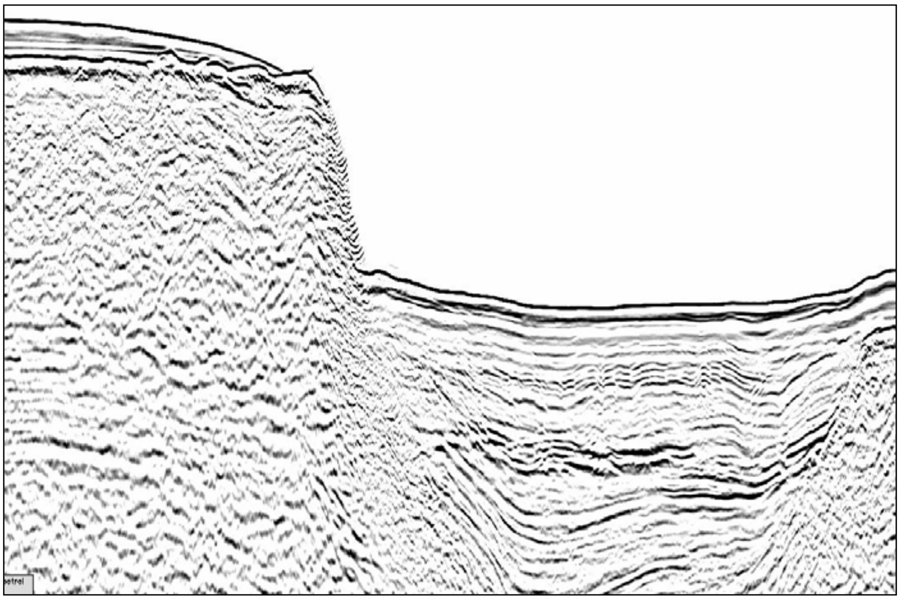


Colour-coded topographic model. Black line is approximate dredge trajectory upslope.



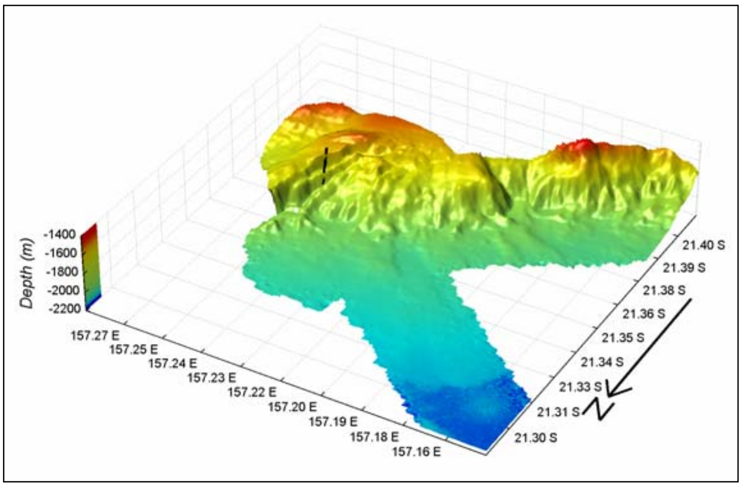


Topographic model overlain by terrain slope (degrees).



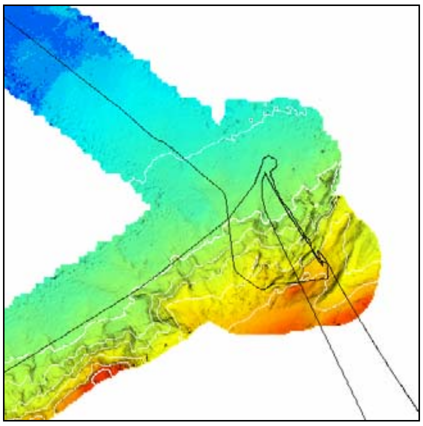
South-southwest to north-northeast seismic line Shell Petrel p701 near dredge site.

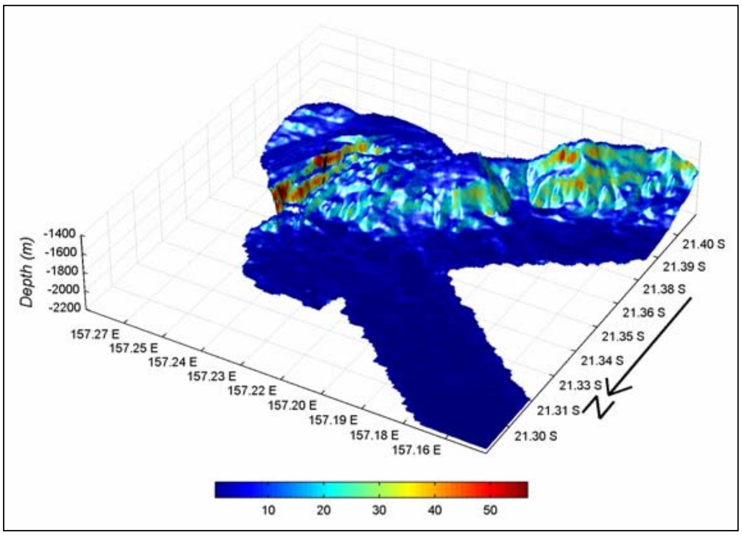
Dredge Site 274/DR09
(Kenn Plateau)



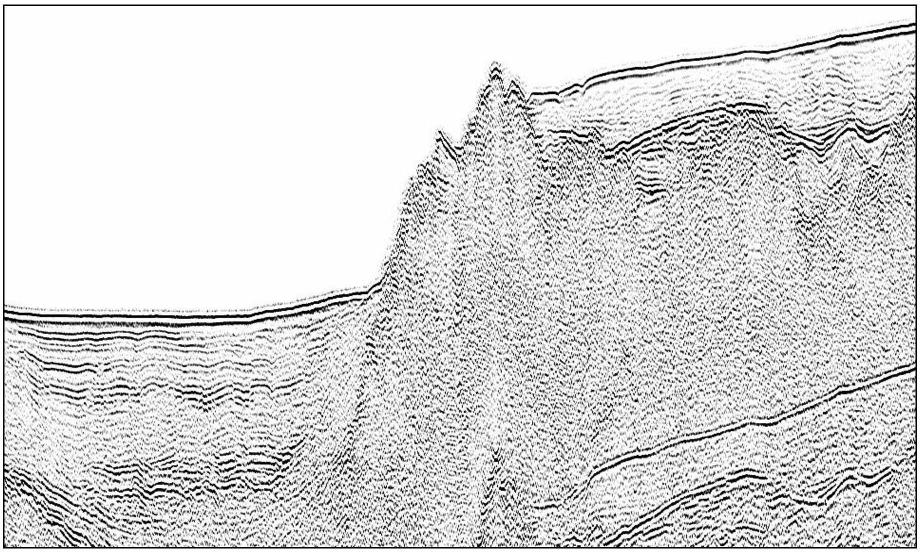
Location:	157° 14.56'E, 21° 21.45'S
Date:	Jan. 29, 2005
Depths:	1800-1600 m
Haulage:	300 kg
Recovery:	calcarenite, calcirudite, volcanic pebbles, manganese crust

Colour-coded topographic model. Black line is approximate dredge trajectory upslope.





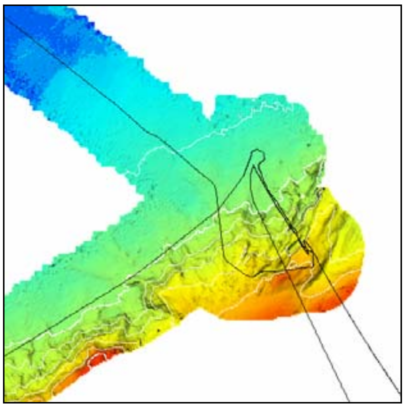
Topographic model superposed by terrain slope (degrees).

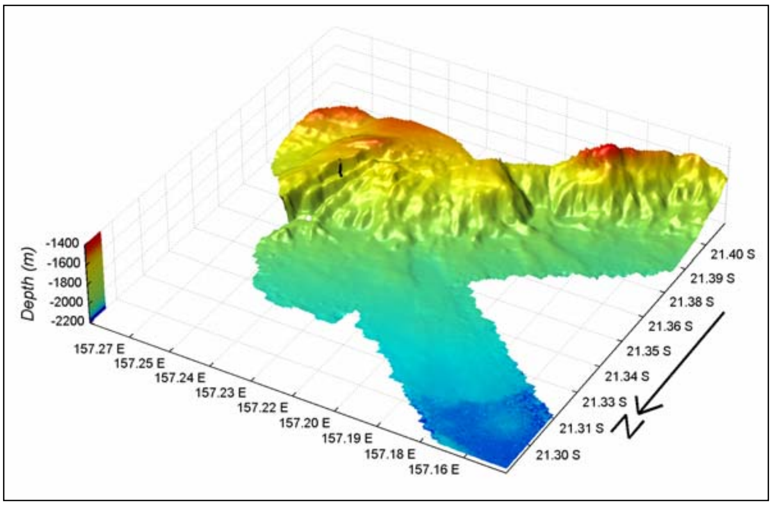


Northwest to southeast seismic line GA 270/04 near dredge site.

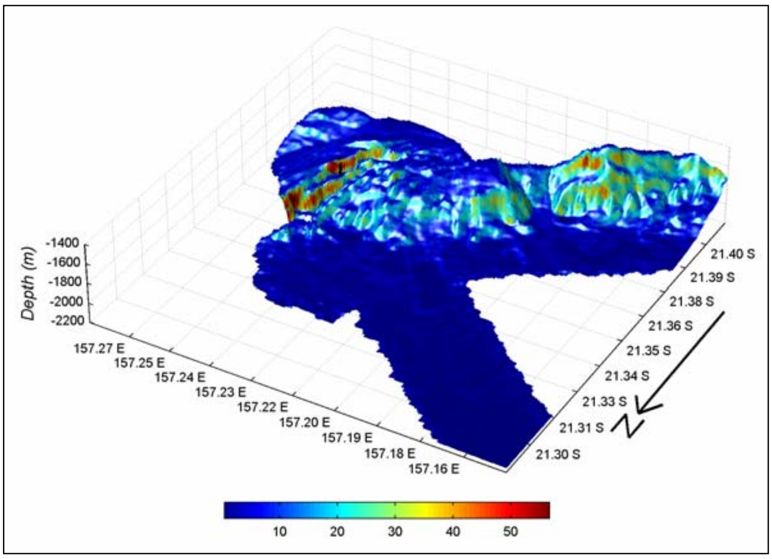
Dredge Site 274/DR10
(Kenn Plateau)

Location:	157° 14.70'E, 21° 21.70'S
Date:	Jan. 29, 2005
Depths:	1750-1650 m
Haulage:	100 g
Recovery:	calcarenite and manganese crust

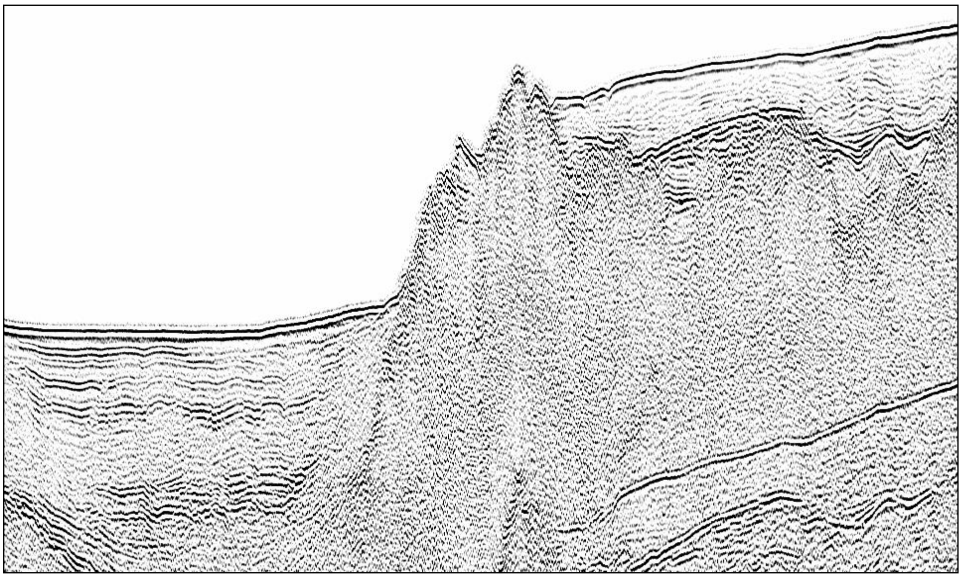




Colour-coded topographic model. Black line is approximate dredge trajectory upslope.

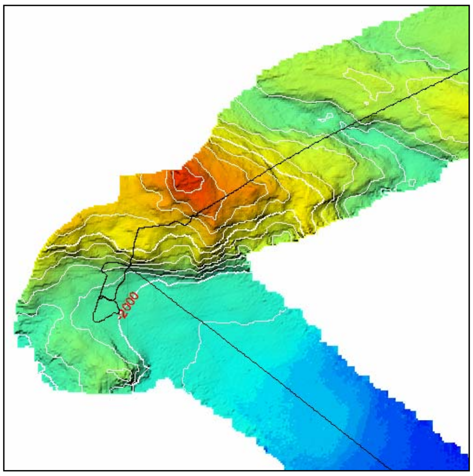


Topographic model superposed by terrain slope (degrees).

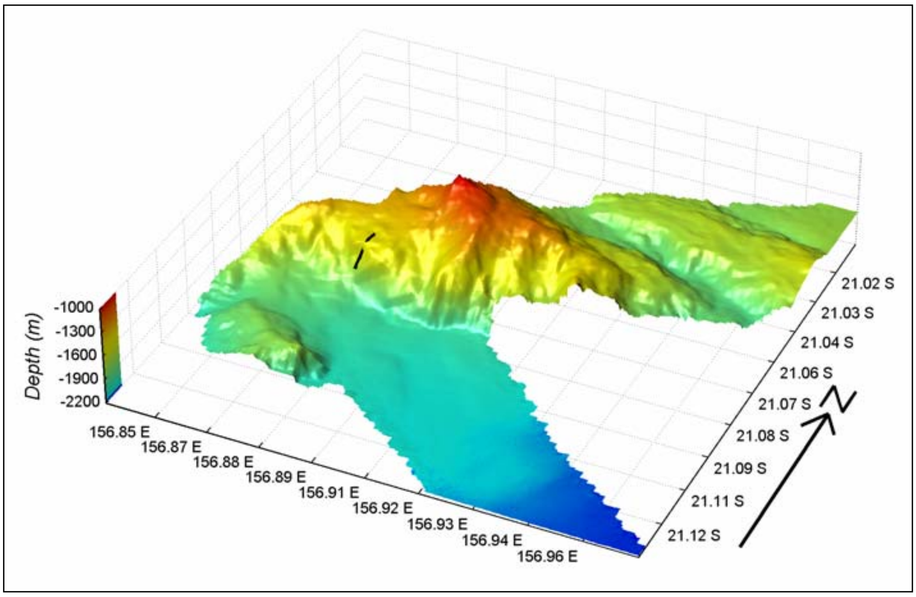


Northwest to southeast seismic line GA 270/04 near dredge site.

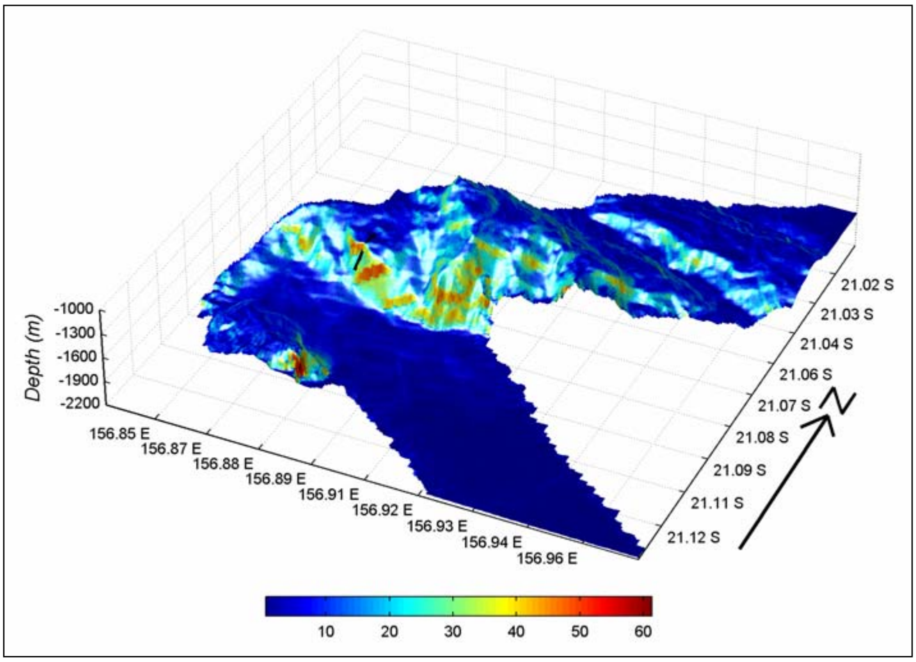
Dredge Site 274/DR11
(Kenn Plateau)



Location:	156° 52.50'E, 21° 04.62'S
Date:	Jan. 30, 2005
Depths:	1750-1500 m
Haulage:	50 kg
Recovery:	metamorphic quartzite, tuff, greywacke and manganese crust

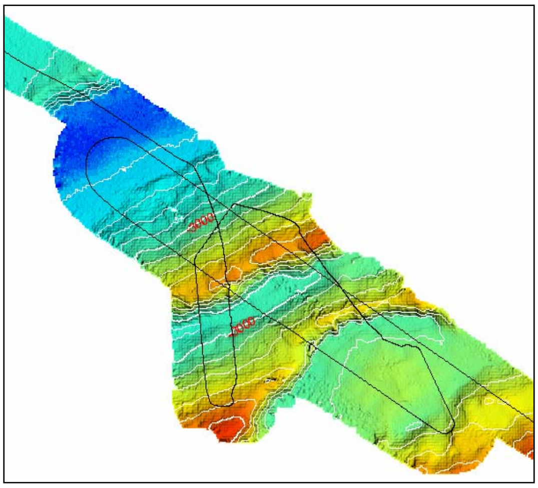


Colour-coded topographic model. Black line is approximate dredge trajectory upslope.

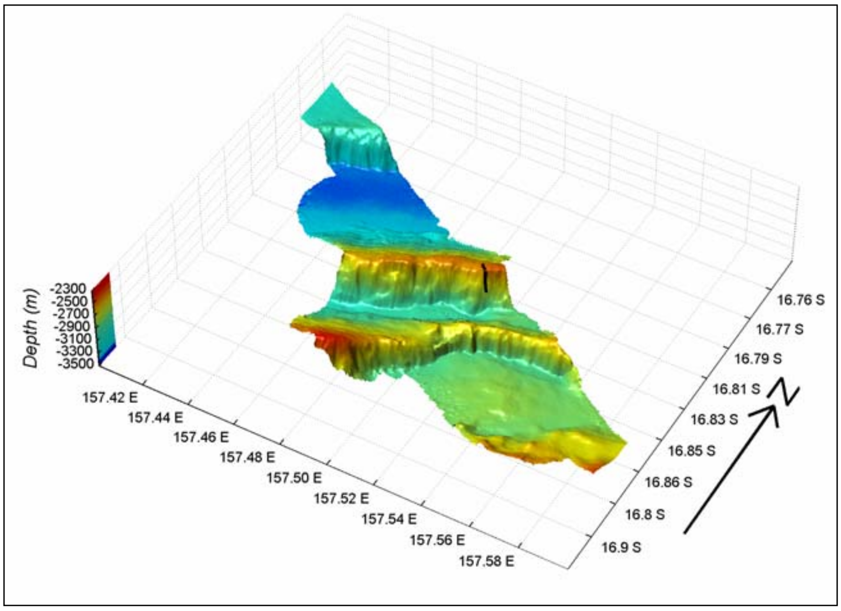


Topographic model superposed by terrain slope (degrees).

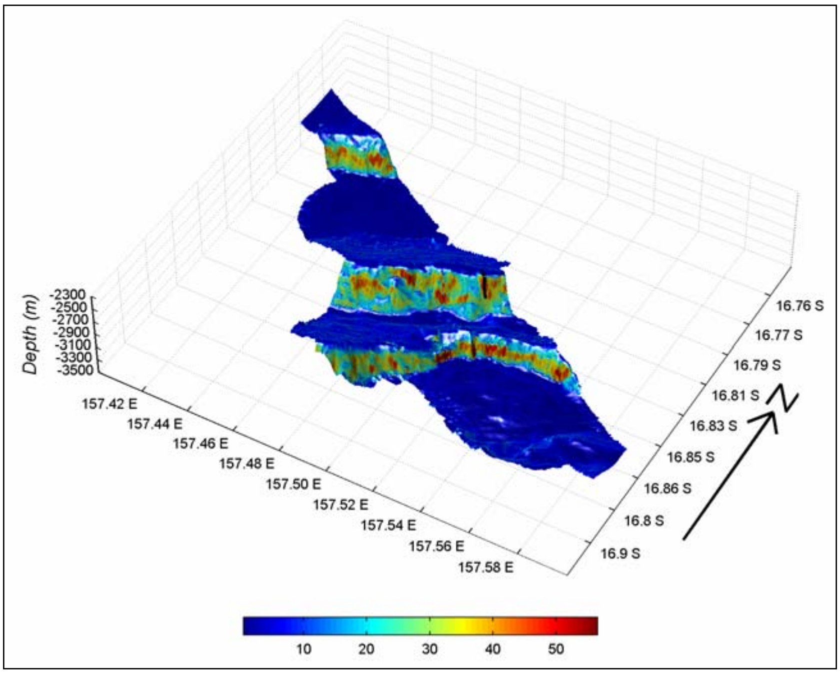
Dredge Site 274/DR12
(Mellish Rise)



Location: 157° 31.26'E, 16° 50.31'S
Date: Feb. 6, 2005
Depths: 2880-2540 m
Haulage: 30 kg
Recovery: porcellanite and manganese crust



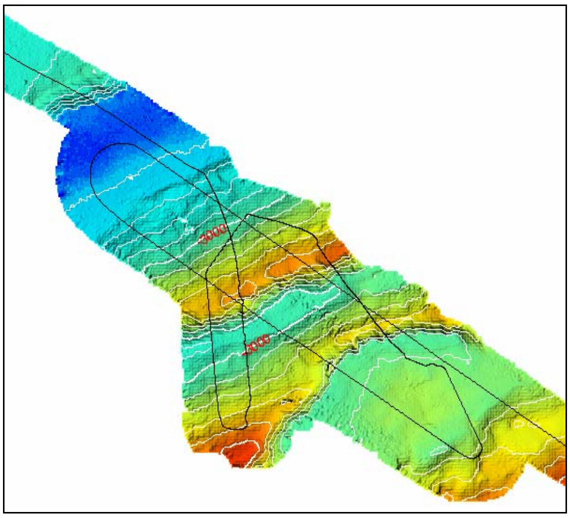
Colour-coded topographic model. Black line is approximate dredge trajectory upslope.

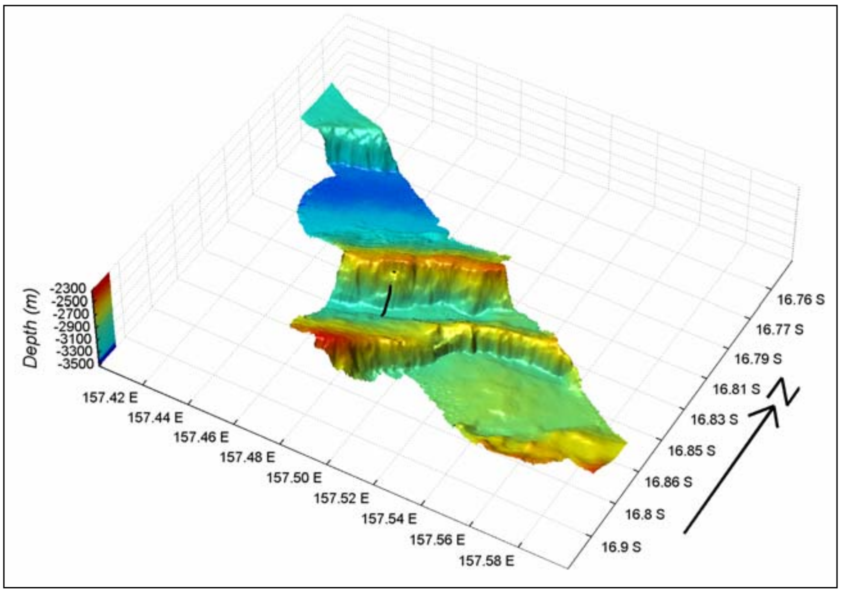


Topographic model superposed by terrain slope (degrees).

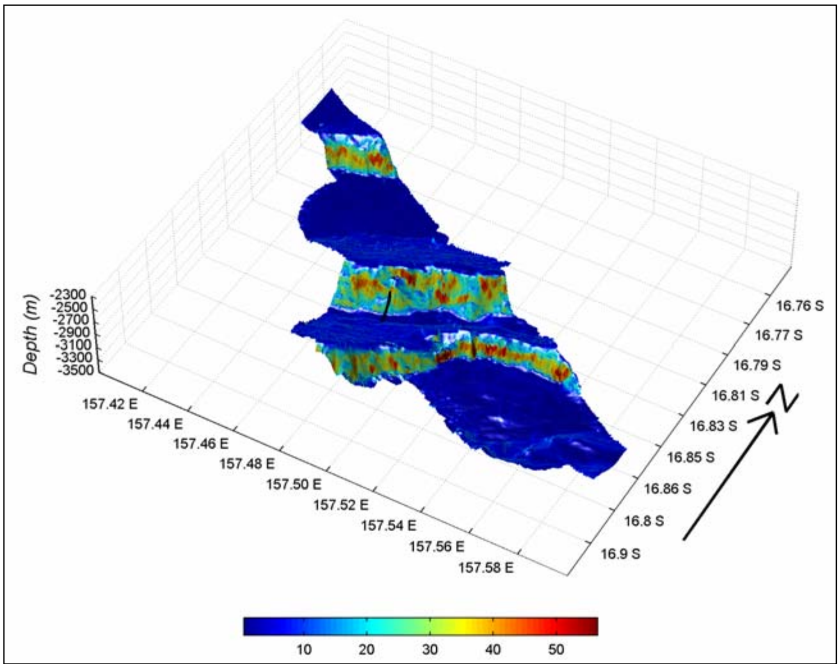
Dredge Site 274/DR13
(Mellish Rise)

Location:	157° 29.24'E, 16° 51.22'S
Date:	Feb. 6, 2005
Depths:	2930-2590 m
Haulage:	100 kg
Recovery:	dolerite, basalt, chert, chalk and manganese nodules





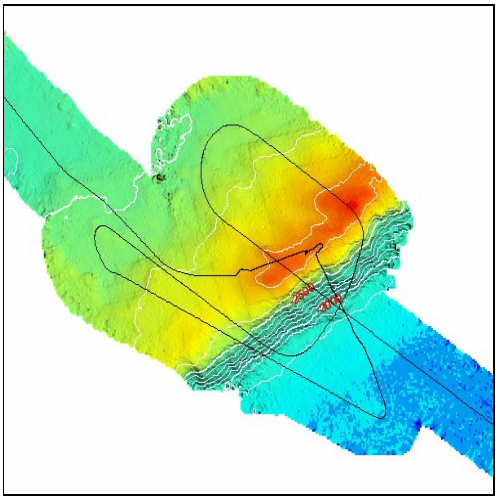
Colour-coded topographic model. Black line is approximate dredge trajectory upslope.

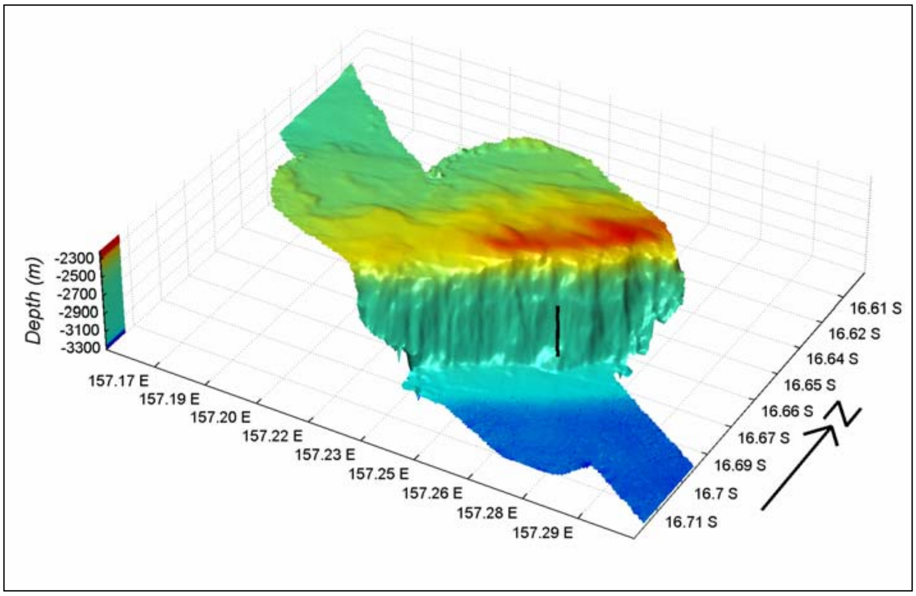


Topographic model superposed by terrain slope (degrees).

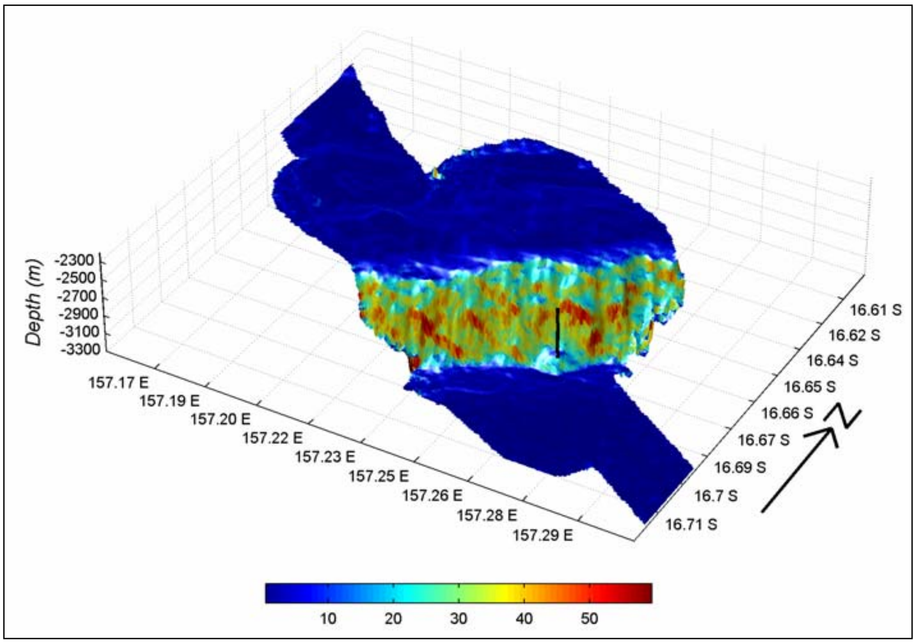
Dredge Site 274/DR14
(Mellish Rise)

Location:	157° 15.88'E, 16° 40.74'S
Date:	Feb. 6, 2005
Depths:	3020-2330 m
Haulage:	500 kg
Recovery:	dolerite, basalt, hyaloclastite, mudstone, calcarenite, chalk and calcareous ooze





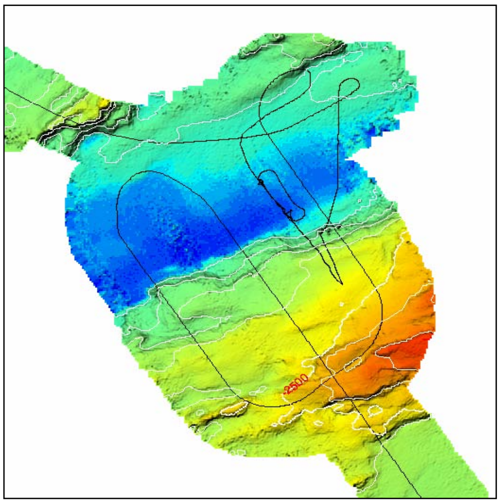
Colour-coded topographic model. Black line is approximate dredge trajectory upslope.

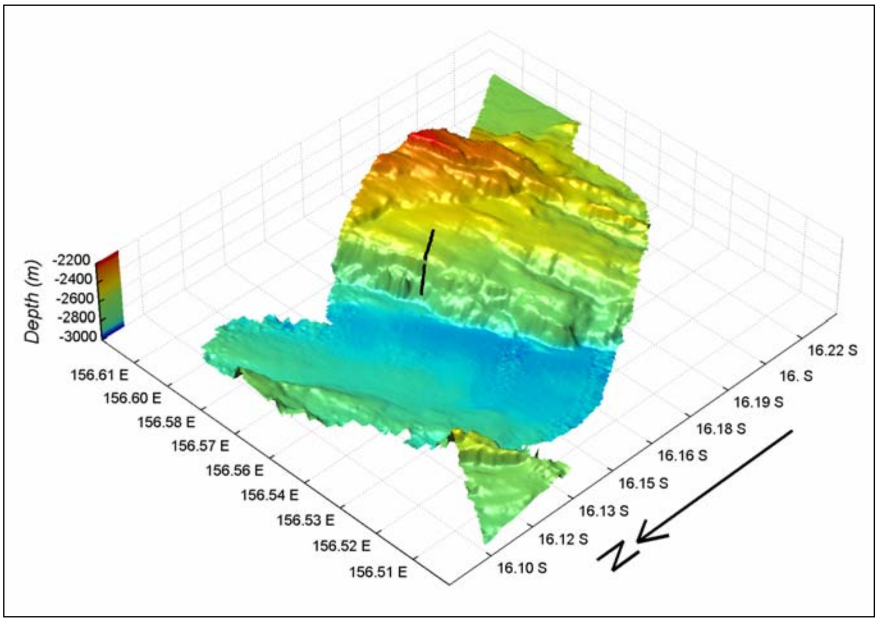


Topographic model superposed by terrain slope (degrees).

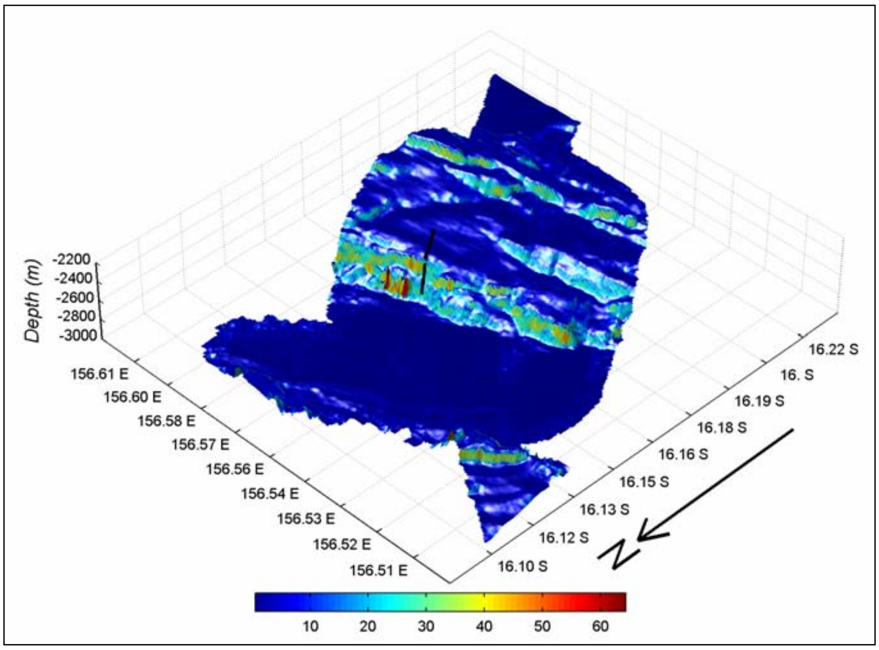
Dredge Site 274/DR15
(Mellish Rise)

Location: 156° 34.64'E, 16° 09.64'S
Date: Feb. 7, 2005
Depths: 2850-2600 m
Haulage: 60 kg
Recovery: basalt, foram chalk and manganese nodules





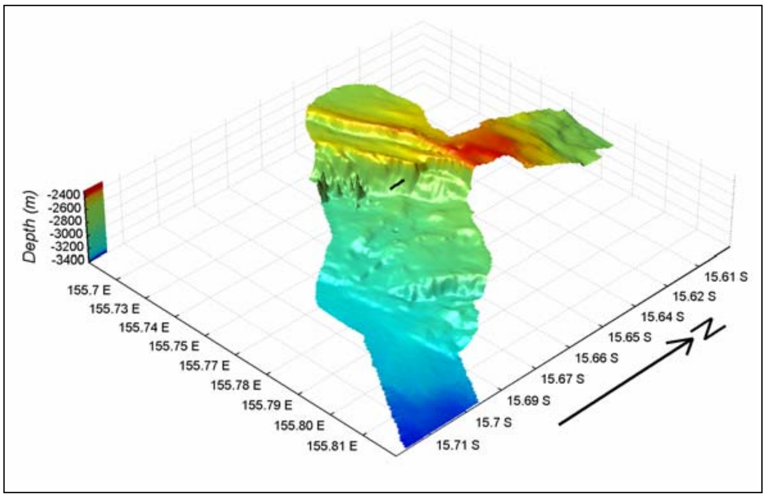
Colour-coded topographic model. Black line is approximate dredge trajectory upslope.



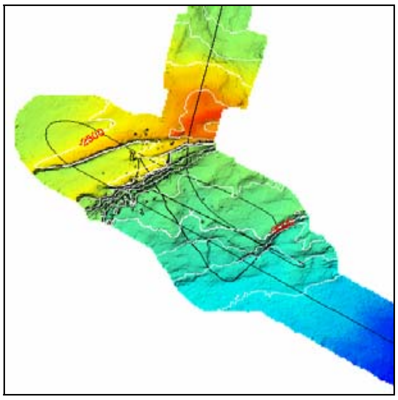
Topographic model superposed by terrain slope (degrees).

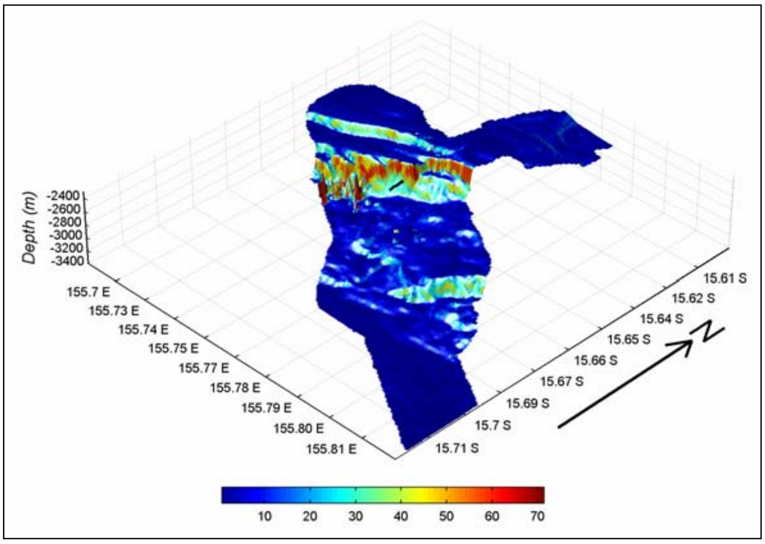
Dredge Site 274/DR16
(Mellish Rise)

Location:	155° 45.44'E, 15° 39.67'S
Date:	Feb. 8, 2005
Depths:	2870-2500 m
Haulage:	15 kg
Recovery:	tuff, manganese nodules and calcareous ooze

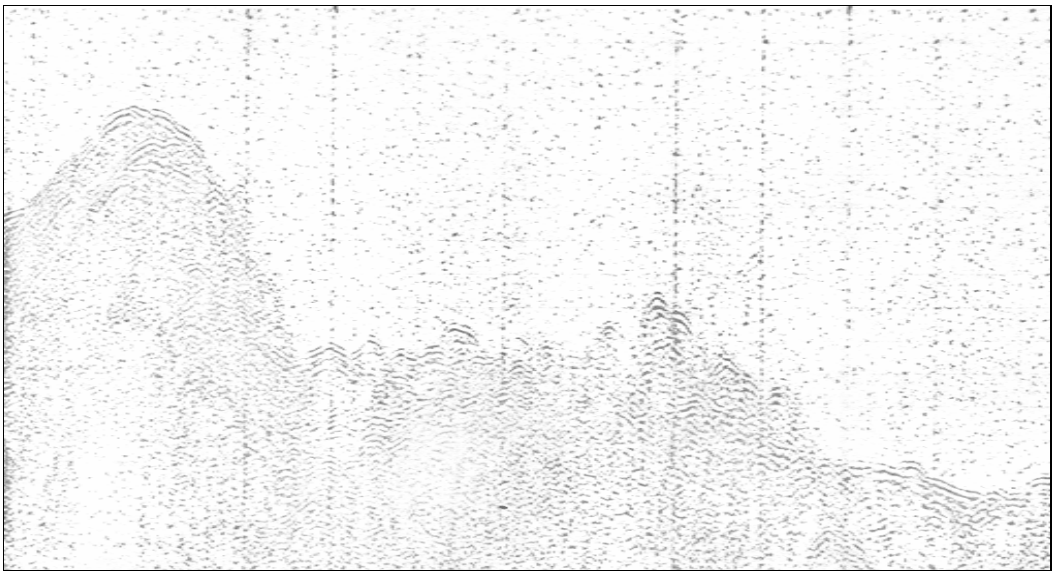


Colour-coded topographic model. Black line is approximate dredge trajectory upslope.





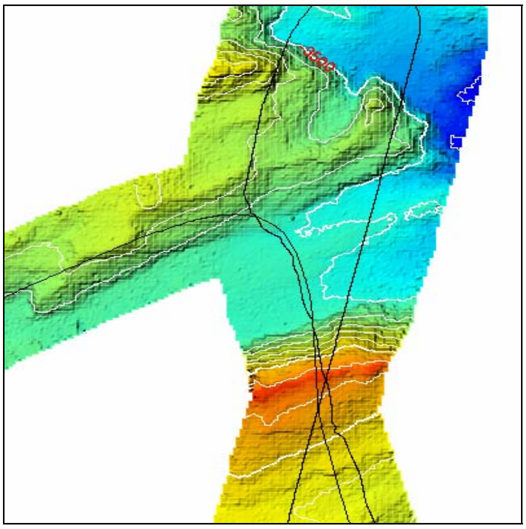
Topographic model superposed by terrain slope. (degrees).

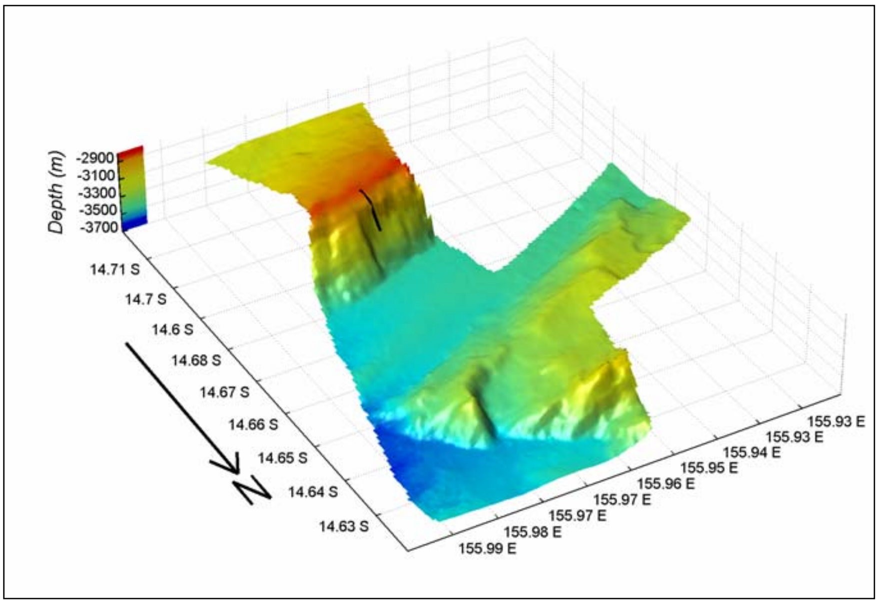


East-west seismic line BMR CM Survey 14 line 56 running through dredge site.

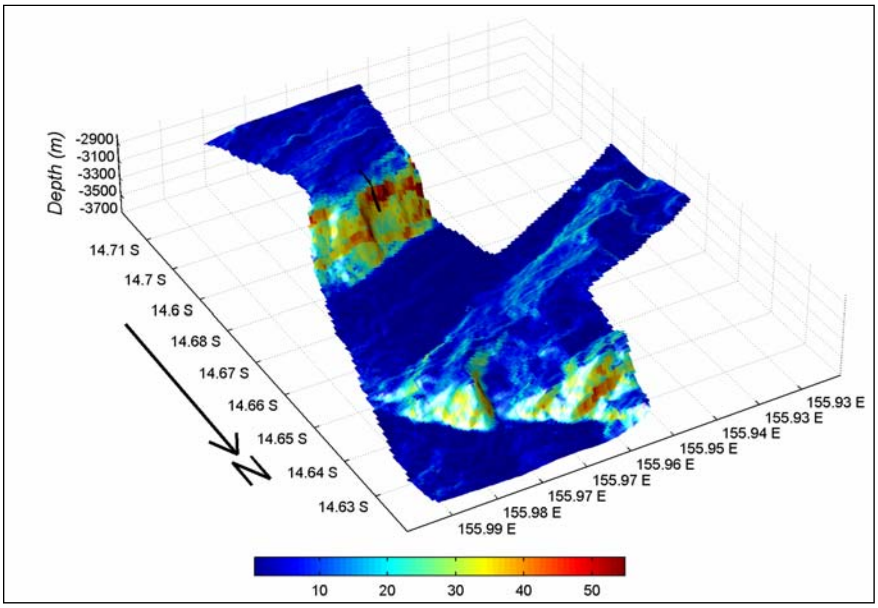
Dredge Site 274/DR17
(Mellish Rise)

Location:	155° 58.22'E, 14° 41.55'S
Date:	Feb. 8, 2005
Depths:	3350-2850 m
Haulage:	500 kg
Recovery:	basalt, agglomerate, marble, mudstone, claystone and calcarenite





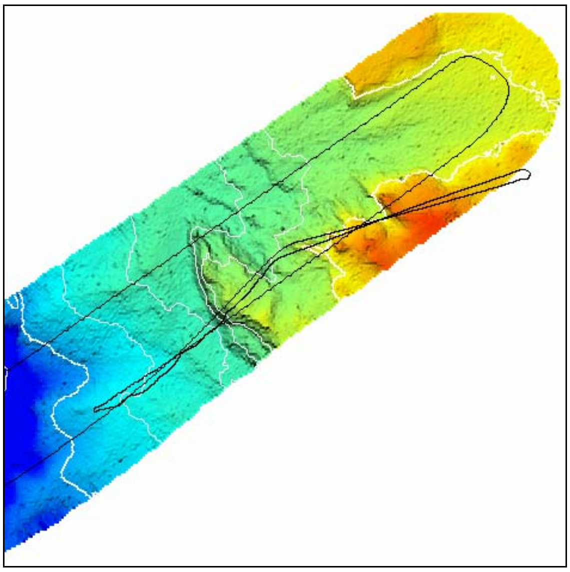
Colour-coded topographic model. Black line is approximate dredge trajectory upslope.

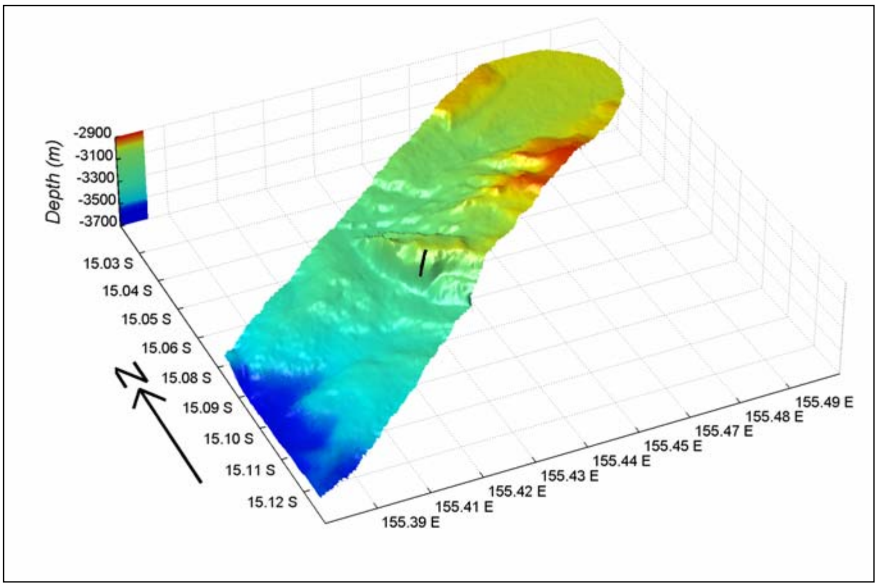


Topographic model superposed by terrain slope (degrees).

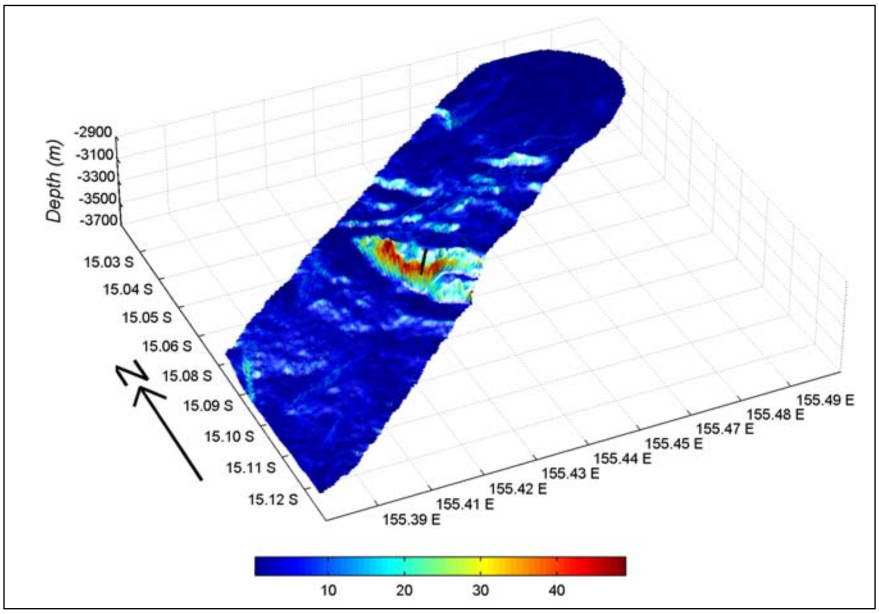
Dredge Site 274/DR18
(Mellish Rise)

Location: 155° 25.90'E, 15° 05.30'S
Date: Feb. 9, 2005
Depths: 3300-3100 m
Haulage: 20 kg
Recovery: basalt and hyaloclastite





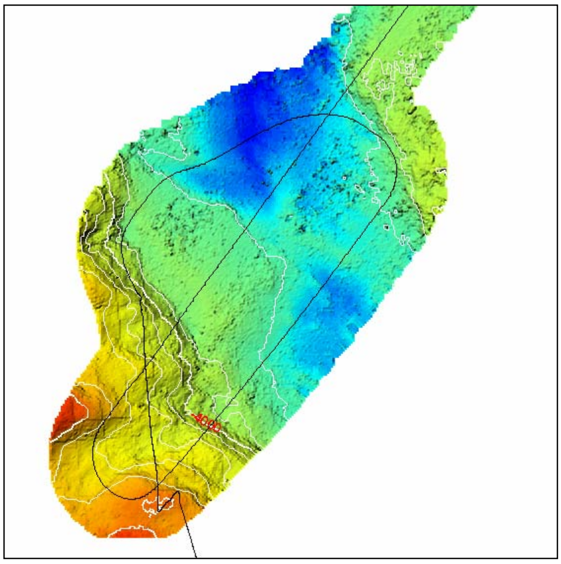
Colour-coded topographic model. Black line is approximate dredge trajectory upslope.

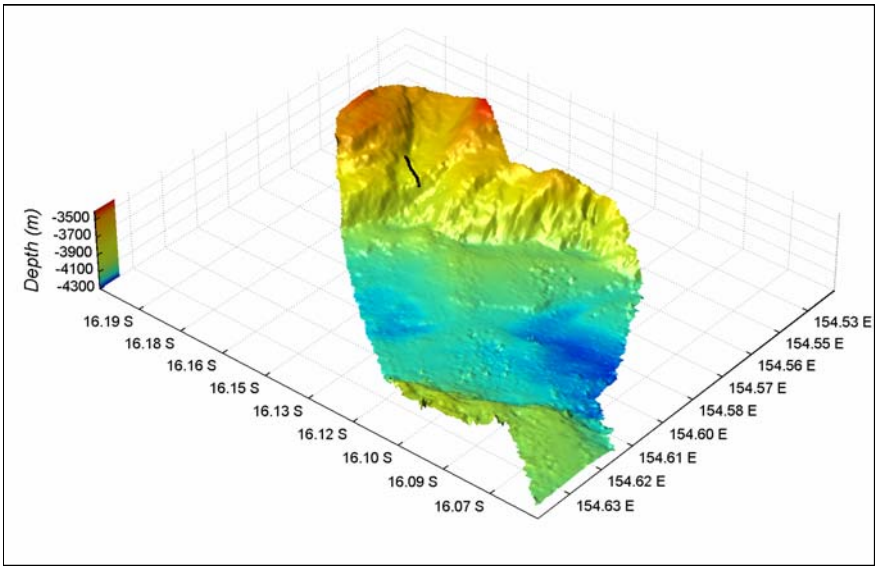


Topographic model superposed by terrain slope (degrees).

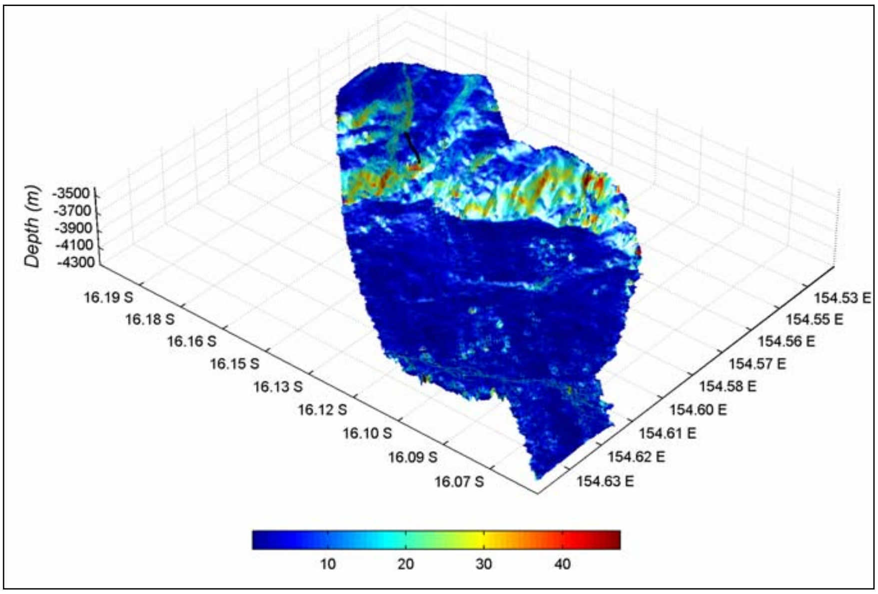
Dredge Site 274/DR19
(Mellish Rise)

Location:	154° 34.15’E, 16° 10.90’S
Date:	Feb. 9, 2005
Depths:	3750-3550 m
Haulage:	400 kg
Recovery:	hyaloclastite and manganese nodules





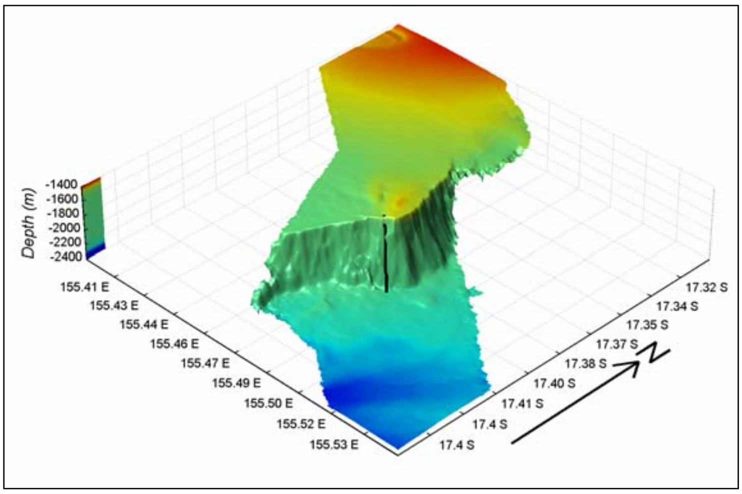
Colour-coded topographic model. Black line is approximate dredge trajectory upslope.



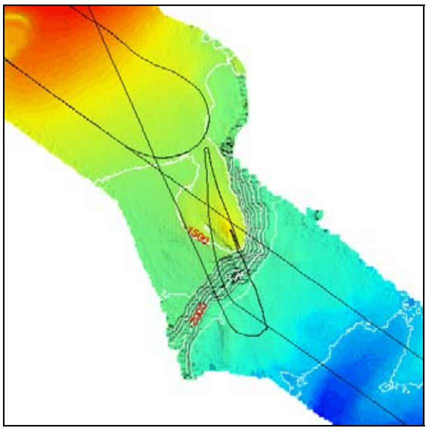
Topographic model superposed by terrain slope (degrees).

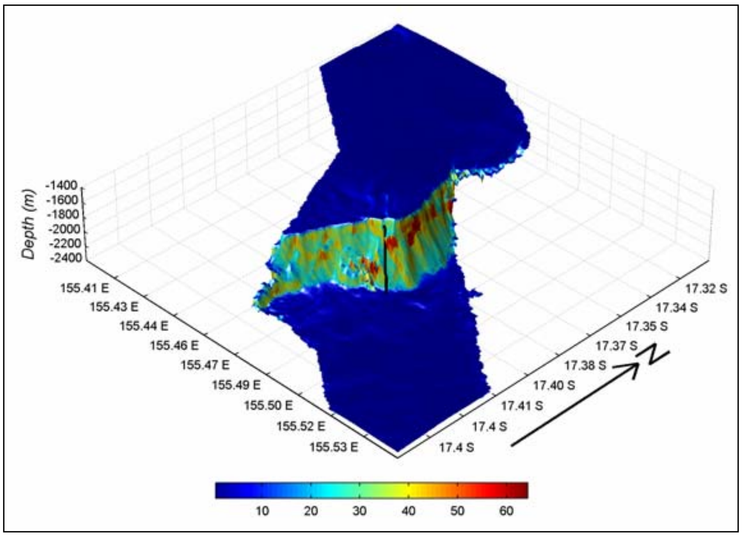
Dredge Site 274/DR21
(Mellish Rise)

Location:	155° 29.30'E, 17° 24.37'S
Date:	Feb 10, 2005
Depths:	1900-1500 m
Haulage:	200 kg
Recovery:	basalt, agglomerate, conglomerate, red and grey claystone

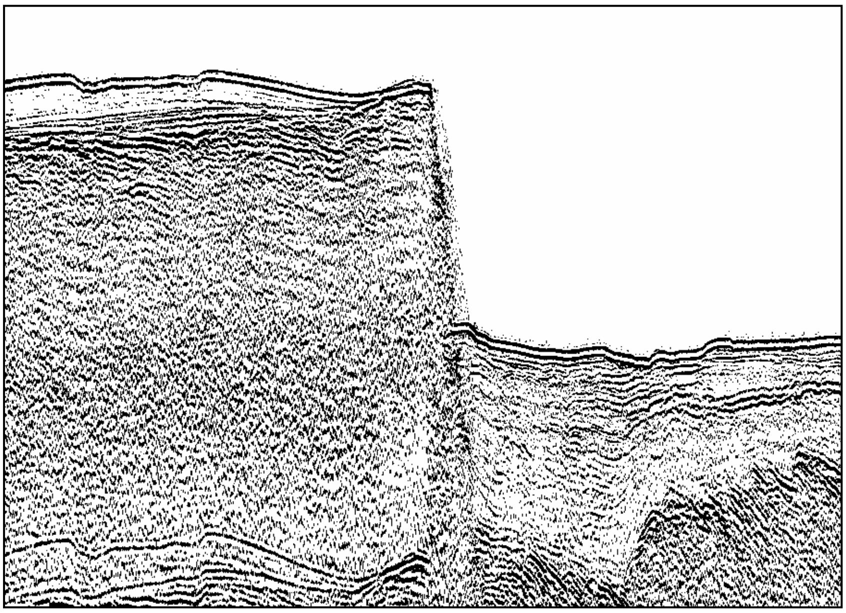


Colour-coded topographic model. Black line is approximate dredge trajectory upslope.





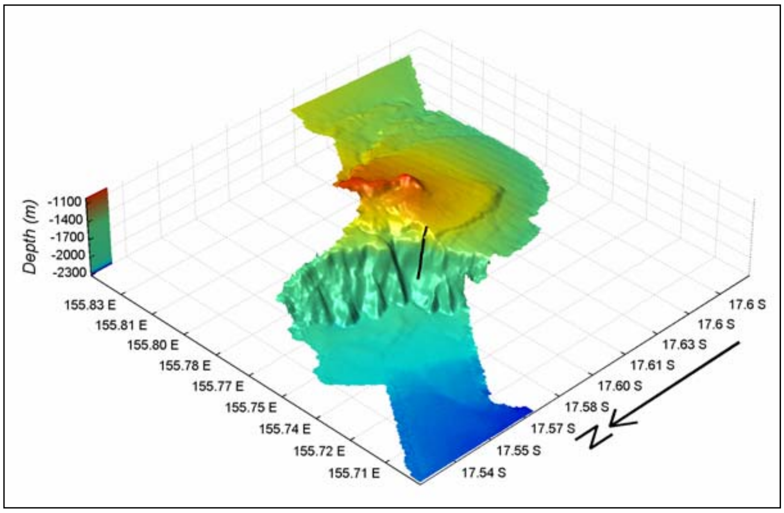
Topographic model superposed by terrain slope (degrees).



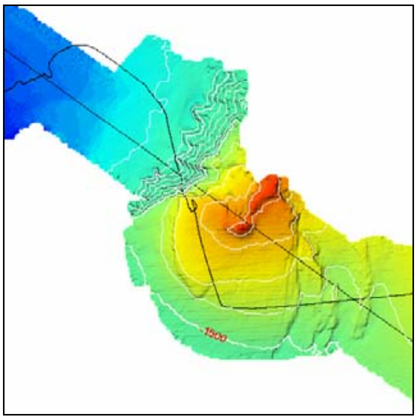
Northwest to southeast seismic line GA 274/03 near dredge site.

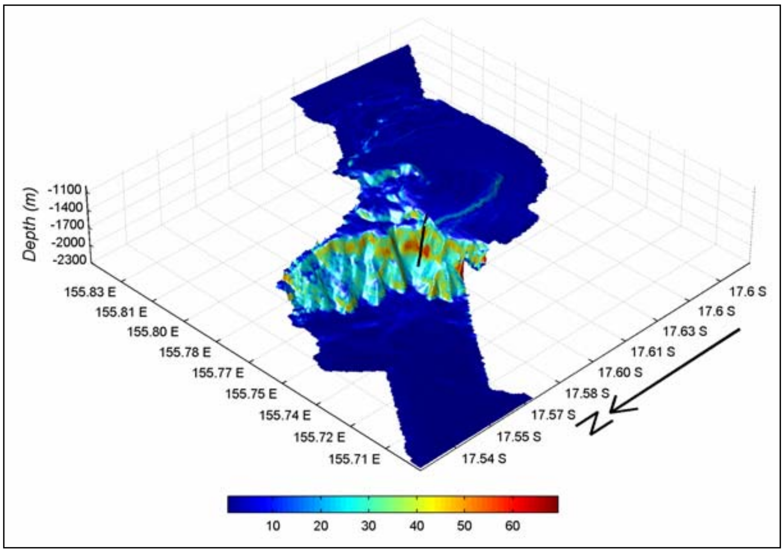
Dredge Site 274/DR22
(Mellish Rise)

Location:	155° 45.73'E, 17° 35.60'S
Date:	Feb 11, 2005
Depths:	1800-1300 m
Haulage:	350 kg
Recovery:	basalt, algal boundstone, calcirudite and calcarenite

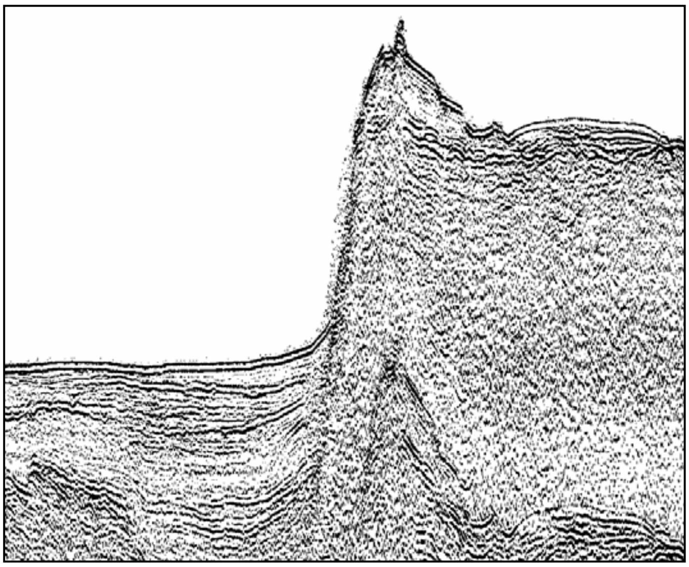


Colour-coded topographic model. Black line is approximate dredge trajectory upslope.





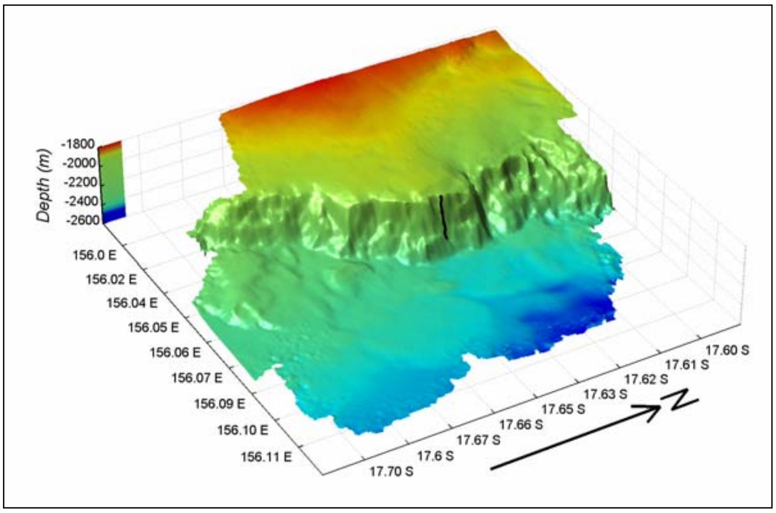
Topographic model superposed by terrain slope (degrees).

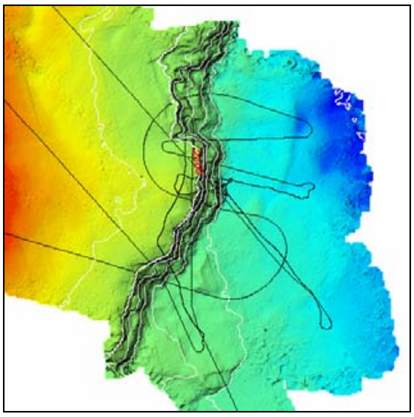


Northwest to southeast seismic line GA 274/03 near dredge site.

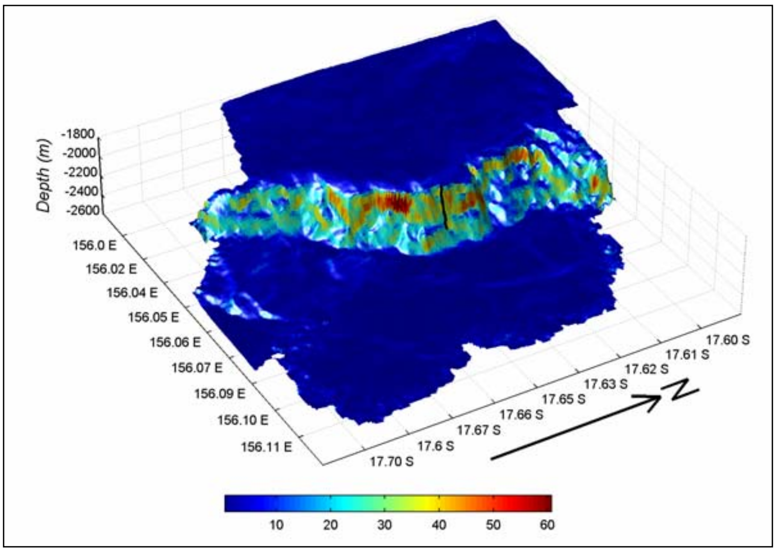
Dredge Site 274/DR23
(Mellish Rise)

Location:	156° 04.04'E, 17° 38.51'S
Date:	Feb 11, 2005
Depths:	2340-1960 m
Haulage:	0.2 kg
Recovery:	hyaloclastite and manganese crust

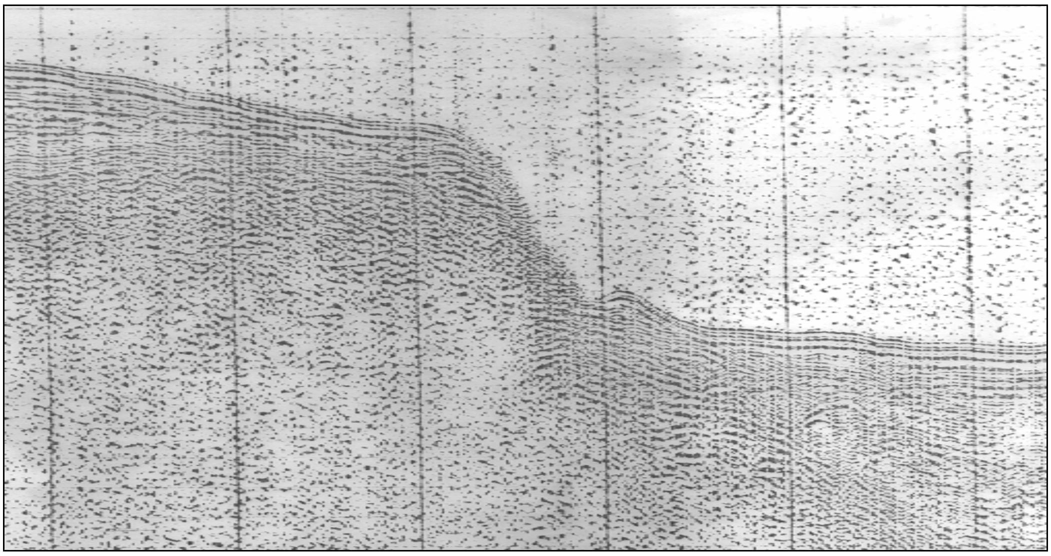




Colour-coded topographic model. Black line is approximate dredge trajectory upslope.



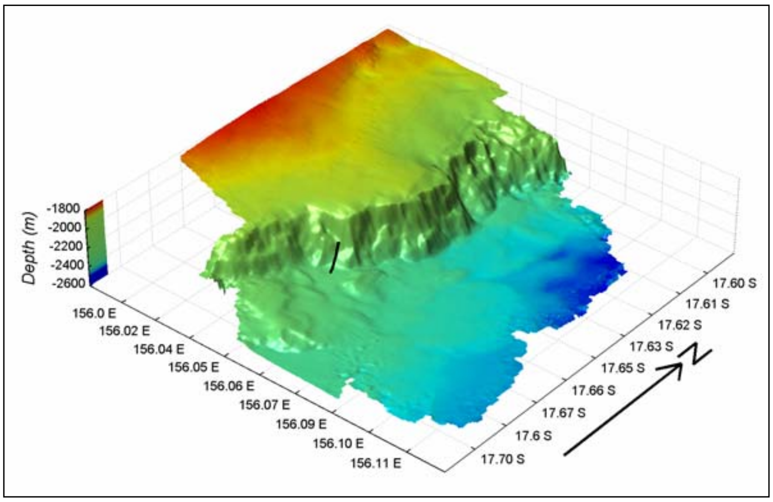
Topographic model superposed by terrain slope (degrees).



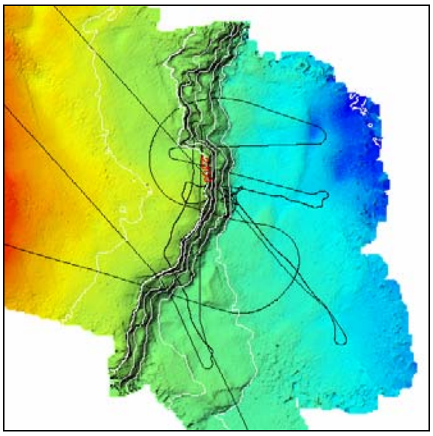
West to east seismic line BMR CM Survey 13 line 72 near dredge site.

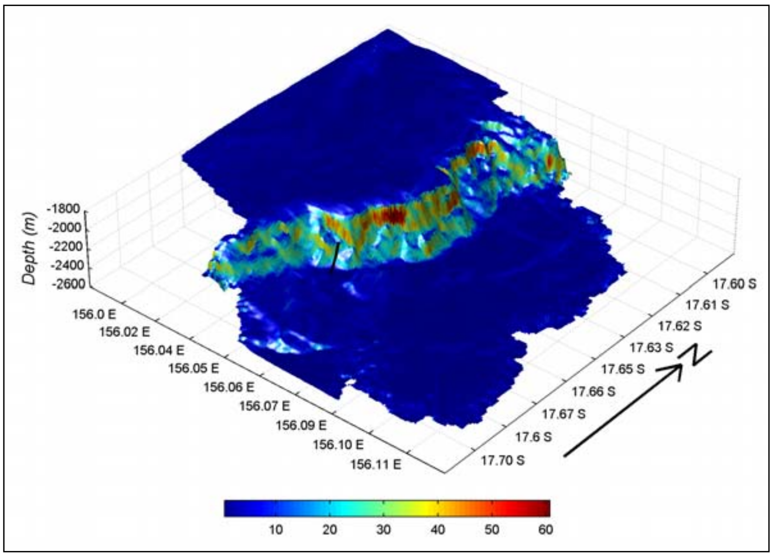
Dredge Site 274/DR24
(Mellish Rise)

Location:	156° 03.19'E, 17° 40.17'S
Date:	Feb 11, 2005
Depths:	2200-1950 m
Haulage:	200 kg
Recovery:	calcarenite, basalt, Conglomerate and calcareous lithic sandstone

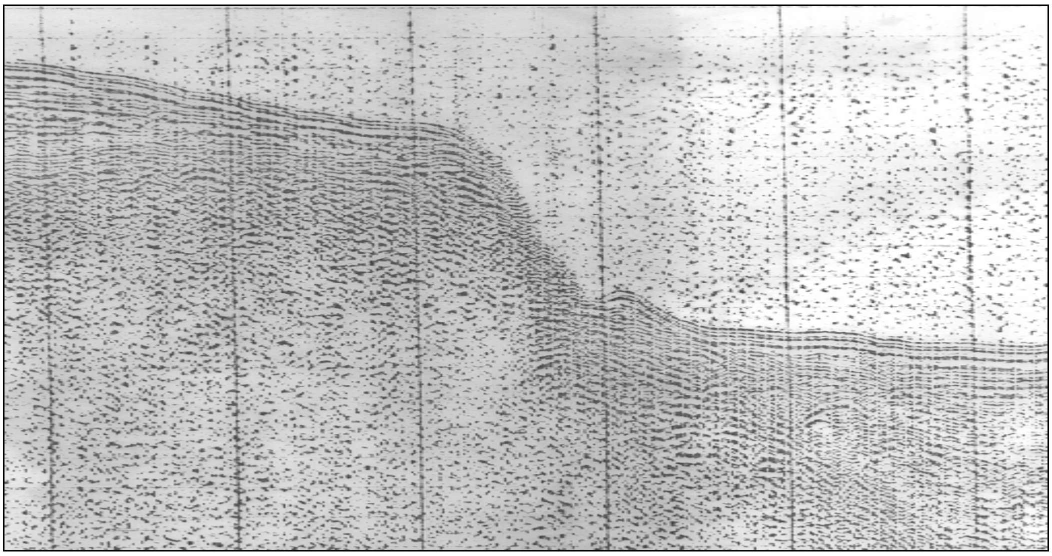


Colour-coded topographic model. Black line is approximate dredge trajectory upslope.





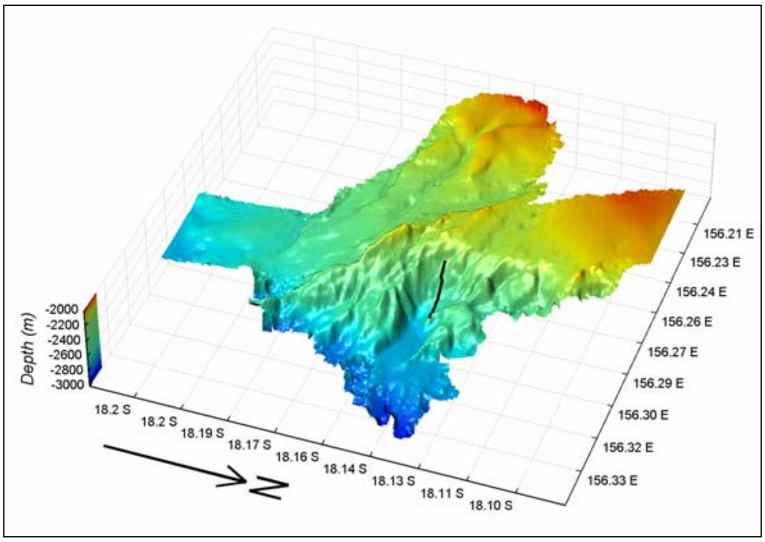
Topographic model superposed by terrain slope (degrees).

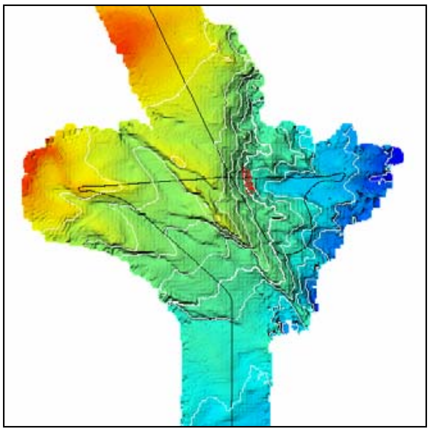


West to east seismic line BMR CM Survey 13 line 72 near dredge site.

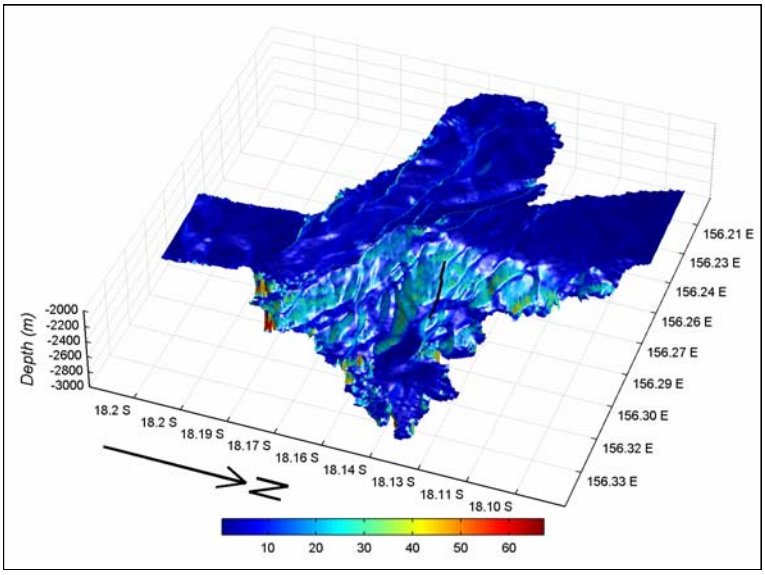
Dredge Site 274/DR25
(Mellish Rise)

Location:	156° 17.54'E, 18° 09.06'S
Date:	Feb 12, 2005
Depths:	2650-2350 m
Haulage:	200 kg
Recovery:	calcarenite and hyaloclastite

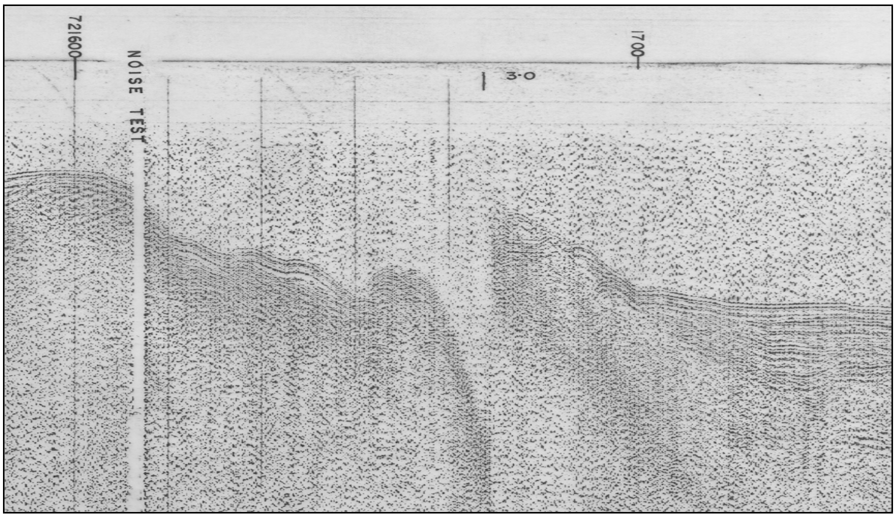




Colour-coded topographic model. Black line is approximate dredge trajectory upslope.



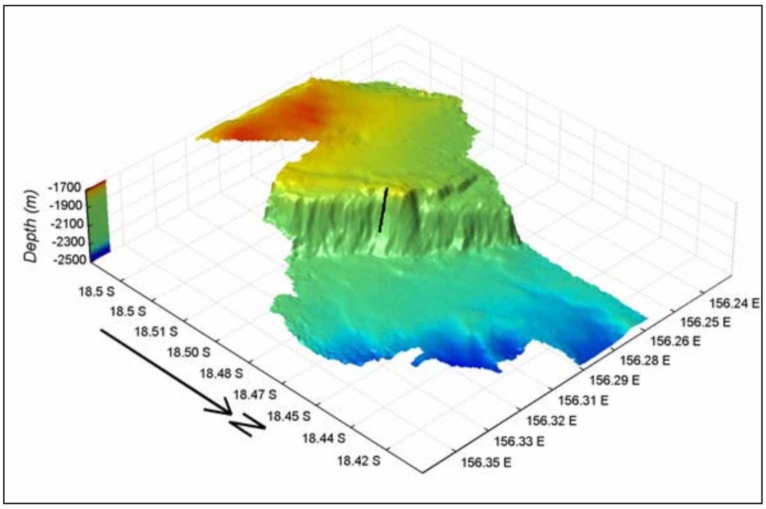
Topographic model superposed by terrain slope (degrees).



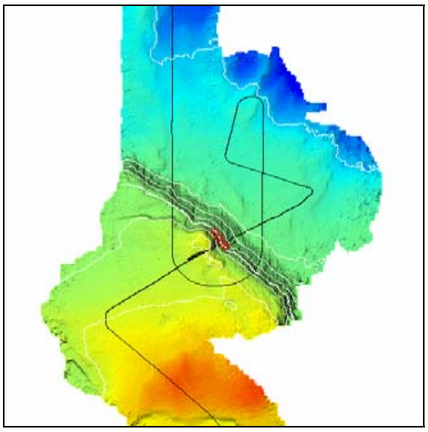
West to east seismic line BMR CM Survey 13 line 64 near dredge site (note time delay jump).

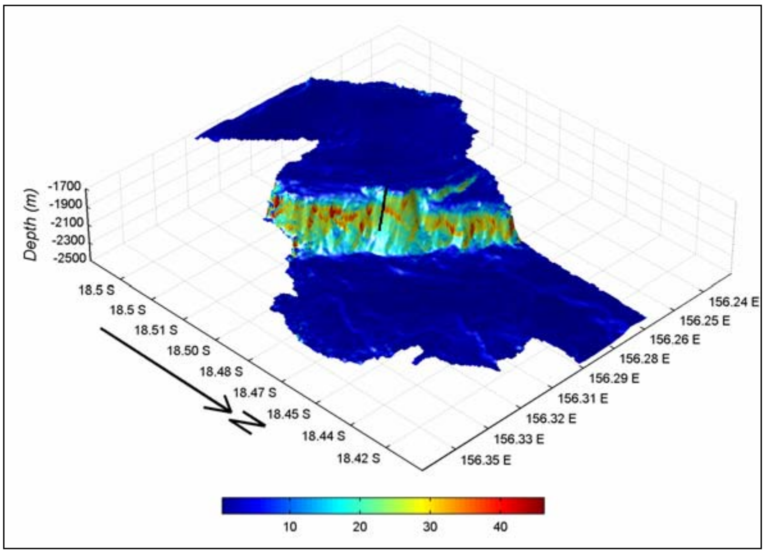
Dredge Site 274/DR26
(Mellish Rise)

Location: 156° 18.27'E, 18° 29.76'S
Date: Feb 12, 2005
Depths: 2200-1800 m
Haulage: 60 kg
Recovery: basalt, conglomerate, calcareous lithic sandstone and manganese crust

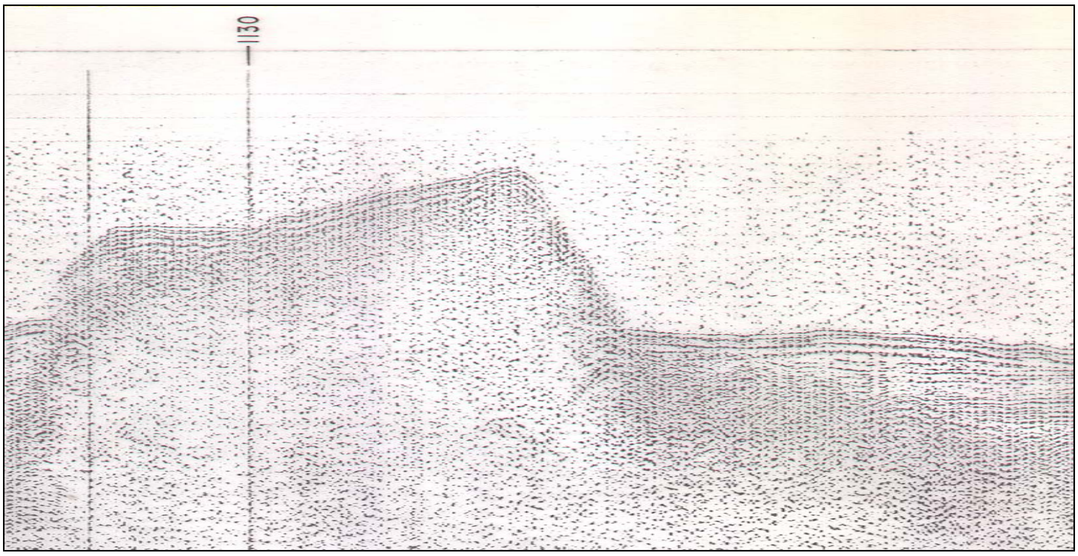


Colour-coded topographic model. Black line is approximate dredge trajectory upslope.





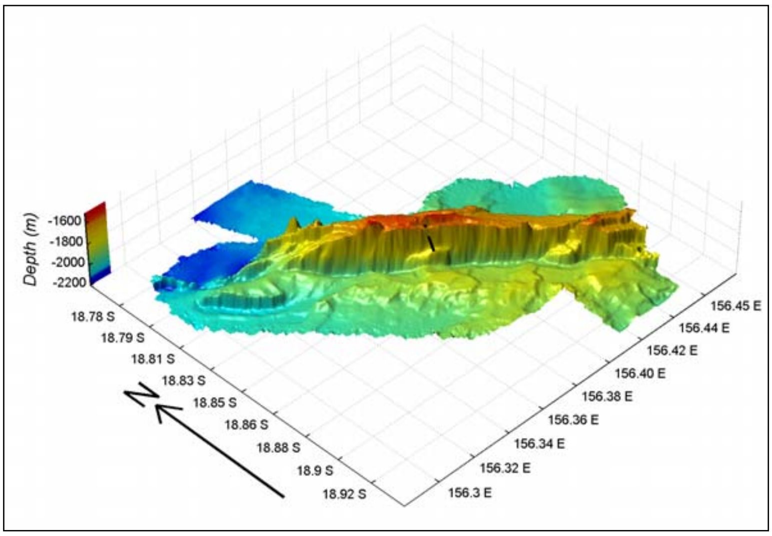
Topographic model superposed by terrain slope (degrees).

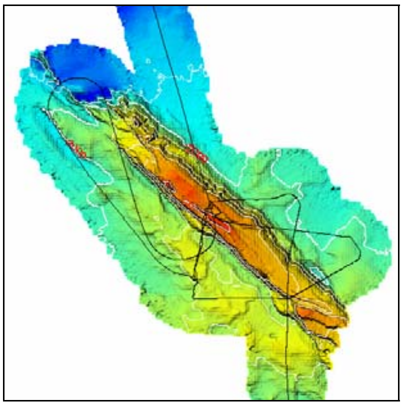


West to east seismic line BMR CM Survey 13 line 62 near dredge site.

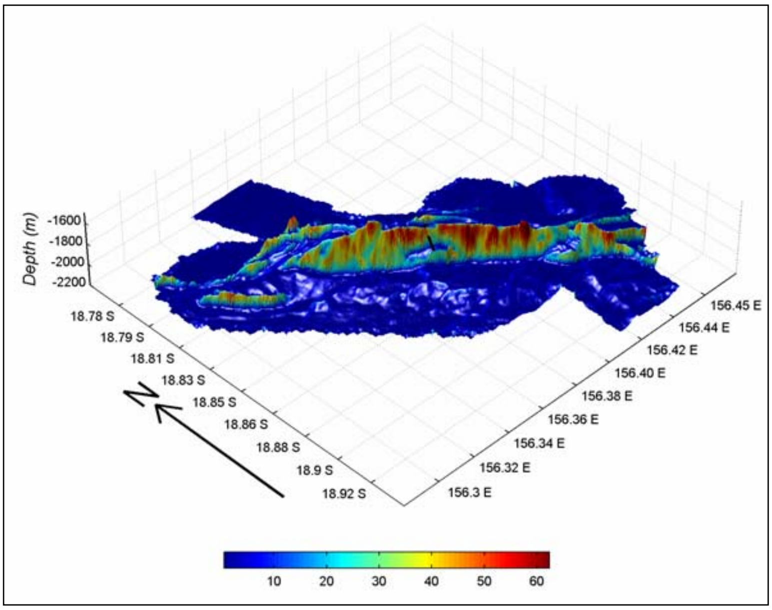
Dredge Site 274/DR27&28
(Mellish Rise – same position)

Location:	156° 23.11'E, 18° 51.83'S
Date:	Feb 12/13, 2005
Depths:	1800-1600 m
Haulage:	0.5 kg & no recovery
Recovery:	conglomerate, manganese crust and corals

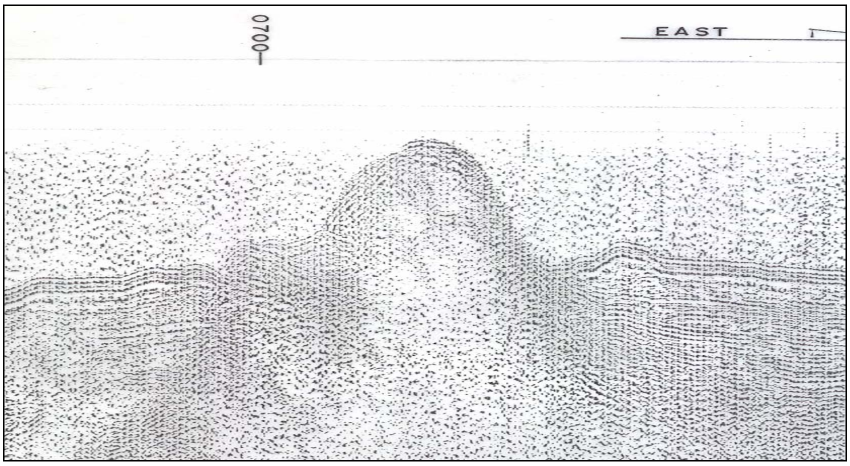




Colour-coded topographic model. Black line is approximate dredge trajectory upslope.



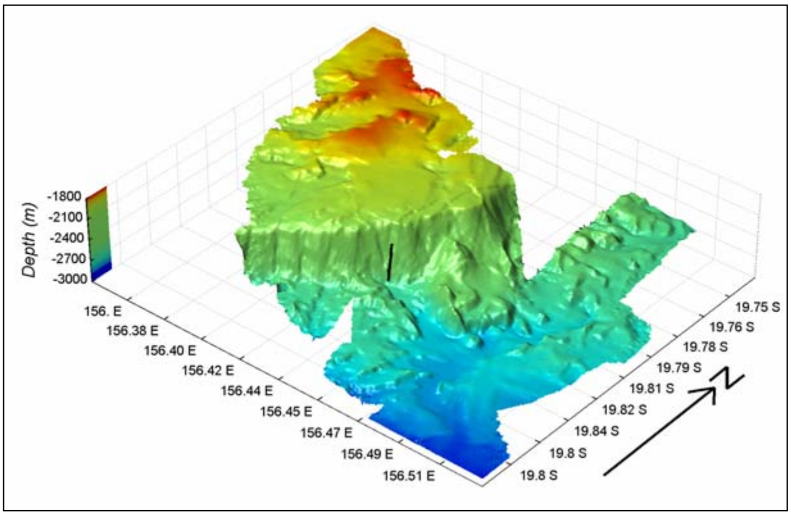
Topographic model superposed by terrain slope (degrees).

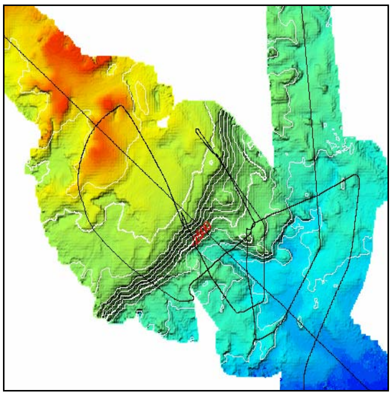


West to east seismic line BMR CM Survey 13 line 60 near dredge site.

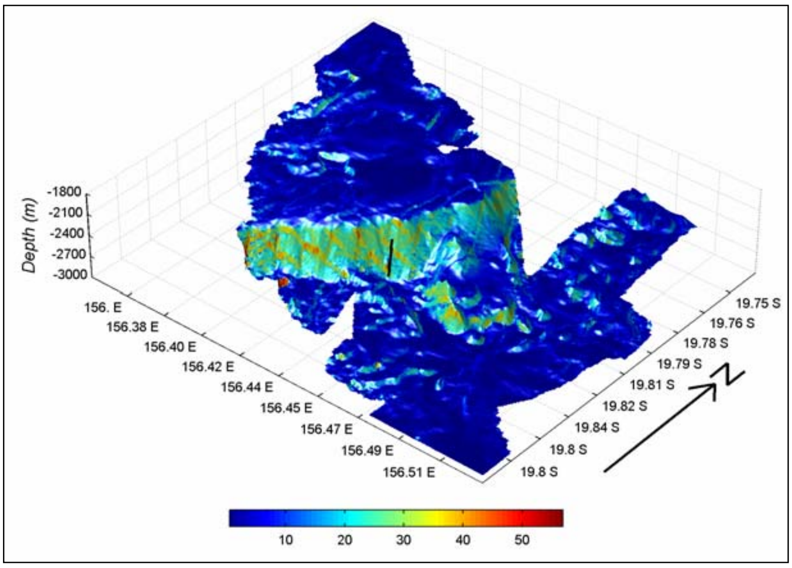
Dredge Site 274/DR30
(Mellish Rise)

Location:	156° 26.31'E, 18° 49.77'S
Date:	Feb 13, 2005
Depths:	2300-2000 m
Haulage:	0.5 kg
Recovery:	basaltic conglomerate, calcareous ooze

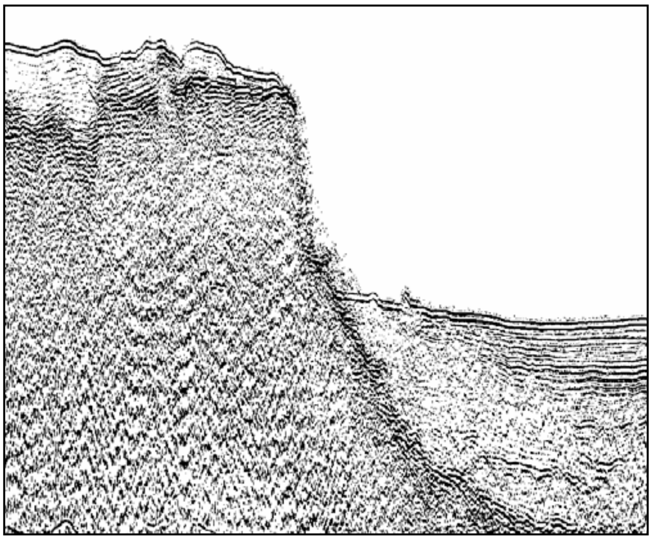




Colour-coded topographic model. Black line is approximate dredge trajectory upslope.



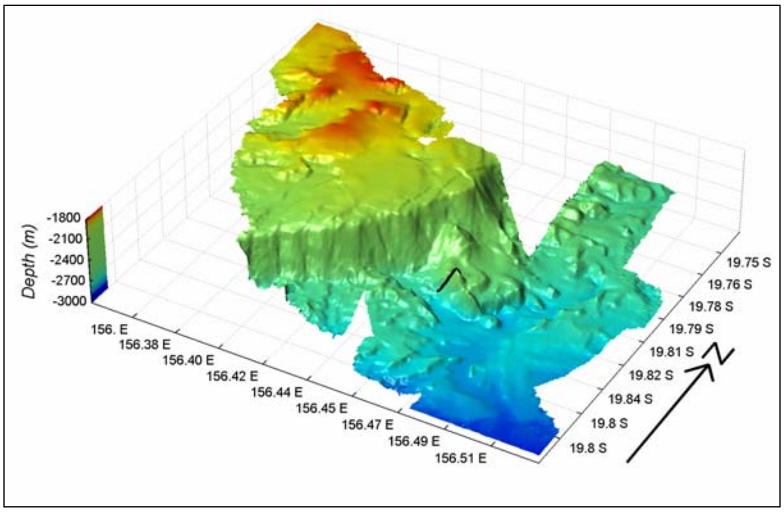
Topographic model superposed by terrain slope (degrees).

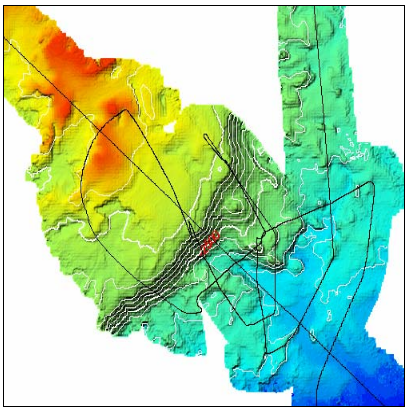


Northwest to southeast seismic line GA 274/01 near dredge site.

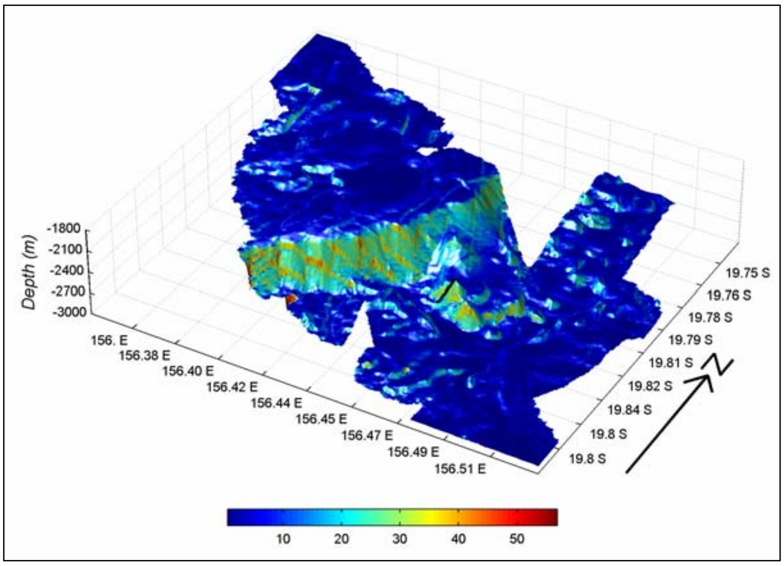
Dredge Site 274/DR31
(Mellish Rise)

Location:	156° 27.55'E, 18° 49.90'S
Date:	Feb 13, 2005
Depths:	2650-2400 m
Haulage:	7 kg
Recovery:	tuff, mudstone, calcareous ooze

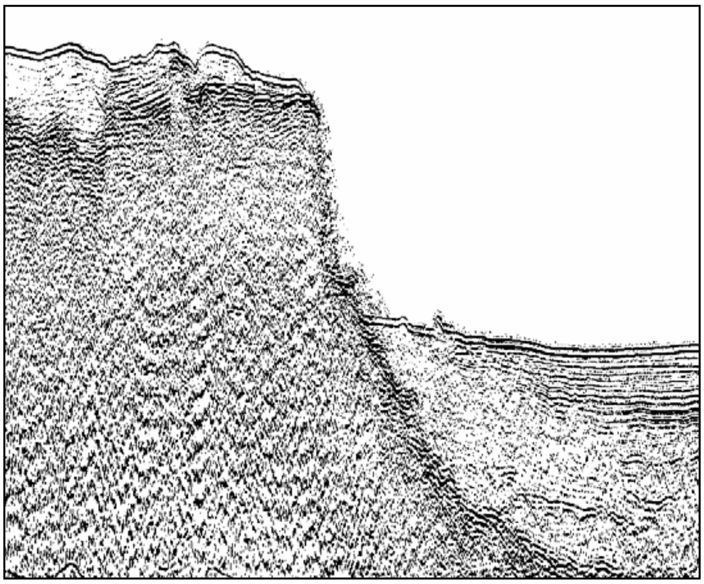




Colour-coded topographic model. Black line is approximate trajectory of dredge upslope.

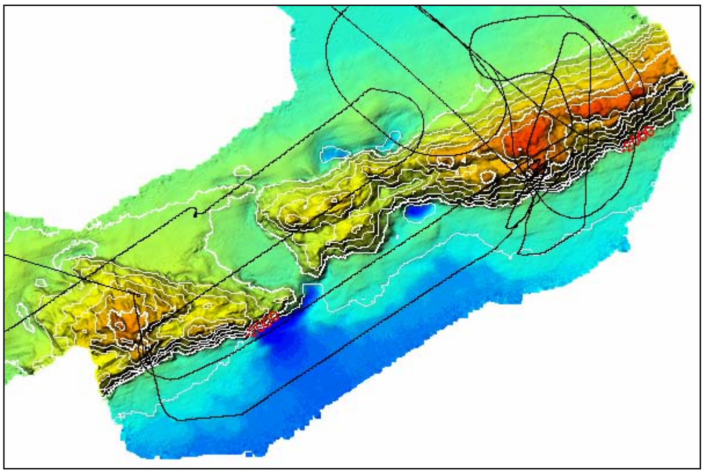


Topographic model superposed by terrain slope (degrees).

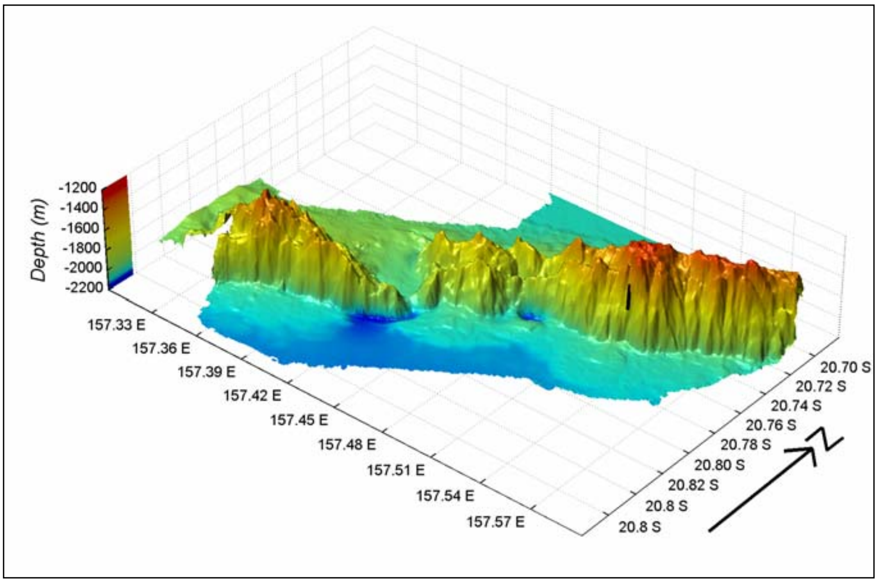


Northwest to southeast seismic line GA 274/01 near dredge site.

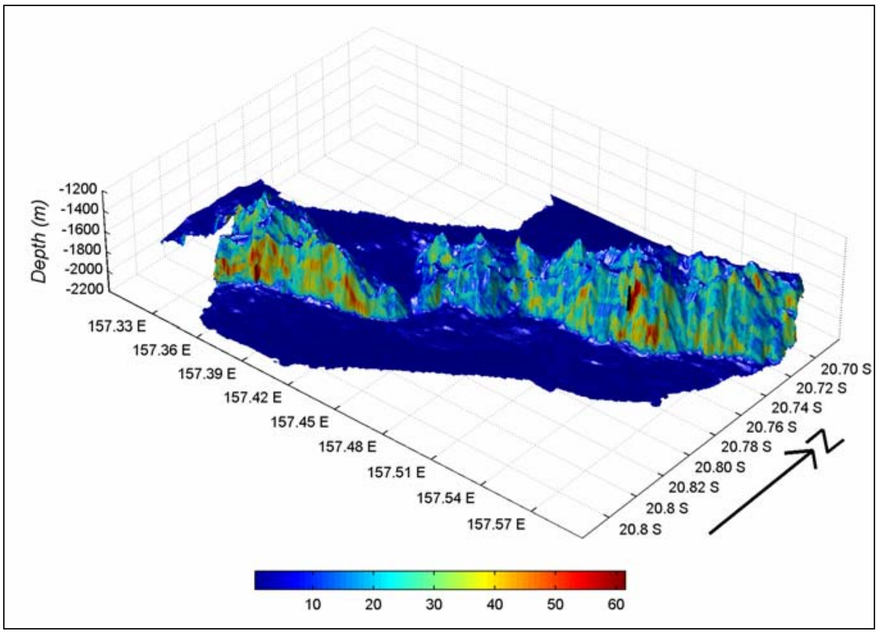
Dredge Site 274/DR32
(Kenn Plateau)



Location: 157° 32.05'E, 20° 45.80'S
Date: Feb 14, 2005
Depths: 1600-1300 m
Haulage: 0.5 kg
Recovery: pumice and manganese crust



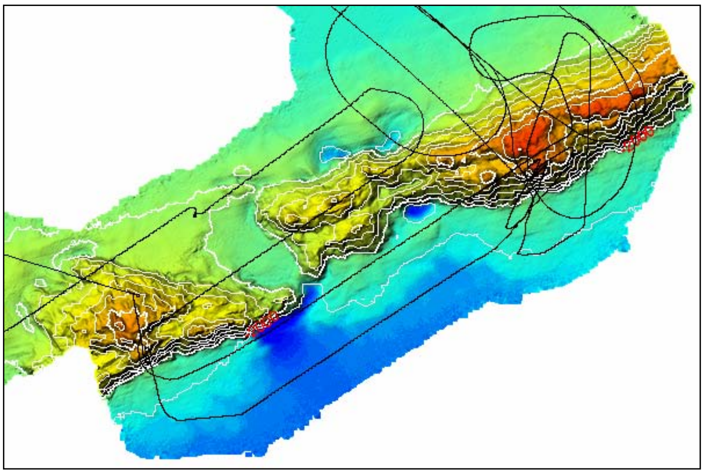
Colour-coded topographic model. Black line is approximate dredge trajectory upslope.

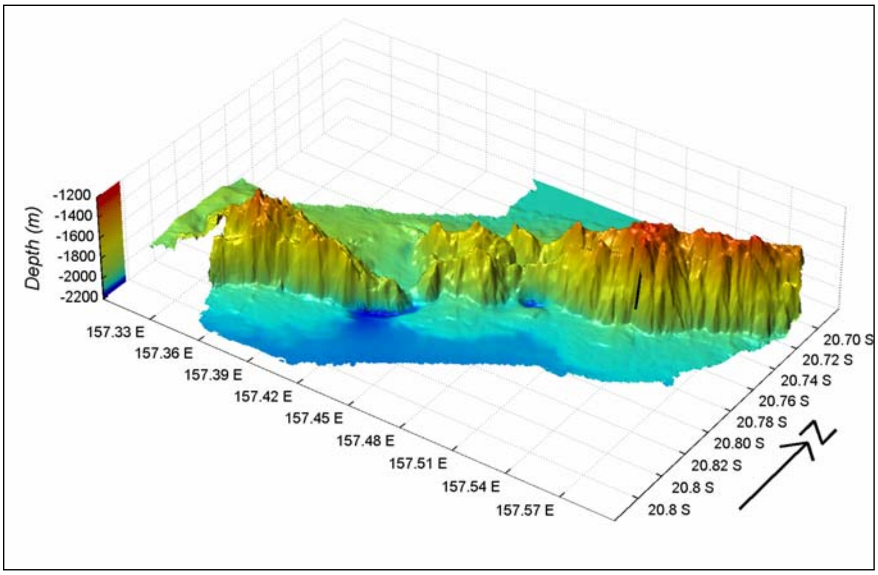


Topographic model superposed by terrain slope (degrees).

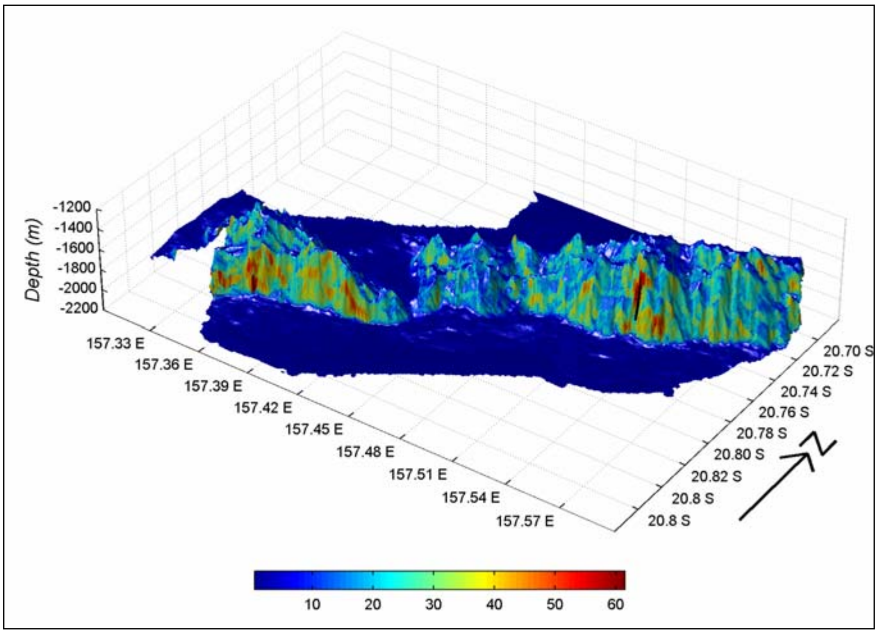
Dredge Site 274/DR33
(Kenn Plateau)

Location:	157° 32.32'E, 20° 45.98'S
Date:	Feb 14, 2005
Depths:	1850-1400 m
Haulage:	0.5 kg
Recovery:	sandstone, chalk and calcareous ooze





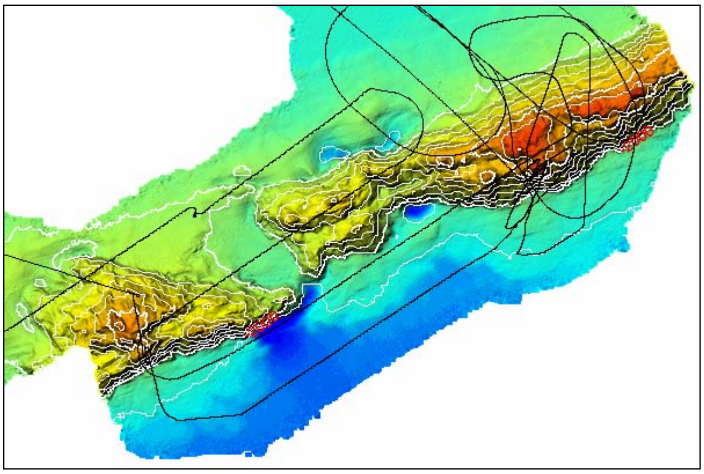
Colour-coded topographic model. Black line is approximate dredge trajectory upslope.

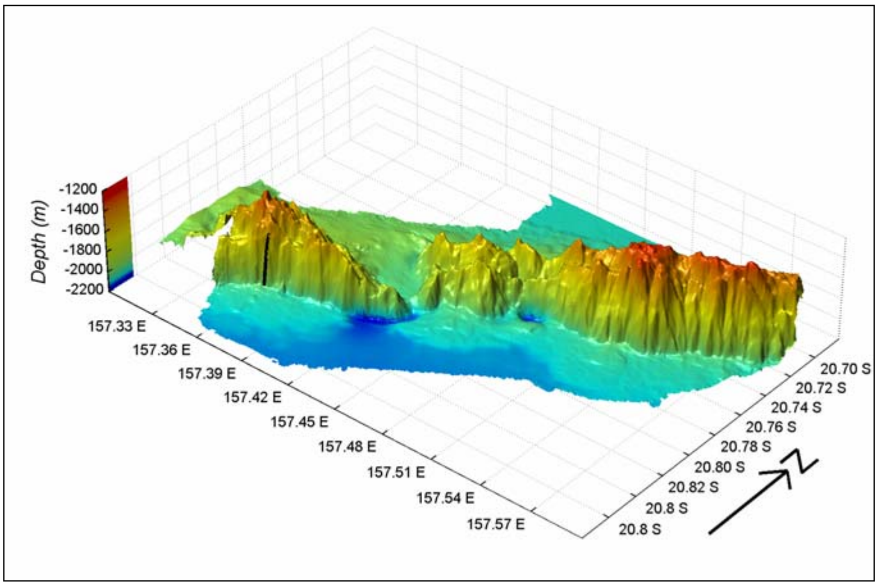


Topographic model superposed by terrain slope (degrees).

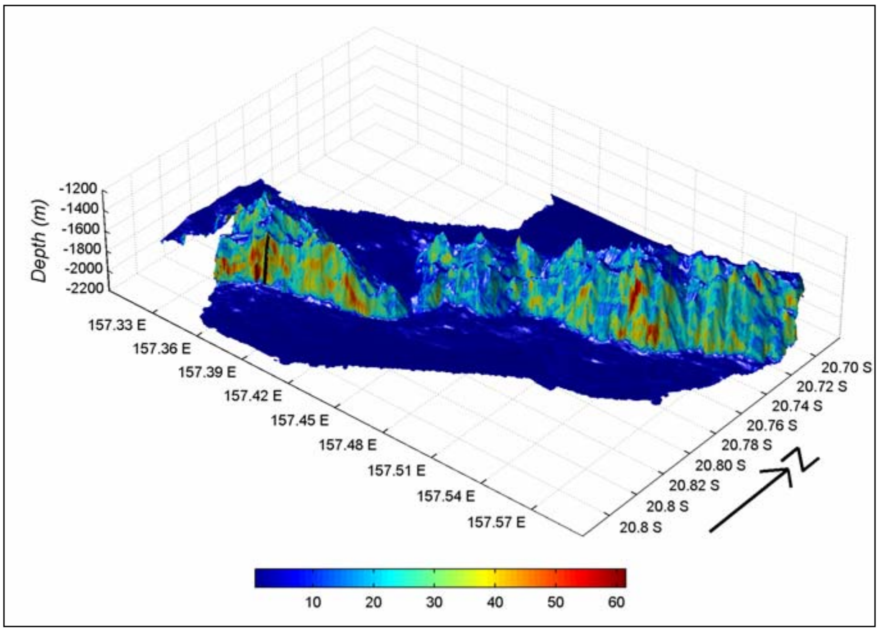
Dredge Site 274/DR34
(Kenn Plateau)

Location:	157° 22.25'E, 20° 50.62'S
Date:	Feb 14, 2005
Depths:	1900-1500 m
Haulage:	4 kg
Recovery:	metadolerite and manganese crust





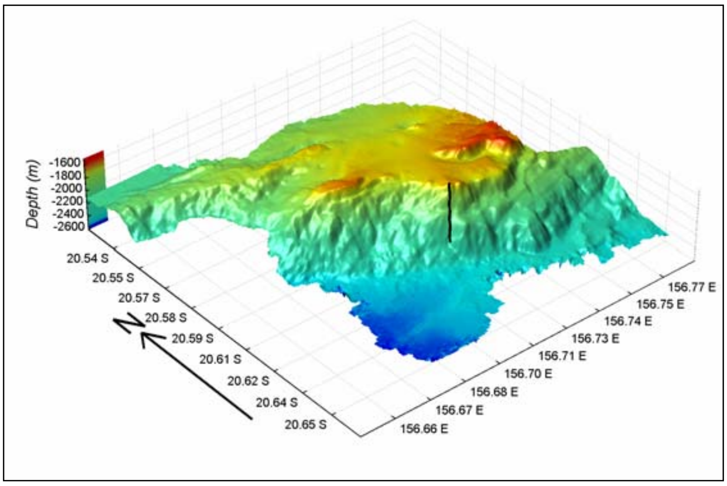
Colour-coded topographic model. Black line is approximate dredge trajectory upslope.



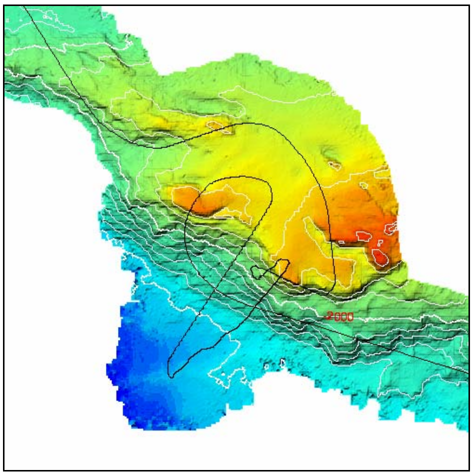
Topographic model superposed by terrain slope (degrees).

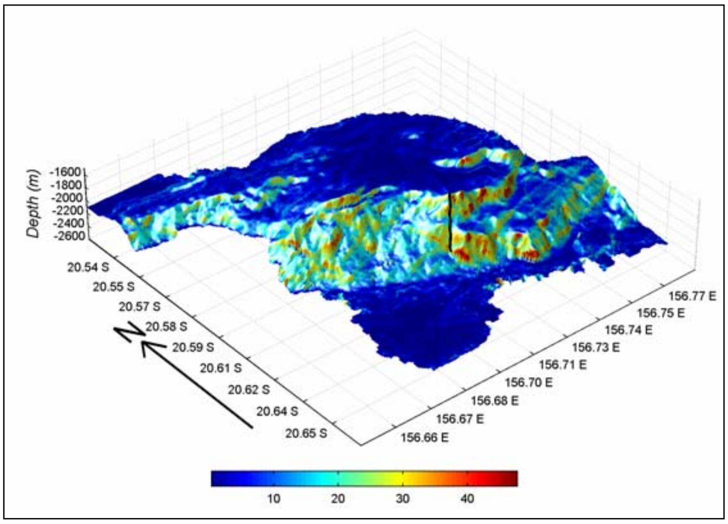
Dredge Site 274/DR35
(Kenn Plateau)

Location:	156° 43.37'E, 20° 36.88'S
Date:	Feb 15, 2005
Depths:	2300-1750 m
Haulage:	150 kg
Recovery:	sandstone, mudstone, claystone, calcarenite and calcareous ooze

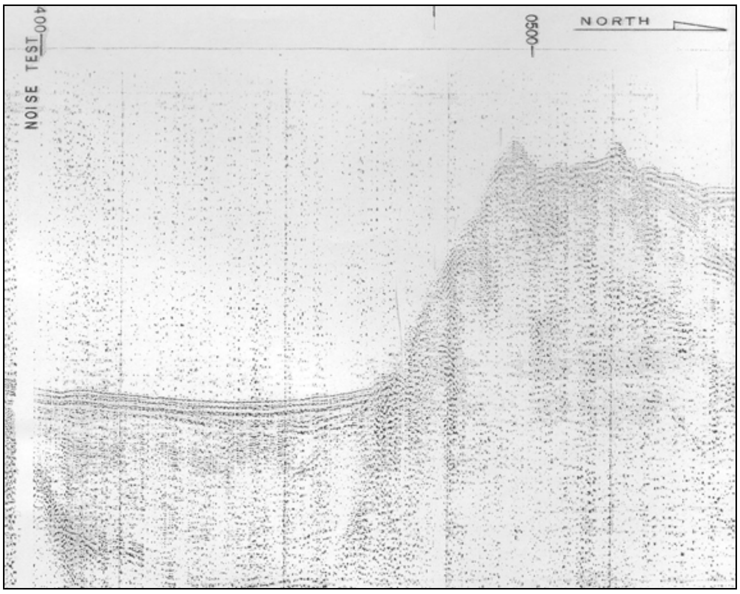


Colour-coded topographic model. Black line is approximate dredge trajectory upslope.





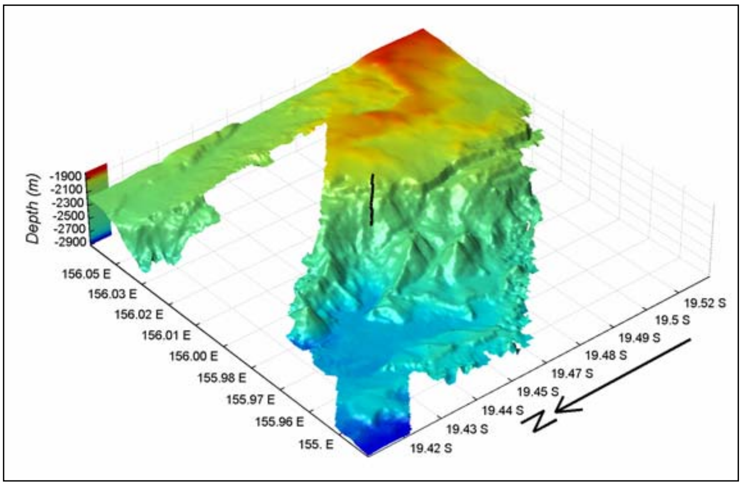
Topographic model superposed by terrain slope (degrees).



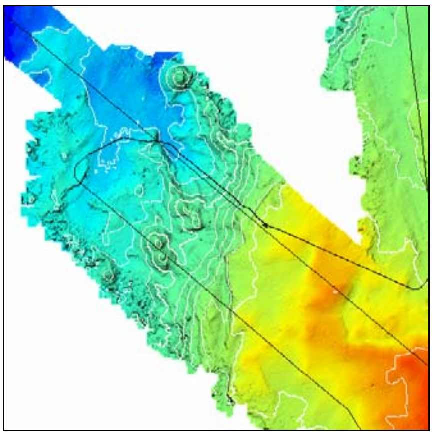
South to north seismic line BMR CM Survey 13 line 50 near dredge site.

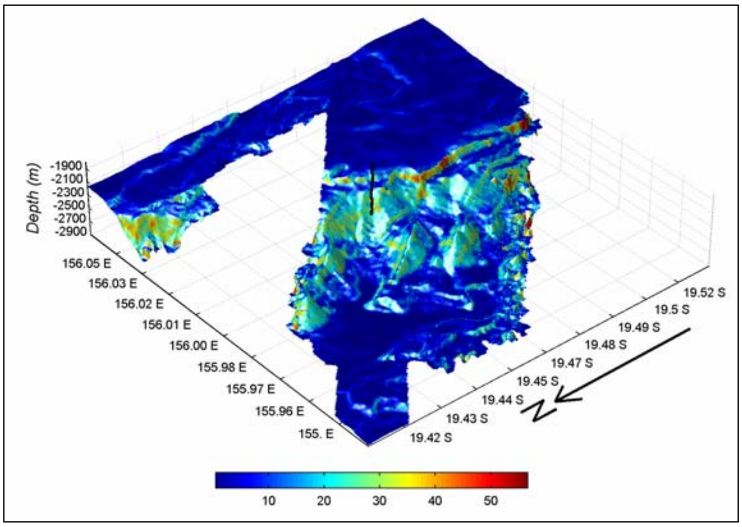
Dredge Site 274/DR36
(Mellish Rise)

Location:	156° 00.18'E, 19° 27.49'S
Date:	Feb 15, 2005
Depths:	2500-2100 m
Haulage:	8 kg
Recovery:	basalt, calcarenite, chalk, clay, manganese crust

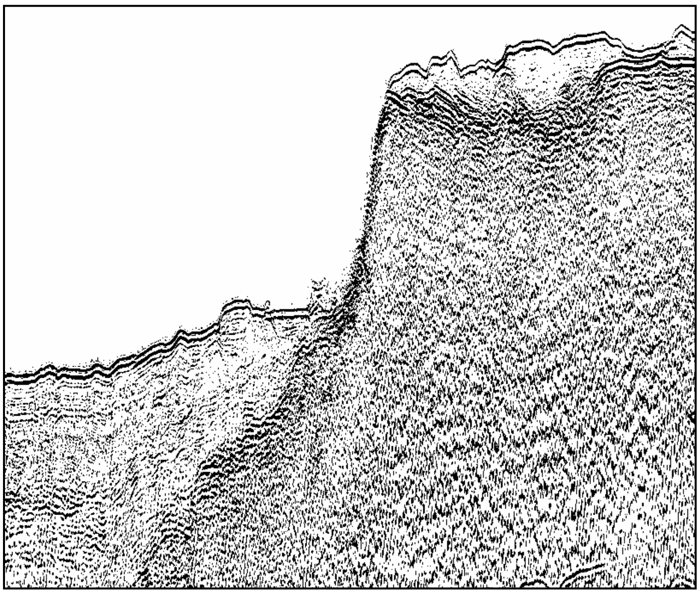


Colour-coded topographic model. Black line is approximate dredge trajectory upslope.





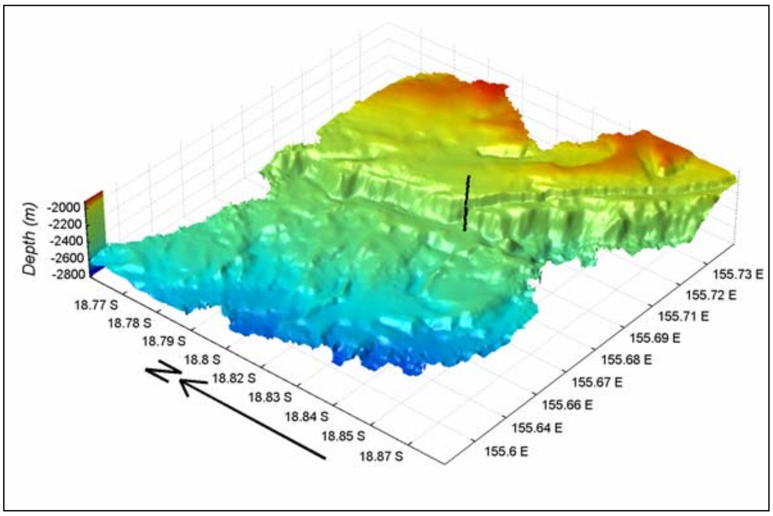
Topographic model superposed by terrain slope (degrees).



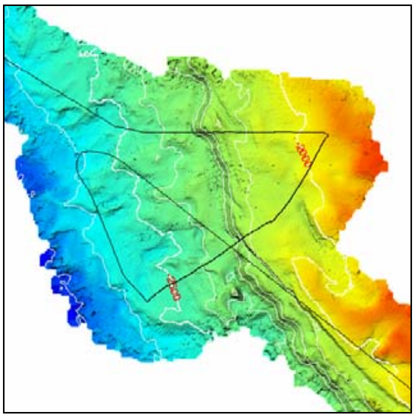
Northwest to southeast seismic line GA 274/01 near dredge site.

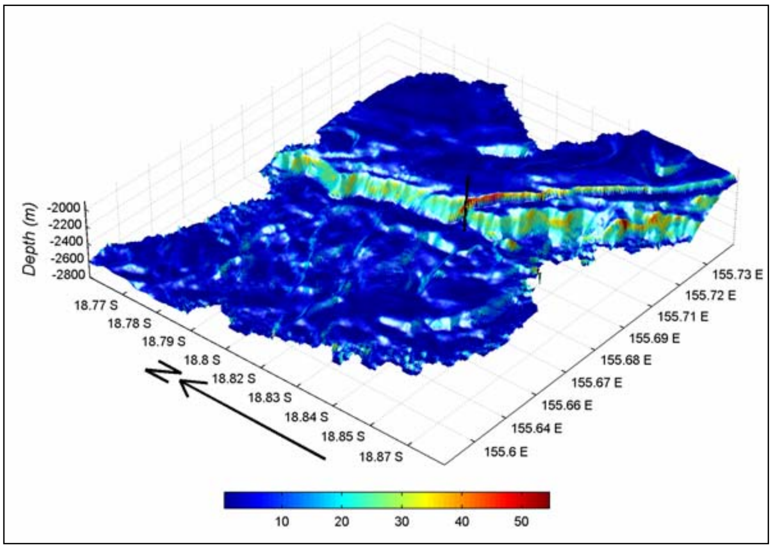
Dredge Site 274/DR37
(Mellish Rise)

Location:	155^{o} 41.55'E, 18^{o} 49.63'S
Date:	Feb 16, 2005
Depths:	2350-2100 m
Haulage:	25 kg
Recovery:	chalk and manganese crust

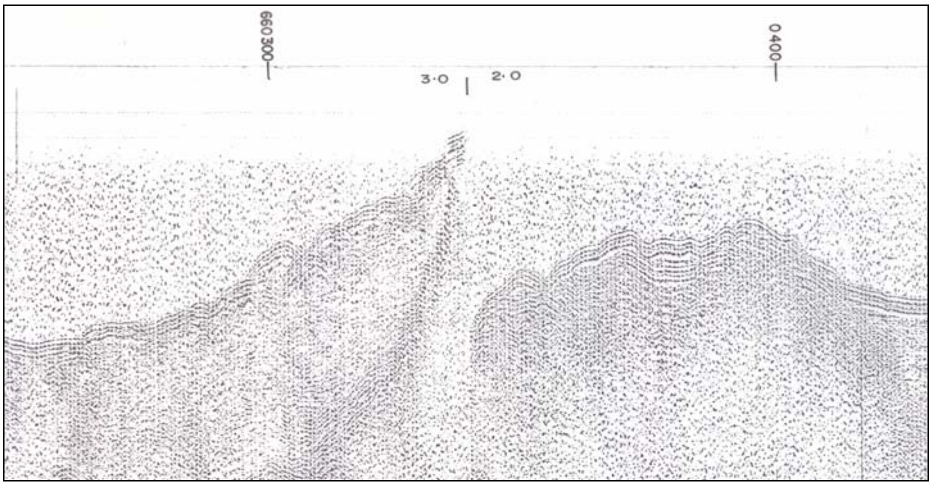


Colour-coded topographic model. Black line is approximate dredge trajectory upslope.





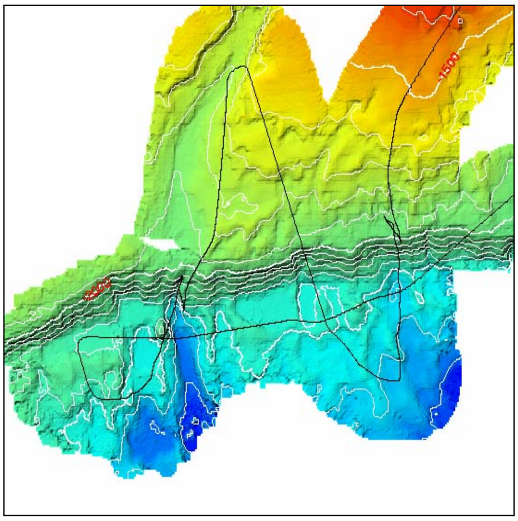
Topographic model superposed by terrain slope (degrees).

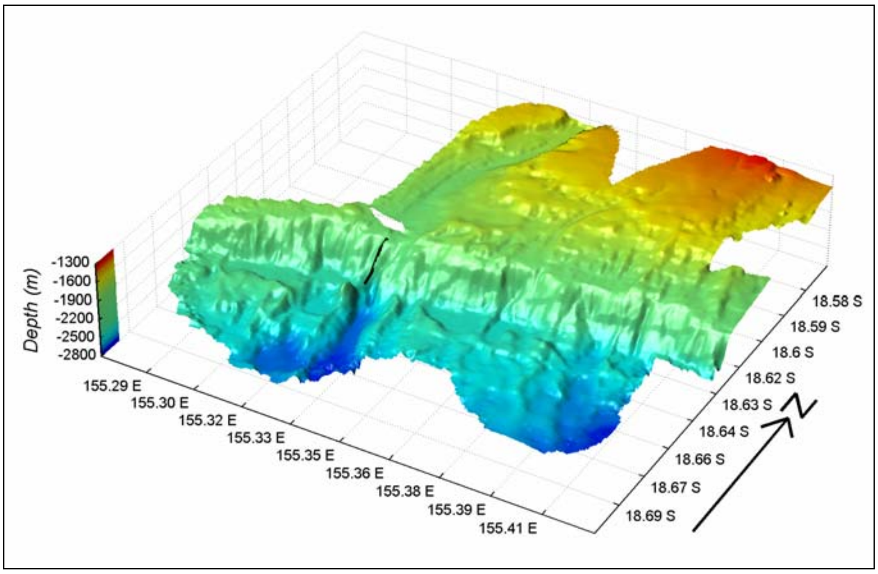


West to east seismic line BMR CM Survey 13 line 60 near dredge site (note time delay jump).

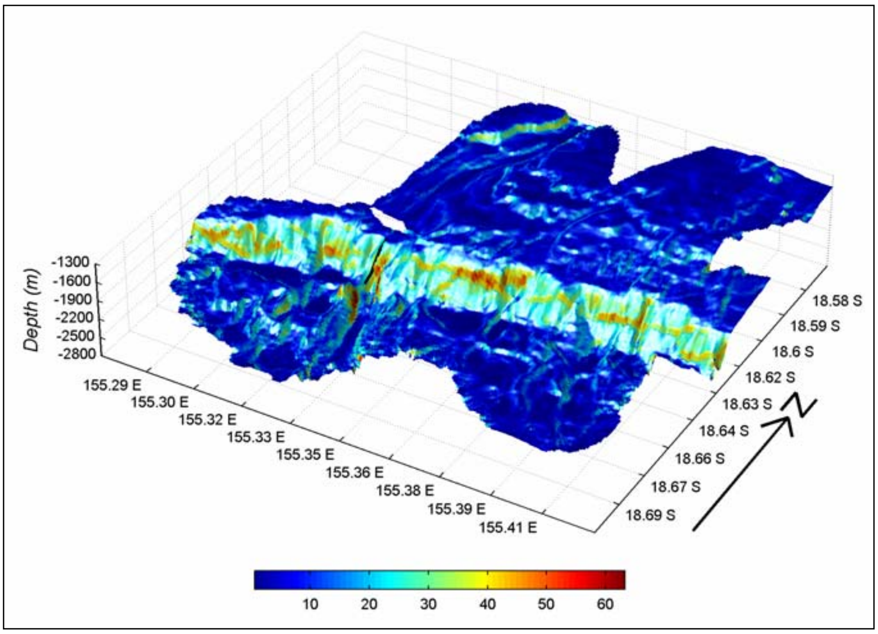
Dredge Site 274/DR38
(Mellish Rise)

Location: 155° 19.66'E, 18° 38.57'S
Date: Feb 16, 2005
Depths: 2600-2000 m
Haulage: 0.1 kg
Recovery: basalt and pumice



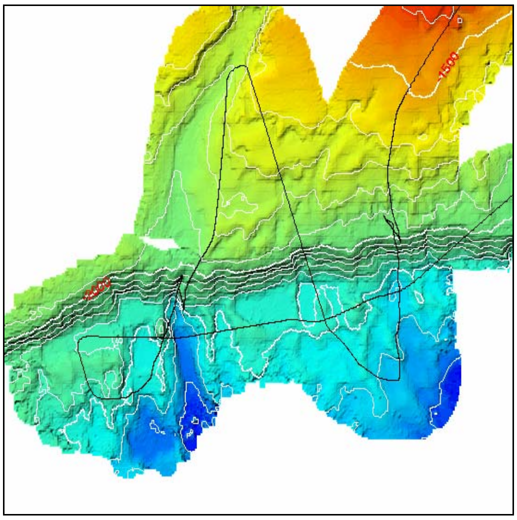


Colour-coded topographic model. Black line is approximate dredge trajectory upslope.

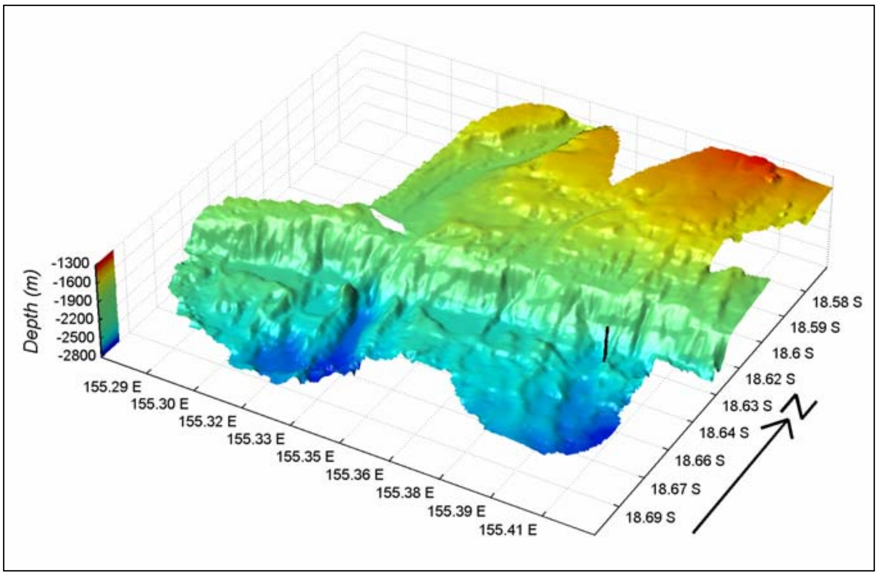


Topographic model superposed by terrain slope (degrees).

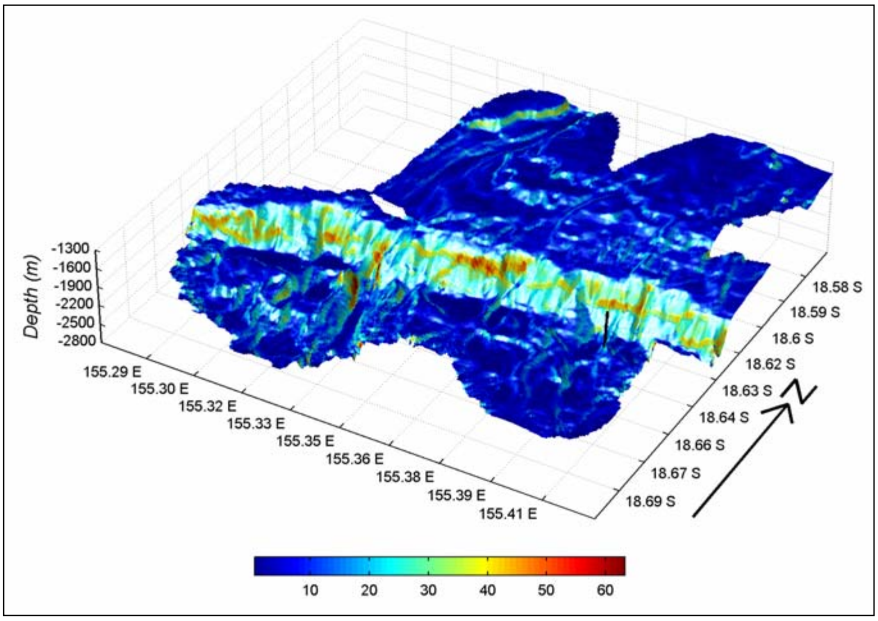
Dredge Site 274/DR39
(Mellish Rise)



Location:	155° 23.60'E, 18° 38.08'S
Date:	Feb 16, 2005
Depths:	2560-1970 m
Haulage:	12 kg
Recovery:	basaltic conglomerate and calcareous tuff



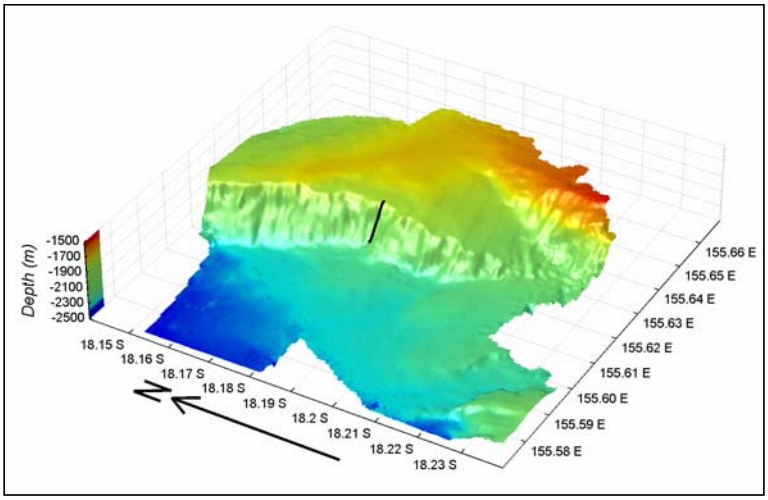
Colour-coded topographic model. Black line is approximate dredge trajectory upslope.

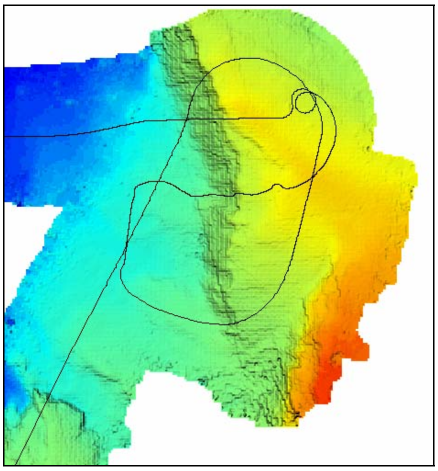


Topographic model superposed by terrain slope (degrees).

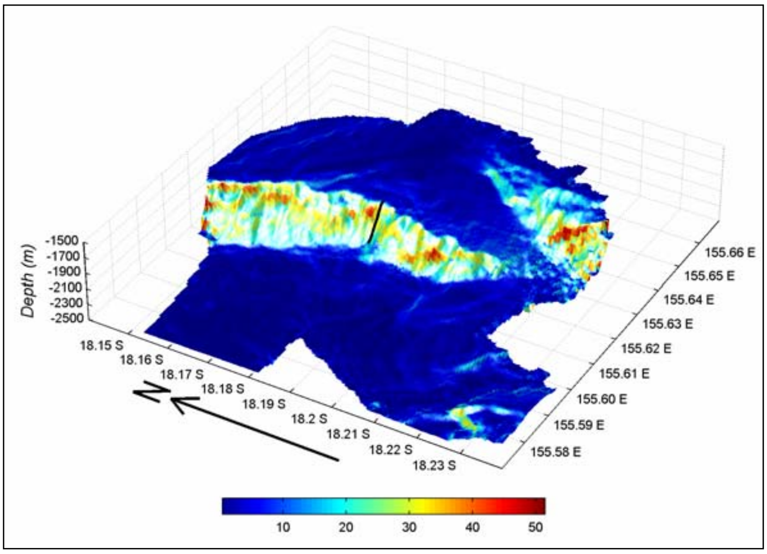
Dredge Site 274/DR40
(Mellish Rise)

Location:	155° 37.48'E, 18° 10.79'S
Date:	Feb 16, 2005
Depths:	2150-1850 m
Haulage:	200 kg
Recovery:	conglomerate, mudstone, basalt, boundstone and calcarenite

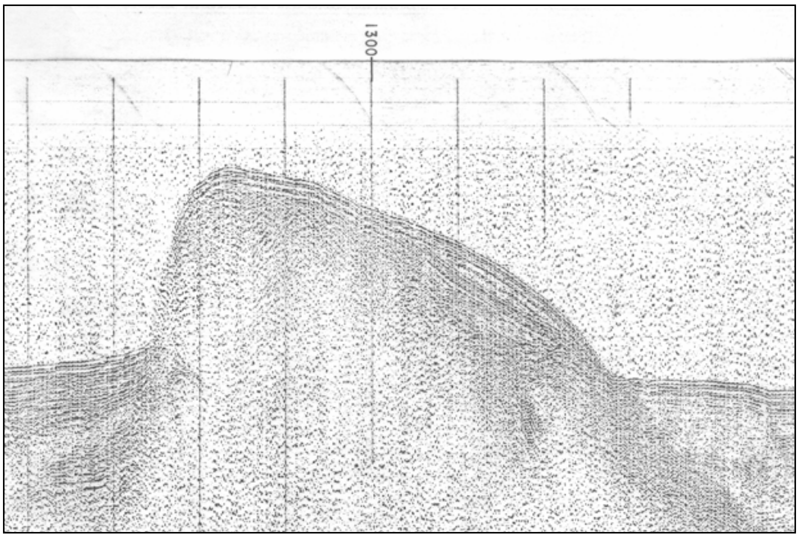




Colour-coded topographic model. Black line is approximate dredge trajectory upslope.



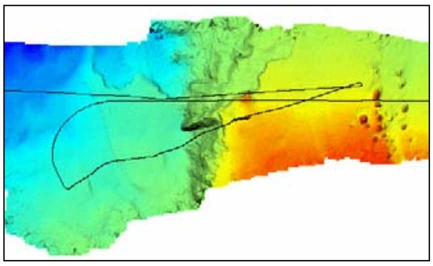
Topographic model superposed by terrain slope (degrees).

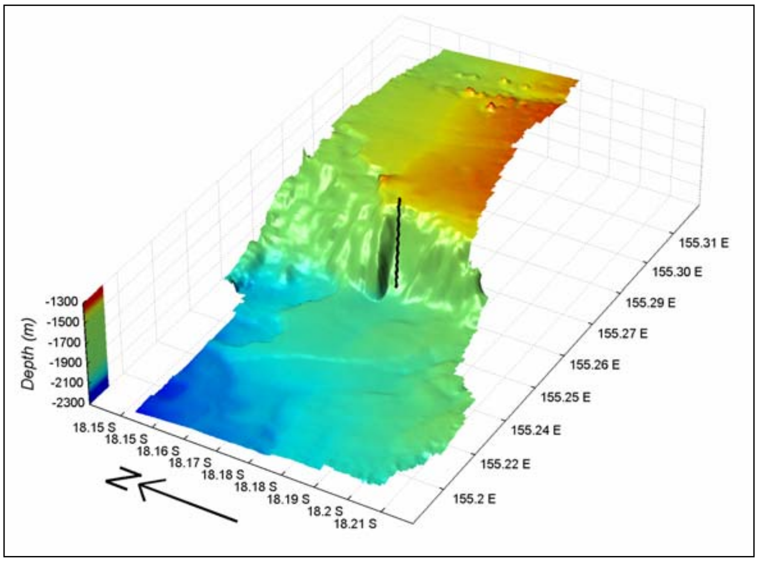


West to east seismic line BMR CM Survey 13 line 64 near dredge site.

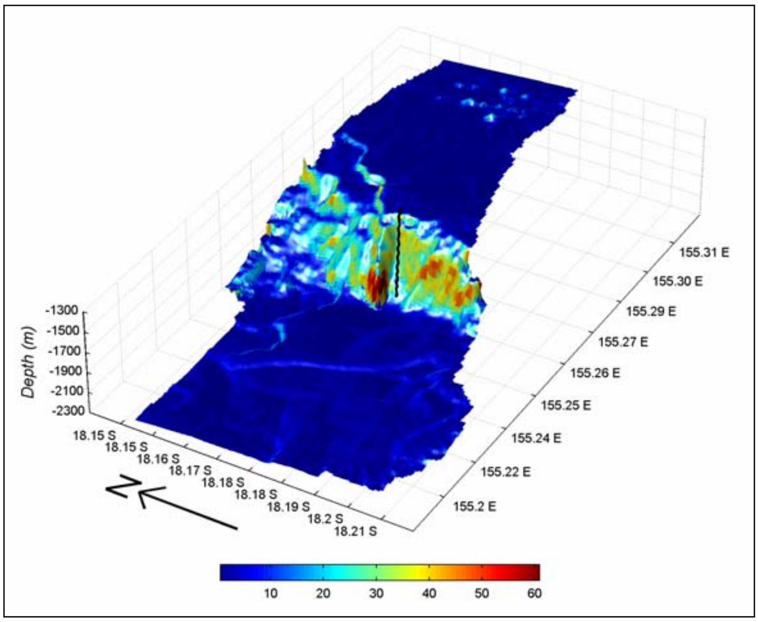
Dredge Site 274/DR41
(Mellish Rise)

Location:	155° 15.59'E, 18° 10.63'S
Date:	Feb 16, 2005
Depths:	1900-1450 m
Haulage:	450 kg
Recovery:	felsic volcanics, basalt, claystone and mudstone

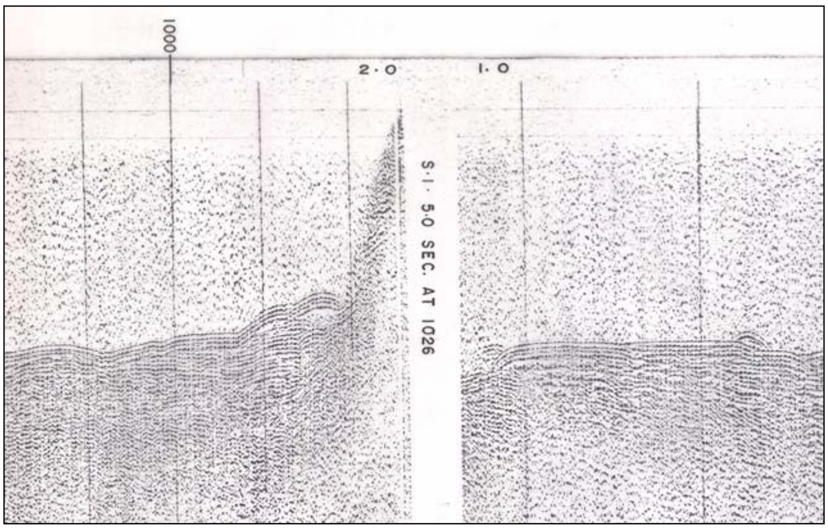




Colour-coded topographic model. Black line is approximate dredge trajectory upslope.

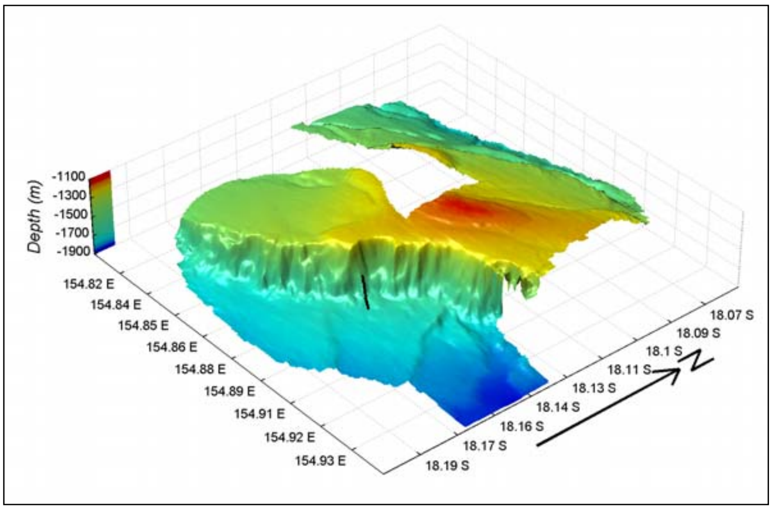


Topographic model superposed by terrain slope (degrees).



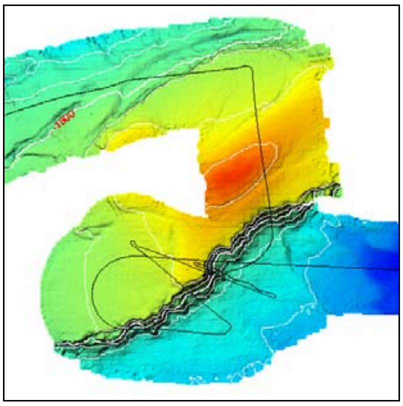
West to east seismic line BMR CM Survey 13 line 64 near dredge site (note time delay jump).

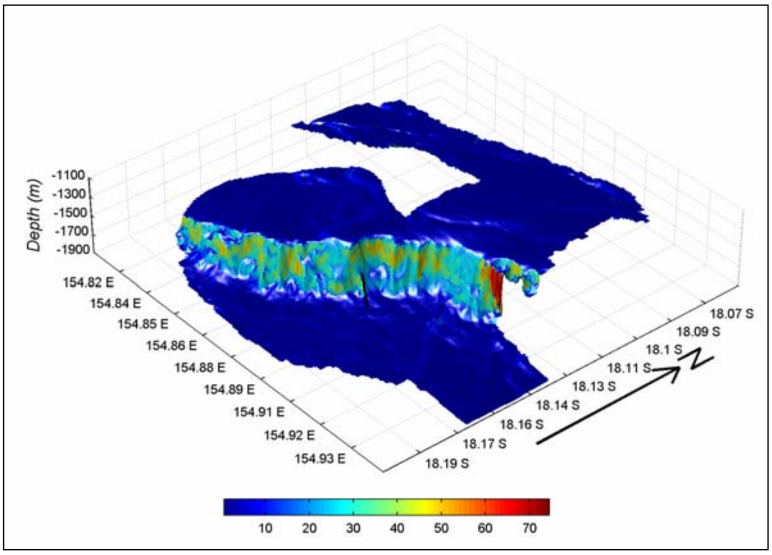
Dredge Site 274/DR42
(Mellish Rise)



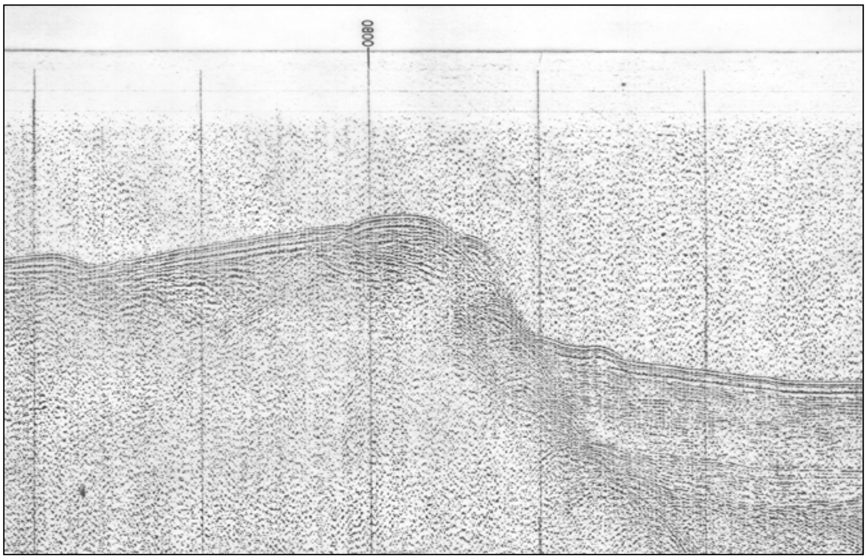
Colour-coded topographic model. Black line is approximate dredge trajectory upslope.

Location:	154° 53.43'E, 18° 09.23'S
Date:	Feb 17, 2005
Depths:	1650-1250 m
Haulage:	20 kg
Recovery:	basalt, chalk and mudstone





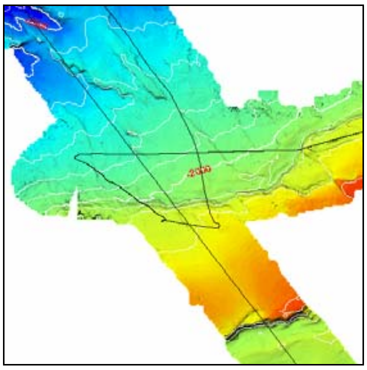
Topographic model superposed by terrain slope (degrees).

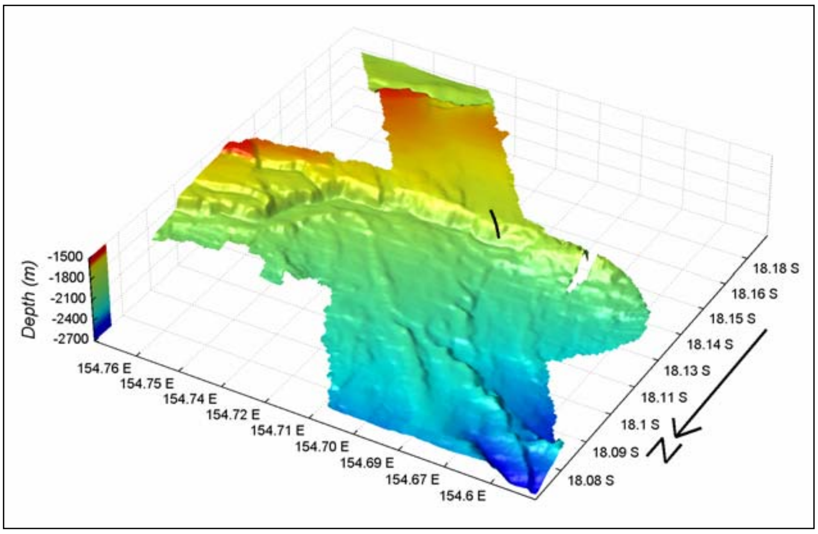


West to east seismic line BMR CM Survey 13 line 64 near dredge site.

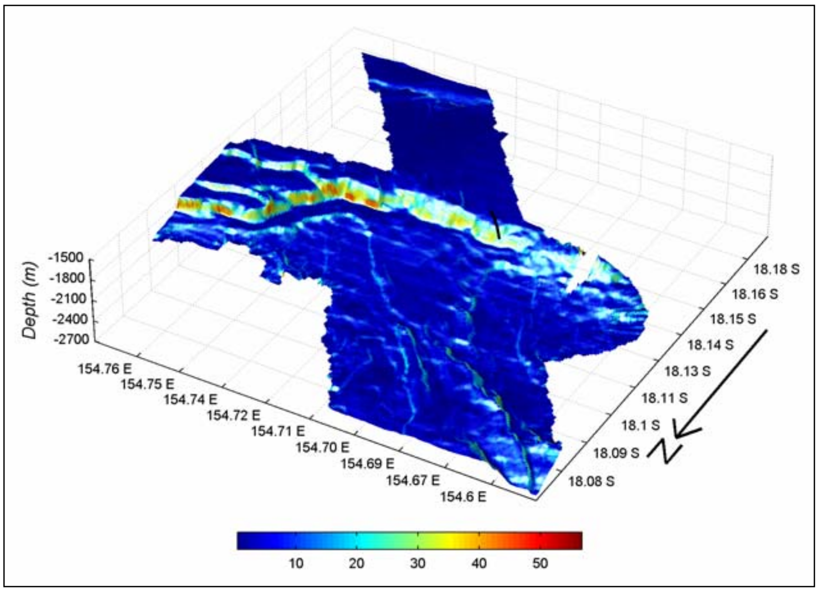
Dredge Site 274/DR43
(Mellish Rise)

Location:	154° 41.94'E, 18° 07.88'S
Date:	Feb 17, 2005
Depths:	2000-1800 m
Haulage:	130 kg
Recovery:	calcarenite and calcareous sandstone

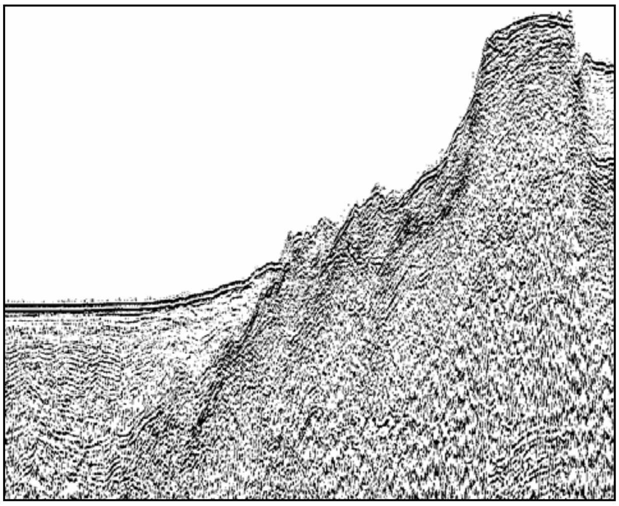




Colour-coded topographic model. Black line is approximate dredge trajectory upslope.



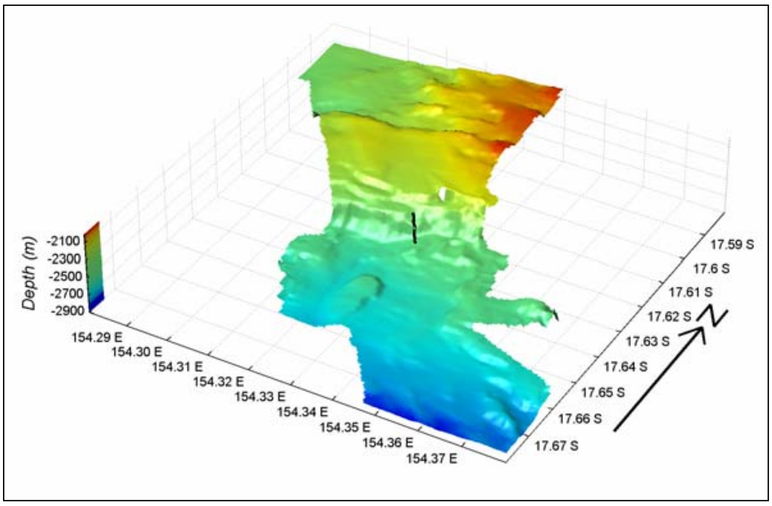
Topographic model superposed by terrain slope (degrees).

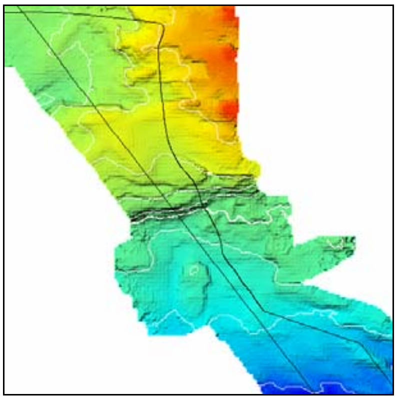


Northwest to southeast seismic line GA 274/01 near dredge site.

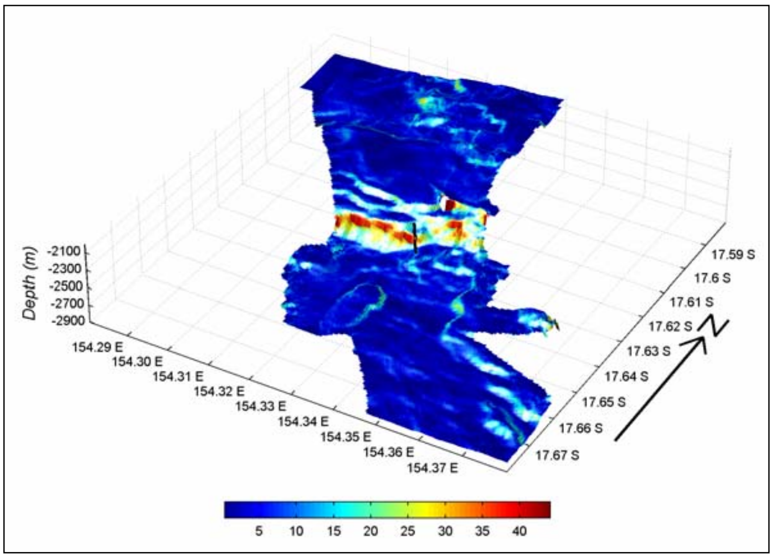
Dredge Site 274/DR44
(Mellish Rise)

Location:	154° 20.36'E, 17° 38.17'S
Date:	Feb 17, 2005
Depths:	2500-2300 m
Haulage:	10 kg
Recovery:	calcarenite, mudstone and manganese crust

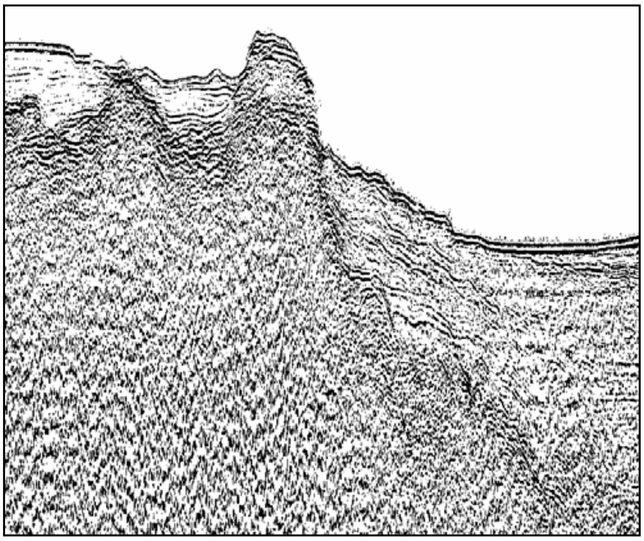




Colour-coded topographic model. Black line is approximate dredge trajectory upslope.



Topographic model superposed by terrain slope (degrees).



Northwest to southeast seismic line GA 274/01 near dredge site.

APPENDIX 7. SELECTED DREDGE PHOTOS AND THIN SECTION DESCRIPTIONS

Tables 1 and 2 below contain a summary of the Kenn Plateau and Mellish Rise, respectively, dredge sample descriptions given in Chapters 5 and 6. Where itemised, thin section spreadsheet descriptions, scanned slide photo images and dredge haul photo images refer to filenames found on the accompanying report CD-ROM.

Table 1. Summary of thin sections taken from rocks on Kenn Plateau dredge sites.

Site	Depth (m)	Rec (kg)	Rock type	Lith	Description	Nanno Age	Foram Age	Environment	GA sample (slide)	Petrographic description filename	Scanned slide photo filename	Text figure number	Dredge sample photo filename
DR01	3200		Sed	A	Foram nanno ooze	Pleistocene to Holocene							
DR02	1700	15	Sed	A	Thick manganese crust with shells								P1010018.jpg
			Sed	B1.1, B1.2	Micritic foram chalk with bivalves	Late Eocene to Oligocene?	Probably Early Oligocene and latest Middle Miocene from lithified ooze (rare basalt clast)	Continental slope to deep sea from foram assemblage					P1270062.jpg
			Meta	C	Fine-grained metasediment								P1270063.jpg
DR03	1770-1620		-		No recovery								
DR04	1700	10	Sed	A	Thin manganese crust								
			Sed	B	Foram nanno ooze	Pleistocene to Holocene							
DR05	1600	30	Sed	A	Chalk	Late Miocene	Late Miocene	Continental slope to deep sea from foram assemblage				Figure 16C	P1280077.jpg
			Sed	B	Foram nanno ooze	Pleistocene to Holocene		Deep sea					
			Sed	C	Foram sand			Deep water sand waves				Figure 8	
DR06	700-400	10	Sed	A	Micritic limestone		Mid Miocene with Quaternary nanno ooze	Photic zone, tropical-subtropical, then 2 ooze deposits					P1290092.jpg

			Sed	B	Pebbly calcarenite	Pleistocene to Holocene	Very early Quaternary	Shallower deposit overlying calcarenite					
			Sed	C	Manganese crust			Deep sea					
			Sed	D	Pebble			Scree					
			Sed	E	White pebble			Scree					
			Sed	F	Shell hash			Littoral					P1290091.jpg
DR07	1600-1500	60	Ign	A	Lithic tuff								P1290095.jpg
			Sed	B	Calcarenite	?	Eocene or Early Tertiary	Seagrass beds in photic zone below wave base					P1290097.jpg
			Sed	C	Shell hash			?Reefal					
			Sed	D	Foram nanno ooze	Pleistocene to Holocene		Deep sea					
			Sed	E	Manganese crust			Deep sea					
DR08	1500-1400	200	Ign	A	Agglomerate	?							P1290125.jpg
			Ign	B	Welded agglomerate								P1290128.jpg
			Sed	C	Volcaniclastic sandstone			Neritic					
			Ign	D	Felsic volcanics								P1290122.jpg
			Sed	E	Manganese crust			Deep sea					
			Sed	F	Lapilli sandstone			Volcanic terrain; lacustrine-neritic	1603232	Thin_section_1603232.xls	Thin_section_1603232.jpg	Figure 15E	P1290129.jpg
			Ign	G	Tuff								
			Sed	H	Foram nanno ooze	Pleistocene to Holocene		Deep sea					
DR09	1800	300	Sed	A	Calcirudite	Mid to Late Miocene	Oligocene-Miocene boundary	Very shallow water with terrigenous influx				Figure 16A	P1290138.jpg
			Sed	B	Manganese crust			Deep sea					
			Sed	C	Volcanic pebbles			Fluvial-littoral					

			Sed	D	Foram nanno ooze	Pleistocene to Holocene		Deep sea					
DR10	1600	100	Sed	A	Calcarenite			Shallow					
			Sed	B	Manganese crust			Deep sea					
DR11	1800-1700	50	Meta	A	Quartzite								
			Ign	B	Lithic tuff or Greywacke								
			Ign	C	Welded tuff								
			Sed	D	Pebbles			Scree					
			Sed	E	Bioclastic remnants, shell hash			?					
			Sed	F	Foram nanno ooze	Pleistocene to Holocene		Deep sea					
			Sed	G	Manganese crust			Deep sea					
DR32	1550	0.5	Ign	A	Pumice stones								P2130240.jpg
			Sed	B	Manganese crust			Deep sea					
			Sed	C	Foram nanno ooze	Pleistocene to Holocene		Deep sea					
DR33	1800-1700	3	Sed	A	Ferruginised quartzose sandstone			Fluvio-lac-neritic				Figure 15A	P2140245.jpg
			Sed	B	Foram nanno ooze	Pleistocene to Holocene		Deep sea					
			Sed	C	Bored Chalk	Early to Mid Miocene		Deep sea					
			Sed	D	Manganese crust			Deep sea					
DR34	1700	6	Ign	A	Dolerite								P2140247.jpg
			Sed	B	Manganese crust on dolerite			Deep sea					P2140250.jpg
DR35	2200-1950	150	Sed	A1.1 & D2	Litharenite & Pebbly foram chalk	?Pliocene chalk (nannos rare)		Lagoonal-littoral	1603486	Thin_section_1603486.xls	Thin_section_1603486.jpg		P2150252.jpg
			Sed	A2.1	Litharenite			Littoral	1603488	Thin_section_160	Thin_section_		

								3488.xls	1603488.jpg		
	Sed	A3.1 & D2	Litharenite & Pebbly foram chalk	Upper Eocene to Upper Oligocene chalk (nannos rare)		Lagoonal-littoral					P2150272.jpg
	Sed	A4	Glauconitic litharenite, siltstone, mudstone			Neritic	1603490	Thin_section_1603490.xls	Thin_section_1603490.jpg	Figure 15C	P2150255.jpg
	Sed	B1	Carbonaceous x-laminated Litharenite			Fluvio-delatic-Littoral	1603492	Thin_section_1603492.xls	Thin_section_1603492.jpg	Figure 15B	P2150258.jpg
	Sed	B3	Carbonaceous MS & Muddy Litharenite			Fluvio-lacustrine-neritic	1603496	Thin_section_1603496.xls	Thin_section_1603496.jpg	Figure 15D	P2150260.jpg
	Sed	C	Bentonitic mudstone with haematitic veins	(rare nannos)		Neritic				Figure 15F	P2150261.jpg
	Sed	D1	Pebbly micritic limestone	(no nannos)		Lagoonal or shelfal				Figure 16B	P2150270.jpg
	Sed	E	Calcareous mudstone/ Concretion			Neritic					P2150268.jpg
	Sed	F	Foram chalk	Upper Eocene to Early Miocene		Deep sea					P2150274.jpg
	Sed	G	Foram nanno ooze	Pleistocene to Holocene		Deep sea					

Table 2. Summary of thin sections taken from rocks on Mellish Rise dredge sites.

Site	Depth (m)	Rec (kg)	Rock type	Lith	Description	Nanno Age	Foram Age	Environment	GA sample (slide)	Petrographic description filename	Scanned slide photo filename	Text figure number	Dredge haul photo filename
DR12	2600	30	Sed	A	Manganese crust			Deep sea					
			Sed	B	Porcellanite	(no nannos)	?Eocene (no forams)	Bathyal below CCD as siliceous					
			Sed	C	Porcellanite in thick manganese crust	Pleistocene to Holocene (rare nannos)	?Eocene (no forams)	Bathyal below CCD as siliceous					dr12_c_porcel.jpg
			Sed	D	Pumice stones			Volcanic terrain					
			Sed	E	Foram nanno ooze			Pelagic					
DR13	2900-2750	100	Ign	A	Vesicular basalt			Littoral				Figure 18G	P2070038.jpg
			Ign	B	Dolerite/Syenite			Hypabyssal					P1010034.jpg
			Sed	C	Porcellanite in Manganese nodule	Lower Eocene (few nannos)	?Eocene	Bathyal below CCD as siliceous					P2070042.jpg
			Sed	D	Bored chalk	Mid Paleocene to Mid Eocene (few nannos)	Late Paleocene	Deep sea ooze					P1010035.jpg
			Sed	E	Chert			Pelagic				Figure 18C	P2070041.jpg
			Sed	F	Pebbly chalk	Eocene to Lower Oligocene (nannos)		Pelagic					P1010031.jpg
			Ign	G	Pumice stones			Volcanic terrain					
			Sed	H	Coral			Neritic					
DR14	2900-2400	500	Ign	A	Quartz gabbro			Plutonic					P2070048.jpg
			Ign	B	Vesicular Basalt			Volcanic terrain					P2070050.jpg
			Ign	C	Hyaloclastite			Marine volcanics					P2070051.jpg
			Ign	D	Serpentinite breccia								

			Sed	E	Bentonitic siliceous claystone	Mixed Upper Eocene to Early Miocene (nannos rare)	?	Deep sea below CCD as siliceous					P2070053.jpg
			Sed	F	Muddy glauconitic chalk	Paleocene to Lower Eocene (nannos)	Late Paleocene	?Outer shelf or upper slope					P2070057.jpg
			Sed	G	Chalk	Lower Eocene to Early Miocene (nannos)	Latest Middle Eocene	Deep sea ooze or cont. slope					
			Sed	H	Foram nanno ooze	Mix Paleocene to Pleistocene-Holocene (nannos)		Deep sea					
			Sed	I	Manganese veneer			Deep sea					
DR15	2630	60	Ign	A	Altered basalt								P2070075.jpg
			Ign	B	Vesicular basalt								P2070073.jpg
			Sed	C	Muddy glauconitic chalk	Pleistocene to Holocene (nannos abundant)	Late Paleocene	Mid shelf					P2070071.jpg
			Sed	D	Manganese crust and nodules			Deep sea					
			Sed	E	Pumice stones								
DR16	2600-2500	15	Ign	A	Microcrystalline Tuff								P2080089.jpg
			Sed	B	Manganese crust			Deep sea					
			Sed	C	Foram nanno ooze	Pleistocene to Holocene (nannos abundant)		Pelagic					
DR17	3250-3000	500	Ign	A	Basalt								P2080118.jpg
			Ign	B	Vesicular basalt								P2080113.jpg

			Ign	C	Agglomerate								P2080109.jpg
			Sed	D1	Sideritic sandy mudstone			Subaerial lateritisation of volcanics, debris flow?	1603331	Thin_section_1603331.xls	Thin_section_1603331.jpg	Figure 17A	P2080110.jpg
			Sed	E	Calcarenite	(no nannos)	?Paleocene	Inner to mid shelf, clear water, no terrigenous					
			Sed	F	Recrystallised calcarenite		?	Very shallow high energy, well washed, strange as from >3km					P2080098.jpg
			Sed	G	Porcellanite	(no nannos)	(no forams)	Echinoid suggests shallow shelf but abundant radiolaria conflicts				Figure 18B	P2080104.jpg
			Ign	H	Microcrystalline basalt								P2080101.jpg
			Sed-Ign	I	Bioturbated mudstone/siltstone or altered basalt?			Fluvio-deltaic or volcanic					P2080096.jpg
			Sed	J	Olivine-rich sandstone			Fluvio-deltaic or neritic					P2080120.jpg
			Sed	K	Manganese crust			Deep sea					
DR18	3300-3100	20	Ign	A	Vesicular basalt								
			Ign	B	Lithic tuff								P2080125.jpg
			Ign	C	Hyaloclastite								P2080123.jpg
			Sed	D	Foram nanno ooze	Pleistocene to Holocene (nannos abundant)		Pelagic					
			Sed	E	Manganese crust			Deep sea					
DR19	3750-3650	400	Ign	A	Hyaloclastite	(no nannos)	?	Marine, siliceous radiolaria and abundant diatoms					P2090145.jpg

			Sed	B	Consolidated ooze in manganese nodules	(no nannos)	Late Paleocene-Early Eocene	Deep sea				Figure 18E	
			Sed	C	Manganese crust and nodules			Deep sea				Figure 18D	P2090142.jpg
DR20	2850-2650	-	-		-								
DR21	1950-1500	200	Ign	A	Microcrystalline basalt								P2100156.jpg
			Ign	B	Microcrystalline basalt with pebbly chalk		Paleocene-Early Oligocene	Marine, near volcanic source as basalt clasts					P2100153.jpg
			Ign	C	Basaltic conglomerate or weathered vesicular Basalt								P2100160.jpg
			Ign	D	Agglomerate								P2100158.jpg
			Sed	E	Red brown Claystone			Lake-shelfal					
			Sed	F	Laminated glauconitic carbonates			Quiet slow sed'n, glauc but nanno chalk so below wave base (?Shelfal)	1603383	Thin_section_1603383.xls	Thin_section_1603383.jpg	Figure 17F	P2100173.jpg
			Sed	G	Foram nanno ooze	Pleistocene to Holocene (nannos abundant)	?	Pelagic					
			Sed	H	Manganese crust			Deep sea					
DR22	1700-1300	350	Ign	A	Basalt								P2100176.jpg
			Ign	B	Brecciated vesicular basalt		?						dr22_b_breccbasalt.jpg
			Ign	C	Vesicular basalt								P2100179.jpg
			Sed	D	Algal boundstone		?Oligocene	Shallow in photic zone and quiet				Figure 17D	P2100184.jpg

			Sed	E	Foram nanno ooze	Pleistocene to Holocene (nannos abundant)		Pelagic					
			Sed	F	Bivalve			Neritic					
			Sed	G	Calcarenite		?	Shallow high energy				Figure 17C	P2100185.jpg
			Sed	H	Calcareous conglomerate/rudstone		Oligocene?	Shallow high energy, reef front					P2110188.jpg
			Sed	I	Manganese crust			Deep sea					
DR23	2300-2000	0.2	Ign	A	Hyaloclastite	?							P2110190.jpg
			Sed	B	Manganese nodules			Deep sea					
DR24	2200-2000	200	Sed	A	Calcarenites (A1&A2 are quartzose)	?	A1&A2-?Late Eocene; A3-Oligocene-Miocene?	A1&A2-Deeper part of photic zone; A3-inner shelf but no terrigenous					P2120210.jpg
			Sed	B	Micritic foram limestone		Mid-Late Miocene or Early Pliocene; Late Eocene-E.Oligocene	Mix of:- Outer shelf, below photic zone and very shallow photic zone					P2120208.jpg
			Sed	C	Calcareous lithic sandstone			Neritic				Figure 16F	P2120205.jpg
			Sed	D	Siliceous hydrothermal deposit - sinter			Terrestrial				Figure 17B	P2120204.jpg
			Sed	E	Manganese crust			Deep sea					
			Sed	F	Volcanolithic conglomerate			Alluvial/fluvial				Figure 16E	P2110197.jpg
			Ign	G	Crystal lithic tuff								P2110202.jpg
			Ign	H	Hyaloclastite								P2110192.jpg
			Ign	I	Basalt		?						P2110194.jpg, P2110198.jpg

			Sed	J	Coral			Reef					
DR25	2650-2350	200	Ign	A	Hyaloclastite								
			Sed	B	Quartzose calcarenite		Eocene	Tropical-warm temperate, lower photic zone					P2120212.jpg
			Sed	C	Foram chalk and nanno ooze infilling voids	Ooze=Pleistocene to Holocene (nannos abundant)	Chalk=Late Eocene-Early Oligocene	Shelf below photic zone					P2120214.jpg
			Sed	D	Manganese crust			Deep sea					
			Sed	E	Bryozoans/corals			Reef					
DR26	2100-1950	60	Ign	A	Vesicular basalt								P2120227.jpg
			Sed	B	Conglomerate	Late Pliocene (nannos abundant)		Marine debris flow?					P2120231.jpg
			Sed	C	Calcareous pebbly litharenite			Marine debris flow?					P2120229.jpg
			Sed	D	Manganese crust			Deep sea					
DR27	1800-1650	0.5	Sed	A	Manganese crust			Deep sea					
			Sed	B	Conglomerate			Marine debris flow?					
			Sed	C	Coral hash	Pleistocene to Holocene (nannos abundant)		Reef				Figure 18H	P2120233.jpg
DR28	-	-	-		No recovery								
DR29	-	-	-		No recovery								
DR30		4	Sed	A	Calcareous volcaniclastic conglomerate			Marine debris flow?					P2130234.jpg

			Sed	B	Foram nanno ooze	Pleistocene to Holocene (nannos abundant)		Pelagic					
			Sed	C	Pumice stone								
DR31	2600-2450	7	Ign	A	Calcareous lithic tuff								P2130237.jpg
			Sed	B	Manganese crust			Deep sea					
			Sed	C	Foram marl	Paleocene to Miocene (nannos)	Late Eocene	Mid shelf with river input, exposed land nearby					P2130238.jpg
			Sed	D	Bentonitic Foram marl	Paleocene to Miocene (nannos)	earliest Late Eocene	Mid to outer shelf, terrigenous input					P2130239.jpg
			Sed	E	Foram nanno ooze	Pleistocene to Holocene (nannos abundant)		Pelagic					
DR36	2500-2150	8	Sed	A	Manganese crust			Deep sea					
			Ign	B	Basalt	Pleistocene to Holocene (abundant nannos)							P2150265.jpg
			Sed	C	Calcarenite	? (no nannos)		Reefal					P2150263.jpg
			Sed	D	Foram chalk	Late Miocene with Pleistocene-Holocene	Late Pliocene	Deep sea ooze					
			Sed	E	Bentonitic Claystone			Shelf - Deep sea					
			Sed	F	Pumice stone								
DR37	2200	25	Sed	A	Greywacke (litharenite)			Neritic					

			Sed	B	Foram chalk	Pleistocene to Holocene & reworked Miocene (nannos common)		Deep sea					
			Sed	C	Foram chalk	Reworked Miocene	Late Pliocene	Deep sea					
			Sed	D	Manganese crust			Deep sea					
			Sed	E	Foram nanno ooze	Mixed Miocene & Pleistocene-Holocene (nannos abundant)		Pelagic					
			Sed	F	Foram nanno ooze from vugh in greywacke	Pleistocene-Holocene		Pelagic					
DR38	2600	0.1	Ign	A	Vesicular basalt								
DR39	2400	12	Ign	A	Hyaloclastite "conglomerate", glassy								P2160280.jpg, P2160283.jpg
			Ign	B	Calcareous tuff	? (nannos not common)							P2160284.jpg
			Sed	C	Foram nanno ooze	Pleistocene-Holocene		Pelagic				Figure 18F	P2160276.jpg
			Sed	D	Manganese crust			Deep sea					
DR40	2100-1850	200	Sed	A	Calcareous conglomerate/ rudstone	Mixed Pliocene & Pleistocene-Holocene		Reef front				Figure 17E	P2160291.jpg
			Sed	B	Algal boundstone			Shallow in photic zone					P2160293.jpg
			Ign	C	Vesicular basalt								P2160296.jpg
			Sed	D	Haematitic bioturbated mudstone	?		Quiet shelf, neritic, original lateritised basalt	1603552	Thin_section_1603552.xls	Thin_section_1603552.jpg		

			Ign	E	Brecciated basalt								P2160300.jpg
			Ign	F	Weathered vesicular basalt				1603557				P2160303.jpg
			Ign	G	Altered porphyritic basalt				1603560				P2160307.jpg
			Ign	H	Weathered basalt				1603562				P2160311.jpg
			Sed	I	Bentonitic mudstone	?		Subaqueous, ash input	1603564	Thin_section_1603564.xls	Thin_section_1603564.jpg		
			Sed	J	Weathered calcarenite	Pleistocene-Holocene		Reef					P2160312.jpg
			Ign	K	Pumice stone								
			Sed	L	Manganese crust			Deep sea					
DR41	1900-1450	450	Sed	A	Haematitic sandy mudstone			Subaqueous debris flow, deltaic?	1603570	Thin_section_1603570.xls	Thin_section_1603570.jpg		P2170333.jpg
			Sed	B1	Volcanogenic pebbly mudstone			Debris flow near volcano	1603573	Thin_section_1603573.xls	Thin_section_1603573.jpg		P2170347.jpg
			Ign	B2	Basalt emplacement into brecciated mudstone			Volcanic terrain	1603576				P2170345.jpg
			Ign	B3	Lateritised vesicular basalt								P2170336.jpg
			Ign	C	Lateritised amygdaloidal basalt								
			Ign	D	Amydgaloidal glassy basalt				1603584				P2170331.jpg
			Ign	E	Basalt								
			Ign	F	Dacite								P2170330.jpg, P2170353.jpg
			Ign	G	Rhyolite								
			Ign	H	Quartz diorite								
			Ign	I	Serpentinised igneous								P2170352.jpg
			Ign	J	Zeolite breccia								

			Sed	K	Weathered algal boundstone	Pliocene to Pleistocene-Holocene		Shallow in photic zone					P2170348.jpg
			Sed	L	Chalk	Mid to Late Miocene		Deep sea					
			Ign	M	Dolerite								P2170350.jpg
			Sed	N	Volcanogenic sandstone			Fluvio-neritic					
			Sed	O	Manganese veneer			Deep sea					
			Sed	P	Coral hash			Neritic					
DR42	1600	20	Sed	A	Foram chalk	Early to Mid Miocene (nannos abundant)		Deep sea	1603617	Thin_section_1603617.xls	Thin_section_1603617.jpg	Figure 18A	P2170315.jpg
			Ign	B	Vesicular basalt								P2170317.jpg
			Ign	C1	Amygdaloidal glassy basalt				1603622				P2170320.jpg
			Ign/ Sed	C2	Amygdaloidal glassy basalt				1603624				P2170318.jpg
			Sed	D	Mudstone conglomerate								P2170322.jpg
			Ign	E	Basalt								
			Sed	F	Grey mudstone			Coastal plain or neritic					
			Sed	G	Manganese crust			Deep sea					
DR43	2000-1850	130	Sed	A	Calcarenite			Reef					P2170338.jpg
			Sed	B	Glauconitic calcarenite	Late Pliocene		Reef	1603635	Thin_section_1603635.xls	Thin_section_1603635.jpg		P2170340.jpg
			Sed	C	Glauconitic calcarenite			Reef	1603638	Thin_section_1603638.xls	Thin_section_1603638.jpg		P2170342.jpg
			Sed	D	Manganese crust and nodules			Deep sea					P2170344.jpg
			Sed	E	Pumice stones								

DR44	Sed	A1, A3	Calcilutitite	Mid-Upper Paleocene (few nannos)							P2180001.jpg
	Sed	A2	Calcareous bentonitic mudstone	Reworked Paleocene?	Paleocene	Shelf					P2180006.jpg
	Sed	B	Manganese nodule with calcareous conglomerate	?		Deep sea					P2180003.jpg
	Sed	C	Manganese nodules and crusts			Deep sea					
	Sed	D	Non-calcareous bentonitic mudstone			Shelf					

APPENDIX 8. CRUISE NARRATIVE

The *Southern Surveyor* sailed from Bundaberg at 1025 on 25 January, and headed east into head winds toward the first sampling site on the southeast Kenn Plateau, 420 km away. On the route we added a swath line to the southern edge of the Ron Boyd (SS1/05) data set off Fraser Island. The *Topas* sub-bottom profiler was tested but caused serious interference to the swath-mapper. The weather was bad with 3 m waves from the east and a swell from the ESE. Winds from the east gusted to 35 knots. Progress was relatively slow, averaging 7.5 knots over the ground, and many aboard were seasick. At 0915 on 26 January we crossed Fraser Seamount (a guyot about 300 m deep) to improve the swath coverage over it.

The first dredge station (DR01) was occupied around 1830 on 26 January on the southwest margin of Kenn Plateau, and recovered only carbonate ooze at 2205 from a water depth of 3200 m at 24º49.0, 156º19.8’E. Gravity core GC01 recovered 320 cm of Quaternary calcareous ooze from 2695 m deep, further north at 24º17.03’S, 156º55.38’E at 0847 on 27 January. Dredge DR02 retrieved shelf limestone and manganese crust at 1640 from a north-trending ridge on the central plateau in a water depth of 1700 m (23º27.7’S, 156º46.8’E). Dredge DR03 was run downwind to the west up an east facing slope in a 30 knot wind and failed (probably because the dredge flew too high at 2.5 knots). The water depths were 1770-1600 m and we started at 23º12.7’S, 156º32.5’E. The dredge was recovered at 2340 on 27 January, and as this was a marginal site and time was pressing, we moved to the next site.

Dredge DR04 was run on the central Kenn Plateau on a west-facing slope and recovered some thin manganese crust and calcareous ooze from 1700 m at 23º13.56’S, 157º00.85’E, at 0550 on 28 January. The weather was better and all hands were back in action. Dredge DR05 was located on the northern Kenn Plateau on the southern side of the Coriolis Ridge. It recovered bored chalk from a depth of 1600 m at 22º08.0’S, 156º44.65’E, at 1650. We then continued to the northern side of the Coriolis Ridge where we ran a short swath survey of the northeast corner of a large un-mapped guyot, with its top at about 280 m, before sampling up its slope. Dredge 06 recovered shallow water limestone from 700-400 m depth at 21º30.85’S, 156º24.7’E, at 0100 on January 29.

Dredge DR07 was run on the northern flank of Coriolis Ridge, and recovered tuff and calcarenite from 1600-1500 m depth at 21º25.5’S, 156º24.45’E, at 0430 on January 29. Two attempts were made to take a core of presumed Palaeogene sediments (GC02) at 21º31.02’S, 156º34.7’E, but both failed and the location was abandoned at 2320. Dredge DR08 recovered volcanic agglomerate, felsic volcanics, pisolitic sandstone and manganese crusts from 1500-1400 m at 21º25.85’S, 157º06.8’E, at 1525. Core GC03 was designed to sample another Palaeogene target at 21º26.71’S, 157º04.83’E, and it recovered a little foram chalk at 1730. Dredge DR09 recovered a huge friable calcarenite boulder, a few waterworn volcanic pebbles, and manganese crusts, from 1800 m depth at 2200, on the middle of three scarps in French territory, at 21º21.5’S, 157º14.6’E. Dredge 10, the last sampling attempt on the northern flank of Coriolis Ridge, recovered a little calcarenite and manganese crusts from the upper scarp at a depth of 1600 m at 0330 on January 30, at 21º21.9’S, 157º14.8’E. Dredge 11, on the southern side of Selfridge Rise at 21º04.5’S, 156º52.6’E, contained metamorphic quartzite, volcanogenic greywacke, welded tuff, and rounded volcanic pebbles, and thick manganese crust, from a depth of 1800-1700 m at 0700.

On the way to the first seismic profile, a 2000 m CTD (conductivity, temperature, depth) probe was deployed to provide water velocity information to improve the settings of the multibeam sonar and maximise its returns. After a safety meeting at 1430 on 30 January, air lines were run to the rear deck and final hydraulic adjustments made. Then the seismic cable, airguns and magnetometer were deployed, and the first shots were fired at 7 knots on the approach to Line 1. Unfortunately, the compressor threw its belts off around 1715, probably because rust had accumulated on the unprotected pulleys during the previous survey. New belts were installed and the compressor was back in action by 1945. The next problem was that the DLT tape drives refused to record. At 0230 on 31 January recording started on the 560 km long Line 1 to the northwest. A computer system crash at 0630, followed by the need to tighten up a pulley on the compressor, led to a cessation of seismic data acquisition until 0944. Things went smoothly though the rest of the day and about 260 km of data had been acquired by midnight.

A major crash of the acquisition system at 0600 on 1 February necessitated a full overhaul of the *StrataVisor*, and the compressor pulley worked loose again. Only at 1430 did acquisition continue on Line 1. Another acquisition crash came at 1925, when a total of 360 km of data had been acquired. After another overhaul of the *StrataVisor* we were recording again at 2100. At 2130 we were continuing northwest along the line at 18º17’S, 154º50’E, in excellent conditions. Seismic acquisition continued uneventfully until the end of Line 1 at 1230 on 2 February, apart from an occasional apparent misfire on one airgun. The acquisition rate for the line was a disappointing 180 km per day, compared to the desired 250 km per day. Parts of the line have been stacked and are of good quality.

At 1230 we went into a large butterfly turn to give us time to haul and repair the guns. The magnetometer (which has huge fluctuations in readings) was hauled in and checked to see whether power was reaching it (it was). The forward gun was pulled down. A small flake from the compressor was in the generator chamber and was believed to have caused the apparent misfires. That proved not to be the case, and we decided to run the 65 km Line 2 to the northeast with a single gun. At 1850 the third stage compressor valve failed, and we looped while the airgun was brought in and overhauled, and the valve replaced. The fourth stage relief valve failed at 2300 during the testing. The fourth stage compressor valve was replaced and the compressor was running again by 0130 on 3 February and we were online at 0340. Compressor problems had us offline at 0400. We were back online at 0725 and the Line 2 was completed at 1008. Production was a disastrous 70 km per day.

After further compressor repairs, the 550 km Line 3 to the southeast started at 1215 on 3 February, but was broken off when the compressor shut down at 1430 for no apparent reason, starting itself again soon afterward. It appears that the apparent misfires from one gun were symptoms of a faulty gun hydrophone, so both guns were employed. We were online again at 1545 and had recorded 130 km of data on the line when the compressor was shut down because of leaks in the second stage at 2030 at 17º21’S, 155º26’E. The weather remained perfect.

Profiling recommenced at 0145 on 4 February, and ended southeast of Mellish Reef at 1045, with 225 km recorded on the line, because of renewed problems in the second stage caused by a burnt out o-ring in a valve. Profiling recommenced at 1620 and ended at 1740 and other failures (machine turning itself off, third stage valve failure) meant that only short pieces of data were acquired until profiling resumed at 2350. Profiling to the east from 18º08’S, 156º32’E, on the modified part B of Line 3, was uneventful until 0507 on 5 February when a fourth stage valve failed. Profiling resumed at 0630 and ended at 1230 when the compressor turned itself off. The cause of this stopping may have been draining of the battery, because the alternator had not been working. Each stop necessitated a battery change. At 1330 we were under way again but at 1535 another compressor stop appears to have been caused by lack of power in the diesel. We restarted profiling at 1715, but the compressor was finally turned off at 1839 on 5 February to end Line 3 at 18º02'S, 158º31'E, meaning that we had recorded 436 km of the planned 550 km on this line. Total production was 1060 km. The weather remained good.

As it was likely to take a couple of days, at least, before seismic could recommence, it was decided to go north to the proposed seismic Line 5, and swath-map and sample northwest along it until the situation was clarified. The hope was that the seismic line could be run later. The magnetometer, the seismic cable and the airguns were brought in and secured by 2050, and we brought speed up to 10 knots at 2140. At 2345 on 5 February, at 17º36'S, 158º43'E, we turned northwest onto the proposed Line 5. After an eight hour run we swath-mapped an area of steep slopes trending northeast on the northern plateau before running Dredge DR12, which recovered thick manganese crusts overlying soft porcellanite from the top of an escarpment in water 2500 m deep at 16º49.9'S, 157º30.9'E, at 1340 on 6 February. A little further south on the same escarpment, dredge DR13 recovered dolerite, vesicular basalt, chert, and large manganese nodules with porcellanite cores at 1825 on 6 February.

Further west, on a similar northeast trending escarpment, at 0350 on 7 February, DR14 recovered quartz gabbro (dolerite), basalt, hyaloclastite, bentonitic mudstone, glauconitic calcareous sandstone and chalk from 2900-2400 m at 16º40.6'S, 157º15.8'E. After a long transit to the northwest, DR15 was almost on the bottom at 1200 to sample another ridge, when problems with the winch control system meant that the dredge had to be brought to the surface. A pilot valve for the tension valve was replaced and the dredge commenced lowering at 1500. DR15 recovered basalt, muddy foram chalk and manganese nodules from 2630 m at 16º10.1'S, 156º34.8'E, at 1852 on 7 February. We then started a long transit to the northwest. During the day we had decided that it was not feasible to get the spare injector pump for the compressor's diesel engine aboard, so no more seismic profiles could be recorded on this survey.

Dredges DR16 and 17 were taken on a southern protrusion of the Louisiade Plateau. DR16 was run up an east-west escarpment to the north, and recovered fine tuff and thick manganese crust from 2550 m at 15º39.5'S, 155º45.3'E, at 0640 on 8 February. After a long transit to the NNE, we dredged DR17 to the south on an east-west escarpment, from 3250 to 3000 m deep at 14º41.6'S, 155º52.2'E. We recovered a large and varied haul: basalt, agglomerate, 'marble', red bed mudstone, grey bioturbated mudstone, green bentonitic claystone and well sorted calcarenite, at 1830 on 8 February.

After a long run to the southwest, dredge DR18 was taken to the northeast up a spur on an irregular slope in a depth of 3300-3200 m, at 15º05.5'S, 155º26.1'E. Basalt and calcareous hyaloclastite were recovered at 0650 on 9 February. We then had a very long transit to the SSW across the easternmost part of the Coral Sea Basin, during which we undertook a 3000 m CTD cast at 15º23.3'S, 155º08.1'E, starting at 1130.

At 0130 on 10 February, dredge DR19 recovered hyaloclastite and manganese nodules from 3700 m depth on a north-facing scarp on the southern flank of the Coral Sea Basin, at 16º10.9'S, 154º34.1'E. Further east on a gentle west-facing scarp of a large block, dredge DR20 failed to recover rocks and probably did not reach bottom at 2850-2650 m depth at 16º54.6'S, 155º15.8'E. The dredge was recovered at 1210 on 10 February and we continued eastward to the eastern side of the block. Dredge DR21 was taken to the NNW up the slope of a plateau and recovered basalt, plus minor basaltic conglomerate and agglomerate, dark red claystone, and laminated calcareous red and grey claystone at 1900, from 1950-1500 m at 17º24.3'S, 155º29.2'E. Core GC04 was taken in a thick Quaternary sequence in a depocentre just west of the block on which Mellish Reef sites. At 1130 on 10 February, 150 cm of foram nanno ooze was recovered from 17º33.2’S, 155º42.6’E.

Dredge DR22 was recovered nearby, from 1700-1300 m depth on the western side of the Mellish block, at 0800 on 11 February at 17º35.7’S, 155º44.8’E. It contained a sequence with basalt lower down and reef limestone (algal boundstone, calcirudite, calcarenite) on top. Dredge DR23 was hung up for some hours on the eastern side of the block before coming free after the shear pin on the dredge broke. The dredge was recovered at 1500 by the safety strop, but only one piece of hyaloclastite and several pieces of manganese crust came back from 2300-2000 m at 17º38.5’S, 156º03.9’E. The damaged dredge was replaced by another one. We then ran two east-west swath lines on the ridge south of Mellish Reef in the search for a shallow dredge target. The pedestal of the reef was visible on the swath data, but was too close to the island for straightforward dredging. We then returned to a slope close to that of DR23, in the hope of dredging both volcanics and limestones. Dredge DR24 was recovered at 2340 from 2200-2000 m depth at 17º40.0’S, 156º03.1’E. It recovered calcarenite, micritic limestone, basalt, volcanogenic conglomerate and muddy calcareous lithic sandstone from the southeast side of the Mellish block.

Dredge DR25 was recovered from southeast of the Mellish block at 0800 on 12 February from 2650-2350 m depth at 18º09.0’S, 156º17.3’E. It contained abundant calcarenite and hyaloclastite. Dredge DR26 was recovered further south at 1700, from 2100-1950 m depth at 18º29.9’S, 156º18.0’E. It contained a huge rounded boulder of basalt with a thick manganese coating, and minor coated lithic conglomerate and sandstone. Dredge DR27 was aimed at a narrow flat-topped ridge further south again and recovered at 2300 from 1800-1650 m depth, at 18º51.8’S, 156º23.1’E. Despite the dredge being hung up, it recovered only one piece of manganese crust, various recently alive organisms including three types of deepwater corals, and calcareous sand. The corals and sand may have come from the upper platform of the ridge.

Dredge DR28 was an attempted repeat of DR27, but never reached the bottom because of strong currents. It was recovered at 0240 on 13 February from 18º51.5’S, 156º23.2’E. We then headed south to Line 1, where we made three sampling attempts on the southeast side of a large block northwest of Selfridge Rise. Dredge DR 29 was aimed at a ridge below the main plateau, and was recovered empty at 1230 from 19º49.8’S, 156º27.7’E. It too had not reached the bottom (despite having the standard 25 % more wire out than the water depth), and we decided to increase wire length in future. Dredge DR30 sampled the slope up to the plateau, and hung up for a considerable time. It recovered a small slab of hard basaltic conglomerate and some calcareous ooze at 1730, from a depth of 2400-2100 m at 19º49.7’S, 156º26.2’S. Dredge DR31 repeated DR29, sampling the small ridge in deep water at a depth of 2600-2450 m at 19º49.8’S, 156º27.6’E. A small haul, recovered at 2145, consisted of calcareous tuff, brown foram-bearing terrigenous mudstone, greenish grey, weakly lithified, nanno foram limey sandstone, calcareous ooze and manganese crust. This suggests that the basaltic plateaus are underlain by older soft sediments.

After a seven hour transit southeast along Line 1 to the Selfridge Rise, dredge DR32 was taken up a steep rise to the north on a northeast trending ridge with terraces, and hung up for some time. Only a little manganese crust was recovered at 0940 on 14 February, from a depth of 1550 m at 20º45.7’S, 157º32.1’E. Dredge DR33 was taken a little to the east on the same ridge, and it hung up for long periods. A piece of hard ferruginous bedded sandstone, containing quartz, lithic fragments and perhaps feldspar, plus a chalk fragment, was recovered at 1445 from a depth of 1800-1700 m at 20º45.9’S, 157º32.3’E. A little quartz-rich metadolerite, cut by fine quartz veins and deformed, plus manganese, was recovered in dredge

DR 34 from 1700 m deep at 20º50.6'S, 157º22.2'E, reinforcing the evidence that Selfridge Rise is continental in origin. Dredge DR35 on the western Selfridge Rise was recovered at 0500 on 15 February from 2200-1950 m depth at 20º36.7'S, 156º43.5'E. It contained hard quartz-rich sandstone, ?bentonitic claystone, pebbly micritic limestone, concretionary micritic mudstone, micritic calcarenite and calcareous ooze.

Dredge DR36 was located on the western side of a block of the Mellish Rise north of the Kenn Reef block, at 2500-2150 m depth at 19º27.6'S, 155º00.3'E. It was recovered at 1715 on 15 February and contained basalt, a little foram-rich calcarenite and foram chalk, a tiny amount of bentonitic clay, and abundant thick manganese crust. Dredge DR37 was taken to the northeast on a block south of Mellish Reef. At 0300 on 16 February it recovered foram-rich chalk and thick manganese crust from 2200 m depth at 18º49.5'S, 155º41.7'E. Dredge DR38 was taken northward up a block south of Mellish Reef. It recovered a handful of basalt and pumice from 2600 m deep at 0830, at 18º38.6'S, 155º19.6'E. Dredge DR39 was taken a little east of DR38. At 1345, it recovered basaltic hyaloclastic conglomerate, containing basalt pebbles in a quartz-bearing matrix of altered glass, and minor calcareous ?tuff from 2400 m deep at 18º37.9'S, 155º23.6'E. Dredge DR40 was taken on a tilted fault block on the same high as DR39 from a depth of 2100-1850 m, at 18º10.8'S, 155º37.6'E, and recovered at 2045 on 16 February. It was a relatively long haul upslope and contained a very varied haul: calcareous conglomerate (fore-reef talus), algal boundstone, weathered calcarenite, vesicular basalt, brecciated vesicular basalt, abundant well-lithified redbed mudstone, weathered red mudstone, hard grey mudstone, greenish grey mudstone and altered mudstone.

Dredge DR41 was taken to the east up the scarp of a guyot, from 1900-1400 m deep and in a relatively long haul centred on 18º10.4'S, 155º15.8'E, and was recovered at 0330 on 17 February. It recovered a large haul of varied rocks: felsic volcanics (dacite, rhyolite, quartz diorite), basalt, volcanics weathered to multicoloured claystone, and the familiar redbed mudstone. Dredge DR42 was taken to the west up a ridge sitting on a plateau, and became seriously hooked up near the starting point. It recovered a moderate haul of basalt, lateritised basalt, foram chalk and grey mudstone from 1600 m deep at 18º09.2'S, 154º53.4'E at 1230. Dredge DR43 was taken to the east up the western slope of the same ridge from 2000-1850 m deep at 18º07.9'S, 154º42.0'E, and was recovered at 1650. It contained a large haul of hard quartz-rich calcareous sandstone, hard cemented calcarenite and friable calcarenite. After travelling WNW for two hours, we deployed gravity corer GC05 in the broad low between two blocks, where the water was 2860 m deep and the sea bed absolutely flat. Unfortunately, we recovered only a few centimetres of very pale brown foram-rich nannofossil ooze from 17º53.98'S, 154º32.99'E, perhaps because there was current-winnowed foram sand at the surface. Dredge DR44 was taken northward up the southeastern slope of the rise connecting Mellish Rise and Queensland Plateau from 2500-2350 m deep, at 17º38.0'S, 154º20.3'E. It was recovered at 0230 on 18 February and contained a small haul of fine grained calcarenite, bentonitic claystone, and manganese nodules and crusts.

We then set course around the southern side of Queensland Plateau with the swath-mapper being used. Because of a misunderstanding with the bridge, the magnetometer was not deployed until 1130 on 18 February. We berthed in Cairns at 0930 on Sunday 20 March.

Technical summary of activities over 26 days

Activity	Timing	Elapsed time	Rate of acquisition
420 km transit from Bundaberg	1030 Jan 25 to 1530 Jan 26	1 day 5 hours	7.7 knots (into high winds)
11 dredges; 3 cores	1530 Jan 25 to 0330 Jan 30	4 days 12 hours	7 hours/station including transits. 3.3 hours/dredge over side
1189 km seismic acquisition	1700 Jan 30 to 1830 Feb 5	6 days 2 hours	9.5 km/hour 200 km/day
33 dredges; 2 cores	1330 Feb 6 to 0230 Feb 18	11 days 14 hours	8 hours/station including transits 3.8 hours/dredge over side
1000 km transit to Cairns	0230 Feb 18 to 1000 Feb 20		9.6 knots (slowed as neared Cairns)
Transits between activities	0330 to 1700 Jan 30; 1830 Feb 5 to 1330 Feb 6	1 day 8 hours	
Total sampling: 44 dredges, 2 cores		16 days 2 hours	8 hours/station including transits

In summary:

1) The seismic program was reduced to one third of the expected kilometres because of the failure of the compressor. Fortunately, two of four critical lines running WNW-ESE were acquired. While in use, data acquisition rates were tolerable and data quality was good.

2) The dredging program was rather slow, and limited by the 12-13 tonne (40 bar) pulling power of the winch with 2000-3000 m of wire out. Of the 44 dredges, 40 recovered something, and 37 (85 %) produced valuable results.

3) The coring program of 5 cores produced three moderately successful cores, but was disappointing overall.

APPENDIX 9. SHIPBOARD PERSONNEL LIST

Scientific contingent

Neville Exon (cruise leader)
George Bernardel (seismic processing and geophysical watch leader)
Kinta Hoffmann (Geological Survey of Queensland, geologist)
Andrea Cortese (swath processing and geology)
Claire Findlay (nannofossil specialist)
Julie Brown (Australian National University, geologist)
Emma Briggs (Sydney University, student)
Jon Stratton (science technician)
Ian Atkinson (science technician)
Franz Villagran (electronics technician)
Craig Wintle (mechanical technician)
Andrew Hislop (mechanical technician)
Don McKenzie (CSIRO, voyage manager)
Bernadette Heaney (CSIRO, computing)
Peter Dunn (CSIRO, electronics)

Ship's crew

Les Morrow (Master)
Bob McManamon (Chief Mate)
Brent Middleton (Second Mate)
Roger Thomas (Chief Engineer)
Rob Cave (First Engineer)
Seamus Elder (Second Engineer)
Tony Hearne (Bosun)
Troy Loveridge (IR)
Russell Williams (IR)
Keith Mitchell (IR)
Fiona Perry (IR)
Peter Williams (Chief Steward)
Patrick Wainwright (Chief Cook)
Ton Beerman (Second Cook)

APPENDIX 10. KEY SURVEY EQUIPMENT

Kongsberg-Simrad EM 300 multibeam sonar swath-mapper

Kongsberg-Simrad Topas PS 18 parametric sub-bottom profiler

Scientific echosounder (12 kHz)

Charge-Air DC330/2000 diesel compressor of 2000 psi capacity for airguns

2 x GI airguns, each of capacity 45/105 cubic inches

Seismic winch

Stealtharray solid seismic cable 550 m long, with 300 m active section and 24 channels

Seismic acquisition system including *Navipak* and *Geometrics StrataVisor NX*

Seismic processing work station

Plotter for seismic profiles and sampling locations

MMC *Seaspy Overhauser* magnetometer and towing winch

Gravity corer, 1 tonne, for 4-6m cores

Dredges, chain bag and pipe

Ship’s winches and deck machinery

Coring cradle

DGPS navigation