GEOSCIENCE AUSTRALIA

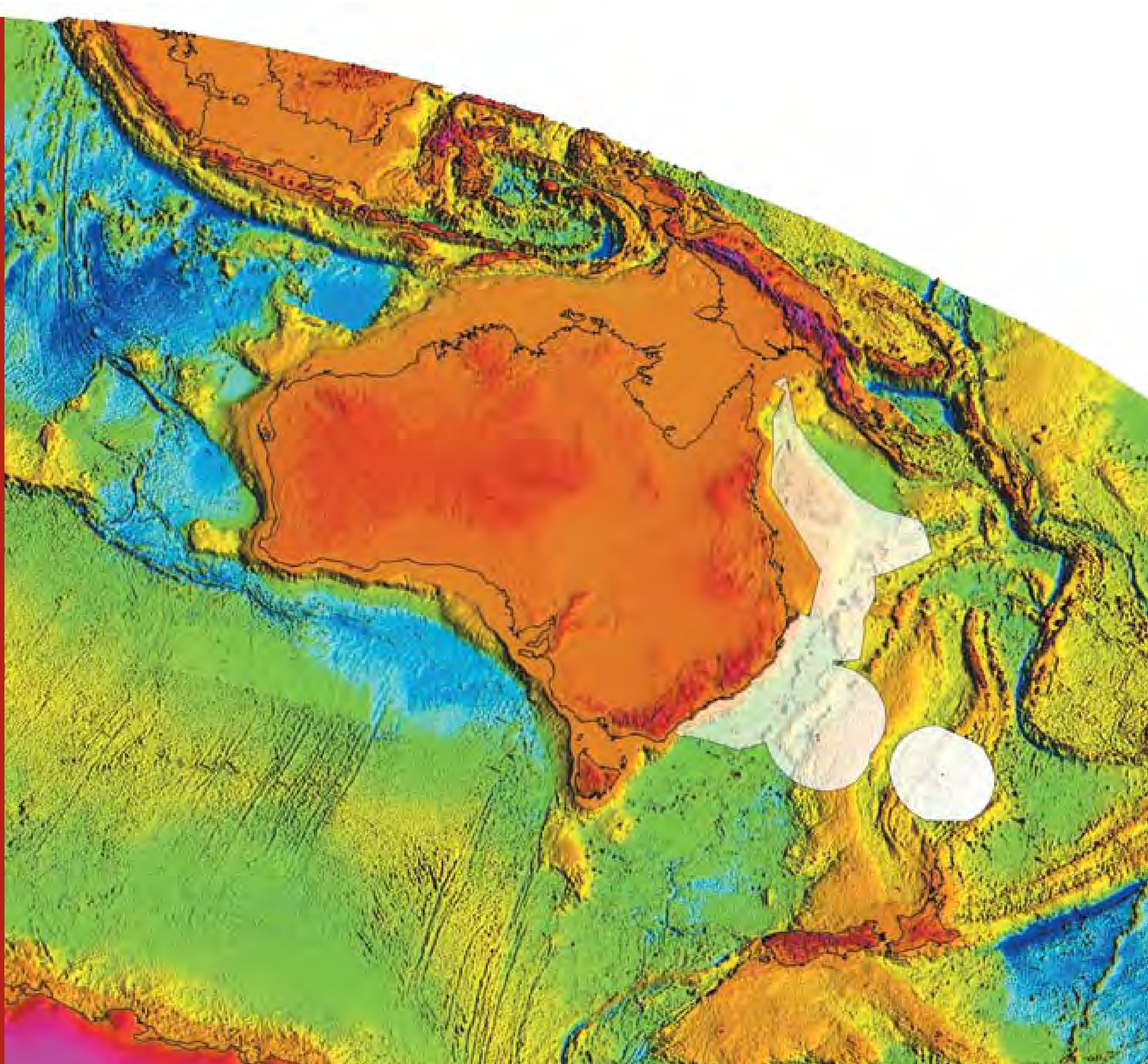
Australian Government
Geoscience Australia

Sedimentology and Geomorphology of the East Marine region of Australia

A Spatial Analysis

Jock Keene, Christina Baker, Maggie Tran and Anna Potter

Record
2008/10



APPLYING GEOSCIENCE TO AUSTRALIA'S MOST IMPORTANT CHALLENGES

Geoscience Australia Record 2008/10

Sedimentology and Geomorphology of the East Marine Region of Australia

Jock Keene, Christina Baker, Maggie Tran and Anna Potter

Geoscience Australia, GPO Box 378, Canberra, ACT 2601, Australia

Australian Government
Geoscience Australia

Department of Resources, Energy and Tourism
Minister for Resources, Energy and Tourism: The Hon. Martin Ferguson, AM MP
Secretary: Dr Peter Boxall AO

Geoscience Australia
Chief Executive Officer: Dr Neil Williams PSM

ISSN: 1448-2177
ISBN Web: 978-1-921236-90-7
ISBN DVD: 978-1-921236-91-4
ISBN Hardcopy: 978-1-921236-92-1

GeoCat No. 65805

Bibliographic reference: Keene, J., Baker, C., Tran, M. and Potter, A., 2008. Geomorphology and Sedimentology of the East Marine Region of Australia. Geoscience Australia, Record 2008/10. Geoscience Australia, Canberra. 262pp.

Correspondence for feedback:
Anna Potter
Geoscience Australia
GPO Box 378
Canberra
ACT 2601

Anna.potter@ga.gov.au

Table of Contents

List of Figures

List of Tables

Acknowledgements

Thanks to those who provided technical and scientific support for the production of this report. Many thanks to David Arnold and the Graphics and Visualisation Team for their outstanding re-production of the figures, the Seabed Mapping and Characterisation Project for information and advice on various aspects of the review and the Palentonology and Sedimentology Labs for analyzing samples. We thank external institutions including: Federal Institute for Geosciences and Natural Resources (BGR) Germany, Lamont Doherty Earth Observatory, James Cook University, Oregon State University, Intergrated Ocean Drilling Program Texas A & M University, Research Centre for Marine Geosciences (GEOMAR) Germany and Lamont-Doherty Earth Observatory for providing sediment samples. We thank the Department of Environment, Water, Heritage and the Arts for their guidance and support for this project. The original text benefited from the thorough reviews of Dr Tony Stephenson and Melissa Fellows of Geoscience Australia and Ben Addison of the Department of Environment, Water, Heritage and the Arts. This record is published with permission of the Chief Executive Officer, Geoscience Australia.

Figure 3.3 and 3.4: Modified from *Journal of Geophysical Research, 103(B6), Gaina, C., Muller, D.R.,Royer, J.Y., Stock, J., Hardebeck, J. and Symonds, P., The History of the Tasman Sea: a puzzle with 13 pieces, pp.12413-12433, copyright (1998),* with permission from the American Geophysical Union.

Figure 3.6: Modified from *Journal of Geophysical Research, 104(B6), Gaina, C., Muller, D.R., Royer, J.Y. and Symonds, P., Evolution of the Louisiade Triple Junction, pp.12927-12939, copyright (1999),* with permission from the American Geophysical Union.

Figure 3.13 and 3.19: Reprinted from *Fraser Island and Hervey Bay – a classic modern sedimentaryenvironment, Boyd, R., Ruming, K., Davies, S., Payenberg, T. and Lang, S.In: Boult, P.J., Johns, D.R. and Lang, S.C. (Editors), Eastern Austrlalasian Basins Symposium II, Petroleum Exploration Society of Australia, Special Publication, pp.551-521, copyright (2004),* with permission from the Geological Society of Australia.

Figure 3.15 and 3.20: Modified from *Quaternary and Tertiary subtropical carbonate platformdevelopment on the continental margin of southern, Queensland, Australia, 25, Marshall, J.F., Tsuji, Y., Matsuda, H., Davies, P.J., Iryu, Y., Honda, N., and Satoh, Y., In: Camoin, G.F. and Davies, P.J. (Eds.), Reefs and Carbonate Platforms in the Pacific and Indian Oceans, pp.163-195, copyright (1998),* with permission from Wiley-Blackwell Publishers.

Figure 3.46: Modified from *AAPG Memoir, 81, A Neogene carbonate platform, slope and shelf edifice shaped by sea level and ocean currents, Marion Plateau (northeast Australia), Isern, A.R., Anselmetti, F.S. and Blum, P., In: Eberli, G.P., Masaferro, J.L. and Sarg, J.F.R. (Editors), Seismic imaging of carbonate reservoirs and systems, pp.291-307, copyright (2004),* with permission from the Ocean Drilling Program, US Government Printers.

Executive Summary

This report contains a review of literature and the results of a study of the sedimentology and geomorphology of the East Marine Region (EMR). The study is a collaboration between Geoscience Australia and the Department of the Environment, Water, Heritage and the Arts (DEWHA). Data generated by this study expands the national fundamental marine samples dataset for Australia's marine jurisdiction, with analyses completed on samples from the EMR consistent to those completed on samples from other regions. Information contained in this report will contribute to Geoscience Australia's national work program through the creation of seascapes (surrogates for seabed habitats) for the EMR, and may be used by the Department of the Environment, Water, Heritage and the Arts to provide data to assist marine bioregional planning.

Geoscience Australia is the national repository and custodian of marine sediment data and has developed a national marine samples database (MARS; http://www.ga.gov.au/oracle/mars) that is a fundamental marine dataset for the Australian margin. This study has significantly improved the distribution of quantitative textural and composition data stored in MARS for the EMR. The principal aim of this study is to provide a regional assessment of the sedimentology and geomorphology of the EMR with the following three objectives devised:

1. Analyse seabed sediment samples (nominally 100) for quantitative grainsize distribution and carbonate content;
2. Identify sources of marine sediment samples and populate MARS with the data; and
3. Produce a report synthesizing and summarizing the oceanography, tectonic history, late Quaternary evolution, geomorphology and sedimentology of the EMR based on these data and previous literature.

Results of the analyses are presented as a regional synthesis, within the framework of the Integrated Marine and Coastal Regionalisation of Australia (IMCRA) and National Bioregionalisation of Australia 2005, and where possible within the constraints of geomorphic features identified in a recent study of the geomorphology of the Australian margin by Heap and Harris (in press). Reporting the results in this way provides both an up-dated and quantitative analysis of the regional sedimentology from previous work, and characterises the broad-scale management zones designed to support marine bioregional planning. Characterising sedimentology by geomorphic feature allows the resolution of relationships between feature and sediment type.

Oceanography, tectonic history, late Quaternary evolution and geomorphology have established the sedimentary setting for the eastern Australian margin. Fourteen bioregions occur within the EMR. Productivity is generally low due to a lack of widespread upwelling. The Southern Tropical Convergence and the Tasman Front are water mass boundaries that occur in the EMR. The East Australian Current (EAC) is the principal current and affects the composition and texture of bottom sediments on the outer shelf and upper slope. Long-shore drift of inner shelf sediments to the north is significant compared to other margins. There is also evidence for present-day deep-water currents eroding and depositing sediments. Sea level changes during the Quaternary mostly affected the shelves and coral reefs, though the associated changing climatic-oceanographic conditions are also preserved as cycles in the deep-sea sedimentary record.

The first-order geomorphic features in the EMR are fault-bounded slopes, ridges and plateaus with steep lower slopes. This reflects the nature of the continental breakup into tectonic blocks by faulting in the late Cretaceous. Rifting and seafloor spreading formed the abyssal troughs and basins between these continental blocks and enabled large canyons to be cut on the slopes. Volcanism since the cessation of spreading has produced numerous volcanic edifices of basalt, some with over 4 km of relief. Active erosion by gravity on the slopes over geologic time has formed slump scars, canyons and valleys of all sizes and relatively low rates of sedimentations have draped, but not buried, these features. Since the Miocene, calcareous organisms have constructed large limestone platforms, particularly on the Queensland and Marion Plateaus.

The regional sedimentology is dominated by marine carbonates. The EMR extends from a tropical carbonate margin in the north to a mixed terrigenous-carbonate margin in the south that comprises shelf, slope, rise and deep ocean floor. Pelagic sedimentation dominates seaward of this margin on plateaus, seamounts, volcanic ridges and abyssal plain/deep ocean floor. Sediment texture and composition show a broad zoning with water depth due to changing sources, depositional processes and solution of carbonate with depth. The main sedimentary trends of the EMR are:

- The most extensive sediments are unconsolidated pelagic carbonate oozes on the plateaus, seamounts and slopes;
- Calcareous silts and clays occur at abyssal depths due to dissolution of most of the carbonate;
- Significant areas of Mn-nodules probably occur at abyssal depths.
- Living and/or fossil carbonate platforms/atolls/banks are significant as geomorphic features and producers of neritic carbonate sediment.
- Limestone platforms are significant on plateaus, ridges, faulted basement highs, volcanic seamounts and on the outer shelf.
- Quartz and clay minerals derived from terrigenous sources are significant components of the sediment along the Australian continental margin. But even here, with the exception of the inner shelf, the carbonate remains of benthic and planktic biota dominate.
- Due to current and wave energy the sediments are coarsest on the inner and outer shelf with finer sands and muds on the mid shelf and slope. Sand also occurs in deep-sea channels, troughs and on ridges where currents are active.
- Banks, mounds and 'hardgrounds' occur on the outer shelf/upper slope where seabed sediments are lithified by carbonate, phosphate and iron oxide minerals.
- Outcrop and boulder/scree material of basement rocks (both sedimentary and igneous) are common on slopes, seamounts, ridges and canyon sides. These rocks are often coated with Fe-Mn crusts up to twenty centimeters thick, depending on the length of time they have been exposed.

Significant outcomes of this study include:

- Production of the most up-to-date and comprehensive representation of the seabed sedimentology for the eastern Australian margin, building on existing regional sediment models;

- Production of a detailed synthesis and review of literature for the EMR;
- Quantification of regional seabed sediment characteristics and distribution in the EMR, and assessment of the sediment variability at a EMR, bioregion and geomorphic feature level;
- Production of a robust, consistent quantitative dataset that permits defensible quantitative comparisons of the seabed sedimentology to be made between the eastern margin and the whole Australian margin; and
- Recognition and quantification of the spatial heterogeneity of seabed sedimentology within the EMR that can be linked to seabed habitat complexity. Capturing the spatial heterogeneity of the seabed sedimentology will allow more accurate and precise mapping of seabed habitats (seascapes), and aids in more effective future sampling strategies.

A principal application of the study is to support research into the associations between physical seabed properties such as sediment texture and composition and the distribution of benthic marine habitats and biota. This research contributes to Geoscience Australia's work on the spatially representation of benthic marine habitats and biota for Australia's vast marine jurisdiction. This work is crucial for developing robust, defensible methods of mapping habitats using spatially abundant physical data combined with site-specific biological data and over thousands of kilometres.

1. Introduction

1.1. BACKGROUND

This report presents the geomorphology and sedimentology of the East Marine Region (Fig. 1.1). The three main outputs of the report include: 1) a review of previous geological research undertaken in the East Marine Region (EMR); 2) the results of a quantitative study of seabed sediment texture and composition for these regions; and 3) a synthesis of this information characterizing regional trends in sedimentology, geomorphology and bathymetry. The study is a collaboration between Geoscience Australia and the Department of the Environment, Water, Heritage and the Arts (DEWHA) and is a continuation of similar work conducted for the North West Marine Region (Potter et al., in press; Baker et al., 2008) and the South West Marine Region (Richardson et al., 2005). By combining results of previous qualitative work and quantitative information generated from existing and new data, this report provides an improved understanding of sedimentology for the EMR. Information contained within this report will contribute to the Department of the Environment, Water, Heritage and the Arts national work program and will also assist in the marine bioregional planning for the East Marine Region.

Previous sediment studies in the EMR have predominantly produced qualitative results at local scales. Geomorphic, sedimentary and biological information has previously been utilised to develop a National Bioregionalisation of Australia's Exclusive Economic Zone (EEZ) (Department of the Environment and Heritage (National Oceans Office), 2005; now the Department of the Environment, Water, Heritage and the Arts) and substantive geomorphic features of the eastern continental margins have already been identified and mapped (Heap and Harris, in press-a). This report adds significantly to these previous studies by incorporating the information in a sedimentological synthesis that includes a discussion of the implications for marine conservation in the EMR.

The physical characteristics of the seabed in the EMR, as described by the sediment texture and composition data, can assist in determining the diversity of benthic marine habitats in the EMR. These data represent enduring features which are elements of the physical environment that do not change considerably and they are known to influence the diversity of biological systems. This is important for marine conservation by contributing to the better definition and characterisation of benthic habitats. Seabed texture and composition are easily measurable parameters that when combined with other physical features can be used to create "seascapes" that serve as broad surrogates for benthic habitats and biota (Whiteway et al., 2007). Seascapes have the potential to be used in informing the marine bioregional planning process.

1.2. SCOPE

1.2.1. Generation and Synthesis of Seabed Information for the EMR

In April 2007, Geoscience Australia and the DEWHA agreed to undertake a collaborative project to identify, analyse and collate existing information on the texture and composition of the seabed in the EMR. The main objectives of this project were to:

- Identify and summarise all previous geological information for the EMR;

- Procure and analyse sediment samples (nominally 100) from the EMR, currently held by Geoscience Australia and other marine science institutions, for grain size and carbonate concentrations;
- Provide data on the texture and composition of the seabed for the EMR to populate Geoscience Australia's national marine samples database (MARS; www.ga.gov.au/oracle/mars) with the data; and
- Produce a report synthesising and summarising the sedimentology and geomorphology of the seabed for the EMR in support of marine bioregional planning and creation of a national system of representative marine protected areas.

Texture and composition data generated from this project will be combined with other physical data on the seabed (i.e., depth, geomorphology, sediment mobility, etc) to create "seascapes" that represent major ecological units based on measurable, recurrent and predictable features of the marine environment.

1.2.2. Expected Project Outcomes

The expected outcomes of this project are:

- To obtain a better understanding of the nature of the seabed for the eastern margin of Australia;
- To improve the available information on the sedimentology of the EMR for the scientific and planning communities, leading to the development of more effective plans for marine conservation sustainable development; and
- To improve access to data on the nature of the seabed through continued population of the MARS database as a national fundamental marine dataset.

1.2.3. Products and Outputs

Key outputs of this project will be:

- 100 quantitative textural and compositional data points for the EMR and associated metadata available in the MARS database;
- A review and synthesis of previous geological information for the EMR (Chapter 3);
- Quantitative analyses of the sedimentology and geomorphology of the EMR (Chapters 4, 5 and 6);
- A synthesis of all previous and new sediment information for the EMR at planning region and bioregion (as defined by DEWHA) scales (Chapters 4, 5 and 6);
- An interpretation of sediment information and discussion of the significant findings and their implications for Marine Bioregional Planning (Chapter 6); and
- A series of web-accessible digital maps to standards appropriate for data coverage and sediment properties in the EMR (Appendix G).

1.3. MARINE REGIONS AND BIOREGIONS

The benthic component of the NMB 2005 management framework consists of a hierarchical set of geographic management units. Below the scale of the major ocean basins that comprise Australia's marine jurisdiction (i.e., the Indian, Southern and Pacific Oceans), the shelf, slope, rise and abyssal plain/deep ocean floor are designated as Primary Bathymetric Units that represent the broadest-scale planning unit, and have areas of several million km^2. Within each of the Primary Bathymetric Units are Provincial Bioregions, which have been defined mainly by the distribution of demersal fish, bathymetry, and geomorphology, and have areas of hundreds of thousands of km^2. The Provincial Bioregions are the principal planning unit for Marine Bioregional Planning. Marine bioregional plans will be developed for each of Australia's five marine regions including the EMR.

1.3.1. The East Marine Region (EMR)

The EMR adjacent to Australia includes the seabed and water column from the coastline and the boundary of the Great Barrier Reef Marine Park to the 200 nautical mile limit drawn from the territorial sea baseline, and from Bermagui in southern New South Wales to Torres Strait in the north. In addition it includes the EEZ around Lord Howe Island, Middleton and Elizabeth Reefs and the EEZ around Norfolk Island (Fig. 1.1). This region comprises 2.5 million km^2 of ocean and seabed and abuts the coastal waters of New South Wales and Queensland. The EMR represents around 27% of the Australian Economic Exclusive Zone (AEEZ) and includes an area of 400 km^2 with water depths <10 m which represents islands and reef zones and has been excluded from our assessment.

1.3.2. EMR Bioregions

The EMR comprises 14 bioregions (Figure 1.2; Table 1.1). The EMR contains part of the Central Eastern Shelf Province, part of the Central Eastern Shelf Transition, and part of the Southeast Shelf Transition. This province and transitions are located on the shelf. Water depths in the Shelf bioregions are between 10 m and 350 m, but are generally <150 m.

Table 1.1. Summary details of the provincial bioregions contained in the EMR.

Bioregion	% of bioregion included in EMR	Water type	% of total EMR area
Cape Province	56	Tropical Waters	3
Central Eastern Shelf Province	76	Warm Temperate Waters	1
Central Eastern Shelf Transition	55	Transition	1
Central Eastern Province	88	Warm Temperate Waters	9
Central Eastern Transition	69	Transition	2
Kenn Province	100	Tropical Waters	2
Kenn Transition	100	Transition	15
Lord Howe Province	100	Warm Temperate Waters	20
Northeast Province	93	Tropical Waters	17
Northeast Transition	88	Transition	5
Southeast Shelf Transition	7	Transition	<1
Southeast Transition	4	Transition	<1
Norfolk Island Province	100	Warm Temperate Waters	18
Tasman Basin Province	100	Warm Temperate Waters	6

The EMR also contains the Cape Province, Central Eastern Province, Central Eastern Transition, Kenn Province, Kenn Transition, Lord Howe Province, Northeast Province, Northeast Transition, Southeast Transition, Norfolk Island Province and Norfolk Island Transition (Table 1.1). These provinces and transitions cover the slope, the rise, plateaus, seamounts and abyssal plain/deep ocean floor. They are bounded by the shelf break and water depths vary from 150 m to over 5,000 m.

Full details of the bioregions are presented in Chapter 5. To support marine bioregional planning in the EMR, the results of this study are discussed in the context of the provincial bioregions, and data are presented for individual bioregions.

1.4. REPORT AIMS AND STRUCTURE

The aim of this report is to provide a regional assessment of the sedimentology and geomorphology of the EMR. The report is structured into three broad sections: First, the existing sedimentology and geomorphology of the EMR is described and reviewed to provide a framework for new data (Chapter 3). The second section presents a regional scale spatial analysis of the sedimentology and geomorphology for the EMR (Chapter 4). The third section provides a spatial analysis of the sedimentology and geomorphology for each provincial bioregion occurring in the EMR. This section (Chapter 5) puts the new data into the context of the planning zones used by DEWHA. Lastly, results of this study and previous work in the EMR are summarised and discussed in terms of their implications for marine planning (Chapter 6).

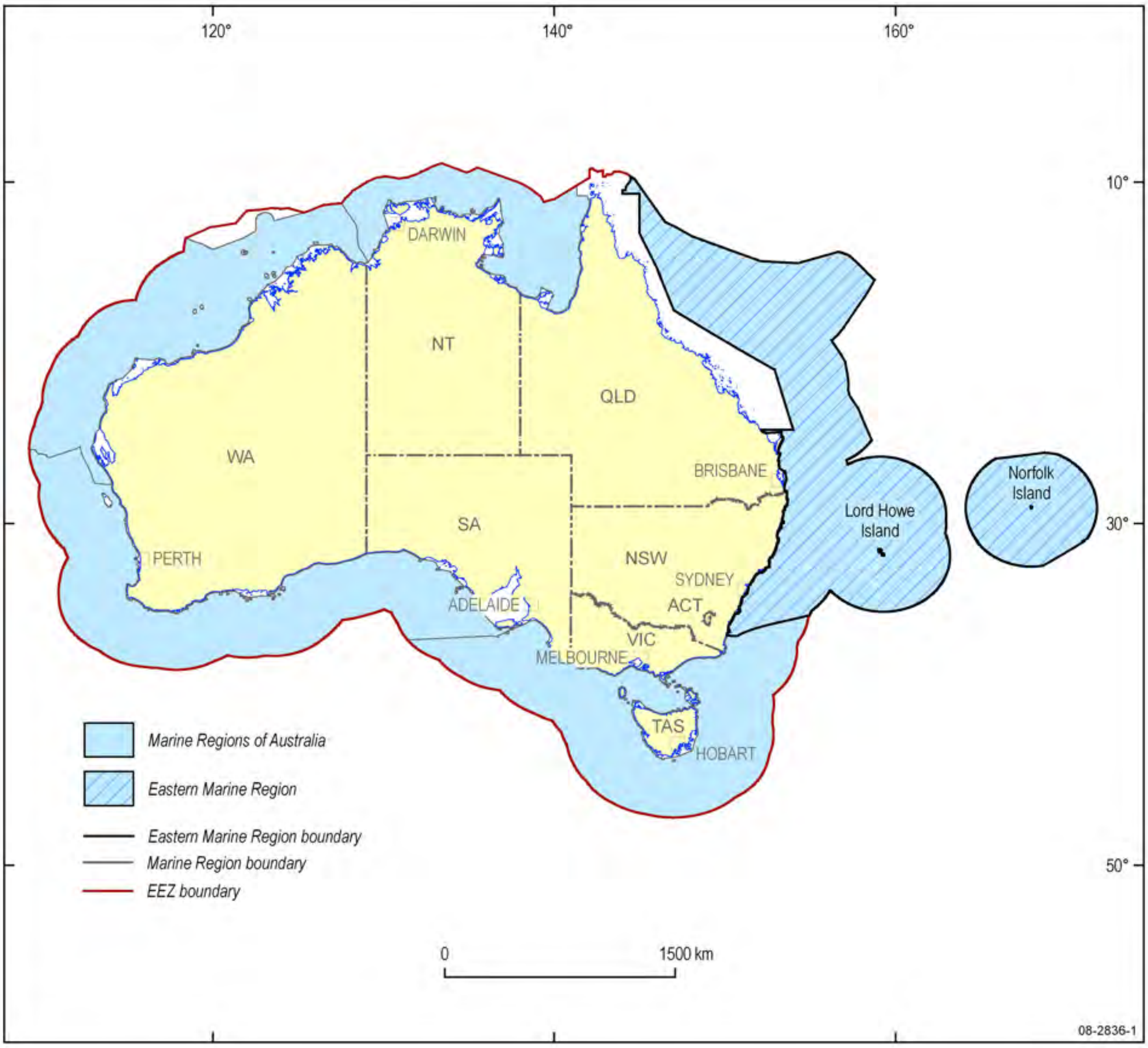


Figure 1.1. Map showing the boundaries of the East Marine Planning Area as defined by the Department of the Environment, Water, Heritage and the Arts. The boundaries extend from the Torres Strait in the north to Montague Island in the south excluding the Great Barrier Reef Marine Park but including other reefs and the islands of Lord Howe and Norfolk. The area encompasses the ocean and seabed from the coast out to the limits of the Exclusive Economic Zone (EEZ).

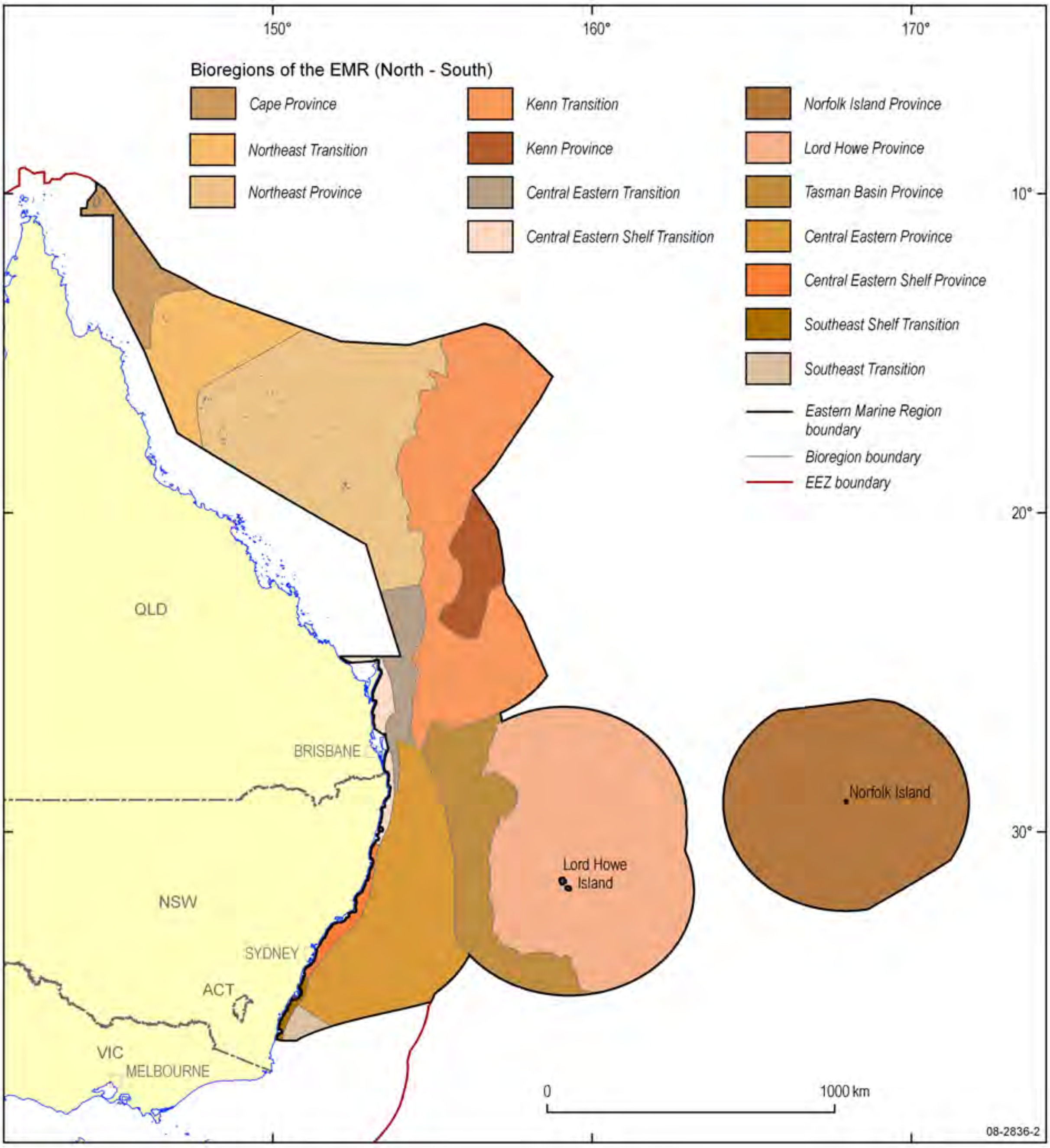


Figure 1.2. Map showing the bioregions of the East Marine Region as defined by the Department of the Environment, Water, Heritage and the Arts.

2. Data and Methods

This chapter outlines the available physical data sets for the EMR and the process of acquiring additional sediment samples to fill gaps in data coverage. Chapters 2.1 – 2.3 provide details of existing quantitative physical data sets for the EMR that have been used in this study and pre-existing sediment data. Chapters 2.4 – 2.7 discuss the procedure for identifying (from both internal and external data repositories), selecting and procuring samples, and generating grainsize and carbonate data. All metadata and assays for samples used to describe quantitative sediment distribution in the EMR are contained in Geoscience Australia's marine samples database, MARS.

2.1. EXISTING PHYSICAL DATA FOR THE EMR

2.1.1. Bathymetry

Bathymetric data for the EEZ and all smaller divisions within it were derived from classifications of the Australian Bathymetry and Topography Grid (June 2005). The grid is a synthesis of 1.7 billion observed data points and resolution at any point is equal to or better than 250 m. It provides full coverage of Australia's EEZ including areas under Australian jurisdiction surrounding Macquarie Island, and the Australian Territories of Norfolk Island, Christmas Island, and Cocos (Keeling) Islands. The area selected does not include Australia's marine jurisdiction off of the Territory of Heard and McDonald Islands and the Australian Antarctic Territory.

Water depths for individual sample data points and ranges for data points were sourced from original survey documentation. The metadata for these sample points did not include water depths for around 30% of the total data points used in this study. Depths for these points were generated by intersecting point data with the Australian Bathymetry and Topography Grid.

2.1.2. Geomorphology

In 2004, a collaborative agreement between Geoscience Australia, CSIRO – Marine and Atmospheric Research, and the then Department of the Environment and Heritage (National Oceans Office), created a National Marine Bioregionalisation (NMB 2005) of Australia (Department of the Environment and Heritage, 2005). The NMB 2005 provides an over-arching management framework for a large part of Australia's marine jurisdiction, and is based on the most up-to-date knowledge of the biophysical properties of Australia's marine environment, including seabed geomorphology and sedimentology. Definitions of geomorphic provinces and features included in the NMB 2005 and used in the spatial analyses in this study are listed in Table 2.1.

Geomorphic province and feature boundaries for the EEZ and all smaller divisions within it were derived from a recent study of the geomorphology of Australia's margin and deep seafloor (Heap and Harris, in press). These boundaries were delineated using the 250 m bathymetry grid and previous local seabed studies. Feature names are based on those endorsed by the International Hydrographic Office (IHO 2001). Features are nested within larger geomorphic provinces of shelf, slope, rise and abyssal plain/deep ocean floor.

Table 2.1. List of geomorphic provinces and features represented in the NWMR (Heap and Harris, in press). Original definitions are adapted from IHO (2001), except for sand waves and sand banks, which are from Ashley et al. (1990).

No.	Name	Definition
Geomorphic Provinces		
-	Shelf	Zone adjacent to a continent (or around an island) and extending from the low water line to a depth at which there is usually a marked increase of slope towards oceanic depths.
-	Slope	Slope seaward from the shelf edge to the upper edge of a continental rise or the point where there is a general reduction in slope.
-	Rise	Gentle slope rising from the oceanic depths towards the foot of a continental slope.
-	Abyssal Plain/ Deep Ocean Floor (AP/DOF)	Extensive, flat, gently sloping or nearly level region at abyssal depths.
Geomorphic Features		
1	Shelf (unassigned)	Area of Shelf Geomorphic Province in which no other geomorphic features have been identified
2	Slope (unassigned)	Area of Slope Geomorphic Province in which no other geomorphic features have been identified
3	Rise (unassigned)	Area of Rise Geomorphic Province in which no other geomorphic features have been identified
4	AP/DOF* (unassigned)	Area of Abyssal Plain/ Deep Ocean Floor Geomorphic Province in which no other geomorphic features have been identified
5	Bank/shoal	Elevation over which the depth of water is relatively shallow but normally sufficient for safe surface navigation. Offshore hazard to surface navigation that is composed of unconsolidated material.
6	Deep/hole/valley	Deep: In oceanography, an obsolete term which was generally restricted to depths greater than 6,000 m. Hole: Local depression, often steep sided, of the seabed Valley: Relatively shallow, wide depression, the bottom of which usually has a continuous gradient. This term is generally not used for features that have canyon-like characteristics for a significant portion of their extent.
7	Trench/trough	Trench: Long narrow, characteristically very deep and asymmetrical depression of the seabed, with relatively steep sides. Trough: Long depression of the seabed characteristically flat bottomed and steep sided and normally shallower than a trench.
8	Basin	Depression, characteristically in the deep seabed, more or less equidimensional in plan and of variable extent.
9	Reef	Rock lying at or near the sea surface that may constitute a hazard to surface navigation.

10	Canyon	A relatively narrow, deep depression with steep sides, the bottom of which generally has a continuous slope, developed characteristically on some continental slopes.
11	Knoll/abyssal hills /hill/mountains/peak	Knoll: Relatively small isolated elevation of a rounded shape. Abyssal Hills: Tract, on occasion extensive, of low (100-500 m) elevations on the deep seabed. Hill: Small isolated elevation. Mountain: Large and complex grouping of ridges and seamounts. Peak: Prominent elevation either pointed or of a very limited extent across the summit.
12	Ridge	(a) Long, narrow elevation with steep sides. (b) Long, narrow elevation often separating ocean basins. (c) Linked major mid-oceanic mountain systems of global extent.
14	Pinnacle	High tower or spire-shaped pillar of rock or coral, alone or cresting a summit. It may extend above the surface of the water. It may or may not be a hazard to surface navigation.
15	Plateau	Flat or nearly flat area of considerable extent, dropping off abruptly on one or more sides.
16	Saddle	Broad pass, resembling in shape a riding saddle, in a ridge or between contiguous seamounts.
17	Apron/fan	Apron: Gently dipping featureless surface, underlain primarily by sediment, at the base of any steeper slope. Fan: Relatively smooth, fan-like, depositional feature normally sloping away from the outer termination of a canyon or canyon system.
19	Sill	Seabed barrier of relatively shallow depth restricting water movement between basins.
20	Terrace	Relatively flat horizontal or gently inclined surface, sometimes long and narrow, which is bounded by a steeper ascending slope on one side and by a steeper descending slope on the opposite side.
21	Tidal sandwave/sand bank	Sandwave: Wave-like bed form made of sand on the sea bed. Sand bank: Submerged bank of sand in a sea or river that may be exposed at low tide.

2.1.3. Sediment Data

A total of 744 samples with quantitative textural and/or compositional sediment data were available in the MARS Database prior to this study for the EMR. These sample locations contained bulk carbonate, grainsize (Wt%; µm) and/or laser grainsize (Vol%; µm) data. The samples were sourced from 17 marine surveys conducted between 1970 and 2006 (Table 2.2), and consist of dredge, grab and core samples. Samples that occur outside of the EMR were included to supplement scarce data for the abyssal plain /deep ocean floor and slope to improve representation of geomorphic features and capture the full spectrum of environments.

All sample and assay data was quality controlled and those samples that failed to meet the minimum metadata standards outlined in Geoscience Australia's Data standards and validation in AGSO

(Lawford, 2000) were excluded from the analysis. Only analyses conducted on dredges, grabs or the top 0.1 m of a core and where the gravel, sand and mud fractions totalled 100% +/- 1% were included. Core samples that did not include depth measurements were also excluded and duplicates were removed. Ongoing quality control of data may have resulted in slight variations between total samples reported in this document and milestone progress reports.

Table 2.2. Metadata for sediment samples with either carbonate and/or grainsize data in the EMR in MARS database following the task.

Survey Name	Vessel	Year	Sample Types	No. of Samples
Geoscience Australia				
Southern Barrier Reef & Northern Tasman Sea	San Pedro Strait	1970	Pipe dredge	113
Tasman Sea and Bass Strait	San Pedro Strait	1972	Pipe dredge	141
North East Australia 1	Rig Seismic	1985	Dredge	2
North Eastern Australia Heat Flow	Rig Seismic	1986	Piston & gravity core	8
East Australia Phosphates	Rig Seismic	1987	Gravity core	17
North East Australia 3	Rig Seismic	1987	Gravity core & dredge	10
North East Australia 4	Rig Seismic	1987	Gravity & piston core & dredge	12
Southern Queensland Margin	Rig Seismic	1991	Gravity core, dredge & grab	207
Continuous Geochemical Tracers	Rig Seismic	1992	Gravity and vibro core	15
Southern Surveyor 5/2004	Southern Surveyor	2004	Dredge	11
Geology and Tectonic Evolution of Mellish Rise	Southern Surveyor	2005	Gravity core & dredge	17
NSW Continental Slope Survey	Southern Surveyor	2006	Gravity core	12
CSIRO				
Sedimentation at Fly River/ North Great Barrier Reef Junction, Gulf of Papua	Franklin	1993	Grab	1
Lamont Doherty Earth Observatory				
Vema Cruise 16, Leg 9	Vema	1960	Piston core	2
Conrad Cruise 10, Leg 6	Robert D Conrad	1966	Piston core	2
Vema Cruise 24, Leg 7 & 8	Vema	1967	Piston core	16
Conrad Cruise 12, Leg 4 & 5	Robert D Conrad	1968	Piston core	2

Vema Cruise 33, Leg 14	Vema	1977	Piston core	1
Macquarie University				
Surficial Sediments between Broken Bay and Botany Bay	Matthew Flinders	1975	Dredge	56
Ocean Drilling Program				
Ocean Drilling Program, Leg 133 & 194	Joides Resolution	1990	Core (unspecified)	18
Oregon State University				
Global Expedition of RV Oceanographer	Oceanographer	1967	Piston core	5
SEAMAP				
SEAMAP 1-86 & 17-86	Unknown	1986	Gravity core	12
SEAMAP 12-87	Unknown	1987	Gravity core	4
Scripps Institute of Oceanography				
LUSIAD Leg 5, NOVA Leg 4 & 5	Horizon	1963	Gravity core	13
Sydney Water Board				
Trace Contaminants in Surficial Sediments adjacent Sydney	15+ m unnamed small boat	1990	Grab	188

2.2. PREVIOUS DATA COVERAGE OF THE EMR

Prior to this study, the majority of samples within the EMR were located from the shelf and upper slope in the south west of the region within the Central Eastern Shelf Transition, Central Eastern Shelf Province, Southeast Shelf Transition, Central Eastern Province and the southern part of the Central Eastern Transition. Sparse sample coverage also existed for the remainder of the Central Eastern Province and the Lord Howe Province (Fig. 2.1). Other bioregions in the EMR contained <3 samples each. A total of 680 of the 744 pre-existing sediment samples in the EMR were located on the NSW shelf and 732 pre-existing samples were located in water depths <1,000 m. Shelf (unassigned), slope (unassigned) and shallow water terraces contained the most number of samples, while significantly fewer samples occurred in abyssal plain/deep ocean floor (unassigned), trench/trough, canyon, plateau, and saddle features. Prior to this task no samples were available for rise, deep/hole/valley, basin and seamount/guyots features in the EMR.

Highest sample density occurred on the shelf in the Central Eastern Shelf Transition, Central Eastern Shelf Province and Southeast Shelf Transition and on areas of the upper slope in the Central Eastern Province and Central Eastern Transition. In these areas, most samples occur within 0-0.025 km of the nearest sample. No samples were located in the Kenn Province and Kenn Transition.

New sample data has significantly improved the sample coverage of the Cape Province, Lord Howe Province, Northeast Province and Northeast Transition, and has provided the first quantitative data for the Kenn Province and Kenn Transition.

2.3. ASSESSMENT OF SIGNIFICANT GAPS IN EXISTING SAMPLE COVERAGE FOR THE EMR

The relationship between data coverage and the other physical variables determines the accuracy of the final interpretations of sediment distribution. The EMR contains areas where samples, for various reasons, provided insufficient coverage to estimate sediment distribution. Recognition of these gaps was used to guide sample selection for this study. A targeted approach for one addition of sediment data allows for more efficient improvement in sediment information for the EMR in the short to medium term. Similar assessment of gaps in data coverage resulting from this task (Chapters 4 & 5) will be used to guide sample collection/procurement in the future.

Three types of data gaps were identified and used to guide sample procurement for this study, namely:

- Gaps in spatial coverage. This was determined by mapping the data density across the EMR, and identifying areas in the Provincial Bioregions, Primary Bathymetric Units and Geomorphic Features where the least samples existed.
- Gaps in spatial coverage of specific features. An assessment of the distribution of samples within the area of a Provincial Bioregion, Primary Bathymetric Unit or Geomorphic Feature was conducted by assessing the coverage of the number of separate occurrences of the feature and degree to which samples are clustered within these. This determined whether assays are likely to be representative of the range and relative proportion of sediment types.
- Knowledge gaps are not always directly related to sample density. Conceptual understanding of seabed morphology in different geomorphic features and high resolution information derived from local studies and seabed images means that we can estimate the sample spacing required to map actual variations in seabed character to a given resolution. Comparison between this required sample density and the density of existing data can be used to identify areas where data are inadequate to estimate sediment properties.

2.4. SAMPLE IDENTIFICATION IN THE EMR AND SELECTION FOR ANALYSIS

2.4.1. Sample Identification

MARS database

Approximately 2,000 samples without quantitative grainsize and 4,000 samples without quantitative carbonate assays were stored in the MARS database prior to this study. The majority of these samples are located on the NSW shelf. More than 1,000 of these are contained in Geoscience Australia's archives. The remaining samples are located in external institutions such as BGR Germany, Lamont Doherty Earth Observatory, James Cook University, Oregon State University, Scripps Institute of Oceanography, Integrated Ocean Drilling Program data repository or contain inadequate sample volumes for analysis. A large number of samples for the EMR are currently stored in the Natural

History Museum, London. Of the samples contained in Geoscience Australia's archives 82 were sub-sampled and analysed for the task.

External Databases

Of the samples identified in external data repositories, 59 were selected that contained adequate sample volumes and filled spatial gaps in the data coverage of the EMR. These samples were located at four international institutions, namely: Oregon State University, Integrated Ocean Drilling Program Texas A&M University, Scripps Institute of Oceanography and Lamont-Doherty Earth Observatory.

2.4.2. Sample Selection

A total of 141 samples were selected for analysis for this study based on the gap analysis. These consisted of core, dredge and grab samples collected on 16 surveys conducted between 1960 and 2005 (Table 2.3). Selected samples include 82 from the Geoscience Australia data repository and 59 from external repositories.

Significant data gaps were identified in the Cape Province, Kenn Province, Kenn Transition, Lord Howe Province, Norfolk Island Province, Northeast Province, Northeast Transition, Southeast Transition and Tasman Basin Province. Sediment samples increase coverage of all bioregions except for the Southeast Transition and shelf bioregions where previous sample coverage was high.

Significant spatial data gaps were identified in deep water areas especially in water depths of >3,000 m. The addition of samples to deep water geomorphic features, including the lower slope, basin, and trench/trough has significantly improved the representation of deep water environments. While this study has improved the sample coverage of geomorphic features within the EMR, significant gaps still exist. No samples are currently available that represent bank/shoal, reef, knoll/abyssal hills/hill/mountains/peak, ridge, pinnacle, and apron/fan within the EMR. Eleven samples have been collected in deep water areas beyond the EMR boundary and these have been used to help characterise the sedimentology of the abyssal plain/deep ocean floor and lower slope within the EMR.

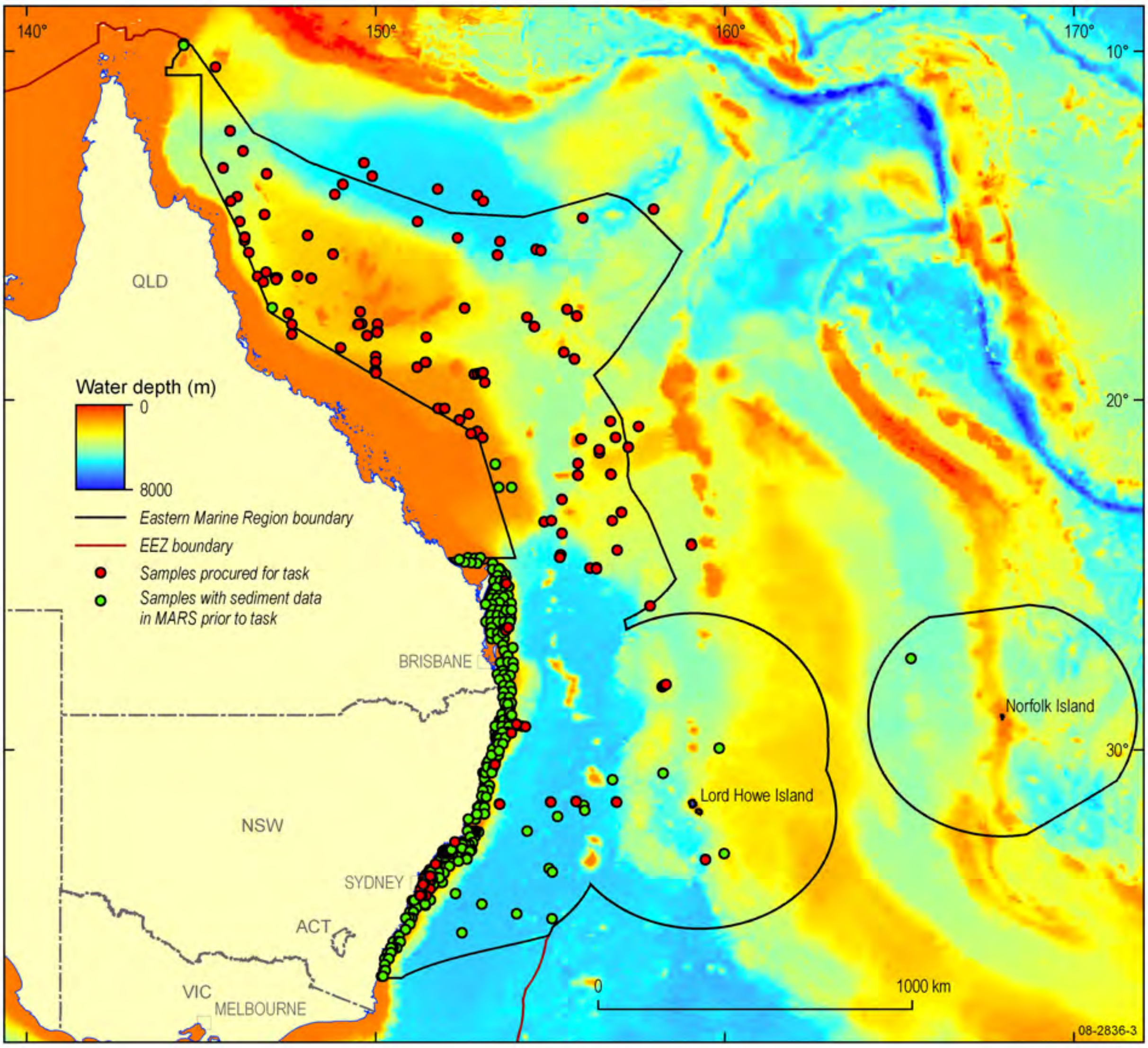


Figure 2.1. The location of all quantitative textural and compositional data for the EMR stored in MARS prior to, and following, the MOU.

Table 2.3. Metadata for sediment samples in the EMR procured and analysed for task.

Survey Name	Vessel	Year	Sample Types	No. of Samples
Geoscience Australia				
North Eastern Australia Heat Flow	Rig Seismic	1986	Piston & gravity core	7
East Australia Phosphates	Rig Seismic	1987	Gravity core	6
North East Australia 3	Rig Seismic	1987	Gravity core & dredge	10
North East Australia 4	Rig Seismic	1987	Gravity & piston core & dredge	12
Southern Queensland Margin	Rig Seismic	1991	Gravity core, dredge & grab	4
Continuous Geochemical Tracers	Rig Seismic	1992	Gravity and vibro core	15
Southern Surveyor 5/2004	Southern Surveyor	2004	Dredge	11
Geology and Tectonic Evolution of Mellish Rise	Southern Surveyor	2005	Gravity core & dredge	17
Lamont Doherty Earth Observatory				
Vema Cruise 16, Leg 9	Vema	1960	Piston core	2
Conrad Cruise 10, Leg 6	Robert D Conrad	1966	Piston core	2
Vema Cruise 24, Leg 7 & 8	Vema	1967	Piston core	16
Conrad Cruise 12, Leg 4 & 5	Robert D Conrad	1968	Piston core	2
Vema Cruise 33, Leg 14	Vema	1977	Piston core	1
Ocean Drilling Program				
Ocean Drilling Program, Leg 133 & 194	Joides Resolution	1990	Core (unspecified)	18
Oregon State University				
Global Expedition of RV Oceanographer	Oceanographer	1967	Piston core	5
Scripps Institute of Oceanography				
LUSIAD Leg 5, NOVA Leg 4 & 5	Horizon	1963	Gravity core	13

2.5. SAMPLE ACQUISITION AND ANALYSIS

Samples from repositories outside Australia were sent to Geoscience Australia. Between 12 and 50 g of sediment were used for grainsize and carbonate analyses. Each sample was analysed as follows:

- **Grainsize (Vol%; µm):** The grainsize distribution of the 0.01–2,000 µm fraction of the bulk sediment was determined with a Malvern Mastersizer 2000 laser particle analyser. All samples were wet sieved through a 2,000 µm mesh to remove the coarse fraction. A minimum of 1 g was used for samples comprising relatively fine material and between 2–3 g for samples comprising relatively coarse material. Samples were ultrasonically treated to help disperse the particles. Distributions represent the average of three runs of 30,000 measurement snaps that are divided into 100 particle size bins of equal size.
- **Grainsize (Wt%):** Gravel, sand, and mud concentrations were determined by passing 10–20 g of bulk sediment through standard mesh sizes (Gravel >2,000 µm; Sand 63 µm-2,000 µm; Mud <63 µm). The resulting gravel, sand, and mud concentrations represent dry weight proportions.
- **Carbonate content (Wt%):** Bulk, sand and mud carbonate concentrations were determined on 2–5 g of material using the 'Carbonate bomb' method of Muller and Gastner (1971). Carbonate gravel concentrations were determined by visual inspection.

All analyses were conducted by the Palaeontology and Sedimentology Laboratory at Geoscience Australia. Where sample volumes were insufficient to complete all analyses, laser grainsize and bulk carbonate were completed as a priority. Further information on the data analysis is available in Appendix C.

2.6. ASSESSMENT OF SIGNIFICANT GEOMORPHIC FEATURES

Analysis of sediment type and distribution has been completed at Planning Region and Bioregion scales. Within these regions, analysis has also been completed for features identified as 'significant'. Significant features are defined as single or groups of geomorphic features that characterise the seabed, and therefore represent potentially significant areas for conservation within that region/at that scale that are based on a set of criteria (Table 2.4). Significant features have been identified for the EMR and individual bioregions within it. Significance of features could not be assessed at international scales as equivalent datasets are not available for areas outside of the AEEZ. Where a feature (significant or otherwise) contained <3 samples, quantitative analysis of sedimentology within this feature was not undertaken due to the low number of samples. Sedimentology for significant features without adequate quantitative data is, where possible, described from previous studies.

Table 2.4. Criteria for assessing significance of geomorphic features in the EMR or Provincial Bioregion.

Criteria	**Explanation**
Feature is best represented in EMR or Bioregion	Feature covers significant area of the EMR or bioregion **OR** Feature is not abundant elsewhere in Australia's EEZ (significant portion of total area of this feature occurs in EMR or bioregion)
Feature is unique to EMR or Bioregion	This occurrence has a physical attribute i.e: -extent -sedimentology -bathymetry -latitude that differs from that of other occurrences of this feature in the EMR or EEZ

2.7. MAP PRODUCTION

2.7.1. Percent Gravel/Sand/Mud and Folk Classification and Percent Carbonate

Maps for %Gravel, %Sand, %Mud, Folk Classification, and %Carbonate were clipped from rasters created for the entire EEZ. These were created by:

- Querying the MARS database to obtain all numeric grainsize and carbonate content data for Australia's EEZ and any samples located outside the EEZ but within 100 km of the boundary;
- Compiling the results into gravel, sand and mud fractions (%), mean grainsize (μm) and carbonate (%);
- Checking that gravel, sand and mud for each sample had all three fractions reported, and that these fractions were in the appropriate range when summed (100 +/- 1%); and then
- Checking for and resolving cases of duplication.

The sediment classification proposed by Folk (1954) has been used to present information on sediment type. Sediment fraction interpolations were combined into a single raster file and values for each cell at 0.05 decimal degree resolution were exported as points. Folk classes were defined from Folk (1954) diagram and a script automating classification based on these definitions was written in Pearl. This script was applied to the to exported point data. Classified cell values were imported back into ArcGIS for map production. Areas for classes on all interpolated maps are calculated only for the interpolated area that lies within the EMR.

3. Review and Synthesis of Literature for the East Marine Region

3.1. INTRODUCTION

The tectonic history, oceanography, late Quaternary evolution and surficial sedimentology of the East Marine Region (EMR) have been the focus of extensive research by various authors and government agencies at different temporal and spatial scales. The eastern margin of Australia covers a vast area and extends from tropical to temperate latitudes and although over 350 references were reviewed for this report there are still large gaps in our basic knowledge. The EMR includes notable geomorphic features such as reefs, seamounts and canyons and covers an extensive area of shelf, slope and abyssal plain/deep ocean floor along with a small area of abyssal rise. Geoscience Australia has contributed extensively to the study of the region and has published records and bulletins on the southeast margin offshore of New South Wales and southern Queensland (Marshall, 1977; Davies, 1979; Marshall, 1980; Colwell & Roy, 1983; Colwell & Coffin, 1987; O'Brien & Heggie, 1990; Heggie et al., 1992; Hill, 1994; Tsuji et al., 1997; Glenn et al., 2007, O'Brien et al., 1994; Maung et al., 1997; Stephenson & Burch, 2004), the Lord Howe Rise (Willcox et al., 1981; Dickens et al., 2001; Stagg et al., 2002; Willcox & Sayers, 2002; Van de Beuque et al., 2003; Alcock et al., 2006), northeast Queensland margin offshore of the Great Barrier Reef (Mutter, 1977; Symonds et al., 1992; Struckmeyer et al., 1994; Wellman et al., 1997; Isern et al., 1998; Earl et al., 2002; Exon et al., 2005; Exon et al., 2006a) and the Norfolk Island region (Bernardel et al., 2002; Exon et al., 2004c).

Several expeditions of the international Deep Sea Drilling Project/Ocean Drilling Program (DSDP/ODP Legs 21, 29, 30, 90, 133 and 194) have made borehole and regional studies in and adjacent to the EMR (Burns et al., 1973; Kennett et al., 1974; Andrews et al., 1975; Kennett et al., 1986; Davies et al., 1991a; McKenzie et al., 1993; Isern et al., 2002; Anselmetti et al., 2006). Drill Sites 206, 207, 208, 209, 210, 283, 287, 587, 588, 589, 811-826 and 1192-1199 provide useful data. The location and water depth of these sites is listed in Appendix C Table 3.1. Key geomorphic features and provinces of the EMR have been mapped using a consistent bathymetric grid of Australia's EEZ (National Bathymetric Map Series, 1976; Kroenke et al., 1983; Webster & Petkovic, 2005; Heap and Harris, in press-a) and past scientific literature (Fig. 1.2 & 3.1).

The EMR has been divided into the four geomorphic provinces as defined in Table 1.1 (Fig. 4.1): the shelf; middle shelf; slope; rise; and abyssal plain/deep ocean floor. These divisions are made on the basis of water depth and the geomorphic provinces described in a recent study on the geomorphology of the Australian margin (Heap and Harris, in press-a). The geomorphic features defined in Table 2.1 are described individually within these provinces.

3.1.1 Tectonic History

The principal geomorphic features in the East Marine Region (EMR) of the Tasman and Coral Seas were formed during rifting and thinning of the continental crust of eastern Australia in the late Cretaceous between ~110 and 80 million years ago (Ma) followed by a period of seafloor spreading with the formation of new basaltic oceanic crust. The sea floor spreading continued until early Eocene (~52 Ma) and created the ocean basins, failed-rift troughs, ridges and plateaus. Since the cessation of seafloor spreading periodic volcanism and subsidence have determined the basic present-day seafloor geomorphology.

3.1.1.1. Tasman Sea

The main geomorphic features in the Tasman Sea are basins, plateaus, ridges and seamounts (Fig. 3.1). Tectonic features related to the geomorphology are the boundaries between oceanic and continental crust, faults and fracture zones, oceanic ridges and younger volcanism delineated by Stagg et al., (1999a) and shown in Figure 3.2. Prior to seafloor spreading a rifting phase started in the middle to late Cretaceous (ca. 110 Ma) with stretching and thinning of the continental crust and the development of topographic highs and basins due to the associated normal and strike-slip faulting (Fig. 3.3; Gaina et al., 1998b, Norvick et al., 2001). The newly formed basins filled, or partially filled, with sediment in a fluvial or lacustrine environment (Stagg et al., 1999b). Volcanism accompanied this rifting but data as to how widespread it was are lacking. On the eastern margin of the Tasman Basin DSDP Site 207 on the southern Lord Howe Rise sampled rhyolitic tuffs and flows dated at 94 Ma (McDougall and van der Lingen, 1974). They have been interpreted as having been deposited in a subaerial or shallow marine environment (Burns et al., 1973). North of the Tasman Basin the rift-related Whitsunday-Proserpine volcanics on the Queensland coast are dated at 120 - 100 Ma (Ewart et al., 1992). On the southeastern Australian margin emplacement of igneous intrusions occurred along the NSW south coast near Montague Island which is composed of lavas from nearby Mt Dromedary and a quartz syenite from this lava is dated as 97 Ma. Offshore of Montague Island, on the mid-continental slope, a quartz monzodiorite (101 Ma) was also emplaced during the rifting phase (Hubble et al., 1992). Rocks of similar age and provenance occur south of the EMR in the Gippsland Basin (O'Halloran and Johnstone, 2001).

Magnetic anomalies in the basaltic oceanic crust beneath the Tasman Sea have been used to determine the age, direction and rate of seafloor spreading (Ringis, 1972, Hayes and Ringis, 1973, Weissel and Hayes, 1977, Shaw, 1979, Gaina et al., 1998b). Rifting was not uniform and resulted in the continental crust being broken up into 13 micro-continental blocks (Fig. 3.3; Gaina et al., 1998b). Seafloor spreading (breakup) in a SW-NE direction started south of 38^{0}S at ~84 Ma (Campanian, Chron 33) where what is now called the Monawai Ridge met its conjugate margin at Bass Strait. Initially, the spreading rate was very slow (4 mm yr^{-1}) forming a narrow ocean propagating to the north.

Spreading reached the southern end of the EMR at 80 Ma when the southern block of the Dampier Ridge separated from what is now the base of the NSW continental slope. At 79 Ma the spreading rate increased to 22 mm yr^{-1} (Van de Beuque et al., 2003). Rifting between the Dampier Ridge and the Lord Howe Rise occurred from 79 to 71 Ma before separation from the NSW margin. This continental crust attenuation formed the Middleton Basin in the north and the Lord Howe Basin in the south. There is no magnetic evidence for oceanic crust in these basins (van de Beuque et al., 2003). Seafloor spreading started west of the Dampier Ridge at 73 Ma and continued to propagate northward until it ceased at 52 Ma (early Eocene) when the direction of spreading was SSW-NNE (Fig. 3.11). Magnetic anomalies date the age of the oceanic crust adjacent to the continental crust at the southern boundary of the EMR as 80 Ma, at Coffs Harbour (32^{0}S) as 67 Ma, and offshore of Fraser Island as 60 Ma (Fig. 3.4; Gaina et al., 1998a). These ages indicate the maximum age for marine sediments resulting from the transgression as a narrow sea flooded the subsiding oceanic crust as it propagated northwards.
The geology on the conjugate margins is related in the following way:

- Kenn Plateau (far northern Lord Howe Rise) with the Maryborough and Nambour Basins of southern Queensland;
- Northern Lord Howe Rise (northern Dampier Ridge; Middleton Basin; Faust and Capel Basins) with the New England Fold Belt and the northern margin of the Sydney Basin;
- Central Lord Howe Rise (southern Dampier Ridge, Lord Howe Basin and Gower Basin) with the Sydney Basin and the Lachlan Fold Belt.

Regional structural lineaments related to tectonic events still shape the present seabed morphology by forming the margins of the major crustal blocks and scarps within those blocks. In particular the lineaments have two trends: northeast-southwest parallel to the Tasman Sea spreading; and northwest-southeast related to the ridge and basin complex in the Norfolk Island region (Stagg et al., 1999b). One of these lineaments, known as the Barcoo-Elizabeth-Fairway Lineament, extends from the slope offshore of Jervis Bay for about 1,800 km northeast as far as the Norfolk Ridge. It dissects the Dampier Ridge, separates the Middleton Basin from the Lord Howe Basin and continues across the Lord Howe Rise (LHR) as the mostly sediment buried Elizabeth-Fairway Lineament. Another major lineament with topographic expression is the Vening-Meinsez Fracture Zone which trends NW from the southern EMR around Norfolk Island and crosses the Lord Howe Rise.

The fabric of the ocean crust in the Tasman Basin is clearly defined in satellite-derived sea surface gravity anomalies and shows major fracture zones (Smith and Sandwell, 1997). These fracture zones were a controlling factor in the shape of the continental crust breakup and their imprint still exists in the bathymetry of the base of the Australian stet slope and its conjugate margin on the Dampier Ridge and Kenn Plateau. The fracture zones also form basaltic ridges in the oceanic crust where they are mostly, but not entirely, buried by subsequent sedimentation.

The change in orientation of the Australian continental margin to NNW in southern Queensland is due to a change in direction of spreading and strike-slip movement (70 - 64 Ma) on the southern margin of the Marion Plateau and opening of the Capricorn Trough as a failed rift (Gaina et al., 1998b; Muller et al., 2000). The 150 km-long NNE trending Cato Fracture Zone forms the northern boundary of the oceanic crust in the Tasman Basin (Exon et al., 2006a) at this location. Further north in the Tasman Sea the Recorder Fracture Zone meets the base of slope where it is offset off Noosa (Queensland) and was formed when the Kenn Plateau moved away from southern Queensland (Hill, 1992). A strike-fault at this time (70 Ma) also formed the steep scarp at the base of the continental slope where it widens northwards from Coffs Harbour to Tweed Heads. Similarly the rectilinear pattern of the western margin of the four blocks that make up the Dampier Ridge and the steep scarps that occur at the base of the continental slope in southern NSW were formed by initial break-up along transform (strike-slip) faults.

The basement rocks of the conjugate margins of eastern Australia and Dampier Ridge/LHR form an asymmetric pair in the subsurface profile. Seismic lines show that the extensional basins formed during the rifting stage are now largely confined to the western half of the LHR with only minor rift basins on the slope of eastern Australia (Fig. 3.5; Willcox and Sayers, 2001). The main sedimentary basins in the sub-seafloor of this 'Central Rift Zone' are the Capel and Faust Basins east of Capel and Gifford Seamounts, the Gower Basin east of Lord Howe Rise and the Monawai and Moore Basins at the southern margin of the EMR (Zhu and Symonds, 1994). These basins contain over 4 km of sediment along with igneous intrusions, some of which reach the seabed as seamounts. In contrast the basement under the eastern half of the LHR is relatively flat ('Lord Howe Platform' of Willcox, et al., 2001).

To account for both the differing crustal thickness of the conjugate margins, and hence current water depth, and the lack of major rift basins on the Australian margin Jongsma and Mutter (1978) concluded the final breakup was asymmetric. Their model had the emplacement of oceanic crust occurring along the western boundary of a wide rift system of basins and ridges. Etheridge et al., (1989) developed this model further with a low angle detachment fault creating the Australian margin as the upper plate margin along with the uplift of the eastern Australian Highlands taking place prior to breakup while the Dampier Ridge/Lord Howe Rise formed from the thinner crust of the lower plate margin.

Since their formation the passive margins of the Tasman Basin have been subsiding to their current depths. The rates and timing of subsidence are not well known. Mudstone samples of late Cretaceous Campanian age (84 to 71 Ma) from the NSW continental slope (Heggie et al., 1992) indicate widespread marginal marine conditions and DSDP drilling suggests fully marine conditions on the northern LHR at this time. By this time the basins formed during rifting have mostly filled with sediment and are no longer topographic basins. Today they underlie the Lord Howe Rise and some of the Australian continental slope. However, topographic basins still exist for the Middleton and Lord Howe Basins. The Cretaceous rocks in these basins have not been sampled but are interpreted from seismic evidence to be fluvial sands and gravels and lacustrine and marginal marine muds. These are overlain by post-breakup pelagic limestone and calcareous oozes.

Since seafloor spreading ceased the region has been moving north at ca. 7 cm yr-1 as part of the Australian plate. During this time three hot spots have resulted in north-south volcanic mountain chains. The most westerly affected the east coast of Australia (Wellman and McDougall, 1974, Sutherland, 1998), the central hotspot formed the Tasmantid Seamount Chain (McDougall and Duncan, 1988), and the eastern hotspot produced the Lord Howe Seamounts on the western flank of the Lord Howe Rise (Vogt and Connolly, 1971, Slater and Goodwin, 1973, McDougall et al., 1981). Other post-breakup volcanics have been sampled and imaged by seismic at many locations on the Lord Howe Rise, Dampier Ridge and on the Australian continental slope (Hill, 1992; Heggie et al., 1992; van de Beuque et al., 2003; Glenn et al., 2007).

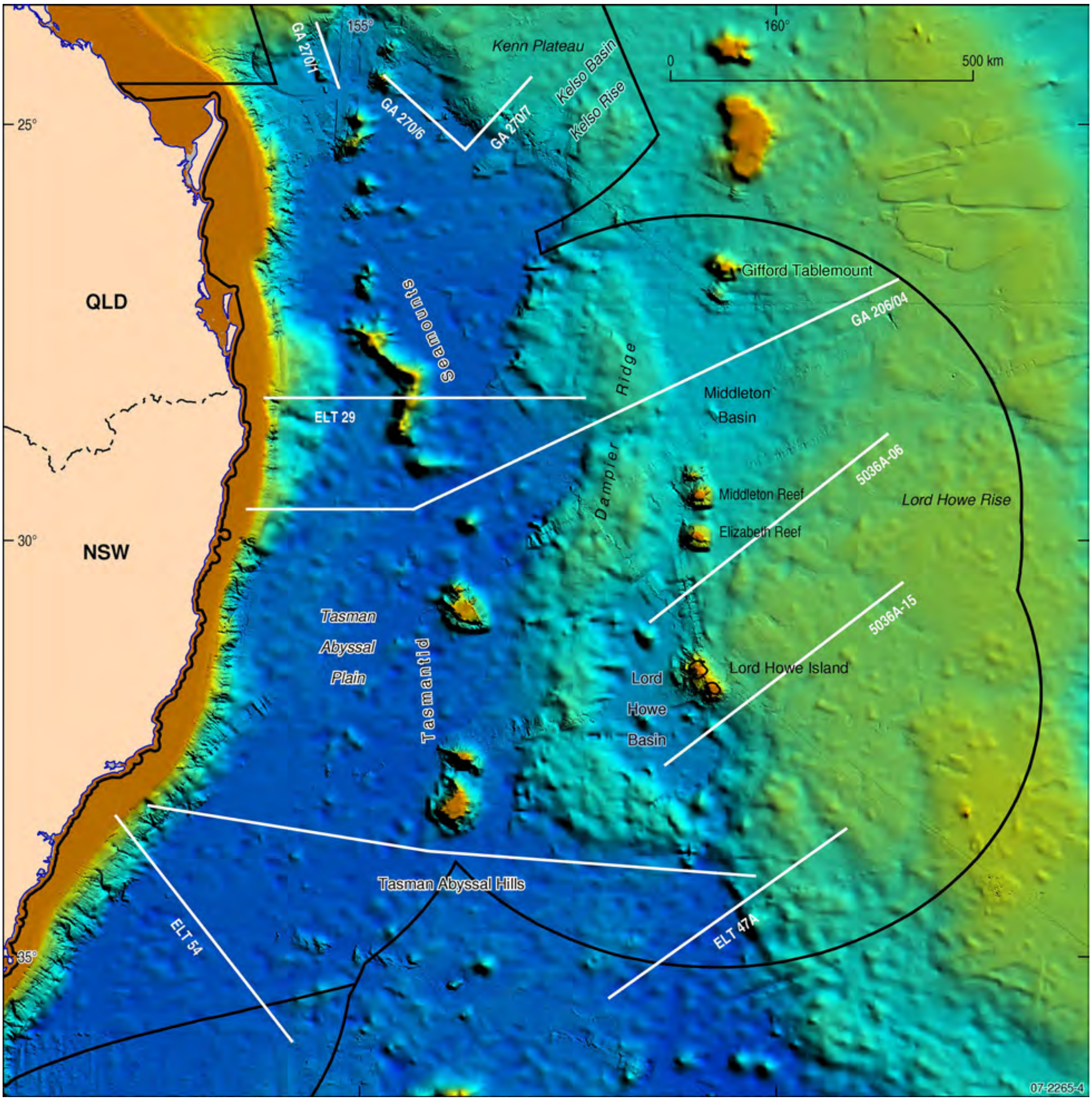


Figure 3.1. False-colour image of the Tasman Sea showing the geomorphology and bathymetry. The main geomorphic features are labelled. Location of features and seismic lines displayed in other figures is marked. Black line is the EMR boundary.

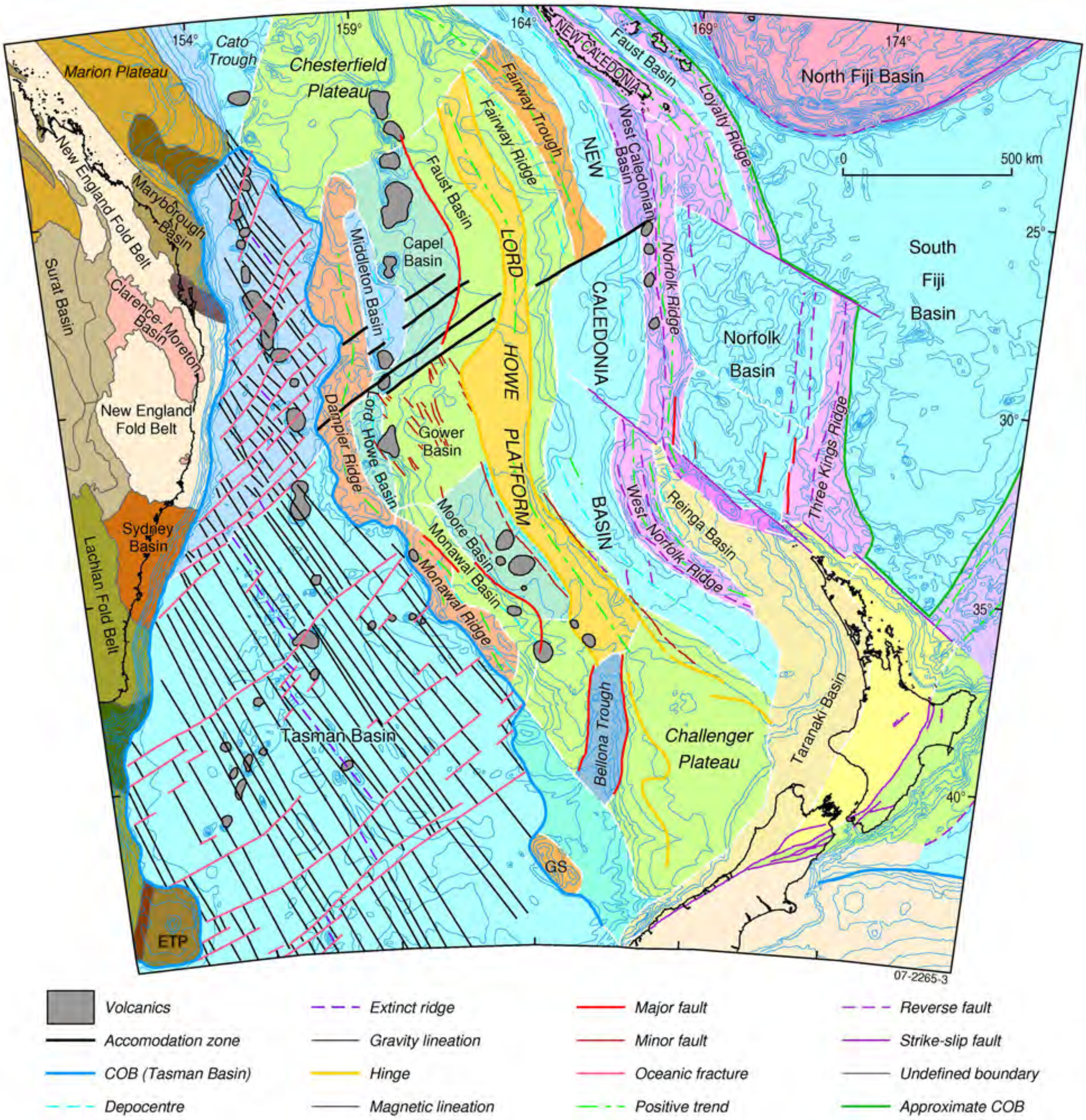


Figure 3.2. Map showing the tectonic features of the Tasman Sea and the geology of the conjugate margins. Stagg *et al.,* (1999a); figure modified by Alcock *et al*., (2006).

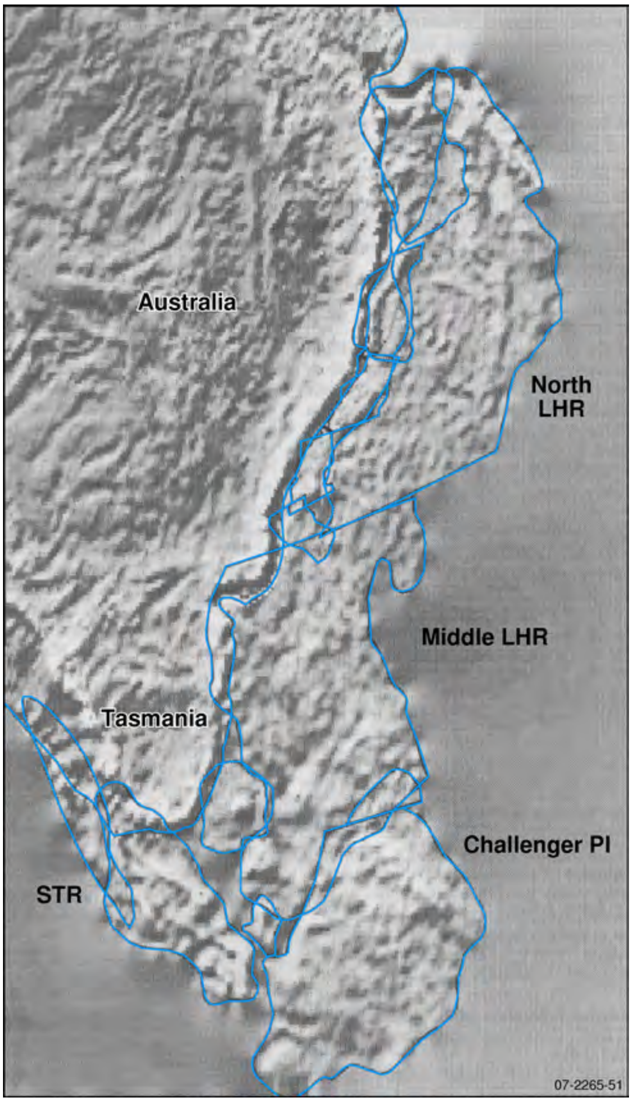


Figure 3.3**.** Mosaic of continental block pre-breakup time (90 Ma). Blue lines are modern boundaries of the continental crust with oceanic crust. Overlap is due to synrift crustal extension. Gaina *et al*., 1998b.

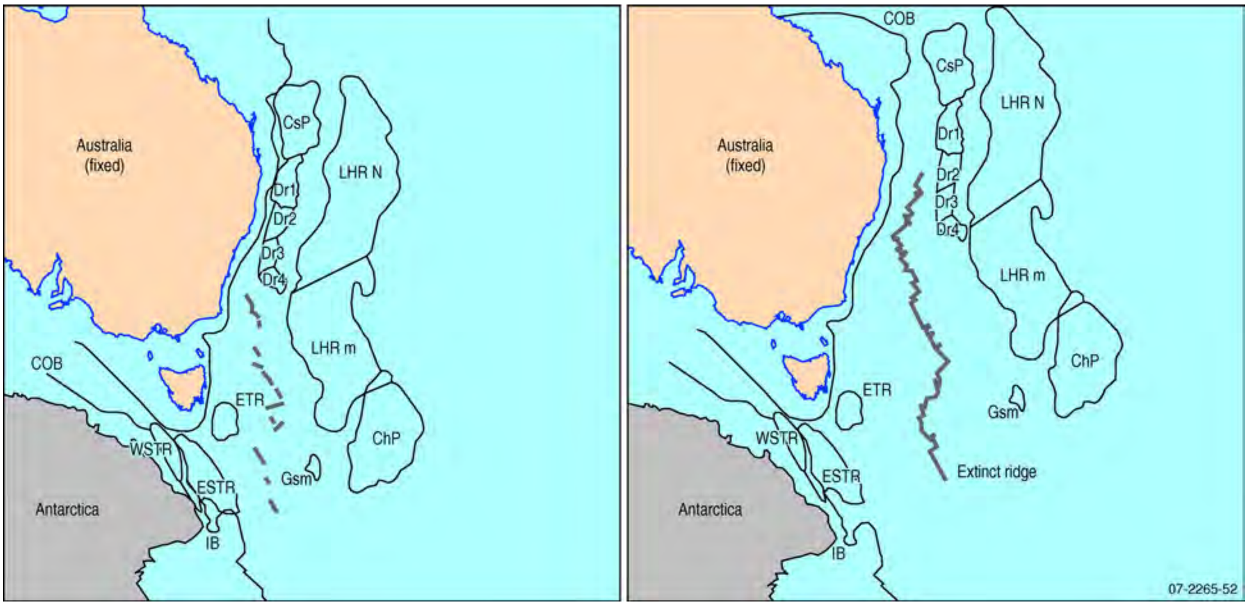


Figure 3.4. Reconstruction of the Tasman Sea opening at 67.7 Ma and at 52 Ma when spreading ceased. Gaina *et al*., 1998b.

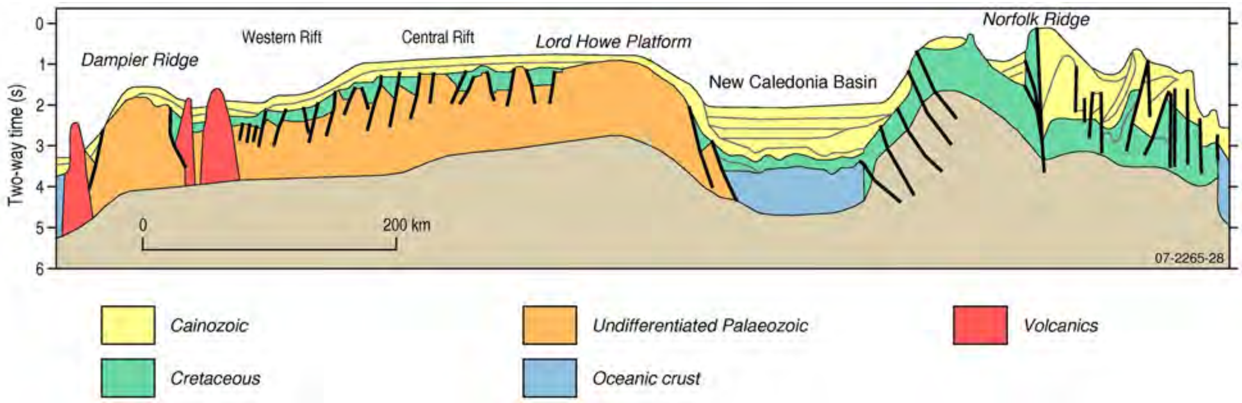


Figure 3.5. Interpreted seismic profile from the Tasman Basin across the Dampier Ridge, Lord Howe Rise, New Caledonia Basin and Norfolk Ridge showing how the tectonic elements of the rifted crust, oceanic crust and volcanics determine the geomorphic features. Note the relatively steep lower slopes, the thick sediment caps on highs and sediment fill in basins. (Alcock et al., 2006).

3.1.1.2. Western Pacific Ocean: Norfolk Island

The shape of the seabed in the EMR around Norfolk Island is controlled by the tectonic fabric that trends north-south as a result of the breakup of the eastern margin of Gondwana and its relationship to the plate boundary along this margin. The EMR extends from the eastern slope of the Lord Howe Rise in the west to the western edge of the Three Kings Ridge in the east. The Norfolk Ridge is the central feature and is part continental crust with relatively thick sedimentary basins, and part island arc volcanics with younger late Cainozoic volcanism adding to the complexity (Eade, 1988; Mortimer et al., 1998).

The Fairway Basin and the New Caledonia Basin lie between the Lord Howe Rise and Norfolk Ridge and were formed in the Early Cretaceous as a result of extension and rifting commencing around 130-120 Ma (Eade, 1988, Muller et al., 2000) and continued as a result of extensive rollback of the Pacific Plate (Crawford et al., 2004). The volcanic basement ridge between the Fairway Basin and the New Caledonia Basin is believed to have formed in the early Cainozoic (Auzende et al., 2000). According to Sdrolias et al. (2002) these basins are underlain by continental crust but others interpret oceanic crust beneath the New Caledonia Basin (Exon et al., 2004c). Continued rifting from 120 and 95 Ma is supported by large amounts of felsic volcanics of this age along the most easterly of these continental fragments, the Norfolk Ridge (Bryan et al., 1997). It must have been at a convergent plate boundary (Crawford et al., 2004). Sdrolias et al. (2001) propose that the Norfolk Ridge was a volcanic arc above a west-dipping subduction zone of the Pacific Plate prior to 100 Ma and that the New Caledonia Basin is a back-arc rift basin with trapped continental crust or Pacific Plate Cretaceous oceanic crust in the Norfolk Basin (a view also proposed by Eade, 1988). They also provided geophysical evidence for a reversal to east-directed subduction from 90 to 45 Ma with the trench lying on the western margin of the Three Kings Ridge but no arc type volcanics of this age have been found. A reversal in subduction at ~45 Ma resulted in the further opening of the Norfolk Basin from 45 to 35 Ma.

Regions of elevated topography in the Norfolk Basin are interpreted as thickened Cretaceous oceanic crust while the topographic basins are underlain by Miocene oceanic crust. Widespread volcanic activity occurred on the plateaus and along their margins in the Miocene before the basins were formed (Herzer et al., 1997; Mortimer et al., 1998, Sdrolias et al., 2004). Mortimer et al. (1998) provide evidence from petrology and isotopic dating of dredge samples to conclude that the Norfolk Basin is a back-arc basin formed by 18-20 Ma. Another view is given by Crawford et al. (2004) who support sea floor spreading east of the Norfolk Ridge from 70 to 55 Ma forming the Norfolk Basin as a back arc basin between the Norfolk Ridge and the Three Kings Ridge, a volcanic arc with a trench to its east. According to these authors subduction had reversed by 50 Ma to become eastward dipping beneath the Three Kings Ridge, and most of the back arc Norfolk Basin was subducted, before subduction ceased at 30 Ma. The plate boundary then jumped eastward and the modern day westward dipping subduction of the Pacific Plate began.

While it is generally agreed that the Norfolk Basin was formed by some kind of back-arc extension there is little agreement on the timing, process and hence nature of the crust. DiCaprio et al. (in press) have synthesized all of the available data, and concluded that the Norfolk Basin is composed of continental fragments along with Cretaceous and Miocene aged oceanic crust. They identify a thrust fault on the Kingston Plateau and metamorphic rocks from the Bates Plateau dated at 38 Ma to indicate compression during the late Eocene. Extension and new seabed formed during the early Miocene, but was limited to the South Norfolk Basin and the Forster Basin.

The Cainozoic volcanic history of the Norfolk Ridge is poorly known because it is covered with a thick sedimentary sequence. Norfolk Island consists of alkaline basalt lavas of Late Pliocene age dated as 3.1-2.3 Ma (Jones and McDougall, 1973). Along the western edge of the Norfolk Ridge is a seamount chain part of which is a large caldera and many small cones (Exon et al., 2004b). A dredge sample of basalt from this chain gave a late Oligocene age of 26.3 Ma (Mortimer et al., 1998). Another chain 100 km to the east occurs as seamounts on oceanic crust. Mortimer et al. (1998) also dated basalt from seamounts in the South Norfolk Basin as being of Miocene age (16.7-21.4 Ma). The West Norfolk Ridge is considered to be an igneous/metamorphic basement block with a generally flat eroded top with varying amounts of sedimentary cover, mostly in half-grabens (Herzer et al., 1997).

3.1.1.3. Coral Sea

The seabed features in the Coral Sea, like the Tasman Sea, are the result of the nature of the breakup of the continental crust along the eastern margin of Gondwana and the location of new oceanic crust. The general pattern of breakup of the northeastern margin of Australia was established by Taylor and Falvey (1977), Mutter (1977), Weissel and Watts (1979) and Shaw (1979). More recently Struckmeyer and Symonds (1997) and Gaina and Muller (1999) have re-evaluated all the geophysical data and show how the breakup and seafloor spreading of northeastern Australia has formed the major tectonic blocks that exist today (Fig. 3.6).

Prior to 62 Ma rifting and extension of continental crust occurred north of the Tasman Sea Basin oceanic crust to form the Townsville and Queensland sedimentary basins which underlie the present-day bathymetric features of the Townsville and Queensland Troughs (Fig. 3.7). The first oceanic crust formed east of the Queensland and Marion Plateaus at Chron 27 (61.2 Ma) when a triple junction formed where the Louisiade Plateau and Mellish Rise continental fragments met the Queensland Plateau (Fig. 3.6). This new seabed propagated northwest, northeast and south forming the Coral Sea/Osprey Embayment, Louisiade Trough and Cato Trough, respectively. Between 57.9 and 55.8 Ma the triple junction migrated south and the transform fault in the Louisiade Trough became extinct and a new strike-slip fault became active between the Mellish Rise and the Kenn Plateau. Spreading became extinct at 52 Ma. An east-west cross section over the Marion Plateau-Cato Trough-Kenn Plateau shows the underlying geology beneath a sediment drape (Fig. 3.8).

Gaina and Muller (1999) identify 190 km of oceanic crust in the Louisiade Trough that formed between 61.2-57.9 Ma, and 150 km of oceanic crust in the Cato Trough and 180 km of oceanic crust in the Osprey Embayment between 57.9 and 52 Ma. They also propose a transform fault along the northwestern part of the Kenn Plateau, which might account for later emplacement of the seamounts that now occur along this trend. The structural trends underlying the complex geomorphology in the Cato Trough area are shown in Figure 3.9. The plateaus and ridges are bounded by major faults, and major volcanic extrusions have utilized these crustal weaknesses.

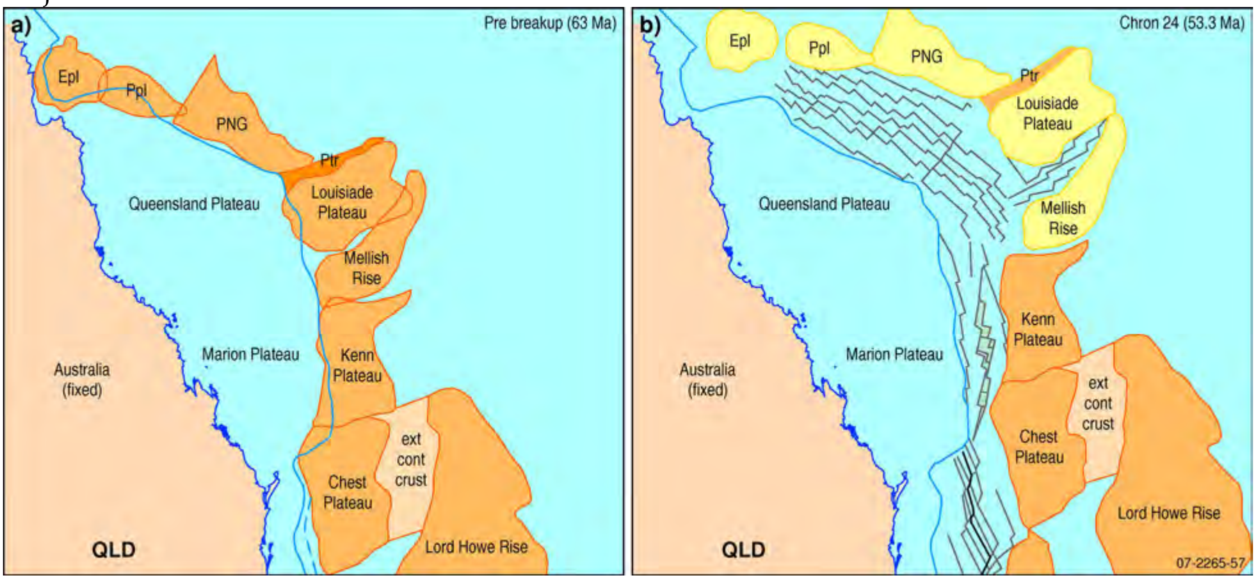


Figure 3.6. Tectonic block reconstructions for the evolution of the plateaus, troughs and basins in the Coral Sea offshore of Queensland. Gaina *et al*., (1999); Exon *et al*., (2005).

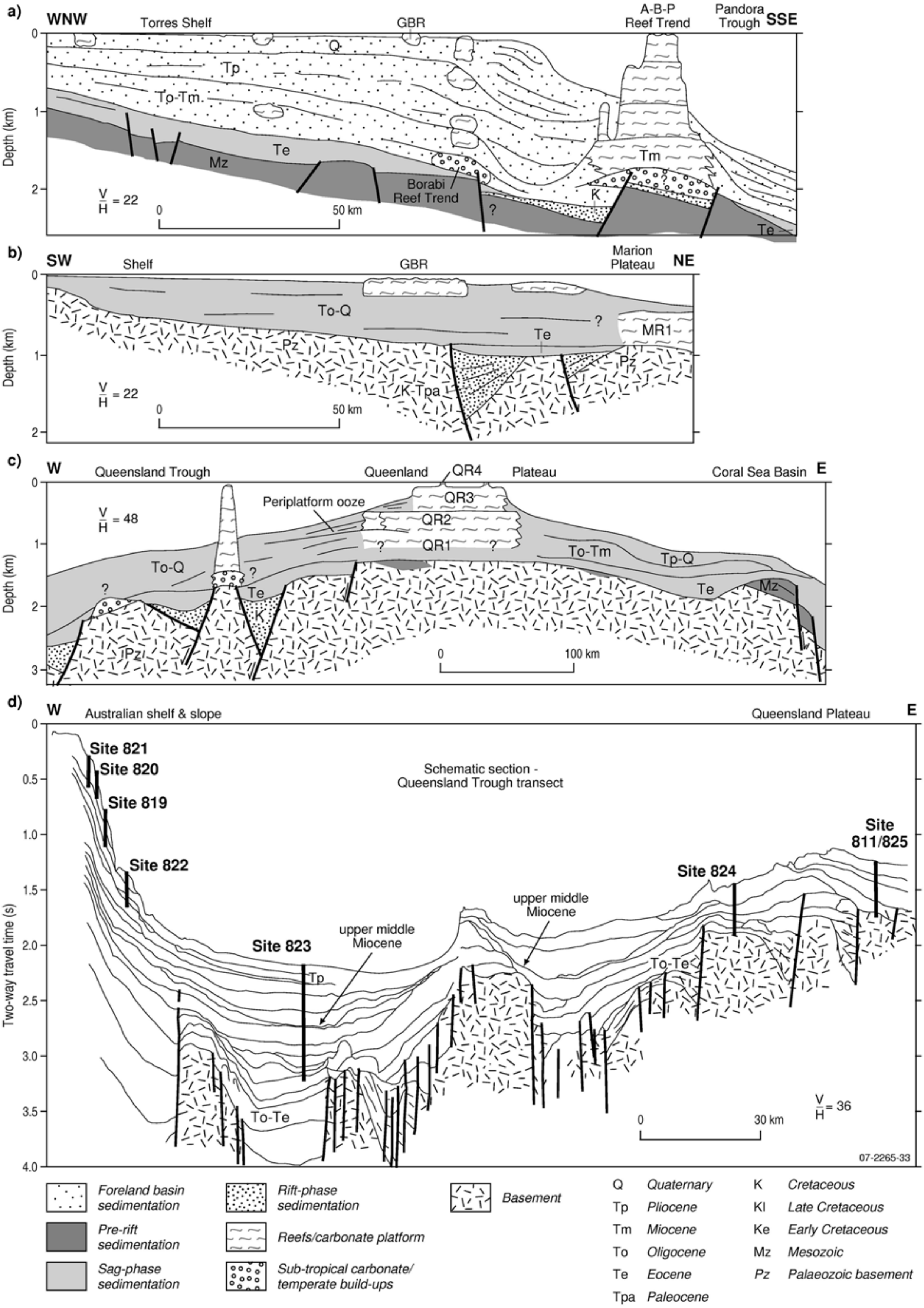


Figure 3.7. Profiles showing generalized basement structure and sedimentary sequences offshore of Queensland. Wellman et al., (1997).

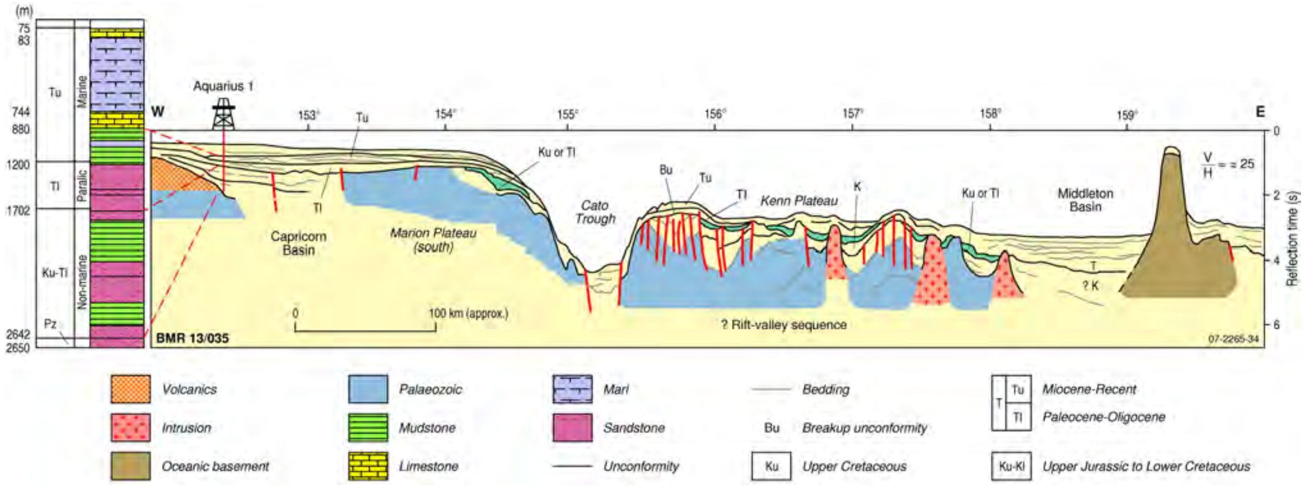


Figure 3.8. Geological and tectonic interpretation of an east-west seismic profile from the Marion Plateau to the Middleton Basin. Line BMR 13/035. Location in Figure 3.44. Willcox, (1981).

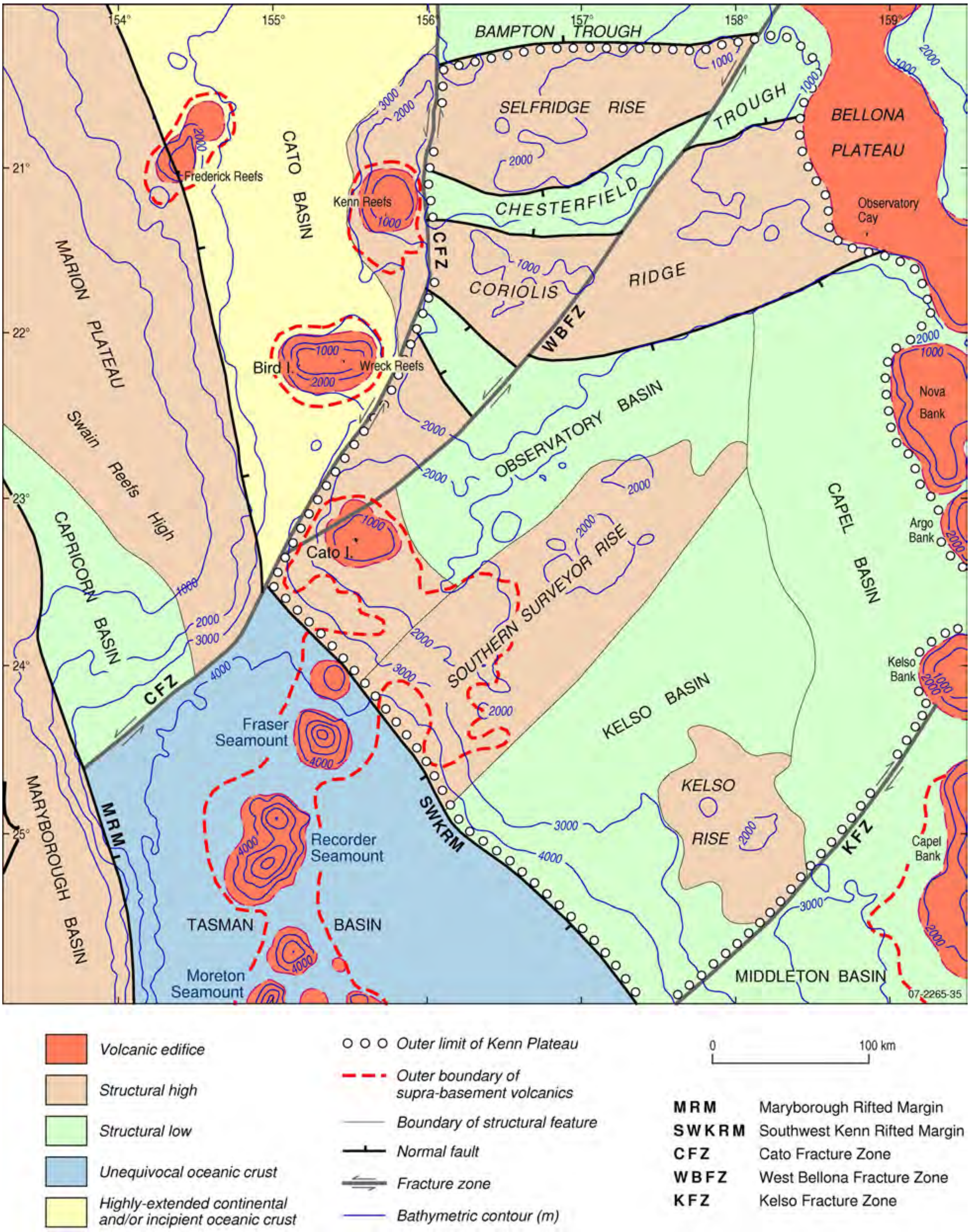


Figure 3.9. Tectonic elements that form the geomorphic features in the Cato Trough – Kenn Plateau area. Exon *et al.,* (2006b).

3.1.2 Oceanography

The surface water circulation in the EMR is dominated by the East Australian Current (EAC) which forms on the Queensland Plateau at -15°S from the South Equatorial Current (SEC) (Pickard et al., 1977; Godfrey et al., 1980, Creswell et al., 1983; Burrage et al., 1996). Part of the SEC forms a clockwise circulation northwards into the Gulf of Papua (Wolanski et al., 1984; Wolanski et al., 1995; Church and Craig, 1998: Keen et al., 2006) while the rest flows over the Queensland Plateau and south over the Queensland Trough seaward of the Great Barrier Reef (GBR). It then flows over the Marion Plateau and along the shelf and upper slope of eastern Australia (Fig. 3.10). It is strongest between 25° and 30°S. The flow is directed off shelf at major headlands such as Fraser Island, Smoky Cape and Sugarloaf Point, and is a significant process in sweeping sediments off the shelf edge (Boland and Hamon, 1970).

At 30°S the EAC is on the outer shelf and upper slope and surface currents of 1-2 ms^{-1} (2-4 knots) have been measured (Godfrey et al., 1980; Church, 1987). South of Sugarloaf Point (32°S) the strength of the current decreases rapidly and the current breaks up into anticyclonic gyres or eddies (Marchesiello and Middleton, 2000). These eddies may impinge on the shelf in the southern part of the EMR and a hydrographic study by Mulhern (1983) infers the influence of EAC eddies down to 2,000 m. Scours and lee-side mounds around bedrock on the upper slope are evidence that the current can modify the sediment down to water depths of 1,000 m (Glenn et al., 2007). The prevailing wind pattern means that upwelling of deeper nutrient-rich water is not a regular phenomenon along this margin (Gibbs et al., 2000).

Part of the EAC is deflected offshore at around 30°S along the Tasman Front (Subtropical Divergence) forming a warm subtropical anticyclonic gyre (Boland and Church, 1981). The Tasman Front forms the interface between the warm waters of the Coral Sea and the cooler waters of the Tasman Sea and it moves north and south with the seasons from 30°S in winter to south of Lord Howe Island and along 34°S in summer (Martinez, 1994a).

A cooler subtropical cyclonic gyre originates in the southern part of the west Tasman Sea and meets subantarctic waters along the subtropical convergence (45°S). Below these water masses at about 1,000 m depth the Antarctic Intermediate Water (AAIW) flows from south to north and beneath it is the Antarctic Bottom Water (AABW) which also flows north in the western part of the Tasman Sea (Tomczak and Godfrey, 1994). Jenkins (1984) mapped erosion on the abyssal floor to infer the clockwise circulation of deep-water currents in the Tasman Basin (Fig. 3.10). Modelling of currents for the GBR suggests a southerly flow of bottom water in the Queensland Trough (Luick et al., 2007).

Storms, longshore currents (littoral drift) and internal waves all affect the nature of the sediment on the seabed. Moderate to high energy southerly swell and much larger storm and cyclone generated north-east and easterly waves affect the NSW and southern Queensland shelf in the EMR (Short and Wright, 1981). Re-suspension, winnowing and transport of sediments by waves occur down to water depth of at least 100 m along this high energy margin (Gordon and Hoffman, 1986; Short and Trenaman, 1992; Roy et al., 1994a; Middleton et al., 1997). On the inner shelf there is northward littoral transport of sediment associated with a northward flowing current (Gordon et al., 1979; Cowell and Nielson, 1984, Huyer et al., 1988). The shelf in the EMR is classified as microtidal so tide generated currents have limited impact except at the entrance to large bays and around islands (Boyd et al., 2008).

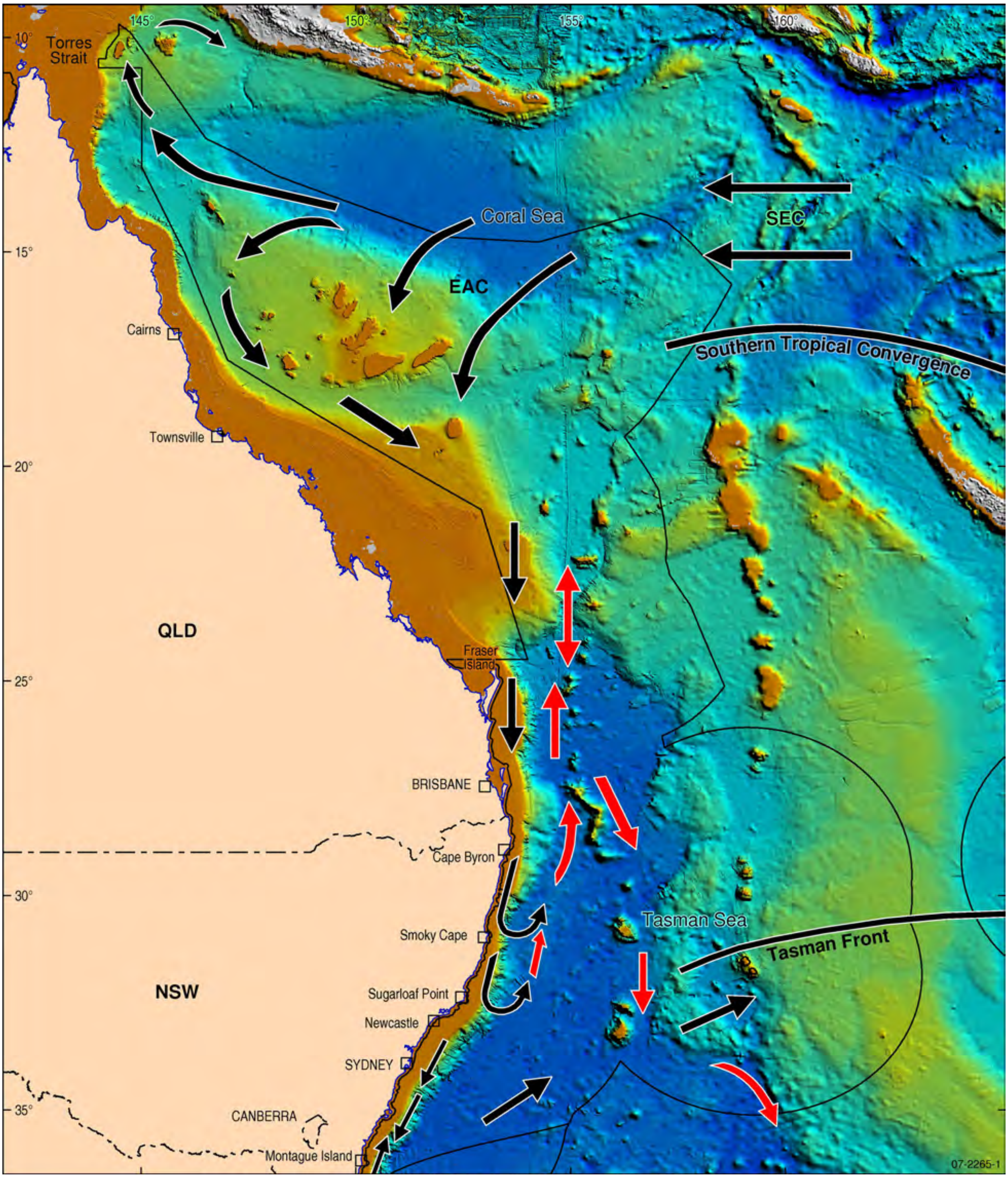


Figure 3.10. Physical oceanography of the EMR, showing the main water masses influencing the region: the East Australian Current (EAC), South Equatorial Current (SEC), West Wind Drift (WWD) and inferred abyssal currents. (CSIRO; Jenkins, 1984; Kawagata, 2001).

3.1.3 Quaternary Evolution

The Quaternary (<2.0 Ma) evolution of the EMR is characterised by a fluctuating climate, oceanography and sea level, which is reflected in seabed sediments and geomorphic features of the region. For half of the past 300,000 years sea level has been 70 to 120 m below its present level (Lea et al., 2002). In half of the last 100,000 years sea level has been at depths between 40 and 80 m. When sea level was lower most of today's shelf was exposed, with a shallow shelf in the Wollongong-Sydney-Newcastle area and very little or no shelf elsewhere along the NSW and Queensland coast. Surprisingly, little terrigenous sediment reached this shelf off Sydney during the last glacial lowstand (Ferland and Roy, 1997). Sediments of this age on the slope off Sydney show an increase in terrigenous mud (Troedson and Davies, 2001). Off Fraser Island the same study found slowly accumulating terrrigenous muds during the lowstand and maximum accumulation rates due to increases in carbonate production during the transgression as the shelf was flooded.

The carbonate platforms, atolls and banks of the Queensland Plateau and Coral Sea have been islands for more than half of the past 300,000 years. The area of these features would not have changed significantly due to their steep sides (>500 m water depth). These features, along with the then-exposed GBR, would have been karstified. In the Cato Trough area, the shallow water connection between the Coral Sea and the Tasman Sea would have been greatly reduced. The Marion Plateau would have been only partly submerged and formed a major promontory along the coastline with a shallow carbonate platform connection to the island formed by Saumarez Reef and Marion Reef at the shelf edge despite sea level rise (Pigram, 1993). The area of the Marion Plateau remaining below sea level was significantly shallower than it is today and swept by strong currents (Liu et al., 1998). East of the Cato Trough the modern day reefs of Mellish, Frederick, Kenn, Wreck and Cato would be slightly enlarged and exposed as islands. East of Kenn Reef, Selfridge Bank would be exposed as an island. South-east of Kenn Reef a bank would be at or near sea level on the Coroilis Ridge.

In the east of the EMR, Norfolk and Philip Islands would become one, much larger island whenever sea level was more than 50 m below present. Areas on the north of Norfolk Ridge currently less than 500 m deep would become banks during low stands. South of Norfolk Island on the boundary of the EMR Wanganella Bank would have been a relatively large island surrounded by a shallow bank for more than half of the past 300,000 years.

The subaerial exposure of what is known today as living reefs probably led to a dramatic reduction in productivity of the shallow water benthic community and a corresponding reduction in carbonate particles from this source. Dunbar et al. (2000) analysed cores from the Queensland Trough and concluded that the glacial lowstand was a period of low terrigenous and carbonate input to the basin. The maximum input of terrigenous muds occurred during the transgression following the lowstand. In the north of the EMR the shoreline was at the shelf edge during the lowstand. This led to a significant input of terrigenous sediment to the slope and basin from the rivers of New Guinea (Francis et al., in press).

The EMR is considered as tectonically stable during the Quaternary with no significant uplift, subsidence or faulting taking place. The larger seamounts continued to subside at a slow rate. Younger seamounts at the southern end of the chains, including Lord Howe Island are currently subsiding faster, but at a rate of centimeters per thousand years. Hydro-isostatic adjustment occurred on the shelf during the Quaternary with rising sea level loading the shelf and falling sea level unloading. Loading during the most recent ocean transgression tilted the shelf seaward by ~1 m.

There is no evidence for volcanic activity during the Quaternary, but it cannot be ruled out as the youngest volcanic flows on Norfolk Island have been dated at approximately 2 Ma and evidence of an undersea eruption 180 km north east of the island was reported in 1981 (Royal Australian Navy

Hydrographic Service, Chart Aus 4602). Other areas with possible Quaternary volcanism occur on the Lord Howe Rise and the Mellish Plateau.

3.2. SOUTHEAST AUSTRALIAN SHELF

3.2.1. Geomorphology

The shelf in the EMR of the Tasman Sea (Montague Island to Fraser Island) is 1, 435 km in length and varies in width from the minimum values of 10 to 20 km off headlands and islands to the maximum of 50 to 75 km off embayments (Fig. 3.11). It is widest between Sydney and Sugarloaf Point (53 km wide off Newcastle) and between Moreton Island and Fraser Island (75 km wide off Noosa) and narrows off Montague Island (17 km), Jervis Bay (16 km), Smoky Cape (12 km), Cape Byron (14 km), Cape Moreton (<10 km) and Sandy Cape (<17 km). The shelf ends at the shelf break, defined as a change in gradient from the shelf with a slope of < 0.50 to > 10 as the seabed deepens on the upper continental slope. The variability in shelf width and depth is illustrated by the 12 profiles superimposed in Figure 3.12.

The shelf is deeper off southern NSW and shallower in northern NSW and southern Queensland. Boyd et al. (2004b) have plotted the shelf break from southern NSW to Fraser Island and show a general trend of shallowing north of Sugarloaf Point (320 30'S) (Fig. 3.13). South of Sugarloaf Point the shelf break is between 145 and 160 m with the deepest shelf break at the margin of the wide shelf between Sydney and Newcastle (172 m) where there is a gradual roll-over on the outer edge of the sediment wedge. Figure 3.14 shows a typical profile of the shelf and upper slope from 40 m to 600 m water depth offshore of Broken Bay where the shelf is wide and the shelf break is not distinct. South of Wollongong the shelf break is relatively sharp. North of Coffs Harbour to Moreton Island the shelf break is between ~80 and 100 m but the break is not as distinct as it is further south and there is a transition to the upper slope. Offshore of Fraser Island there is a distinct terrace and nick-point at a depth of 105 m below a 20 m cliff which forms the shelf break (Fig. 3.15, Marshall et al., 1998). At Breaksea Spit at the north end of Fraser Island the shoreline and inner shelf is effectively at the shelf edge (55 m water depth) as the sand island extends itself across the entire shelf.

The depth and morphology of the shelf is controlled by the underlying basement geology, the prograding depositional sediment wedge, carbonate reef/mound growth (north of Sugarloaf Point), differential subsidence and erosion (Jones et al., 1975; Davies, 1975, 1979). Most of the shelf in the EMR can be divided on the basis of morphology into an inner shelf (<60 m water depth), middle shelf (60-120 m) and an outer shelf (120 m to shelf break). In general, the inner shelf is relatively steep down to 60 m water depth, the middle shelf has a more gently slope seaward and the outer shelf is a flat, near-horizontal plain. Figure 3.14 shows a typical profile off Sydney where the mid-shelf in this area has a gradient of 0.30-0.50 and the outer shelf plain 0.10 (Ferland and Roy, 1997). Davies (1979), Marshall (1979) and Roy and Thom (1981) also present figures that display the variety of shelf profiles from south to north.

At the few places where detailed surveys by side-scan sonar, multibeam or bottom photography have been made significant geomorphic variability is revealed on the shelf (Jones and Kudrass, 1982;

Gordon and Hoffman, 1986; Marshall et al., 1998; Boyd et al., 2004b; Roberts and Boyd, 2004; Payenberg et al., 2006). Using detailed bathymetry of two areas of the NSW shelf Boyd et al. (2004a) recognise 6 shore-parallel zones: shoreface, inner plain, inner mid-slope, outer mid-slope, flat outer plain and hummocky outer plain. They also recognized considerable along-shelf variability in morphology enabling further subdivision into mounds, lobes, tongues, depressions, deltas and bedrock. Mounds, reefs and banks are significant features near the shelf edge off Sugarloaf Point and Fraser Island. The variability of the seafloor at scales of one to hundreds of meters is visible on side-scan sonar images of the inner shelf plain in water depths between 15 and 60 m off northern NSW (Roberts and Boyd, 2004). They distinguished gravel patches, bedrock reefs, sand ripple fields and featureless seafloor.

The inner shelf is generally concave-up and steeper off headlands (1-50) where the bedrock outcrops on the seabed. Shelf sand bodies are often present on the inner to mid-shelf adjacent to prominent bedrock headlands in water depths of 20-120 m (Ferland, 1991). These are linear, shore-parallel features with lengths of 5-35 km and widths of 1-5 km. Terraces and nick-points are common down to 160 m and were formed by erosion during lower sea levels (Jones et al., 1975). Relict drowned beach-barrier systems also occur and underlie the inner shelf plain where it occurs (Browne, 1994, Boyd et al., 2004a).

Topographic depressions on the shelf are rare. Boyd et al., (2004a) document a series of linear depressions oriented along the mid-shelf 2.5-5 km wide over distances of 20 km and relief of up to 10 m. They interpret them as erosional and occurring offshore of the submarine extension of headlands, such as Sugarloaf Point, where the East Australian Current is accelerated due to the constriction. Evidence for strong currents on the mid-shelf also comes from side-scan sonar and seabed photographs that show dunes and ripples in sand in water depths of 50-70 m off northern NSW (Jones and Kudras, 1982).

In the south of the EMR the outer shelf plain is the main geomorphic feature and it is particularly extensive from Montague Island (360 10°S) north to Sugarloaf Point (32° 30’S). South of Montague Island the shelf is oriented N-S, is narrow (18 km), and has a relatively smooth and steady gradient from the shoreline to a distinct shelf break at 142 m. At Montague Island the orientation of the shelf break changes to NNE. On the landward side of Montague Island currents have scoured a channel to a depth of 46 m, some 20 m deeper than the surrounding seabed. East of the island the seafloor is concave-up with thin sediment cover and rock outcrop with seismic profiles indicating erosion by currents (Roy and Thom, 1991). Sand waves on the outer shelf (water depth 70-100 m) with amplitude of 4-9 m and wavelengths of 300-500 m were also reported by Roy and Hudson (1987). The eroded sand has been redeposited to form a convex-up shelf sand body extending 30 km south from the island in 50-110 m water depth (Ferland, 1991). The 115 and 120 m isobaths on the outer shelf immediately north of Montague Island define a 10 km long broad (5 km) ridge oriented south and extending towards the shelf edge. This may be a sand lobe deposited by the southerly flowing current.

Between Montague Island and Jervis Bay the outer shelf plain is 15-18 km wide with three broad basins 15 x 5 km, ~5 m deep and oriented along shelf. At Jervis Bay (35°S) the shelf narrows and there are broad N-S ridges on the outer shelf with 5 m of relief defined by the 140 m isobath. The heads of three canyons between 35° 22’S and 35° 07’S have incised the shelf break by 1-2 km. North of Jervis Bay a ridge with up to 20 m of relief, known as Sir John Young Banks, extends 12 km NE across the inner and mid-shelf to 90 m water depth where it becomes buried by sediments. This has been interpreted as a basement high by Phipps (1966, 1967) and Davies (1975) that is a continuation of a fault at the coastline. North of this ridge the outer shelf plain widens and the orientation of the shelf break becomes ENE.

Between Jervis Bay and Sugarloaf Point Phipps (1966) and Davies (1979) define terrace nick points at 40-60 m, 80-100 m and 120-140 m water depth and suggest they were cut by erosion during still-stands of sea level during the Pleistocene. Offshore of The Entrance (33° 24′S) there is a 10 km long N-S ridge on the mid-shelf with up to 25 m of relief that is probably rock outcrop. The relatively steep inner shelf adjacent to headlands along this section of coastline is associated with elongate, shore-parallel sand bodies. These have been mapped south of Port Jackson (Field and Roy, 1984; Ferland, 1991; Albani and Rickwood, 2000). These sand bodies generally lie in water depths of 40-80 m, 1-5 km offshore and are 10-30 m thick. They are underlain by bedrock and often terminate abruptly against bedrock outcrop. They form a convex-up seabed with the seaward face the steepest at 30-70.

At Sugarloaf Point the shelf again narrows and there are N-S ridges of sand on the outer shelf along with mounds near the shelf break described in detail by Boyd et al. (2004a). The mounds are 2-10 km long and 0.6-3 km wide with local relief of 5 to 15 m. North of Sugarloaf Point the shelf narrows and trends more northerly. At 31° 40′S a broad depression (canyon head?) has incised 5 km into the shelf edge to the 112 m isobath. North of this the shelf break is less distinct as it merges seaward with a gentle upper slope. This continues to Coffs Harbour (30° 20′S) where the upper slope again becomes steeper. From 30° 20′S to 29° 50′S there are numerous small islands that rise steeply from water depths of 40 m on the inner shelf (<60 m) which itself extends halfway across the shelf, 12 km from shore. These islands are part of structural trends in the basement rock. North of here the shelf widens significantly to ~30 km which is maintained until Stradbroke Island. In this area Roberts and Boyd (2004) identify an inner shelf plain (slope: 0.16-0.310) extending from the base of the shoreface to 60 m water depth (8-12 km), a mid-shelf slope (0.31-0.630), and an outer shelf plain with a width of 6-12 km and a slope of 0.16-0.470. The only feature on this flat shelf seaward of the 40 m isobath is Windarra Bank (28° 28′S, south of Tweed Heads), a small pinnacle of bedrock that rises steeply from depths of 50-60 m to 31 m.

The northern ends of both Stadbroke and Moreton Islands extend eastward across the shelf, reducing its width to less than 10 km with shoals extending to the shelf edge offshore of Cape Moreton. North of Moreton Island the shoreline steps westward 30 km and the shelf widens. Here, there are several banks of notable size on the outer shelf with a broad (several kilometers wide), shallow (4-5 m deep), linear depression for 75 km along shelf behind them. Barwon Bank (260 30′S) extends for 15 km along the shelf edge offshore of Noosa. It is <2 km wide and has relief of 10-15 m and a minimum depth of about 22 m. North of Barwon Bank the shelf edge and slope step eastward 20 km to create the widest shelf on this margin (75 km).

Offshore of Fraser Island the shelf edge starts to trend NNW and there are significant banks. North Gardner Bank and Gardner Bank extend some 30 km parallel to the 85 m isobath (Marshall et al., 1998). These banks rise from depths of 50-60 m on the outer shelf to within 22-30 m of the sea surface (Marshall, 1977; Harris et al., 1991). They have generally rugged topography and are cemented hardgrounds believed to have developed on drowned reefs and aeolian sand ridges (Marshall, 1977; Jones and Kudras, 1982; Marshall et al., 1998). These carbonate platforms form the shelf edge and because they are lithified create a particularly steep (140) steps on the upper slope (Payenberg et al., 2006) (Fig. 3.15).

Breaksea Spit extends for 30 km north from Fraser Island as a submerged sand ridge to reach the shelf edge which is only 20 m deep at this location (Boyd et al., 2008). Immediately north of Breaksea Spit there is an incised, sinuous valley on the shelf, up to 50 m deep, 600 m wide and at least 5 km long, cut into a lithified carbonate platform (Payenberg et al., 2006). This valley was the course of the Mary and Burnett Rivers during the last sea level lowstand. Multibeam mapping of the seabed in this area by Boyd et al. (2004b) has revealed large subaqueous dunes with amplitudes of 1-2 m and wavelengths of 100 m that are migrating from the south. These dunes cover the carbonate platform underlying the shelf in this area and sand transported by the dunes has partly filled the shelf valley. Scours in the valley indicate erosion by tidal currents (Payenberg et al., 2006). Between Breaksea Spit and the shelf valley is Stingray Shoal, a roughly circular carbonate reef approximately 1 km across at the top. It rises steeply from the sand dunes which surround its base in 35-40 m of water to come within 17 m of the surface (Boyd et al., 2004b).

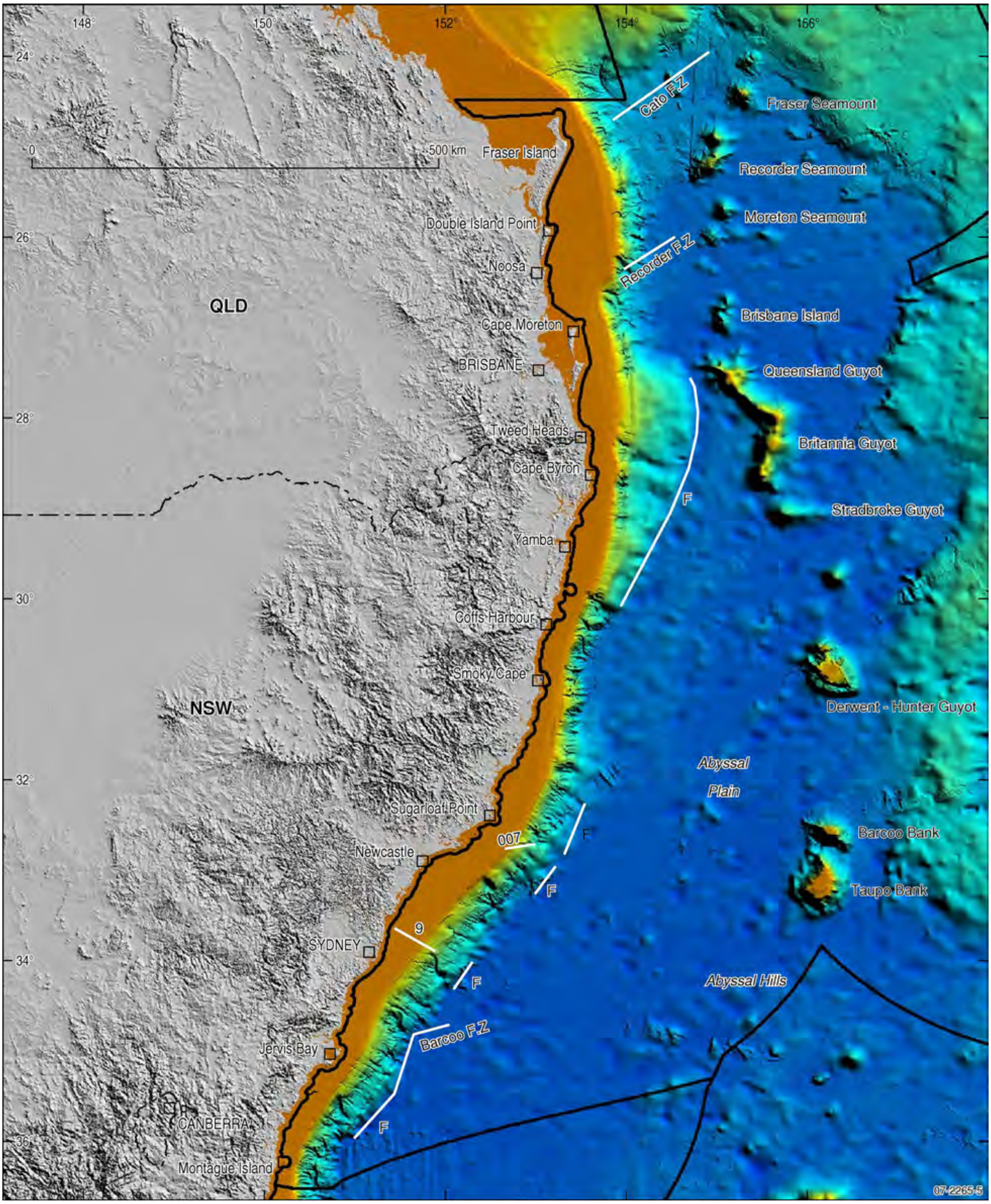


Figure 3.11. False colour map showing the geomorphology and bathymetry of the east Australian margin. Note the varying width of the continental shelf and continental slope and the relationship between the location of major fracture zones in the oceanic crust and shape of the continental slope. The location of seismic profiles 007 and 9 are shown. F = major fault scarps.

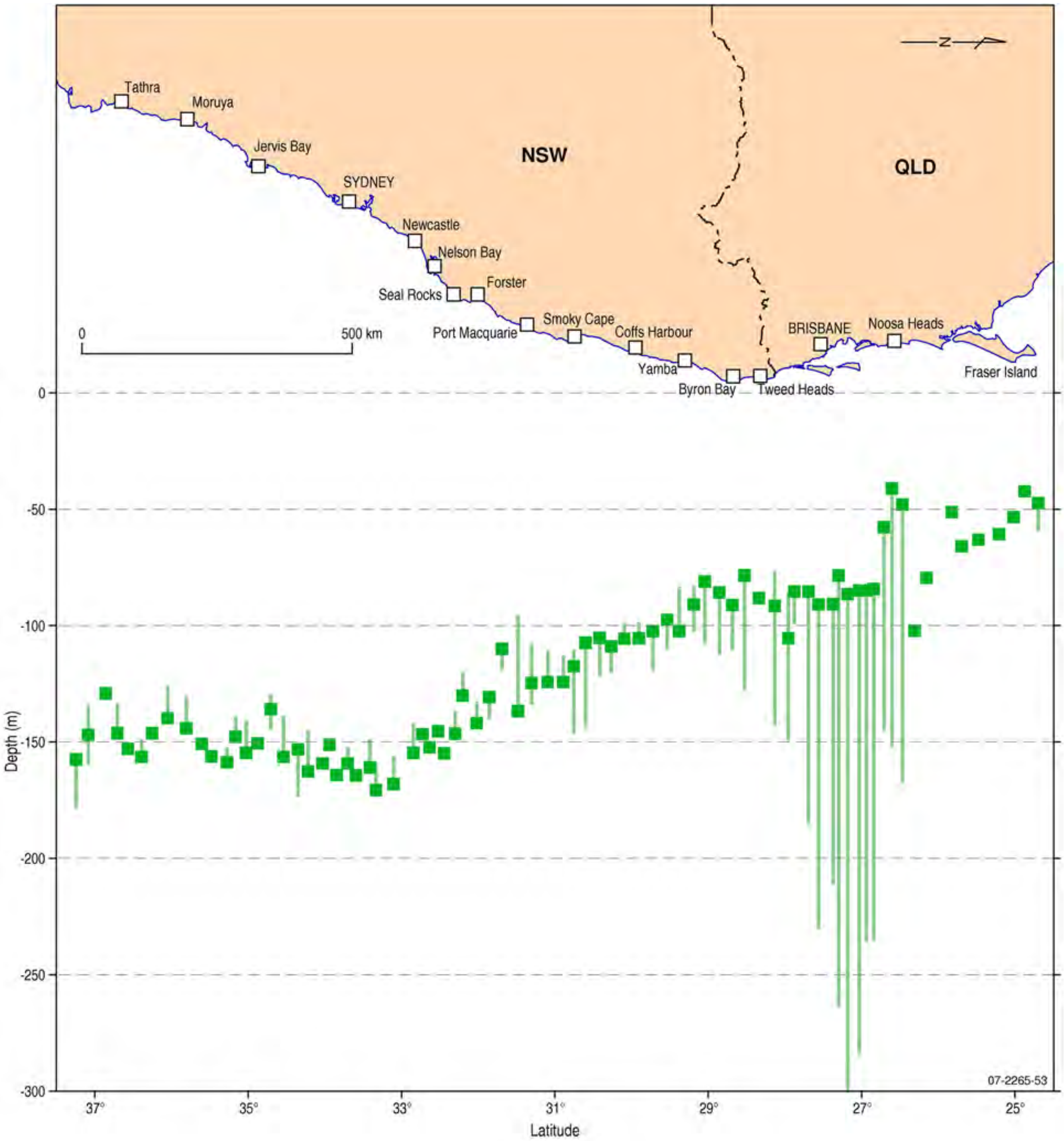


Figure 3.12. Plot of the depth of the shelf break on the eastern Australian margin. Green bars indicate a transitional zone from shelf to slope. (Boyd et al., 2004b).

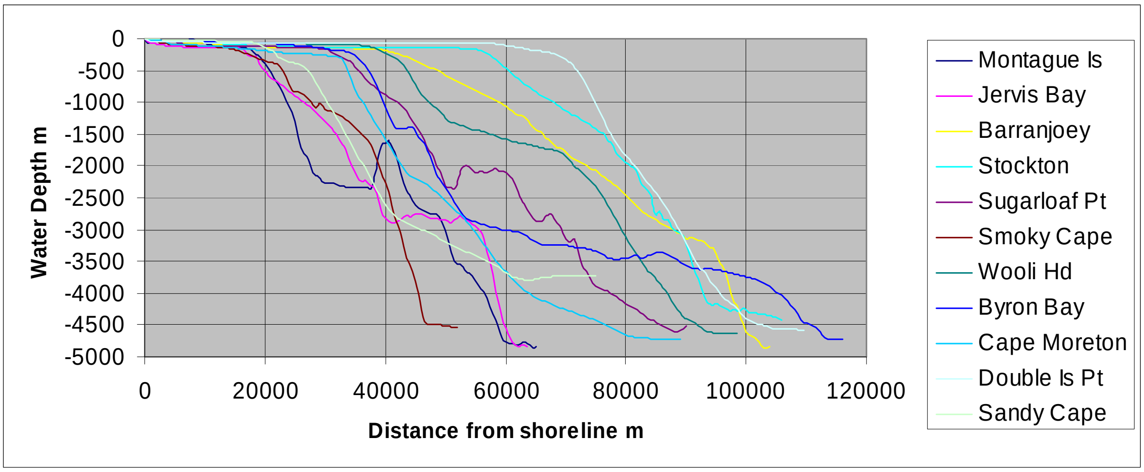


Figure 3.13. Profiles of the continental shelf in the EMR normal to the shelf break from the shoreline to the shelf break. It shows the variety of depths and widths of this shelf. Approximately equally spaced from Montague Island to Fraser Island.

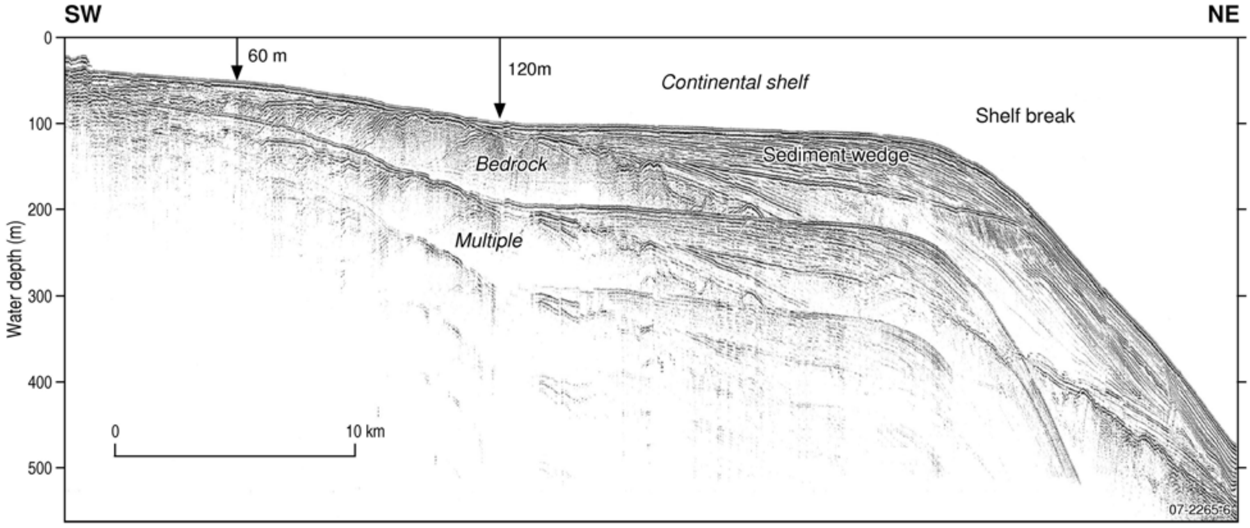


Figure 3.14. Seismic profile of the continental shelf and upper slope offshore of Barranjoey Head, Broken Bay, NSW, showing the relatively steep inner to mid shelf with rock outcrop and the outer shelf plain forming the top of the prograding sediment wedge. The location of the 60 m and 120 m isobaths are marked to show the location of the midshelf mud deposit. The shelf-break is gradual along this part of the coast at ~150 m. Location on Figure 3.11. Line 9A, (Heggie et al., 1992).

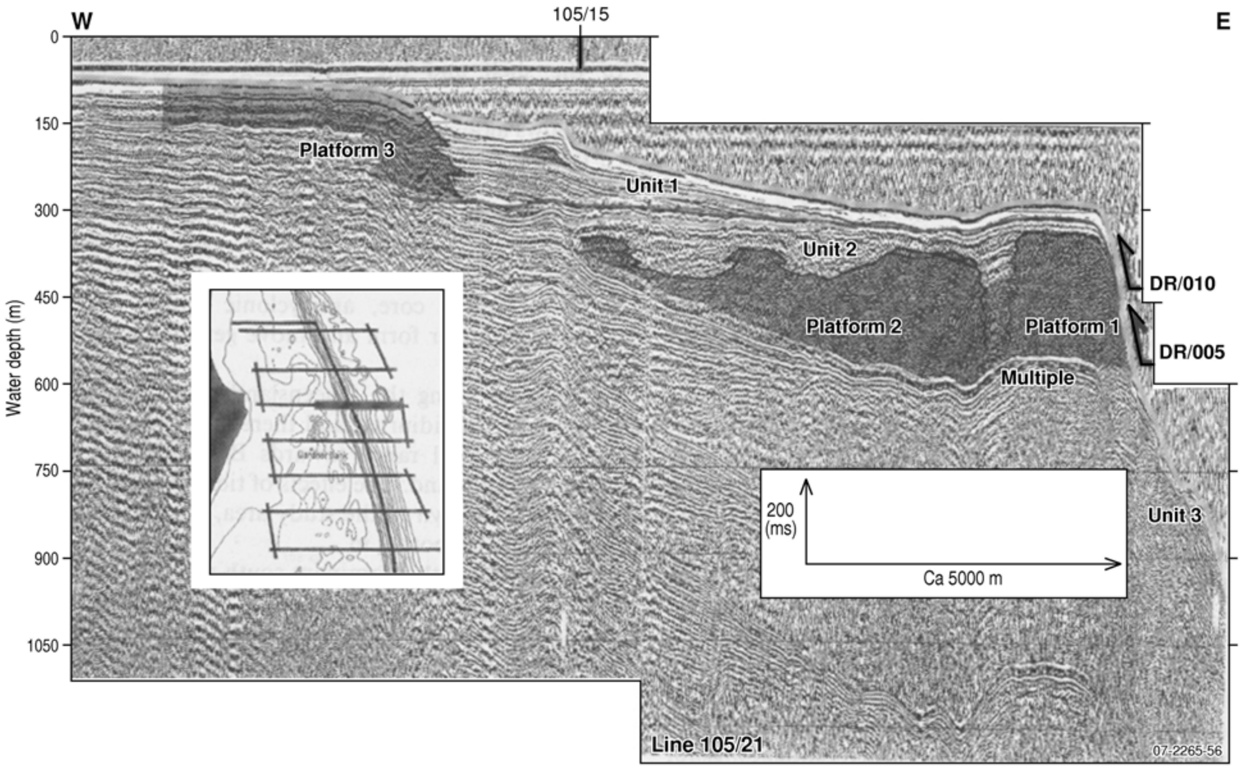


Figure 3.15. Seismic profile showing the carbonate platforms and sedimentary units on the outer shelf and upper slope offshore of Fraser Island (Marshall et al., 1998).

3.2.2. Surface Sediments and Rocks

There is a relatively simple first-order division of surface sediments along the east Australian continental shelf with terrigenous quartzose sediments on the inner shelf and carbonate dominated-sediments on the outer shelf (Fig. 3.16; Davies, 1979: Marshall, 1980; Lane and Heggie, 1993). This boundary is generally at about 100-120 m water depth for the NSW shelf and shallower (~50 m isobath) on the southern Queensland shelf (Marshall et al., 1998). Because of the high wave energy and EAC along this shelf there is little mud accumulation. The grain size trend is medium to coarse sand on the inner shelf, fine sand (with mud in limited areas) on the mid shelf and coarse sand and gravel on the outer shelf (Figs. 3.17 and 3.18). Overall this shelf is one that has had a low sediment supply throughout the late Cainozoic. Most of the sediment deposited along this margin has accumulated over the shelf edge on the upper slope, forming a wedge of sediment that has prograded with time. This wedge of sediment is usually at its maximum thickness below the shelf break in the Sydney-Newcastle area where it is up to 700 m thick (Rule et al., 2007). Thus the shelf break is a depositional feature on the top of this sediment wedge. A consequence of low sediment supply is the occurrence of bedrock outcrop as patches at all depths on the shelf. Relict features such as terraces and shorelines from lower sea levels also occur on the present-day seabed (von Stackelberg, 1982a). Details about the cores and bottom photographs from the shelf are given in Appendix C Tables 3.2 and 3.3.

Bedrock outcrop is common on the inner shelf along with concave-up sand bodies. Rock outcrop has been mapped out to the 50 m water depth 6 km offshore just south of Yamba and for a similar distance offshore off Sydney to the limit of the mapping in 80 m of water (Albani et al., 1988; Gordon and Hoffman, 1989). The shore-parallel sand bodies are composed of well-sorted, fine- to medium-grained quartzose sand with <10% biogenic carbonate and are either relict shoreline sand ridges or regressive deposits formed as sea level rose to its present level (Ferland, 1991; Roy, 1998). The 'inner plain' (20-75 m) of Boyd et al., (2004a) is more common north of Sugarloaf Point and is interpreted as the top of drowned beach ridges that now fill the shelf valleys and form a thin veneer of sand on bedrock (Fig. 3.19).

South of Sugarloaf Point the NSW shelf sediments can be divided into inner shelf, mid-shelf and outer shelf zones based on texture (Shirley, 1964; Davies, 1979). The inner shelf extends down to depths of ~60 m is mantled in medium- to coarse-grained, orange-yellowish quartzose sand with a carbonate content of less than 10% (Gordon and Hoffman, 1989). From Jervis Bay to Sugarloaf Point on the mid-shelf between 60 and 120 m there are muddy sands and sandy muds that form a discontinuous strip of carbonate-rich, olive-green sediment containing gravel sized calcareous shells and worm tubes. This mud-rich belt is 10-20 km wide of muddy sands with mud content between 10 and 30% (Matthai and Birch, 2000a and b). Highest mud content in this zone occur offshore of the major rivers, namely: Shoalhaven, Hawkesbury and Hunter, and the lowest mud contents occur off Sydney (Boyd et al., 2004b). In general, the highest mud contents correspond to where the shelf is widest. Birch and Davey (1995) and Matthai and Birch (2000b) found that the concentrations of heavy metals in the mud fraction off the major urban areas of Wollongong, Sydney and Newcastle were above the regional background values due to dumping of harbour sediments and sewage outfalls.

South of Jervis Bay the mid-shelf sediments continue to be finer grained than those of the inner and outer shelf only with less mud than those sediments further north. North of Sugarloaf Point mud is lacking on the shelf. Only offshore of the Manning and Clarence Rivers is there a mid-shelf zone of fine sand and slightly muddy fine sand, respectively (Marshall, 1980; Boyd et al., 2004a; Roberts and Boyd, 2004).

South of Sugarloaf Point the outer shelf extends from 120 m to the shelf edge and is mantled in coarse-grained, brownish-grey, calcareous, gravelly-sands. The carbonate content is 50-80% (Shirley, 1964; Roy and Thom, 1981; Ferland and Roy, 1997). The outer shelf is particularly coarse grained off the Shoalhaven River and south of Montague Island (Fig. 3.17; Davies, 1979). The biogenic components of the outer shelf sediments are a mix of modern and relict grains consisting of molluscan skeletal fragments, bryozoa, foraminifera and calcareous worm tubes. Pelagic foraminifers become the dominant species towards the shelf break. The non-carbonate components are authigenic glauconite, quartz and cemented ferruginous pebbles. Some of the shells are corroded and colonized by boring sponges, worm tubes and other encrusting organisms and are clearly relict, deposited during a previous low sea level (Roy and Thom, 1981). Beach-rock from 128 m water depth off Sydney has been dated as 15,925 BCE. (Jones et al., 1975). Offshore of Newcastle there are mounds on the outer shelf described by Boyd et al. (2004a) as cemented carbonate consisting of bivalves, bryozoans and other shelly debris. These mounds are interpreted as temperate carbonate reefs formed at the shelf edge during lower sea levels.

North of Sugarloaf Point the texture of the sediment on the outer shelf continues as a coarse sand with some gravel and the carbonate content of the sediment remains high (>60%). Significant amounts of calcareous red algae occur on the outer-shelf north of 30°S (Marshall and Davies, 1978). The carbonate content is reduced in some areas due to the presence of siliceous sponge spicules and glauconite formation. The outer shelf offshore of the Clarence River has less carbonate (Boyd et al., 2008). Offshore of northern NSW carbonate sands and hardgrounds occur on the outer shelf seaward of the 75 m isobath (Roberts and Boyd, 2004). The hardgrounds consist of carbonate sands cemented by calcite, encrusting bryozoans, and by calcareous algae. Seismic profiles in this area indicate mounds at the shelf edge which are interpreted by Roberts and Boyd (2004) as temperate-water reefs.

Off southern Queensland quartz sand continues to form a narrow inner shelf belt with carbonate dominating the mid- and outer-shelf (Fig. 3.20). Carbonate forms >90% of the sediment on the modern biohermal accumulations known as Gardner and Barwon Banks where red algae is a common component (Marshall and Davies, 1978; Marshall, 1980; Tsuji et al., 1997; Marshall et al., 1998; Davies and Peerdeman, 1998). The coralline algae are encrusting and have bound other skeletal fragments to form banks and hardgrounds (Marshall, 1980). The mid- to outer- shelf sediments offshore from Fraser Island are sands, gravels and crusts consisting of coralline algae, hermatypic corals, large benthic foraminifers, bryozoans, Halimeda, molluscs and algal rhodoliths up to pebble-sized (Marshall et al., 1998). Seafloor photographs in Marshall et al., (1998) show living corals on Gardner Bank and rhodolith gravel blanketing the sediment surface on the outer shelf off Fraser Island. The East Australian Current sweeps the seabed here and the rhodoliths are moved by southerly flowing bottom currents with speeds of up to 1.34 ms^{-1} in water depths of 40-140 m (Harris et al., 1996). A limestone platform underlies the present day sediments on Gardner Bank and outcrops where it forms the shelf edge. Barwon Bank hosts few corals and lacks Halimeda but has abundant bryozoans, barnacles, benthic foraminifers, serpulid encrustations and pelecypods to form a temperate reef (Tsuji et al., 1997).

North of Fraser Island, in Hervey Bay, the shelf is underlain by a lithified (limestone) tropical carbonate platform covered by a thin veneer of migrating quartz sand dunes (Marshall, 1977, Boyd et al., 2004b, Payenberg et al., 2006). A multibeam image of Stingray Shoal shows it to be roughly circular, approximately 1000 m across at the top (17 m water depth) and rising steeply from the sand dunes which surround its base in 35-40 m of water (Boyd et al., 2004b). It is composed of coral and coralline algae, some living. Shoreward (west) of these outer-shelf dunes are poorly-sorted fine to coarse sands with some gravel and shell particles, which form the seabed in Hervey Bay (20 m water depth). Their composition of feldspar and rock fragments show them to from the local rivers and reworked Pleistocene shore ridges (Boyd et al., 2004b).

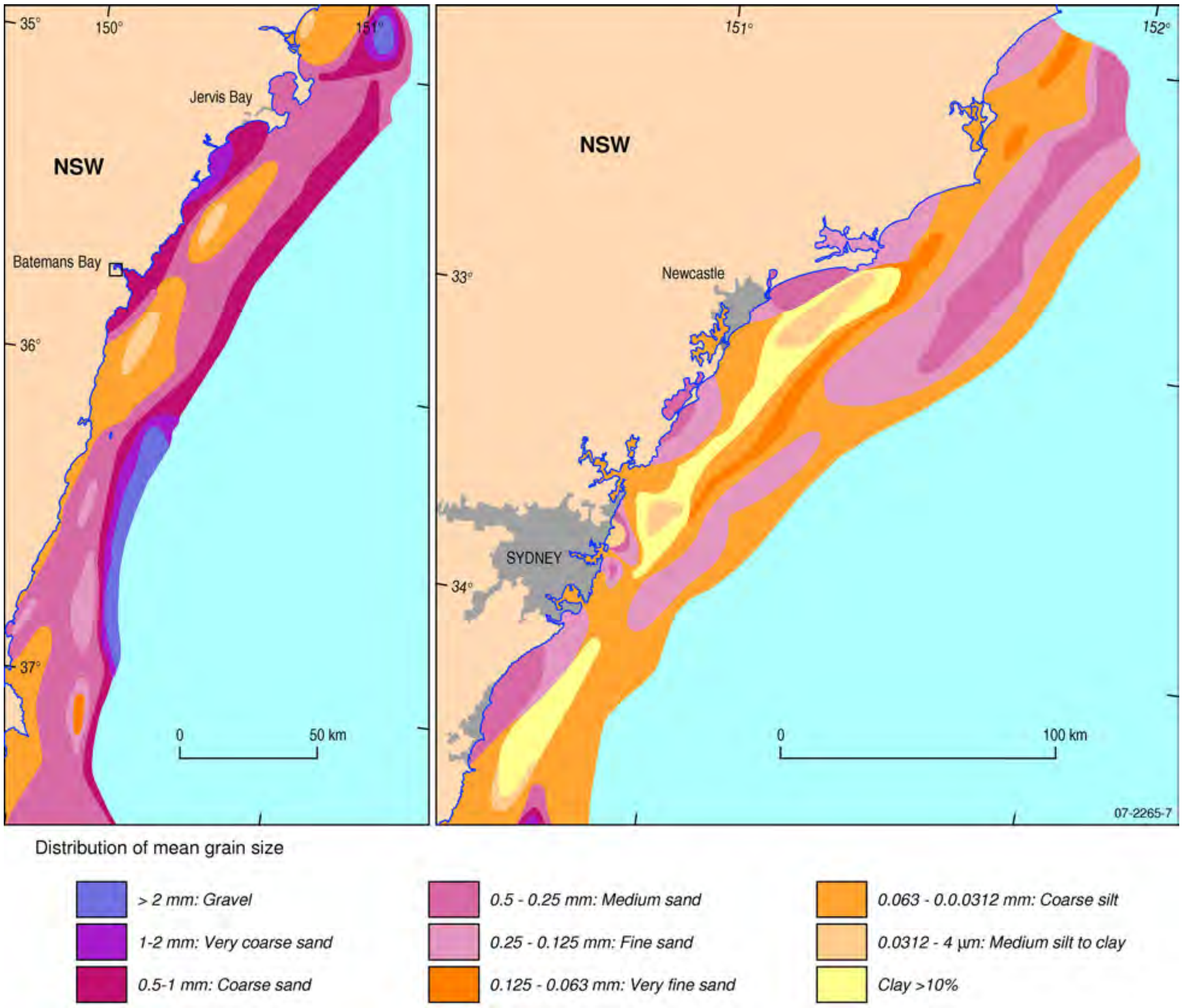


Figure 3.16. Maps showing the distribution of grain size of surface sediment on the continental shelf and upper slope south of 32^{0}S. (Davies, 1979).

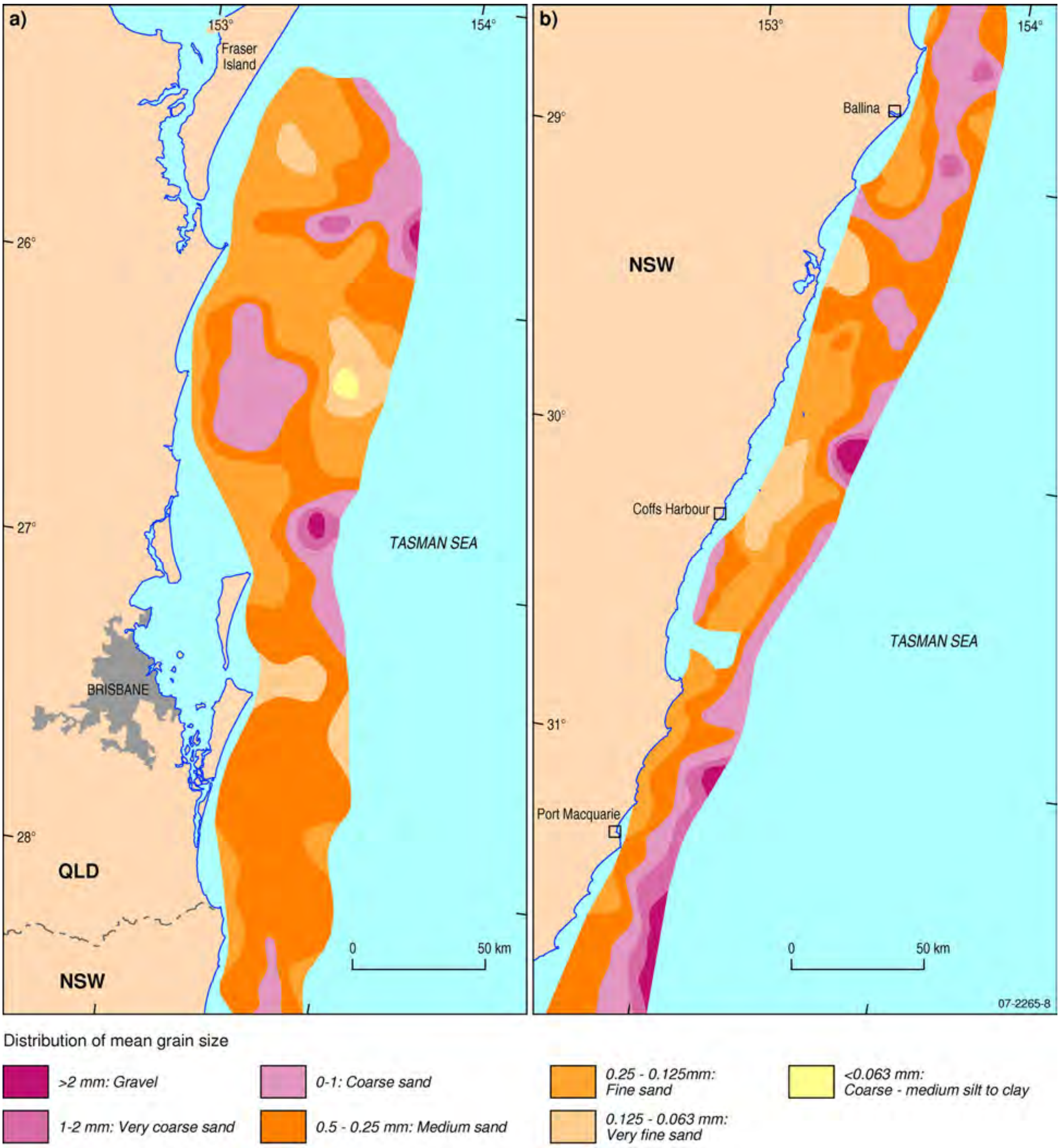


Figure 3.17. Maps showing the distribution of grain size of surface sediments on the continental shelf and upper slope from Fraser Island to 32^{0}S. (Marshall, 1980).

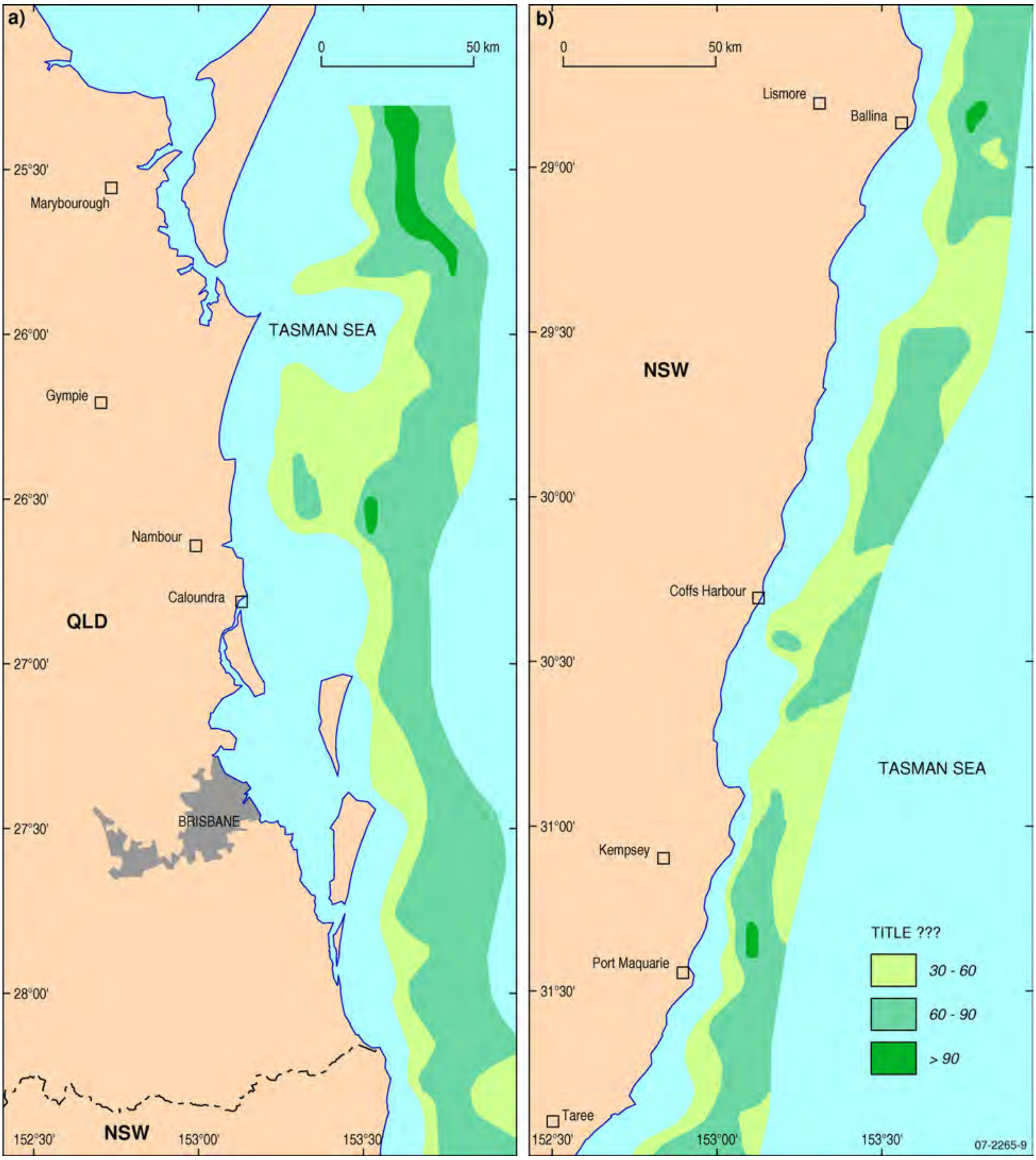


Figure 3.18. Maps showing the distribution of calcium carbonate (weight %) in surface sediments on the continental shelf and upper slope from Fraser Island to 32^{0}S. (Marshall, 1980).

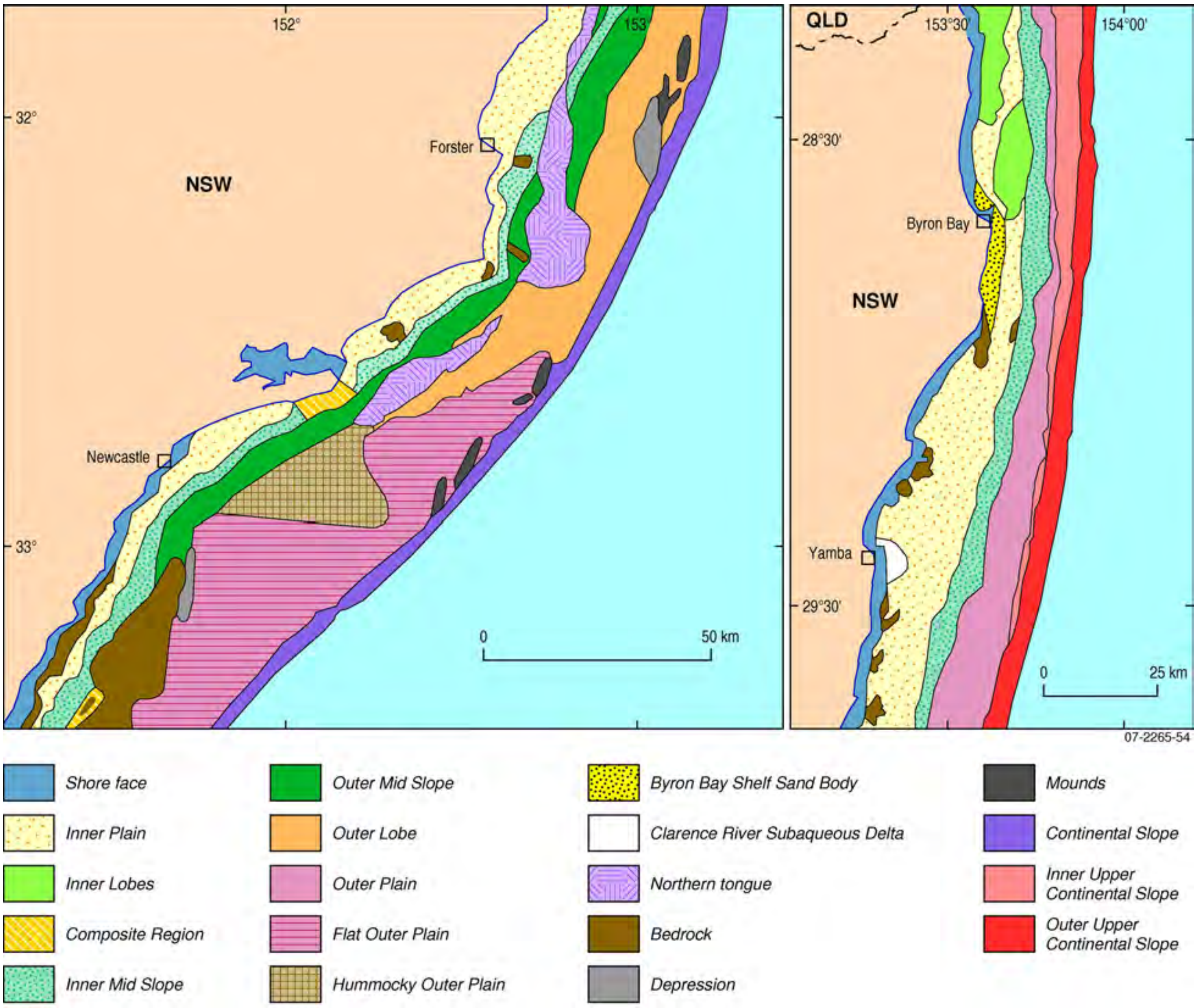


Figure 3.19. a) Distribution of morphological units and location of profiles, central NSW. Boyd et al*.*, 2004. b) Distribution of morphological units and location of profiles, northern NSW. (Boyd et al., 2004).

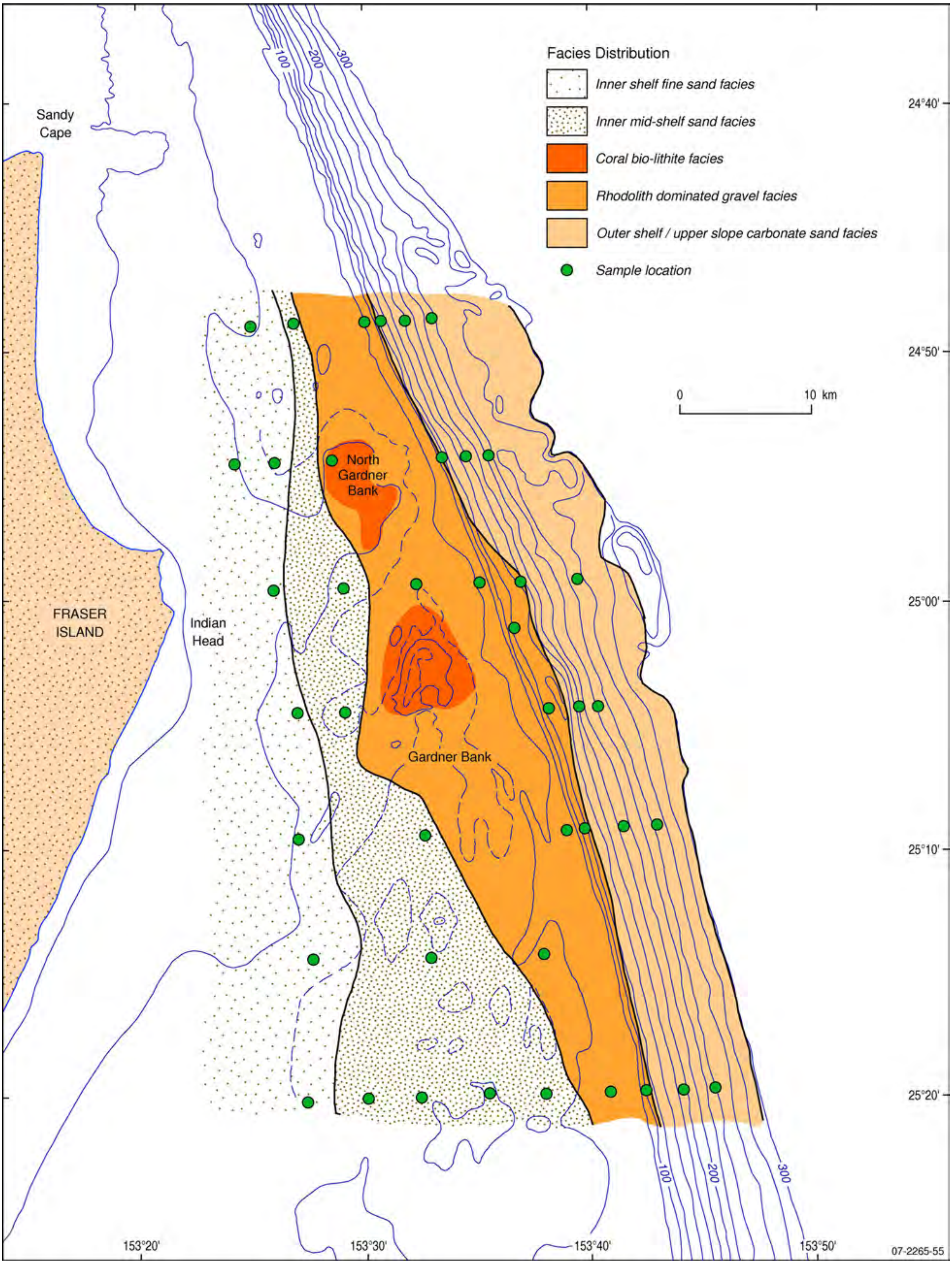


Figure 3.20. Bathymetric map offshore of Fraser Island showing the distribution of sedimentary facies on the shelf and upper slope around North Gardner Bank and Gardner Bank. (Marshall et al.,1998).

3.3. NSW AND SOUTHERN QUEENSLAND SLOPE

3.3.1. Geomorphology

The bathymetric data used for this review of the geomorphic features on the continental slope consists of two single-beam navy surveys collated by Packham (1983), a multi-beam survey of the central NSW slope by Glenn et al., (2007) and multi-beam surveys of the slope off Fraser Island by Boyd et al., (2004b, 2008). Ships of opportunity have also contributed their multi-beam bathymetry to the Geoscience Australia 250 m grid digital dataset but considering the area of the continental slope the multi-beam coverage is low (Petkovic and Buchanan, 2002). Seismic profiles of the slope have also been used to identify geomorphic features and subsurface geology by Jenkins (1984); Colwell et al. (1987); Heggie et al. (1992); Jenkins and Keene (1992); Colwell et al. (1993) and Glenn et al. (2007).

A characteristic of the NSW and southern Queensland continental slope is that its overall shape and orientation has been inherited from the initial rifting of the continental crust (Fig. 3.11). Canyons and mass wasting have modified this initial slope. Only on the upper slope has sedimentation determined the morphology. Most of the geomorphic features on the mid and lower slope are controlled by basement structures, particularly ridges and faults (Colwell et al., 1993; Glenn et al., 2007) (Fig. 3.21). Canyons exploit structural trends such as faults and along with mass wasting have shaped the slope, particularly below 1,500 m water depth. The location and pattern of canyon development is partly determined by tectonic features and underlying lithologies. Most canyons have linear segments where they are diverted by basement ridges or follow structural weaknesses. Many also have steps in their floors with scoured depressions as they descend over resistant strata.

The width of the slope from the shelf break to the abyssal plain/deep ocean floor varies by a factor of six. It is relatively narrow (40-50 km) in the south of the EMR, wider (50-60 km) off Sydney-Newcastle, wider still (60-70 km) off Sugarloaf Point-Port Macquarie, then narrower (20-35 km) off Port Macquarie-Coffs Harbour, gradually becomes wider (90-120 km) off Cape Byron-Moreton Island and then steps westward and gradually narrows to be 25-30 km wide off Fraser Island (Fig. 3.11) (Heap and Harris, in press). This variable width results in a range of slopes from 3° to 10°. Profiles of the slope vary from location to location but on a regional scale they can be used to divide the slope into: a) a generally convex upper slope above ~1,500 m that is relatively steep (4°-10°) particularly below 500 m; b) a rugged generally concave mid-slope down to ~3,000 m with locally steep scarps along slope, box canyons and flat terraces; and c) a very steep (10°-30°) and rugged lower slope below 3,000 m. The variety of slope profiles and widths is shown in Figure 3.22.

The two sections where the slope is particularly narrow are off Montague Island (south of 36°S) and between Port Macquarie and Coffs Harbour (310 30'S to 30°S). In these areas the slope is concave with many small canyons eroding the upper slope and joining to form large canyons down slope that cut through exhumed basement to make their way to the abyssal plain. Only remnants of a mid-slope terrace are preserved between the canyons or upslope from resistant ridges. It appears that these slopes have undergone considerable retreat due to erosion.

Off Montague Island the upper slope is steep (average 8°-10°) with many small slumps and canyons that amalgamate into larger canyons on the mid-slope. There are remnants of a mid-slope terrace at

2,200-2,400 m separated from the lower slope by a distinct along-slope basement ridge rising to 1,500 m that has dammed sediments on its up-slope side (Fig. 3.21; Colwell et al., 1993). The large canyons on the mid-slope are diverted along slope by this resistant basement ridge. At the northern end of this ridge is a large canyon with a dome-shaped seamount on the north side formed by an early Cretaceous igneous intrusion (Hubble et al., 1992). The lower slope is also steep and dissected by large canyons. The base of the slope is an abrupt contact with the abyssal plain/deep ocean floor at 4,850-4,870 m water depth.

Off Port Macquarie and Coffs Harbour there are no basement ridges but the large canyons have up to 2,000 m of relief on their sides on the lower slope. At both locations the large canyons have many small tributaries with their heads on the upper slope at 200-500 m water depth (Packham, 1983). At 30°S, offshore of Coffs Harbour, a particularly large canyon has incised to the 120 m isobath. A list of the canyons that have their heads at the 200-300 m isobath are given in Table 3.1. Such canyons may be younger than those with their heads in deeper water. They also provide access for deeper water to reach the shelf via upwelling.

Table 3.1. Location of canyon heads that reach the 200-300 m isobath

Canyon Head Offshore of:	Latitude
Montague Island	36^0 18'S
Jervis Bay	35^0 22'S
Jervis Bay	35^0 12'S
Jervis Bay	35^0 07'S
Newcastle	33^0 22'S
Newcastle	33^0 14'S
Port Macquarie	31^0 15'S
Port Macquarie	31^0 40'S
Coffs Harbour	30^0 00'S
Cape Byron	28^0 45'S
Tweed Heads	28^0 15'S
Noosa	26^0 16'S
Sandy Cape	24^0 40'S

The slope between Montague Island and Port Macquarie (36°S to 31° 30'S) is distinguished by a sediment wedge forming the upper slope and large canyons occurring approximately every 50 to 100 km on the mid and lower slope. The canyons are separated by a slope where the terrace between 2,000 and 3,500 m is largely preserved. The canyons are of two general types: those that have developed wide 'box' heads in the mid slope at ~1,500 m (e.g, Newcastle Canyon) and those like Sydney Canyon that have linear segments, few tributaries and have their heads in the upper slope.

The Newcastle Canyon and box canyons off Jervis Bay also have small, narrow tributary canyons that have incised the upper slope to the shelf break. There are many slumps on the mid-slope along this section of margin, plus some in the toe of the upper slope sediment wedge.

Between Coffs Harbour (30°S) and Moreton Island (27°S) the mid-slope terrace widens to form what can be defined as a small marginal plateau 300 km long and up to 120 km wide (Figs. 3.23 & 3.33). Two large, long canyons cut this plateau but little detail is known because this section of the slope is mostly unsurveyed.

North of Moreton Island the southern Queensland slope lacks a mid-slope terrace and also lacks large canyons, but is cut by many small to moderate size canyons. At 26° 35'S the slope steps east by 20 km. This step in the slope coincides with a possible change in basement lithology (Palaeozoic basement/Maryborough sedimentary basin) and the Recorder Fracture Zone in the adjacent oceanic crust (Hill, 1994; Exon et al., 2006a and b). A canyon has formed at this location and heads in 220 m of water (Marshall, 1978). The slope continues north with a width of 50-60 km until it turns NNW at 25° 20'S, again at a fracture zone, and again there is a relatively large canyon on the slope. Here the trend of the slope is probably controlled by the Maryborough rifted margin fault (Exon et al., 2006a) as it gradually curves westward until 24° 40'S, offshore of Sandy Cape and at the Cato Fracture Zone which is the northern boundary of oceanic crust. At this location the slope trends NW and becomes more gentle. The break in slope at its base is less distinct and shallower at approximately 3,700-3,500 m. This section of slope was formed later in the history of the opening of the Tasman Basin which, along with the lack of a large drainage basin in the hinterland may explain the absence of large canyons. Substrate geology controls the shape and course of canyons.

The base of the slope and its orientation is defined in several locations by linear fault scarps formed in the late Cretaceous-Paleogene as the result of rifting of the crust (Fig. 3.24). South of 36°S the base of slope trend north. At 36°S the orientation of the base of slope changes abruptly to trend more easterly and becomes a distinct linear scarp, probably the expression of a strike-slip fault formed during rifting. This ridge rises to 2,800 m and descends on its eastern side by a spectacular 1,000-2,000 m high scarp (average gradient 25°) to the abyssal plain/deep ocean floor at 4,800 m. It may have been formed immediately prior to spreading by the strike-slip fault proposed by Norvick et al., (2001). This trend continues to 34° 50'S where the base of slope steps seaward. This step is where the Barcoo Fracture Zone in the oceanic crust meets the continental crust of the continental slope. North of the Barcoo Fracture Zone the base of slope continues to the NE with a sharp contact with the abyssal plain/deep ocean floor at depths of 4,810-4,870 m and the slope becomes wider (47 to 65 km) to the north. At 33° 10'S (east of Newcastle) the base of slope again steps eastward to become a 10 km long, 800 m high scarp (4,000 to 4,860 m water depth) trending NE. This corresponds with an increase in the width of the lower slope. North of this scarp the base of slope trends more northerly at depths of 4,400 – 4,550 m. This continues to 31° 30'S off Port Macquarie.

The contact at the base of slope with the abyssal plain is shallower where small sediment fans occur off the Hunter River (base of slope 4,100 m) and off Port Macquarie - Coffs Harbour where three small fans give the base of slope an undulating contact ranging from 4,500 to 4,000 m (Packham, 1983; Jenkins, 1984). It is possible there is also a fan off the Clarence River but data are lacking. South of Moreton Island the base of the slope is very steep with a 1,200 to 1,400 m high scarp between 28° 03' and 28° 17'S and a sharp contact with the abyssal plain at water depths between 4,800 m and 5,000 m (Figs. 3.23 and 3.33). North of Moreton Island the base of the slope shoals to 4,500 m off Noosa, but remains a steep lower slope of faulted basement with an abrupt contact with the abyssal plain/deep ocean floor (Hill, 1992). The base of slope occurs at depths of ~3,800 m east of Fraser Island and shallows further to 3,500 m east of Breaksea Spit (Boyd et al., 2004b) and 4,000 m along the southern margin of the Marion Plateau (Fig. 3.35). This shoaling of the abyssal plain northward, and hence base of slope, is due to increased sedimentation on the abyssal plain in the north. Basement outcrop is common on the lower slope because sediment supply to the slope has been low and erosion has occurred.

In contrast to the rugged lower slope the upper slope, (above 1,500 m) is generally smooth because it is formed by deposition on the distal face of the prograding sediment wedge. Some geomorphic features do occur on the upper slope as bedrock outcrop, or due to currents scouring depressions and depositing ridges as well as mass wasting forming canyons and slump scars. Incipient slumps form arcuate ridges on the upper slope and are common below 1,000 m water depth. South of Jervis Bay the upper slope is less convex due to the steeper slope above 500 m compared with that depth interval further north.

The only canyons to erode into the shelf break are offshore of Jervis Bay. Three canyons have their heads in 150 m of water and are known as the Shoalhaven Canyons. Off Newcastle three of the Hunter Canyons have incised their heads to water depths of 200 m and the Manning Canyon off Taree starts in 370 m of water.

Significant basement outcrops occur on the upper slope off Wollongong, off Sydney and off Port Macquarie. On the upper slope off Wollongong and extending for 11.4 km along slope is a large outcrop of basement that has a relief of at least 111 m, rising to a depth of 650 m from water depths of 790-680 m and continuing down slope as rock outcrop to 990 m on the eastern side (Fig. 3.25). It has an erosional moat along the western margin, presumably due to the south flowing EAC. A depositional lee ridge has accumulated sediment in the southern or downdrift area behind the basement block. Offshore of Sydney the Mt Woolnough seamount rises 130 m from the surrounding seabed (~550 m) to three peaks, the shallowest being 383 m (Fig. 3.26). It is a rugged feature (1 km wide at base) and is the eroded remains of a basalt volcanic cone. Associated smaller rock outcrops extend 4 km to the NE with up to 50 m of relief. To the SE, in 780 m of water, are five en echelon ridges of rock 1.3 km long with up to 25 m of relief. The effect of the EAC encountering the Mt Woolnough seamount and nearby rock obstacles can be clearly seen in the sediment bedforms. The current eddies in the lee (south side) have eroded a 40 m deep moat at the base of the seamount with a broad (800 m wide) 10 m high depositional levee forming a 2 km long tail downstream. There is a similar sediment ridge extending 2 km on the north side. The rock outcrops at 800 m water depth also have current scours in the surrounding sediment indicating that the EAC erodes sediment to at least this depth.

Another basement outcrop occurs offshore of Port Macquarie between the 200 and 300 m isobaths. It is 8 x 2 km forming a ridge along the upper slope rising to within 175 m of the surface with a scoured channel to depths of 254 m on its upslope side and outcropping to 280 m on its down-slope side. Boyd et al. (2004a) describe mounds on the upper slope (140-165 m) north of Port Stephens (Fig. 3.19a). They interpret them as temperate carbonate reefs or possibly gravity slumps.

The width of the slope offshore of Jervis Bay is 47 km. The Jervis Bay region has a very steep upper slope of 80 to 90 between the 400 and 600 m isobath and 70 to 80 down to approximately 1,500 m.

Prominent features on the upper slope are six narrow canyons and many smaller down slope gullies (Fig. 3.24). In their upper reaches these canyons are 200 m deep, meander and are v-shaped. Below 1,100 m water depths the canyons erode into the lower part of the sediment wedge and are flat-bottomed, 200-400 m wide and only 100 m deep. The slope of their thalweg becomes abruptly steeper below 1,500 m (from 4.30 to 90) where they join a large box canyon on the mid slope. On the mid-slope between 1,500 and 2,500 m there are scarps up to 180 and there are numerous retrogressive slides. Below 2,500 m is a 15 km wide terrace, largely un-surveyed, with a prominent linear ridge forming its outer margin.

The narrow and relatively straight canyons extending up the slope in the Jervis Bay region are related to the Shoalhaven River drainage and its deposition of sediment on the shelf and slope during the Cainozoic. They were incised into the sediment wedge above the 1,500 m isobath by turbidity currents carrying sediment down slope. Meanders in the canyons are caused by deflection by more resistant strata in the sediment wedge as are steps in their otherwise flat floors. The particularly large step down in the floor of the canyon at 1,500 m is caused by a change to a more resistant basement lithology.

Large mass wasting features occur off Wollongong. Figure 3.25 images a straight-sided slide in the upper slope sediment wedge that is 5-7 km wide and extends down slope for 15 km between depths of 400 m and 1,300 m. It starts as two broad slumps at the 400 m isobath. The floor of the slide scar is asymmetrically deeper to the south, with the southern scarp up to 200 m high and the northern scarp stepped, and a maximum of 120 m high. The floor of the slide has grooves ranging from 2-40 m deep, from 90-500 m wide, and up to 5.5 km long. To the north of this slide is the Bulli Slide (Fig. 3.25) located immediately down slope from the large outcrop of basement described earlier. It is the largest gravity failure feature discovered so far on the margin. It has an arcuate plan shape with a maximum width in the upper erosional slide area of 11 km. The slide feature descends from 950 m to over 3,300 m water depth over a distance of 22 km. The floor of the slide has a slope of 5.90. The margins of the slide are up to 200 m high.

The head of Sydney Canyon is relatively subdued, consisting of slump scars in 880 m of water that open down slope into a broad amphitheatre 4 km wide with 140 m relief at 1,000 m. The relief on the slumps is subdued and slope-parallel, perhaps because they are draped by younger sediment or have been modified by the EAC. From here the canyon runs down slope to the southeast for 11 km to 1,800 m. The southern side is linear and steeper than the northern side. Subdued slump scars are common on the continental slope on either side of the canyon from around its head to 1,800 m where it turns south and is linear and oblique to the slope for further 12 km to 2,800 m and joined by four tributaries. Relief in the main canyon is greatest (750 to 600 m) where the canyon floor is between 1,800 and 2,500 m, the steepest side is initially the western side but below a floor depth of 2,100 m the steepest side is on the east (seaward) as the floor continues to descend to the south. A linear ridge forms its eastern side like a rampart along this length. It then turns southeast where the floor descends from 2,300 to 3,100 m over a series of steps with 'plunge pools' and continues for 20 km to 3,850 m before turning south. The floor of the canyon at 3,850 m steps down 300 m into a 'plunge pool' that is 100 m deep (water depth 4,200 m) in the 3.5 km wide floor. At this point the canyon sides have relief of 600 m up to the adjacent slope depths of 3,600 m. The canyon continues for a further 12 km to exit on the abyssal plain at 4,896 m as a broad, 6 km wide channel 400 m deep. The total length of the canyon is 55 km.

Seaward of the Hunter River mouth the most obvious features on the slope are a series of seven canyons on the upper slope that begin in around 200 m water depth, with incision of around 350 m and canyon widths of 1-2 km and continue down slope for 15-20 km to 1,500-2,000 m depth where they join a large box-canyon (Fig. 3.27). The canyons are sinuous and the v-shaped (20-25° slopes) down to the 800 m isobath. In deeper water they become linear, flat bottomed and terraced. Parts of the toe of the sediment wedge between these small canyons have been removed by gravity slides. On one slip surface are circular depressions up to 600 m across and 70 m deep (Fig. 3.27), which may be due to water and/or gas seepage.

The seven small canyons on the upper slope feed into a large box-canyon feature beginning in ~1,200 m water depth at the top of several failure scars have eroded the mid-slope. These failure scars coalesce down slope forming a single narrow canyon 7 km wide with over 800 m of relief. This is known as the Newcastle Canyon and is mainly developed in bedrock with around 400 m of relief at its head (Fig. 3.28). The canyon continues for 22 km before ending in around 4,300 m water depth where it is incised into a fan forming the rise. Irregular topographic features on the order of 400 m high and 2 km wide occur in the canyons and on the slope below 1,500 m off Newcastle. These narrow ridges and pinnacles occur as resistant bedrock within the canyons and on the edge of scarps and are most likely eroded volcanic intrusions (Fig. 3.28).

Offshore of Sugarloaf Point several significant slides occur on the seaward edge of the sediment wedge at water depths of 800-1,500 m (Fig. 3.29). One is from 3-5 km wide, is a minimum of 6 km long and has steep sides (20°) up to 140 m high. The slide mass has fed into a canyon down slope. The floor of the slide has a slope of around 3°. Another slide begins in a relatively shallow 800 m water depth and its erosional scar is up to 3.6 km wide and 3 km long and extends to 970 m water depth. This slide is unusual in that it has formed a debris flow that has been preserved further down slope with more than 80 individual blocks up to 40 m high strewn across a debris apron 5 km long and 4 km wide. The blocks are probably semi-consolidated clays and chalks. Boyd et al. (2008) used multi-beam bathymetry to describe the slope in the area off Fraser Island in detail. This is the only area where significant amounts of sediment are moving across the shelf and reaching the heads of canyons on the upper slope. These canyons can be considered active whereas the canyons further south are not receiving sediments, because they have been cut off from the rivers that supplied them by the rise in sea level. Off Fraser Island the slope is relatively narrow (20-30 km), highly erosional and steep with average gradients of 6.5-100 (Boyd et al., 2008). The upper slope is steep (14°) and consists of two or three steps formed by lithified Quaternary carbonate platforms (Payenberg et al., 2006). Below this at a depth of 150 m many gullies have their heads. They are up to 330 m wide and 40 m deep and they join to form larger canyons in the middle-lower slope, which in turn feed into the Capricorn Sea Valley at the base of the slope. The abyssal plain abuts a steep lower slope at 3,500 m. To the south of this area, off Gardner Banks, the top of the slope is at 85 m water depth where there is a 'nick-point' at the base of a 20 m high cliff (Marshall et al., 1998). Seaward of this reef there is a gently sloping (1-30) terrace for 6-10 km with a mound on its outer margin at 300 m water depth, seaward of which the slope increases. Marshall et al., (1998) choose this outer change in slope due to a submerged carbonate platform as their shelf break resulting in their shelf breaks in southern Queensland being particularly deep at between 210 and 450 m. The lower slope is steep and basement outcrops along a fault which meets the abyssal plain/deep ocean floor at 4,500 m water depth (Hill, 1991).

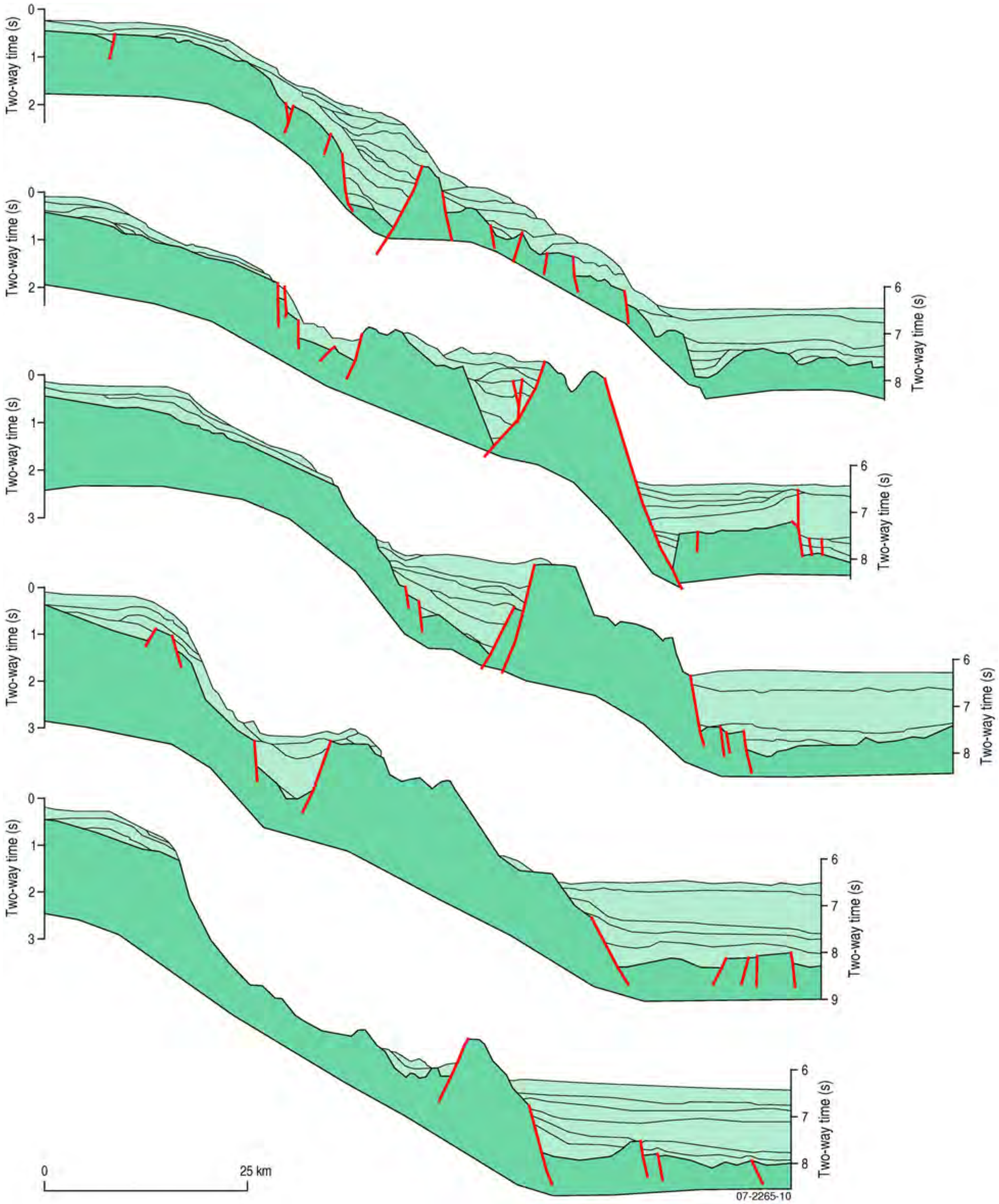


Figure 3.21. Line drawings of interpreted seismic profiles from the southern NSW slope and adjacent abyssal plain showing the relationship of sediments to basement. Note the convex upper slope with sediment wedge, concave mid-slope with erosion or sediments behind an outer ridge and a rugged and steep lower slope. BMR Survey 68, (Colwell et al., 1993).

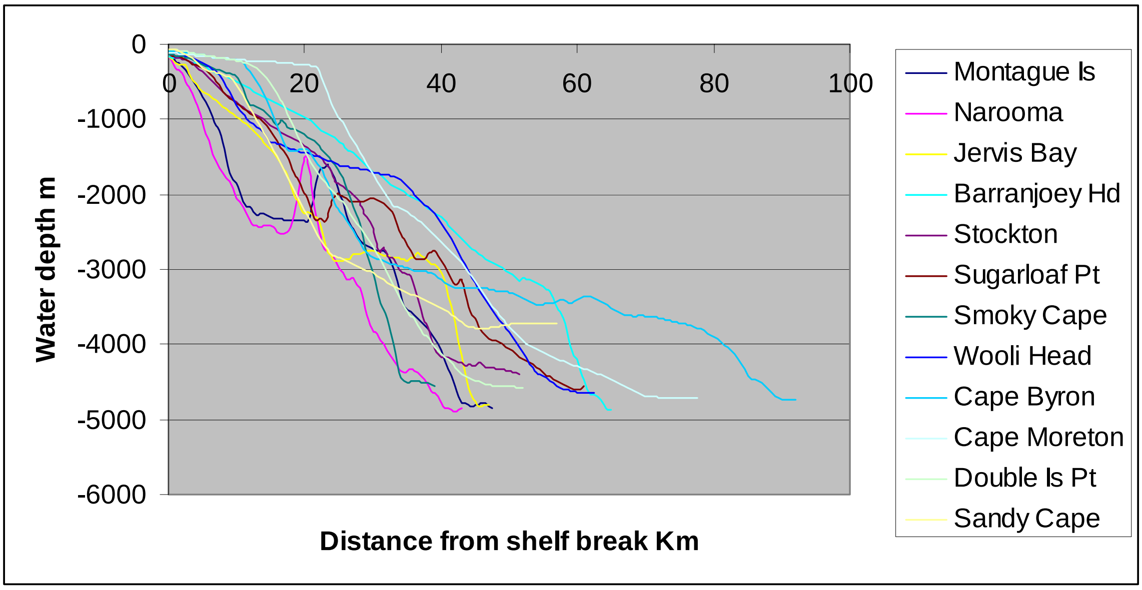


Figure 3.22. Profiles of the slope from the shelf break to the abyssal plain. A range of widths and slopes occur on this margin. Profiles are approximately equally spaced from Montague Island to Fraser Island.

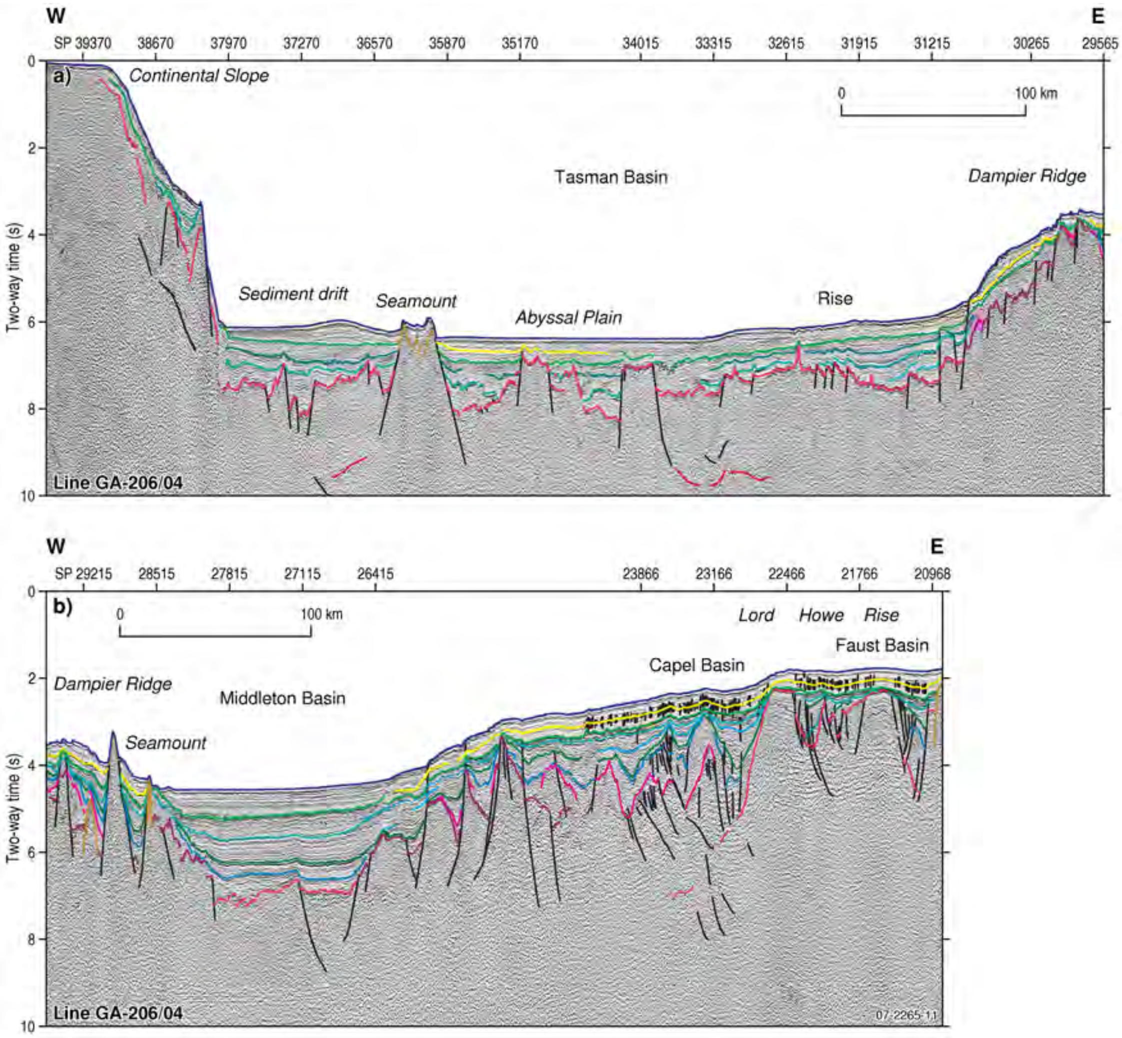


Figure 3.23. Seismic profile from Yamba, NSW, across the Tasman Basin to the Dampier Ridge. It shows the wide slope, lack of rise, abyssal plain and the rise at the foot of the Dampier Ridge. Note the drift deposit on the abyssal plain/deep ocean floor and the basement seamount. Location on Figure 3.1. (Van der Beuque et al., 2003).

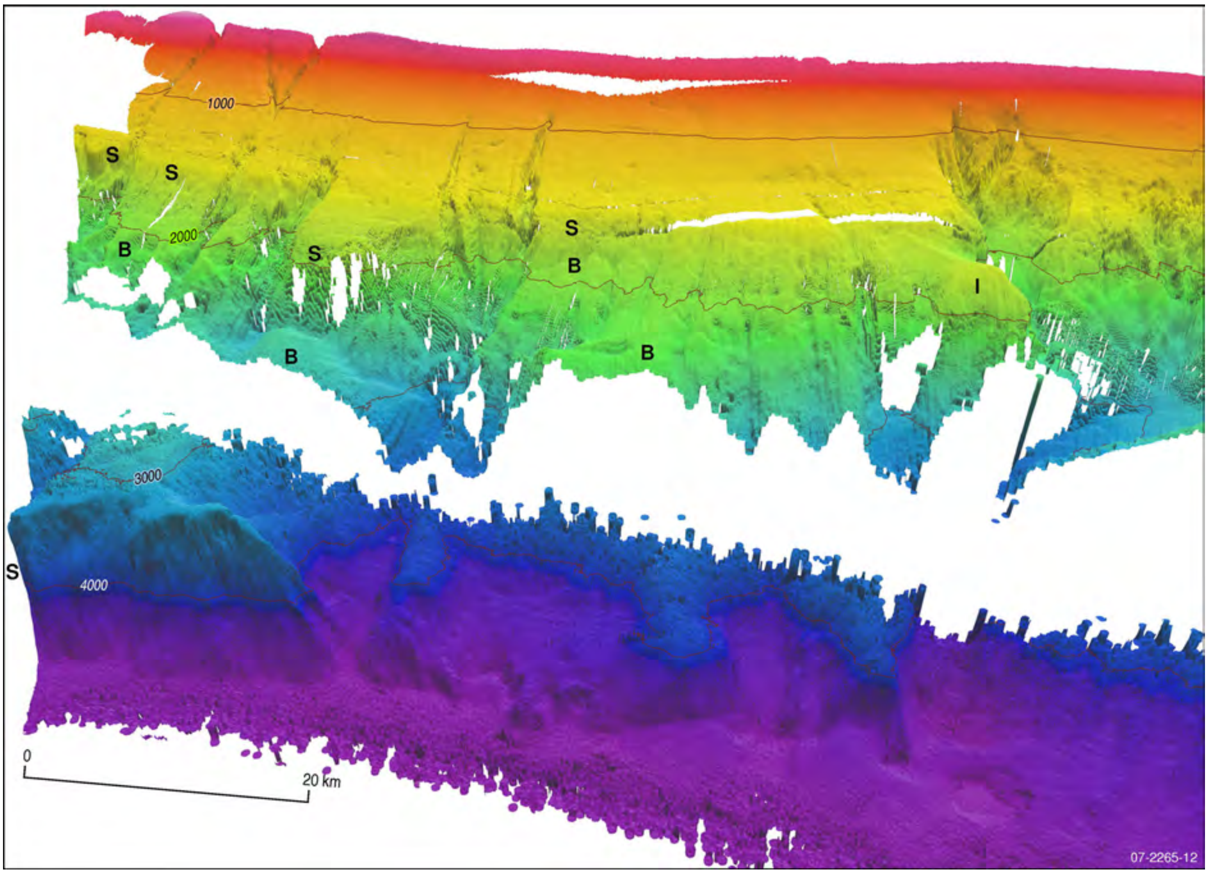


Figure 3.24. Oblique view of the slope off Jervis Bay looking up slope to the west. Note the canyons in upper slope, mid slope terrace and large canyons. Other features are domed hills of resistant igneous rocks (I), scarps (S) and slide blocks (B). The scarp at base of slope is a major feature. V.E. 6x. Location on Figure 3.11.

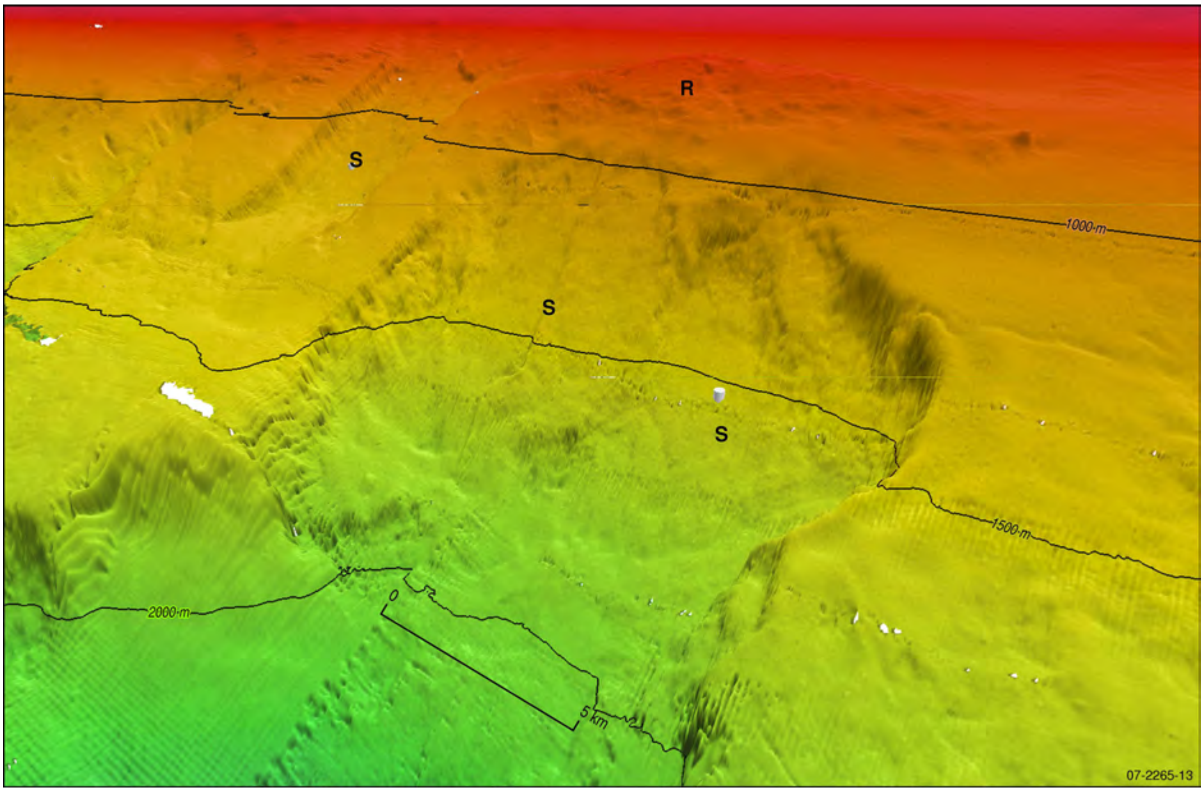


Figure 3.25. Oblique view looking up slope off Wollongong to the west. Note the rock outcrop (R) on the upper slope, slide scars (S). The slide on the left is in the sediment wedge whereas the larger slide is on the seaward face of the basement outcrop. V.E. 6x. Location on Figure 3.11.

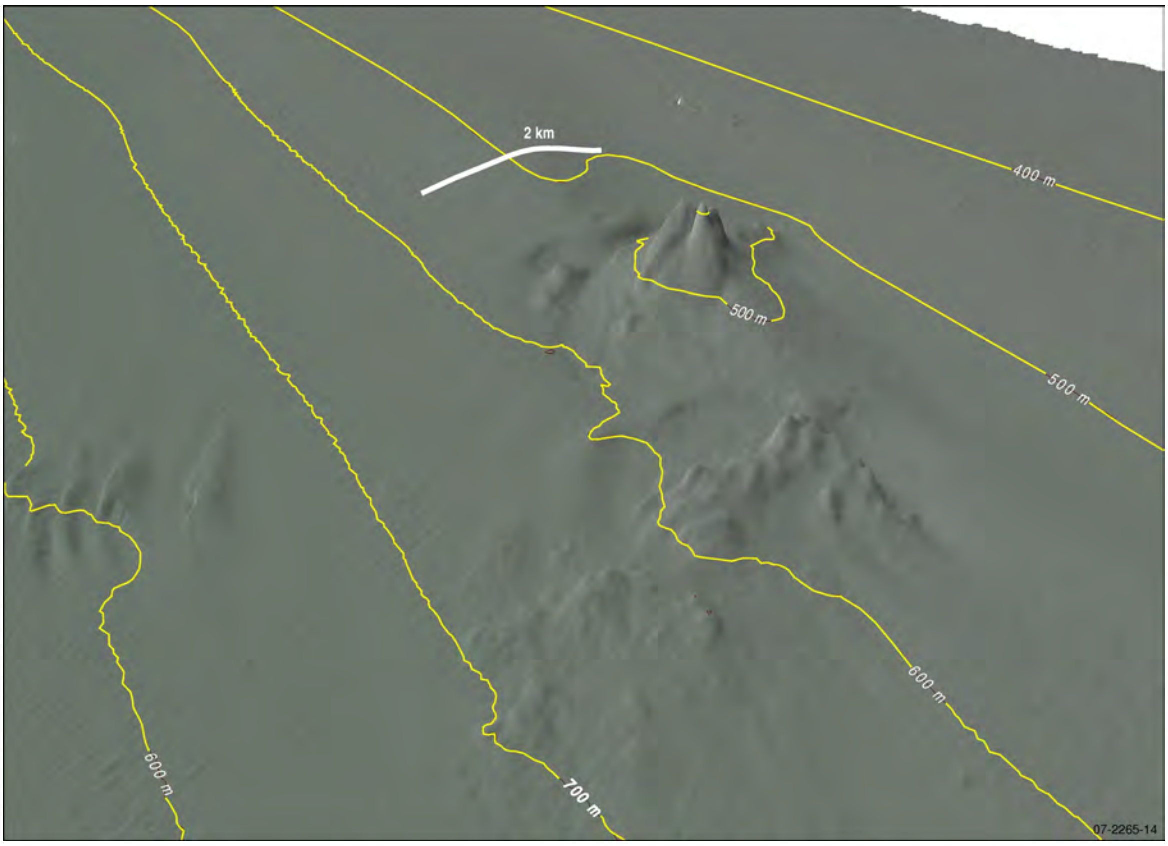


Figure 3.26. Oblique view of Mt Woolnough on the upper slope offshore of Sydney looking southwest. Note the erosion moat and depositional lobes down to 800 m water depth around the bedrock due to the EAC. V.E. 6x. Location on Figure 3.11.

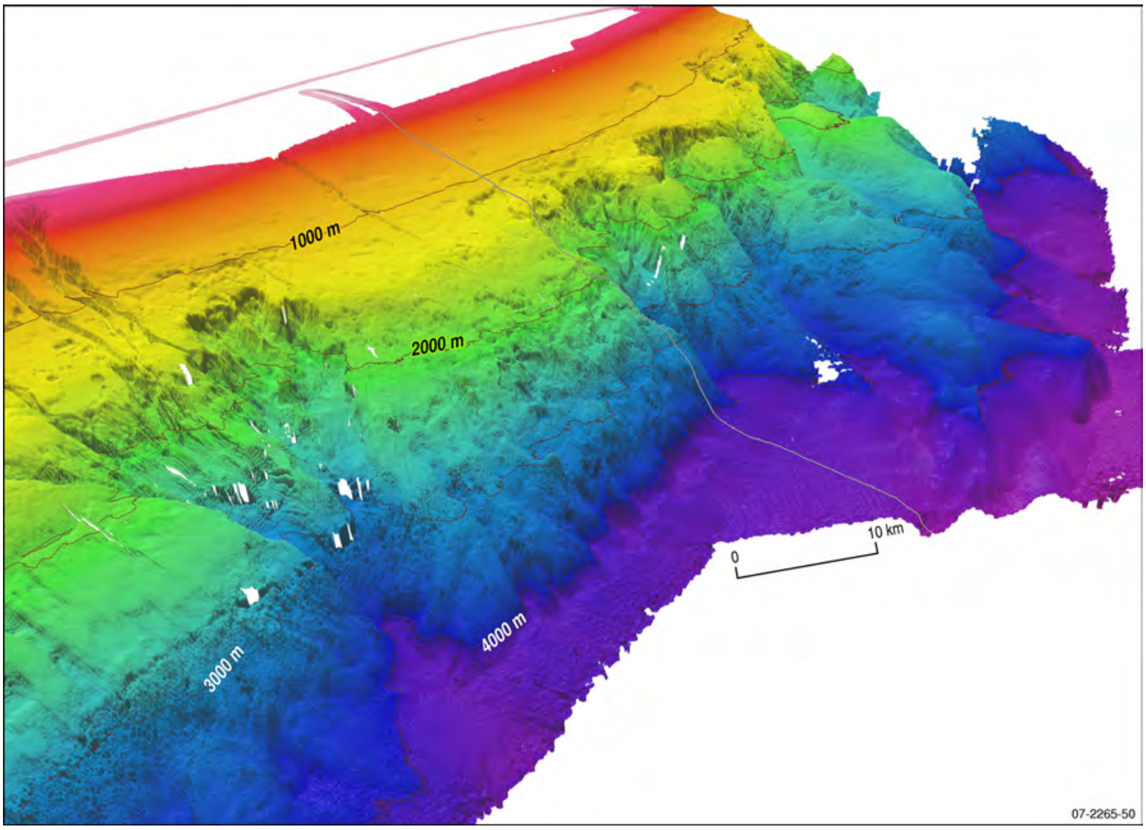


Figure 3.27. Oblique view looking north up slope off Newcastle to the northwest. Note the small canyons (Hunter Canyons) and slumps in the upper slope sediment wedge. They feed into wide box-canyons on the mid-slope. The lower slope is

rugged with linear (fault?) scarps. The canyon on the left (Newcastle Canyon) has incised into a fan at the base of slope. Note the offset of the lower slope to the east at the top right of image. V.E. 6x. Location on Figure 3.11.

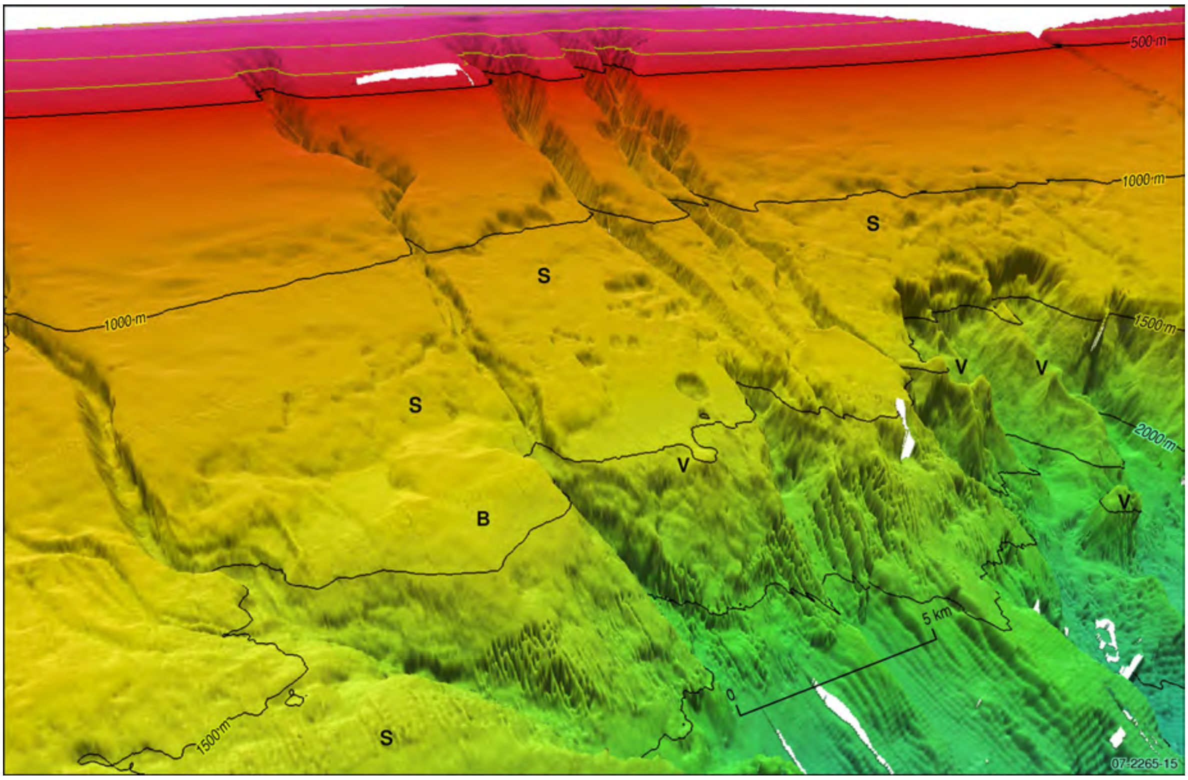


Figure 3.28. Oblique view enlargement of Figure 3.27 showing the Hunter Canyons incised in the upper slope sediment wedge. They feed into the wide box canyon in the mid and lower slope. Isolated round peaks are interpreted as volcanic (V). Slide scars (S) and displaced blocks (B) indicate headward erosion of the box-canyon. V.E. 6x.

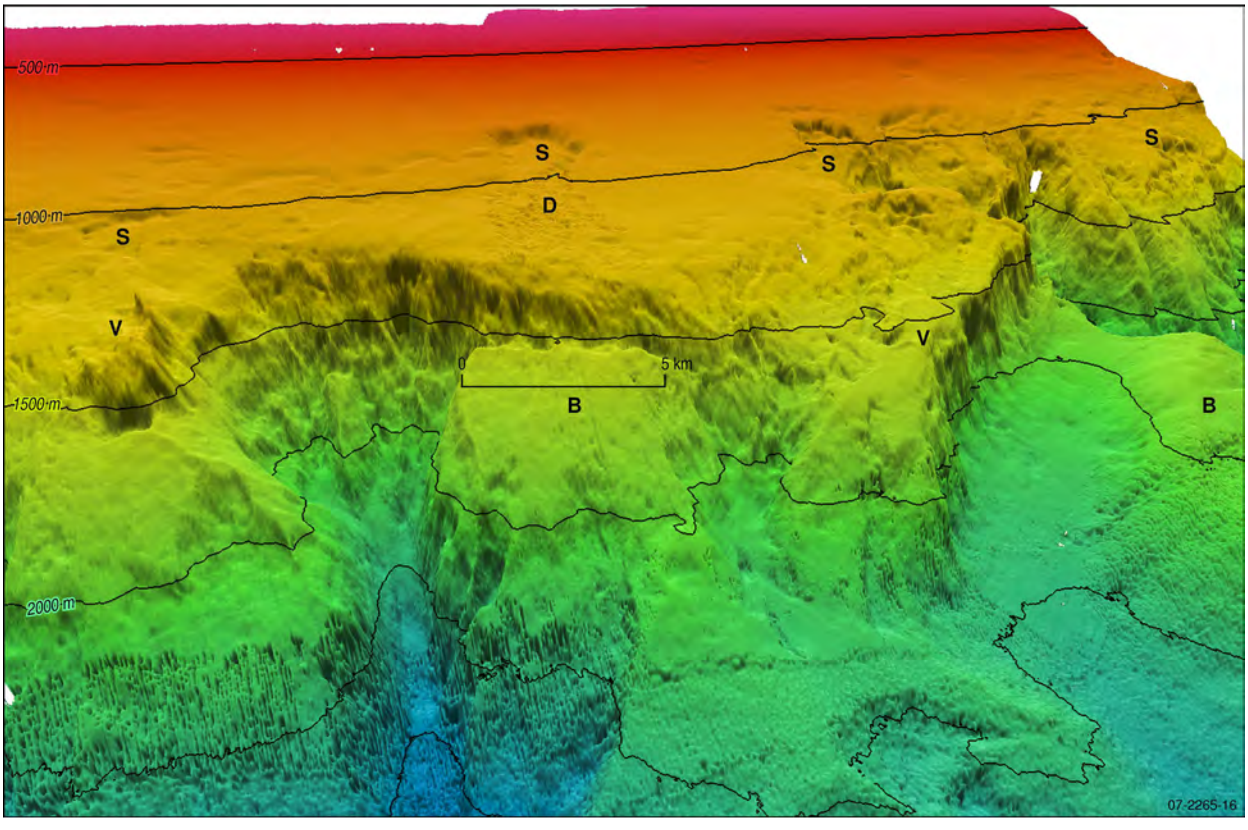


Figure 3.29. Oblique view enlargement of Figure 3.27 showing slope failure in toe of the sediment wedge (S = slide scars), debris flow (D), displaced blocks (B) and volcanic ridges and pinnacles (V). V.E. 6x.

3.3.2. Surface Sediments and Rocks

The surface sediments on the slope of the EMR are typical for this hemi-pelagic environment: a suite of biogenic and terrigenous sediments coming from the shelf mixing with the remains of plankton that live in the water column above the slope and benthos that live on and in the seabed. Packham, (1983), Hubble and Jenkins (1984a and b), Heggie et al., (1992), Howard (1993), Lane and Heggie (1993), Troedson (1997) and Troedson and Davies (2001) have made studies of parts of the slope. A summary of the published data on bottom photographs, cores and dredges from the continental slope is given in the Appendix C Tables 3.4, 3.5 and 3.6.

The main terrigenous components in the slope sediments are clay minerals and silt-size quartz, whereas the main plankton components are foraminifers, coccolithophores and minor pteropods. The principal remains of slope benthos are echinoderms and sponges (both siliceous and calcareous). Green glauconite pellets are a common sand-size authigenic mineral on the upper slope and phosphate nodules and clasts occur off northern NSW (von der Borch, 1970; O'Brien and Heggie, 1990). The texture and composition of the sediment varies with water depth and their colour is various shads of grey and olive with a very thin brownish oxidized layer at the surface. Bioturbation keeps the sediment relatively homogenous.

The upper slope sediment is calcareous muddy sand or a sandy mud, due to the relatively high content of sand-size foraminifers, glauconite, benthic particles and fine-sand size quartz. The texture varies along the margin. O'Brien and Heggie (1990) found sediment off northern NSW between 350-460 m water depth to be sands containing 30-60% carbonate (mostly planktic foraminifers), 20-35% silt to fine-sand size angular quartz, 7-30% glauconite pellets with coccoliths and clay minerals in the minor amount of mud. Boyd et al. (2004a) report significant amount of siliceous sponge spicules in the sediment on the upper slope offshore of Tweed Heads. The sediments on the upper slope offshore of major rivers tend to be less calcareous, presumably due to turbid plumes, and the sediments on the slope off southern Queensland are the most carbonate rich due to particles from the shelf, particularly algae (Troedson, 1997; Glenn et al., 2007).

The sediments on the mid-slope are more mud-rich due to the remains of coccoliths. The carbonate content is generally higher than for those on the upper slope, as there is less dilution by terrigenous mud. The oxygen minimum zone is poorly developed so the seabed is well oxygenated. The organic carbon content of the sediments is <1%. Bioturbation is abundant but beneath a brownish grey oxidizing layer of a few centimeters the sediments are an olive grey colour and are reducing. The lower slope sediments are also muds but have undergone carbonate dissolution because they are below the lysocline. The foraminifers are preferentially dissolved. Siliceous plankton such as diatoms and radiolarians are a rare component of the sediment because of the relatively low productivity in the waters along this margin. Thus there is no impact on the benthos of the oxygen minimum zone as is the case in more productive areas.

Cores from the upper and mid-slope (500-3,000 m) offshore of Sydney show surface sediment with increasing mud with depth: from 25% at 500 m, 40-55% at 1000-1500 m and >80% at 2,000-3,000 m, and with carbonate content varying between 40-50% (Howard, 1993; Troedson and Davies, 2001). Quaternary glacial/interglacial cycles have been reorganized in these sediment cores, through the changing mud and particularly carbonate content. Dating of the cores gives a sedimentation rate of 2-

5 cm ka-1 for the Holocene. A 5 m core from the lower slope off Port Macquarie (water depth 3768 m) consisted of surface sediment of calcareous mud (46% CaCO3), with fine terrigenous sediment mixed with foraminifers and coccoliths (Eade and van der Linden, 1970). Below the reddish oxidized surface the sediment is olive grey to yellowish grey, bioturbated with no bedding present and the carbonate content varies from 30 to 57%. The surface sediments from cores on the slope offshore of Noosa (Queensland) in water depths of 842 and 1,022 m are 70-80% mud and 50-60% carbonate (Troedson and Davies, 2001).

The distribution of sediments on the slope, and hence their texture and composition, is also affected by physical processes such as contour currents, turbidity currents, grain flows and debris flows. Colwell et al. (1993) and Glenn et al. (2007) identified debris flow deposits and current scouring and redeposition of sediment particularly around basement highs. Troedson (1997) recognised sandy turbidites in cores from the slope, and Marshall et al. (1998) reported redeposited carbonate sands to a depth of over 300 m offshore of Fraser Island. Boyd et al. (2008) found quartz sands from the inner shelf in the floor of submarine canyons down the entire slope off Breaksea Spit. This is in contrast to the hemi-pelagic mud and carbonate ooze on the slope adjacent to the canyons, that contain 23-57% mud and 25-43% carbonate. Marshall et al. (1998) found similar values in slope sediments down to 250 m offshore of Fraser Island with the mud content increasing from <5% to >20% and the carbonate content decreasing from >90% to < 50% down slope in less than 5 km.

A feature of the upper slope off northern NSW is the presence of hardgrounds, iron rich nodules and phosphate nodules in water depths <450 m (von der Borch, 1970; O'Brien and Veeh, 1980; Marshall, 1983; O'Brien and Heggie, 1990). These have been recognized on seismic profiles, in bottom photographs and by sampling. Many hardgrounds are present at water depths of 250-380 m north from Yamba (29° 25'S to 29° 08'S) and south of Coffs Harbour to Port Macquarie (O'Brien and Heggie, 1990). Ferruginous phosphorite occurs as both discrete dark-brown nodules 1-15 cm in diameter and as iron cemented hardgrounds. Marshall (1983) found nodules with iron contents up to 36% on the upper slope in shallower water depths of 197-274 m. Von der Borch (1970) distinguishes three types of phosphatic sediments on the seafloor: a) equant light to dark grey nodules 2-3 cm in size encrusted with calcareous organisms, b) nodules that have a thick coating on iron oxide and contain glauconite, and c) ferruginous-glauconitic- phosphorite conglomerate slabs 10 cm or more in size. The phosphate-rich nodules have a late Pleistocene or Holocene age whereas the iron-rich nodules are older than 800,000 years and probably Miocene (O'Brien and Veeh, 1980; Kress and Veeh, 1980; O'Brien and Heggie, 1990). O'Brien et al. (1981) propose that the younger nodules form by cementation with bacterial apatite.

Roberts and Boyd (2004) cored mud-rich biogenic gravel (bryozoa and sponge spiclules) and carbonate cemented clastic hardgrounds in 125 m water depth off northern NSW. Similar mounds with hardground outcrop have been identified on seismic profiles further south between 32° 30'S and 32° 55'S offshore of Sugarloaf Point and Nelson Bay (Boyd et al., 2004a; Glenn et al., 2007). They occur as strong seafloor reflectors on the shelf edge and upper slope between water depths of 150 to 180 m along with an exposed older surface that could be a hardground. This surface also outcrops where erosion has occurred further south (33° 15'S) near the heads of the Newcastle canyons in water depths of 180 m.

The upper slope in northern NSW is the only place where phosphate and silica sponge spicules form a significant part of the surface sediment. Both are indicators of relatively high surface water productivity in this area. The presence of nodules, slabs and hardgrounds on the seabed in this area is probably due to the low sedimentation rate because of winnowing and erosion by the EAC. Local upwelling also occurs where canyon heads have cut into the upper slope. Currents probably flow up and down these canyons on a regular basis and winnow the sediment on the seabed. Thus these canyons may have a more sandy floor than those in deeper water.

Seismic profiling has confirmed the presence of basement and volcanic outcrop as ridges normal to the slope (Fig. 3.30). They have been dissected by canyons and exposed by slumping. Dredging on the slope has revealed a variety of rock types representing basement lithologies (metamorphic rocks, igneous rock, sandstones, shales and limestone), igneous intrusions contemporaneous to rifting (monzodiorite, serpentinite), syn-rift sediments (mudstones and sandstones), post-rift sediments (limestones and chalks) and volcanic rocks (Heggie et al., 1992; Hubble et al., 1992; Quilty et al., 1997; Quilty and Packham, 2006). Rock outcrop on the seafloor also provides habitats for benthic organisms. One dredge offshore of Sydney in 1,600 m of water recovered a benthic community of living corals, sponges, annelids, echinoderms, brachiopods, bivalves and gastropods (Heggie et al., 1992). The location and composition of dredge samples from the EMR continental slope are given in the table in Appendix C Tables 3.6.

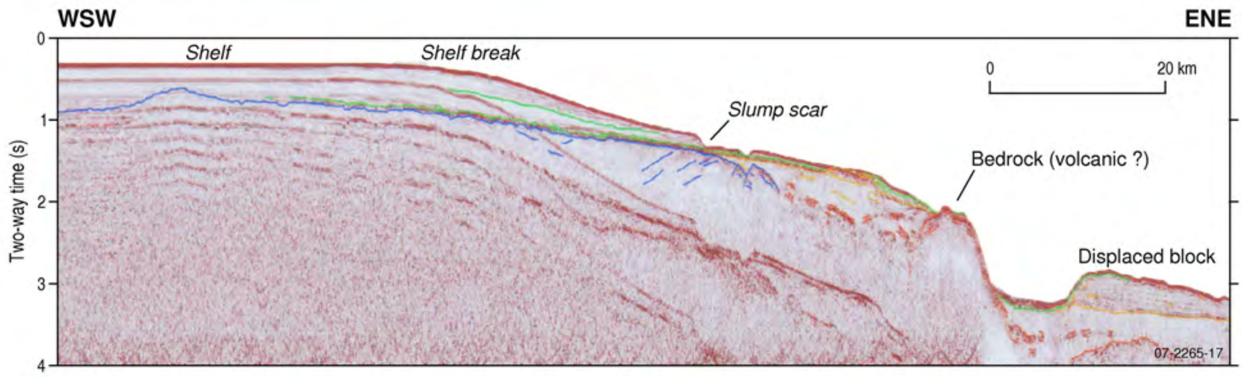


Figure 3.30. Seismic profile across the slope illustrated in Figure 3.29. Note the upper slope sediment wedge, slide scar, older rift sediment basin in the mid slope with a volcanic ridge exposed on the down slope side. Location on Figure 3.11. Line 007, Glenn et al., (2007).

3.4. ABYSSAL PLAIN/DEEP OCEAN FLOOR

3.4.1. Geomorphology

The Tasman Sea Basin is roughly triangular in shape with its apex in the north at the southern flank of the Marion Plateau and Cato Trough and widening to the south. This shape reflects its plate tectonic origin when the faulted margins of continental crust opened from the south and new oceanic crust was emplaced (Gaina et al., 1998a & b). The rectilinear margins of the basin, on a scale of 10 to 200 km persist today as a result of this original structural break-up pattern of the continental crust (Fig. 3.1). Within the EMR the basin is 1,200 km from north to south and 800 km wide at the southern boundary. Most of the seabed in the basin lies at depths of between 4,500 and 4,900 m and it gradually shoals to the north where the seabed is 3,500 m and 3,750 m off the northern tip of Fraser

Island and at the entrance to the Cato Trough respectively (Walker 1992; Exon et al. 2005; Boyd et al., 2008).

The floor of the basin is unusual in that the greatest depths are adjacent to the slope off NSW where the seabed is at 4,900-5,000 m and similar depths are reached at the base of the Monawai Ridge which forms the western margin of the southern Lord Howe Rise (Stagg et al., 2002). The maximum depth detected is over 5,100 m in eroded channels along the eastern margin of the basin and in depressions south of Taupo Seamount.

The basin can be divided into two geomorphic areas: a) the abyssal plain which forms the northern and western two-thirds of the seabed and, b) deep ocean floor that forms the eastern third of the seabed. The boundary between the two topographic styles of seabed is sharp (Fig. 3.31). The base of the slope along the eastern margin of the basin is generally a sharp contact and varies in depth between 3,500 m and 4,500 m. This absence of a rise and submarine fans is unusual for a basin of this age and reflects the lack of sediment input and erosion by bottom currents, particularly in the Neogene.

In the southern part of the EMR the basin is 800 km wide extending from the base of the slope off southern NSW to the base of the Monawai Ridge. North of this the basin narrows to 400 km at 33°S (Newcastle to Dampier Ridge) because both margins step basinward. It narrows again to 250 km at 28°S off Tweed Heads and it then widens to 350 km at 26°S off Noosa. Seamounts of all sizes and shapes rise from the seabed in both the abyssal plain and deep ocean floor areas (Fig. 3.1). Edgeworth David (David, 1932) was the first to draw a profile across the Tasman Sea. His figure is based on the west to east track of SS Britannia off Tweed Heads and identifies Globigerina (foraminifer) ooze adjacent to the Australian margin, then seamounts, red clay and manganese. He described one seamount as rising 4,880 m from the seabed to within 910 m of the surface along with a dredge sample of volcanic rock from its side (28° 42’S; 155° 37’W). He named it Britannia Seamount, which is now part of the Tasmantid Seamount chain (Standard, 1961) which rises from the seabed along a north-south line from the Cato Trough. General descriptions of the main features of the Tasman Sea floor are also given by Standard (1961) and Conolly (1968 and 1969).

The abyssal plain occupies the western part of the basin where it extends from the base of the slope to a sharp boundary with abyssal hills of the deep ocean floor (Figs. 3.31 and 3.32). Features on the abyssal plain are isolated basement outcrops forming seamounts and ridges, minor fans/debris deposits/channels at the base of slope on the western margin, and elongate drift mounds on the plain itself. The plain is readily identifiable on seismic profiles because it is near horizontal, smooth and internally consists of parallel reflectors. This reflects the principal mode of deposition by turbidity currents. Along its southeastern margin the plain is up to 50 m lower than the sediment draped abyssal hill region (Fig. 3.31). In the south the plain extends more than half way across the basin and the surface of the plain rises gradually to the north. It is 200 to 250 km wide in the southern part of the EMR where it extends eastward to Taupo, Barcoo, and Derwent Hunter Seamounts. It maintains this width northwards to occupy most of the basin north of these seamounts (Conolly, 1969; Jenkins, 1984). The turbidites of the abyssal plain have an abrupt contact with the Kenn Plateau in the northeast (Fig. 3.34).

A characteristic of the Australian margin is the lack of depositional fans at the base of the slope. The only submarine fans identified along the western margin of the basin are very small, less than 30 km wide, and located off the Hunter River (Newcastle), Macleay River (Smoky Cape, NSW) the Clarence River (Yamba, NSW) and Breaksea Spit (Sandy Cape, Fraser Island). Off the Maclay River Packham (1983) described three small fans at the base of slope at 4,000 m and extending to 4,500 m water depth. At 26°S offshore of Noosa Hill (1991) used a seismic profile to defined a slump mass forming positive relief on the seabed in 4,500 m of water and extending nearly 20 km out from the base of the slope. This slump mass is not recent as it has been eroded at the base of slope and is onlapped by turbidites of the abyssal plain on its basinward side.

The eastern margin of the basin adjacent to the Dampier Ridge also lacks fans and is of a similar depth to the conjugate western margin. What appears to be a rise 100 km wide occurs where the seabed shoals into an embayment in the Dampier Ridge between 28° 30′ and 29° 30′S (Figs. 3.1 and 3.23). The seismic profile in Figure 3.23 across this rise, along with a multibeam line further south, show it to have irregular topography on the order of 10's of meters interspersed with flat lying sediments. Small rises occur elsewhere along the base of the Dampier Ridge, and are formed by the accumulation of sediment debris redeposited from the slopes possibly by less subsidence in the underlying crust (Fig. 3.33). The basin is deep (~4,800 m) along the base of the Dampier Ridge where the seamounts are close. There is evidence for erosion by bottom currents in these areas (Baker et al., 1988a). Distinct erosion channels occur at the western foot of the Dampier Ridge where the abyssal seabed between the Dampier Ridge and the Taupo and Barcoo Seamounts is only 50 km wide (Jenkins, 1984). Moats 6-30 km wide and 18-332 m deep also occur at the foot of Recorder Seamount (west side), Britannia Seamount (east side), the Monawai Ridge and an un-named seamount (Appendix C Table 3.9; Fig. 3.33; Jenkins, 1984).

Jenkins (1984, 1992b) has described the depositional drift deposits and current erosion on the floor of the Tasman Basin. A large drift exists 150 km offshore of northern NSW and extends from 33°S for 600 km to the north until it abuts the Britannia Seamount (28°S) with a massive piling-up of sediments (Fig. 3.33). The drift is between 100 and 300 m high and 30 to 50 km wide. At its edges it merges with the abyssal plain. Jenkins (1984) named it the Kennedy Drift and uses internal bedding and erosion scours around small seamounts to conclude that the drift formed between a north flowing Western Boundary Undercurrent and a south-flowing current further east. Jenkins (1984) also defines a smaller sediment drift extending south of Stradbroke Seamount (29.5°S; 155.5°W).

A distinct erosional moat occurs in the abyssal seabed at the base of the slope offshore of Tweed Heads-Stradbroke Island, where the gap between the base of slope and the Queensland and Britannia Seamounts is only 40-80 km (Fig. 3.33). This north flowing current may also explain why the greatest depths on the abyssal plain are adjacent to the base of slope further south. The troughs along the base of slope in the south are smaller, about 20-50 m deep and a few kilometers wide. The shape of the subsurface reflectors suggests non-deposition due to current winnowing formed these troughs (Conolly, 1969; Jenkins, 1984; Colwell et al., 1993). The presence of relatively strong currents on the Tasman Basin seabed has been confirmed by current indicators in seabed photographs of the abyssal plain near the western margin (Jenkins et al., 1986).

At the northern end of the Tasman Basin the abyssal plain shallows to 3,500 m as a depositional rise at the base of slope, but it is not fan shaped (Fig. 3.35). The Capricorn Sea Valley is incised into this deposit (Boyd et al., 2008). It is a prominent feature on the seabed as it curves eastward from the base of the Marion Plateau slope, and runs south-south-east for over 120 km into water depths of 4,700 m. In contrast, at the southern end of the basin the Sydney Canyon exits onto the abyssal plain at the base of the slope (4,896 m) as a broad, 6 km wide channel some 400 m deep and with no evidence of a fan deposit.

Abyssal hills characterise the deep ocean floor in the south eastern part of the basin and are generally shallower (3,500 – 4,500 m) than the abyssal plain but with some depressions down to 5,100 m. The features forming the abyssal hills are broad ridges, hills and swales draped with sediment and with low relief (< 100 m), and hills and ridges of exposed basement with relatively steep relief of 100 to 1,000 m and often with eroded channels at their base.

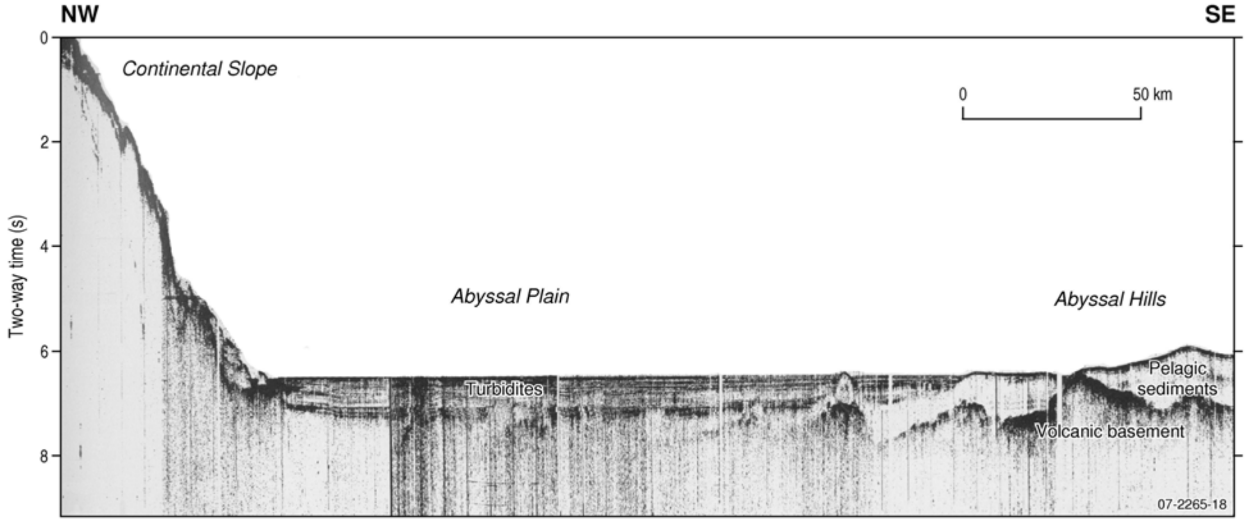


Figure 3.31. Seismic profile to the south-east of Newcastle showing the flat, near horizontal abyssal plain formed by turbidites and the sharp contact with the abyssal hills draped with pelagic sediments of the deep ocean floor region. Basaltic basement outcrops as small seamounts or where sediment is eroded. Location is on Figure 3.1. Eltanin Line 54.

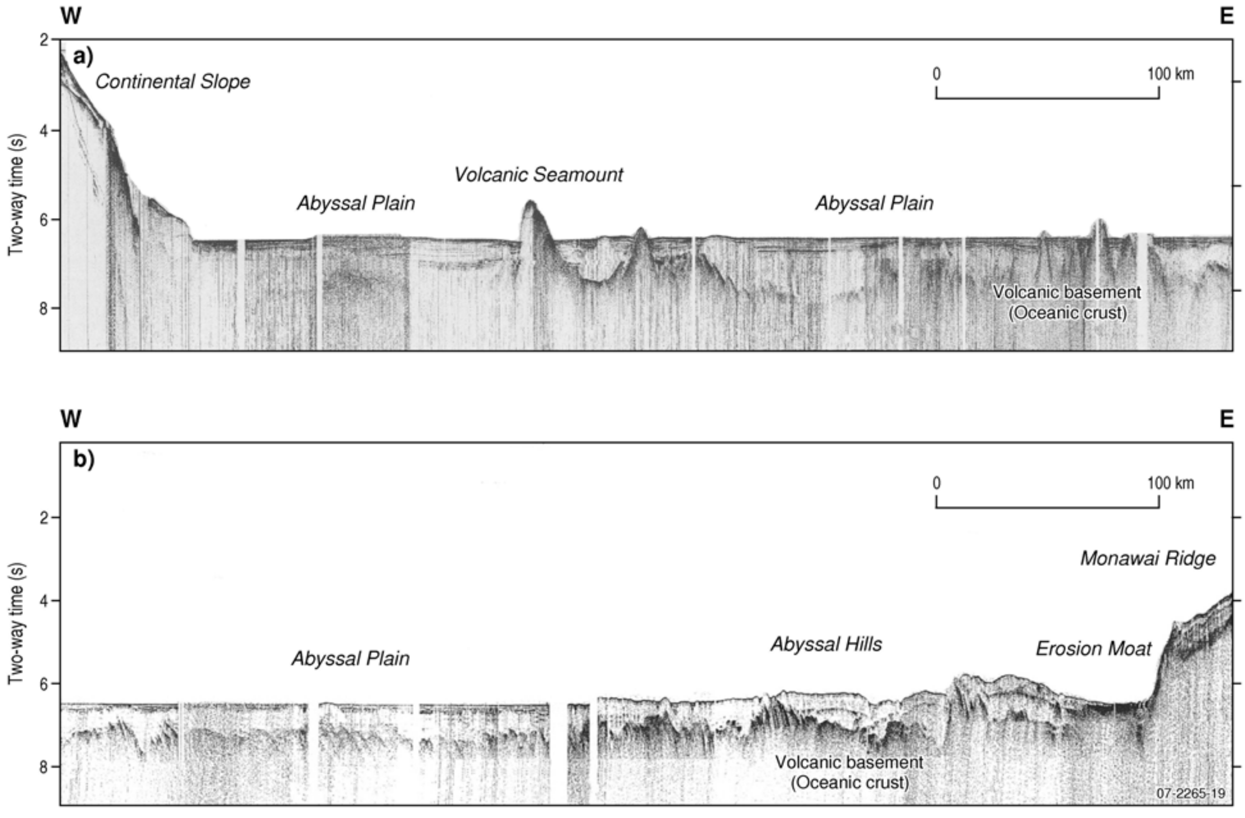


Figure 3.32. Seismic profile from the shelf off Newcastle across the Tasman Basin to the southern Lord Howe Rise. a) The seismic profile to the east of Newcastle shows the flat slightly convex-up abyssal plain. Note the broad moats at the base of the small seamounts of basement rock and b) Pelagic sediments in the eastern part of the basin show draping on underlying

basement topography and erosion adjacent to basement ridges. Note the scarp and the erosion moat at the base of the Monawai Ridge which forms the western margin of the Lord Howe Rise at this location. The Tasman Basin seabed along this transect is mostly in a narrow depth range from 4,800 to 4,900 m. Location is on Figure 3.1. Eltanin Line 47A.

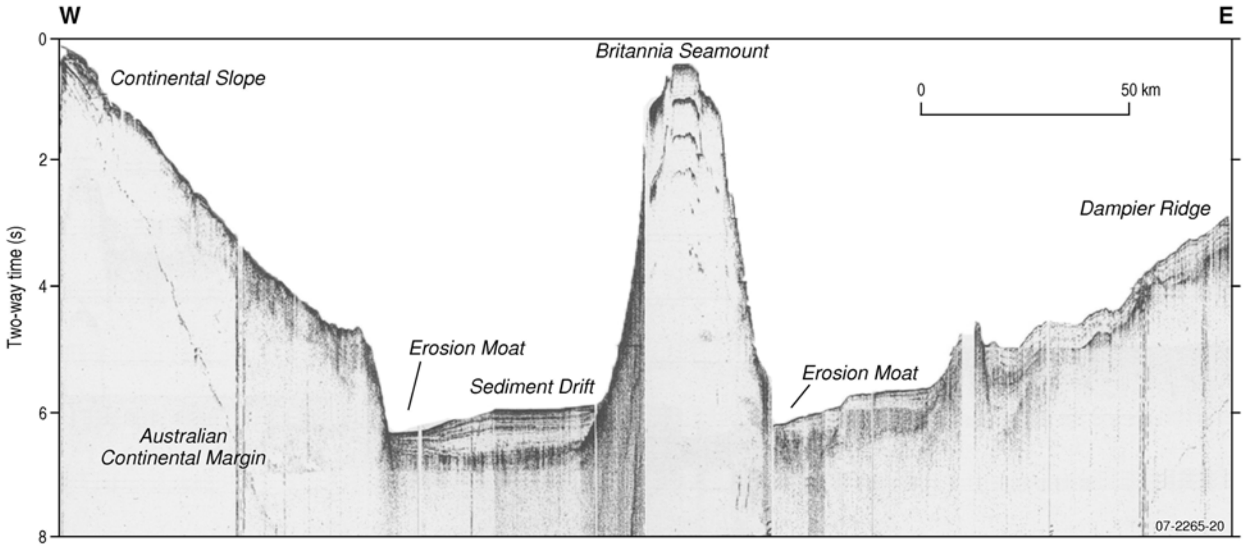


Figure 3.33. Seismic profile in the north Tasman Basin from east of Tweed Heads to the Dampier Ridge passing over Britannia Seamount. Note the wide mid-slope and steep lower slope with erosion moat at its base in the abyssal plain. Deposition by bottom currents has formed a sediment drift and apron at the base of seamount. There is an erosion moat on the east side of Britannia Seamount. Location is on Figure 3.1. Eltanin Line 29.

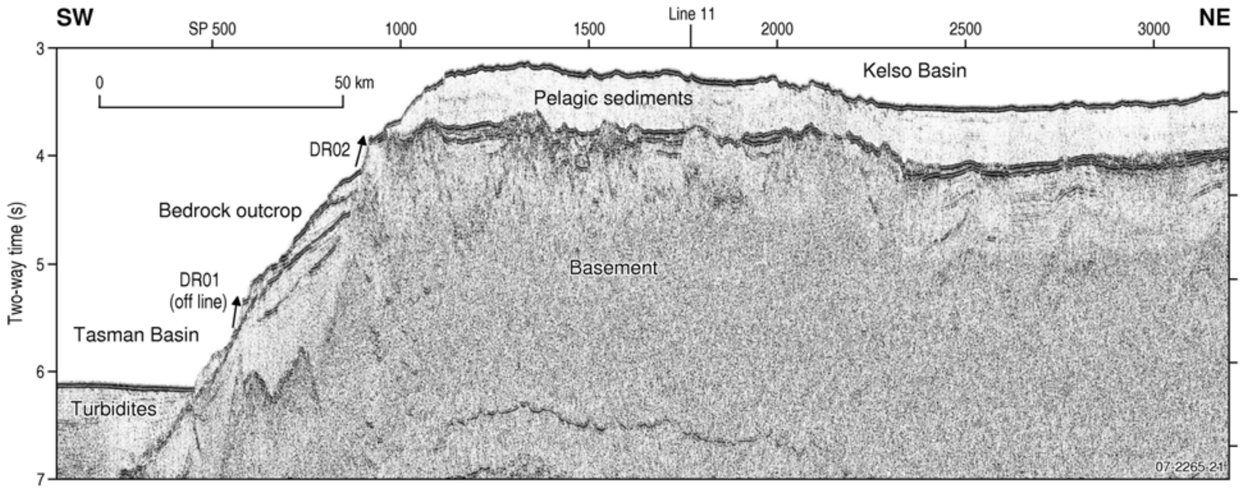


Figure 3.34. Seismic profile showing abyssal plain turbidites in sharp contact with the steep margin of the Kenn Plateau north Tasman Basin. Note the sediment blanket on the plateau. Location is on Figure 3.1. Line 270-7, Exon et al., (2005).

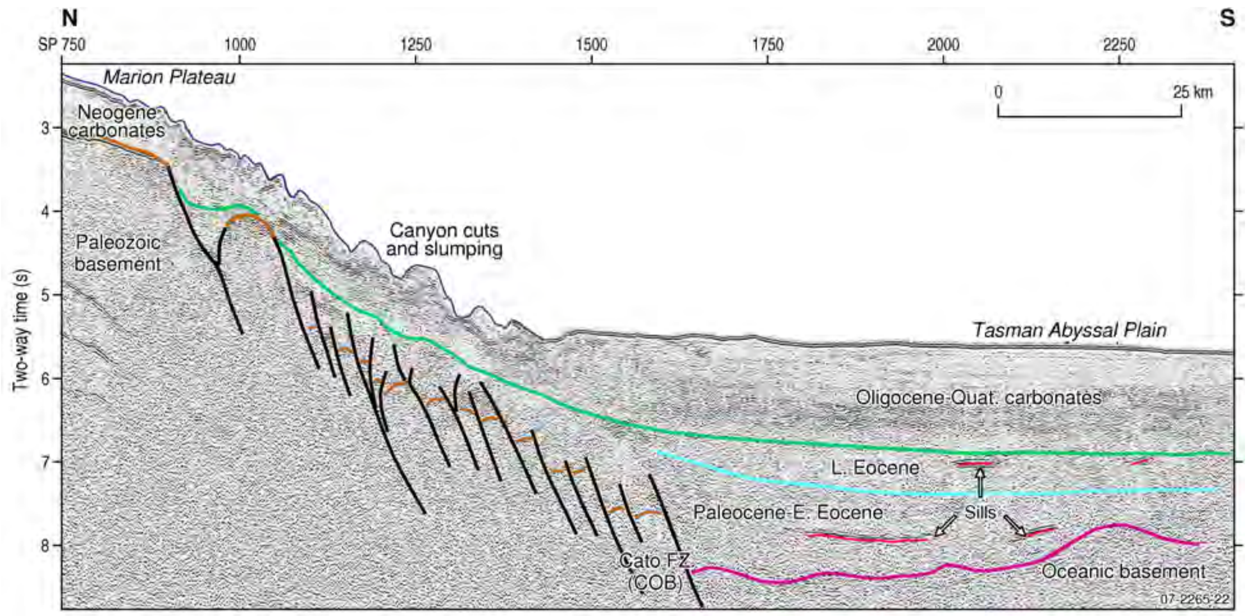


Figure 3.35. Seismic profile showing sediment slumping from the Marion Plateau and relatively shallow turbidites forming the abyssal plain, north Tasman Basin. Note the location of the Cato Fracture Zone separating oceanic crust from continental crust. Location is on Figure 3.1. Line 1. Exon et al., (2005).

3.4.2. Surface Sediments and Rocks

Very few cores or surface samples have been described from the Tasman Basin within the EMR. A list of the bottom photographs and samples described in the literature are given in Appendix C Tables 3.7 and 3.8. In general, calcareous ooze is present where the seabed is above 4,500 m and pelagic brown calcareous 'red' clay at greater depths (Conolly, 1969). The most detailed core analyses are in Eade and van der Linden (1970) and Hubble et al. (1987). They analysed 6 cores along a transect from the lower slope (one core) off Port Macquarie across the abyssal plain/deep ocean floor (four cores) to the flank of the Dampier Ridge (one core).

The composition and texture of the sediments deposited in the Tasman Basin is controlled by their sources, the water depth and the process of deposition. Terrigenous sands, silts and clays are supplied from the Australian continent by wind and currents and similar sized particles come from the ocean, mostly as biogenic debris from planktonic but with some benthonic particles. Their relative proportions depend on their supply/productivity and on water depth. Martinez (1994b) determined the present day lysocline for the Tasman Sea to be at ~3,600 m in the Tasman abyssal plain and ~3,100 m in the New Caledonia Basin to the east. Below the lysocline the calcium carbonate particles, particularly of foraminifers, start dissolving extensively until the calcite compensation depth (CCD) is reached. The CCD is where the rate of carbonate sedimentation is equal to the rate of solution and hence no pelagic carbonate survives on the seafloor below the CCD. Most of the Tasman Sea basin is just above the CCD as the cores analysed contain pelagic carbonate. The processes of deposition in this environment are pelagic settling, turbidity currents, debris flows and reworking by bottom currents. The near-surface strata beneath the plain are younger than the pelagic sediments draping the abyssal hills because they clearly onlap the hills on seismic profiles (Fig. 3.31).

The five cores from the Tasman Basin analysed by Eade and van der Linden (1970) come from water depths of 4,565 and 4,654 m on the abyssal plain, 4,689 and 4,838 m in the abyssal hills and 4,283 m on the flank of the Dampier Ridge. They range in length from 1.6 to 5.4 m. All have a carbonate content in the surface sediment of between 40 and 55%. The sediment type is dominantly light olive grey calcareous mud containing foraminifers in various states of preservation and coccoliths. The core at 4,565 m is only 60 km from the slope and has distinct layers in the upper 55 cm containing shallow water benthic foraminifers. These layers are interpreted as deposits from turbidity currents. Carbonate cycles are present down-core in four of the cores and represent Pleistocene glacial/interglacial cycles. The exception is the deepest core which is 60 km SW of the Derwent-Hunter Seamount and may be a turbidite from that source. A core in 4,747 m of water between Brisbane Seamount and the northern Dampier Ridge had a 15 cm thick graded bed of foraminiferal sand at the seabed with other graded beds below (Jenkins et al., 1986). Photos of the seabed between Derwent-Hunter Seamount and the Dampier Ridge (water depth 4,600 m) show rock debris and ripples as clear evidence of bottom water flow (Baker et al., 1988a and b).

The presence of debris flow deposits at the base of the NSW slope are confirmed by bottom photographs of pebbles and blocks of rock in bioturbated muds in 4,820 m of water adjacent to the slope (Jenkins et al., 1986). These are relatively recent as they are at the surface. Other photos in Harris et al. (1987) show evidence of currents on the abyssal plain near the base of slope off Wollongong (water depth 4,860 m), off Sydney (water depth 4,800 m) and off Port Macquarie (water depth 4,550 m).

The only evidence for present day activity of turbidity currents in the basin is provided by Boyd et al. (2008) who sampled quartz sand along with estuarine and shelf carbonate detritus in the floor of the Capricorn Sea Valley in 3,920 m water depth off Fraser Island. Luminescence dating of the quartz returned modern ages indicating this valley is an active conduit for gravity driven transport processes such as grain flows or turbidity currents.

Debris aprons occur around some of the seamounts and are likely to consist of fine to coarse volcanic sediment and lithified carbonate from their summits. Seabedphotographs in the eroded moat at the base of Gascoyne Seamount showed it to contain gravel and larger rocks as a lag deposits (Appendix C Table 3.10; Jenkins et al., 1986).

A field of manganese nodules has been sampled just south of the EMR by Glasby et al. (1986). Their photographs show abundant manganese nodules covering the seafloor at water depths of 4,408 to 4,717 m in the abyssal hills adjacent to the abyssal plain (Appendix C Table 7). The nodules are coated with a light dusting of calcareous brown clay. Most of the nodules sampled were discoidal in shape and 6 to 10 cm in diameter. Chemically the nodules have a relatively high Mn/Fe ratio of 2.5 along with moderate concentrations of nickel (av. 0.83%) and copper (av. 0.40%). Exon et al. (1980) also found nodules associated with greenish-grey calcareous clay further south and in shallower water (4,300 m). They contained more iron and less manganese, nickel and copper and 0.06% cobalt. Presumably the sedimentation rates are low in this region because the seabed is below the lysocline and this allows the growth of manganese nodules. This nodule field probably extends north into the EMR but its extent is unknown. Cochran and Osmond (1976) calculated a relatively high sedimentation rate of 2.1 cm ka-1 for a core containing 45% carbonate near this area. They concluded that the sedimentation rate in the area varies and is strongly affected by winnowing and deposition by bottom currents and that low accumulation rates occur on the crest of ridges and rises and faster rates occur on the flanks.

3.5. SEAMOUNT CHAINS OF THE TASMAN SEA

Two parallel seamount chains form prominent N-S features on the seafloor in the EMR. They were constructed as the Australian plate moved north over two hot-spots in the underlying mantle. The youngest seamounts are in the south. The western chain extends south from Cato Trough and follows the abyssal seabed of Tasman Basin. The other is along the western margin of the LHR. The chains are 300-400 km apart and the volcanic edifices that come to the surface or within a few hundred meters of the surface are named in Figures 3.1 and 3.11. The major seamounts are listed in Table 3.2 along with the depth of their summits below sea level and the depth of the surrounding seabed. Many smaller seamounts also occur along these two chains. Once extinct these volcanoes subside and if they were above sea level their tops are eroded flat by waves. Reefs have grown on some as they subsided to form limestone caps. Submerged seamounts that are flat-topped are called guyots. Appendix C Tables 10 and 11 list the bottom photographs and samples in the literature from the two seamount chains.

Table 3.2. Seamounts of the Tasmantid and Lord Howe Chains within the EMR. Data from Slater and Goodwin, (1973), McDougal and Duncan (1988) and Royal Australian Hydrographic Office.

Seamount	Depth to summit m	Depth of base m
Unnamed 30 km SW of Taupo	2,549	5,000
Taupo	120	~4,800
Barcoo	251	~4,800
Derwent-Hunter (two platforms)	280	~4,800
Unnamed 100 km north of D-H	2,375	~4,800
Stradbroke	800	~4,800
Unnamed 25 km S of Britannia	3,370	~4,800
Britannia (two platforms)	411 and 397	~4,800
Queensland (two platforms)	410 and 390	~4,800
Brisbane	1,458	~4,800
Moreton	753	4,400-4,600
Unnamed 50 km NE of Moreton	3,509	4,400-4,600
Unnamed 40 km N of Moreton	2,827	4,400-4,600
Recorder (two platforms)	410 and 1,170	4,400-4,600
Fraser	361	4,000-4,100

Unnamed 40 km N of Fraser	2,445	4,000-4,100
Cato Island	0	1,500
Bird Island/Wreck Reef	0	3,000
Kenn Reef	0	3,000
Frederick Reef	0	3,000
Balls Pyramid Is.	+552	~2,000
Lord Howe Is.	+864	~2,000
Elizabeth Reef	0	~3,000
Middleton Reef	0	~3,000
Unnamed 25 km N of Middleton	303	~3,000
Unnamed 30 km S of Gifford	330	~3,000
Gifford Tablemount	261	~3,000

3.5.1. Geomorphology

3.5.1.1. Tasmantid Seamount Chain

The Tasmantid Seamount chain extends northward onto the eastern margin of the Kenn Plateau and into the Cato Trough (Exon et al., 2005). Cato Island, Bird Island/Wreck Reef, Kenn Reef and Frederick Reef are all volcanic seamounts capped by limestone reefs of varying thickness (Fig. 3.38). Cato Island and Kenn Reef rise from depths of less than 2,000 m because they are on the continental crust of Kenn Plateau (Exon et al., 2005, 2006b). The four oldest seamounts in the north of the chain have living reefs on the limestone that caps the underlying volcano (Fig. 3.9). They have grown to maintain themselves at sea level. Further south Moreton, Brisbane and Stradbroke seamounts remain as volcanic peaks as they have never reached sea level whereas the other named seamounts have all subsided below sea level and been planated. A detailed multibeam survey around Cato Island by Exon et al. (2005) revealed numerous small volcanic cones and larger submerged limestone platforms (Figs. 3.36 and 3.38).

Taupo Seamount is the largest in the EMR and is 60 km in diameter at its base rising from depths of 4,800 m to a flat top only ~120 m below sea level. This shallow platform with relief of less than 10 m is approximately 40 km north to south and up to 15 km wide (McDougall and Duncan, 1988). Barcoo also rises from over 4,800 m to within 300 m of the surface. Its platform is 20 km x 6 km. Derwent-Hunter has an oval-shaped platform 30 by 20 km at about 300 m water depth. Britannia and Queensland both have remarkably flat summits at a depth of approximately 400 m and Recorder has an uneven top at about 450 m. Britannia and Recorder both have bases 43 km across. Fraser rises from a base 20 km across in 4,000 m of water to a small circular platform 4 km across at a depth of 361 m (Exon et al., 2005). Some of the seamounts, for example Fraser (Fig. 3.36), are near circular in plan while others are a complex of several volcanoes elongate parallel to the trend of the volcanic chain.

Fraser Seamount has distinct terraces at 1,030 m and 1,350 m which represent former sea levels. There are many smaller un-named and unsurveyed seamounts along this chain as well as subsidiary cones on the flanks of larger edifices.

The slopes on the side of the seamounts are commonly in the range of 10-20^0 and locally can be much steeper or form a flat terrace cut at sea level (Fig. 3.36). These slopes consist of rugged rock outcrop and boulders and blocks with only a relatively thin drape of sediment cover. The seamounts shed sediment to the adjacent seabed to form an apron at their base (Fig. 3.37). In some cases this apron is removed by bottom currents to form a moat.

McDougall and Duncan (1988) have sampled basalt from Taupo Bank to Queensland Guyot and obtained ages of 6.4 to 24 Ma (late Miocene to early Miocene). The ages of the volcanoes get progressively older to the north, confirming that they were formed as the crust moved over a hot-spot in the mantle. The northern seamounts were probably formed in the Oligocene (Exon et al., 2005). Assuming the hot spot is fixed then the average rate of northward movement of the Australian plate is 6.7 cm year^{-1} over that time interval.

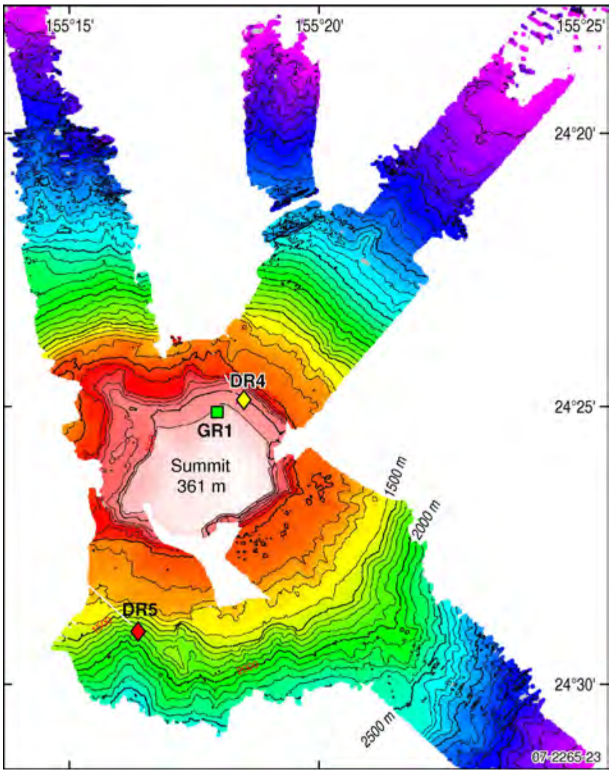


Figure 3.36. Multibeam bathymetric map of Fraser Seamount showing it to be a guyot with a flat summit and steep sides with two prominent benches at 1,000-1,100 and 1,300-1,400m. Location on Figure 3.1. Exon et al., (2005).

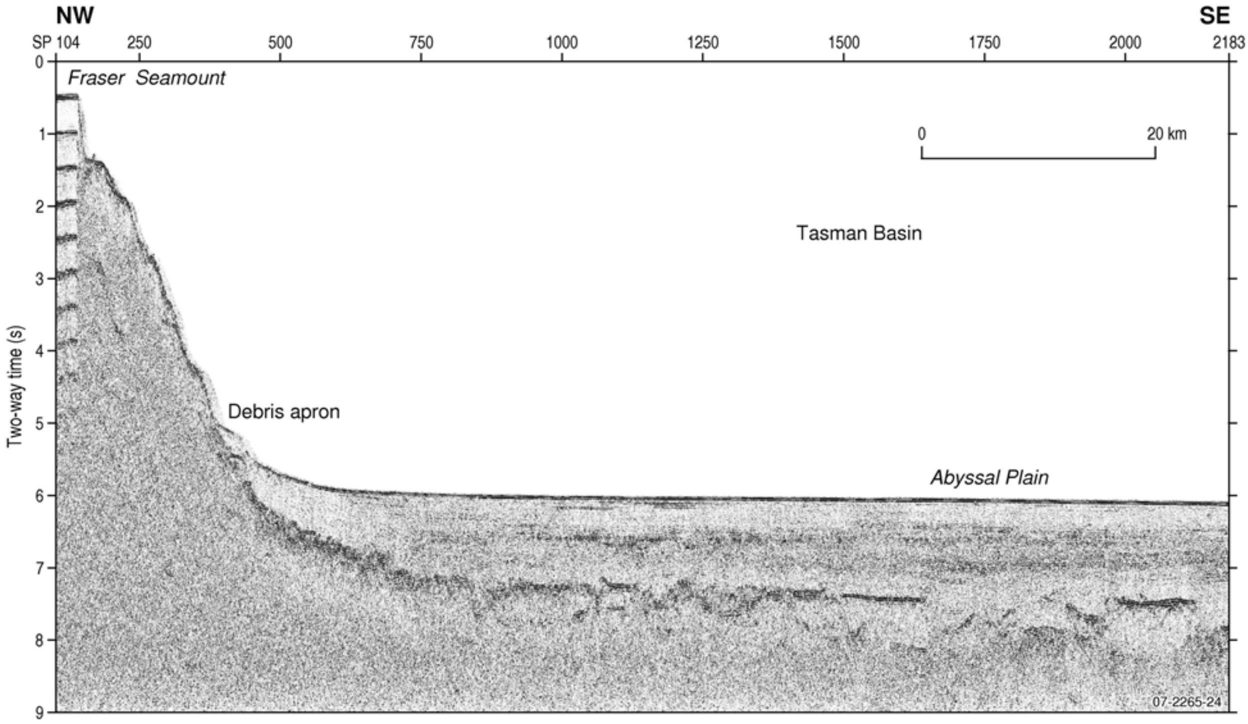


Figure 3.37. Seismic profile of Fraser Seamount showing an apron of slump material at its base merging with the Tasman abyssal plain. Location on Figure 3.1. Exon *et al.*, (2005).

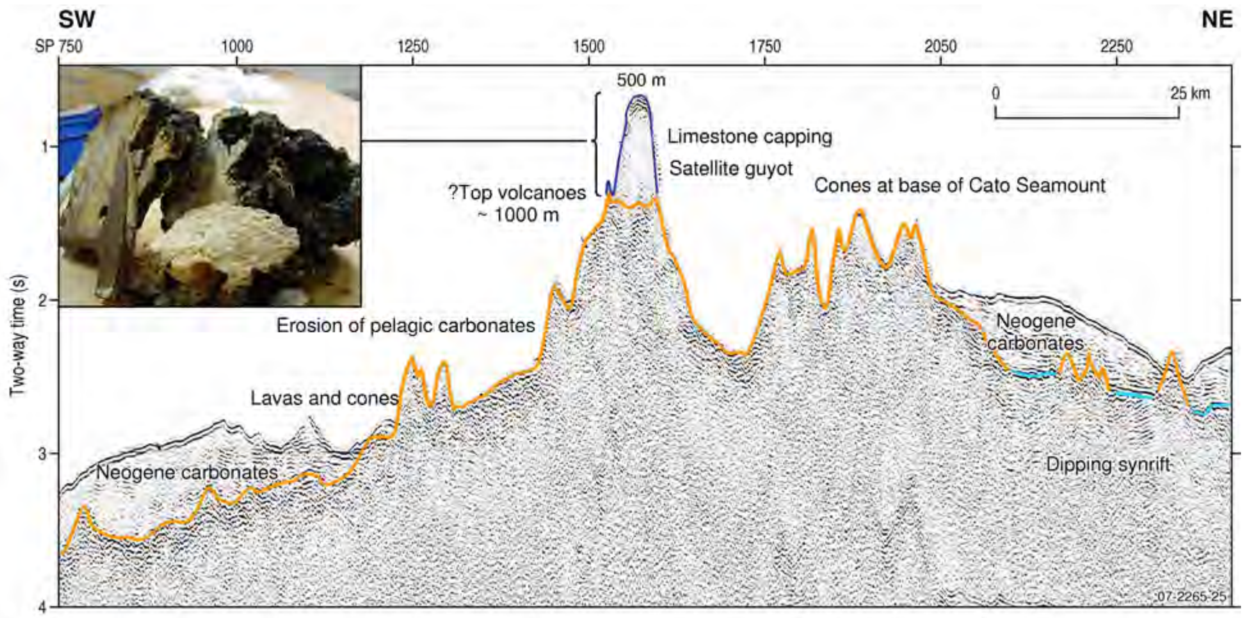


Figure 3.38. Seismic profile across Cato Seamount showing erosion, exposure of bedrock, sediment drifts and carbonate reef as a cap on the volcanic peak. Location on Figure 3.1. Line 3, Exon *et al*., (2005).

3.5.1.2. Lord Howe Seamount Chain (Balls Pyramid, Lord Howe Island, Elizabeth Reef, Middleton Reef, Gifford Tablemount.)

The Lord Howe Seamounts form a linear N-S chain along the western flank of the LHR from Balls Pyramid and Lord Howe Island in the south to Elizabeth Reef, Middleton Reef and Gifford Guyot in the north of the EMR (Fig. 3.39). This chain is parallel to the Tasmantid Chain some 300 km to the west. It is believed that this chain is also formed by the northward movement of the Australian Plate over a 'hot spot' in the mantle. The older seamounts to the north have subsided below sea level allowing reefs to develop limestone platforms on their summits. Gifford Guyot near the northern boundary of the EMR is a 2,000 m high guyot that comes to within ~300 m of the surface and is capped by a drowned limestone platform (Slater and Goodwin, 1973). Other smaller and un-named seamounts occur both along this chain and adjacent to it in the Lord Howe Basin. South of Balls Pyramid seamounts continue along the margin of the LHR, the largest being Flinders Seamount on the Monawai Ridge.

Within the EMR the largest of the seamounts in this chain is the Lord Howe Island/Balls Pyramid volcanic edifice. It is the only one whose age has been determined. It is a basaltic volcano built between 6.9 and 6.4 Ma ago (McDougall et al., 1981). Its base is elongate NW-SE some 40 km wide by 80 km long. It rises steeply from water depths of over 3,000 m on its western and southern sides. Its eastern side merges with the Lord Howe Rise at water depths of less than 2,000 m. Game (1970) describes at least three major eruptive episodes probably starting in the mid-Tertiary and dated the youngest at 7.7 Ma.

There is a broad shelf around both Lord Howe Island and Balls Pyramid due to marine planation (Woodroffe et al., 2005). They present a bathymetric chart around Lord Howe showing that the shelf is nearly square in shape (20 x 20 km) and oriented NW-SE with the shelf break between 40 and 60 m water depth. Most of the coral reef is on the mid-shelf. Balls Pyramid shelf has no reef and is 16 x 8 km and 4 km southeast of the Lord Howe shelf and linked to it by a 500 m deep sill.

Middleton Reef and Elizabeth Reef are located on the saddle joining the Dampier Ridge with the Lord Howe Rise, and separating the Middleton Basin in the north from the Lord Howe Basin in the south. They have roughly circular bases with diameters of ~40 km and rise steeply from 2,500 m water depth. They have also undergone wave erosion as they subsided below sea level resulting in a planated surface for coral growth to form oval shaped rim reefs enclosing a lagoon. Elizabeth Reef is an oval atoll oriented NW-SE and is 10.7 km long by 6.2 km wide (Kennedy and Woodroffe, 2004). It is slightly larger than Middleton Reef which is 9.3 x 5.7 km and oriented NE-SW. The lagoons have a maximum depth of 30 m, but are mostly infilled with sediment and on average are less than 5 m deep (Kennedy and Woodroffe, 2004). On the seaward side of the reef there is a steep drop-off at 30-40 m water depth.

The Lord Howe chain was formed in a similar way to the Tasmantids but only Lord Howe Island has been dated. Exon et al. (2004b) have used sediment associated with basalt from seamounts on LHR north of the EMR to indicate a Miocene age of the eruption. Similar small seamounts are quite common on the seabed of the LHR and the Dampier Ridge and may be the result of more widespread volcanism during the Miocene than that dated from the two dominant chains.

3.5.2. Surface Sediments and Rocks

Slater and Goodwin (1973) dredged four of the seamounts and recovered unconsolidated shelly sands along with limestone, phosphorite and basalt cobbles. Limestone of late Pliocene to early Pleistocene age along with basalt pebbles was recovered from Taupo, Barcoo and Derwent-Hunter. Phosphorite and limestone was recovered from Gifford and phosphorite was also found on Derwent-Hunter. Quilty (1993) identified Miocene shallow-marine limestone from Derwent-Hunter and Barcoo seamounts. McDougall and Duncan (1988) sampled basalt, including well-rounded cobbles, from the flanks of Taupo, Derwent-Hunter, Britannia and Queensland Seamounts in water depths of 500 to 1900 m.

The shelf around Lord Howe Island has well established coral reef. This is the southernmost occurrence of coral reefs in the Tasman Sea. There is a submerged fossil reef on the mid-shelf around Lord Howe Island but Woodroffe et al., (2005) could find no evidence of subsidence since the last interglacial (c.a. 120 ka). Coralline algae are the dominant sediment component with coral and algal rhodoltihs also common (Kennedy et al., 2002). Gravelly muds occur within the lagoon.

Kennedy and Woodroffe (2004) collected sediments from the seabed from around Middleton Reef down to a water depth of 368 m and from within the lagoon of Middleton and Elizabeth Reefs. Gravelly sands and sands dominate in the lagoons with some mud in the deepest parts. The sediment is composed of coral and coralline algae with lesser amounts of Halimeda, molluscs and foraminifera.

3.6. PLATEAUS OF THE TASMAN SEA

3.6.1. Geomorphology

3.6.1.1. Southern Kenn Plateau, Dampier Ridge and Lord Howe Rise

The eastern margin of the Tasman Sea Basin within the EMR is formed by the submerged margins of three tectonic blocks of continental crust clearly outlined by the 3000 m isobath. From south to north they are: the Monawai Ridge (southern LHR), Dampier Ridge and southern Kenn Plateau. The EMR extends over the Dampier Ridge, northern Monawai Ridge and onto the Kenn and Lord Howe Plateaus (Figs. 3.1 and 3.39).

In the south the Monawai Ridge is a linear NW trending feature 100 km wide on the eastern flank of the Lord Howe Rise extending into the planning area for 160 km. On its western side it rises from the abyssal floor depths of ~5,000 m of the Tasman Basin to depths of 2,000-3,000 m (Fig. 3.32). This steep scarp is up to 1,500 m high. Flinders Seamount is a volcanic intrusion along this scarp, and rises from water depths of ~5,000 m in the Tasman basin to water depths of 1,740 m at its summit giving a relief of over 3,000 m (Fig. 3.40c, Stagg et al., 2002). The seabed on its eastern side is at depths of 2,300 m. Between the Monawai Ridge and the Lord Howe Rise proper is the broad 100 km wide Monawai Sea Valley (Alcock et al., 2006).

The Dampier Ridge extends south from the southern Kenn Plateau for 900 km and is approximately 80 km wide (Fig. 3.39). In detail it can be divided into four plateaus in 2,000-3,400 m water depth representing the four continental fragments of Gaina et al., (1998b). They are joined by narrow saddles (20-40 km wide) in 3,500-3,600 m water depth. The southern plateau extends 200 km NW from the northern end of the Monawai Ridge. Its western margin is steep and is only 40-60 km from

Taupo and Barcoo Seamounts. To its north is the smallest of the plateaus 100 km N-S by 80 km. Further north are two more plateaus each 200 km long, and 100 km and 150 km wide respectively, with irregular tops. The western margin of the Dampier Ridge is generally steep, with scarps of 1,000 to 1,500 m common reflecting its plate tectonic origin as transform faults (Gaina et al., 1998b). Gaina et al., (1998b) also identified intrusions along this margin forming seamounts. Wherever the margin is surveyed it shows small canyons eroding the slope and scarps along slope caused by slumping or faulting.

Between the Dampier Ridge and the LHR lies a depression that is divided into two basins, the Lord Howe Basin in the south and the Middleton Basin in the north (Figs. 3.39 and 3.40). The Lord Howe Basin is between 4,000-4,200 m deep, 300 km N-S and 100 km wide with Lord Howe Island and Balls Pyramid on its eastern margin. At the northern end of the basin the depression is occupied by three large seamounts: Elizabeth Reef, Middleton Reef and an un-named seamount that does not reach the surface. North of these seamounts the depression deepens to 3,500 m to form the Middleton Basin (200 km N-S and 100 km E-W). Gifford Guyot is at the northern end of this basin. Both basins have a relatively flat seabed, and small canyons occur on the slopes around the margins of the basins.

The EMR extends approximately two-thirds (400 km) of the way across the LHR and extends N-S for over 800 km. In the southern area the plateau is less than 1,000 m water depth while to the north it is mostly 1,200-1,500 m. In general the seabed on the plateau is smooth because it is draped by thick sediment (Fig. 3.40, Willcox and Sayers, 2002) and it gradually descends to the west into the basins. Exceptions to this do occur, particularly in the south where the margin with the Lord Howe Basin can be steep and rugged (Fig. 3.40b, Willcox and Sayers, 2002). Along this slope are small seamounts protruding though the sediment cover, and small scale roughness on the seabed indicates erosion and mass movement of sediment. In the northeast of the EMR the LHR is cut by the NW trending Vening-Meinsez Fracture Zone resulting in linear scarps, rough topography and seamounts (Fig. 3.41). Erosion by bottom currents has created moats in the sediments at the base of these ridges (Fig. 3.42).

The relationship of the seamounts on the LHR and Dampier Ridge to the Lord Howe seamount chain is unknown. Willcox and Sayers (2002) present seismic images showing numerous igneous intrusions beneath the eastern LHR that dome the seabed sediments and in some cases reach the seabed to form volcanic seamounts, presumably composed of basalt. A relatively large seamount protrudes from the LHR where it is less than 1,000 m deep in the south of the EMR. More recently, a seismic survey on the northern LHR within the EMR discovered numerous intrusions that have domed the seafloor sediments to form broad hills 4-10 km across with relief of 50-100 m (Kroh et al., 2007). Some of these have also reached the seafloor to form steep sided volcanic pinnacles, often with erosional moats 1-2 km wide and ~50 m deep in the sediments at their base. Kroh et al. (2007) suggest that some of this volcanism is very recent because it intrudes young sediment and disrupted sediment above other subsurface intrusions may create pathways for hydrothermal fluids to reach the seafloor.

The northern Tasman Basin is flanked on its east by the southern part of the Kenn Plateau which extends from the Dampier Ridge north to the Bampton Trough. Immediately north of the Dampier Ridge on the Kenn Plateau is the Kelso Rise, a relatively small 100 x 100 km area of seabed at 1,000-1,200 m water depth.

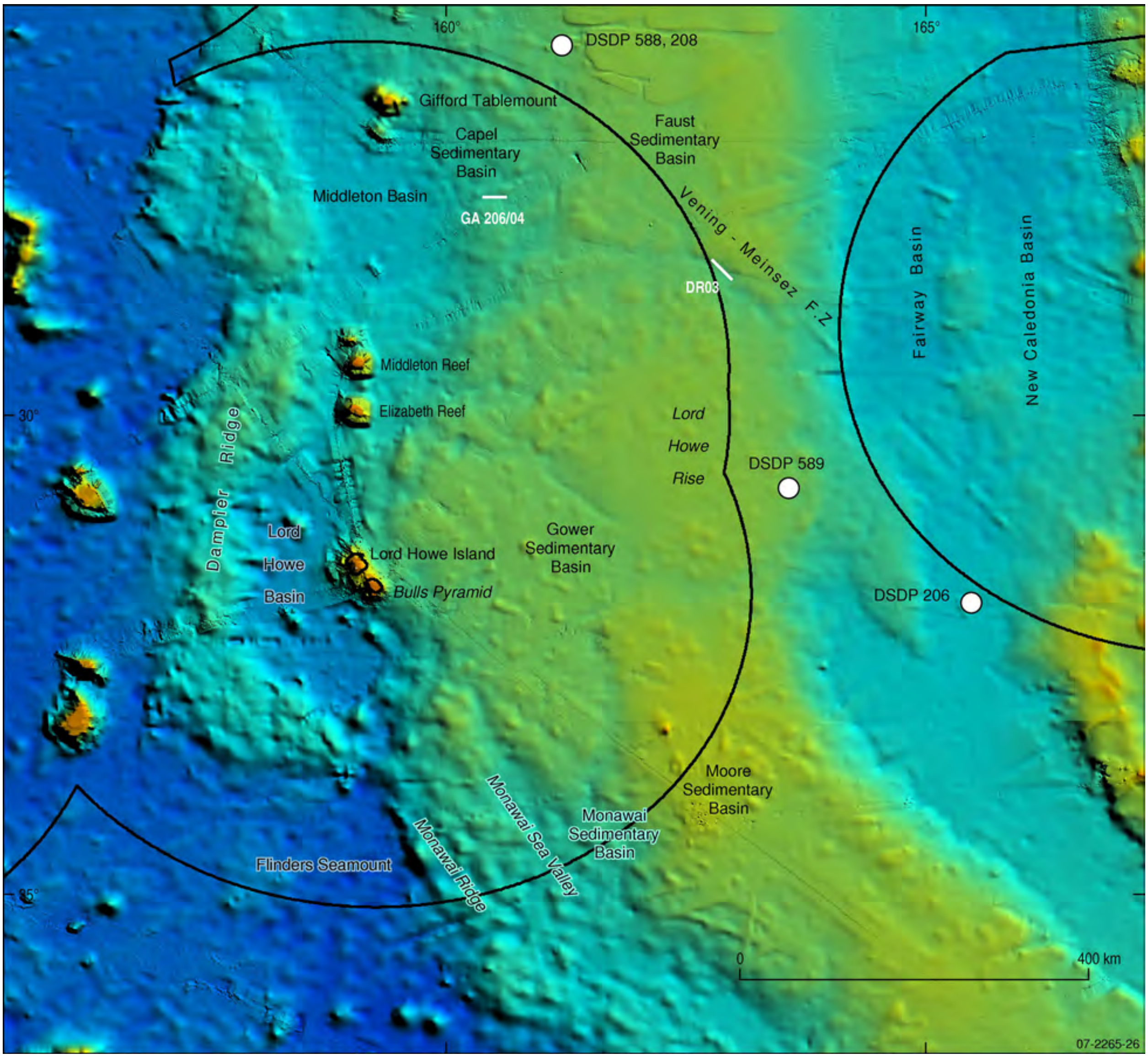


Figure 3.39. False colour image showing bathymetric features including Dampier Ridge, Lord Howe Rise, Middleton Basin, Lord Howe Basin,Lord Howe seamount chain, Monawai Ridge and Flinders Seamount. Location of other figures is marked by a white line. Black line is the EMR boundary. DSDP/ODP drill sites are shown.

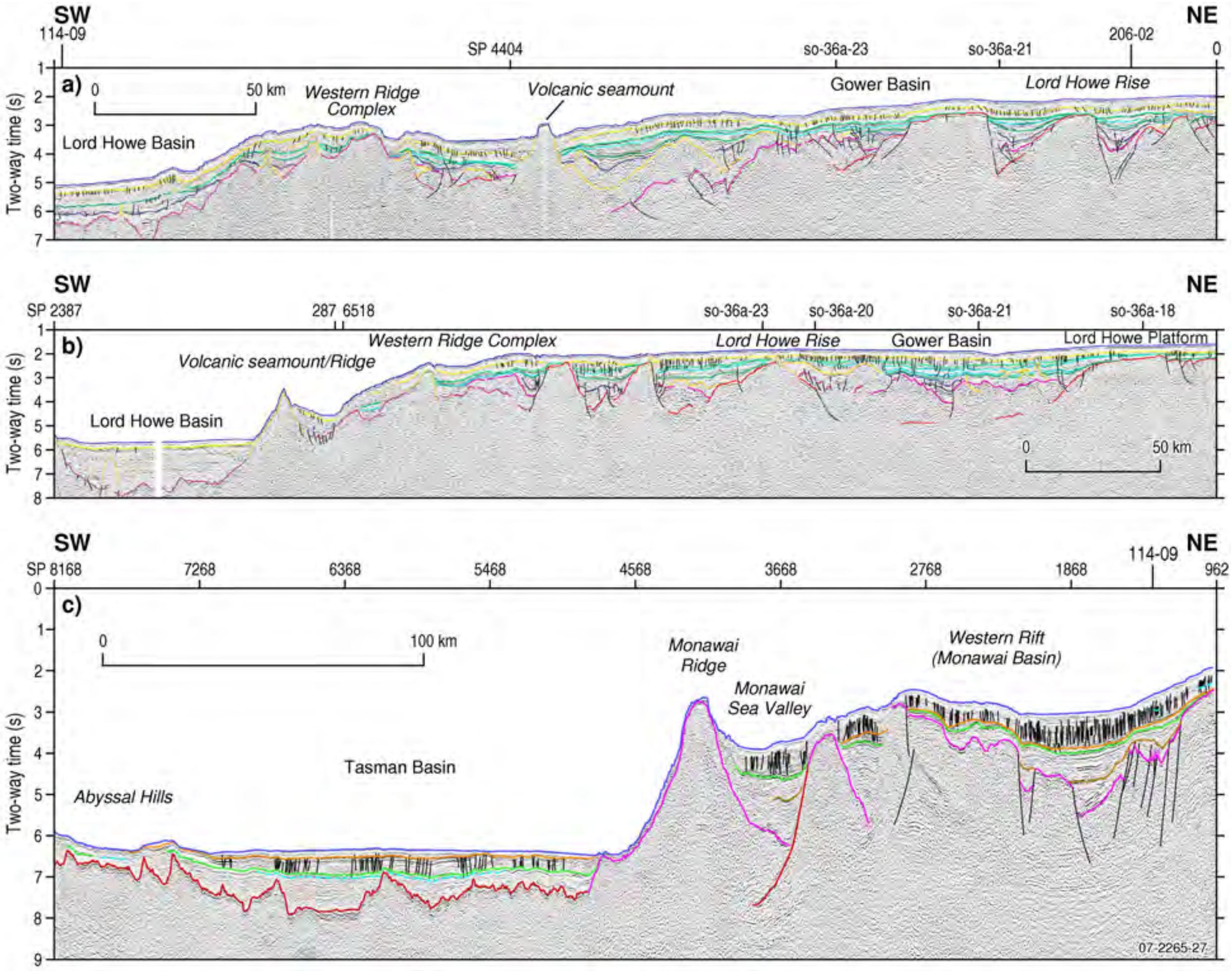


Figure 3.40. a) Seismic profile across the northern Lord Howe Rise showing more topographic relief and volcanic seamounts along the western margin. Line SO30A-06/06AWillcox and Sayers (2002), b) Seismic profile across Lord Howe Basin and central Lord Howe Rise showing abyssal plain in the basin and steep volcanic western flank of the rise. Line 15/15A. Willcox and Sayers (2002) and c) Seismic line from the Tasman Basin across the Monawai Ridge and southern Lord Howe Rise. Note the steep volcanic ridge forming the margin of the plateau and the topographic relief on the rise mimicking the underlying basement. Line LHRNR-E. Stagg et al., (2002).

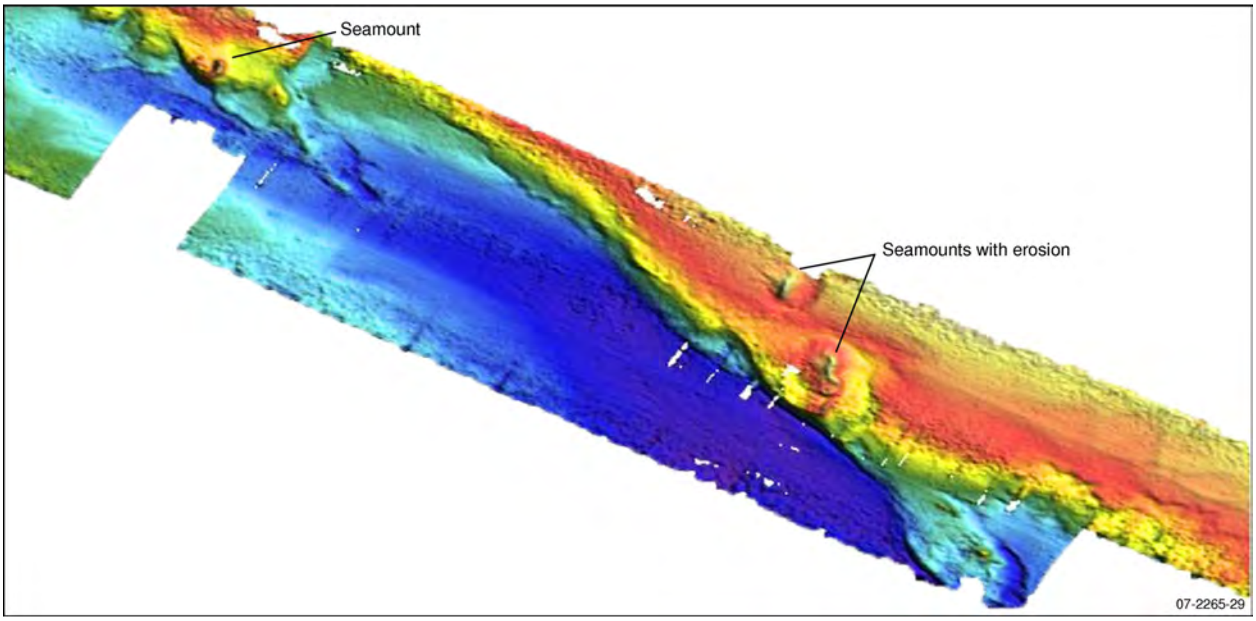


Figure 3.41. Multibeam bathymetry showing a series of fault scarps of the Vening-Meinesz Fracture Zone where it crosses the central part of the Lord Howe Rise. Located on the margin of the EMR but continues to the NW into the EMR. Volcanic seamounts also outcrop. Location DR08 in Figure 3.39. Colwell et al., (2006).

3.6.2. Surface Sediments and Rocks

Our direct knowledge of the composition and stratigraphy of the Lord Howe Rise and Dampier Ridge is from limited sampling. Appendix C Tables 3.12 and 3.13 list the location of samples. The most relevant are:

- Deep Sea Drilling Project (DSDP) and Ocean Drilling Project (ODP) Sites 207, 208, 588, 589, 590 on LHR (Burns et al., 1973, Kennett et al.,1974 and 1986)
- Dredge samples (Launay et al., 1976; Willcox et al., 1981; Roeser et al., 1985; Herzer et al., 1997; Colwell et al., 2006)
- Continental rocks (metamorphosed granite) of Permian age was dredged from the Dampier Ridge (McDougall et al., 1994).

Based on seismic evidence Willcox et al., (2001) agree that the southern Dampier Ridge is continental crust but suggest that the more rugged northern part is volcanic, perhaps of the same age or even younger than the Tasmantid Seamounts. A dredge sample from a scarp on the west flank of the Dampier Ridge in water depths of 2,400-2,700 m (BMR seismic 15/058) contained 20 cm thick Fe/Mn crusts on granite, gabbro and feldspathic sandstone (Roeser et al., 1985, Bolton et al., 1990). Analyses of the manganese crusts showed relatively low Mn/Fe ratios of 0.48-0.91 and low Ni, Cu and Co. Dredges samples from the Vening-Meinesz Fracture Zone just outside the Planning Area have included a variety of continental rocks including sandstone, conglomerate and limestone along with basaltic volcanic rock (Fig. 3.41; Roeser et al., 1985, Colwell et al., 2006). The rocks were covered with a thick manganese crust and a community of benthic organisms used this outcrop as substrate (Fig. 3.42). The biological samples included: Gorgonians, black coral, soft coral, crinoids, bryozoans, bivalves, gastropods, silica sponges, brittle stars, ascidians, tunicates and polychaete worms.

The LHR is draped with pelagic calcareous sediments known as oozes. These oozes at the surface on the seabed are very pale brown to white in colour and consist almost entirely of the calcite remains of foraminifers and coccolithophorids, planktonic protozoans and algae. DSDP Sites on the south and north LHR along with other cores have sampled this rather uniform sediment type (Burns et al., 1973; Kennett et al., 1986; Colwell et al., 2006). The sediments sometimes contain minor amounts of calcareous spicules, radiolarians, silicoflagellates, diatoms and volcanic glass.

Eade and van der Linden (1970) analysed two cores from the LHR in the southern part of the EMR. One was a 3.5 m length core on the western flank in 3,609 m of water, and had carbonate values varying from 72 to 87% with a foraminiferal sand forming the upper 250 cm consisting of 85% carbonate. The second core, 4.2 m, on the rise itself in 1,450 m of water, had more carbonate, ranging from 80 to 97% with 93% at the surface. Colour cycles are also recognizable subsurface in both cores with the sediment alternating between light olive grey and yellowish grey. Bioturbation is also abundant.

Kawagata (2001) use benthic and planktic foraminifers and oxygen isotope stratigraphy from three cores from the crest of the LHR to determine past changes in sea surface temperatures and productivity, and from this determined the position of the Tasman Front over the past 250 ka. One of the cores is from within the planning area in 1,160 m of water while the others are just outside the northern and southern boundary. Nees (1997) also used benthic foraminifers and oxygen isotope stratigraphy to determine that ocean productivity above the LHR was greater during the last glacial period. The samples came from two cores at 1,340 and 1,450 m water depth on the LHR within the EMR.

Kawahata (2002) analysed three cores from the LHR within the EMR to determine the rate of mineral dust accumulation. The sediment in these cores was a light yellow to light grey foraminiferal coccolith ooze. The organic carbon content of these cores was also measured and had a maximum of 0.38% by weight at the surface and generally less than 0.30% subsurface. Variations in dust content in the cores reflect changing wind patterns during the late Pleistocene.

There is evidence in the subsurface of the LHR that diapirs have had an affect on the seabed by causing uplift and possibly faulting (Fig. 3.44). Above some of the diapirs on the seismic profiles there are faults that appear to reach the surface (Exon et al., 2007). There is a characteristic hummocky seabed above these structures that could be the result of fluid escape. These areas also have a bottom simulating reflector at about 500 m sub-seafloor. Exon et al., (1998) interpreted this as the presence of gas hydrates in the sediments.

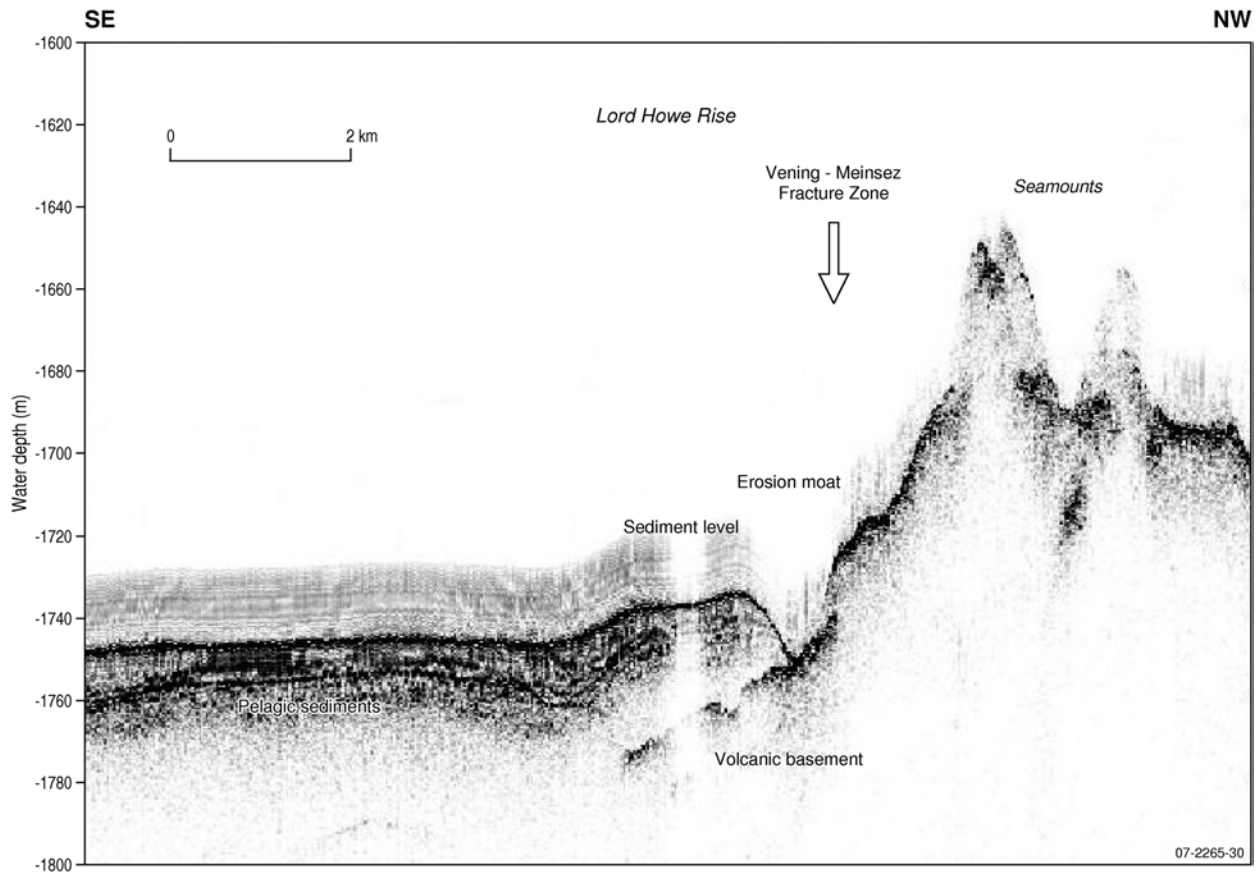


Figure 3.42. Seismic profile across the Vening-Meinesz Fracture Zone on the Lord Howe Rise showing erosion by bottom currents at the base of volcanic ridges. Location on Figure 3.39. Colwell et al., (2006).

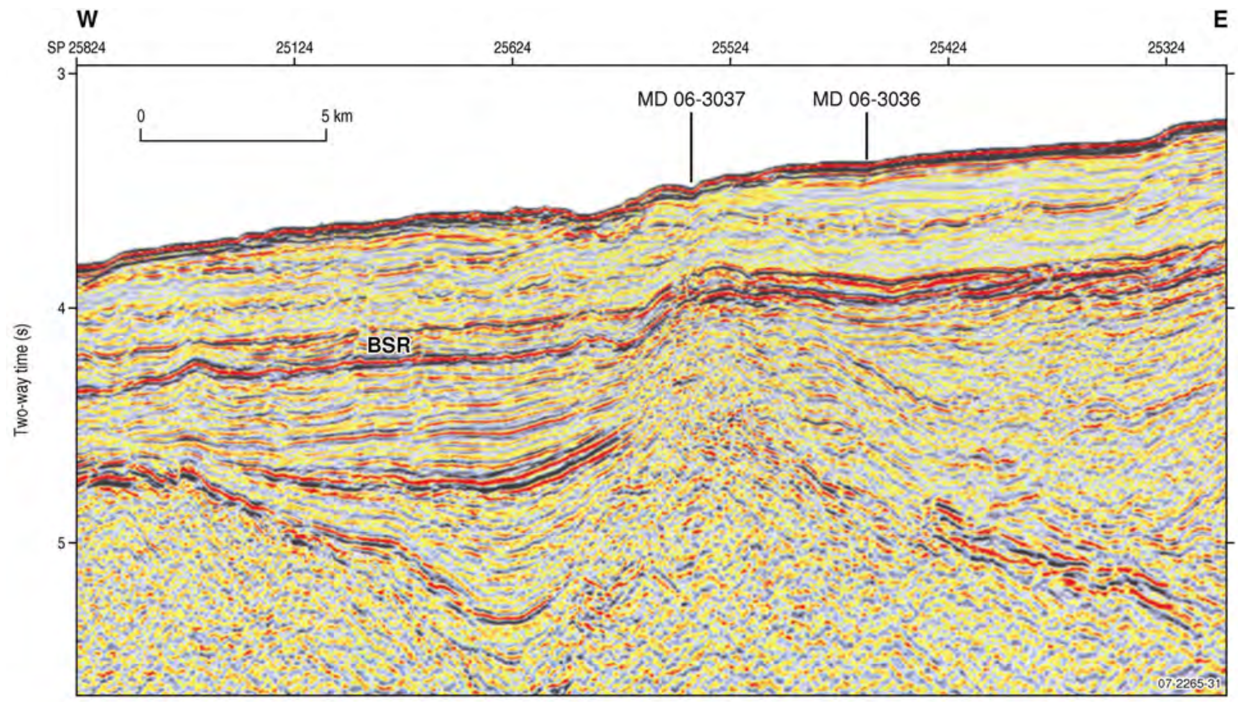


Figure 3.43. Seismic profile showing bottom simulating reflector (BSR) in Capel Basin, western flank of Lord Howe Rise and location of cores. Note the seafloor is irregular above subsurface domes. Location on Figure 3.39. GA line 206/04, Colwell et al., (2006).

3.7. NORTHEAST AUSTRALIAN CONTINENTAL MARGIN CORAL SEA:

3.7.1. Geomorphology

The major features on the seabed in the EMR off northeastern Australia were determined by the breakup pattern of the continental crust and subsequent seafloor spreading (Davies et al., 1989; Pigram, 1993). Subsidence, eustatic sea level and paleoceanographic changes have also controlled the pattern of sediment accretionary features on this margin, particularly for calcium carbonate. Offshore of the Great Barrier Reef are three large marginal plateaus: the Marion Plateau, the Queensland Plateau and the Eastern Plateau (Figs. 3.44 and 3.45). They are separated by deep water embayments known as the Townsville Trough and Queensland Trough/Osprey Embayment. East of the Marion and Queensland Plateaus are a series of smaller troughs and plateaus. To the northeast of the Queensland Plateau is the abyssal plain of the Coral Sea Basin.

Since the tectonic activity ended 52 Ma (early Eocene) the area has undergone differential subsidence and the plateaus were flooded and carbonate sediments began accumulating (Davies et al., 1991b; Isern et al., 2002). Starting in the early Miocene the plateaus have been modified by significant accumulations of carbonate reefs that developed on structural highs (Mutter, 1977; Davies et al., 1989). These reefs formed broad limestone platforms that underpin approximately half of the Marion and Queensland Plateaus (Mutter, 1977; Mutter and Karner, 1980; Isern et al., 2002). These platforms are either exposed as limestone on the seabed or covered by a thin veneer of recent sediment and they form the foundation for extensive present day atoll reefs. The plateau surface surrounding the platforms has a generally flat surface built up by pelagic carbonate ooze and biogenic particles swept off the platforms by currents (Isern et al., 2004). The troughs are also smooth seabed because of the relatively high accumulation rate of redeposited and pelagic sediment. Smaller scale features occur throughout the region and are the result of erosion and deposition by currents, gravity slides and volcanism.

3.7.1.1. Marion Plateau, Capricorn Trough (Channel), Cato Trough, Cato Basin, Kenn (Chesterfield) Plateau, Mellish Rise and Associated Reefs (Saumarez Reef, Marion Reef, Cato Island, Bird Island, Wreck Reefs, Frederick Reef, Kenn Reefs, Selfridge Bank and Mellish Reef)

The Marion Plateau is seaward of the Great Barrier Reef and has a length of about 600 km and an area of 77,000 km^2. It can be divided into two parts because of its varying width and orientation. In the north it extends 200 km NE from the GBR to Marion Reef and in the south it extends SE from the southern end of the GBR for 200 km to the Cato Trough. Isern et al. (2004) describe the two major and two minor carbonate platforms that form about half of the area of the surface of the plateau. They were drowned in the early Pliocene after a period of subaerial exposure and karstification. The southern platform is exposed on the seabed and stands out topographically with moderate relief whereas the northern platform is covered with a veneer of sediment. Two reefs survived the Pliocene drowning: Marion Reef which is built on one of the small platforms and Saumarez Reef which is on the seaward margin of the southern platform. The past and present asymmetric shape of the Marion Plateau platforms is determined by the EAC with the up-current side of the southern platform swept of sediment and forming an erosion moat and deposition occurring on the down-current side (Isern et al., 2001; Isern et al., 2004).

The surface of the northern Marion Plateau has relatively little relief. It is smooth and undulating away from the platform and has a gentle slope to the NE from water depths of 300 m to depths of 600 m (Fig. 3.46; Isern et al., 2004). The southern Marion Plateau slopes east from 300 m to 800 m water depth. Most of the plateau is between 300 m and 400 m water depth.

The southern margin of the plateau runs E-W for 100 km and is relatively steep and rough descending from 800 m to 3,600 m (Fig. 3.35, Exon et al., 2005). A seismic line at 1,500 m water depth crosses volcanic peaks on the seabed several hundred meters high and 3-5 km across (Hill, 1992). The rough topography on this southern slope is also due to erosion of canyons and mass movement of sediment into the northern end of the Tasman Basin. The Capricorn Sea Valley has its origin as a canyon on this slope. The southern margin of the plateau is separated from the Hervey Bay continental shelf by the Capricorn Trough which lies within the Great Barrier Reef marine park.

The eastern margin of the Marion Plateau is relatively straight and trends SSE for 550 km from Marion Reef. Marion Reef and Saumarez Reef lie along this margin. The margin is a relatively gentle convex slope into the Cato Basin where water depths are 3,000 – 3,500 m. The slope is much steeper into the Cato Trough because of a faulted basement ridge forming the lower slope (Mutter and Karner, 1980). Slump deposits are present along the base of this margin (Fig. 3.47; Exon et al., 2005).

The northern margin of the plateau follows the Townsville Trough for 300 km west of Marion Reef. In its eastern section it is relatively steep with a sharp break in slope at about 450 m water depth where a limestone platform crops out and forms the steep upper slope (Fig. 3.46a; Davies et al., 1989). The slope has been modified by currents and drift deposits. The western section is a gradual slope into the Townsville Trough.

The only deep water connection between the Tasman Sea and the Coral Sea is through the Cato Trough. This trough is bounded on the east by the Kenn Plateau and on the west by the southern Marion Plateau and it extends for 550 km from the Tasman Basin to the Mellish Rise. The trough is at its narrowest in the south where for 50 km of its length the flat seabed is only 10 km wide and water depths are 3,400 to 3,500 m (Fig. 3.47). Both sides are steep due to exposure of basement ridges. The trough opens northwards into what is called the Cato Basin by Exon et al. (2005). The Cato Basin is triangular in shape, 200 km E-W and 500 km N-S, with the Mellish Rise along its northern margin. The eastern margin of the Cato Basin trends north-south and rises abruptly from 3,000 m water depth. It is complex in detail as it is formed by steep-sided tectonic blocks of the northern Kenn Plateau. Many small canyons and several larger ones flow into the basin down the eastern margin of the Kenn Plateau (Exon et al., 2005). Cato Island and Kenn Reef are two seamounts that reach the surface along this margin. In contrast the western margin is blanketed in sediment and rises gradually to the Marion Plateau. The basin has a relatively smooth floor 3,100 to 3,200 m deep in the east with occasional seamounts including two that rise to the surface as carbonate banks: Frederick Reef and Wreck Seamount (Wreck Reef and Bird Island).

Most of the Kenn Plateau, as defined by Exon et al. (2005), lies within the EMR (Fig. 3.44). This plateau consists of a series of ENE trending ridges shallower that 2,000 m and troughs (basins) with water depths of 1,800 – 3,000 m (Figs. 3.34, 3.48 and 3.49). The major features from south to north are:

Southern Surveyor Rise (~1,600 m), Observatory Basin (~1,800 m), Coroilis Ridge (~1,000 m), Chesterfield Trough (~2,200 m) and Selfridge Ridge (1,000-2,000 m). The Coroilis Ridge has a 15 km wide platform in 100-300 m of water on its northwestern corner. Selfridge Ridge joins Kenn Reef and banks with Selfridge Rock (water depth 44 m) on the boundary of the EMR.

The margins of the Kenn Plateau are steep with many small canyons and fault scarps and slump scars exposed. Figure 3.50 shows fields of sand dunes occur on the western top of Coriolis Ridge in water depths of ~1,000 m (Exon et al., 2006b). They are 4 to 5 m high, have asymmetric sinuous crests and a wavelength of 250-350 m. These dunes along with scours around pinnacles indicate the currents are flowing to the east or northeast.

To the north of the Kenn Plateau is Bampton Trough, 3,000 m deep and 50 km wide ,which separates the Kenn Plateau from an area of seabed that is generally shallower than 2,500 m, trends NE and is about 700 km long and 250 km wide. It is irregular in shape and with considerable relief but known as Mellish Rise (Exon et al., 2006a). In the southwest Mellish Reef rises as a limestone-capped volcanic seamount from where the plateau is shallower than 2,500m (Terrill, 1975). Other seamounts are common and may represent a northern extension of the Tasmantid Seamount chain (Exon et al., 2006a). The topography is a complex of ridges and valleys possibly caused by faulting and partial breakup of a large plateau (Exon et al., 2006a). Tilted basement blocks are well imaged by multibeam bathymetry in Figure 3.50.

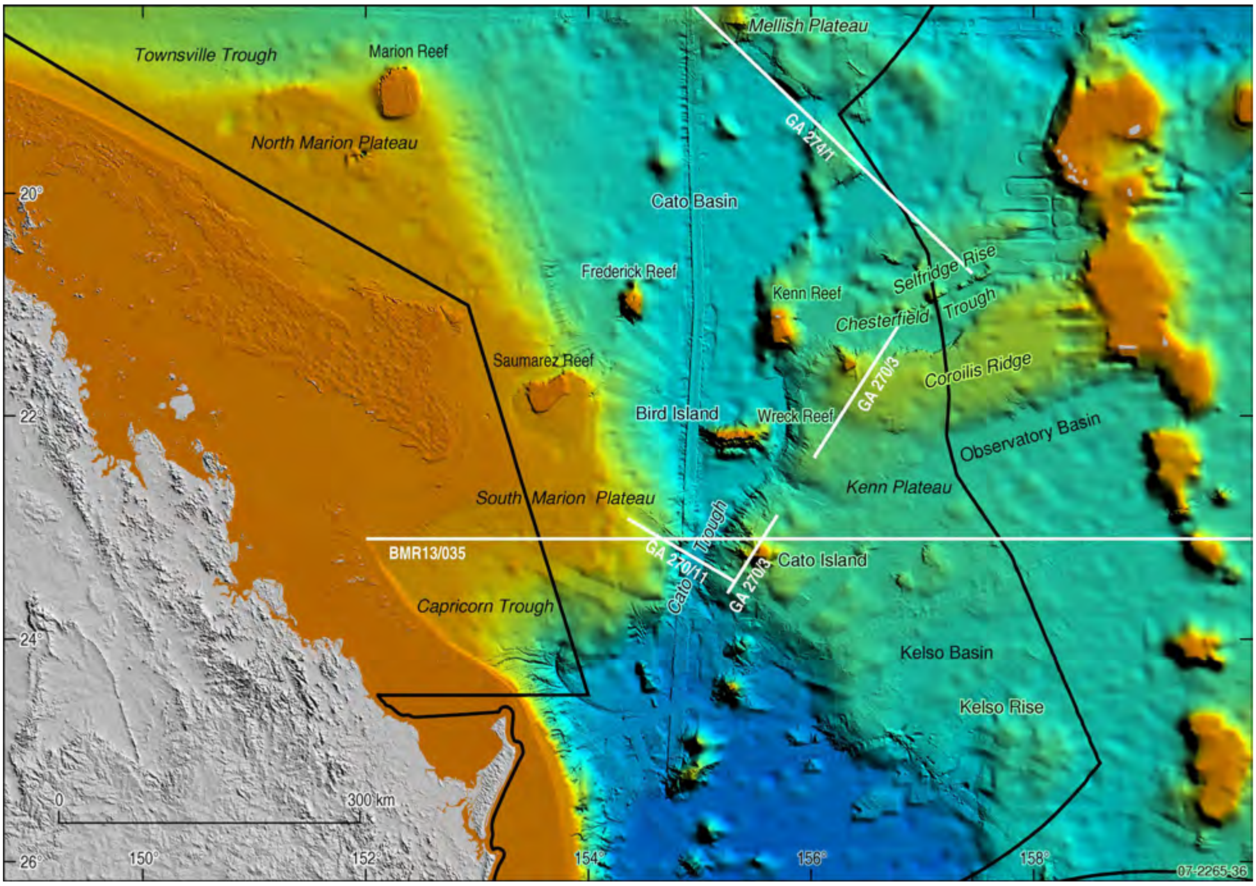


Figure 3.44. False colour image showing geomorphic features of the Cato Trough, Cato Basin, Kenn (Chesterfield) Plateau, Mellish Rise, Marion Plateau and associated reefs. Locations of features and seismic lines displayed in other figures are marked. Black line is the EMR boundary.

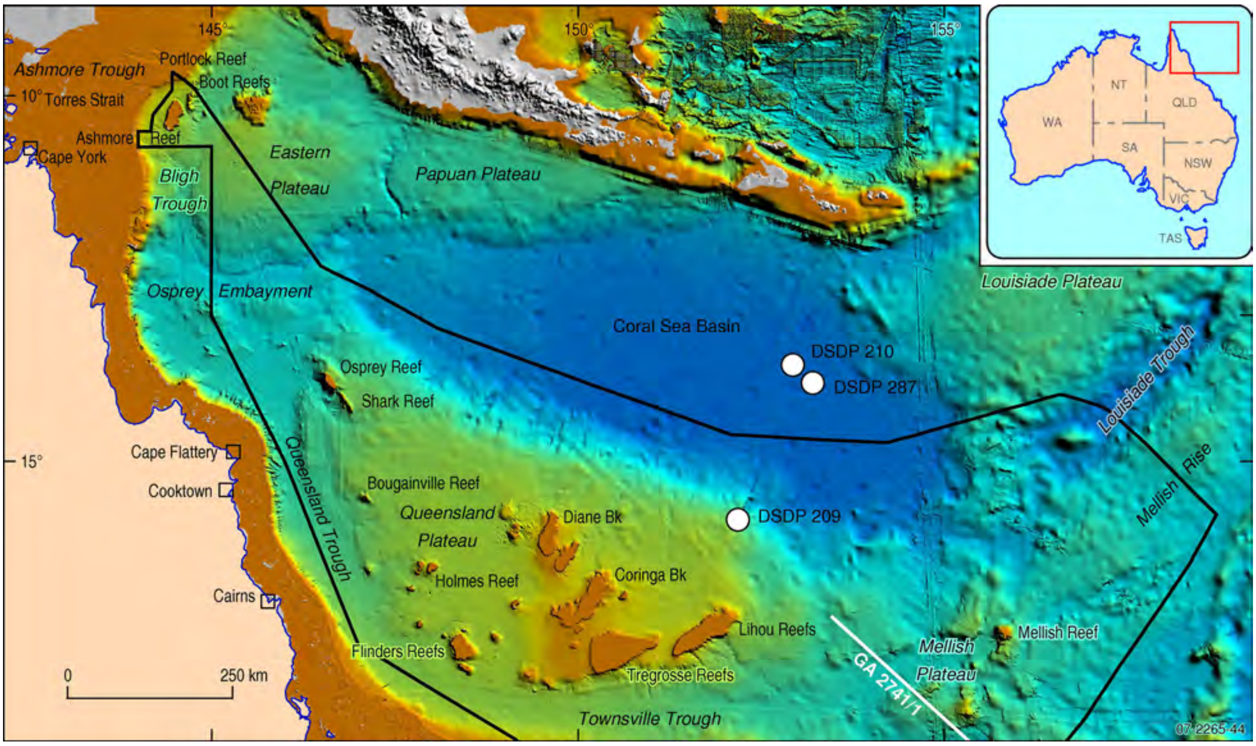


Figure 3.45. False colour image showing geomorphic features of the Queensland Plateau, Townsville Trough, Queensland Trough, Osprey Embayment, Eastern Plateau and associated reefs. Locations of DSDP drill sites are indicated. Black line is the EMR boundary.

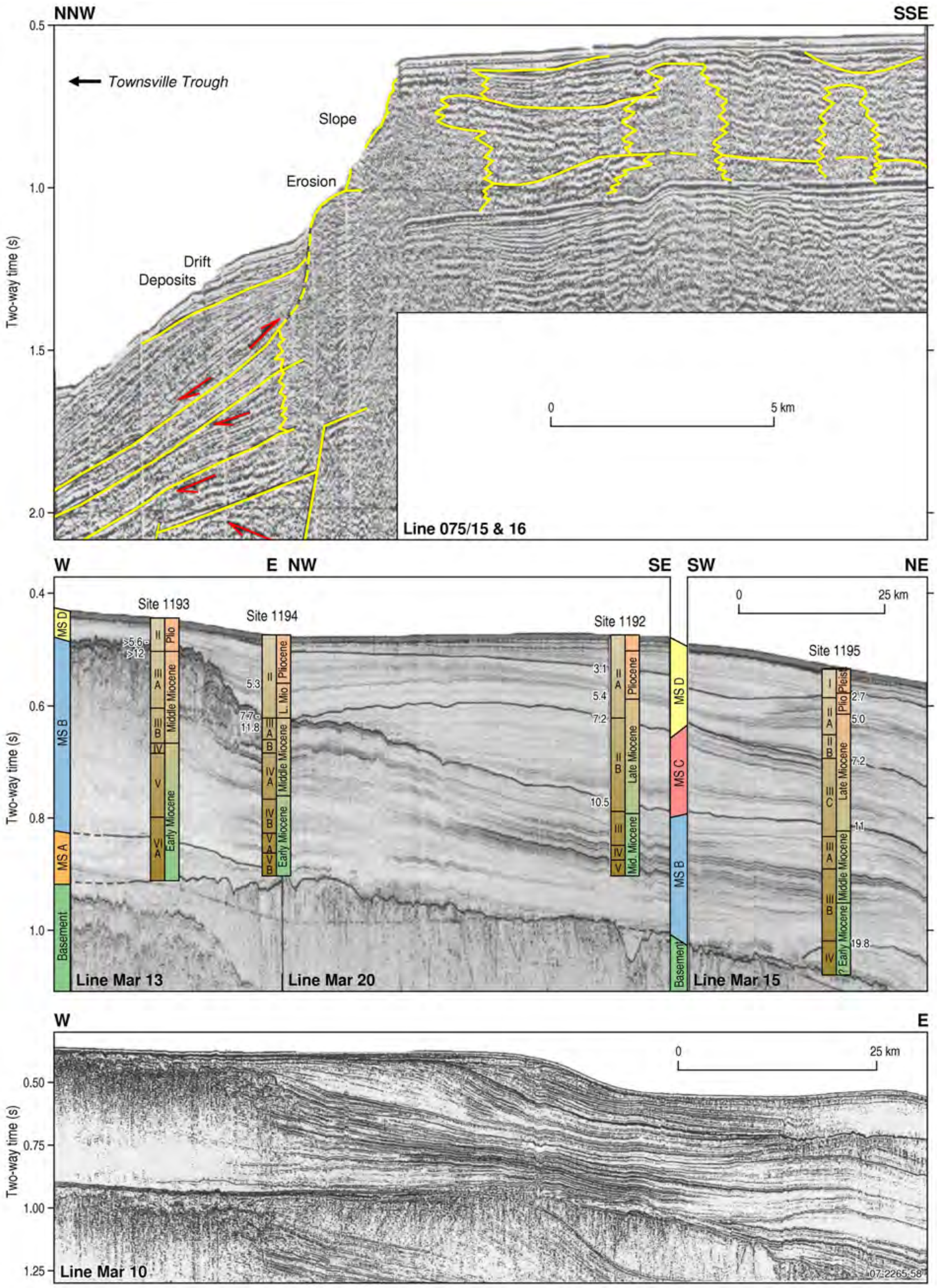


Figure 3.46. a) Seismic profile across the northern Marion Plateau carbonate platform adjacent to the Townsville Trough. Note the sharp break at the platform edge and the erosion and drift deposits on the slope. The sediments beneath the seabed are interpreted as barrier reef (BR), lagoon (L), patch reef (PR) and forereef periplatform (P). (Davies et al., 1989), b) Seismic profile across the southern part of the northern Marion Plateau showing location and results of ODP drill sites. (Isern et al., 2004) and c) Seismic profile across the central part of the northern Marion Plateau from west to east. (Isern *et al.,* 2004).

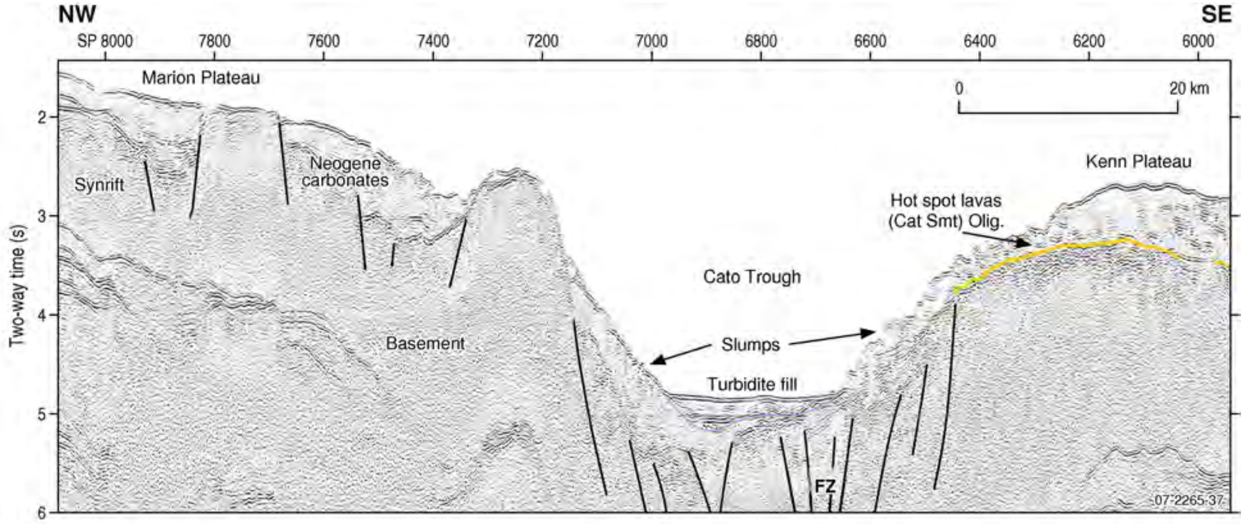


Figure 3.47. Seismic profile across the Cato Trough showing erosion, exposure of bedrock, sediment slumps on the slopes and turbidites in floor of trough. Line 11. Location in Figure 3.44. Exon *et al*., (2005).

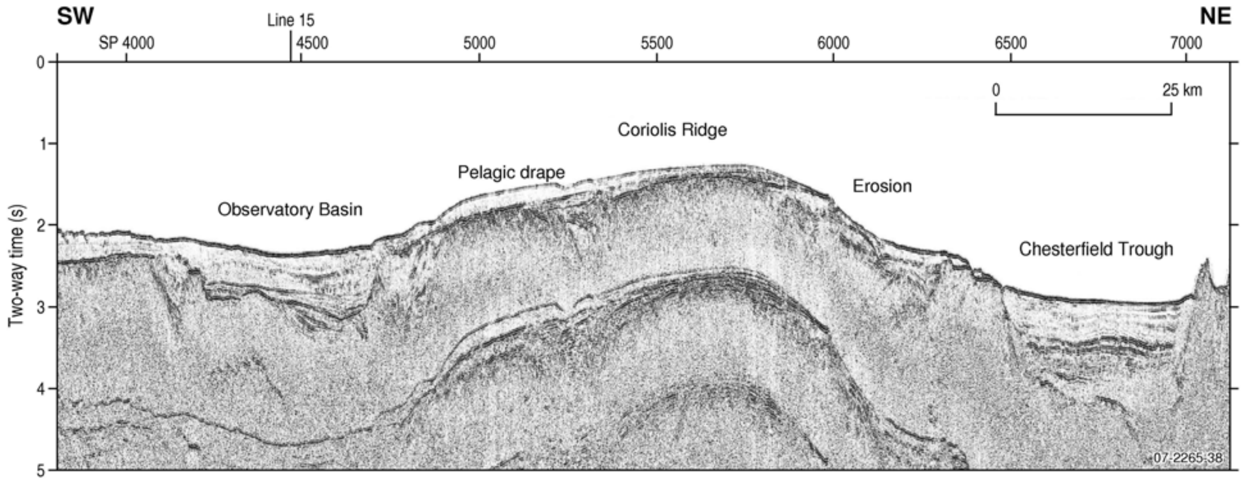


Figure 3.48. Seismic profile across the Observatory Basin, Coriolis Ridge and Chesterfield Trough showing general drape of pelagic sediments. Line 270-3. Location in Figure 3.44. Exon *et al*., (2005).

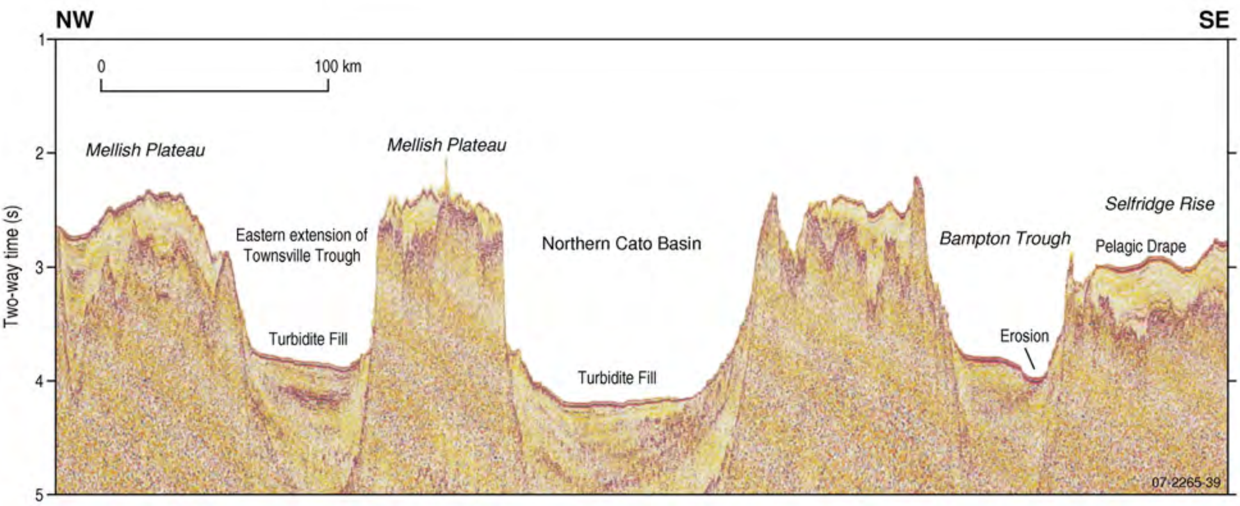


Figure 3.49. Seismic profile from Selfridge Rise to Mellish Rise showing the trough and ridge topography typical in this area. Line GA274/01. Location in Figures 3.44 and 3.45. Exon *et al*., (2006a).

*3.7.1.2. Queensland Plateau, Townsville and Queensland Troughs and Reefs(*Lihou Reefs and Cays, Tregrosse Reefs, Malay Reef, Abington Reef, Flinders Reefs, , Coringa Bank, Magdeline Cays, Willis Islets, Diane Bank, Moore Reefs, Holmes Reefs, Herald Cays, Flora Reef, Bougainville Reef, Shark Reefs and Osprey Reef*)*

The Queensland Plateau is roughly triangular in shape with its northeast side facing the Coral Sea Basin for 800 km, its western side is the Queensland Trough for 550 km and its southern side is the Townsville Trough for 500 km, an area of about 165,000 km^2. Both troughs are rift basins partly filled by sediment (Symonds et al., 1983; Scott, 1993). On the northeast margin there is a change in trend of the contact between the slope and the abyssal plain at 14° 20'S. The slope is 40-60 km wide and occurs between 2,000 and 4,000 m water depth. In the north it has an abrupt contact with the abyssal plain at ~ 4,000 m whereas in the south there is a rise extending out from the base of slope at ~3,500 m. The slope has a convex shape, steeper in the southern section, and is cut by many canyons (Gardner, 1970; Mutter, 1977). East of Lihou Reefs the plateau deepens to form two terraces at depths of 1,400-1,600 m and 2,200 m with a shallow trough between them.

On the basis of water depth the plateau can be divided into half along a line drawn from where the two troughs meet the Coral Sea Basin. The plateau is 350 km wide at this point and the southeast half is mostly shallower than 1,000 m and the north-west half is mostly between 1,000 and 2,000 m water depth with a gentle slope to the north. The seabed on the plateau is generally flat and smooth with numerous steep-sided reefs ranging in size from very small pinnacles to those that reach the sea surface and have formed large platforms. The living reefs, at or near present sea level, form 10-15% of the area of the plateau and are most common in the south and along the western margin (Davies, 1988).

The Miocene was a period of extensive reef growth that formed extensive limestone platforms that are a feature of the Queensland Plateau (McKenzie and Davies, 1993). Modern day reefs have formed smaller platforms on the submerged and largely buried Miocene platforms (Davies et al., 1989; Betzler et al., 1995). The largest of the modern platforms are the Tregrosse Reefs and Lihou Reefs on the southern margin of the plateau. They are each nearly 100 km long from east to west and 50 and 25 km wide, respectively. They rise steeply from water depths of >1,000 m where they are near the edge of the plateau and from ~500 m water depth on the plateau. To their north are the slightly smaller Coringa Bank and Diane-Willis complex of reefs. Osprey Reef on the northern end of the plateau rises steeply from over 2,000 m water depth on its western side to reach sea level. Terraces occur around some of these reefs indicating more extensive growth in the past. A major terrace occurs at 450-500 m and another at 50 m (Davies et al., 1989). Mutter (1977) reports that sediment aprons surround the base of these reefs and extend a considerable distance from them. Slumping, mass transport and shedding of carbonate material from the reefs have created these aprons.

Numerous drowned reefs have been reported on the plateau (Taylor, 1977; Mutter, 1977; Davies et al., 1989). Large isolated pinnacles occur along the western margin of the plateau. Some of these are only 1-2 km across and rise from over 1,000 m water depth to within 10 m of sea level. A pinnacle in the Queensland Trough east of Flinders Reef rises steeply 500 m from a flat seabed to within 675 m of the surface. Davies et al., (1989) sampled reef limestone from this pinnacle. Seismic evidence shows that some of these pinnacles form on the raised corners of fault blocks (Davies et al., 1989). Along the southern margin of the plateau there are numerous small canyons cut in the slope leading down from Tregrosse Reefs and Lihou Reefs into the Townsville Trough.

The Townsville Trough extends from the GBR eastward into the northern end of the Cato Basin and continues as a topographic trough into the Mellish Plateau (Fig. 3.45). The trough is a broad U-shaped feature some 100 km wide at the 2,000 m isobath at its eastern end. It narrows and shoals gradually to the west for 500 km to reach a sill depth of 900 m offshore of Townsville. On the north side of this sill is the Queensland Trough. It extends for 550 km to the north from 18-14°S gradually deepening to 2,900 m north of Osprey Reef where it widens (200 km) into the Osprey Embayment. The floor of the trough is flat with a northerly slope of <10°.

The southern section of the Queensland Trough is broad (90 km) and asymmetric with a much steeper slope on the western margin as it rises to the GBR. North of Bougainville Reef at 15° 10'S it abruptly narrows due to a basement ridge, making the eastern side also steep with 150 to 500 m of relief and a distinct terrace before rising to the plateau. This terrace continues north to Osprey Reef. The GBR side of the trough is mostly outside the EMR but is also steep with many canyons and scars from submarine slides. Johnson (2004) reports failures up to 30 km wide and 50 km long south of Cooktown. North of Cooktown the shelf edge and upper slope are deeply incised by canyons.

3.7.1.3. Osprey Embayment, Eastern Plateau and Reefs (Bligh Trough, Ashmore Reef, Boot Reef, Portlock Reef and Ashmore Trough).

The EMR is narrow here and covers only part of the Osprey Embayment and a wedge-shaped part of the Eastern Plateau (Fig. 3.45). This plateau is between 1,000 and 2,000 m deep with the Bligh Trough along its western margin. North-west of the Eastern Plateau across a sill (1,500 m water depth) separating the northern end of the Bligh Trough from the Pandora Trough are two significant reefs in the EMR. They are Ashmore Reef and Boot Reef which rise from depths on their eastern side of 1,000-1,500 m to form carbonate platforms in less than 100 m of water. Both platforms are elongate N-S. Ashmore is the largest platform at 45 x 20 km and Boot is 20 x 10 km. Boot Reef is only 10 km to the north-east of Ashmore Reef and separated by a narrow, 700 m deep channel. Ashmore is only 50 km east of the GBR from which it is separated by the 700 m deep Ashmore Trough. This trough is a valley that drains south into the Bligh Trough. North of these reefs the shelf edge runs nearly east-west. The shelf edge here is distinguished by a very sharp break and steep upper slope (Harris et al., 1996b). It is interpreted as a drowned barrier reef that was constructed on a beach ridges in the late Pleistocene (Frances et al., in press). At its eastern end is a relict delta from a lower sea level. Further east is Portlock Reef which is a partly buried atoll now on the shelf edge. Boot Reef is an atoll 25 km south of Portlock Reef. The saddle joining Boot Reef with the slope is at 500 m water depth and the saddle at the northern end of Ashmore Reef joining it to the slope is at 650 m water depth. The valley between the two reefs and one north of Boot Reef both drain east into the Pandora Trough. Scalloped morphology on the margins of Ashmore Reef, Boot Reef and Portlock Reef suggest large gravity failures. The possibility of failure is enhanced on atolls because the upper slope (<500 m) is very steep, leading to failure.

The Osprey Embayment extends west for 300 km from the Coral Sea Basin to the GBR. It is 200 km wide from north to south. The seabed has a general slope to the north and consists of small plateaus and ridges with a relief of several hundreds of meters separated by troughs. Its major feature is a broad, sinuous deep sea valley along its northern margin where it is deepest (3,600 m). This channel was named the Bligh Canyon by Winterer (1970) and it meanders east across the EMR for 160 km.

Winterer (1970) mapped a 60 km long section of the canyon in the EMR and showed that it was flat-floored, 10 km wide and entrenched about 100 m below the surrounding seabed. A smaller channel, only a few meters deep, meanders across the flat floor of the canyon. The Queensland and Bligh Troughs act as tributaries to the eastward trending Bligh Canyon.

3.7.1.4. Coral Sea Basin Abyssal Plain, southern Louisiade Plateau and Louisiade Trough

There is a paucity of data for this area. The Louisiade Trough separates the Mellish Rise from the Louisiade Plateau. The southern extensions of both are within the EMR. Like the Mellish Rise the southern margins of the Louisiade Plateau are irregular and the topography, where surveyed, is rough and rises steeply from the surrounding seabed. The geomorphology is inherited from their tectonic origins. Between the Louisiade Plateau and the Mellish Rise lies the Louisiade Trough which runs NE-SW and is deepest in the north. It has a maximum width of about 100 km but its margins are not well defined by surveys. Over 250 km of its length are within the EMR and it is up to 4,500 m deep.

The abyssal plain/deep ocean floor of the Coral Sea Basin extends into the EMR for a distance of up to 140 km over a length of 1,000 km seaward of the Queensland Plateau. It extends from the Osprey Embayment in the north-west, gradually deepening to the southeast where it abuts the southern part of the Louisiade Plateau. The plain lies at a depth of 4,000 to 4,500 m, and in the north it has a gradual contact with the slope of the Queensland Plateau forming a rise.

3.7.2. Surface Sediments and Rocks

The sediments in this area are dominated by pelagic carbonate deposits but with significant contribution of carbonate from the shallow water reefs. The whole area is above the calcite compensation depth so preservation of the carbonate is excellent except in the Coral Sea Basin. The ocean in the area is not highly productive so siliceous plankton are missing from the sediments except in the northeastern margin, where diatoms are found in the sediment beneath the South Equatorial Current. Information about samples and bottom photographs from this area is collated in Appendix C Tables 14 to 20

In general the GBR acts as a barrier to terrrigenous sediments reaching the slope. An exception is the Queensland Trough where up to 40% of the sediment on the seafloor is terrrigenous mud that has been flushed through the GBR from the shelf (Francis et al., 2007). Further north in the Osprey Embayment and in the Coral Sea Basin, there is also significant dilution of the carbonate sediment by terrigenous mud from the rivers of Papua New Guinea. Sediments on the topographically isolated Eastern Plateau have up to 50% terrrigenous muds (Francis et al., in press).

ODP drilling of the limestone and carbonate sediment forming the Marion Plateau showed it to be 450-650 m thick and to have accumulated since the Oligocene (Isern et al., 2002). The limestone lies on basement which was sampled at five ODP sites and consisted of volcanic flows and breccias of altered basalt. They suggest the basalt was emplaced at the time of rifting in the late Cretaceous-Paleocene. This basement outcrops on the faulted margin where the Marion Plateau descends into the

Cato Trough. On the Queensland Plateau the basement was sampled at two sites at depths of 400-450 m below the seabed, and consisted of meta-sedimentary rocks; the overlying limestone deposition started in the middle Eocene (Davies et al., 1991b).

Sedimentation on the Marion Plateau is dominated by the EAC creating erosion around limestone outcrop but elsewhere the current has smoothed the relief and created undulations on the seabed where it has deposited large sediment drifts. Bottom photographs at water depths of 348 m and 374 m show ripple marks in the sand along with cemented slabs encrusted by sponges on the plateau surface east of the northern platform (Isern et al., 2002). Photographs and samples taken on the southern platform show the seabed to be a ferromanganese-stained hardground of limestone, bored and encrusted with serpulids and bryozoans with some unconsolidated carbonate sediment in depressions (Heck et al., 2007). There are also scoured channels around Saumarez Reef on its north and west sides. Away from the platforms the sediment is a sand or muddy sand dominated by planktonic foraminifers with minor skeletal grains of bryozoans, scaphopods, solitary corals, sponge spicules and pteropods (Isern et al., 2002, 2004). Cores analysed by Heck et al., (2004) from east of the southern platform have sedimentation rates of 2.6-3.5 cm ka^{-1} and carbonate content ranges from 79% to 93% reflecting the glacial-interglacial cycles down-core with the higher values from sediment at the surface and at other interglacials intervals. ODP Sites 815 and 816 on the northern margin of the Marion Plateau sampled foraminifer coccolith ooze on the seafloor at water depths of 466 m and 438 m.

Sediments in the Cato Trough and Basin are pelagic oozes (Walker, 1992). Photos of the seabed show ripples in foraminiferal sand where the Trough is narrow and debris blocks from the adjacent slopes (Figs. 3.51 and 3.52). Away from the narrow pass the muddy sand has a rich epifauna and grazing trails and burrows are common (Fig. 3.53). A core from the central Cato Basin in 3,152 m sampled graded beds of foraminifer coccolith ooze with pteropods deposited by turbidity currents (Jenkins et al., 1986). The sediment was >90% carbonate.

Sedimentation on the Queensland Plateau is dominated by very pale orange to greyish orange calcareous pelagic ooze consisting of foraminifers and coccoliths with lesser amounts of pteropods (Gardner, 1970; Burns et al., 1973). The living reefs on the Queensland Plateau are similar to those on the GBR (Done, 1982). These reefs are shedding carbonate particles, particularly coral, algae, foraminifers and molluscs down their steep slopes and onto the surrounding seabed (Orme, 1977). ODP drilled at seven locations on the western and southern Queensland Plateau to sample a variety of depositional environments. Close to reefs on the plateau (Site 811/825, 812, 813, 814) in 462-940 m water depth foraminifer coccolith pelagic oozes were interbedded with redeposited shallow water carbonate sediments and foraminifer-pteropod sands with carbonate values of >95% and sedimentation rates of 1 to 2.4 cm ka-1 (Davies et al., 1991b). Away from the reef platforms, at Sites 817, 818 and 824 in water depths of 749 to 1,017 m on the gently sloping margin of the plateau, the sediments are more mud-rich due to an increased proportion of coccoliths and less foraminifers and pteropods. Interbedded with the pelagic ooze are thin beds of coarser carbonate consisting of molluscs, bryozoans, corals and coralline algae. These along with slump folds in the cores indicate downslope transport of sediment. On the northeast margin of the plateau DSDP Site 209 in water depth of 1,428 m sampled very pale orange to grayish orange foraminifer coccolith ooze (Burns et al., 1973).

The Queensland Trough is filling with hemi-pelagic sediments and redeposited sediments from the GBR and Queensland Plateau. Four large (5-10 km wide and 10s km long) sediment gravity flows have been mapped on the seafloor between 15° and 16° 30’S by Dunbar et al. (2000). They originate as failures on the seaward slope of the GBR and flow down slope and curve north down the trough axis. Cores in these deposits show chaotic sediment structure. Turbidite layers are common in cores in the trough (Watts et al., 1993; Blakeway, 1991; Dunbar et al., 2000). The near surface sediment on the seabed sampled at ODP Site 823 consisted of hemipelagic, clay-rich, foraminifer coccolith mud with 60% carbonate, interbedded with redeposited layers interpreted as turbidites and debris flows (Davies et al., 1991a).

Carbonate content in the surface sediment generally increases from the GBR slope to the trough and plateau and decreases northwards down the axis of the trough (Dunbar, 2000; Dunbar and Dickens, 2003a). It decreases from >90% at the sill with the Townsville Trough to 60% in the north. The carbonate content is >90% on the Queensland Plateau and 100% near isolated reefs. On the GBR slope Francis et al., (2007) have identified a zone between 15^0 and 17^0S with the lowest carbonate content of 40-80% and suggest that inter-reef passages supply the terrigenous mud that dilutes the carbonate in the trough. They further suggest that the pattern of clay mineral concentration indicates transport to the south by surface and bottom currents.

Harris et al. (1990) analysed cores from the western slope of the Queensland Trough offshore of Townsville and found that the surface sediment was sandy mud and muddy sand (20-45% foraminifer-pteropod sand) with 80-90% carbonate in water depths of 690 m to 1,200 m. Below the surface there were cycles with less carbonate due to an increase in terrigenous muds which Harris et al., (1990) interpreted as lowstand deposits. More recent analyses of numerous cores from the Queensland Trough and its slopes have recovered siliciclastics (quartz, feldspar, clay minerals) in surface sediments indicating a considerable flux of terrigenous sediment through the passages in the reef during the present-day sea level highstand when more carbonate was expected to be supplied (Harris et al., 1990; Dunbar et al., 2000; Dunbar and Dickens, 2003a, 2003b; Page et al., 2003; Page and Dickens, 2005; Francis et al., 2007).

Average sedimentation rates for the past 6.5 ka are highest on the slope in front of the GBR (up to 55 cm ka-1), 2-3 cm ka-1 in the floor of the trough and low (<1.5 cm ka-1) on the Queensland Plateau adjacent to the trough (Dunbar et al., 2000). On the southern slope of the Queensland Plateau Cotillon et al. (1994) calculated the late Pleistocene average sedimentation rate to be 5.2 cm ka-1.

Ashmore Reef and Boot Reef are carbonate platforms less than 100 m deep and rise steeply from about 1,000 m. They are separated from each other and the shelf by a 600-700 m deep known as the Ashmore Trough. Portlock Reef forms the outer rim of the continental shelf of eastern Torres Strait. This is the largest modern example of a tropical mixed siliciclastic/carbonate depositional system (Davies et al. 1989). Significant quantities of clay, sand (rock fragments, feldspar and quartz) and other weathering products are discharged from PNG rivers to a shelf, where it is deposited with large amounts of carbonate produced from algae (e.g, Halimeda), foraminifera, mollusks and corals. These shelf sediments along with pure carbonate sediment from platform tops/barrier reef then shed aragonite and high-Mg calcite particles onto the surrounding slopes and basins where they accumulate with low-Mg calcite pelagic carbonates. It appears that large slumps have occurred from the summits of these atolls, and large limestone blocks have been transported to the surrounding seabed.

In the north of the EMR the significant input of sediment, mostly terrigenous muds, from the PNG shelf reaches the slope (Brunskill et al., 1995; Walsh and Nittrouer, 2003). A core taken from the Ashmore Trough at the northern end of the EMR in water depths of 760 m consists of dark grey/pale gray laminated calcareous muds. This hemipelagic sediment consists of 75% carbonate (coccoliths, foraminifers and pteropods) at the surface which decreases down core to 25% during the Last Glacial Maximum (20,000 y.b.p.). The core is useful for paleoclimate studies because it has a very high sedimentation rate of ~25 cm ka-1 and the depositonal laminae have not been bioturbated which allowed de Garidel-Thoron et al. (2004) to use carbon isotopes to suggest possible methane escape from near here that triggered abrupt climate warmings in the Pleistocene. Francis et al. (in press) determined that the sedimentation rate in Ashmore Trough is low for the Holocene. The slope here and in the Osprey Embayment is blanketed in mud drifts deposited from turbid waters from the PNG shelf, probably transported by the clockwise deep water current in the Gulf of Papua (Keen et al., 2006). During the last glacial maximum sea level lowstand beach ridges and deltas formed at the shelf edge and upper slope. During the low stand and regressions leading up to it large volumes of organic-rich sediments were deposited on the toe of slope of the northern Ashmore Trough at 600-800 m of water depth. The laminations in the cores suggest the basin was poorly ventilated. These sediments contain a high resolution archive of Earth climate variability, particularly of the Western Pacific Warm Pool (Beaufort et al., 2005).

The Coral Sea abyssal plain/deep ocean floor has been sampled by shallow cores (Gardner, 1970; Beiersdorf, 1989; Jenkins et al., 1986) and by DSDP Sites 210 and 287 (Burns et al., 1973; Andrews et al., 1975). All the surface samples from the southwest of the basin were similar: a white pelagic foraminifer coccolith ooze at the surface generally less than a meter thick overlying interbedded turbidites and pelagic ooze. In the far east of the basin (15° 15′S; 154° 45′E) in water depths of 4,590 m Jenkins et al., 1986 sampled a diatomaceous foraminifer coccolith ooze overlying olive grey silty clays. This is the only known occurrence of significant quantities of diatoms in sediments in the EMR. The turbidites at both locations are olive grey graded beds of fine sand, silt and clay. The graded beds are terrigenous sediment transported by turbidity currents down canyons to the abyssal plain. Most of the sediment comes from the deltas along the PNG coast, but some turbidites are calcareous and consist of redeposited pelagic and shallow water carbonate from the Queensland Plateau. Gardner (1970) concluded that the pelagic ooze accumulated at a rate of 3.6 cm ka-1.

Coring on the Kenn Plateau recovered pale brown to white calcareous ooze consisting predominantly of foraminifers and coccoliths (Exon et al., 2006a). This is as expected for these water depths and productivity. Cores on Coriolis Ridge near the sand dunes recovered a foraminiferal sand confirming the presence of strong bottom currents.

Dredging on the Mellish Rise by Exon et al. (2006a) recovered basalts and fragmented volcanic debris along with pelagic sediments of late Cretaceous to Cainozoic age. Further south on Selfridge Rise they recovered quartzite indicating continental crust. Rocks from both the Kenn Plateau and Mellish Rise are coated with manganese crust generally <10 cm thick but with some up to 20 cm thick. One dredge on Mellish Rise in 2,630 m water depth recovered manganese nodules along with basalt (Exon et al., 2006a).

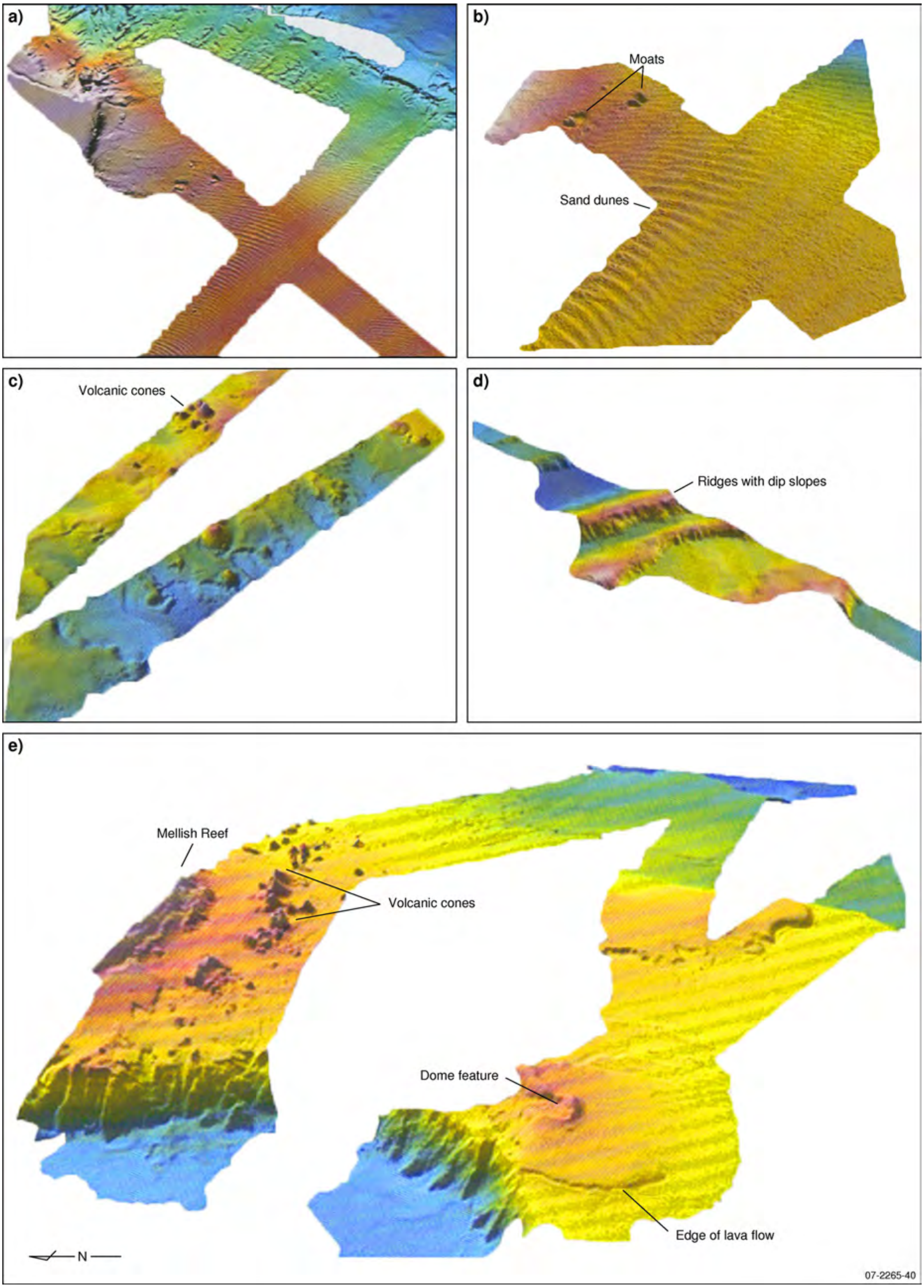


Figure 3.50. Multi-beam 3D imagery of bedforms, erosion and outcrop patterns on the Mellish Rise.a and b) Flat seabed with sand dunes (wavelength of 300 m) and outcrop with erosional moats, c and d) Volcanic cones and tilted basement ridges and e) volcanic cones, domes and lava flows. Locations in Figure 3.44 and 3.45. Exon *et al*., (2006).

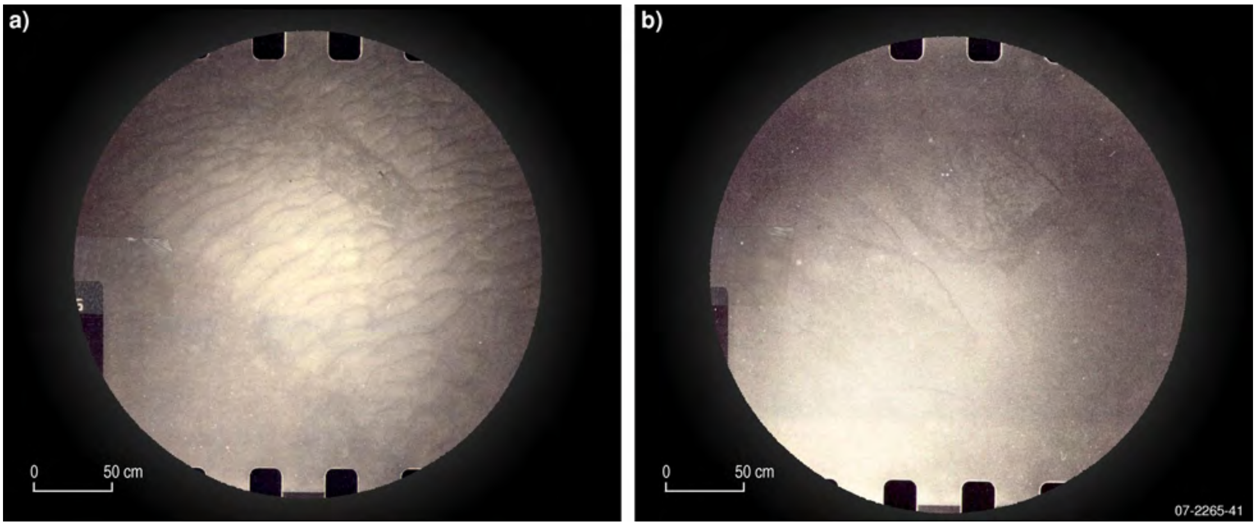


Figure 3.51. Seabed photos from the Cato Pass showing active ripple marks in sand and blocks of rock with organism bending in the current. BC1, Location in Figure 3.44. Walker, (1992).

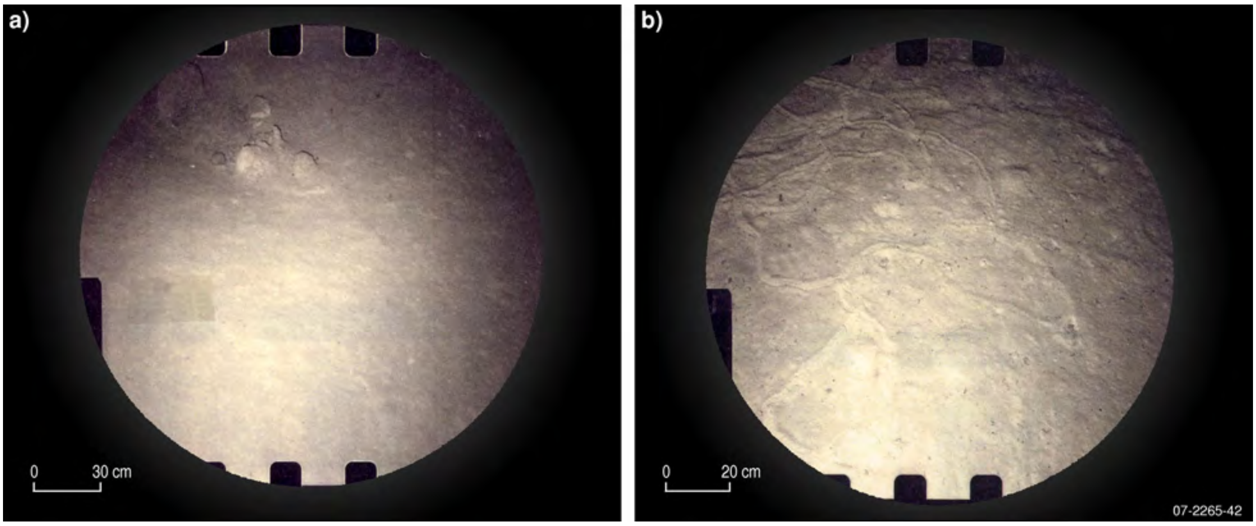


Figure 3.52. Seabed photos from the eastern side of the Cato Trough showing active mounds and tracks in muddy sand and rounded boulders draped with sediment . BC2, Location in Figure 3.44. Walker, (1992).

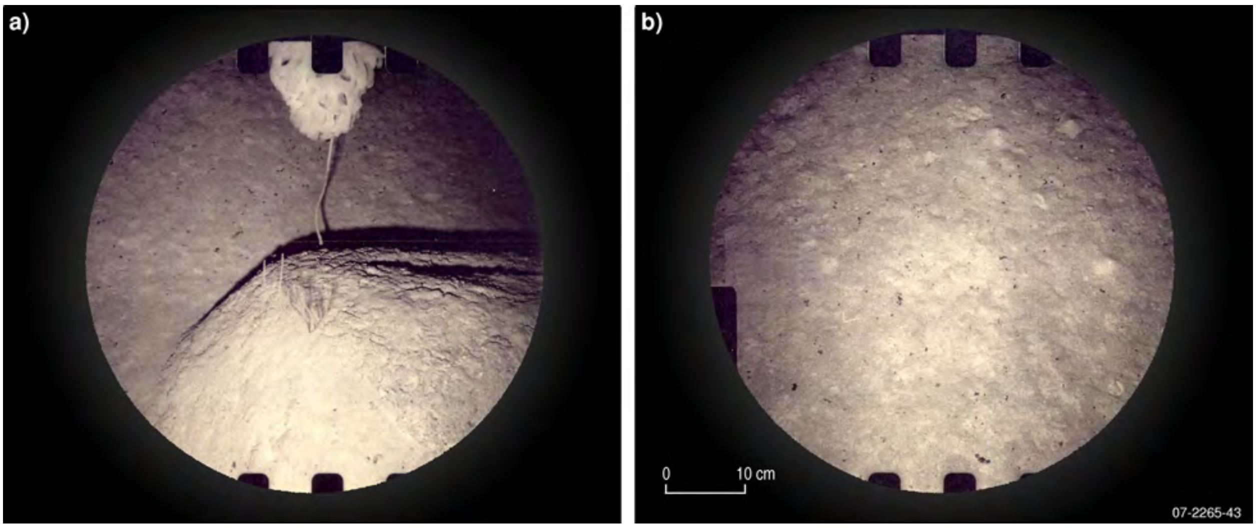


Figure 3.53. Seabed photos from the central Cato Trough showing bioturbated sediment and mounds with sponge and other epifauna. BC3, Location in Figure 3.44. Walker, (1992).

3.8. WESTERN PACIFIC OCEAN: NORFOLK ISLAND

3.8.1. Geomorphology

New Caledonia Basin, Norfolk Ridge, West Norfolk Ridge, North Norfolk Basin, South Norfolk Basin, Vening-Meinesz Fracture Zone, North Norfolk Plateau, Forster Basin, Nepean Saddle, Kingston Plateau, Bates Plateau, Philip Trough.

The geomorphology in the EMR surrounding Norfolk and Philip Islands is dominated by north-south trending rugged volcanic ridges separated by basins partly filled by sediments. The major feature is the Norfolk Ridge which bisects the region (Fig. 3.54). Apart from a slight western offset north of Norfolk Island the ridge runs straight north-south. It is 750 km in length from the northern boundary of the EMR to the southern boundary. Its width varies from 80 to 100 km and is mostly flat-topped at depths shallower than 1,500 m, with steep sides sloping into the New Caledonia Basin on the west and Norfolk Basin on the east (Figs. 3.55 and 3.56). Numerous small canyons cut these slopes. There are three shallower plateaus along its length. One in the north is 150 x 50 km and 500-1,000 m water depth, another around the islands is 200 x 50 km and rises steeply from 500 m water depth to a planated basalt surface at about 75 m, and the third at the southern end is 100 x 50 km, trends NW-SE, rises to 300-600 m water depth and is known as the Reinga Ridge. The orientation of this southern block is north-west as its NE margin is part of the Vening-Meinsez Fracture Zone. A 2,000 m deep narrow (20 km) gap separates this ridge from the Wanganella Bank (water depth 100-1,000 m) on West Norfolk Ridge in the south of the EMR.

To the west of Norfolk Ridge is the N-S trending New Caledonia Basin, an area of very flat seabed 3,500 m deep at the northern margin where it is 150 km wide and shoaling and narrowing to the south where it is 2,500 m deep (Fig. 3.56b). The West Norfolk Ridge forms the southern margin of the basin. This ridge continues NNW across the EMR as a discontinuous bathymetric feature known as the Northern West Norfolk Ridge and separates the Caledonia Basin on its east from the 100 km wide, 3,000 m deep Fairway Basin on its west (Exon et al., 2007). This ridge is probably volcanic and consists of steep sided ridges and seamounts with steep relief of 1,000 m where it rises from the 3,200 m abyssal floor of the New Caledonia Basin (Fig. 3.57).

The Fairway Basin is also N-S trending in the EMR. It is also 150 km wide and slopes to the south from 3,000 m in the north to 3,200 m in the south. The seabed is generally flat in the south of the basin but in the north there are ridges and hills with 100 m of relief and the seabed slopes east (Fig. 3.56a, Exon et al., 2007). These hill and ridges on the seabed appear to have been formed by underlying igneous intrusions and possibly sedimentary diapirs. The EMR extends across the Fairway Basin to take in the lower slopes of the eastern margin of the LHR. The contact of the LHR with the flat abyssal plain is abrupt and the lower slopes are steep, as the sediment cover has draped over the underlying normal-fault scarp formed during rifting (Willcox et al., 1980).

East of the Norfolk Ridge is a zone of complex topography on the seafloor known generally as the Norfolk Basin, but composed of plateaus, seamounts, basins, depressions and fault-bounded troughs (Fig. 3.55). The extent of these geomorphic features has only recently been revealed by multibeam surveys over the central part of the basin (Bernardel et al., 2002, Sdrolias et al., 2004).

Along the northern boundary of the EMR is the North Norfolk Plateau 2,000-3,000 m deep. South of this plateau is the North Norfolk Basin 200 x 100 km and 3,000–3,500 m deep separated from the deeper (4,000–4,250 m) South Norfolk Basin by the Nepean Saddle at 30°S. The basin floors are flat due to sediment fill of several hundreds of meters, thickest at the margins and base of ridges (Eade, 1988). Numerous volcanic ridges, generally oriented NNE-SSW, protrude from the basin floor with varying relief.

East of the North Norfolk Basin and separated from it by a ridge is the deeper Forster Basin (>4,000 m) which continues its NE trend outside the EMR to the Cook Fracture Zone. A large seamount in the Foster Basin has a summit only 800 m below the sea surface. Evidence of a submarine eruption was reported from this area in 1981 (RAN Hydrographic Office chart). South of the Forster Basin is the Kingston Plateau, a large, irregular shaped area approximately 200 x 150 km and between 2,000 and 3,000 m water depth. This plateau has many seamounts, some rising to within 1,000 m of the sea surface. Along its southern margin a ridge rises to water depths of 400-600 m. It is joined to the Norfolk ridge at its south western margin by the 50 km wide Nepean Saddle that is 900-1,400 m deep. Numerous small seamounts on the Nepean Saddle have a linear E-W trend at approximately 290 40'S and may correspond to a fault at this location (Sdrolias et al., 2004).

Southeast of the Kingston Plateau is the Bates Plateau. They are separated by the NNE trending Philip Trough, 3,000 to 3,500 m deep and 20-50 km wide with an irregular boundary. The margins of the plateaus are steep with slopes up to 270 (Sdrolias et al., 2004). Bates Plateau is similar to the Kingston Plateau having a relatively smooth surface at water depths of 2,100–2,600 m with low relief crenulations and the general absence of abyssal hills or ridges. However, they do have many seamounts, some are part of linear volcanic ridges along the margins of the plateaus. The eastern margin of the Bates Plateau has a N-S chain of seamounts in the EMR with three of them rising to depths of 800, 840 m and 570 m respectively (DiCaprio et al., in press). South of Bates Plateau and separated form the South Norfolk Basin by a ridge is an un-named group of small basins deeper than 4,000 m and separated by ridges.

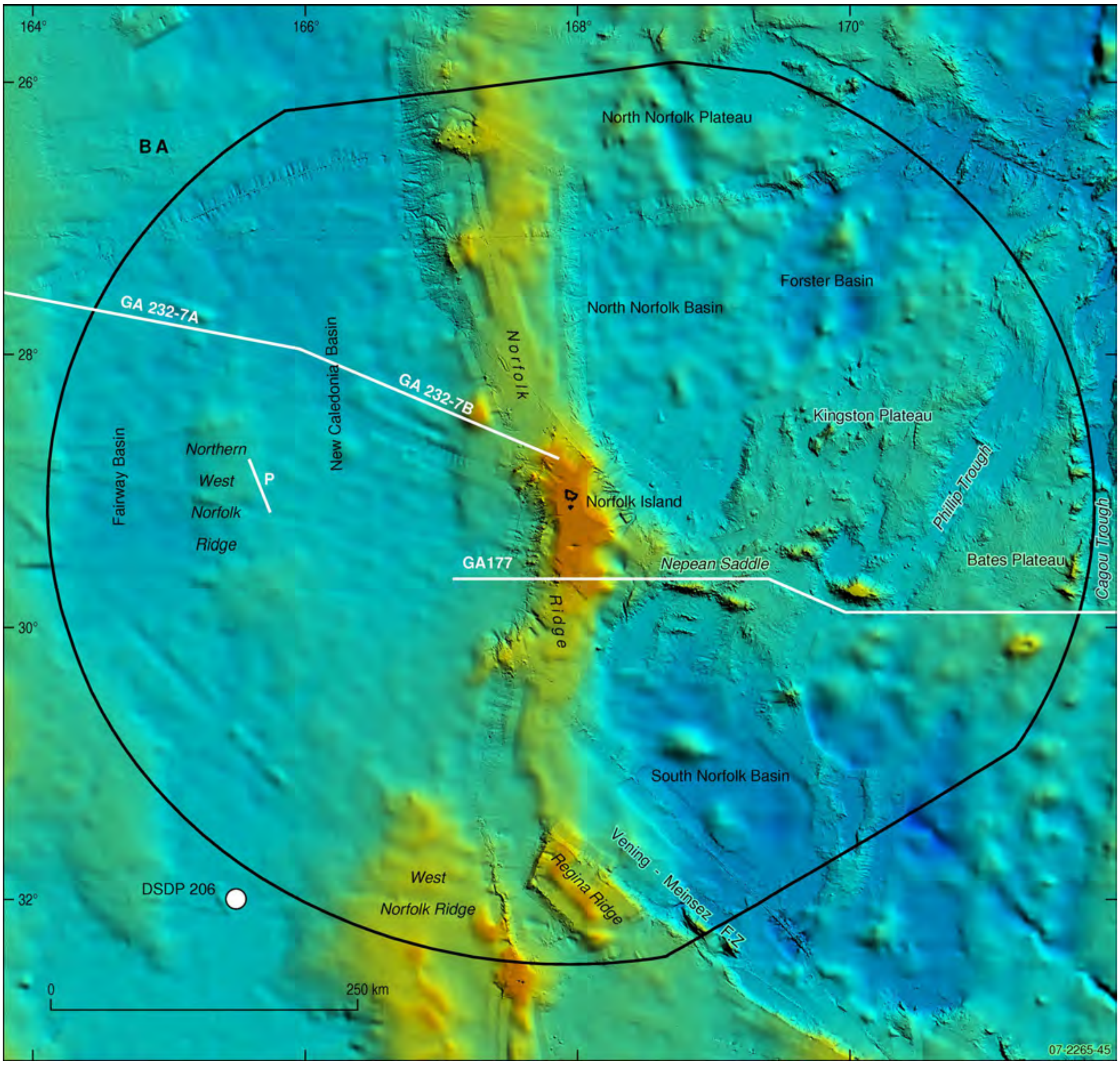


Figure 3.54. False colour image showing the geomorphic features around Norfolk Island. Locations of DSDP drill sites and of features and seismic lines displayed in figures 3.55 and 3.58 are marked. Black line is the EMR boundary.

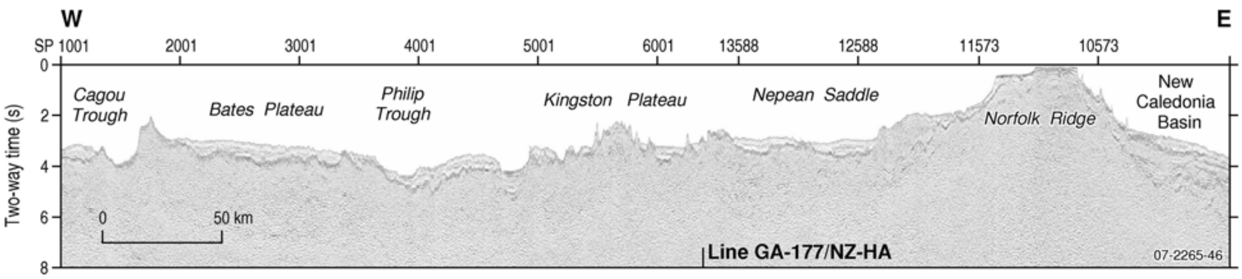


Figure 3.55. Seismic profile from the Norfolk Ridge to the eastern margin of the EMR showing the slope up from the New Caledonia Basin and the rugged topography of the ridges, troughs and plateaus. Location in Figure 3.54. Alcock *et al*., (2006).

3.8.2. Surface Sediments and Rocks

Sediments in this area are dominated by pelagic carbonate consisting of the calcite remains of foraminifers and coccoliths. There is also a minor contribution from siliceous plankton (radiolarians and diatoms). Volcanic ash and pumice are the minor contribution forming non-biogenic particles. Near rock outcrops boulders, blocks and pebbles of rock fragments become common. A list of cores and other samples from the area is given in Appendix C Table 3.21.

The New Caledonia and Fairway Basins are blanketed in a pale brown to light grey foraminifer-rich coccolith pelagic ooze containing minor amounts (<2%) of volcanic glass, radiolarians and diatoms (Dickens et al., 2001; Exon et al., 2004c). The New Caledonia Basin was sampled at DSDP Site 206 just outside the southwestern margin of the EMR (Burns et al., 1973). Sedimentation rates of ~2.5 cm ka^{-1} were calculated by Exon et al. (2004a). Little sediment sampling has been done from the more rugged areas on and to the east of Norfolk Ridge, but it is likely that foraminifer coccolith ooze dominates with redeposited sediments at the base of slopes. Air fall and submarine volcanic ashes and pumice may be mixed with the sediment in some areas.

Sedimentary diapirs occur in the subsurface of the Fairway Basin in the northwest of the EMR and are thought to be shale or possibly even salt (Auzende et al., 2000). Some diapirs have intruded through 3 to 4 km of sedimentary section and have raised the seabed. The diapirs are associated with a Bottom Simulating Reflector (BSR) which occurs at depths of 520-600 m below the seabed (Exon et al., 1998). This has led to speculation that an extensive area of gas hydrates and free methane gas may occur in this area.

Basement ridges occur along both sides of the Norfolk Ridge. They are strongly faulted and often outcrop or are only thinly covered by sediment (Eade, 1988). The ridge on the west is wider than the one on the east and is believed to be volcanic. Between the ridges the sediments are at least 3 km thick (Eade, 1988). The only sediment core from the Norfolk Basin was taken in 4,000 m water depth and contains 66% carbonate and consists of a foraminiferal coccolith ooze with some diatoms and radiolaria (Baker et al., 1988a and b).

DiCaprio et al. (in press) have collated the results of dredging in the region. A wide range of volcanic and metamorphic rocks have been recovered, most encrusted with manganese. Figure 3.56b shows a large volcano that is part of the chain of volcanoes along the western side of Norfolk Ridge. It rises to within 900 m of the sea surface and has a caldera at least 17 km across (Exon et al., 2004b). It has sediment drifts on its top that indicates the possible presence of foraminiferal sand winnowed by currents.

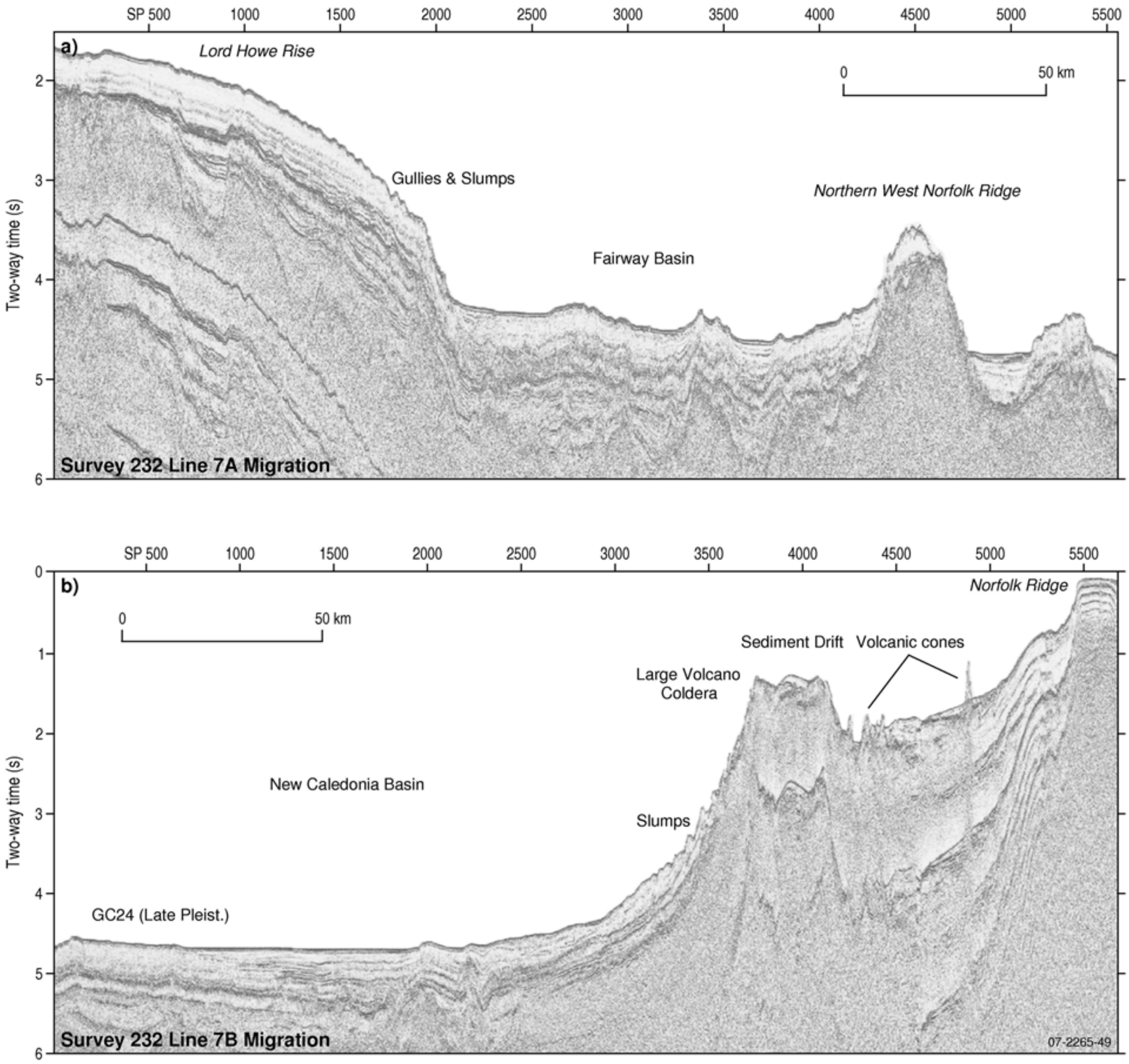


Figure 3.56.a)Seismic profile from Lord Howe Rise across the South Fairway Basin to the Northern West Norfolk Ridge showing hills in the basin and steep ridges and b) Seismic profile from the New Caledonia Basin to Norfolk Ridge showing volcanic cones, sediment drifts and slumping. Lines 232-7A and 7B, Exon et al., (2004b).

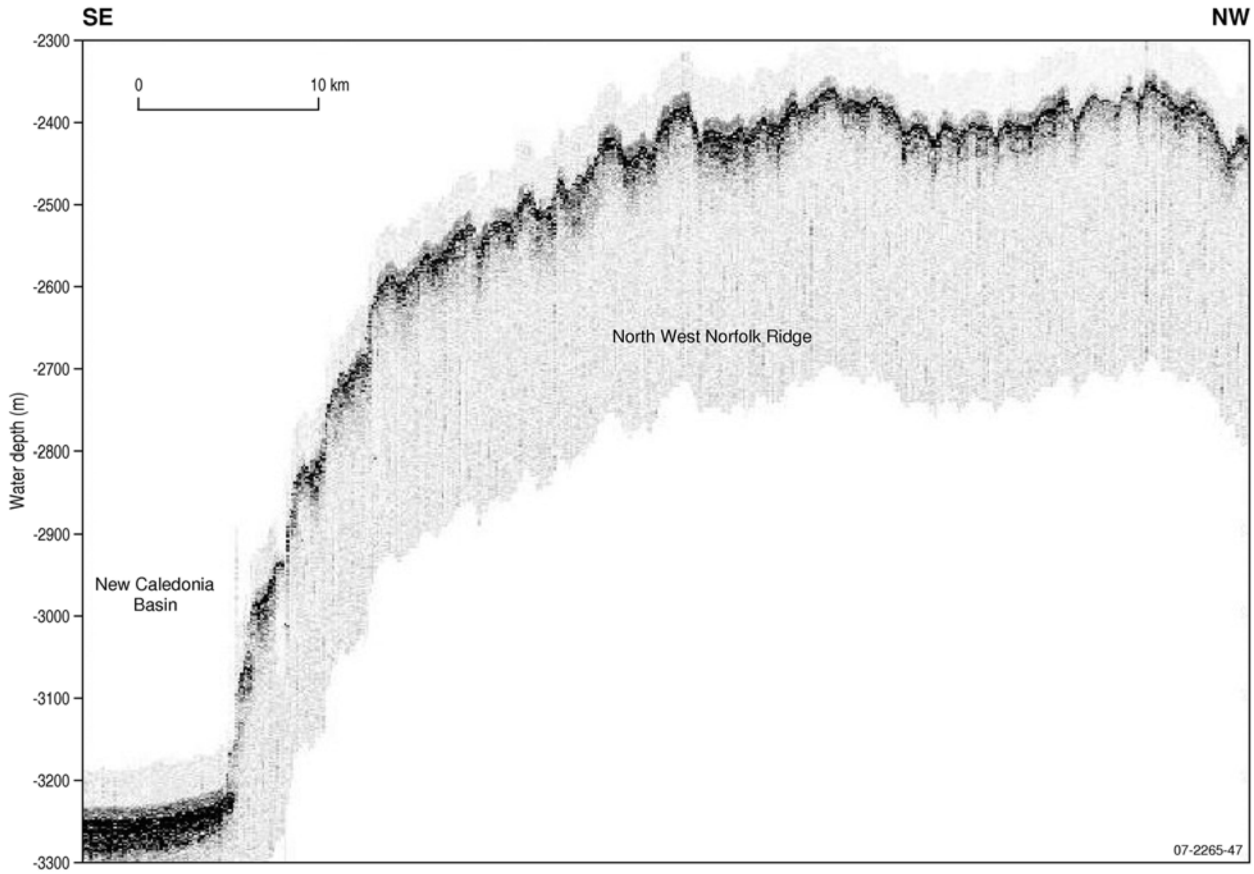


Figure 3.57. Profile of North West Norfolk Ridge showing rough topography on ridge, steep lower slope and flat floor of the Fairway Basin. Location in Figure 3.54. Colwell, (2006).

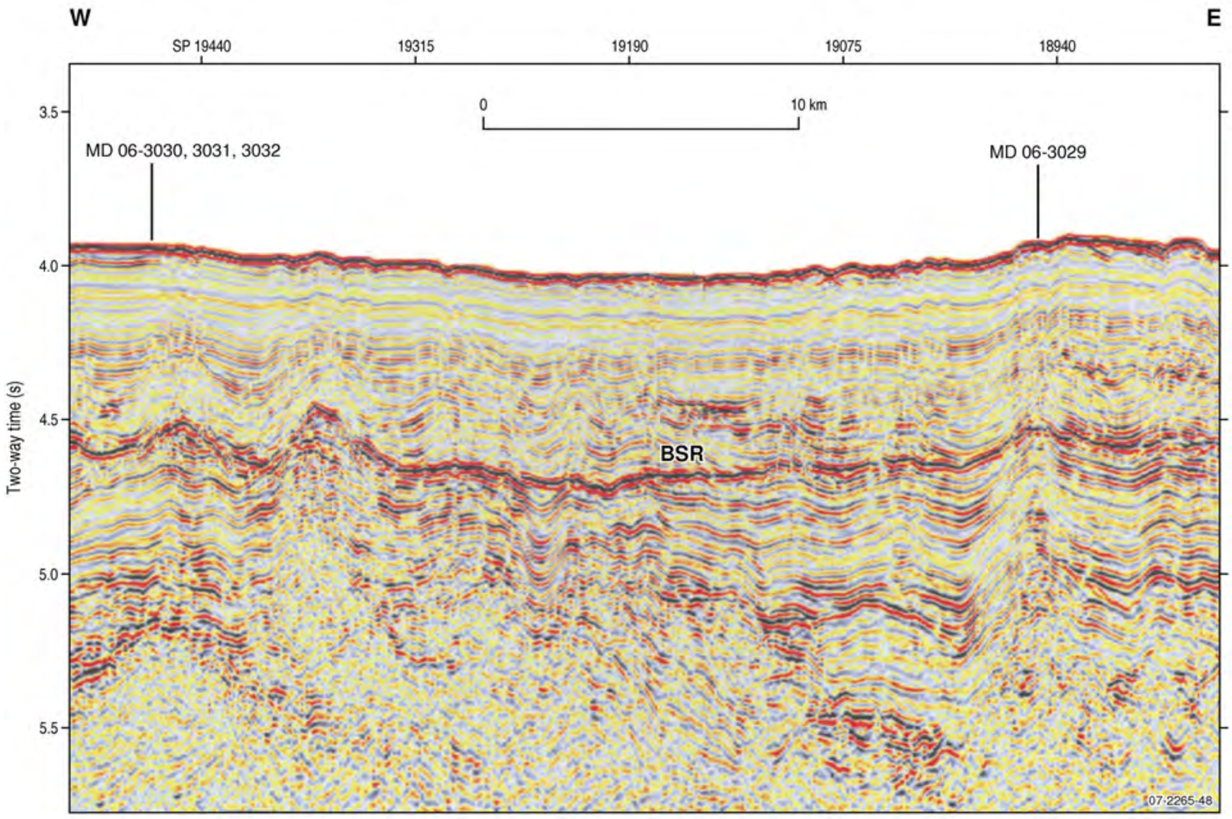


Figure 3.58. Seismic profile at eastern flank of central Fairway Basin, showing the distinctive bottom simulating reflector (BSR) and location of cores. GA line 177/LHRNR-BA, Location in Figure 3.54. Colwell et al., (2006)

4. Quantitative Description of the EMR

4.1 GEOMORPHOLOGY

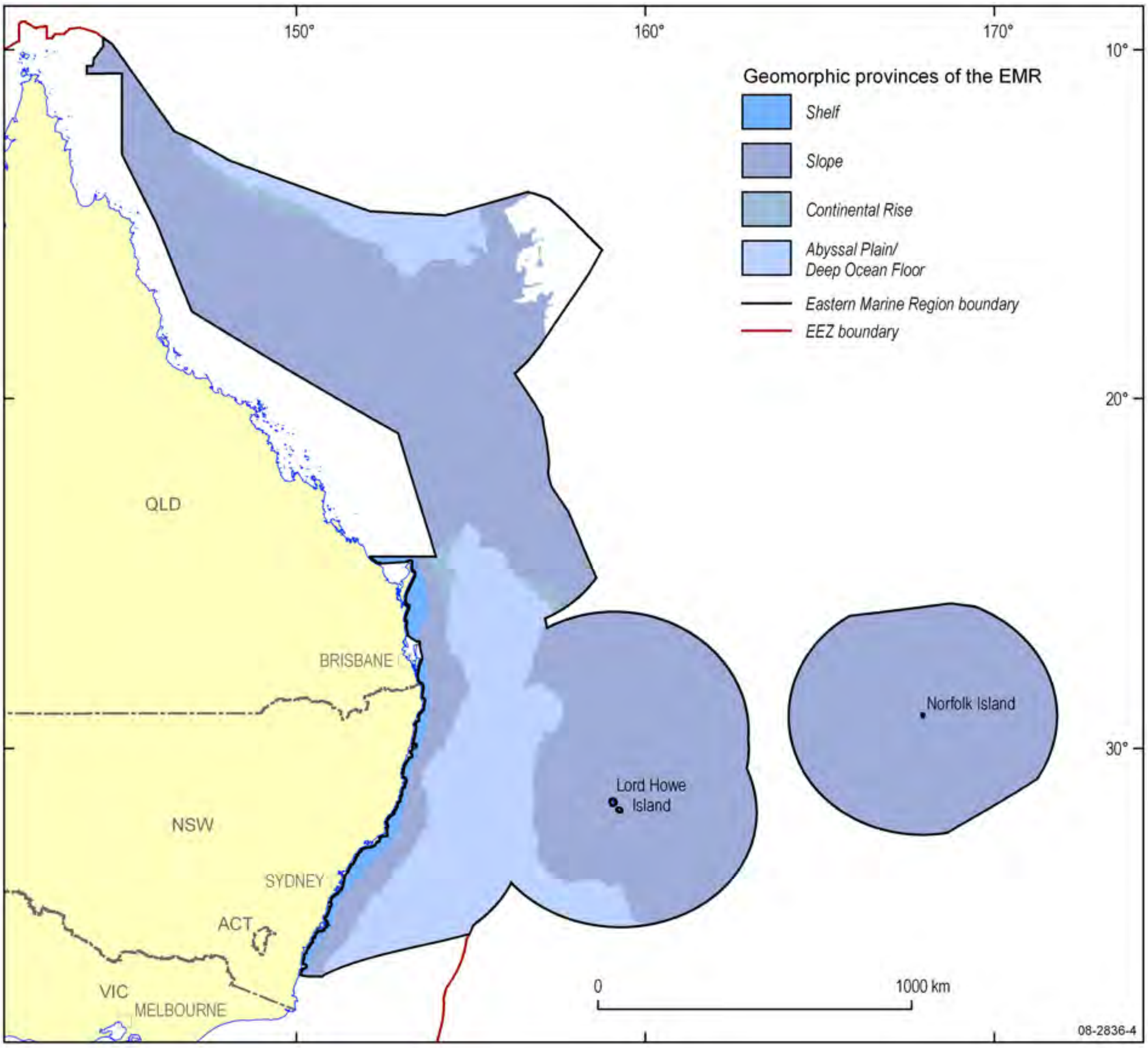
Four geomorphic provinces occur in the EMR (Fig. 4.1; Table 4.1). Slope makes up the largest area (77%, 1,837,670 km^2), followed by abyssal plain/deep ocean floor (20%, 485,660 km^2), shelf (2%, 38,080 km^2), and rise (1%, 30,430 km^2) (Table 4.1). Relative to the rest of Australia's EEZ the EMR has a significantly larger percentage of slope, and far lower percentage of shelf. The EMR contains approximately 31% of area of slope in the entire AEEZ (Fig. 4.1; Table 4.1).

Of the 21 geomorphic features defined on the Australian margin, 18 are represented in the EMR. Tidal sand wave/sand banks and escarpments are not represented (Fig 4.2; Table 4.1).

Large areas of the shelf, slope, rise and abyssal plain/deep ocean floor in the EMR have no geomorphic features identified within them. These areas comprise 26% of the total EMR area (shelf = 1%, slope = 9%, continental rise = 1% and abyssal plain/deep ocean floor = 15%). Geomorphic features covering significant areas of these provinces with quantitative data include basins, deepwater trenches/troughs, shallow and deep water terraces and plateaus, which combined comprise 1,534,590 km^2 or 62% of the area of these provinces in the EMR. Geomorphic features with no quantitative data available include apron/fans, deep/hole/valleys, canyons, knoll/abyssal hills/mountains/peaks, saddles, pinnacles, reefs and seamounts/guyots, which together comprise 200,250 km^2 or 8% of the area of these provinces in the EMR.

The EMR contains a large proportion of the total area of several geomorphic features over the EEZ. Relative to the entire EEZ, the EMR contains relatively large areas of plateaus, saddles, basins and trench/troughs. Plateaus in the EMR cover 1,027910 km^2 or 69% of the total area of plateaus in the EEZ, followed by saddles (94,610 km^2; 65%); basins (366,190 km^2; 51%); and trench/troughs (82,160 km^2; 47%) (Fig 4.2; Table 4.1).

a)



150°
160°
170°
10°
20°
30°
Geomorphic provinces of the EMR
Shelf
Slope
Continental Rise
Abyssal Plain/
Deep Ocean Floor
Eastern Marine Region boundary
EEZ boundary
QLD
BRISBANE
NSW
SYDNEY
ACT
VIC
MELBOURNE
Lord Howe
Island
Norfolk Island
0
1000 km
08-2836-4

b)

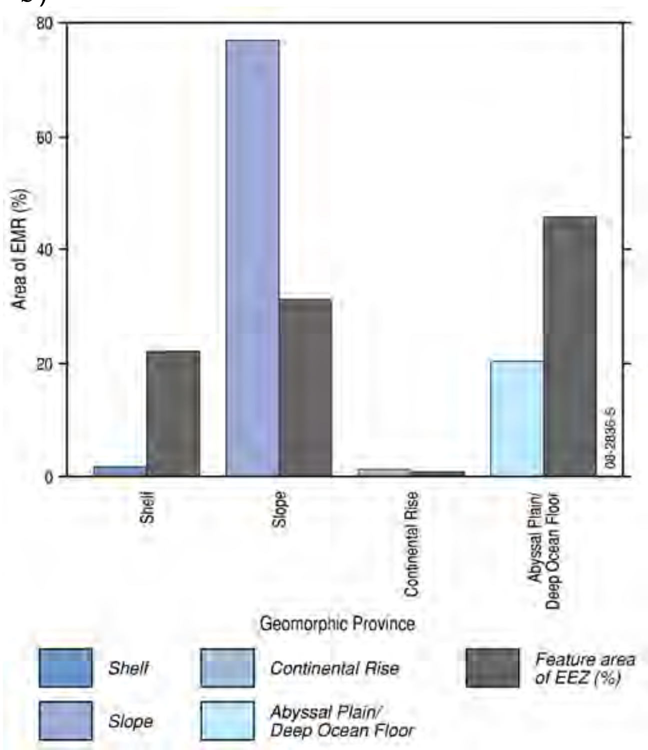
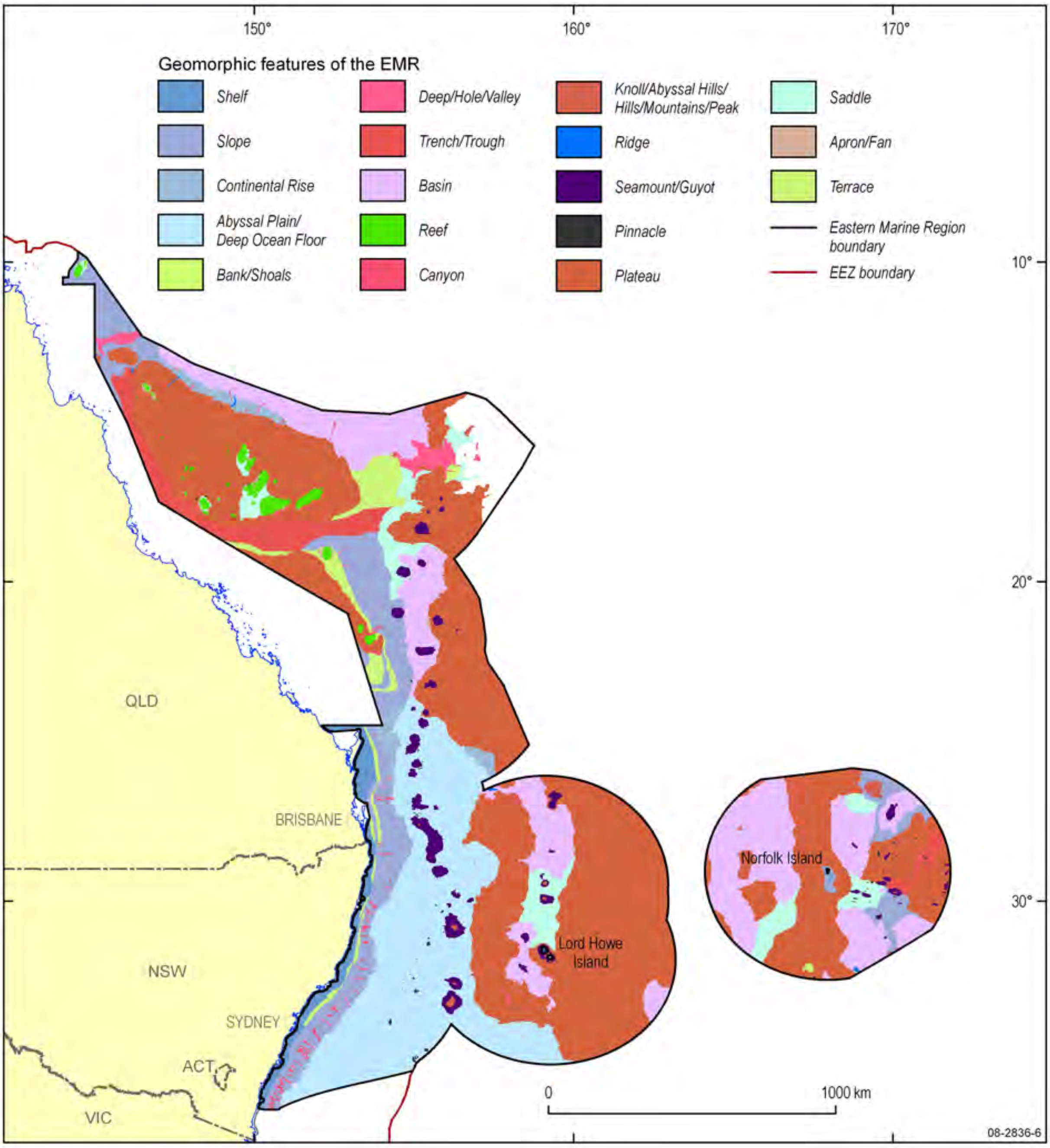


Figure 4.1. a) Geomorphic Provinces of the East Marine Region (EMR); and b) Percentage area of each geomorphic province within the EMR and EEZ.

a)



Geomorphic features of the EMR
Shelf
Slope
Continental Rise
Abyssal Plain/ Deep Ocean Floor
Bank/Shoals
Deep/Hole/Valley
Trench/Trough
Basin
Reef
Canyon
Knoll/Abyssal Hills/ Hills/Mountains/Peak
Ridge
Seamount/Guyot
Pinnacle
Plateau
Saddle
Apron/Fan
Terrace
Eastern Marine Region boundary
EEZ boundary
150°
160°
170°
10°
20°
30°
QLD
BRISBANE
NSW
SYDNEY
ACT
VIC
Lord Howe Island
Norfolk Island
0
1000 km
08-2836-6

b)

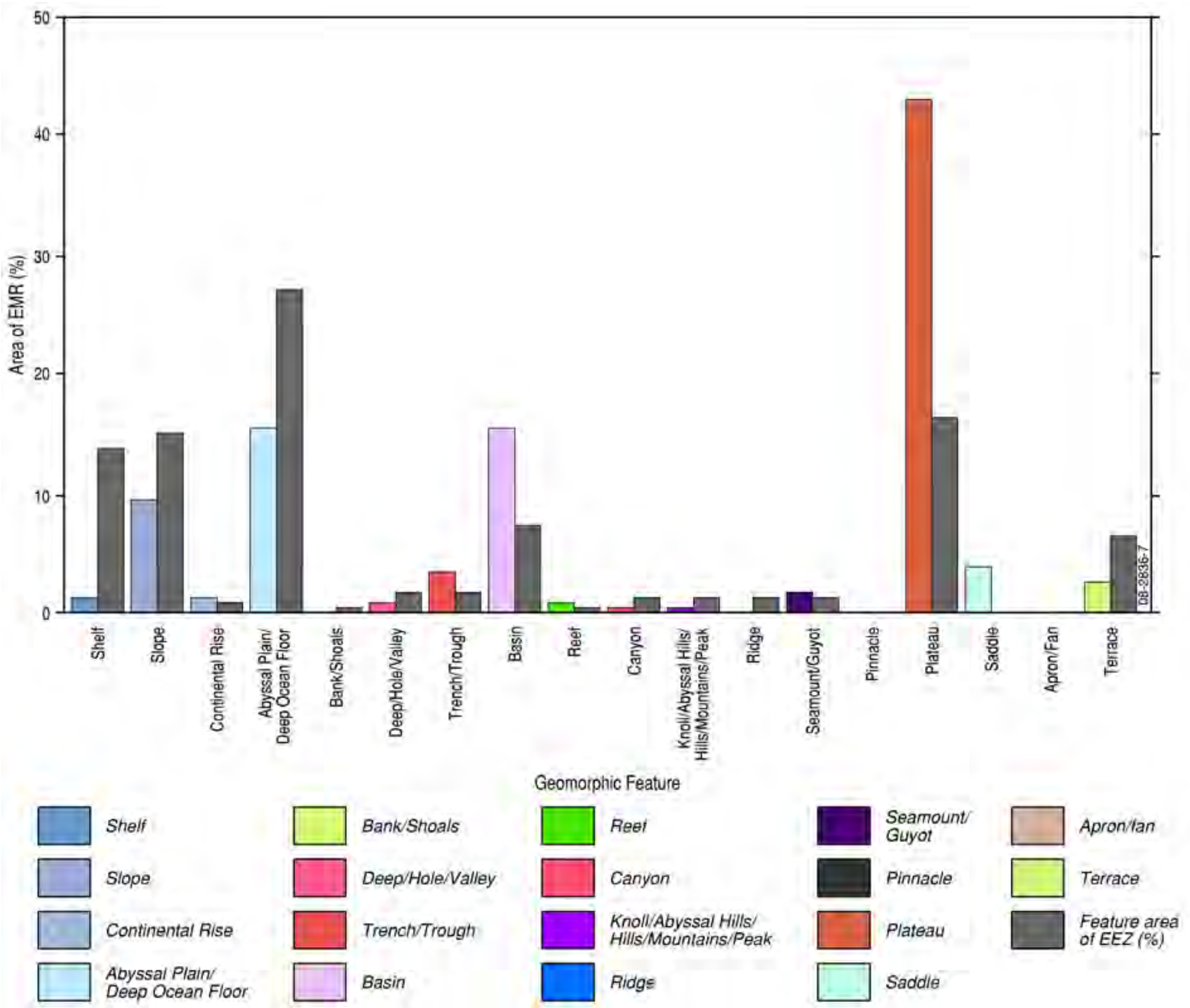


Figure 4.2. a) Geomorphic Features of the East Marine Region (EMR); and b) Percentage area of each geomorphic feature within the EMR and EEZ.

Table 4.1. Statistics of geomorphic provinces and features of the EMR.

Feature	Area in EMR	% total* EMR Area	% EEZ Area	Proportion of the total EEZ area of this geomorphic feature that is located in EMR	Water Depth Range** in EMR (m)
Geomorphic Provinces					
Shelf	38,080	1.59	21.91	1.39	2 - 250
Slope	1,837,670	76.83	31.31	48.40	230 – 5,270
Rise	30,430	1.27	1.08	30.16	1,925 – 4,665
AP/DOF*	485,660	20.30	45.71	20.15	125 – 5,270
Geomorphic Features					
Shelf (unassigned)	34,110	1.39	13.69	2.75	2 - 255
Slope (unassigned)	221,760	9.03	15.17	16.15	25 – 5,270
Rise (unassigned)	29,180	1.19	1.11	28.92	2,480 – 4,655
AP/DOF* (unassigned)	370,130	15.07	26.03	15.70	1,585 – 5,270
Apron/fan	2,650	0.11	0.07	40.10	15 – 3,195
Bank/shoal	710	0.03	0.56	1.39	205 – 1,420
Basin	366,190	14.91	7.89	51.26	260 – 4,955
Deep/hole/valley	18,870	0.77	1.88	11.07	85 – 4,445
Canyon	9,820	0.40	1.78	9.22	85 – 4,885
Knoll/abyssal hills/hills/ peak	9,690	0.40	1.24	8.63	4 – 4,480
Saddle	94,610	3.85	1.61	64.62	55 – 3,875
Pinnacle	2,470	0.10	0.06	44.73	75 – 5,055
Plateau	1,027,910	41.84	16.45	69.04	90 – 5,140
Reef	20,010	0.81	0.54	41.12	230 – 2,290
Ridge	1,110	0.05	1.30	0.94	960 – 4,070
Seamount/guyot	42,130	1.72	1.11	41.78	25 – 5,150
Terrace	58,330	2.37	6.37	10.12	50 – 4,540
Trench/trough	82,160	3.34	1.94	46.78	480 – 3,900
TOTAL	*4,783,680*				

* AP/DOF = Abyssal plain/deep ocean floor.
** Does not include areas designated as land and water shallower than 10 m totalling 7,300 km².

4.2. BATHYMETRY

Water depths in the assessed area of the EMR range from 230 to 5,269 m (Fig. 4.3). The EMR is relatively deep with >80% of the total area in water depths between 1,000 m and 5,000 m, although water depths >5,000 m comprise <1% of the EMR (Fig. 4.3). Areas with shallow water depths (<500 m) cover less than 6% of the EMR and comprise 3% of the total EEZ area for these water depths. This depth distribution reflects the major slope and abyssal plain/deep ocean floor provinces that occur along much of the eastern Australian margin.

Some features in the EMR occur in water depths at which they are not commonly found elsewhere in the EEZ. Compared to occurrences elsewhere on the Australian margin, reefs in the EMR occur in greater water depths (230- 2,290 m) (Table 4.1). Across the entire EEZ, reefs occur mainly in water depths <500 m, and all reefs in water depths >500 m are located in the EMR (Fig. 4.4). Across the entire EEZ, deep/holes/valleys, basins, and pinnacles occur at a range of water depths. However, in the EMR these occur mainly at water depths >3,000 m and occasionally include areas with depths > 5,000 m. (Fig. 4.4; Table 4.1). Approximately 65% of the area of deep/hole/valleys in the EEZ in water depths between 2,000 and 4,000 m occurs in the EMR. Approximately 25% of the area of basins in the EEZ in water depths between 3,000 and 5,000 m occurs in the EMR. More than 35% of the area of pinnacles in the EEZ in water depths between 2,000 and 5,000 m occurs in the EMR.

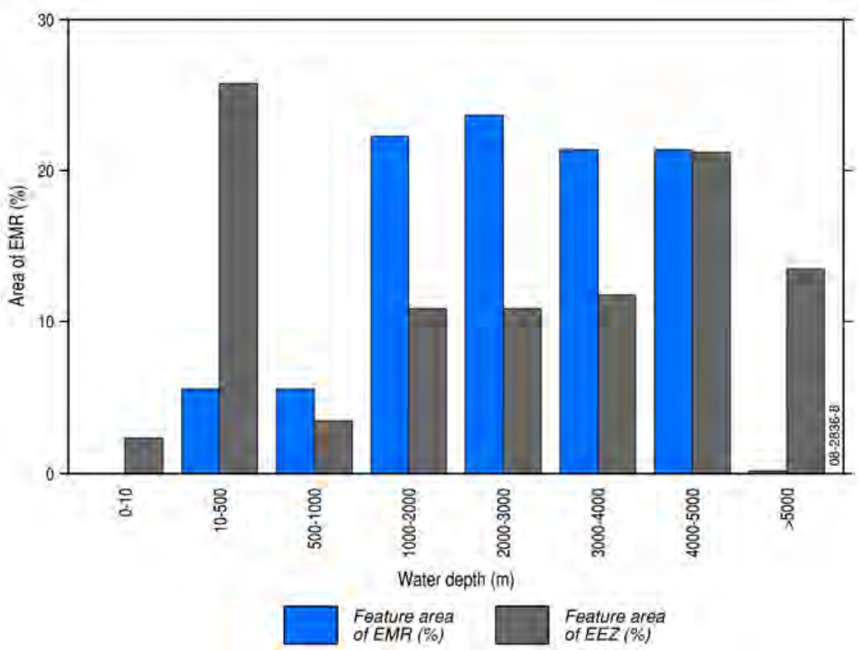
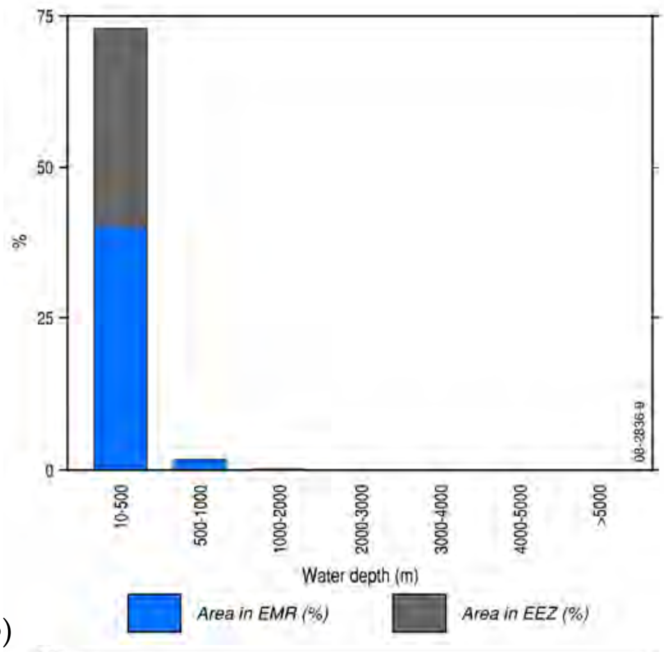
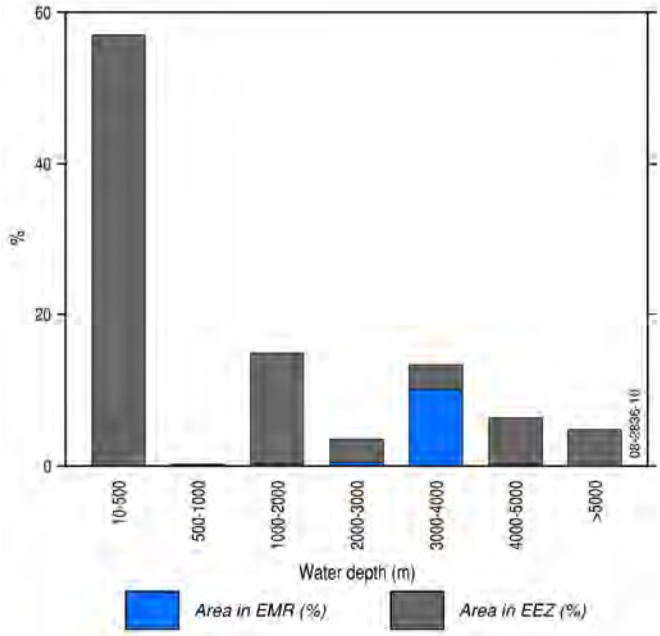


Figure 4.3. Distribution of water depth classes by percentage area within the East Marine Region in comparison to water depths of the whole EEZ.

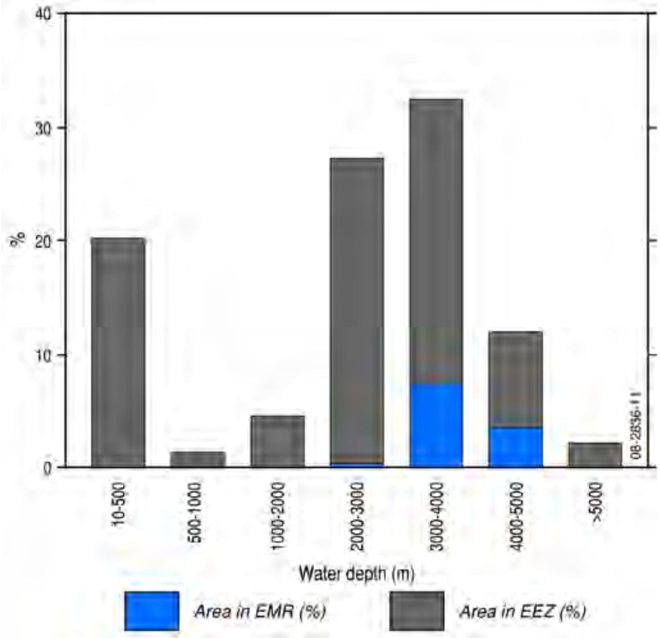
a)


75
50
25
0
%
10-500
500-1000
1000-2000
2000-3000
3000-4000
4000-5000
>5000
Water depth (m)
08-2836-9
Area in EMR (%)
Area in EEZ (%)

b)


60
40
20
0
%
10-500
500-1000
1000-2000
2000-3000
3000-4000
4000-5000
>5000
Water depth (m)
08-2836-10
Area in EMR (%)
Area in EEZ (%)

c)



d)

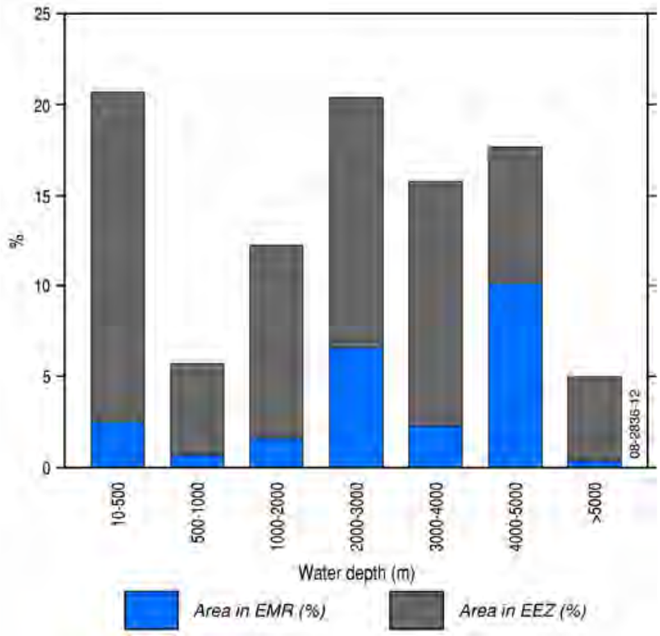


Figure 4.4. Distribution of water depths for a) reefs, b) deep/hole/valleys, c) basins and d) pinnacles in the EMR and the contribution of these to the total area of each feature in the EEZ.

4.3. QUANTITATIVE DESCRIPTION OF SEDIMENT DATA COVERAGE IN THE EMR

4.3.1. Quantitative Textural and Compositional Data

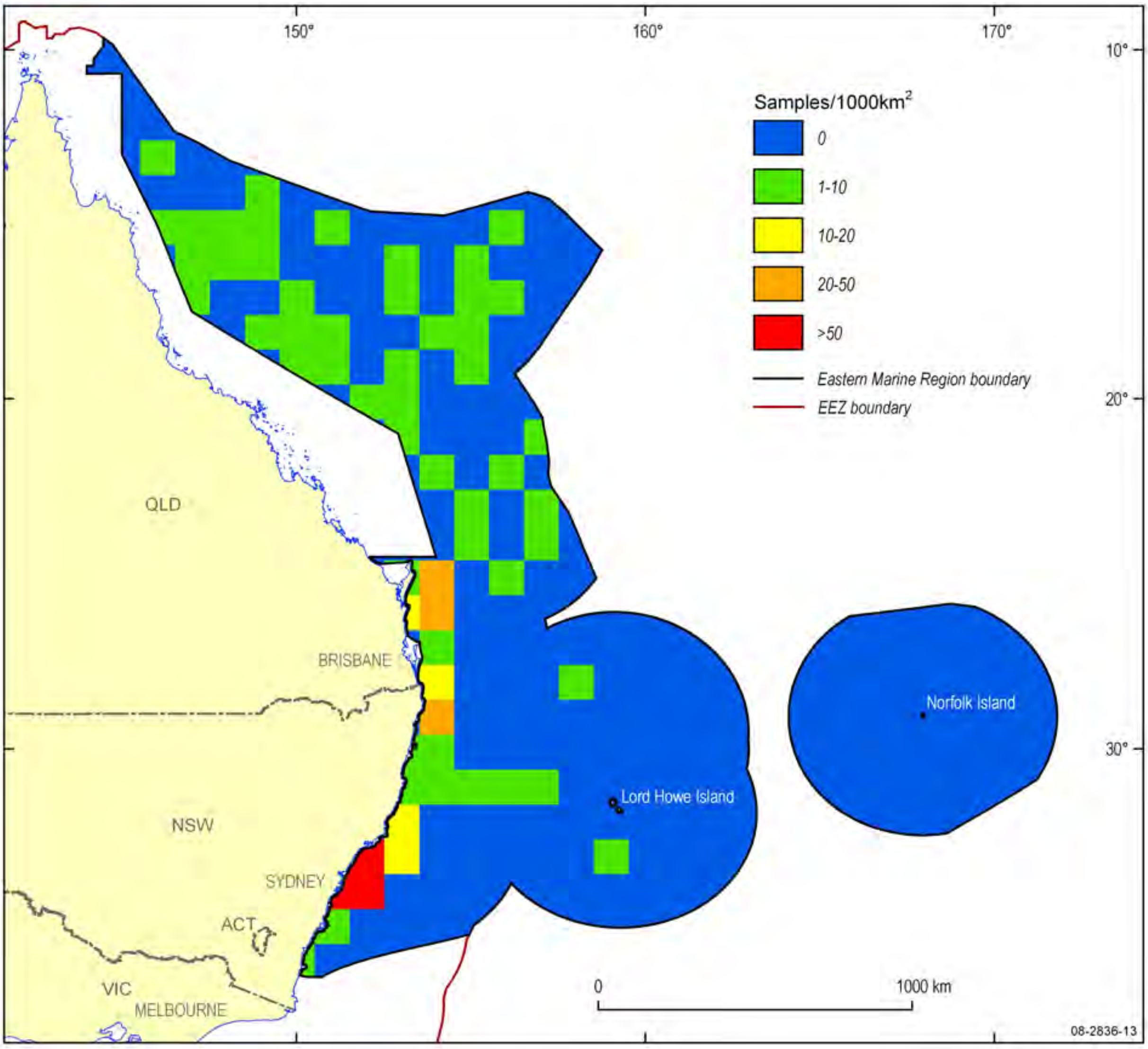
Sample density varies significantly across the EMR (Fig. 4.5). Sample density exceeds 10 samples per 1,000 km² for approximately 4% of the total area of the EMR. Sample density does not attain 1 sample per 1,000 km² for approximately 73% of the EMR (Fig. 4.5). Samples are clustered as a result of collection on surveys in shallow water areas (shelf and upper slope) or targeting significant topographic features offshore. In general, sample coverage is most dense in the southeast of the EMR where the boundaries include a narrow area of shelf (Fig. 4.6). Samples are very sparse in deepwater areas which cover the majority of the EMR, particularly in the southeast (Fig. 4.7).

A total of 539 samples (62% of samples) occur clustered on the relatively small area of shelf (38,080 km², <2% of the EMR area) that occurs in the southwest along the EMR boundary. This results in a relatively high average density of approximately 15 samples per 1,000 km² for the shelf (Fig. 4.6; Table 4.2). A total of 140 (16%) samples occur on the slope resulting in an average density of approximately 0.2 samples per 1,000 km². A total of 14 (<2%) samples occur on the rise and abyssal plain/deep ocean floor. These provinces form approximately 515,000 km² (22%) of the EMR area and have an average sample density of <0.04 samples per 1,000 km² (Fig. 4.6). Samples achieve coverage considered sufficient to assess the sedimentology in 8 of the 18 geomorphic features present in the EMR. No samples were collected from bank/shoals, reefs, knoll/abyssal hill/hill/mountain/peaks, ridges, pinnacles and apron/fans. Together, these features cover approximately 36,640 km² (<2%). Less than three samples were collected from each of rise, deep/hole/valley, canyon and seamount/guyot features. Together, these features cover approximately 100,010 km² (4%) of the EMR (Table 4.1).

Average sample density exceeds 1 sample per 1,000 km² in only shelf (unassigned), and terrace features. These cover approximately 4% of the EMR. For other features containing adequate samples for analysis, highest sample densities were achieved for slope (unassigned), trench/troughs and canyons (densities >0.2 samples per 1,000 km²) (Table 4.2). Low numbers of samples and/or clustering of samples on some features mean that assays may not be representative of seabed properties for the entire feature across the EMR. Low numbers of samples may significantly affect results for rise, Deep/hole/valley, Canyon and Seamount/guyot features. Clustering may significantly affect results for canyons, ridges, and terraces. Sample coverage at depths >4,000 m was achieved for slope, basin, plateau and abyssal plain/deep ocean floor features.

Despite targeted addition of data points, coverage remains poor for some areas of the abyssal plain/deep ocean floor (1:22,080 km²) and rise (1:30,430 km²), and (<0.1 sample per 1,000 km) for many features, particularly those located in deep water. Additional data improved coverage of plateaus and trench/troughs occurring in up to 4,280 m water depth. However, data does not achieve coverage of apron/fans, knoll/abyssal hills/hills/peaks, pinnacles, ridges, canyons and saddles occurring in deepwater areas of the slope, rise and abyssal plain/deep ocean floor in the EMR. It is important to note that average densities and areas given for these will vary depending on the scale (Marine region/province/feature) at which density is being assessed).

a)



b)

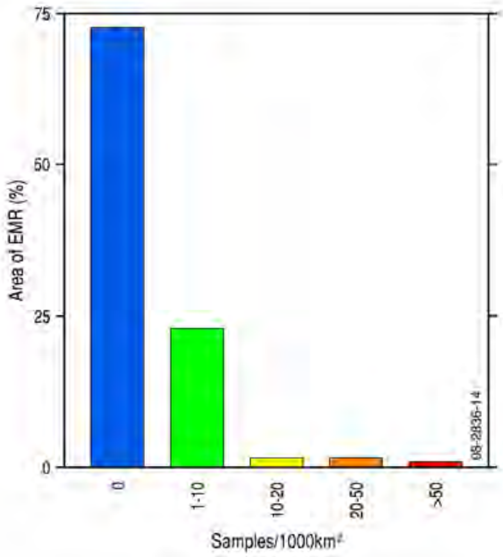


Figure 4.5. a) Sample density distribution across the EMR, and b) Frequency distribution of sample density.

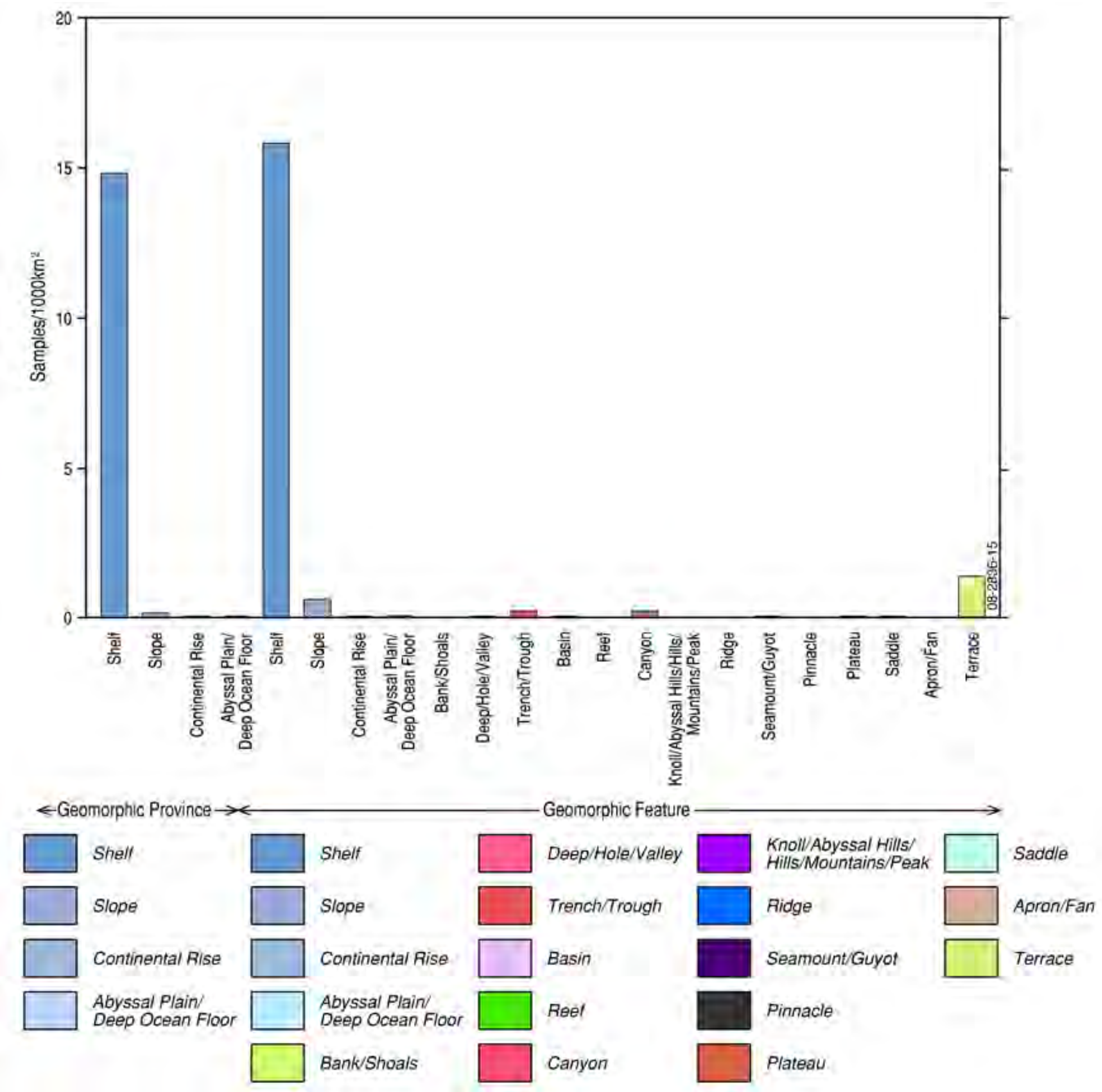


Figure 4.6. Sample density in each geomorphic province and feature of the EMR (y axis shows average density measured as samples per 1,000 km²).

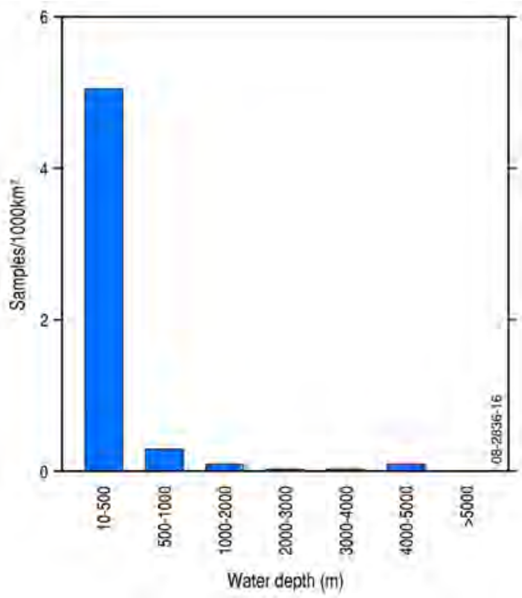


Figure 4.7. Sample density in each water depth class for the entire EEZ (sample density measured as samples per 1,000 km^2).

Table 4.2. Description of average density per geomorphic provinces and features containing samples.

PROVINCE/ # Feature	No. sample points	% EMR Area	Average sample density (samples per 1,000 km²)
Geomorphic Province			
Shelf	565	1.55	14.84
Slope	283	74.80	0.15
Rise	1	1.24	0.03
AP/DOF*	22 + 14 in deepwater outside EEZ	19.77	0.05
Geomorphic Features			
1 Shelf (unassigned)	539	1.43	15.80
2 Slope (unassigned)	140	9.27	0.63
3 Continental Rise (unassigned)	1	1.22	0.03
4 AP/DOF (unassigned)	13	15.47	0.04
5 Bank/Shoals	0	0.03	0.00
6 Deep/Hole/Valley	1	0.79	0.05
7 Trench/Trough	19	3.44	0.23
8 Basin	8	15.31	0.02
9 Reef	0	0.84	0.00
10 Canyon	2	0.41	0.20
11 Knoll/Ah/M/P	0	0.41	0.00
12 Ridge	0	0.05	0.00
13 Seamount/guyot	2	1.76	0.05
14 Pinnacle	0	0.10	0.00
15 Plateau	62	42.98	0.06
16 Saddle	4	3.96	0.04
17 Apron/Fan	0	0.11	0.00
20 Terrace	80	2.44	1.37

4.4 QUANTITATIVE REGIONAL SEDIMENT DISTRIBUTION IN THE EMR

4.4.1. Overview of Distribution and Properties

Sample assays indicate that the seabed in the EMR is characterised by a range of sediment types. The majority of samples are located on the shelf where sand is the most dominant size fraction. A total of 626 samples (83%) contain >50% sand, and 515 (70%) contain >80% sand (Fig 4.8). Only 19 samples contained <10% sand. Sand is most dominant on the shelf and upper slope.

A total of 83 samples (11%) contained >50% mud and 299 samples (40%) contained <10% mud. Mud is absent from 207 (28%) samples. Mud is the dominant size fraction on the slope and abyssal plain/deep ocean floor. Samples containing <10% mud occur less frequently on the shelf and upper slope, particularly offshore of Port Douglas and Bowen.

Gravel is detected in 406 (54%) samples, but is the dominant size fraction in only 19 (3%) samples. Gravel forms a minor component (<10%) in 316 samples (42%) and is absent in 345 samples. Gravel occurs most frequently on the slope and is generally absent in deep water areas. The abundance and distribution of sediment containing gravel is likely to be understated in the data due to sparse sample coverage of areas on the slope and rise.

Carbonate is the dominant constituent of sediments in the EMR with 452 (66%) of samples containing >50% carbonate, and 219 (32%) containing >80% carbonate (Fig 4.9). Carbonate forms <10% of sediment in 24 samples (4%) and is absent from three samples. Carbonate content generally decreases with increasing water depth and increasing distance from the coast. The highest bulk carbonate contents occur in sediment located within the shallow reaches of shelf and upper slope (Fig. 4.14). Bulk carbonate contents are consistently lower on the lower slope, rise and abyssal plain/deep ocean floor with around 73% of samples from these areas containing <50% carbonate. An exception to this is in the Coral Sea Basin, where carbonate content ranges from 16 to 86%.

All size fractions are dominated by carbonate grains (Fig 4.9). Carbonate content of mud was analysed for 87 samples and attains 50% in 78 (92%) of these. Carbonate content of mud generally shows variation over large distances with assays of similar concentrations observed to be clustered even at a regional scale. The majority of the samples (64) with mud containing >50% carbonate are located in plateau, slope and trench/trough features.

Carbonate is the dominant constituent of the sand sized fraction. Sand carbonate content was generated for 172 samples and attains >50% in 128 (74%) of these. The carbonate content of sand varies most in areas in close proximity to the coast, where carbonate content of sand is <25% at 24 sites. On the shelf and upper slope offshore Hervey Bay, Maroochydore and Sydney, highly variable carbonate content of sand is well documented by data.

Carbonate content of the gravel size fraction was assessed for 65 sites and attains 50% in 56 (86%) of these. Carbonate content of gravels <20% occur at 4 sites. These all occur on the Kenn Plateau within the Kenn Transition and Kenn Province. High carbonate contents of gravels (78 and 100%) generally occur on the shelf and upper slope. Gravel carbonate content decreases with increasing water depth and distance from the coast, with contents generally not exceeding 20% on the lower slope, rise and AP/DOF.

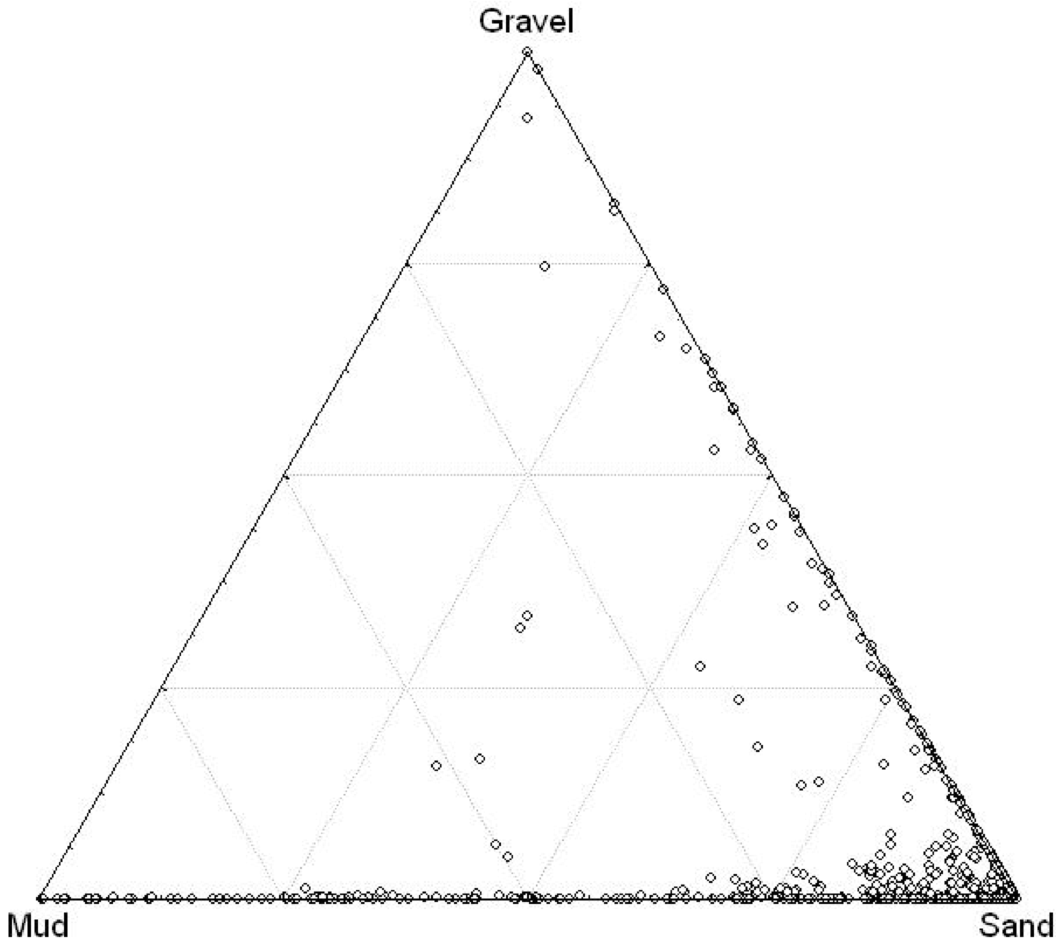
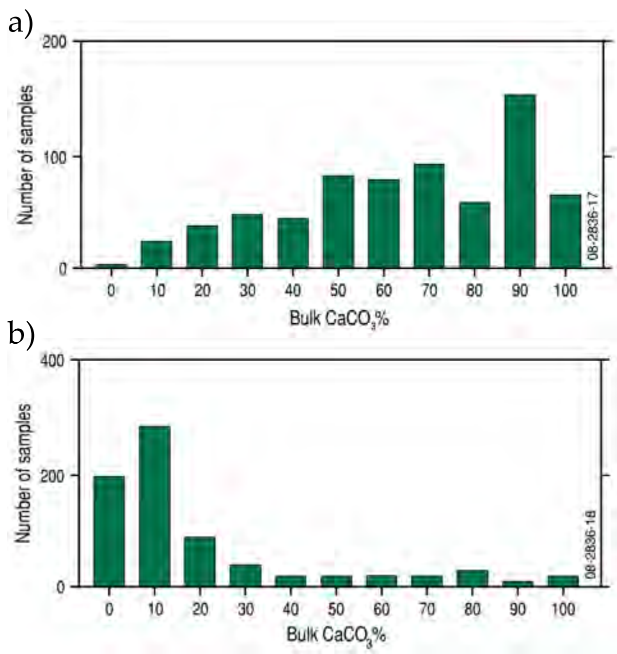


Figure 4.8. Textural composition (mud:sand:gravel ratio) of sediments within the EMR.



c)

d)

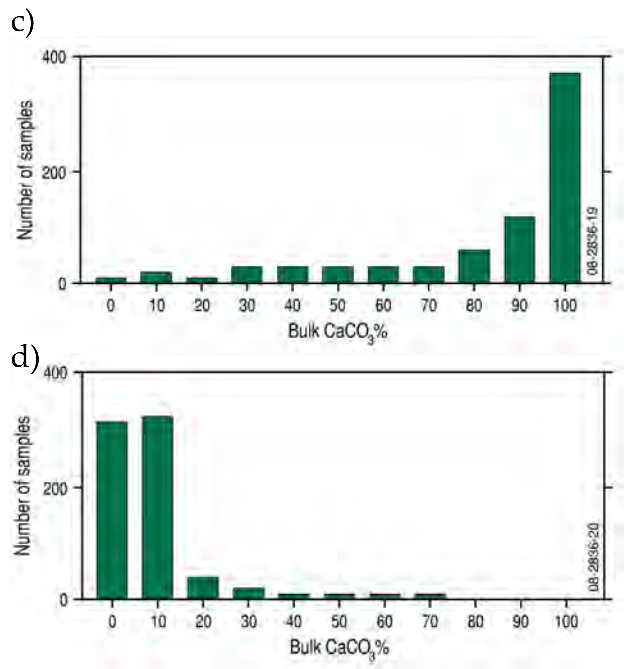


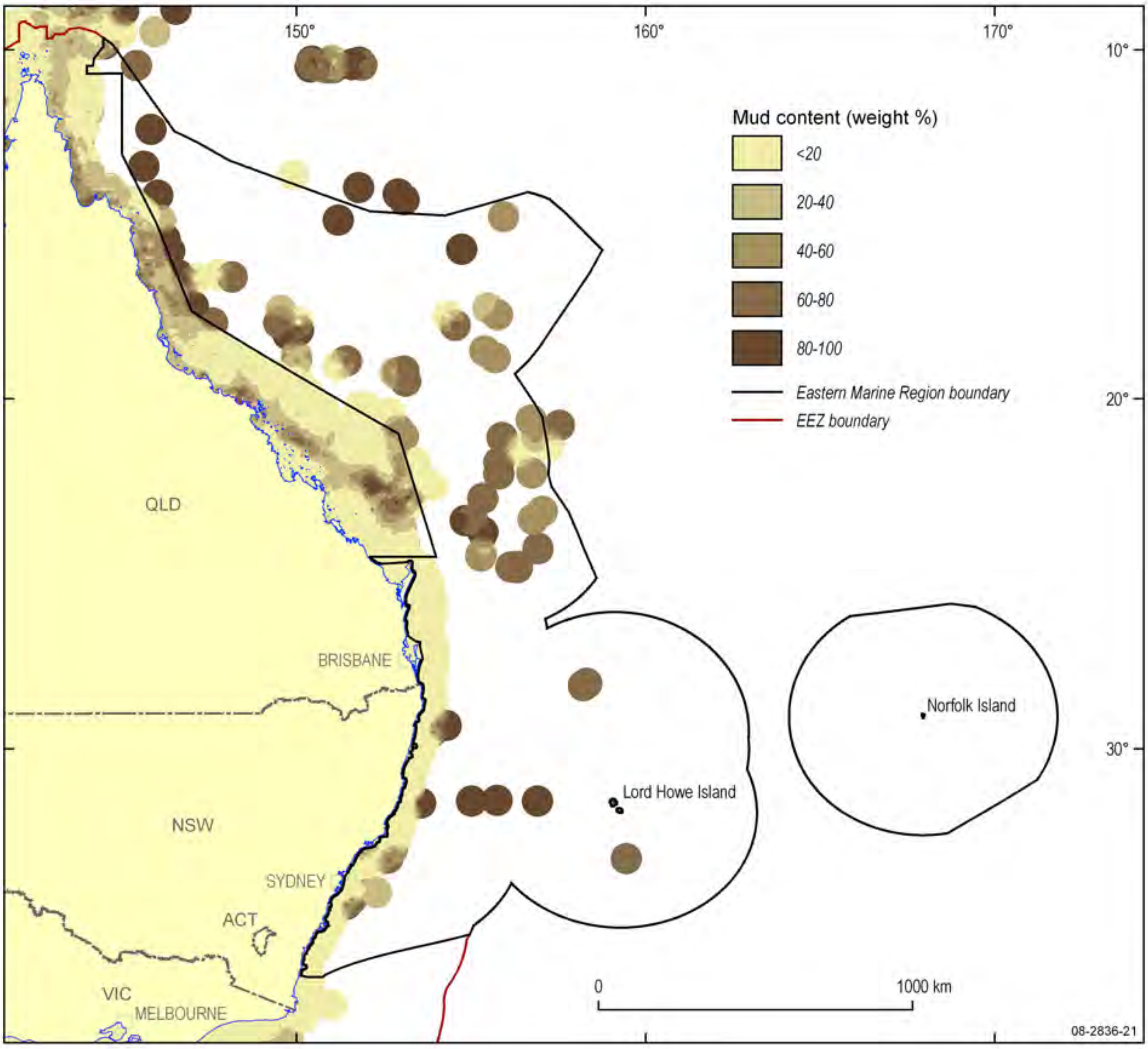
Figure 4.9. Carbonate content of the a) bulk fraction; b) mud fraction; and c) sand fraction; and d) gravel fraction of sediments in the EMR.

Sediment assays were interpolated using the methods described in Chapter 2 to give an estimate of regional distribution of sediment properties in the EMR. Interpolated grainsize data achieves coverage of around 454,800 km² (20%) of the total EMR (Figs. 4.10 - 4.12). Uneven distribution of data points in the region means that interpolated sediment data covers 37,400 km² (98%) of the shelf; 362,700 km² (20%) of the slope and 52,800 km² (10%) of the rise/ abyssal plain/deep ocean floor. Interpolated bulk carbonate data and folk classified data cover similar areas of each geomorphic province (Figs. 4.13 & 4.14).

The interpolated sediment maps give an interpretation of possible regional distribution of sediment properties. Areas with the highest sand (50-100% sand) and lowest mud (<50% mud) content are predicted to occur on the inner- to mid-shelf (Figs 4.10 & 4.11) except offshore of Hervey Bay where large variations of gravel (10-90%) and sand (0-100%) content occur. Mud contents increase significantly with water depth, with the highest mud contents occurring on the lower slope, rise, and abyssal plain/deep ocean floor. High gravel contents occur on the slope and locally in the north of the Tasman Basin (Fig. 4.12).

From the Folk Classification (Fig 4.14), gravelly sand (gS) and sand (S) with smaller quantities of slightly gravelly sand ((g)S) were most common on the shelf and upper slope. The lower slope is dominated by muddy sand (mS) and gravelly muddy sand ((g)mS). Muddy sand (mS), mud (M), and sandy mud (sM) become more common as water depth increases, occurring most frequently on the abyssal plain/deep ocean floor. An exception to this occurs offshore between Lorna Doone and Bambaroo, with highly variable sediment texture and relatively high (~70%) carbonate content. This change is best observed in the Folk Classification (Fig. 4.14) where an increase in gravelly muddy sand (gmS) is observed.

a)



b)

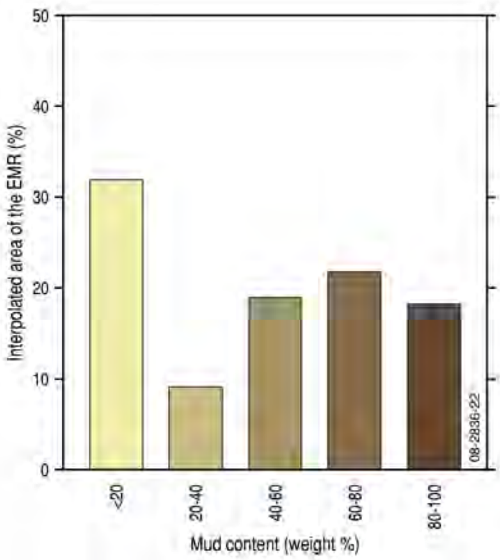
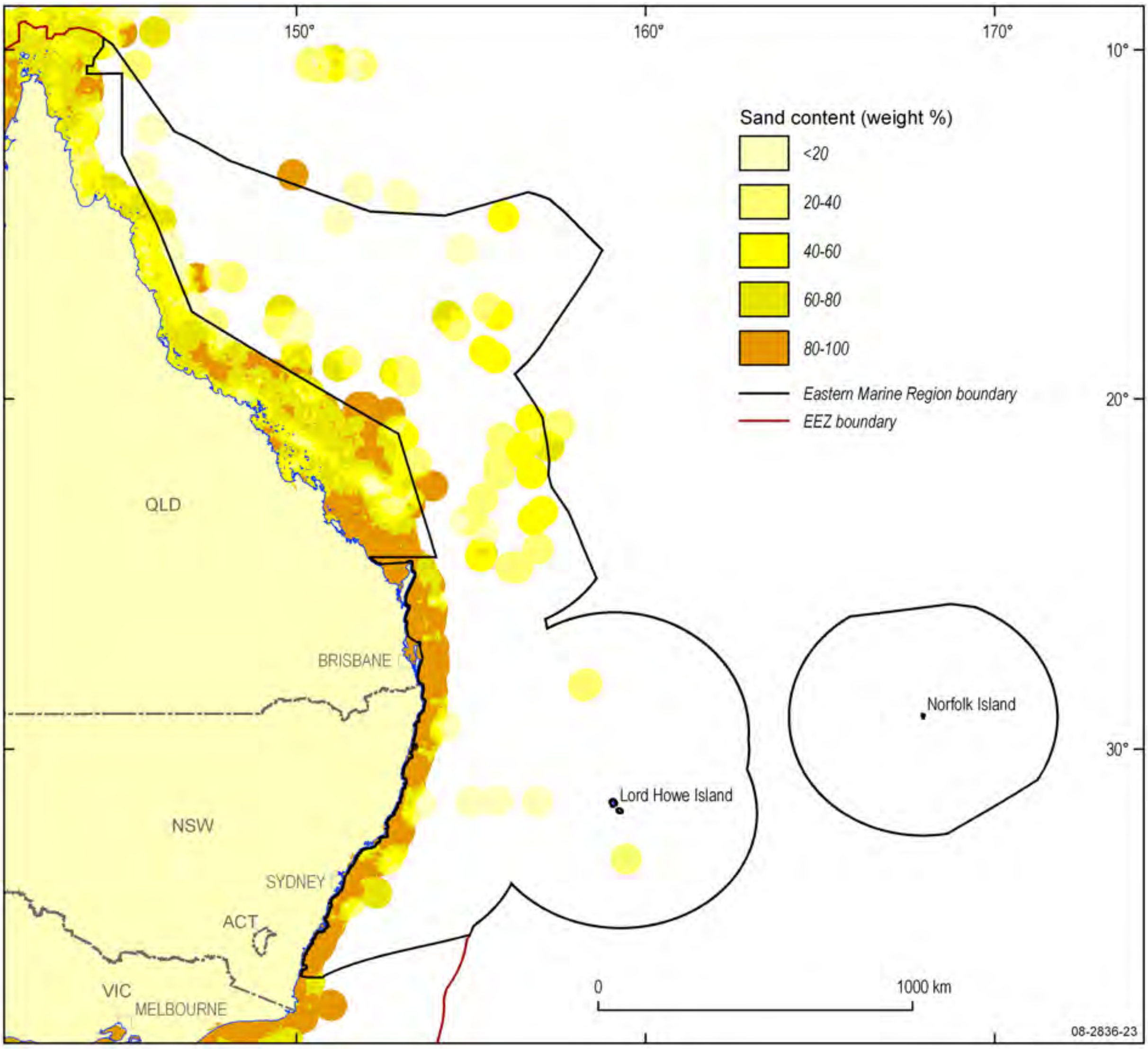


Figure 4.10. a) Distribution of mud in the EMR; b) % area of mud classes within the EMR derived from interpolated data.

a)



b)

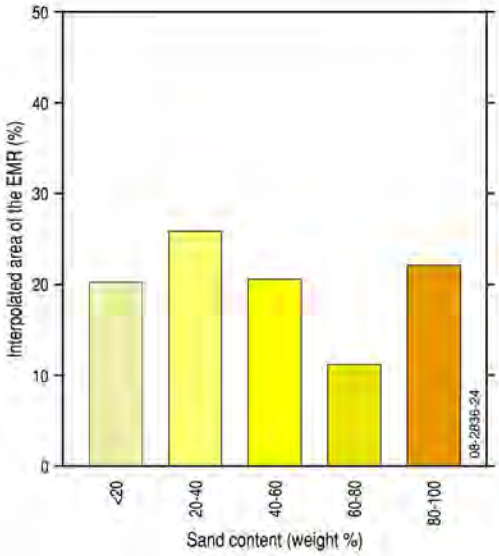
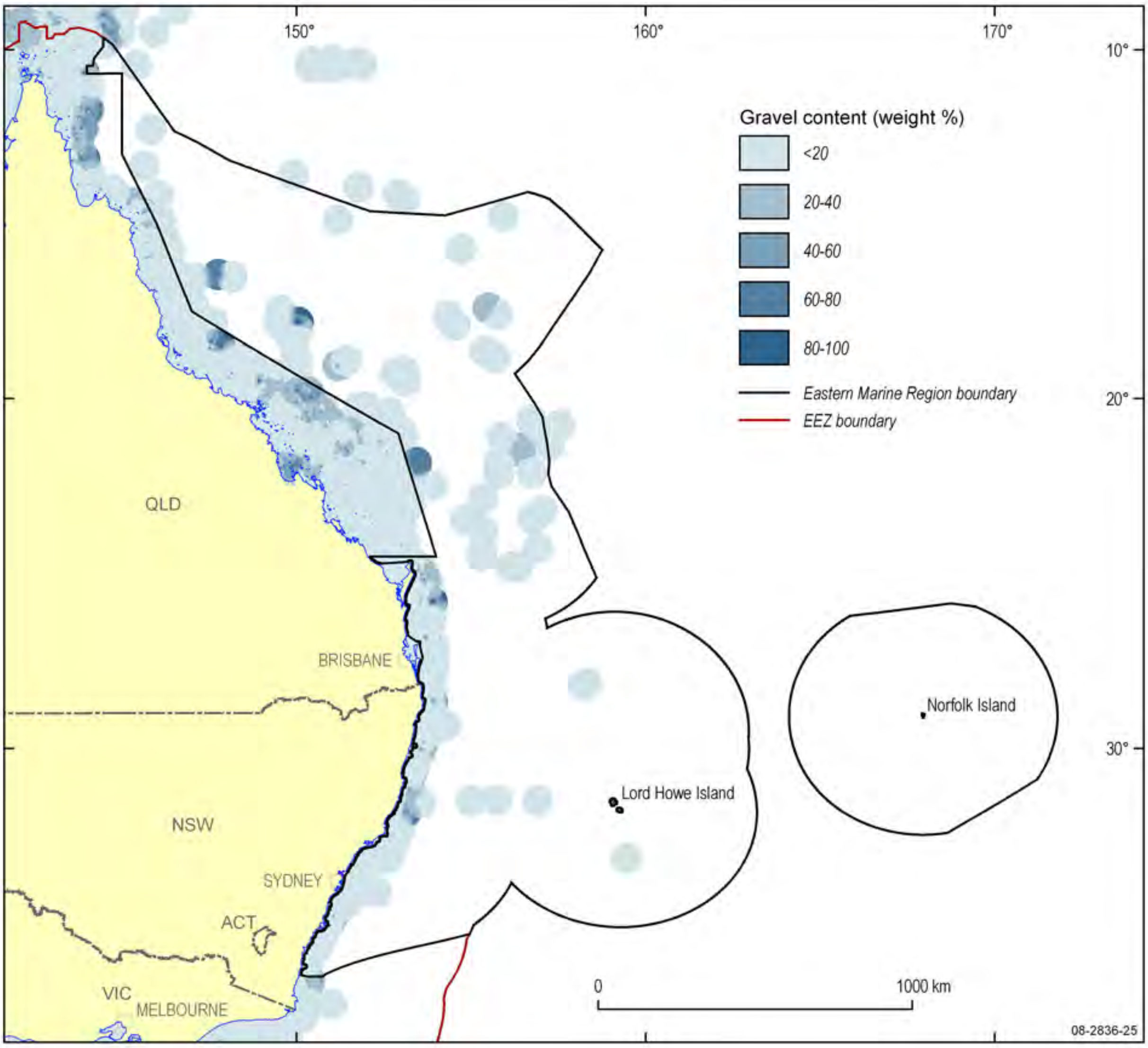


Figure 4.11. a) Distribution of sand in the EMR; b) % area of sand classes within the EMR derived from interpolated data.

a)



b)

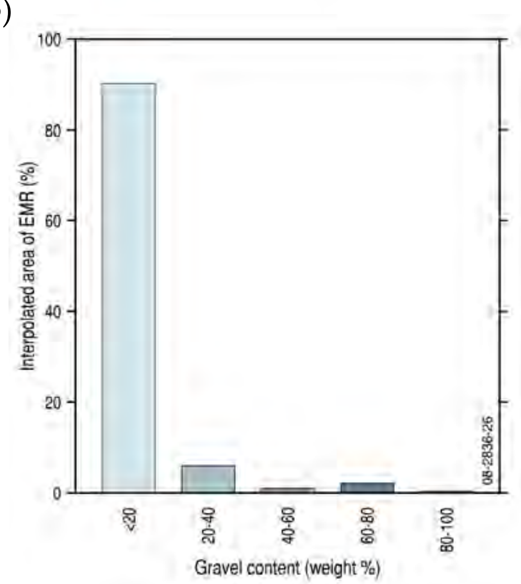
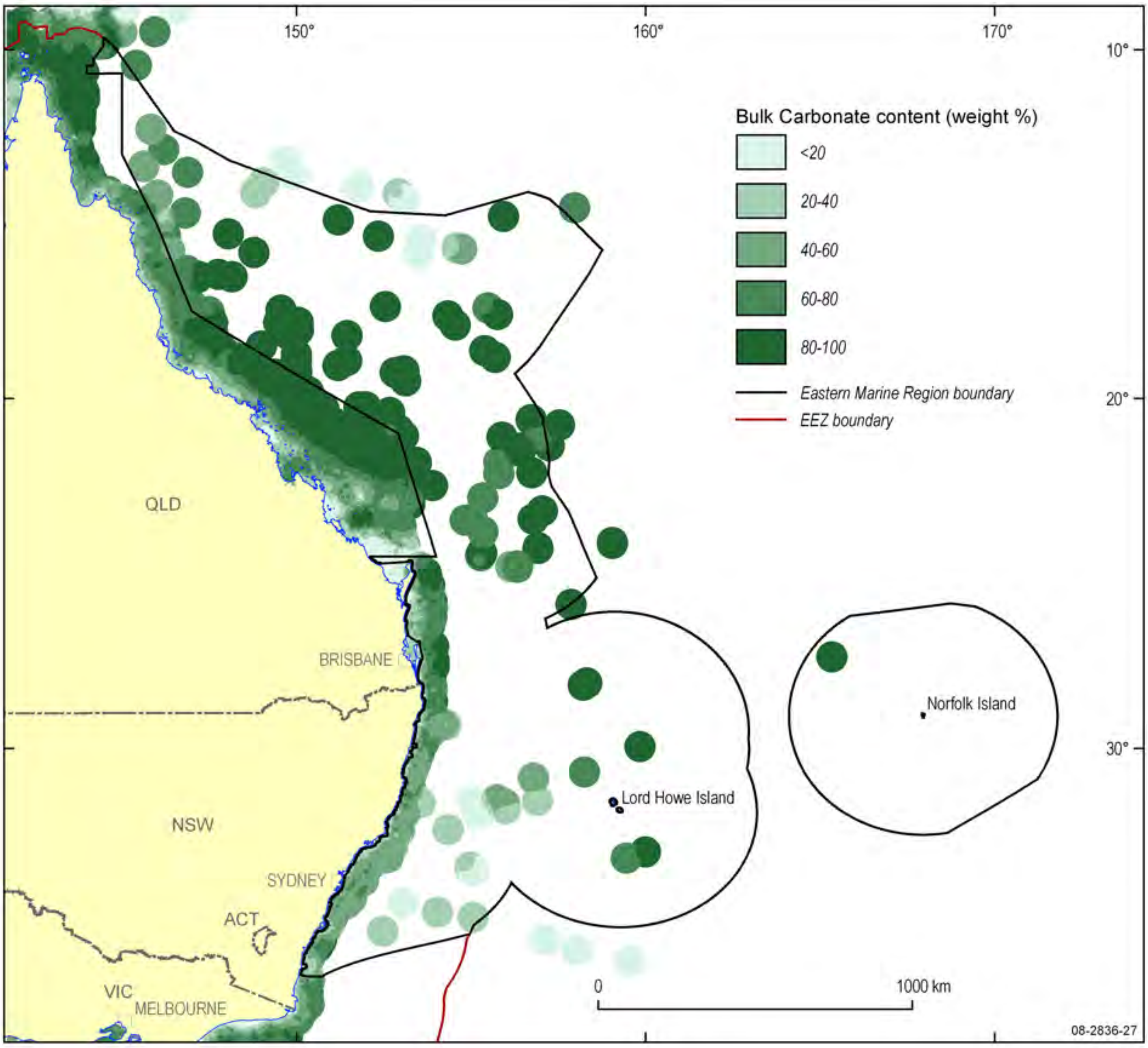


Figure 4.12. a) Distribution of gravel in the EMR; b) % area of gravel classes within the EMR derived from interpolated data.

a)



b)

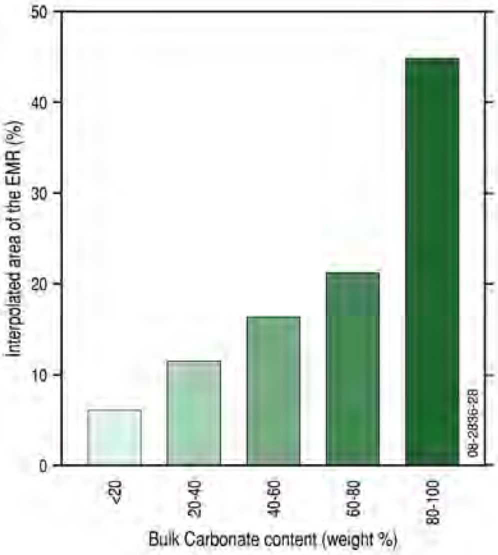
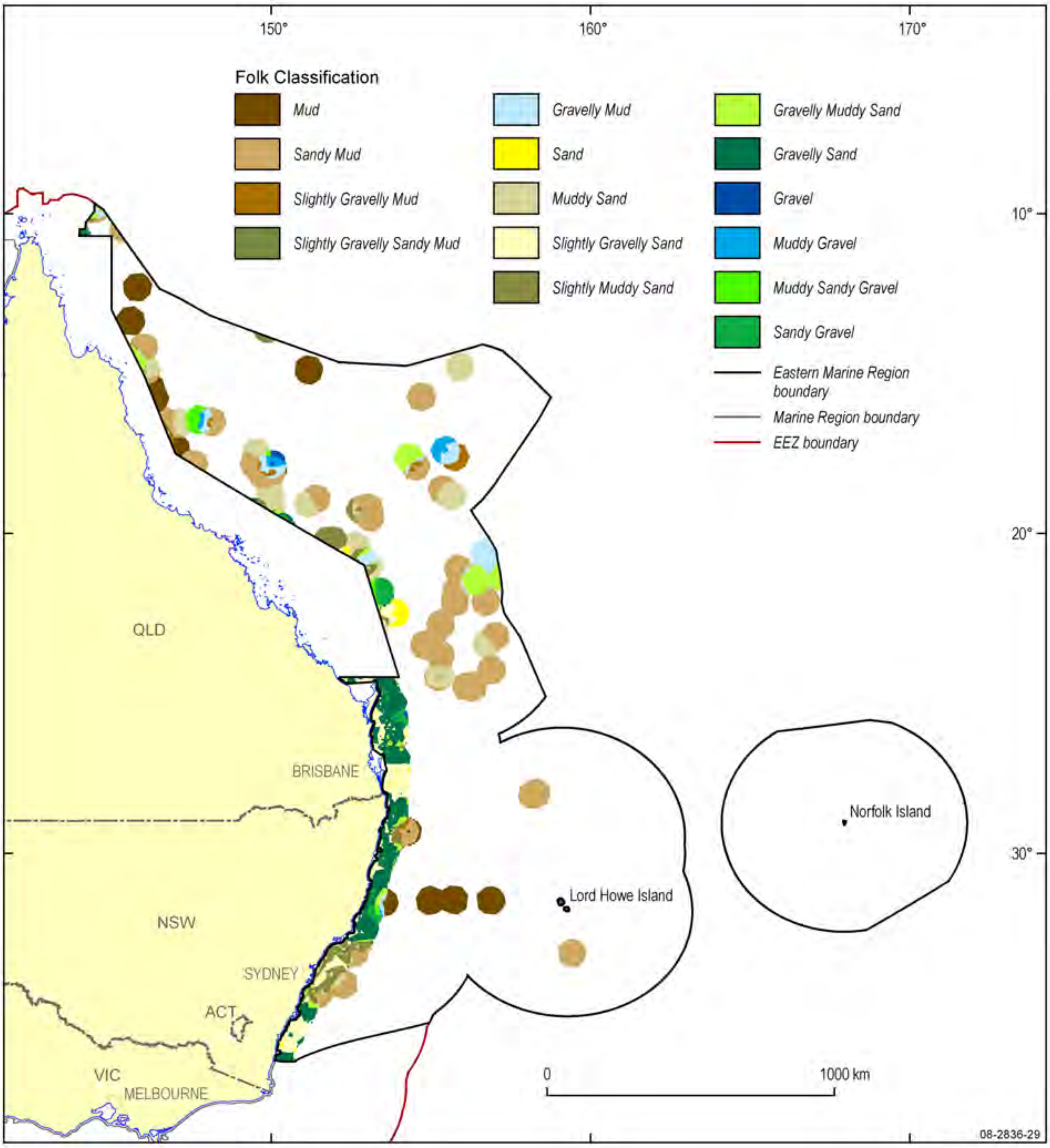


Figure 4.13. a) Distribution of bulk carbonate in the EMR; b) % area of carbonate content classes within the EMR derived from interpolated data.

a)


150°
160°
170°
10°
20°
30°
Folk Classification
Mud
Sandy Mud
Slightly Gravelly Mud
Slightly Gravelly Sandy Mud
Gravelly Mud
Sand
Muddy Sand
Slightly Gravelly Sand
Slightly Muddy Sand
Gravelly Muddy Sand
Gravelly Sand
Gravel
Muddy Gravel
Muddy Sandy Gravel
Sandy Gravel
Eastern Marine Region boundary
Marine Region boundary
EEZ boundary
QLD
BRISBANE
NSW
SYDNEY
ACT
VIC
MELBOURNE
Lord Howe Island
Norfolk Island
0
1000 km
08-2836-29

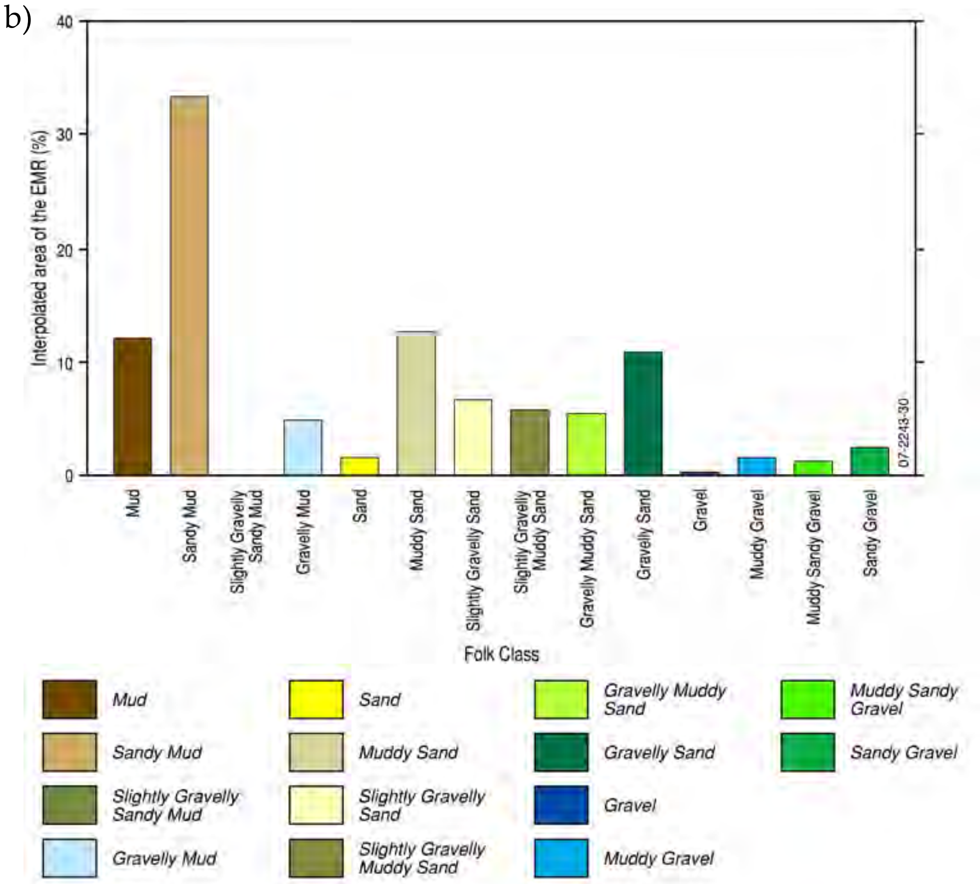


Figure 4.14. a) Distribution of folk classified sediments in the EMR; b) % area of folk classes within the EMR derived from interpolated data.

4.4.2. Sedimentology of Geomorphic Provinces and Significant Features of the EMR

Quantitative sedimentology is reported for features judged significant at a planning region scale that attain adequate sample coverage. Where coverage is only of local occurrence for a feature, sedimentology is assessed at a bioregion scale. Where occurrences of a feature form distinct groups based on morphology or water depth, each group has been described separately. Where a feature is judged as significant, but does not attain adequate data coverage, features are noted as significant at a planning region or bioregion scale. Properties and distribution of sediment within these features is, where possible, assessed from previous literature and summarised in Chapter 6. Significant features with no sedimentological assays include; rise (unassigned), apron/fans, deep/hole valleys, canyons, knoll/abyssal hill/hills/peaks, saddles, pinnacles, reefs and seamounts/guyots, but will be summarised in Chapter 6.

4.4.2.1. Shelf Province

The shelf in the EMR contains 485 grainsize and 375 carbonate assays. Over most of the area of the shelf, seabed sediment is characterised by sand (>60), with lesser gravel and/or mud (Fig 4.15a & Fig. 4.16a). Sand forms >60% of sediment at 459 (94%) sites sampled, and >90% at 322 (66%) sites. A total of 41 (8%) samples contain >25% mud, and 19 (4%) contain >25% gravel. Sediment containing significant proportions of mud (>25%) is generally restricted to the inner- to mid- shelf, however samples containing up to 75% mud occur locally on the outer shelf. Samples containing >25% gravel occur most frequently on the outer shelf, however samples containing up to 80% gravel occur locally on the mid-shelf off the east coast of Fraser Island.

Bulk carbonate content of sediment exceeds 75% in 99 (26%) samples from the shelf, and exceeds 90% in 26 (7%) samples (Fig. 4.16). Sediments containing significant proportions (>35%) of carbonate occur most frequently on the middle and outer shelf. Bulk carbonate contents are generally lower (<50%) in areas of the EMR closest to the shore.

Where the carbonate content of the gravel size fraction was measured, carbonate content exceeds 40% at all except two sites within Hervey Bay and Coffs Harbour. Where carbonate content of mud was measured, carbonate content does not exceed 37% except two sites located in Port Macquarie and offshore between Sydney and Gosford. Where carbonate content of sand was measured, carbonate exceeds 75% in 82 (22%) samples and exceeds 90% in 16 (4%) samples. Carbonate content of sand frequently exceeds 50% in three areas: 1) The mid- to outer shelf offshore of Fraser Island. Samples containing <30% carbonate sand are also common in this area. 2) Samples on the mid- to outer shelf offshore of Caloundra. Samples containing <20% carbonate sand also occur in this area. 3) Samples on the mid- to outer shelf offshore between Sydney and Gosford. While carbonate sand dominates locally in this area, sand carbonate content of sand is more commonly <40%.

4.4.2.2. Slope Province

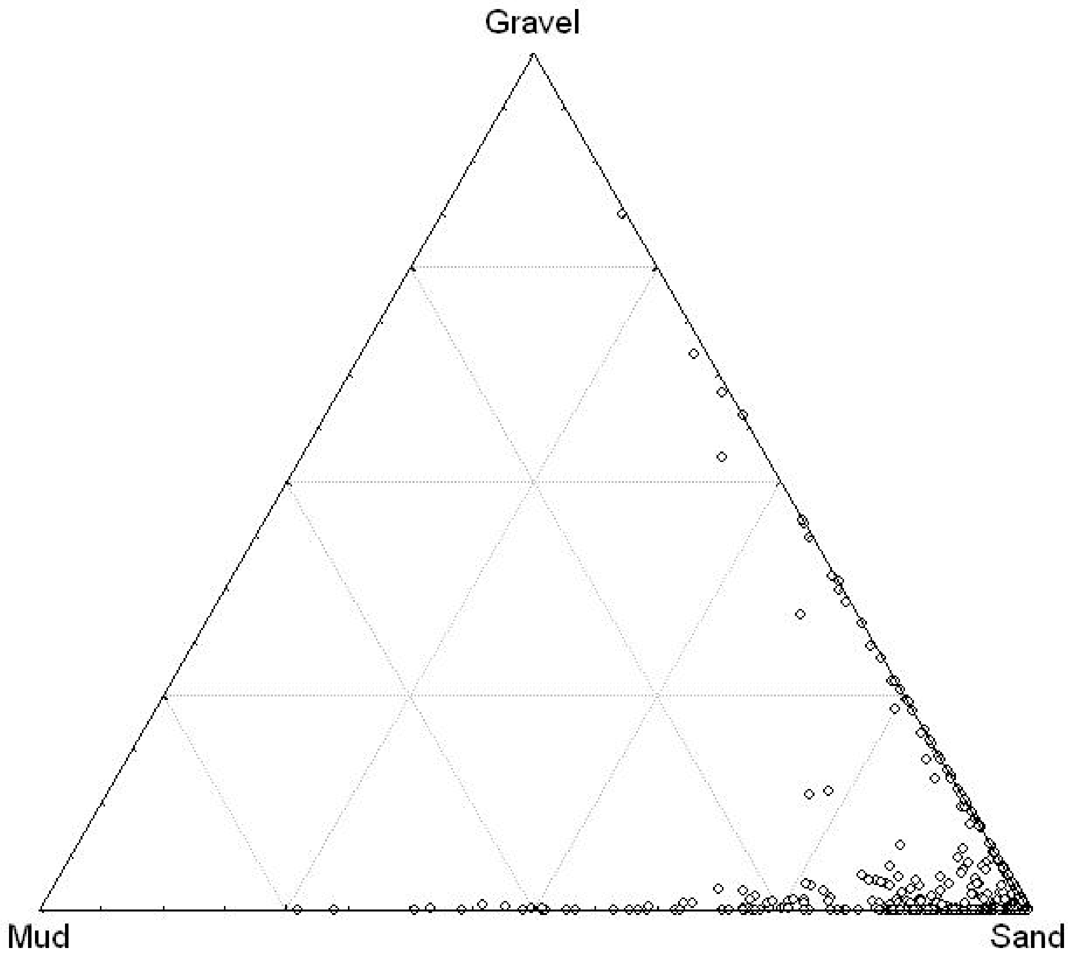
The slope in the EMR contains 113 grainsize and 118 carbonate assays; these are located mainly near the shelf break. Mud is interpreted to be the dominant size fraction across most of the area of the slope, though spatial clustering of assays means that overall statistics for the province do not reflect this (Fig. 4.15b). Sediment texture is zoned with water depth, with gravel and sand contents decreasing and mud content increasing with increasing water depth. Mud content of samples on the slope varies from 1 to >90%, however sediment composition in this area is highly variable with around 26% of samples containing <1% mud (reflecting sedimentology on the adjacent shelf), and around 19% of samples containing >70% mud. Gravel forms <1% of sediment at 63 (56%) sites sampled. All samples containing gravel >1% were collected within 100 km of the shelf break, gravel content at these sites ranges from 1 to 63%, with 102 (90%) samples containing <20% gravel. Sand content of slope sediment ranges from 3 to 100%, but rarely exceeds 30% in areas more than 100 km from the shelf break. Sand forms between 1 and 30% of sediment at >90% of sites sampled on the mid- and lower slope.

Carbonate content on the slope varies from 21-96%, with sediment on the upper slope generally containing >70% carbonate and mid to lower slope sediment showing highly variable bulk carbonate content with no apparent zoning with water depth (Fig. 4.16b). Carbonate mud content on the slope shows zoning with distance from the coastline of the Australian continent. On the upper slope it generally exceeds 60%, and attains >80% carbonate at nearly 50% of sites. Carbonate gravel content exceeds 80% at 80% of sites. Carbonate sand content varies between 42 and 93%, and exceeds 80% at 69% of sites sampled. Sand containing >80% carbonate was distributed across all areas of the slope.

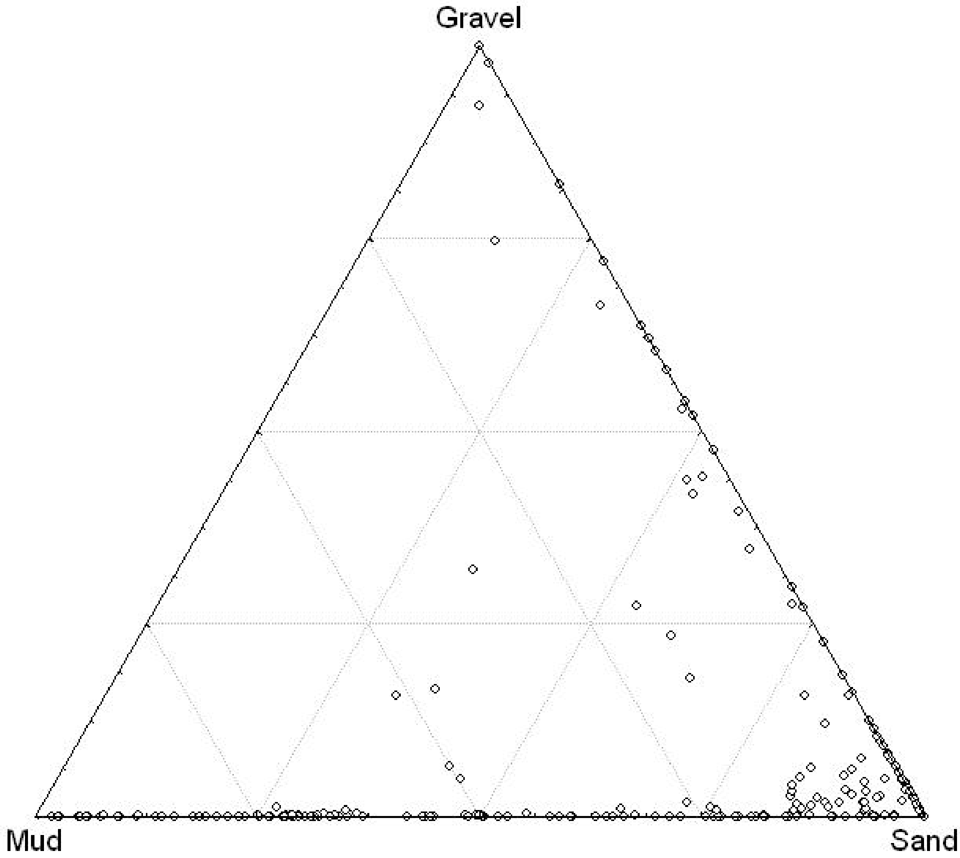
4.4.2.3. Abyssal plain/deep ocean floor province

The abyssal plain/deep ocean floor in the EMR contains two grainsize and 13 carbonate assays. Mud dominates sediment on the abyssal plain/deep ocean floor with both samples containing >95% mud, with the residual sediment made up of sand (Fig. 4.15c). Gravel was not detected on the abyssal plain/deep ocean floor. Bulk carbonate varies from 5 to 55% with the highest carbonate contents (45 to 55%) in two samples from the Tasman Basin Province (Fig. 4.16c). Carbonate mud content was available for two samples and ranged from 22 to 52%. Carbonate content of sand was not analysed.

a)



a)



b)

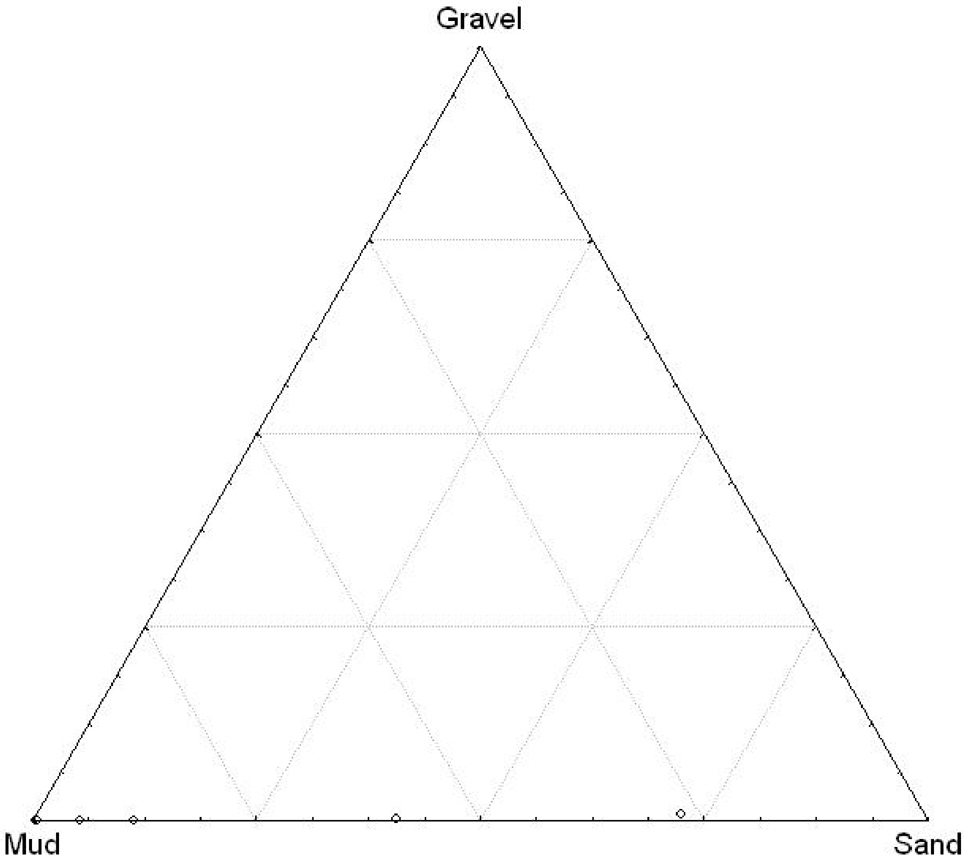


Figure 4.15. Textural composition (mud:sand:gravel ratio) for geomorphic provinces in the EMR, a) shelf; b) slope; and c) abyssal plain/deep ocean floor.

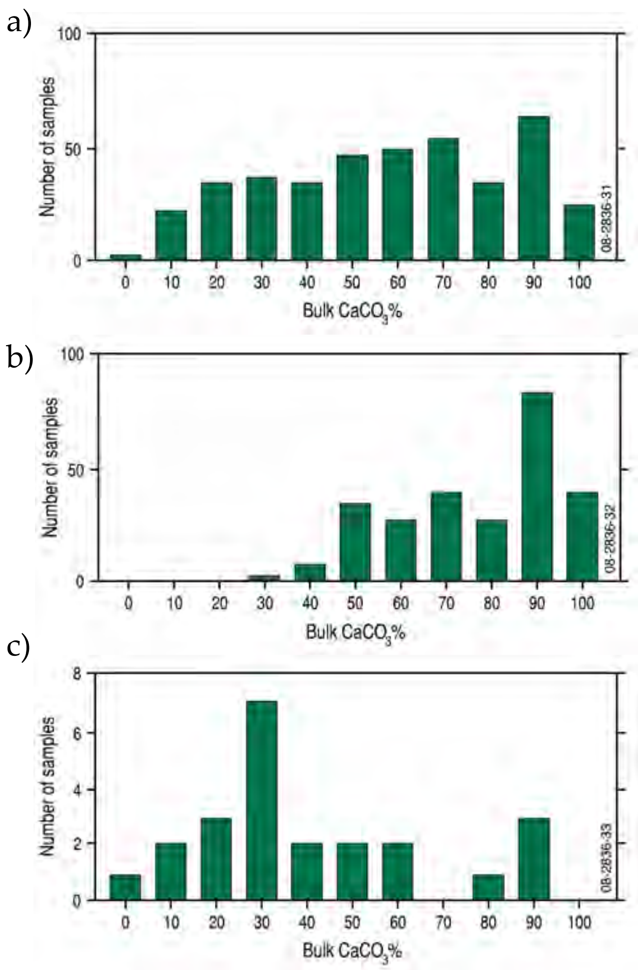


Figure 4.16. Carbonate content for geomorphic provinces in the EMR, a) shelf; b) slope; and c) abyssal plain/deep ocean floor.

4.4.2.4. Basins

A total of eight samples were obtained from basins. Basins contain seven grainsize and eight carbonate assays, all samples were located within the basin and coincident to the east and north boundary of NET and NEP, respectively. Five of the seven grainsize samples have only mean grainsize data. Mud is the dominant fraction with contents ranging from between 88 and 99%. Sand is the next most abundant sediment fraction with contents ranging between 1 and 11%. No gravel was detected. Bulk carbonate content ranges from 16 to 86% with four out of eight samples attaining 75%. Carbonate mud content ranges from 58 to 89% in two out of eight samples. Carbonate gravel and sand content were not analysed.

4.4.2.5. Deep water trenches/troughs

Deep water trenches/troughs contain 19 grainsize and carbonate assays. Mud is the dominant fraction with contents ranging between 21 and 97% (Fig. 4.17a), with six (32%) samples containing >75% mud. Sand is the next most abundant fraction, with contents ranging from 2 to 79%. Gravel content is <2% in 11 (58%) samples. Bulk carbonate content ranges from 37 to 94% with nine (47%) samples attaining 75% (Fig. 4.18f). The gravel fraction of sediment is entirely composed of carbonate in seven samples. Carbonate content of sand was analysed for six samples and ranges from 93 to 97%. Carbonate content of mud was analysed for 13 samples and ranges from 51 to 95%.

4.4.2.6. Shallow water terraces

Shallow water terraces in the EMR contain 22 grainsize and 29 carbonate assays. Sand is the dominant fraction with contents ranging from 31 to 100%, and exceeding 75% in 19 (86%) samples (Fig. 4.17b). The remainder of sediment is composed of gravel generally ranging from 0 to 53%, and smaller amounts of mud, ranging between 1 and 4%. Bulk carbonate content varies between 42 and 90% (Fig. 4.18). Carbonate sand ranges between 52 and 86% in six (27%) samples. No carbonate mud or gravel contents were measured.

4.4.2.7. Deep water terraces

Deep water terraces in the EMR contain 38 grainsize and 49 carbonate assays. Sand is the dominant fraction with contents ranging from 4 to 100%, and exceeding 75% in 31 (82%) samples (Fig. 4.17c). Gravel is the next most abundant fraction with contents attaining 40% in 31 (82%) of samples, and attaining 60% in three (8%) samples. Mud content generally ranges from 1 to 35%, but attains 60% in one sample. Bulk carbonate content of sediment ranges from 39 to 94%, and exceeds 75% in 22 (45%) samples (Fig. 4.18). Carbonate content of size fractions is available for 22 samples. Carbonate content of sand ranges from 43 to 94%, and exceeds 75% in five (23%) samples. Carbonate content of mud exceeds 40% in five (23%) samples and exceeds 75% in two (9%) samples. Carbonate content of gravel exceeds 30% in six (27%) samples and exceeds 75% in five (23%) samples.

4.4.2.8. Plateaus

A total of 62 samples were obtained from plateaus. Plateaus contain 55 grainsize and 62 carbonate assays which are located mainly in areas of these features that occur on the slope. Mud is the dominant size fraction with contents ranging from 6 to 98% and exceeding 50% in 29 (53%) of samples (Fig. 4.17d). Sand is the next most abundant fraction with contents ranging from 2 to 92%, and exceeding 50% in 14 (25%) samples. Gravel content is generally <30%, although three samples contain gravel ranging from 72 to 82%. Bulk carbonate content of sediment ranges from 32 to 82% and exceeds 75% in 49 (89%) samples (Fig. 4.18d). Carbonate content of sand ranges from 80 to 98% and exceeds 90% in 33 (55%) samples. Carbonate content of mud ranges from 34 to 96% and exceeds 90% in 11 (20%) samples. Carbonate content of gravel ranges from 5 to 100%. Gravel is composed entirely of carbonate clasts in 23 (42%) samples.

4.4.2.9. Pinnacles

A total of three samples were obtained from pinnacles. At a planning region scale, pinnacles show a common sedimentology that distinguishes them from other geomorphic features. Gravel is the dominant size fraction with contents generally ranging from 56 to 100%. Sand is the next most abundant fraction ranging from 14 to 40%. Mud content is <10% for all samples. Bulk carbonate content consistently exceeds 75%. The small number of assays for this feature means that results may not represent all sediments present in pinnacles in the EMR.

4.4.2.10. Plateaus on the Shelf or near the Shelf Break

A total of 48 samples were obtained from plateaus located on the shelf or near the shelf break. Sand is the dominant fraction with contents generally ranging from 25 to 100% (Fig. 4.17e) and exceeding 50% in 38 (79%) of samples. An exception to this is a single sample collected adjacent to a pinnacle that contains <5% sand. Mud is the next most abundant fraction with contents generally ranging from

3 to 49%. A total of 19 (40%) samples contained <20% mud and 12 (25%) contained no mud. Gravel content ranges from 1 to 100%, with 31 (65%) samples containing <20% gravel and 6 (13%) containing no gravel. Bulk carbonate content generally ranges from 17 to 99% and exceeds 50% in 40 (83%) samples (Fig. 4.18).

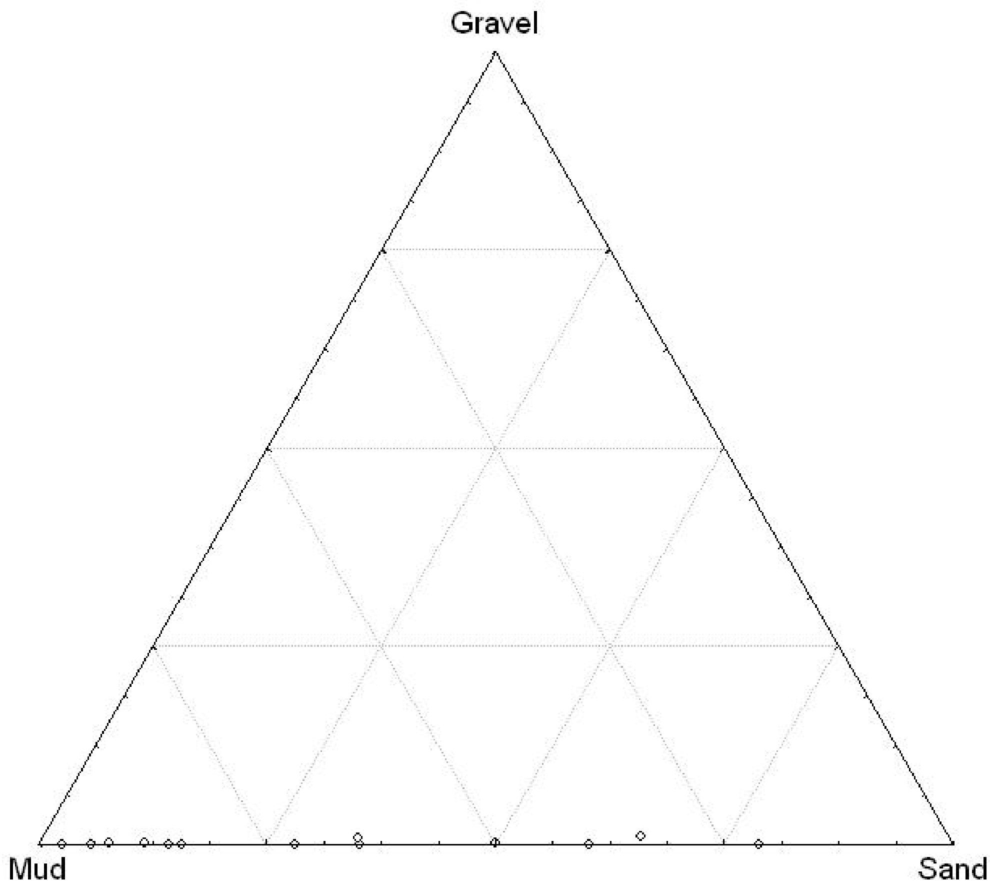
4.4.2.11. Offshore Plateaus and Terraces

A total of 78 samples were collected from offshore plateaus and terraces. Sand is the dominant size fraction in sediments with contents generally ranging from 2 to 100% (Fig. 4.17f), and exceeding 50% in 38 (49%) samples. Mud is the next most abundant fraction with contents ranging from 3 to 97%, with 10 (13%) of samples containing no mud. Gravel content is <25% in 32 (41%) samples, and <1% in 48 (62%) samples. Three samples (4%) contain between 27 and 45% gravel. Where data are available, bulk carbonate content generally ranges from 50 to 99% (Fig. 4.18).

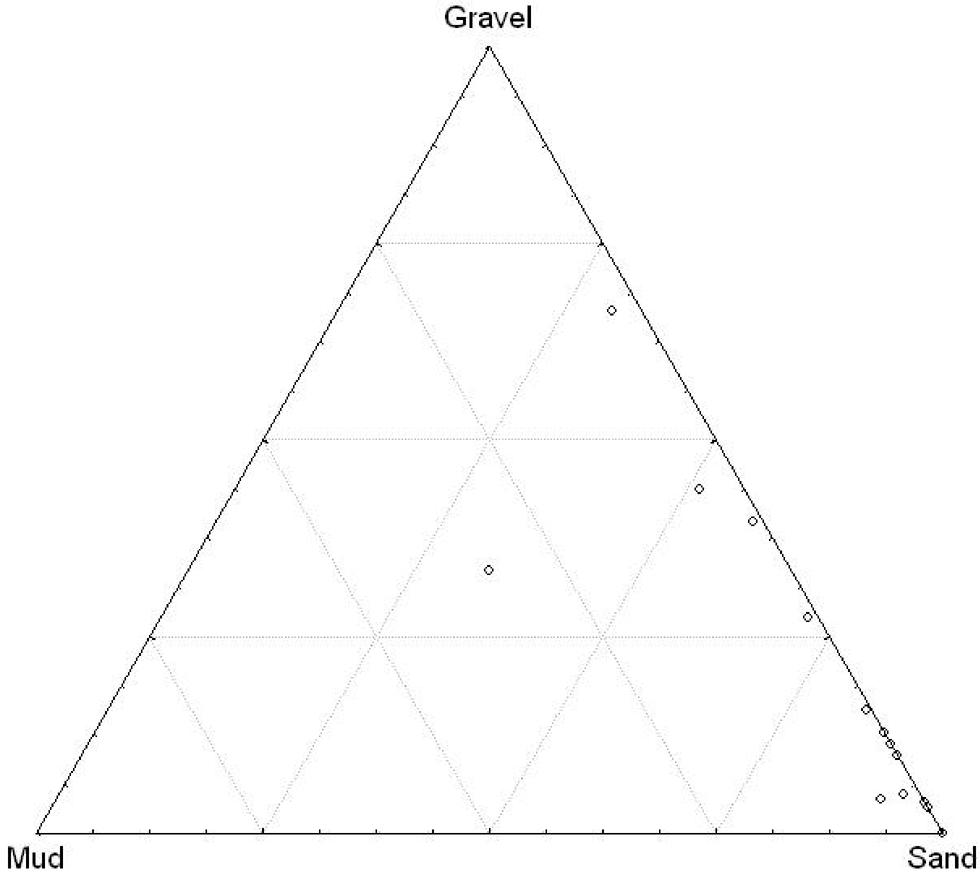
4.4.2.12. Terraces Located on the Shelf or Near the Shelf Break

A total of 210 samples were collected from terraces located on the shelf or near the shelf break. Sand is the dominant fraction in sediment with contents generally ranging from 8 to 100% (Fig. 4.17g) and exceeding 50% in 159 (76%) samples. Mud is the next most abundant fraction although the content is highly variable, ranging from 1 to 91%. Mud content exceeds 50% in 27 (13%) samples, while 37 (18%) contain no mud. Gravel content ranges from 1 to 88% in 75% of samples, and attains 100% in one sample. Where analysed, bulk carbonate content of sediment generally ranges from 42 to 99% (Fig. 4.18).

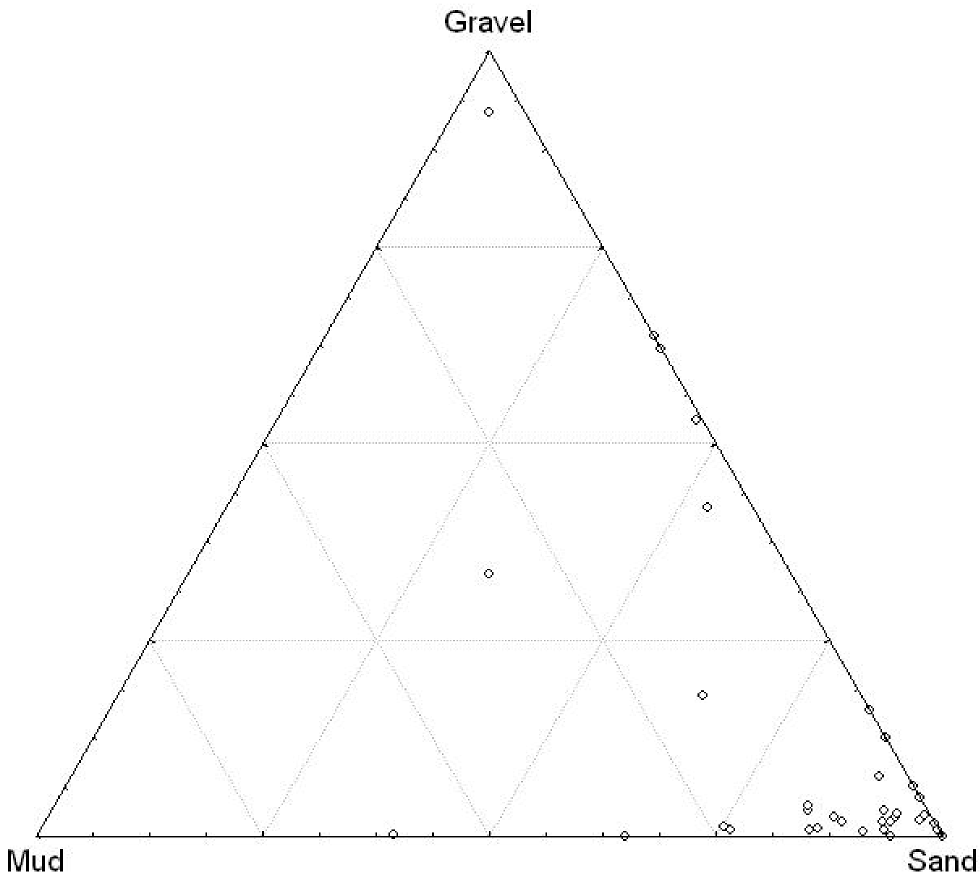
a)



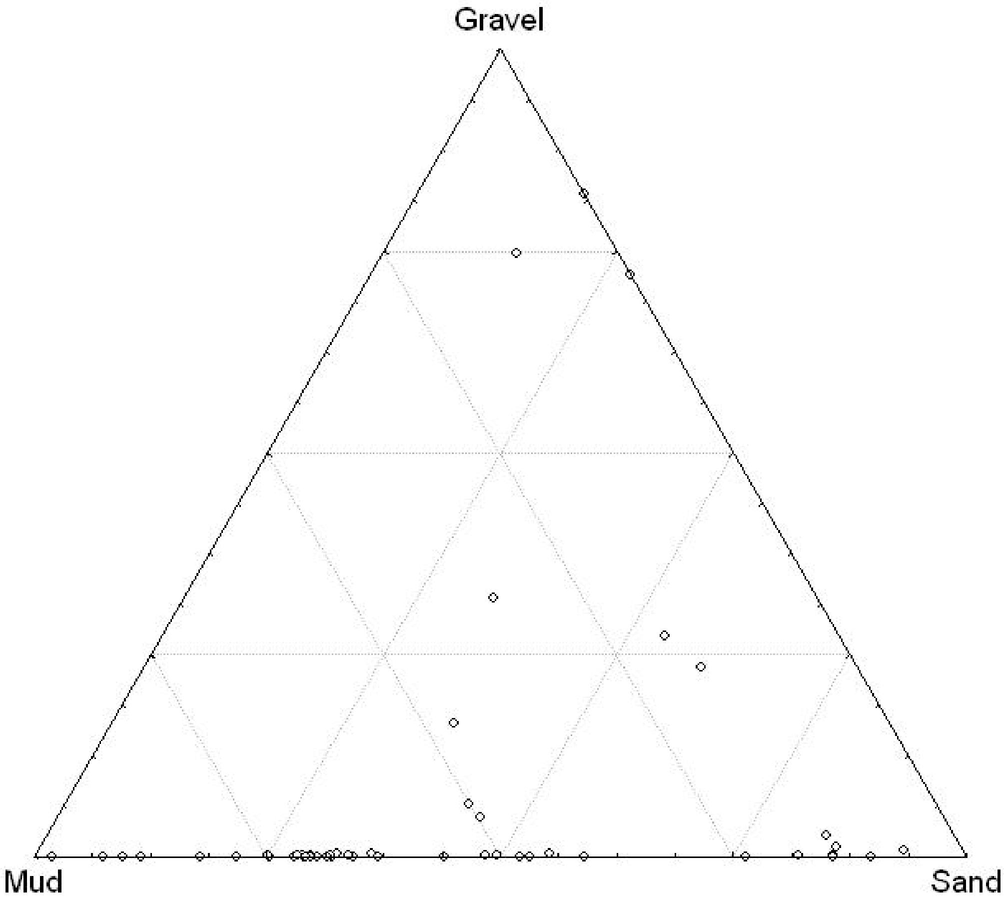
b)



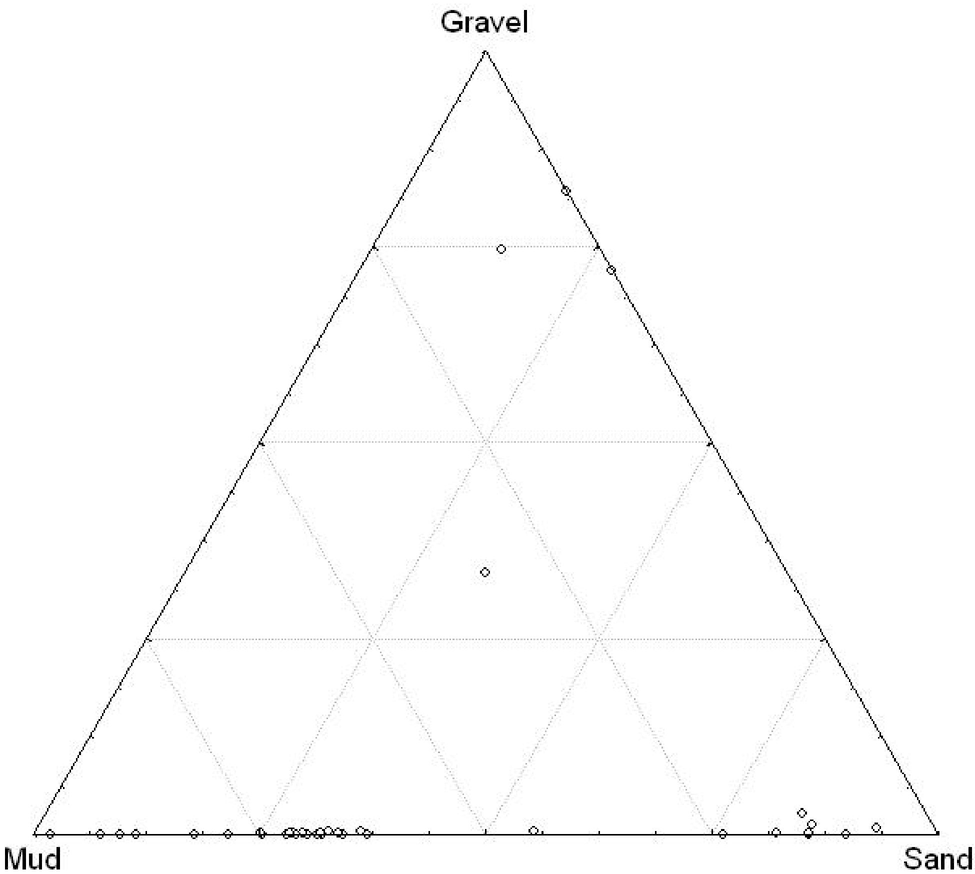
c)



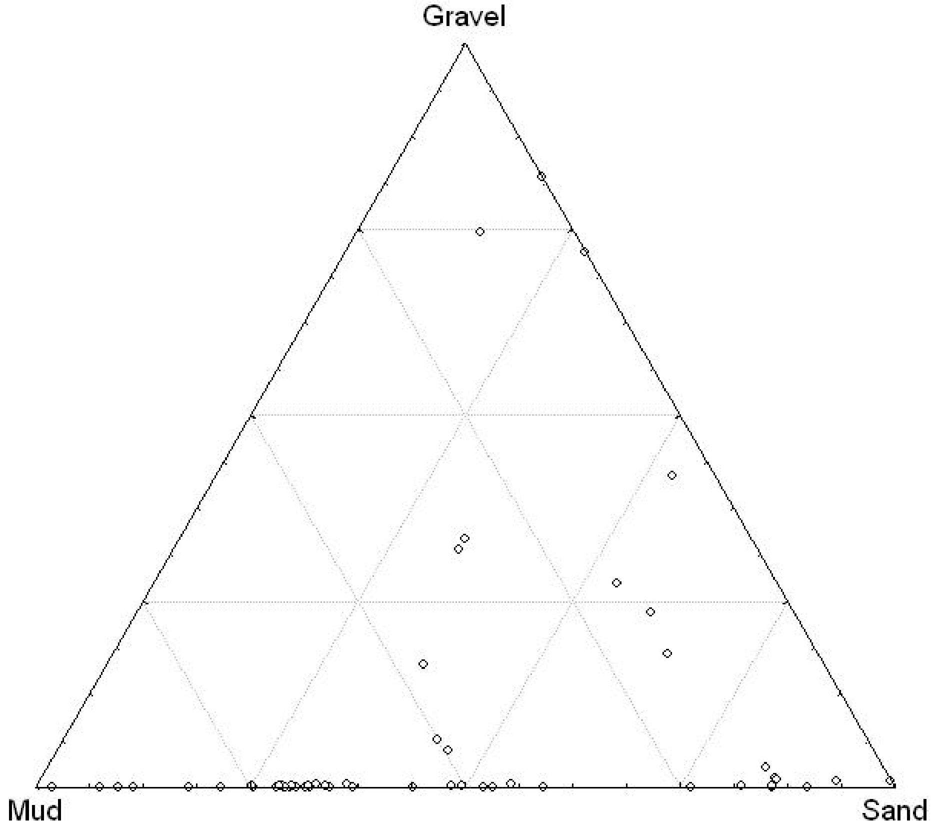
d)



e)



f)



g)

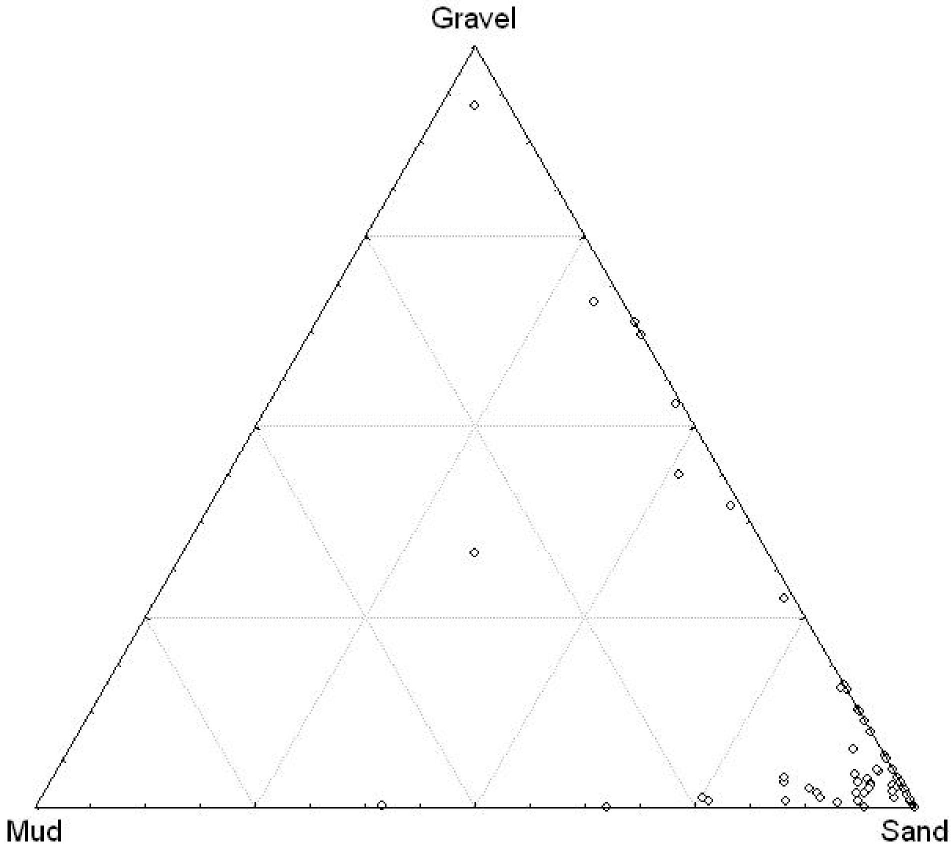
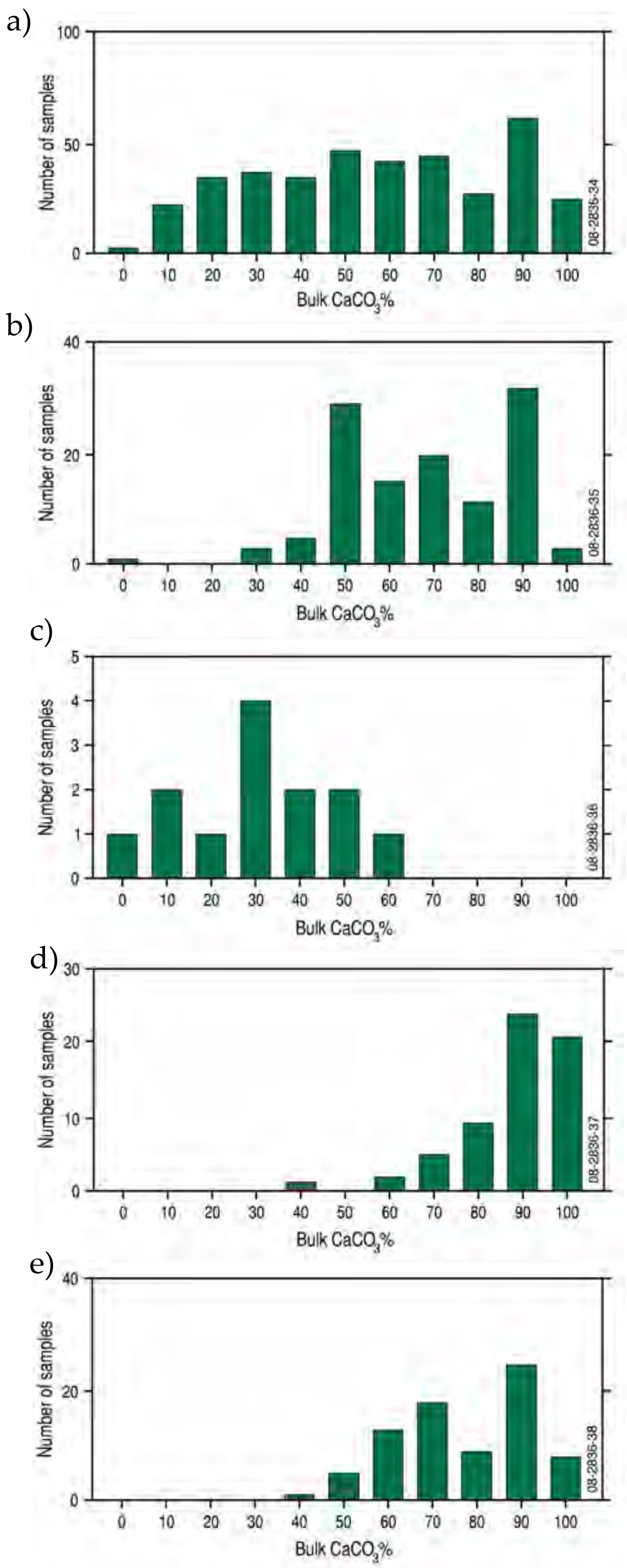


Figure 4.17. Textural composition (mud:sand:gravel ratio) of geomorphic features in the EMR, a) deepwater trench/trough; b) shallow water terrace; c) deepwater terrace; d) plateau; e) plateaus on the shelf or near the shelf break; f) offshore plateaus and terraces; and g) terraces located on or near the shelf break.



a)
Number of samples
Bulk CaCO3%
08-2836-34
b)
Number of samples
Bulk CaCO3%
08-2836-35
c)
Number of samples
Bulk CaCO3%
08-2836-36
d)
Number of samples
Bulk CaCO3%
08-2836-37
e)
Number of samples
Bulk CaCO3%
08-2836-38

f)

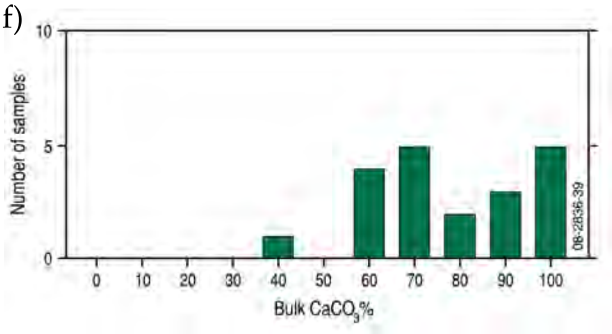


Figure 4.18. Carbonate content of geomorphic features in the EMR, a) shelf (unassigned); b) slope (unassigned); c) abyssal plain/deep ocean floor; d) plateau; e) terrace; and f) trench/trough.

5. Geomorphology and Sedimentology of Bioregions

5.1. INTRODUCTION

At the completion of this task there are a total of 883 samples in the EMR with either quantitative grainsize and/or carbonate data. These are distributed across 13 of the 14 bioregions (Fig. 5.1; Table 5.1). New data significantly improve the sample density in six of the 14 bioregions and provide the first sediment data for the Kenn Province and the Kenn Transition in the EMR.

Of the 883 samples, 636 (72%) occur in the three shelf bioregions which comprise <2% of the total EMR area. The remaining 236 (25%) occur in the 11 offshore bioregions which comprise 98% of EMR area (Fig. 5.1.). Eleven samples located outside the EMR have been included in our analysis as they occur in extensions of geomorphic features which have poor sample coverage within the EMR. These samples occur in extensions of features in the Northeast Transition (2), Northeast Province (3), Kenn Transition (3), Kenn Province (2), Cape Province (1). New data adds 13 samples to the shelf bioregions, increasing coverage of this area by 2% and 114 samples to offshore bioregions, increasing coverage by 85%.

Average sample densities in shelf bioregions are >5 samples per 1,000 km^2 (Table 5.1) and lower in offshore bioregions: <1 sample per 1,000 km^2. Sample density is lowest (<0.01 samples per 1,000 km^2) in the Norfolk Island Province which covers 17% of the EMR and contains only one sample. Sample density in offshore bioregions is highest in the Central Eastern Transition (0.78 samples per 1,000 km^2) and the Central Eastern Province (0.36 samples per 1,000 km^2).

This section provides a quantitative assessment of the geomorphology, bathymetry and sedimentology of each bioregion and significant geomorphic features. Sample coverage is adequate to describe the sedimentology of significant features in all the shelf bioregions and for select features within offshore bioregions. The sedimentology of slope, abyssal plain/deep ocean floor, trench/trough, basin, plateau, and terraces is assessed in individual bioregions. Where present, pinnacles, reefs and rise are considered significant geomorphic features at a bioregion scale. However, these features do not contain sufficient samples to quantitatively describe their sedimentology in individual bioregions.

Bioregions of the EMR can be distinguished from one another based on sediment texture and composition, and by the spatial distribution of these properties relative to other physical data sets such as bathymetry and geomorphology. Sediments within shelf bioregions can be distinguished from those in offshore bioregions by grainsize and carbonate content. Shelf bioregions are dominated by sand with lesser amounts of mud and negligible gravel (Fig. 5.2.). Offshore bioregions display a more varied sedimentology dominated by mud. Bioregions adjacent to the Great Barrier Reef Marine Park (Cape Province, Northeast Transition and Northeast Province) are distinguished by sediments dominated by carbonate mud (Fig. 5.3.). Limited sample coverage has prevented a detailed quantitative assessment of the sedimentology of the Norfolk Island Province, Southeast Transition and Tasman Basin Province.

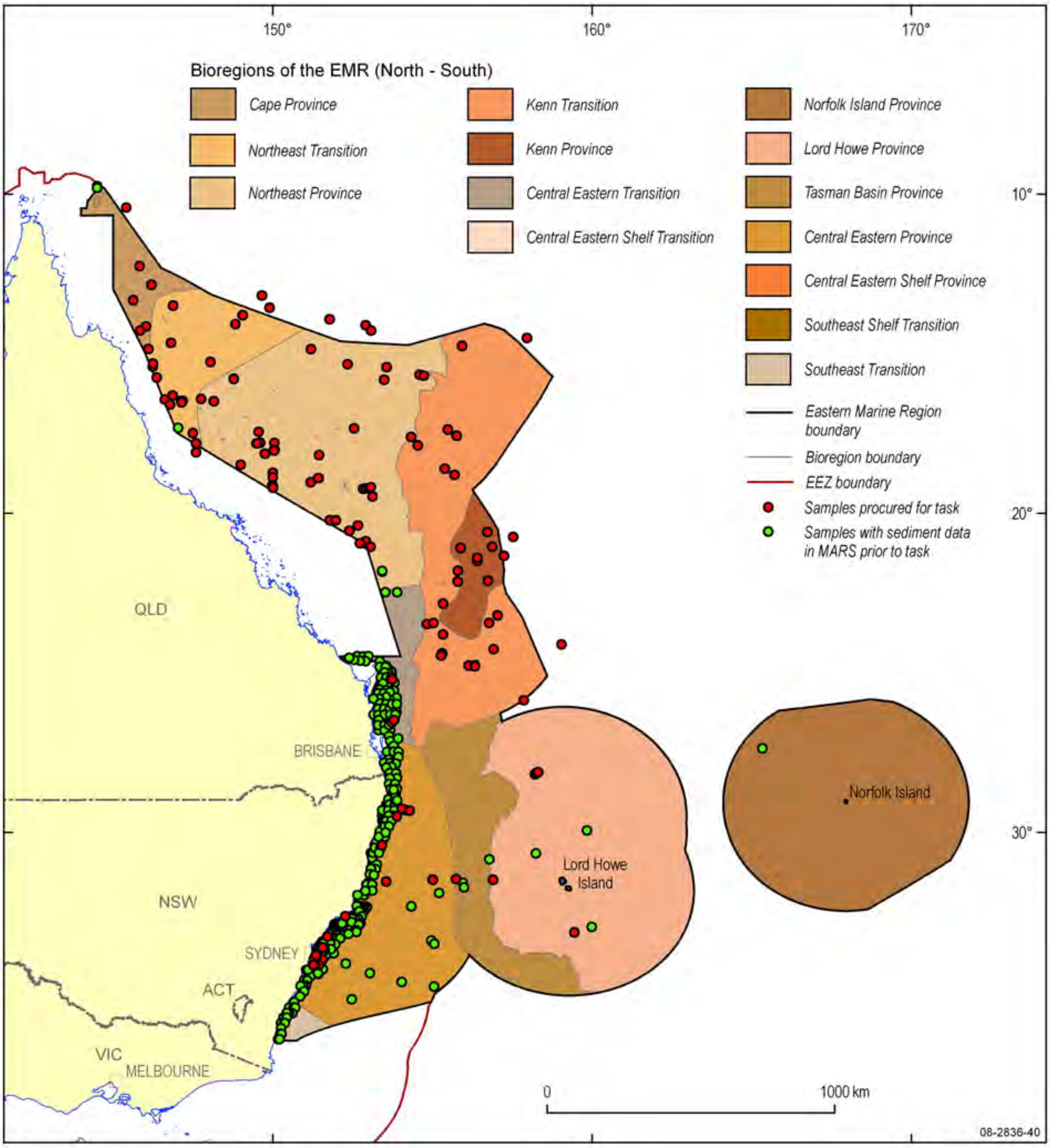


Figure 5.1. Distribution of sediment samples in the EMR bioregions.

Table 5.1. Description of change in sample coverage in bioregions with task.

Bioregion	No. sample points (+ no. added for task)	% EMR Area*	Average sample density (samples per 1,000 km²)
Southeast Shelf Transition	23 (0)	0.2	5.62
Central Eastern Shelf Province	312 (13)	0.6	22.47
Central Eastern Shelf Transition	230 (0)	1.0	10.90
Central Eastern Province	106 (10)	9.5	0.36
Central Eastern Transition	84 (4)	1.8	0.78
Kenn Province	6 (6)	2.3	0.10
Kenn Transition	20 (20)	15.4	0.05
Lord Howe Province	9 (5)	19.7	0.02
Northeast Province	50 (47)	17.2	0.12
Northeast Transition	18 (15)	5.4	0.14
Tasman Basin Province	3 (1)	6.4	0.02
Cape Province	8 (6)	2.5	0.13
Southeast Transition	1 (0)	0.4	0
Norfolk Island Province	1 (0)	17.5	<0.01

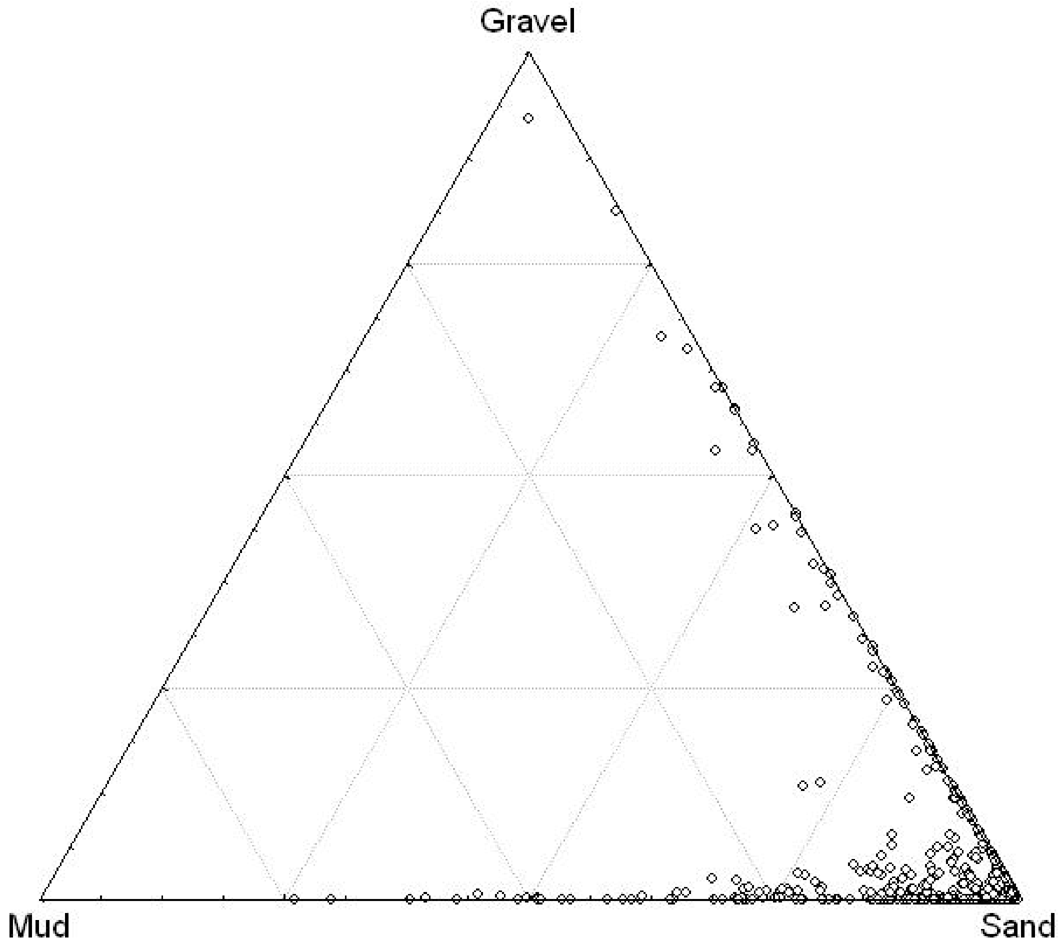
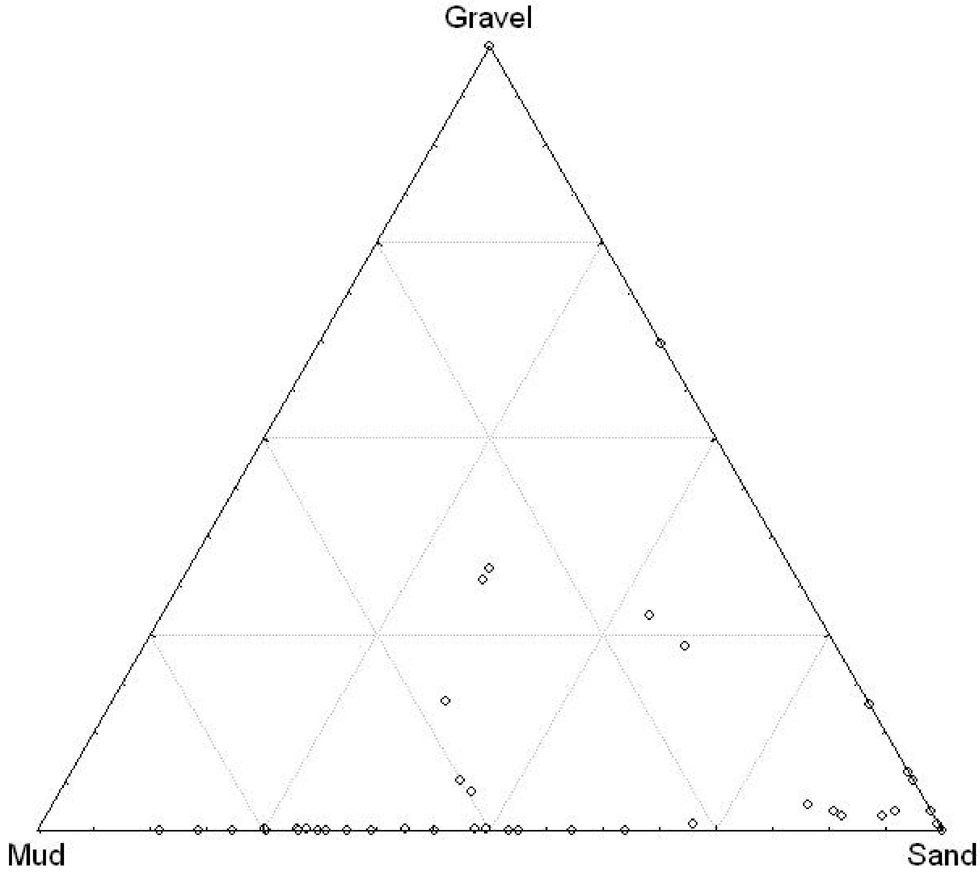
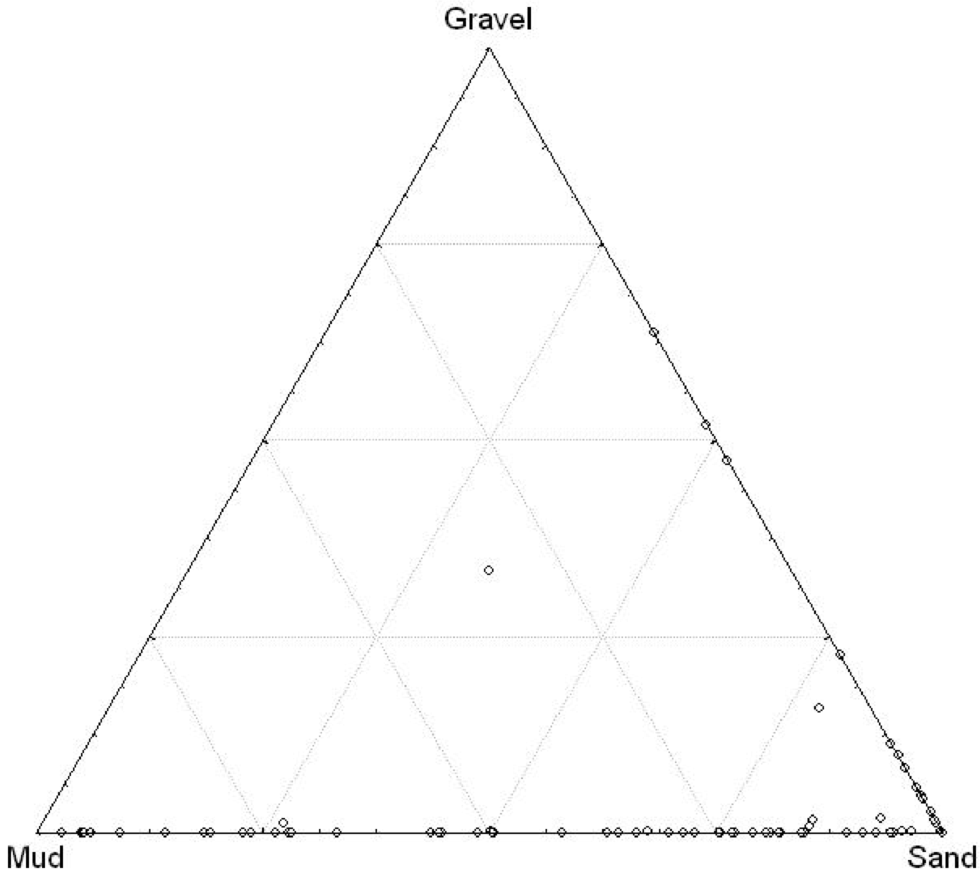


Figure 5.2. Textural composition (mud:sand:gravel ratio) of sediments in shelf bioregions of the EMR.

a)



b)



c)

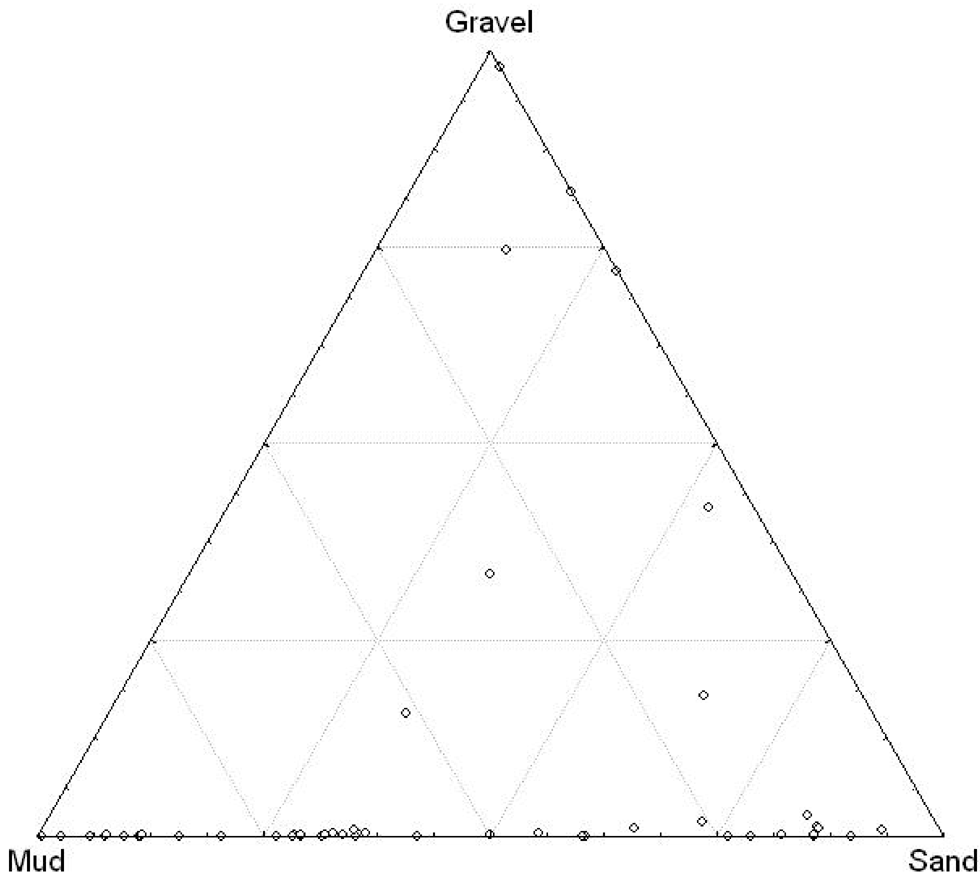


Figure 5.3. Textural composition (mud:sand:gravel ratio) of sediments in offshore bioregions of the EMR, a) the Central Eastern Transition, Kenn Province, and Kenn Transition; b) Cape Province and Central Eastern Province; and c) Northeast Province and Northeast Transition.

5.2. CENTRAL EASTERN SHELF PROVINCE (CESP)

5.2.1. Geomorphology and bathymetry

The CESP covers an area of 13,310 km² or 1% of the EMR (Table 5.4). It is located on the shelf between the towns of Macksville and Minnamurra and is bounded to the north by the CEST, to the south by the SEST, and to the east by the CEP. The CESP runs parallel to the coast and includes an elongate area of seabed ranging in width from 10 – 60 km.

The width of the shelf in the area of the CESP is narrow, ranging from 10 – 50 km. A series of small terraces run parallel to the shoreline at the shelf edge covering an area of 2,310 km² or 17% of the bioregion (Fig. 5.4.). Unassigned shelf and slope and shallow water terraces (Chapter 4) are identified as significant geomorphic features of the CESP. Shallow water terraces cover around 1,640 km² or 12.3% of the bioregion and comprise 4% of the total area of shallow water terraces within the EMR (Table 5.2.).

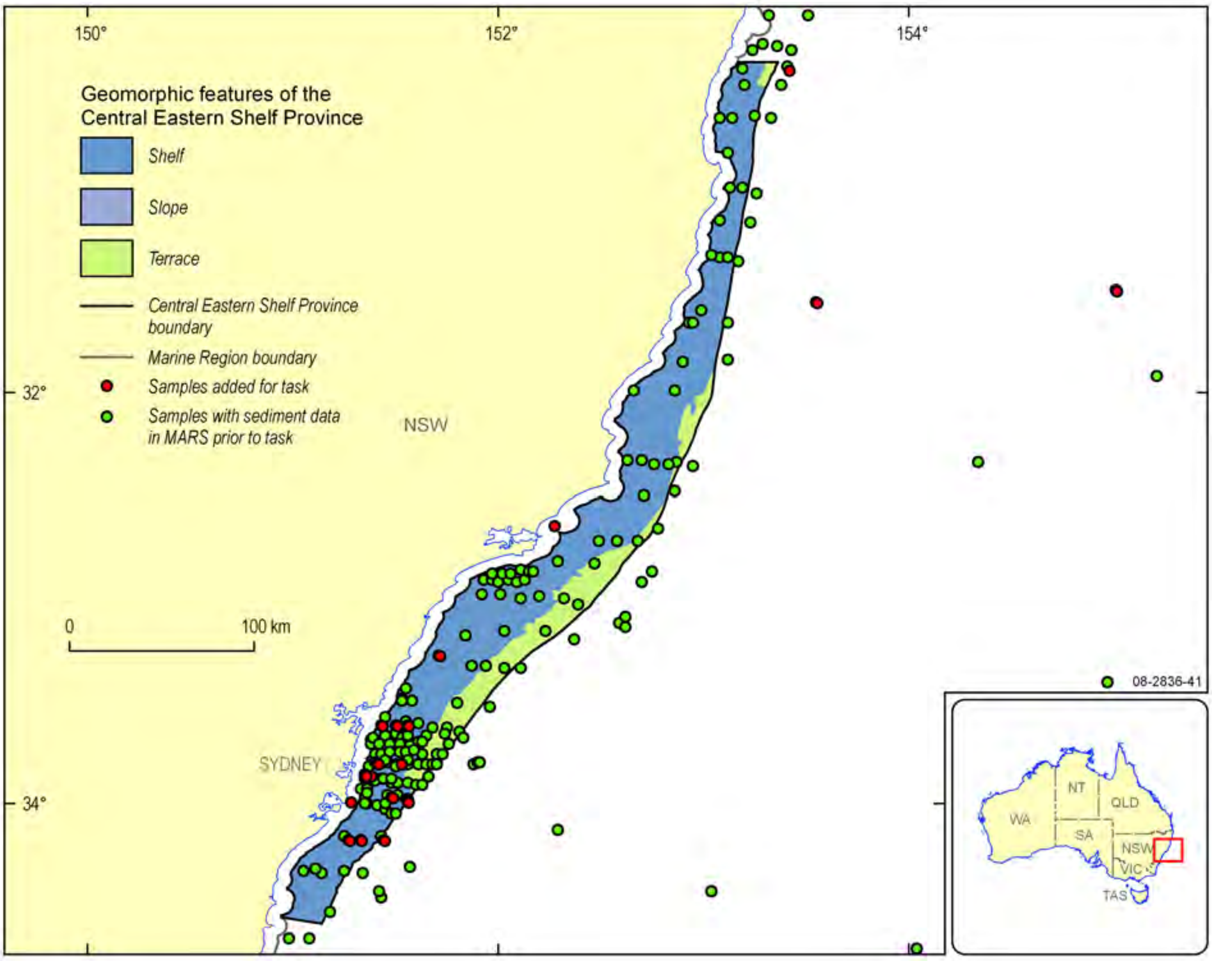
Water depths in the CESP range from 20 – 385 m with an average depth of 115 m. A total of 13,740 km² or 95% of the CESP occurs in water depths of 50 – 200 m (Table 5.3.; Fig. 5.5). Water depths in areas of unassigned shelf and slope range from 20 – 385 m with an average depth of 105 m. Terraces occur in water depths of 110 – 205 m with an average depth of 145 m.

5.2.2. Sample Coverage

The CESP contains 325 samples. These provide coverage of both unassigned shelf and slope and terraces. The majority of samples (305, 94%) occur on unassigned shelf and slope. More than 98% of these occur in water depths of <200 m. Twenty samples are located in shallow water terraces in water depths of 140 – 160 m.

Average sample density for the CESP is 1:45 km² however, samples are clustered on the shelf adjacent to Sydney Harbour resulting in significantly lower sample density elsewhere in the bioregion. Samples achieve densities of 1:40 km² for unassigned seabed and 1:112 km² for shallow water terraces. As sample density was relatively high in this bioregion prior to the MOU, only 13 samples were selected to be analysed for this area.

a)



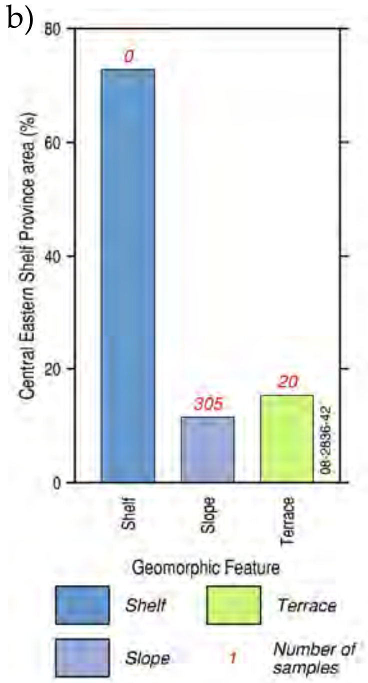


Figure 5.4. a) Geomorphology of the Central Eastern Shelf Province (CESP) with location of sediment samples; and b) Percentage area of each geomorphic feature within the CESP with number of corresponding sediment samples (on top of columns).

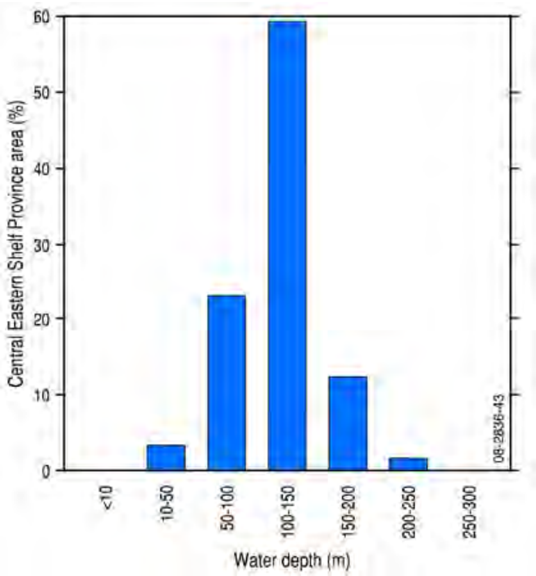


Figure 5.5. Distribution of water depth classes by percentage area within the CESP.

Table 5.2. The percentage area of geomorphic units found in the Central Eastern Shelf Province.

Feature	% area of bioregion	% area of geomorphic unit within the EMR	% area of geomorphic unit within the EEZ
Geomorphic Feature			
Unassigned shelf and slope	84.50	-	-
Terrace	15.50	3.84	0.39

Table 5.3. The water depth of geomorphic units found in the Central Eastern Shelf Province.

Feature	Depth Range (m)	Mean Depth (m)
Geomorphic Feature		
Unassigned shelf and slope	20 – 385	110
Terrace	110 – 205	145

5.2.3. Sedimentology of the Central Eastern Shelf Province

A total of 347 grain size assays and 159 carbonate assays are available for the CESP. Sediments in the south of the CESP differ significantly from those in the north. South of Wyong, sediment texture is relatively homogeneous and generally dominated by sand. Mud dominates locally, mainly on areas of the shelf offshore of Sydney and Newcastle. Sediments contain between 60 and 100% sand, with >60% in 274 (79%) samples and >90% in 179 (52%) samples (Fig. 5.2). Mud ranges from 0 to 60% and is <20% in 228 (66%) samples. Gravel generally forms <2% of sediment except offshore of Wollongong and Newcastle, and at the shelf break adjacent to Port Macquarie where gravel contents range from 20-40%.

North of Newcastle, sediment texture is more variable. Sand and gravel dominate, with sand content ranging from 10 - 100% and gravel from 0 - 65%. The distribution of sand and gravel reflect similar sediment patterns to those observed in the adjacent Central Eastern Shelf Transition (Section 5.3). Mud content ranges from 0 – 15% except in a small area off the coast of Newcastle where sediments are significantly finer and attain 60% mud content. Adjacent to Newcastle, mud ranges from 0-70% of sediment and the majority of samples contain no gravel.

A total of 158 bulk carbonate assays are available for the CESP. Carbonate contents of these samples range from 3 – 95% and exceed 70% in 29 (18%) samples. Carbonate contents generally increase towards the shelf break. Few carbonate assays are available for textural size fractions; however, those present give average carbonate mud content around 45%, and carbonate sand content ranging from 7 - 72%. Carbonate content of gravel is 100% in all eight samples analysed.

5.2.4. Sedimentology of Significant Geomorphic Features

5.2.4.1. Shelf (unassigned)

A total of 290 samples were obtained from the shelf (unassigned). Sand is the dominant sediment fraction with contents ranging from 26 - 100% and 251 (87%) samples attaining >75% (Fig. 5.6). Mud is the next most abundant fraction ranging from 1 - 76%. Gravel content is low ranging from 0 – 34% and attaining <1% in 222 (77%) samples. Bulk carbonate content ranges from 3 - 94% and attains >75% in eight (7%) samples (Fig. 5.7.). Carbonate gravel totals 100% in all seven samples containing a carbonate gravel assay. Carbonate sand content is available for eleven samples and ranges from 6 - 72%. Carbonate mud content was assessed for only one sample and totalled 45%.

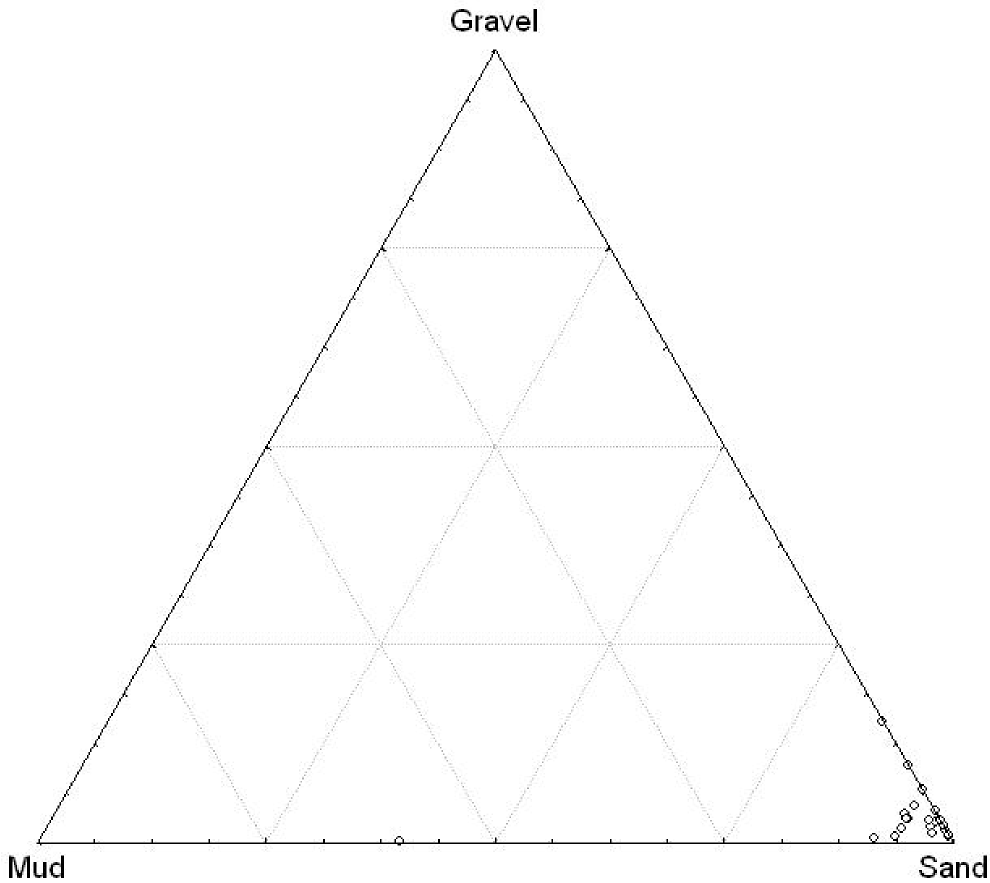
5.2.4.2. Slope (unassigned)

A total of 15 samples were obtained from the slope (unassigned). Sand is the dominant sediment fraction with contents ranging from 42 -100% and attaining >75% in 12 (80%) of samples (Fig. 5.6). Gravel is the next most abundant fraction with contents ranging from 1 - 58% and attaining >50% in three (20%) of samples. Mud content ranges from 4 - 7%. Bulk carbonate content ranges from 21 to 82% and attains >75% in three (21%) samples (Fig. 5.7). Carbonate content of sand and gravel fractions are available for only 1 sample. Gravel is 100% carbonate and sand 67%. Carbonate content of mud was not assessed.

5.2.4.3. Shallow-water Terraces

A total of 20 samples were obtained from terraces. Sand is the dominant sediment fraction with contents ranging from 39 - 99% and 18 (90%) of samples attaining 75% (Fig. 5.6). Mud content ranges from 0 – 60%, however 16 (85%) samples contain <5% mud and 1 sample contains 60% mud. Gravel was detected in all samples but does not exceed 15% and amounts to <5% in 17 (90%) samples. Bulk carbonate content ranges from 52 - 77% with 2 (10%) samples attaining >75% (Fig. 5.7). Individual fractions were not analysed for carbonate content.

a)



b)

c)

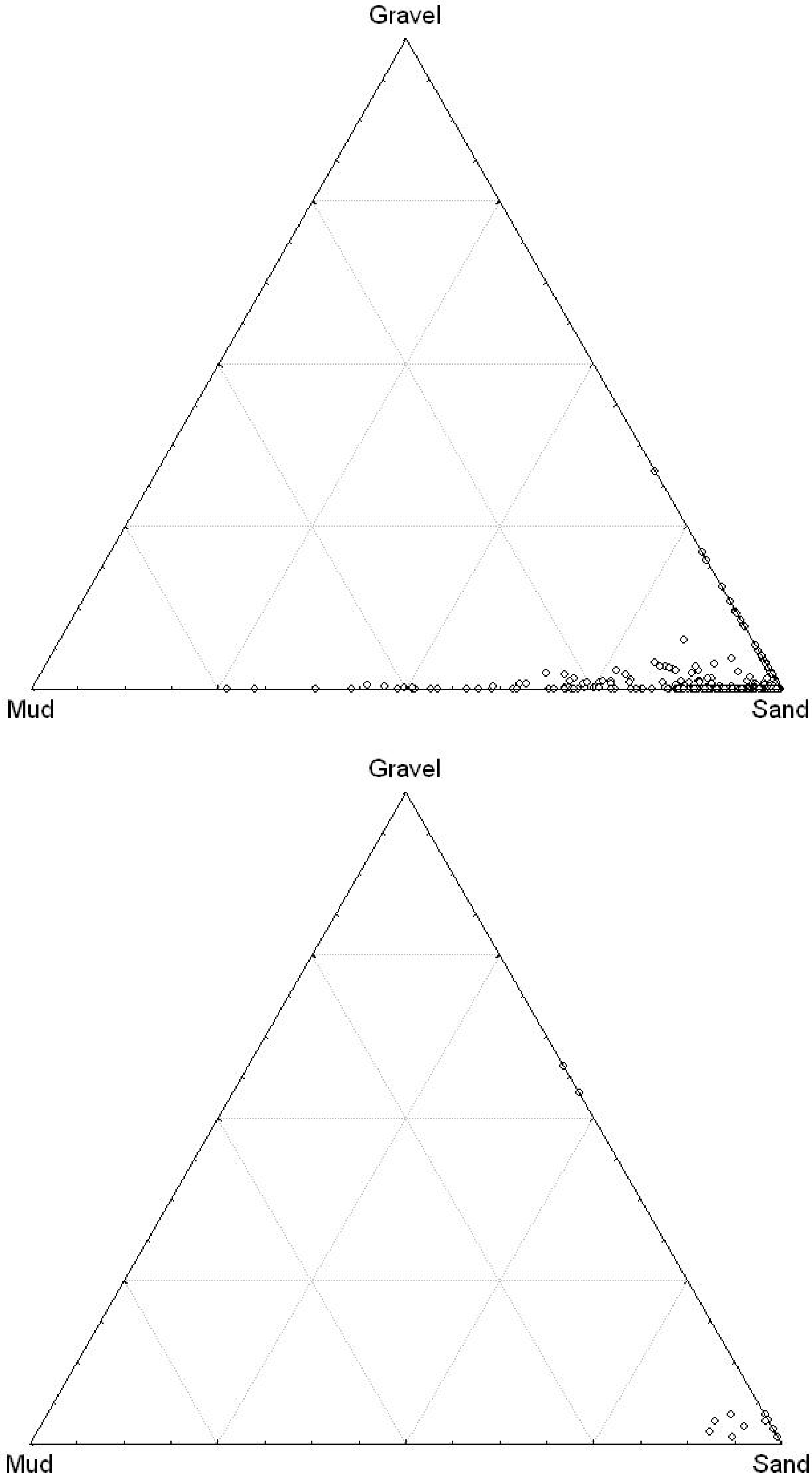


Figure 5.6. Textural composition (mud:sand:gravel ratio) of: a) shallow water terrace sediments; b) shelf sediments; and c) slope sediments, of the CESP.

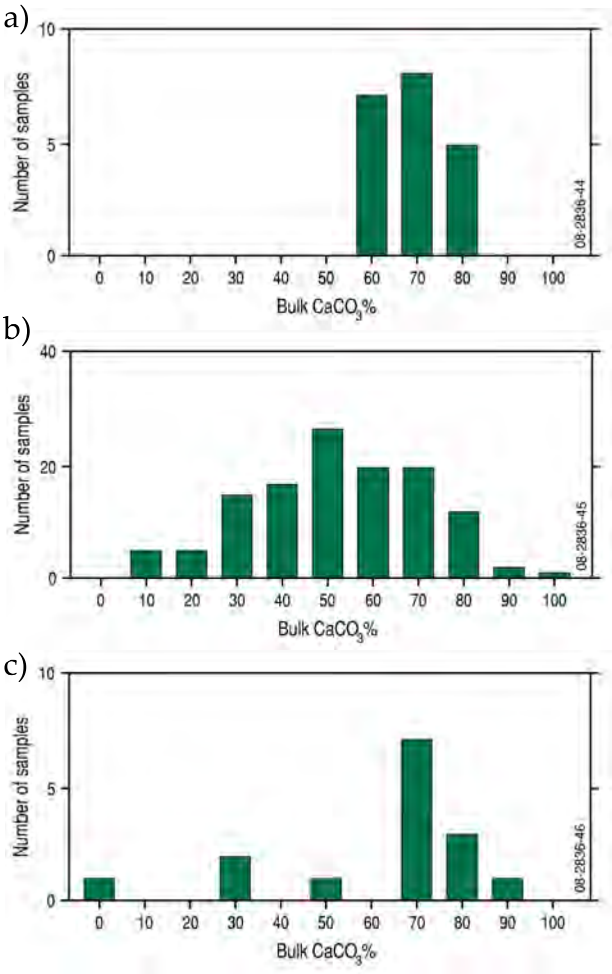


Figure 5.7. Carbonate content of: a) shallow water terrace sediments; b) shelf sediments; and c) slope sediments, of the CESP.

5.3. CENTRAL EASTERN SHELF TRANSITION (CEST)

5.3.1. Geomorphology and bathymetry

The Central Eastern Shelf Transition (CEST) covers 26,335 km^2 or 1% of the EMR. The CEST is located on the shelf between Fraser Island and Macksville. It lies on the western boundary of the EMR and is bound to the south by the CESP, to the north-east by the CET and to the northwest by the CEP. The Great Barrier Reef Marine Park is situated directly north of the CEST.

The CEST is located predominantly on the shelf and includes a small section of upper slope (Table 5.4). The shelf varies in width from 130 km to the north of Fraser Island to <25 km adjacent to Macksville. Shelf covers 20,615km^2 or 78% of the bioregion and Slope 5,719 km^2 or 21% of the bioregion. The CEST contains unassigned shelf (18,959 km^2, 71%); unassigned slope (4,093 km^2, 15%); terrace (3,245 km^2, 12%); reef (2 km^2, <1%); canyon (34 km^2, <1%) and pinnacle (<1 km^2, <1%) geomorphic features (Fig. 5.8). Significant features include: three shallow water terraces that run parallel to the coast, and separate the shelf from the upper slope; a small area of reef to the north of Fraser Island and two canyons that occur on the slope offshore of Coolangatta and extend offshore of the bioregion boundary into the CEP.

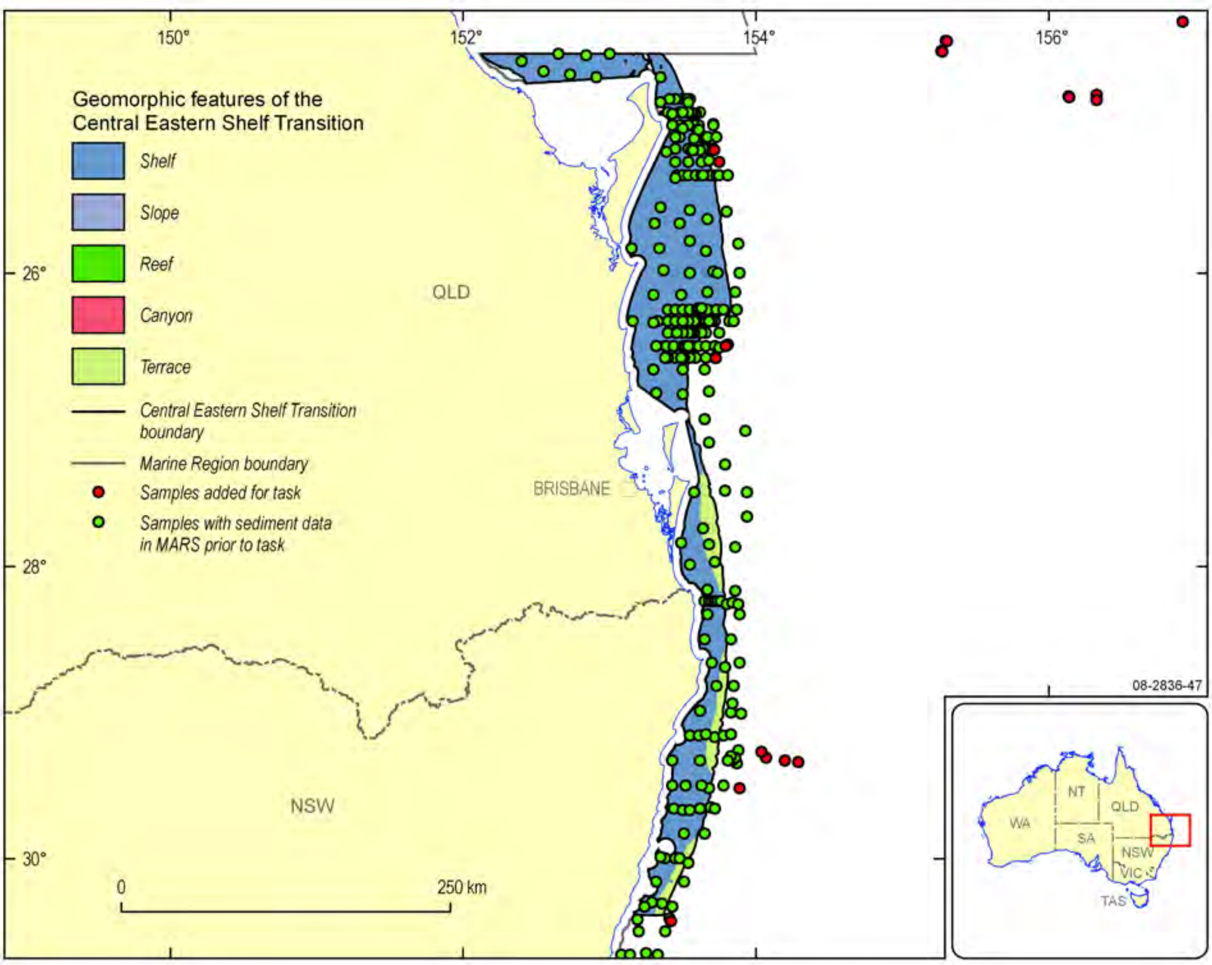
Water depths in the CEST range from 0 – 470 m with an average depth of 80 m (Table 5.5). Approximately 90% of the CEST area occurs in water depths of between 10 and 150 m (Fig. 5.9). Reefs and unassigned shelf are generally the shallowest areas of the bioregion with average water depths of 8 m and 50 m respectively. Water depths increase on the slope (average 140 m). Terraces and canyons occur on the slope and have average water depths of 130 m and 150 m, respectively.

5.3.2. Sample coverage

The CEST contains 287 sample points (Fig. 5.8). Most samples occur along transects that run perpendicular to the shelf break. Samples occur in water depths ranging from 15 – 235 m, however 272 samples (95%) occur on the shelf and slope in water depths of between 15 and 170 m. Samples occur in 4 of the 6 geomorphic features in the CEST. A total of 226 (79%) samples occur in unassigned shelf, 26 (9%) in unassigned slope, 34 (12%) in terraces and 1 (>1%) in canyons.

Average sample density of the CEST is 1:90 km². Samples attain sufficient coverage to describe the sediment distribution on the shelf (unassigned), slope (unassigned) and terraces. Approximately 80% of the samples in the CEST occur on the shelf offshore of Fraser Island and Maroochydore, achieving densities of around 1:45 km² for these areas.

a)



b)

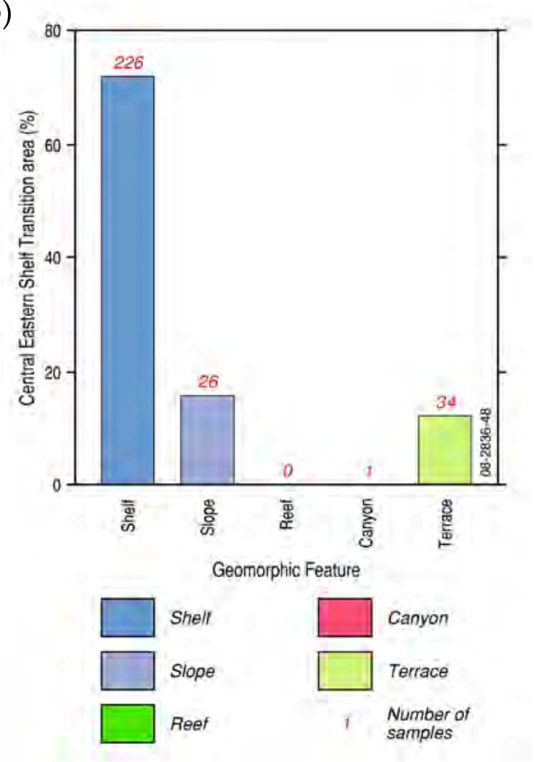


Figure 5.8. a) Geomorphology of the Central Eastern Shelf Transition (CEST) with location of sediment samples; and b) Percentage area of each geomorphic feature within the CEST with number of corresponding sediment samples (on top of columns).

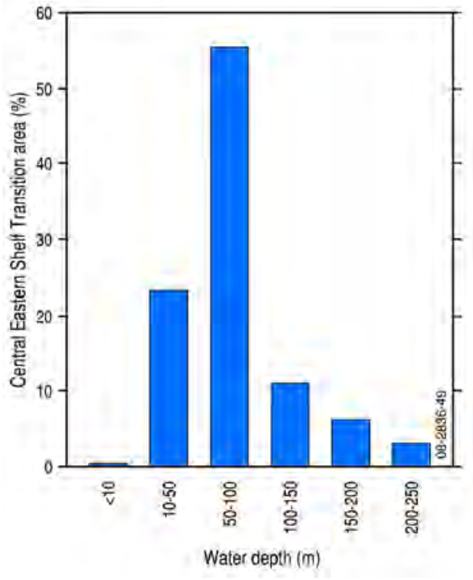


Figure 5.9. Distribution of water depth classes by percentage area within the CEST.

Table 5.4. The percentage area of geomorphic units found in the Central Eastern Shelf Transition.

Feature	% area of bioregion	% area of geomorphic unit within the EMR	% area of geomorphic unit within the EEZ
Geomorphic Feature			
Unassigned shelf and slope	87.54	-	-
Reef	<0.01	<0.01	<0.01
Canyon	0.13	0.35	0.03
Terrace	12.32	5.56	0.56

Table 5.5. The water depth of geomorphic units found in the Central Eastern Shelf Transition.

Feature	Depth Range (m)	Mean Depth (m)
Geomorphic Feature		
Unassigned shelf and slope	0 – 430	70
Reef	0 – 15	8
Canyon	85 – 210	150
Terrace	55 – 450	130

5.3.3. Sedimentology of Central Eastern Shelf Transition

A total of 200 grain size and 286 carbonate assays are available for the CEST. Sediment texture in the CEST is relatively homogeneous. Sand is the dominant size fraction in all samples with contents generally ranging from 34 - 100%. Sand content exceeds 95% in 106 (61%) samples. Gravel forms <45% of sediment volume in 169 (97%) samples, and exceeds 80% in only two (1%) samples. Mud is <1% in 139 (70%) samples and exceeds 10% in only eight (4%) samples.

Bulk carbonate content ranges from 3 - 98% with 219 (77%) samples exceeding 30% carbonate content. The carbonate content of sediments increases towards the shelf edge where it attains 60 – 100%. The carbonate content of the sand fraction is high and ranges from 1 - 100%, with 59 (61%) samples attaining >50% carbonate sand. No carbonate assays are available for mud and gravel textural size fractions.

5.3.4. Sedimentology of Significant Geomorphic Features

5.3.4.1. Shelf (unassigned)

A total of 227 samples were collected from the shelf (unassigned). Carbonate data is available for all samples and grain size data for 125 samples. Sediments in this area are relatively homogenous and dominated by sand. Sand content ranges from 1 - 99% with 125 (85%) samples containing >75% sand (Fig. 5.10.). Mud content ranges from 0 – 40%, however 135 (90%) samples contain <5% mud. Gravel content ranges from 0 – 81% although 94 (75%) samples contain <5% gravel. Bulk carbonate content ranges from 3 - 98% and is >75% in 86 (38%) samples (Fig. 5.11.). The carbonate content of the sand fraction ranges from 1 - 100% with 48 (67%) containing <75% carbonate sand. No samples were analysed for the carbonate content of the mud and gravel fractions.

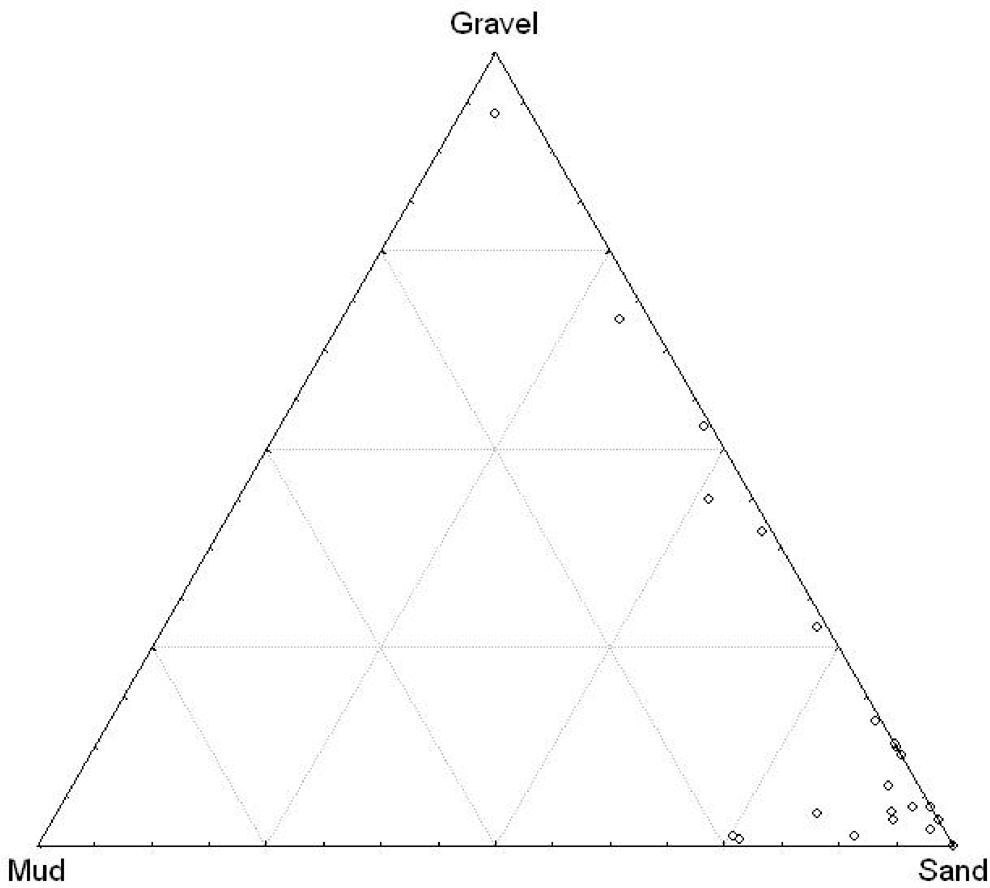
5.3.4.2. Slope (unassigned)

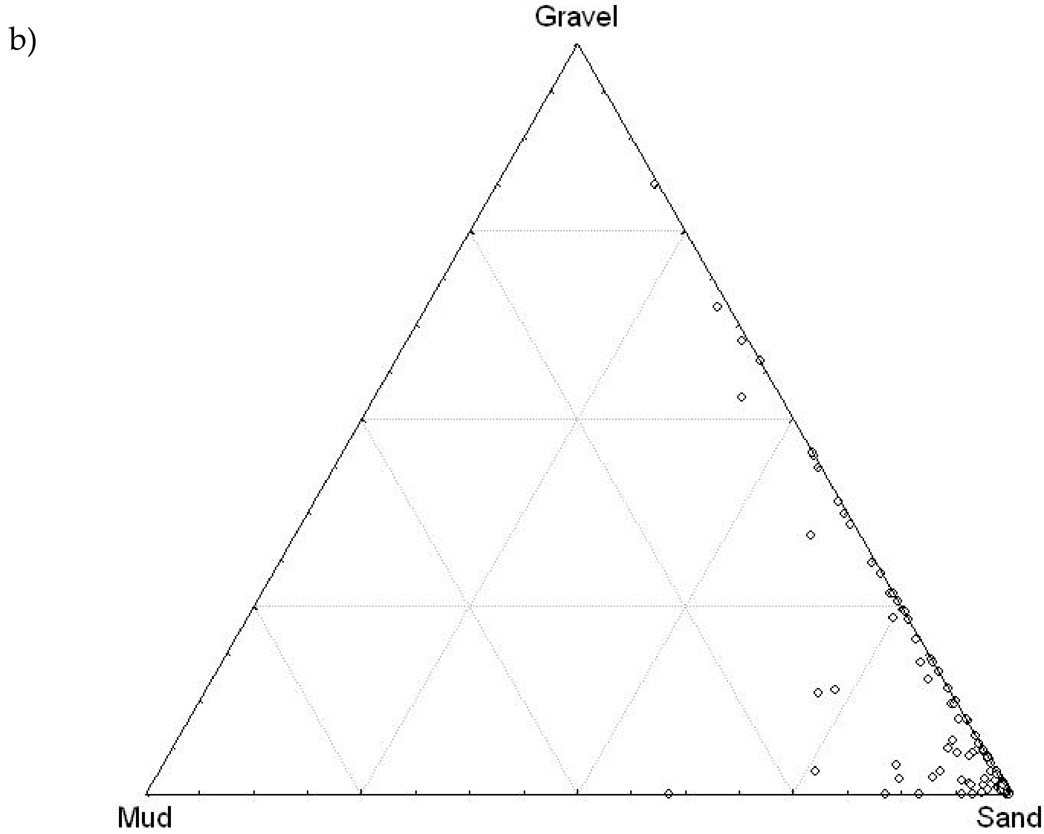
A total of 23 samples were obtained from the slope (unassigned). Sand is the dominant size fraction with contents ranging from 40 - 100% and exceeding 75% in 19 (83%) of samples (Fig. 5.10). Gravel is the next most abundant size fraction with contents ranging from 1 - 60%. Mud did not exceed 13%, and was absent from 11 (48%) of samples. Bulk carbonate content ranges from 41 - 88% and exceeds 75% in 12 (52%) of samples (Fig. 5.11). No samples have been analysed for carbonate mud or gravel content.

5.3.4.3. Shallow-water Terraces

A total of 34 samples were obtained from terraces. Sand is the dominant size fraction with contents ranging from 4 - 100% and exceeding 75% in 20 (80%) samples (Fig. 5.10). Gravel is the next most abundant size fraction with contents ranging from 1 - 92%. Gravel constitutes <15% of the sediment in 19 (75%) samples. Mud content ranges from 0 – 24% but is <5% in 21 (85%) samples. Bulk carbonate content ranges from 39 - 100% and exceeds 75% in 20 (60%) samples (Fig. 5.11.). Carbonate content of the sand fraction ranges from 45 - 82% with 14 (93%) samples containing >50% carbonate sand.

a)





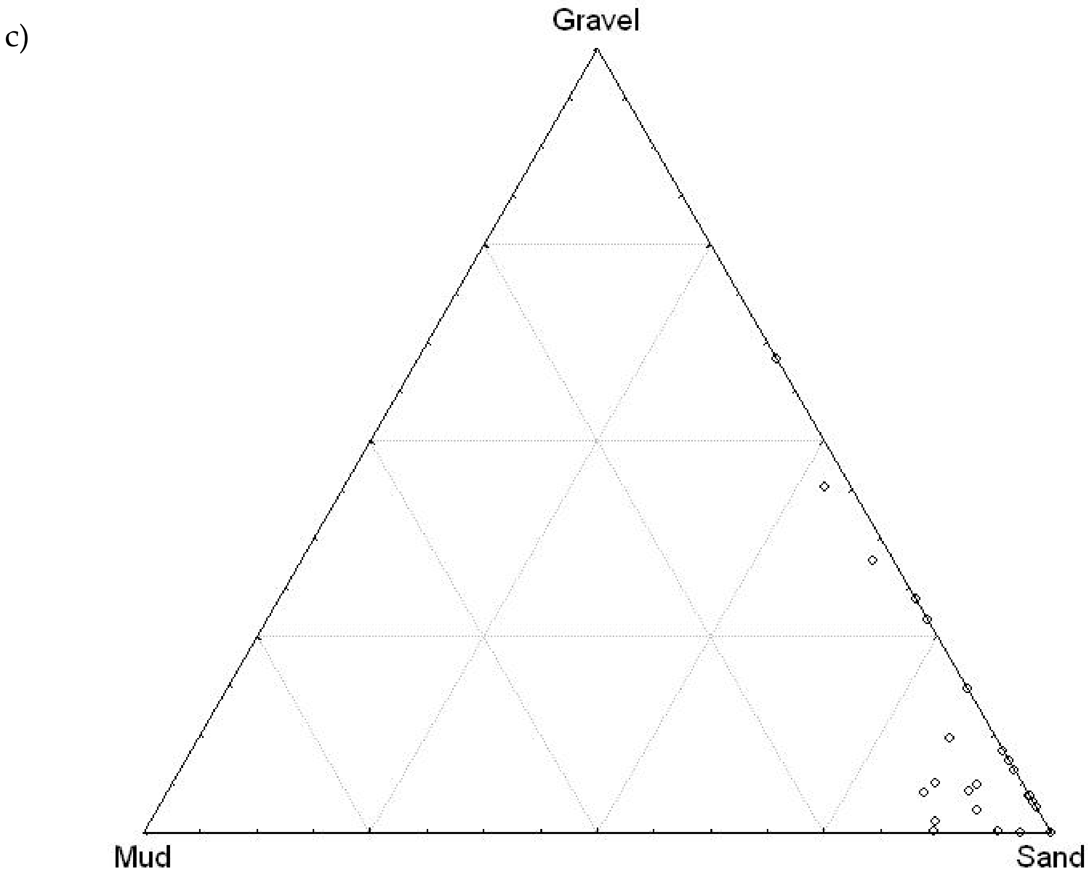


Figure 5.10. Textural composition (mud:sand:gravel ratio) of a) shallow water terrace sediments; b) shelf sediments; and c) slope sediments, from the CEST.

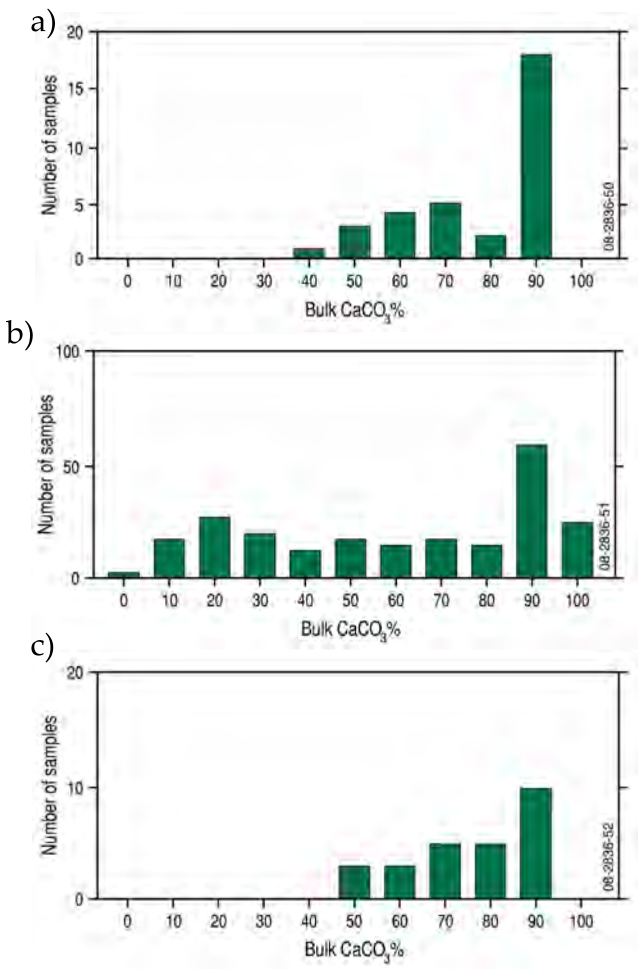


Figure 5.11. Carbonate content of a) shallow water terrace sediments; b) shelf sediments; and c) slope sediments, for the CEST.

5.4. SOUTHEAST SHELF TRANSITION (SEST)

5.4.1. Geomorphology and bathymetry

The SEST covers an area of 59,615 km² of which 4,270 km² lies within the EMR. This area covers <1% of the total EMR area. The SEST is located predominantly on the shelf with a small section of the upper slope between Kiama and Bermagui, and it is the most southerly shelf bioregion in the EMR. The bioregion is relatively narrow (5 – 30 km wide) and runs parallel to the coast. It is bounded to the north by the CESP, to the east by the CEP and SET, and to the south by the EMR boundary. The narrowest sections of the SEST occur adjacent to Sussex Inlet and Mystery Bay.

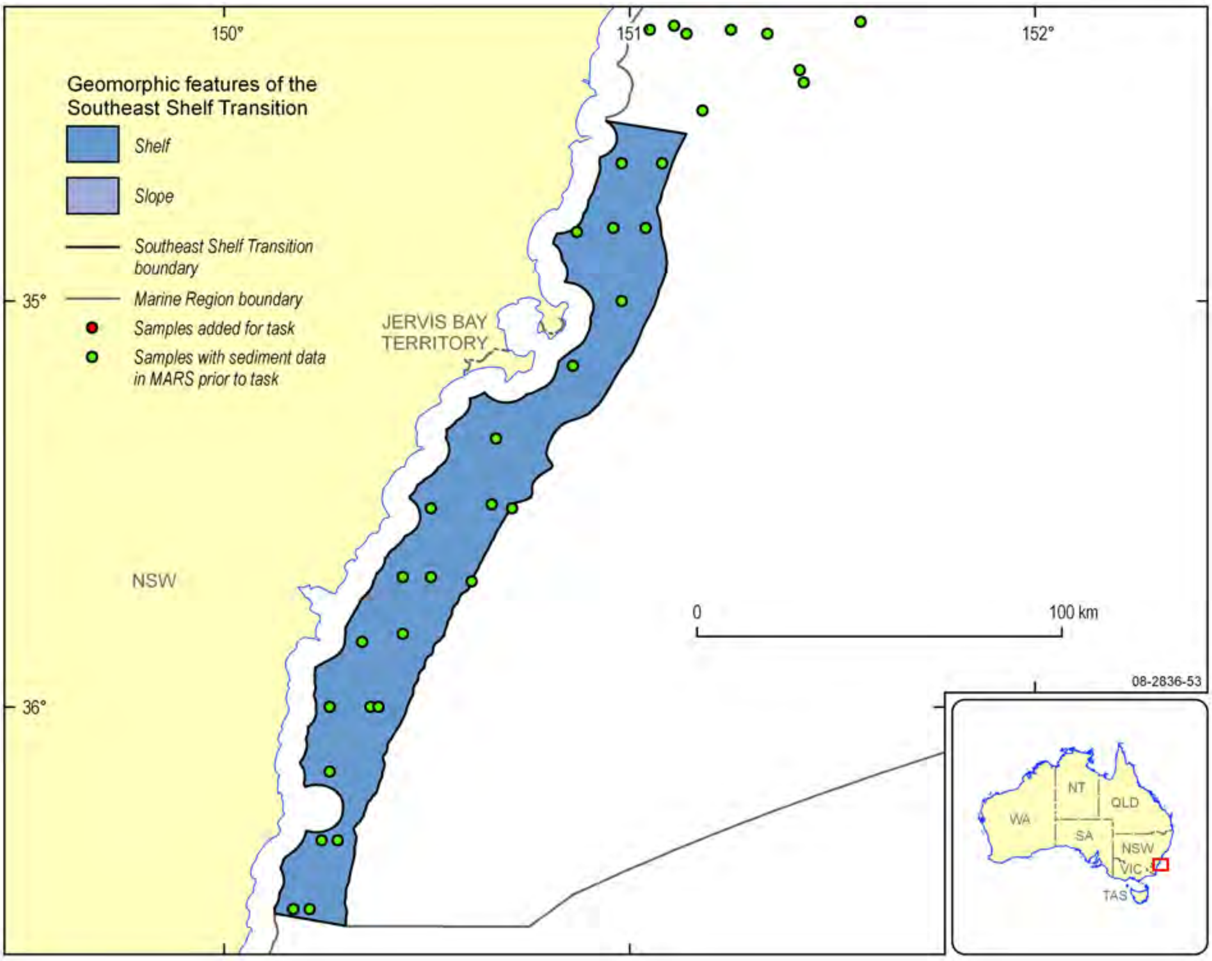
Shelf covers 3,930 km² or 92% of the bioregion and slope covers 340 km² or 8% (Fig. 5.12). No additional geomorphic features are identified within these provinces. Unassigned shelf is considered the only significant geomorphic feature of the SEST.

Water depths in the SEST range from 25 – 325 m, with an average depth of 125 m. A total of 3,140 km² (75%) of the SEST occurs in water depths of 100 – 150 m (Fig. 5.13). Due to the physical homogeneity of the bioregion, no geomorphology or bathymetry summary table is provided.

5.4.2. Sample Coverage

The SEST contains 24 samples, giving an average sample density of 1:180 km^2. All of these samples occur on the shelf in water depths of between 55 and 160 m. Due to the small area and relatively high sample density existing for the SEST prior to this task, no additional data points were procured and analysed for this bioregion. Sample density is sufficient to assess the sedimentology of unassigned shelf.

a)



b)

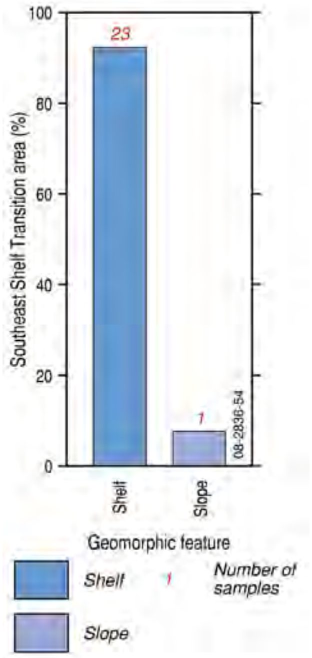


Figure 5.12. a) Geomorphology of the Southeast Shelf Transition (SEST) with location of sediment samples; and b) Percentage area of each geomorphic feature within the SEST with number of corresponding sediment samples (on top of columns).

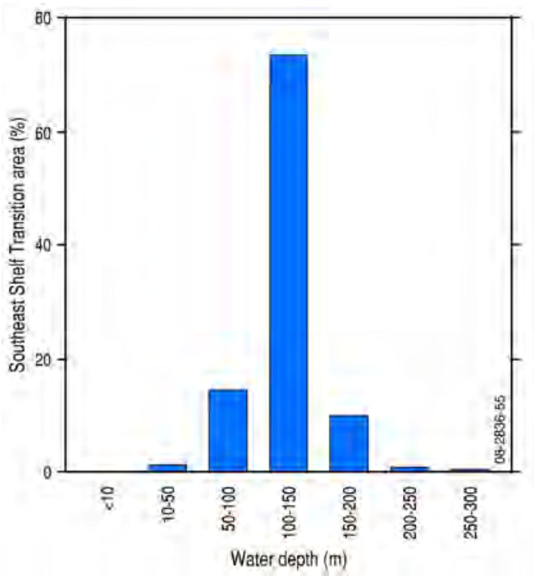


Figure 5.13. Distribution of water depth classes by percentage area within the SEST.

5.4.3. Sedimentology of the Southeast Shelf Transition

The SEST contains 24 grainsize and carbonate assays (Fig. 5.12.). Sediment texture is relatively homogeneous and dominated by sand. Sand forms >60% of sediment in all samples, and exceeds 90% in 15 (65%) samples. Mud and gravel comprises <20% in 22 (96%) samples except for one sample located on the shelf off Minnamurra which contains 26% mud and 38% gravel. The bulk carbonate content of sediments ranges from 23 - 88% and (19) 80% of samples contain between 30 – 60% carbonate content. No carbonate assays are available for textural size fractions.

5.4.4. Sedimentology of Significant Geomorphic Features

5.4.4.1. Shelf (unassigned)

As shelf is the only geomorphic feature represented by samples in the SEST (see above section 5.13.3 for a description of sediment texture and composition). Sand is the most abundant sediment fraction (Fig. 5.14.) and bulk carbonate ranges from 23 – 88% (Fig. 5.15.)

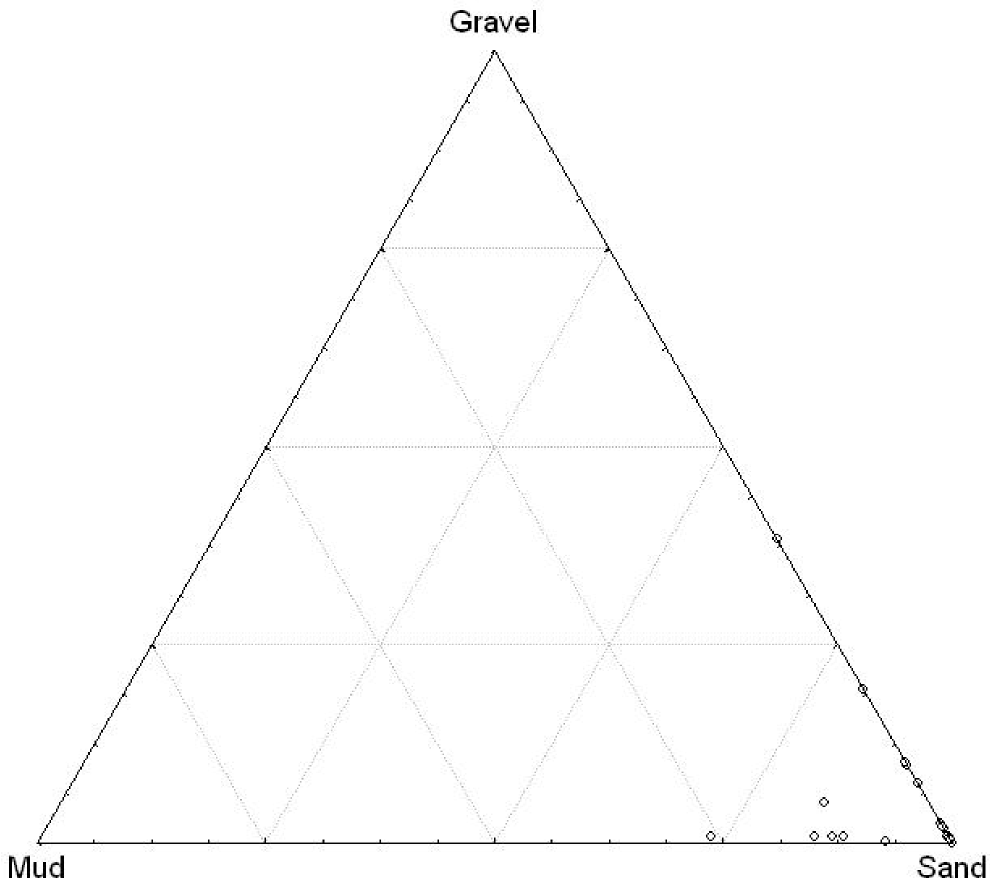


Figure 5.14. Textural composition (mud:sand:gravel ratio) of shelf sediments within the SEST.

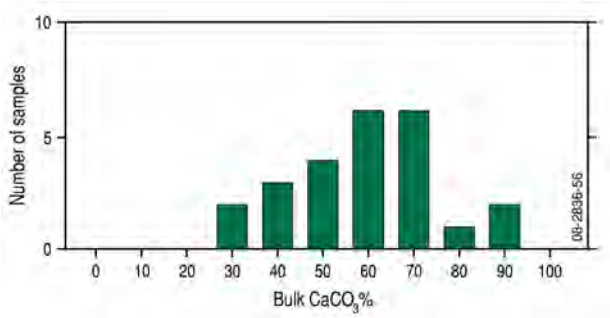


Figure 5.15. Carbonate content of shelf sediments within the SEST.

5.5. CAPE PROVINCE (CP)

5.5.1. Geomorphology and bathymetry

The Cape Province (CP) covers a total area of 109,340 km^2 of which 62,520 km^2 occurs in the EMR. This bioregion represents 2.5% of the total area of the EMR (Table 5.1). The CP is situated on the slope between Cape York and Cape Flattery (Fig. 5.2). It is the northern-most bioregion of the EMR and is bound to the south by the Northeast Transition.

The majority of the CP is situated on the slope province. Within this area, 10 geomorphic features have been identified: Trench/trough (7,930 km^2, 13% CP area); plateau (6,450 km^2, 10%); deep/hole/valley (4,890 km^2, 8%); basin (2,090 km^2, 3%); reef (950 km^2, 2%); saddle (580 km^2, 2%); terrace (180 km^2, <1%); ridge (170 km^2, <1%); and canyon (10 km^2, <1%) (Fig. 5.16 & Table 5.6). An area of 130 km^2 of shelf off Cape York with no other geomorphic features identified within it is also included in the CP.

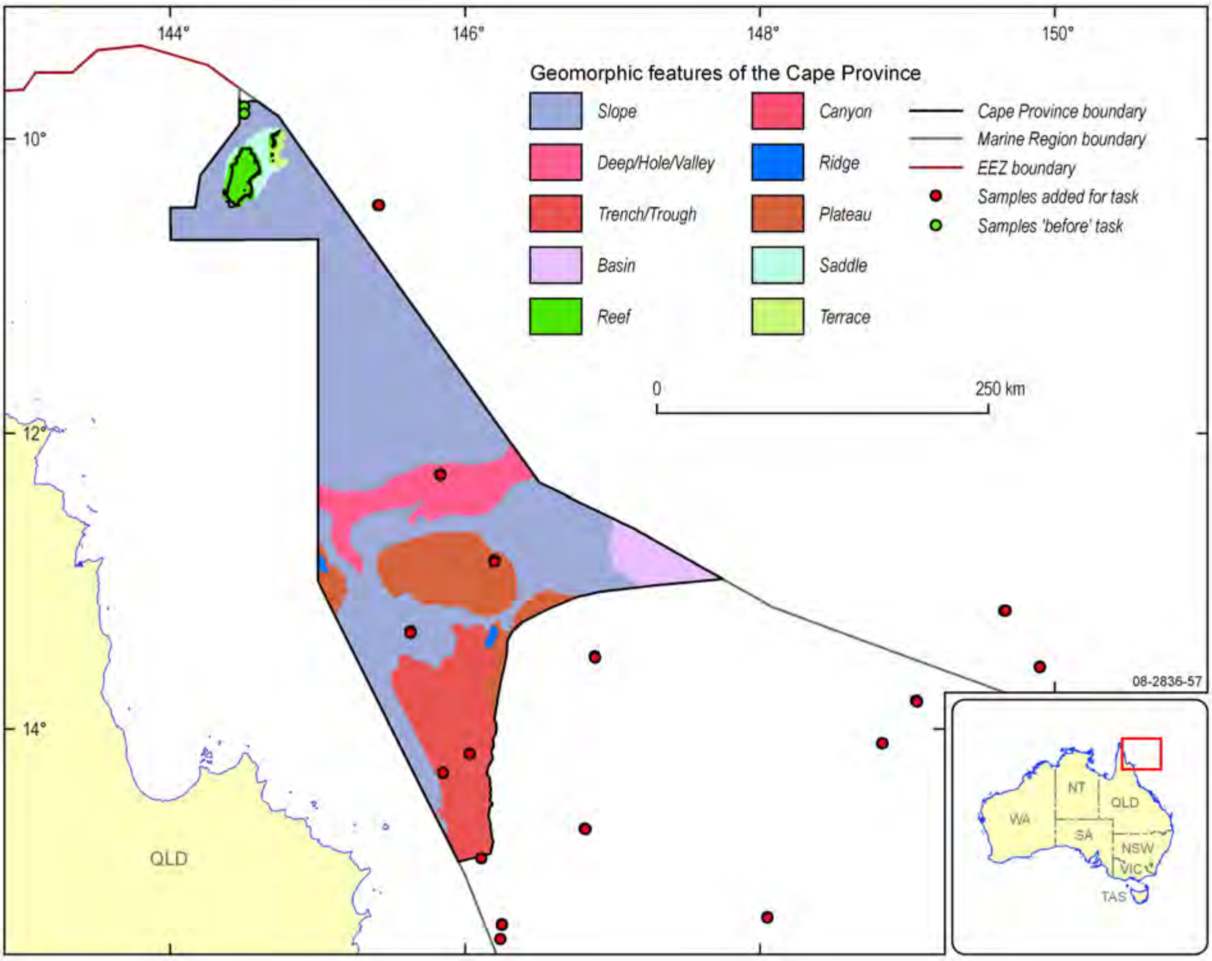
Slope (unassigned), plateau, trench/trough, deep/hole/valley, ridges and reefs are identified as significant features of the CP. Slope (unassigned), plateau and trench/trough features each cover a significant portion (>10,000 km^2 or >10%) of the bioregion. Deep/hole/valleys cover around 8% of the bioregion and this area represents 26% of the total area of deep/hole/valleys in the EMR. While the area of ridge features within the CP occupies <1% of the bioregion, this represents >15% of total area of ridges within the EMR. A large area of reef (950 km^2) is located in the north of the bioregion and includes Ashmore and Boot Reefs. While these reefs have been little explored they are situated to the east of the Great Barrier Reef and may have significant biological importance for the CP.

Water depths in the CP range from 0 – 4,230 m (Table 5.7). More than 90% of the CP occurs in water depths of 1000 – 4000 m (Fig. 5.17). Water depths on the shelf range from 105 – 135 m, with an average depth of 120 m, and on the slope range from 0 – 4,025 m, with an average depth of 2,475 m. Water depths in reefs on the slope average 190 m. Water depths on the abyssal plain/deep ocean floor range from 3,605 – 4,230 m, with an average depth of 4,055 m.

5.5.2. Sample Coverage

The CP contains eight data points with either quantitative textural and/or compositional data (Fig. 5.16.). These occur on the slope in water depths of 225 – 3,425 m. Samples provide adequate coverage for unassigned slope, trench/trough, plateau and deep/hole/valley features. No data are available for East Field Reef, or ridge and plateau features. Quantitative assessment of the sedimentology of significant features within the CP is limited by poor sample coverage of all features except unassigned slope.

a)


Geomorphic features of the Cape Province
Slope
Deep/Hole/Valley
Trench/Trough
Basin
Reef
Canyon
Ridge
Plateau
Saddle
Terrace
Cape Province boundary
Marine Region boundary
EEZ boundary
Samples added for task
Samples 'before' task
0
250 km
144°
146°
148°
150°
10°
12°
14°
QLD
08-2836-57
NT
QLD
WA
SA
NSW
VIC
TAS

b)

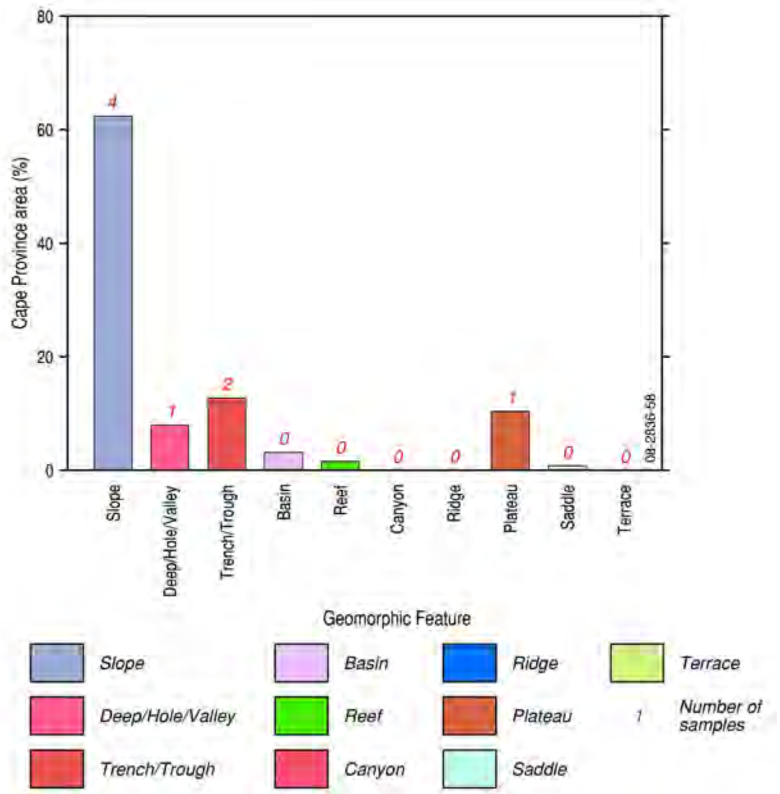


Figure 5.16. a) Geomorphology of the Cape Province (CP) with location of sediment samples; and b) Percentage area of each geomorphic feature within the CP with number of corresponding sediment samples (on top of columns).

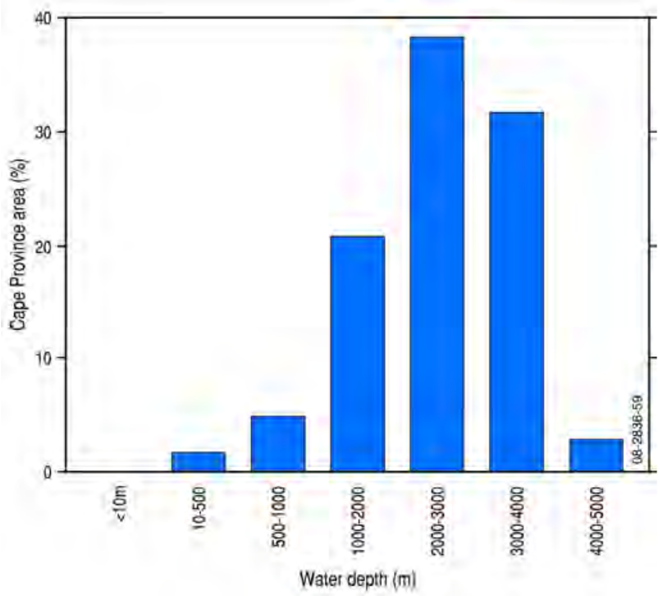


Figure 5.17. Distribution of water depth classes by percentage area within the CP.

Table 5.6. The percentage area of geomorphic units found in the CP.

Feature	% area of bioregion	% area of geomorphic unit within the EMR	% area of geomorphic unit within the EEZ
Geomorphic Province			
Shelf	0.12	0.91	<0.01
Slope	96.54	3.28	1.59
AP/DOF	3.35	0.43	0.09
Geomorphic Feature			
Slope (unassigned)	62.57	17.64	2.85
Basin	3.35	0.57	0.31
Canyon	0.02	0.10	0.01
Deep/hole/valley	7.84	26.31	9.73
Plateau	10.32	0.63	0.43
Reef	1.53	5.14	2.21
Ridge	0.27	15.20	0.15
Saddle	0.92	0.61	0.39
Terrace	0.29	0.31	0.03
Trench/trough	12.71	9.65	4.56

Table 5.7. The water depth of geomorphic units in the Cape Province.

Feature	Depth Range (m)	Mean Depth (m)
Geomorphic Province		
Shelf	105 – 135	120
Slope	0 – 4,025	2,475
AP/DOF*	3,605 – 4,230	4,055
Geomorphic Feature		
Slope (unassigned)	0 – 4,025	2,310
Deep/hole/valley	105 – 3,695	3,370
Trench/trough	2,115 – 3,065	2,810
Basin	3,605 – 4,230	4,055
Reef	0 – 1,060	190
Canyon	2,120 – 2,315	2,225
Ridge	2,200 – 2,965	2,725
Terrace	40 – 1,360	830
Plateau	2,180 – 3,190	2,880
Saddle	350 – 1,355	945

5.5.3. Quantitative sediment distribution for the Cape Province

Six samples with grainsize data and eight with bulk carbonate data occur in the CP. Sediment texture is relatively fine and carbonate content relatively low compared to other offshore bioregions in the EMR. Mud content ranges from 56 - 95% and sand from 5 - 44%. Gravel comprises <1% in all samples.

Bulk carbonate content ranges from 45 - 85%. Six assays are available for the mud size fraction and two assays are available for the sand size fraction. The carbonate content of the mud fraction ranges from 47 - 84%, and the sand fraction from 79 - 90%. Gravel did not occur in adequate volumes to analyse for carbonate content.

5.5.4. Sedimentology of Significant Geomorphic Features

5.5.4.1. Slope (unassigned)

A total of four samples were obtained from slope (unassigned) within the CP. These are characterised by relatively homogeneous sediment dominated by carbonate mud. All of these samples contain 56 – 95% mud, 5 – 43% sand, and <1% gravel (Fig. 5.18). Bulk carbonate content ranges from 49 – 85% (Fig. 5.19). Carbonate content is highest in the mud fraction where it ranges from 48 – 85%. Four carbonate mud and two carbonate sand assays are available and these range from 48 – 95% and 80 – 90% respectively.

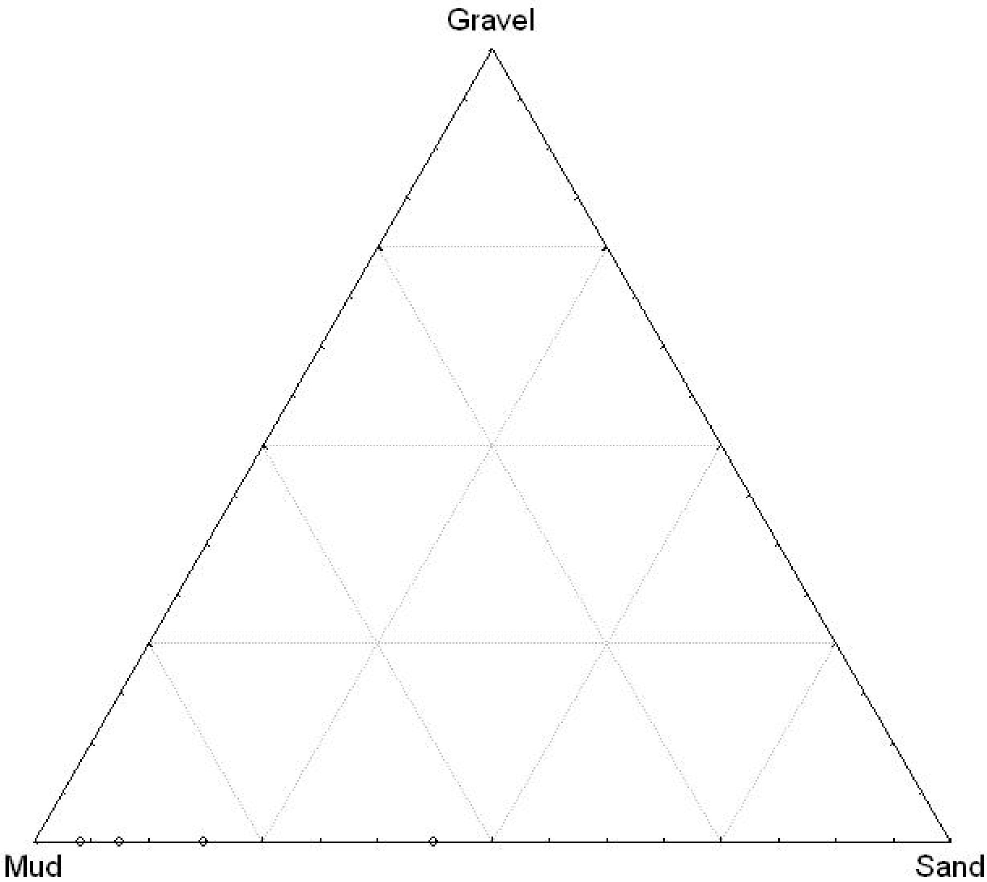


Figure 5.18. Textural composition (mud:sand:gravel ratio) of slope sediments within the CP.

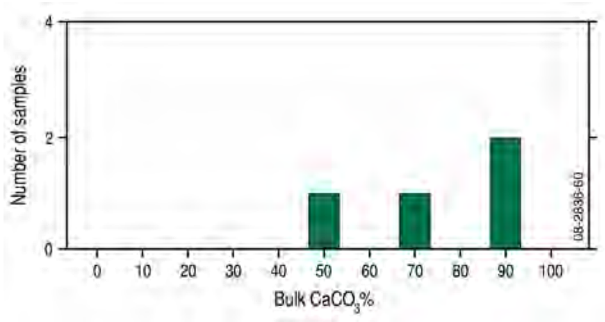


Figure 5.19. Carbonate content of slope sediments within the CP.

5.6. CENTRAL EASTERN PROVINCE (CEP)

5.6.1. Geomorphology and bathymetry

The CEP covers an area of 233,816 km² which represents 10% of the EMR (Table 5.1). The CEP is located offshore between North Stradbroke Island and Ulladulla and shares a boundary with seven other bioregions including the KT and CET to the north, the TBP to the east, the SET and SEST to the south and the CEST and CESP to the west.

The CEP is located predominantly on the slope and abyssal plain/deep ocean floor. Seven geomorphic feature types occur in this area including canyons (3,820 km², 2% of CEP area); terraces (1,140 km², <1%); pinnacles (860 km², <1%); knolls/abyssal hill/hill/mountain/peaks (62 km², <1%); and bank/shoals (3 km², <1%) (Fig. 5.20.; Table 5.8.) No geomorphic features are identified on 60,260 km² of the slope and 169,542 km² of the abyssal plain/deep ocean floor. These represent 26% and 72% of the CEP respectively. Pinnacles occur clustered on the upper slope adjacent to Yamba and also scattered across the abyssal plain/deep ocean floor. A series of canyons extend from the upper slope to the abyssal plain/deep ocean floor and are oriented broadly orthogonal to the coast. Elongate shallow water terraces run parallel to the coast on the upper slope. These are similar to terraces in the CEST and CESP.

Five significant geomorphic features are located within the CEP. These include, slope (unassigned), abyssal plain/deep ocean floor (unassigned), canyons, pinnacles and shallow water terraces. Although pinnacles and canyons constitute only <1% and <2% the total area of the CEP, respectively, they represent 17% and 4% of the total area of these features in the EMR. Sample coverage is adequate to assess the sedimentology of the slope (unassigned), abyssal plain/deep ocean floor (unassigned), and shallow water terraces.

Water depths in the CEP range from 130 – 5,170 m (Table 5.9.). Around 80% of the area of the CEP occurs in water depths between 4,000 – 5,000 m (Figure 5.21.). Water depths on the slope range from 40 - 5,025 m, with an average depth of 2,655m. Water depths on the abyssal plain/deep ocean floor range from 3,740 – 5,175 m, with an average depth of 4,775 m. Terraces are located in water depths of 165–780 m and banks/shoals in depths of 200 – 190 m. Pinnacles on the upper slope occur in water depths of 200-400 m and pinnacles on the abyssal plain/deep ocean floor in water depths >4,000 m.

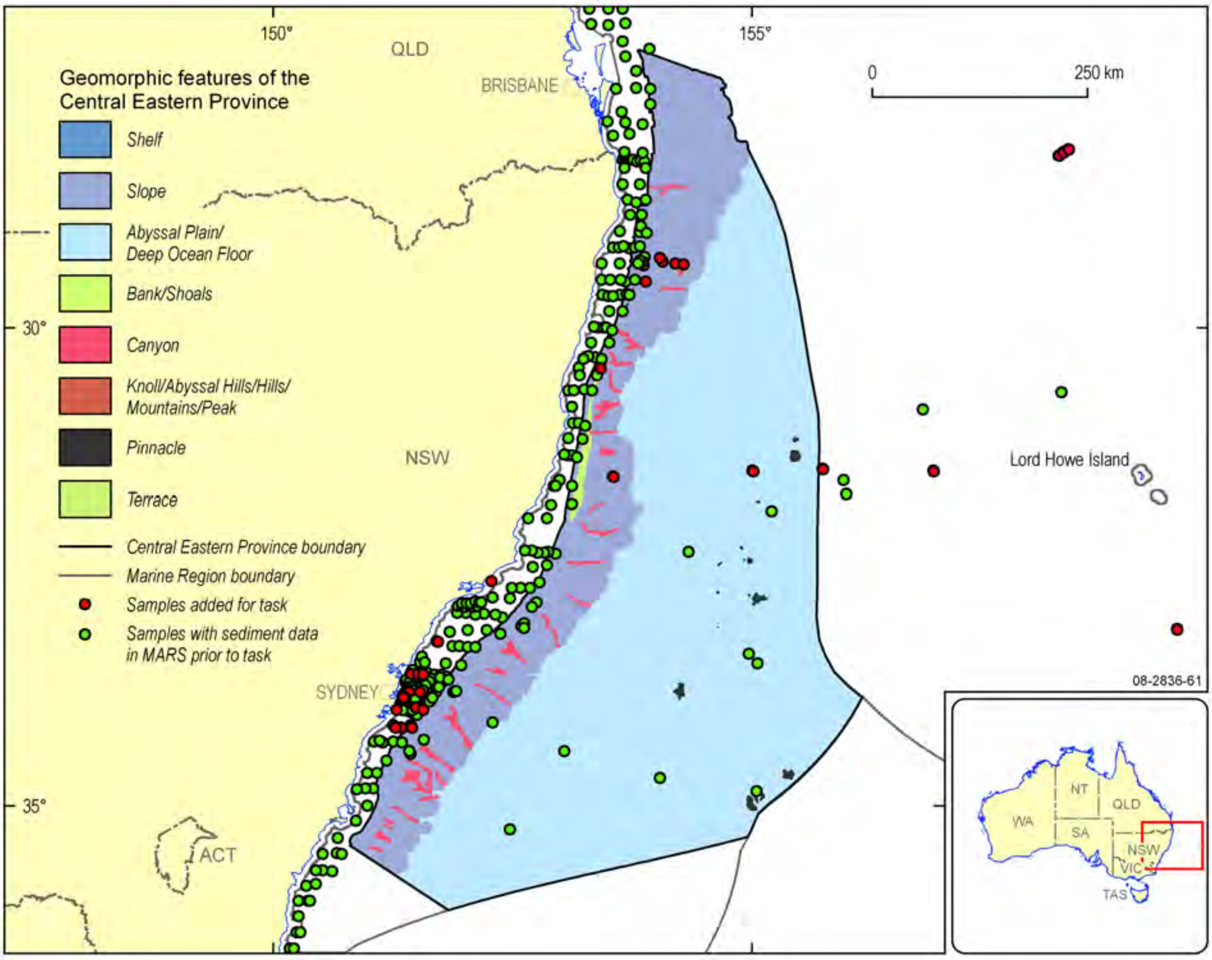
5.6.2. Sample Coverage

The CEP contains 86 samples with either quantitative textural and/or compositional data. Seventy-one of these (83%) are located on the upper slope adjacent to the CESP and CEST. Ten (12%) samples occur on the abyssal plain/deep ocean floor and 3 (3%) on terraces.

Average sample density in the CEP is 1:2,750 km². Samples achieve sufficient coverage to quantitatively describe the sedimentology of: terraces, slope (unassigned), and abyssal plain/deep ocean floor (unassigned). The majority of samples are clustered on the upper slope, meaning that statistics for the whole bioregion are likely to mainly represent sediments present on the slope and not necessarily represent sediments present on the abyssal plain/deep ocean floor.

A total of 10 samples were added to this bioregion for this study, increasing coverage for slope (8), terrace (1), and abyssal plain/deep ocean floor (1). Despite targeted sample addition, sample coverage remains inadequate to quantitatively assess the sedimentology in bank/shoal, canyon, knoll/abyssal hill/hill/mountain/peak and pinnacle features in the CEP.

a)



b)

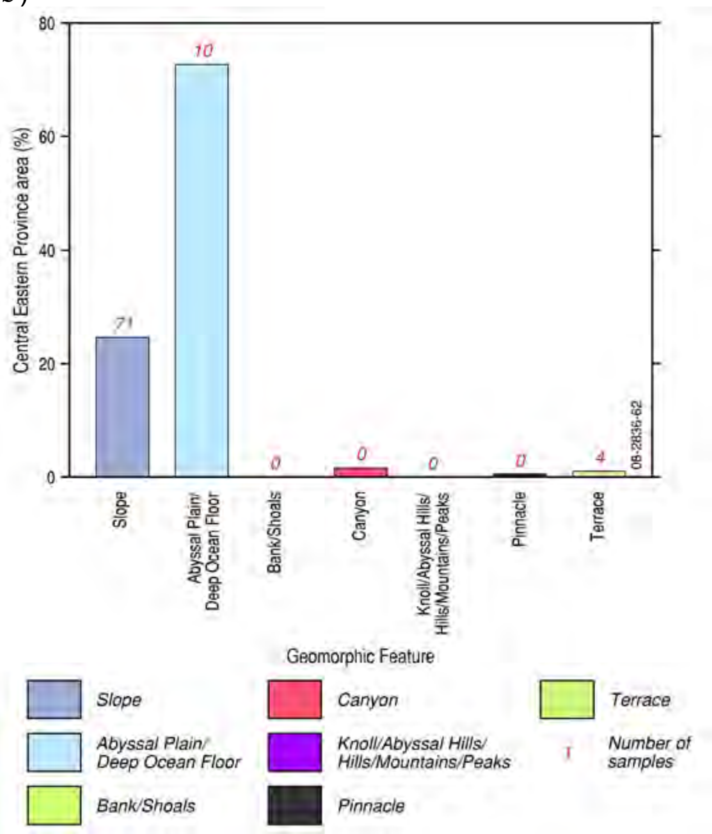


Figure 5.20. a) Geomorphology of the Central Eastern Province (CEP) with location of sediment samples; and b) Percentage area of each geomorphic feature within the CEP with number of corresponding sediment samples (on top of columns).

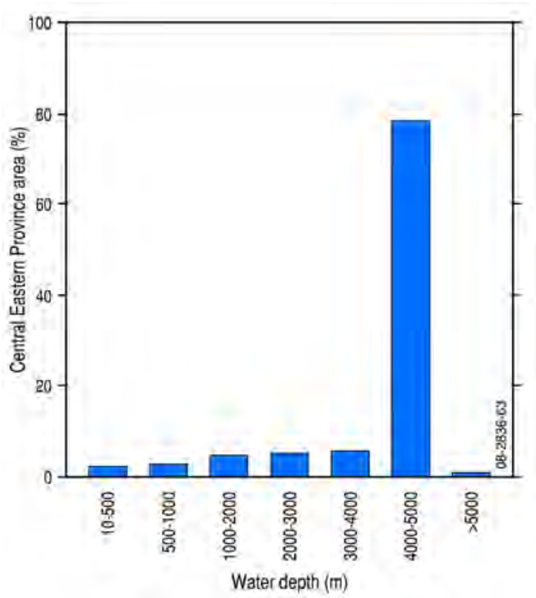


Figure 5.21. Distribution of water depth classes by percentage area within the CEP.

Table 5.8. The percentage area of geomorphic units found in the Central Eastern Province.

Feature	% area of bioregion	% area of geomorphic unit within the EMR	% area of geomorphic unit within the EEZ
Geomorphic Province			
Slope	27.11	3.45	1.67
AP/DOF	72.87	35.08	7.07
Geomorphic Feature			
Slope (unassigned)	24.54	25.87	4.18
AP/DOF (unassigned)	72.51	45.81	6.88
Bank/shoals	<0.01	0.43	<0.01
Canyon	1.66	39.41	3.63
Knoll/abyssal hills/mountains/peak	0.03	0.64	0.05
Pinnacle	0.37	34.96	16.82
Terrace	0.88	3.52	0.35

Table 5.9. The water depth of geomorphic units found in the Central Eastern Province.

Feature	Depth Range (m)	Mean Depth (m)
Geomorphic Province		
Shelf	155 – 170	160
Slope	40 – 5,025	2,600
AP/DOP	3710 – 5,175	4,775
Geomorphic Feature		
Shelf (unassigned)	155 – 170	160
Slope (unassigned)	40 – 5,025	2,655
AP/DOF	3740 – 5,175	4,775
Bank/shoals	200 – 290	240
Canyon	195 – 4,885	2,965
Knoll/abyssal hills/mountains/peak	3135 – 4,235	3,675
Pinnacle	150 – 4,940	4,360
Terrace	165 – 780	330

5.6.3. Sedimentology of the Central Eastern Province

A total of 64 grain size and carbonate assays occur in the CEP. Sediment texture is variable with higher gravel content present in sediments located to the north of Hawks Nest. Mud content ranges from 0 – 97% but is <75% in 56 (88%) samples. Areas with the highest mud content are located on the lower slope and abyssal plain/deep ocean floor. Sand content ranges from 3 – 100% and is most dominant on the upper slope. Sand exceeds 60% in 40 (63%) samples and exceeds 90% in 17 (27%) samples. Gravel content ranges from 0 – 64%, although 58 (90%) samples contain <5% gravel.

Bulk carbonate content of samples ranges from 0 - 88% and exceeds 40% in 49 (77%) samples. The carbonate content of the mud and sand fractions were assessed for eight samples and these contain 21 - 88% and 0 – 85% carbonate respectively. The carbonate content of gravel was assessed for three samples, giving a range of 20 – 100%. Carbonate contents are lower (generally <50%) in samples with high mud content, suggesting carbonate content of the mud tends to be lower than that of sand in this area.

5.6.4. Sedimentology of Significant Geomorphic Features

5.6.4.1. Slope (unassigned)

A total of 71 samples were obtained from the slope (unassigned). Sixty of these samples have grain size data and fifty have carbonate data. Sand is the dominant fraction with contents ranging from 3 - 100% and exceeding 50% in 41 (69%) samples (Fig. 5.22). Mud is the next most abundant fraction with contents generally ranging from 5 - 97%, although 43 (72%) samples contain <50% and no mud is present in 15 (25%) samples. Gravel content is generally low and ranges from 0 – 63%, with 54 (90%) samples containing >5% gravel content. Bulk carbonate content ranges from 21 - 89% and is between 30 – 60% in 35 (70%) samples (Fig. 5.23). Carbonate content of mud was assessed for six samples and ranges from 33 – 88%. Carbonate content of sand was assessed for four samples and ranges from 59 - 85%. Two carbonate gravel assays are present and these equal 20% and 95% carbonate content.

5.6.4.2. Abyssal plain/deep ocean floor

A total of ten samples occur on the abyssal plain/deep ocean floor in the CEP. Grainsize data are available for only 1 sample (95% mud, 5% sand). Bulk carbonate content was assessed for all 10 samples, and ranges from 5 – 42% (Fig. 5.23.). Data is available for the carbonate content of mud fraction for one sample and this equals 22%. Low sample density in this area means that data may not adequately represent the range and relative proportions of sedimentary environments present on the abyssal plains/deep ocean floor in the CEP.

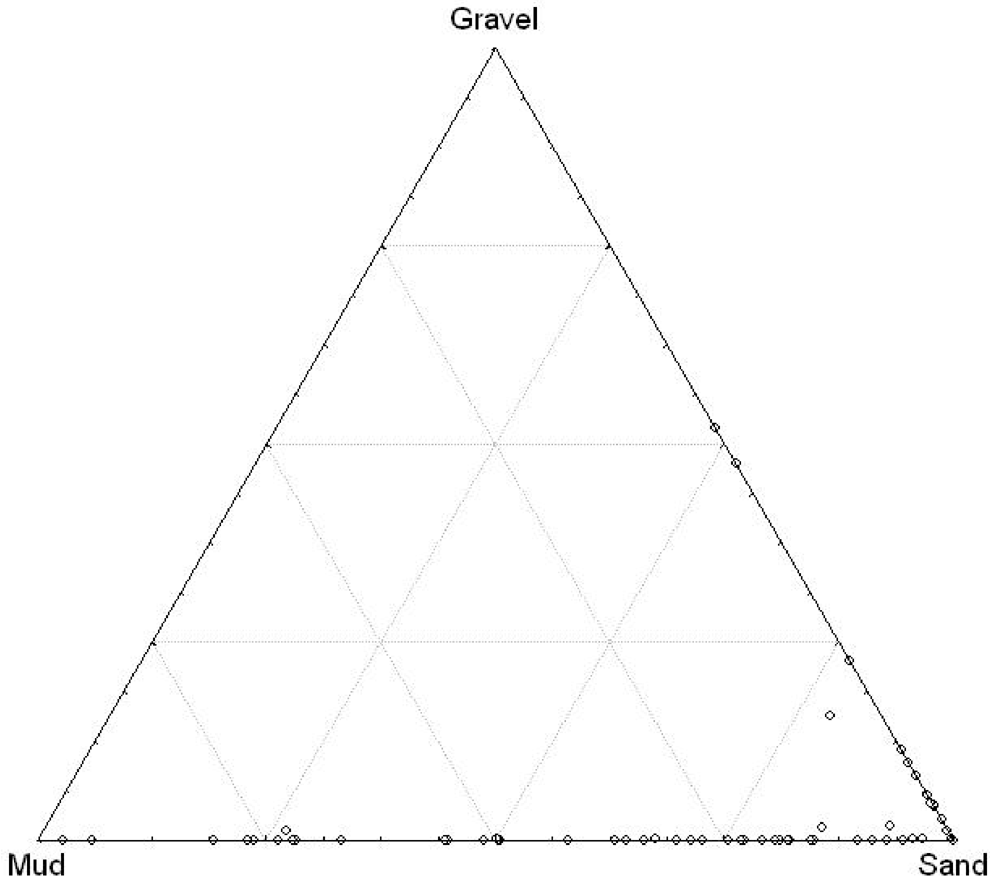


Figure 5.22. Textural composition (mud:sand:gravel ratio) of slope sediments within the CEP.

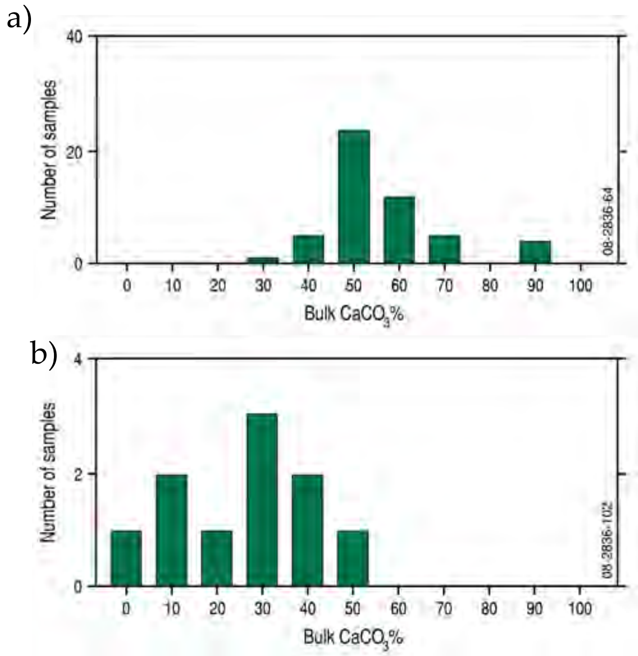


Figure 5.23. Carbonate content of a) slope; and b) abyssal plain/deep ocean floor sediments within the CEP.

5.7. CENTRAL EASTERN TRANSITION (CET)

5.7.1. Geomorphology and bathymetry

The Central Eastern Transition (CET) covers an area of 67,150 km^2 of which 44,840 km^2 (67%) occurs in the EMR (Fig. 5.1). This bioregion represents 2% of the total area of the EMR (Table 5.1). The CET is situated on the slope and rise to the east of Fraser Island, and to the southeast of the Great Barrier Reef Marine Park (Fig 5.24; Table 5.10). It shares a boundary with four bioregions including the NEP to the north, KT to the east, CEP to the south and CEST to the west.

The CET is dominated by slope (35,205 km^2 or 79%) and contains a small area of rise (9,633 km^2 or 21%). Two geomorphic features types are identified within the slope: canyons 597 km^2 (1%); and terraces 8,775 km^2 (20%). A total of 25,834 km^2 (58%) of the bioregion is unassigned slope. No features are identified within the area of the rise. Slope (unassigned); rise; canyons; and terraces are identified as significant geomorphic features. The rise within the CET occurs to the east of the bioregion and separates the slope from the abyssal plain/deep ocean floor and represents the second largest area of rise in the EMR. A large terrace borders the western boundary of the CET and a series of canyons cut the slope.

Water depths in the CET range from 110 – 4,735 m with an average depth of 2,110 m. Water depths on the slope range from 80 – 1,740 m (average 1,910 m) and on the rise range from 2,775 – 4,650 m (average 4,030 m). Terraces occur in the shallower areas of the CET, with water depths ranging from 80 – 880 m (average 420 m). Water depths are relatively evenly distributed over the CET (Fig. 5.25).

5.7.2. Sample Coverage

The CET contains 35 samples with either quantitative textural and/or compositional data (Figs. 5.24). The average sample density in the bioregion is 1:1,281 km^2. A total of 16 samples are located on the slope (unassigned) and 19 on terraces. All but one sample occur in water depths of 165 – 450 m. One sample is located on the slope to the north of the bioregion in 1,845 m water depth. Four samples were added to the CET during this task. These improve coverage of terraces on the upper slope.

Sample density is sufficient to describe the sedimentology on the slope (unassigned) and terraces. Despite targeted sample selection, no samples are available for rise and canyons features.

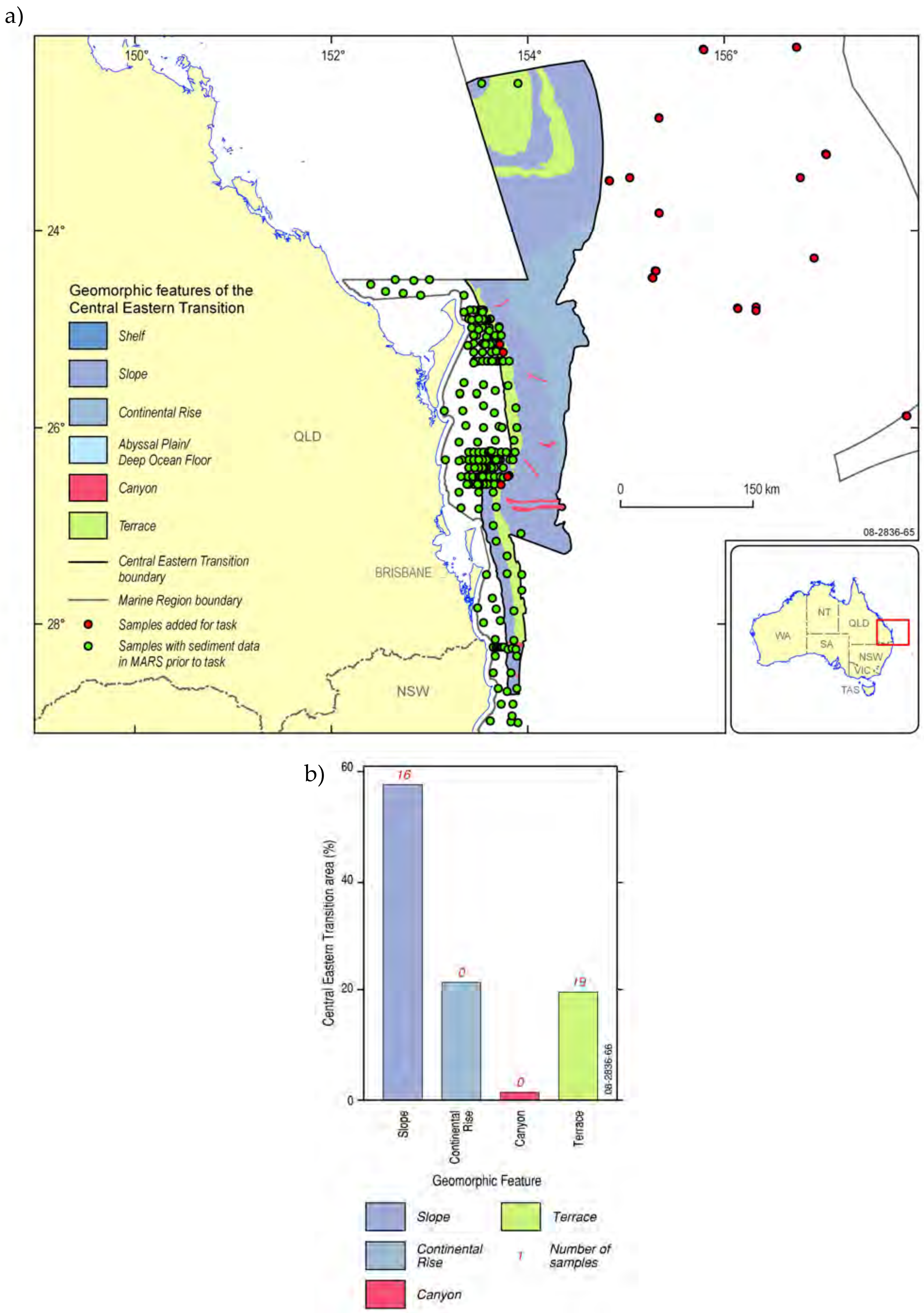


Figure 5.24. a) Geomorphology of the Central Eastern Transition (CET) with location of sediment samples; and b) Percentage area of each geomorphic feature within the CET with number of corresponding sediment samples (on top of columns).

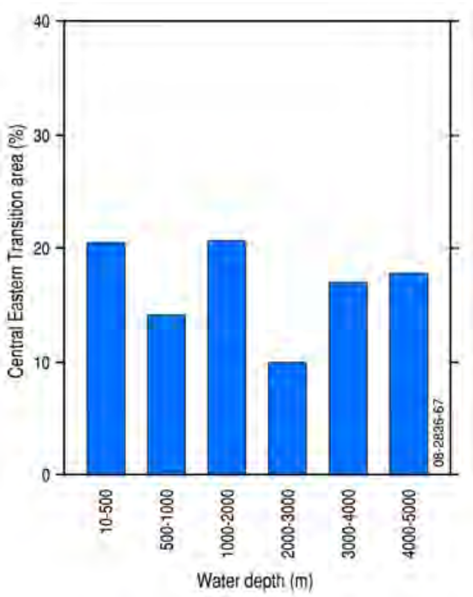


Figure 5.25. Distribution of water depth classes by percentage area within the CET.

Table 5.10. The percentage area of geomorphic units found in the Central Eastern Transition.

Feature	% of bioregion area covered	% of EMR area this unit lies within this bioregion	% of EEZ area this unit lies within this bioregion
Geomorphic Province			
Slope	80.94	1.92	0.93
Rise	19.06	31.66	9.55
Geomorphic Feature			
Slope (unassigned)	57.29	11.65	1.88
Rise (unassigned)	19.06	33.01	10.06
Canyon	1.34	6.08	0.56
Terrace	22.31	15.04	1.51

Table 5.11. The water depth of geomorphic units found in the Central Eastern Transition.

Feature	Depth Range (m)	Mean Depth (m)
Geomorphic Province		
Slope	80 – 4,735	1,565
Rise	2,775 – 4,650	4,025
Geomorphic Feature		
Slope (unassigned)	120 – 4,735	1,910
Rise (unassigned)	2,775 – 4,650	4,025
Canyon	1,205 – 4,715	3,415
Terrace	80 – 885	420

5.7.3. Sedimentology of the Central Eastern Transition

The CET contains 12 grainsize and 35 carbonate assays. Sediment in the CET is relatively homogenous and dominated by sand. Sand content ranges from 65 -100% and exceeds 60% in 11 (92%) of samples and exceeds 90% in six (50%) samples. Mud content ranges from 0 – 35%, although eight (67%) samples contain <10% mud. Gravel content ranges from 0 – 100% however ten (83%) samples contain <10% gravel.

Carbonate content of sediment does not show any clear spatial relationship to geomorphology or bathymetry within this bioregion. Bulk carbonate content ranges from 46 - 96% and exceeds 60% in 32 (91%) samples and exceeds 90% in 11 (31%) samples. Few carbonate assays are available for textural size fractions however, those present indicate carbonate content of mud is approximately 55% (two samples), carbonate content of sand ranges from 52 - 81% (five samples) and carbonate content of gravel is 100% (two samples).

5.7.4. Sedimentology of Significant Geomorphic Features

5.7.4.1. Slope (unassigned)

A total of 16 samples were obtained from the slope (unassigned). Textural data is available for two samples. Sand is the dominant size fraction with contents ranging from 93 - 98% (Fig. 5.26), with the remainder of sediment composed of gravel. Bulk carbonate content was assessed for all samples and ranges from 46 - 96% and exceeds 75% in 13 (81%) of samples (Fig. 5.27). Carbonate content was not assessed for the mud, sand and gravel fractions.

5.7.4.2. Terraces

A total of 19 samples were obtained from terraces. Carbonate assays are available for all of these samples and grain size assays are available for ten samples. Sand is the dominant size fraction and ranges from 0 - 100% with eight (80%) samples exceeding 80% sand (Fig. 5.26). Gravel is the next most abundant fraction and ranges from 1 - 16%, excluding one outlier sample composed of 100% gravel. Mud ranges from 0 – 35% with five (50%) samples containing no mud. The remaining five (50%) samples contain 6 – 35% mud. Bulk carbonate content ranges from 49 - 95% and exceeds 75% in 11 (58%) of samples (Fig. 5.27). Carbonate content of sand was assessed for five samples and ranges from 52 - 81%. Carbonate content of mud was assessed for two samples and ranges from 50 - 55%. Where assessed, gravel was composed entirely of carbonate.

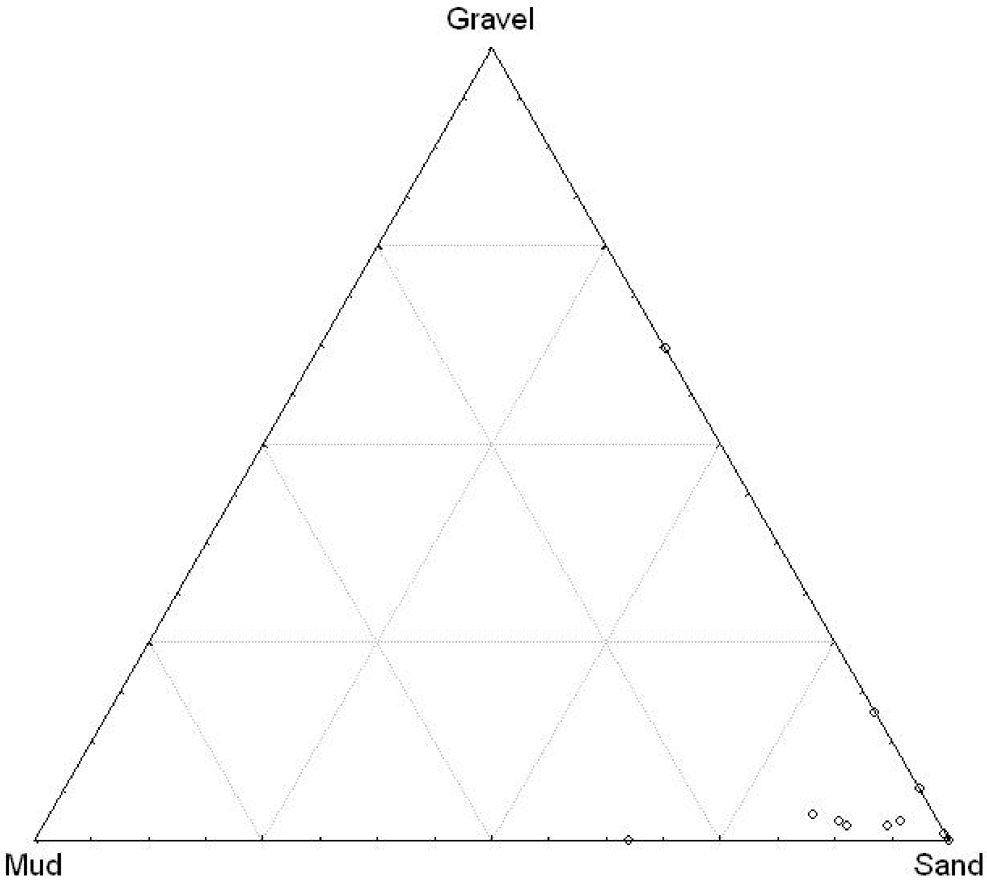


Figure 5.26. Textural composition (mud:sand:gravel ratio) of terrace sediments within the CET.

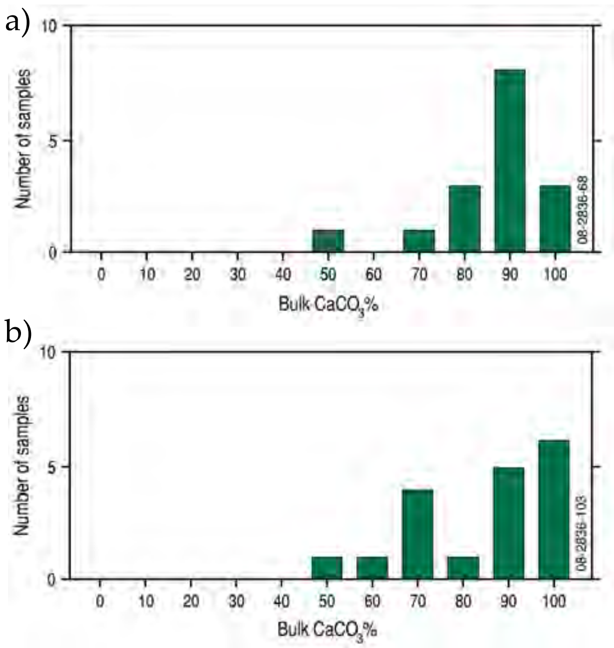


Figure 5.27. Carbonate content of: a) slope; and b) terrace sediments within the CET.

5.8. KENN PROVINCE (KP)

5.8.1. Geomorphology and bathymetry

The Kenn Province (KP) covers 57,419 km^2 or 2% of the total area of the EMR (Table 5.1). The KP is situated on the Kenn Plateau which is located at the junction of the Coral and Tasman Seas and occupies the eastern portion of the EMR. The KP is bounded by the KT to the north, west and south, and extends to the EEZ boundary in the east.

The Kenn Plateau covers a total area of 55,580 km^2 or 97% of the KP. Three additional geomorphic features also occur within the KP. These include, seamount/guyots (1,730 km^2, 3% of total KP area), basins (60 km^2, <1%) and pinnacles (16 km^2, <1%) (Fig. 5.28 & Table 5.12). Three seamounts/guyots and two pinnacles are located on the Kenn Plateau. The KP includes a small area of a larger basin that occurs to the west of the bioregion boundary. Seamount/guyots and plateaus are identified as significant features of the KP.

Water depths in the KP range from 0 – 3,190 m with an average depth of 1,890 m (Table 5.13). Around 95% of the total area of the KP occurs in water depths of between 1,000 - 3,000 m (Fig. 5.29). Seamounts/guyots occur in relatively shallow areas of the bioregion, with water depths from the base to summit of these features ranging from 0 – 1,880 m (average 645 m). Pinnacles occur in average water depths of 1,640 m. Water depths in the area of the Kenn Plateau within the KP range from 100 – 3,190 m. Water depths in the area of the basin within the KP average 3,170 m.

5.8.2. Sample Coverage

The KP contains six sediment samples that have quantitative textural and compositional data; all of these samples were collected and procured for the task (Fig. 5.28.). Samples are unevenly distributed, with the majority located in the northern section of the province. All samples occur at water depths of 726 – 2,210 m and give an average density of 1:9,570 km^2 for the bioregion. While sample density of the region is low, the predominant geomorphic feature within the bioregion (the Kenn Plateau) contains adequate data points to assess sedimentology of this feature (average sample density 1:9,570 km^2). Pinnacles and seamounts/guyots are considered significant features of the KP but contain inadequate data points to quantitatively assess sedimentology in these areas.

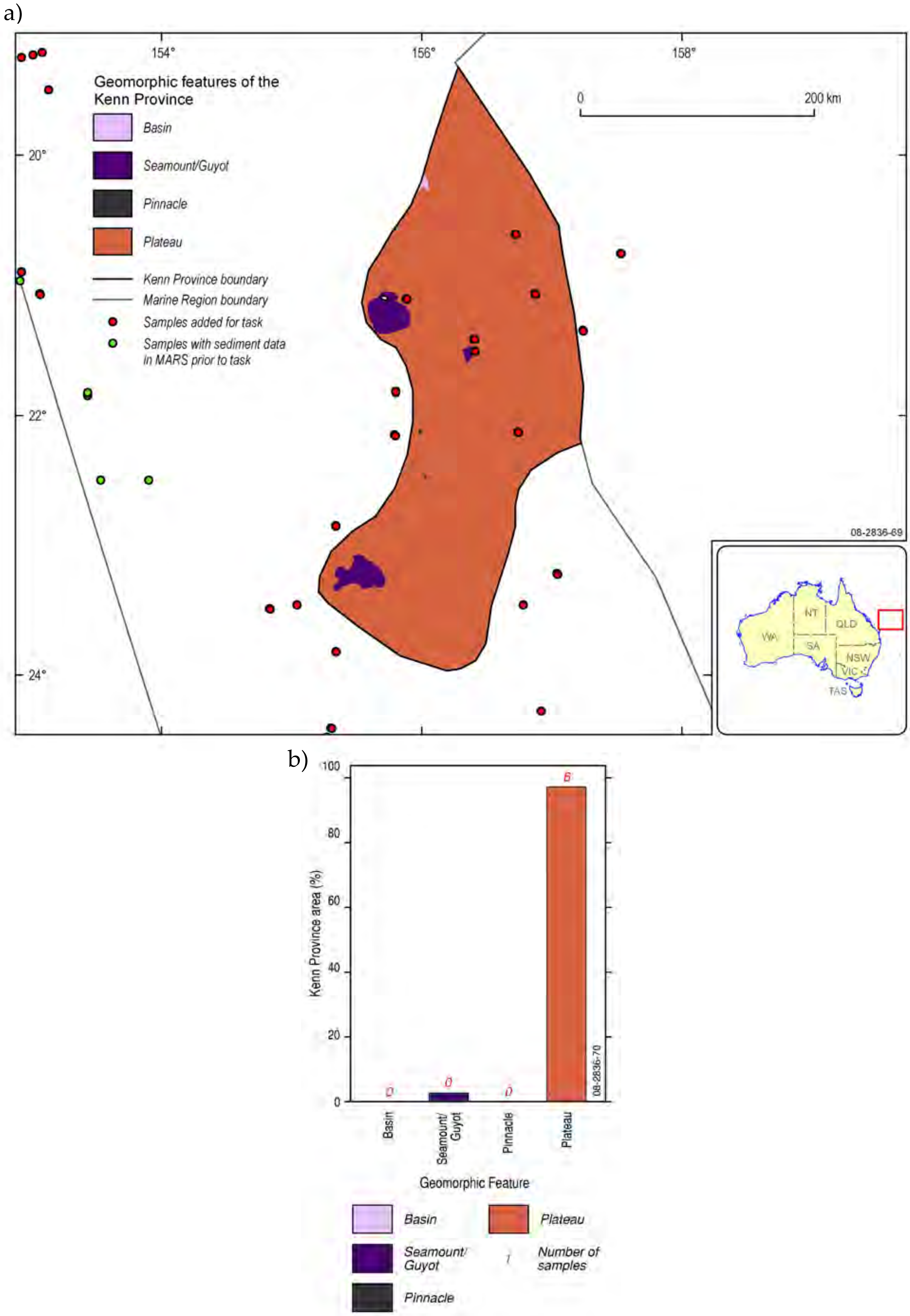


Figure 5.28. a) Geomorphology of the Kenn Province (KP) with location of sediment samples; and b) Percentage area of each geomorphic feature within the KP with number of corresponding sediment samples (on top of columns).

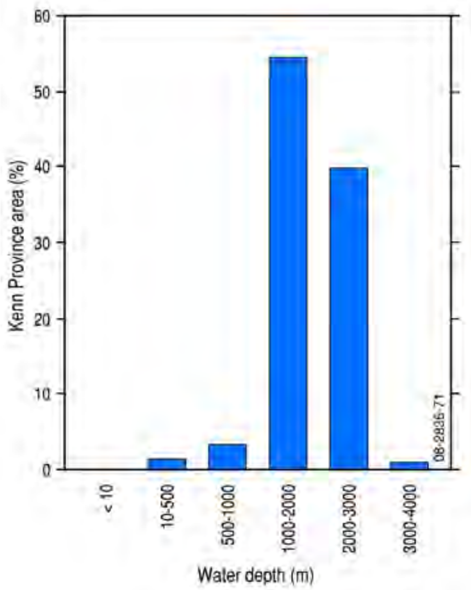


Figure 5.29. Distribution of water depth classes by percentage area within the KP.

Table 5.12. The percentage area of geomorphic units found in the Kenn Province.

Feature	% of bioregion area covered	% of EMR area this unit lies within this bioregion	% of EEZ area this unit lies within this bioregion
Geomorphic Province			
Slope	100	3.12	1.51
Geomorphic Feature			
Basin	0.11	0.02	0.01
Pinnacle	0.03	0.67	0.32
Plateau	96.85	5.41	3.72
Seamount/guyot	3.02	4.14	1.73

Table 5.13. The water depth of geomorphic units found in the Kenn Province.

Feature	Depth Range (m)	Mean Depth (m)
Geomorphic Province		
Slope	0 – 3,190	1,890
Geomorphic Feature		
Basin	3,025 – 3,190	3,170
Seamount/guyot	30 – 1,880	645
Pinnacle	1,570 – 1,710	1,640
Plateau	100 – 3,190	1,930

5.8.3. Quantitative sediment distribution for the Kenn Province

The KP contains six grain size and carbonate assays. Sediments in this area show variable textural properties. Mud is the dominant size fraction and ranges from 17 – 71%. Sand content is less variable and ranges from 29 – 60% in all samples. Gravel content ranges from 0 – 27%, although four (67%) samples contain <20% gravel.

Bulk carbonate content ranges from 74 - 91%, and exceeds 85% in five (83%) samples. Samples with highest bulk carbonate content correspond to those with lowest mud contents (Fig. 5.30). Samples with lower bulk carbonate contents (<85%) generally occur on the plateau and adjacent to seamounts/guyots where samples have significant mud fractions (generally >60%). Carbonate content of sand ranges from 84 - 95% and exceeds 90% in five (83%) samples (Fig. 5.31). Carbonate content of mud ranges from 86 - 89% and is highest in the centre of the Kenn Plateau. Carbonate content of gravel ranges from 10 - 80% but is <50% in all but one sample.

5.8.4. Sedimentology of significant geomorphic features

5.8.4.1. Plateau

As all of the samples were collected from plateau within the KP, the description of the sediment distribution is in Section 5.7.3. The grain size distribution and bulk carbonate content of these samples are shown below (Figs. 5.30 & 5.31).

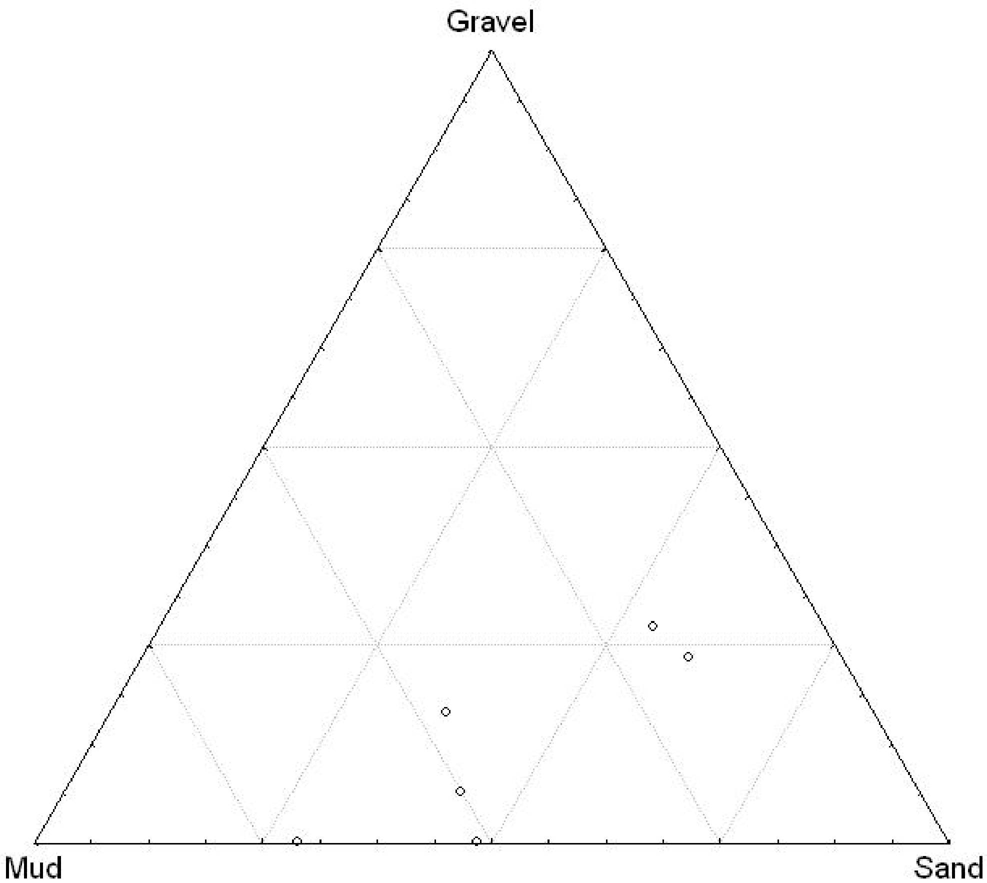


Figure 5.30. Textural composition (mud:sand:gravel ratio) of plateau sediments within the KP.

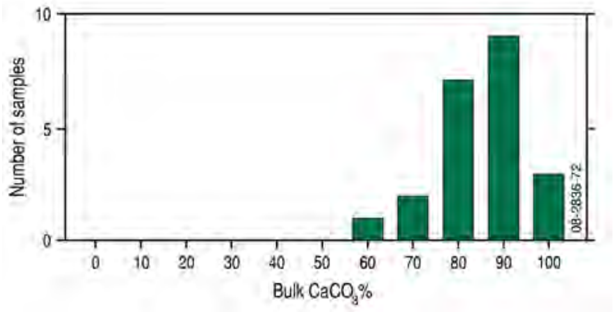


Figure 5.31. Carbonate content of plateau sediments within the KP.

5.9. KENN TRANSITION (KT)

5.9.1. Geomorphology and bathymetry

The Kenn Transition (KT) covers an area of 377,130 km² or 15% of the EMR (Table 5.1). The KT occurs mainly on the lower slope and abyssal plain/deep ocean floor offshore between Cooktown and North Stradbroke Island. The KT is bounded to the west by the NEP and the CET, to the south by the TBP and extends to the EEZ boundary in the east.

The KT includes areas of slope (242,026 km² or 64% of total KT area); rise (5,378 km² or 1%); and abyssal plain/deep ocean floor (64,988 km² or 17%)(Table 5.14). Paucity of data has prevented geomorphology from being interpreted for an area of approximately 64,740 km² (17%) in the east of the KT. Fourteen geomorphic features are identified in the KT: deep/hole/valley (13,010 km², 3%); basin (43,580 km², 12%); canyon (105 km², >1%); knoll/abyssal hills/hills/mountains/peak (593 km², >1%); seamount/guyot (10,569 km², 3%); pinnacle (167 km², >1%); saddle (32,113 km², 9%); apron/fan (365 km², >1%); and terrace (2,734 km², >1%). No features were identified for 3,315 km² (<1%) of the slope and 60,380 km² (93%) of the abyssal plain/deep ocean floor. Not features were identified on the rise (Fig. 5.32. & Table 5.14).

Eight significant geomorphic features are identified within the KT. These include abyssal plain/deep ocean floor (unassigned), rise (unassigned), plateaus, basins, saddles, deep/hole/valleys, seamount/guyots, and apron/fans. Rise (unassigned) in the KT represents 18% of total rise in the EMR. The Kenn Plateau is a large plateau situated in the centre of the bioregion and is a prominent physical feature of the KT representing 14% of the total area of plateaus within the EMR. A large basin, the Cato Trough, covers 43,640 km² (12%) of the KT and separates the northern from the southern area of the bioregion. This basin forms approximately 12% of the area of basins in the EMR, and approximately 7% of the area of this feature type in the EEZ. A series of large seamounts/guyots ranging in area from approximately 80 – 1,600 km² occur within the area of the plateau, basin and abyssal plain/deep ocean floor. These represent 25% of the total area of seamounts/guyots in the EMR, and 10% of the total area of this feature in the EEZ. Areas of abyssal plain/deep ocean floor and apron/fan within the KT are significant as they represent 16% and 14% respectively, of the total area of this feature found in the EMR. Saddles within the KT constitute 22% of all saddles found in the EEZ.

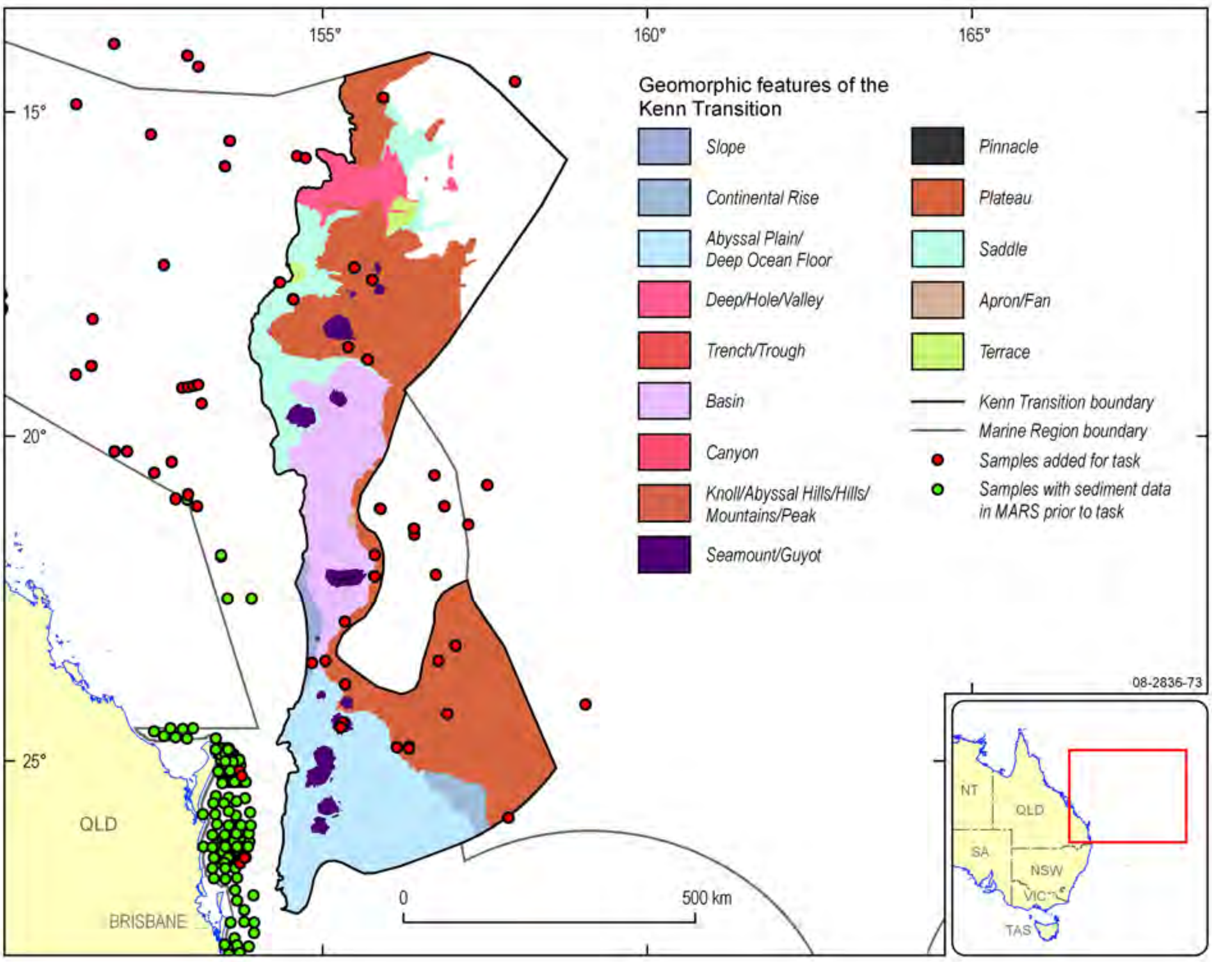
Water depths in the KT ranges from 0 – 4,890 m, with an average depth of 3,130 m (Table 5.15). Approximately 95% of the KT occurs in water depths of 2,000 – 5,000 m (Fig. 5.33). Water depth is greatest on the abyssal plain/deep ocean floor in the south of the bioregion, averaging 4,520 m. Water depths are shallowest on seamounts occurring on the Kenn Plateau in the north of the bioregion, with depths as shallow as 30 m.

5.9.2. Sample Coverage

The KT contains 20 sample points with quantitative textural and compositional data (Fig. 5.32). These samples occur on the slope (unassigned) (1 sample, 5%), on seamount/guyots on the abyssal plain/deep ocean floor (2, 10%), on plateaus (16, 80%), and saddles (1, 5%). Samples occur in water depths from 730 – 4,020 m, with 15 samples (75%) in depths >2,000 m.

Average sample density in the KT is 1:18,860 km². All samples in the KT were procured and analysed for this task, allowing the first quantitative assessment of sedimentology for this region. Samples achieve adequate coverage to assess the sedimentology of the Kenn Plateau only. Targeted sample collection resulted in addition of two samples from seamounts/guyots but data coverage remains inadequate to assess sedimentology in these features.

a)



b)

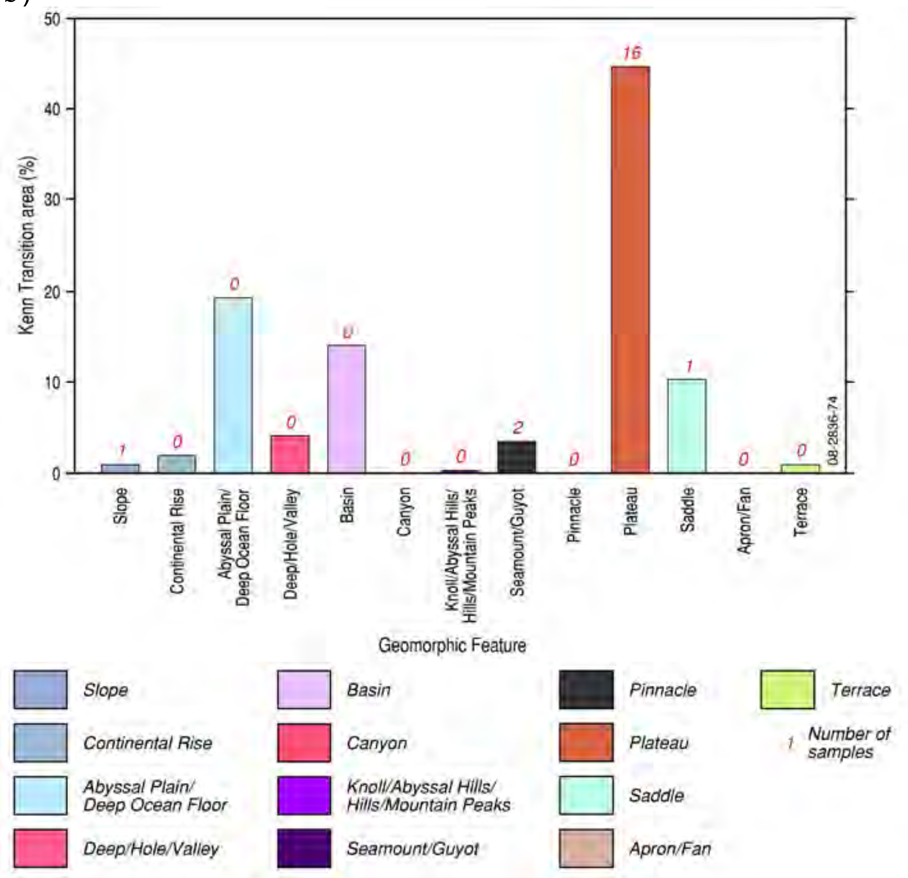


Figure 5.32. a) Geomorphology of the Kenn Transition (KT) with location of sediment samples; and b) Percentage area of each geomorphic feature within the KT with number of corresponding sediment samples (on top of columns).

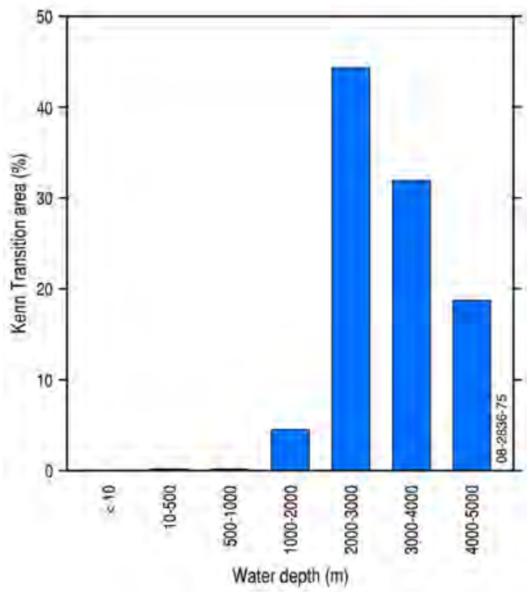


Figure 5.33. Distribution of water depth classes by percentage area within the KT.

Table 5.14. The percentage area of geomorphic units found in the Kenn Transition.

Feature	% of bioregion area covered	% of EMR area this unit lies within this bioregion	% of EEZ area this unit lies within this bioregion
Geomorphic Province			
Slope	64.18	13.17	6.37
Rise	1.42	17.67	5.33
AP/DOF	17.23	13.38	2.70
Geomorphic Feature			
Slope (unassigned)	0.88	1.49	0.24
Rise (unassigned)	1.42	18.43	5.61
AP/DOF (unassigned)	16.01	16.31	2.45
Deep/hole/valley	3.45	68.93	7.88
Basin	11.56	11.90	6.56
Canyon	0.03	1.08	0.10
Knoll/abyssal hills/hills/mountains/peak	0.16	6.12	0.50
Seamount/guyot	2.80	25.08	10.50
Pinnacle	0.04	6.75	3.25
Plateau	44.84	13.62	9.36
Saddle	8.52	33.94	21.93
Apron/fan	0.10	13.76	3.11
Terrace	0.72	4.69	0.47

Table 5.15. The water depth of geomorphic units found in the Kenn Transition.

Feature	Depth Range (m)	Mean Depth (m)
Geomorphic Province		
Slope	15 – 4,740	2,740
Rise	3,130 – 4,650	4,145
AP/DOF	320 – 4,885	4,435
Geomorphic Feature		
Slope (unassigned)	1,700 – 4,715	2,860
Rise (unassigned)	3,130 – 4,650	4,145
AP/DOF	2,115 – 4,885	4,520
Deep/hole/valley	2,215 – 4,175	3,545
Trench/trough	2,645 – 2,825	2,770
Apron/fan	2,660 – 3,195	3,040
Basin	1,155 – 4,175	3,160
Canyon	2,760 – 4,720	3,245
Knoll/abyssal hills/mountains/peak	2,370 – 4,290	3,645
Seamount/guyot	30 – 4,700	2,460
Pinnacle	1,105 – 4,795	3,665

Plateau	100 – 4,740	2,515
Saddle	1,995 – 3,810	2,515
Terrace	2,255 – 3,650	2,955

5.9.3. Sedimentology of the Kenn Transition

The KT contains 20 quantitative grain size and carbonate assays. Sediment texture across most of the bioregion is relatively homogeneous. Mud is the dominant size fraction with contents ranging from 27 - 86% and exceeding 50% in 14 (70%) samples. The sand content of samples ranges from 14 – 72% and is below 60% in 19 (95%) samples. Four (20%) samples are sand dominated samples and these are located offshore Townsville and adjacent to the southern border of the KP. Gravel forms <1% of the sediment volume in 18 (90%) samples. Gravel attains 5% and 32% in two (10%) samples located offshore Cairns.

Bulk carbonate content in the KT ranges from 57 – 90%, and exceeds 70% in 16 (80%) samples, and exceeds 80% in nine (45%) samples. Carbonate content is highest in the north of the bioregion with carbonate contents ranging from 76 - 90%. This contrasts to the south of the bioregion where carbonate content ranges from 60 - 81%. Carbonate content of mud ranges from 52 - 88% and exceeds 70% in 14 (70%) samples. Carbonate content of sand ranges from 81 - 96%and exceeds 90% in 18 (90%) samples. Carbonate content of gravel ranges from 0 - 100% with 11 (55%) samples containing >5% carbonate gravel and eight (40%) samples exceeding 80% carbonate gravel.

5.9.4. Sedimentology of significant geomorphic features

5.9.4.1. Plateau

A total of 16 samples were obtained from the Kenn Plateau in the KT. Mud is the dominant size fraction, with contents ranging from 34 - 83%. Eleven (70%) of the 16 samples contain >50% mud. Sand is the next most abundant fraction with contents ranging from 18 - 59%. Gravel content ranges from 0 - 32% and 14 (88%) samples contain <1% gravel (Fig. 5.34). Bulk carbonate content ranges from 57 - 90% and exceeds 75% in 10 (63%) samples (Fig. 5.35). Carbonate content of sand ranges from 81 - 96% and exceeds 90% in 15 (94%) samples. Carbonate content of mud ranges from 52 - 88% and exceeds 75% in nine (56%) samples. Carbonate content of gravel ranges from 5 - 100% and is absent in eight (50%) samples and 100% in five (31%) samples.

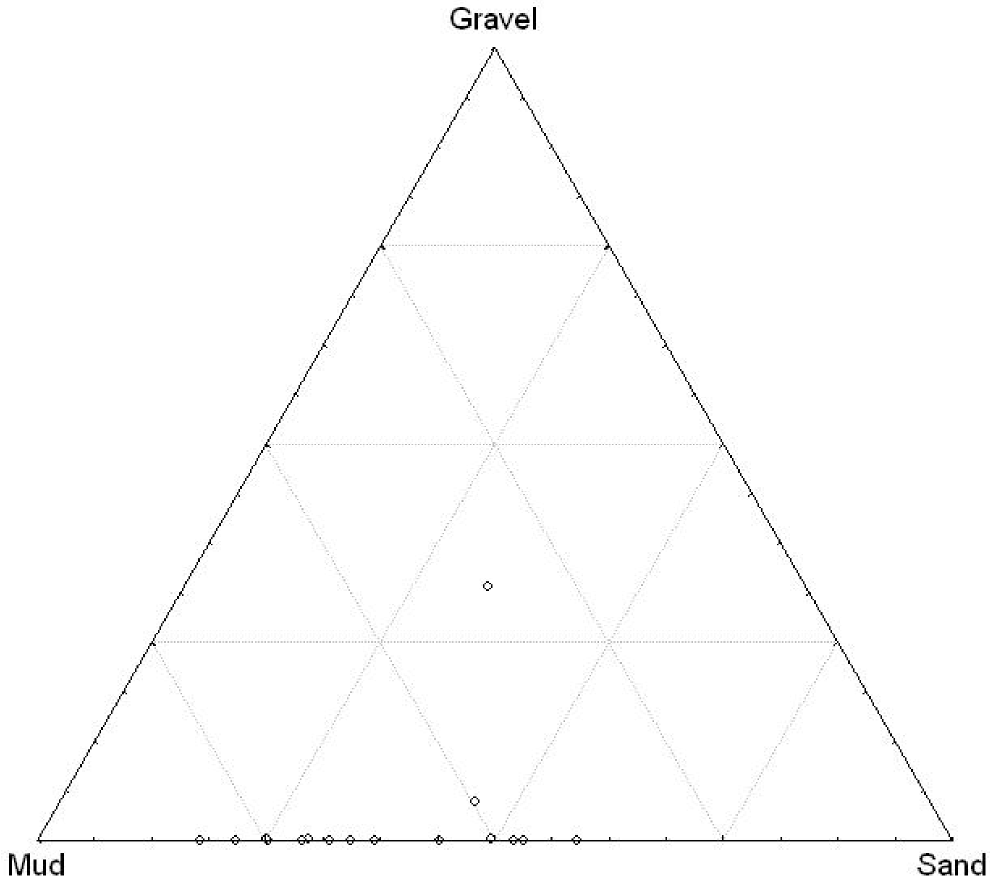


Figure 5.34. Textural composition (mud:sand:gravel ratio) of plateau sediments within the KT.

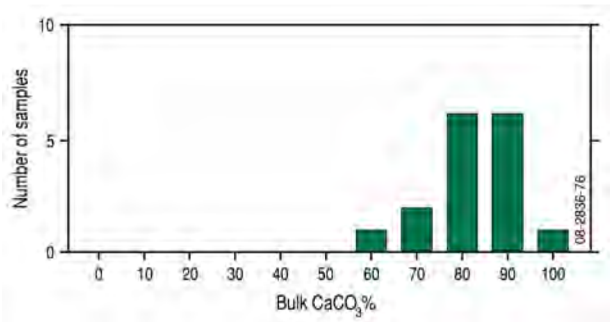


Figure 5.35. Carbonate content of plateau sediments within the KT.

5.10. NORFOLK ISLAND PROVINCE (NIP)

5.10.1. Geomorphology and bathymetry

The NIP covers an area of 430,790 km^2 which represents 18% of the EMR. The NIP surrounds Norfolk Island and is isolated from the rest of the EEZ. The province is separated from the LHP to the east by a strip of seabed approximately 100 km wide.

The NIP is located predominantly on the slope (430,156 km^2, or 99% of total NIP area). The remainder comprises a small area of shelf that surrounds Norfolk Island (675 km^2, >1%). The NIP contains a complex geomorphology with thirteen geomorphic features identified on the slope: bank/shoal (705 km², >1%); deep/hole/valley (9 km², >1%); trench/trough (9,825 km², 2%); basin (167,445 km², 39%); canyon (625 km², >1%); knoll/abyssal hills/hills/mountains/peak (6,785 km², 2%); ridge (275 km², >1%); seamount/guyot (4,575 km², 1%); pinnacle (790 km², >1%); plateau (178,025 km², 41%); and saddle (29,795 km², 7%) (Fig. 5.36. & Table 5.16). No geomorphic features are identified on 31,300 km² or 7% of slope. No geomorphic features are identified on the shelf. Together basins and plateaus cover 345,470 km² or 80% of the NIP. This area includes the Kingston Plateau, New Caledonia Basin, North Norfolk Basin, and South Norfolk Basin.

Due to the complex geomorphology of the NIP, nine significant features are identified. These include slope (unassigned), bank/shoals, trench/troughs, basins, knoll/abyssal hills/hills/mountains/peaks, seamount/guyots, pinnacles, plateaus and saddles. Pinnacles and seamount/guyots occur in slope, trench/trough, basin, plateau, and saddle geomorphic features in the east of the bioregeion. These features each represent a significant portion of the total area of the feature type in the EMR. 14% of slope, 99% of banks/shoals, 12% of trench/troughs, 45% of basins, 40% of knoll/abyssal hills/hills/mountains/peaks, 11% of seamount/guyots, 32% of pinnacles, 17% plateaus, and 31% of saddles within the EMR are located within the NIP.

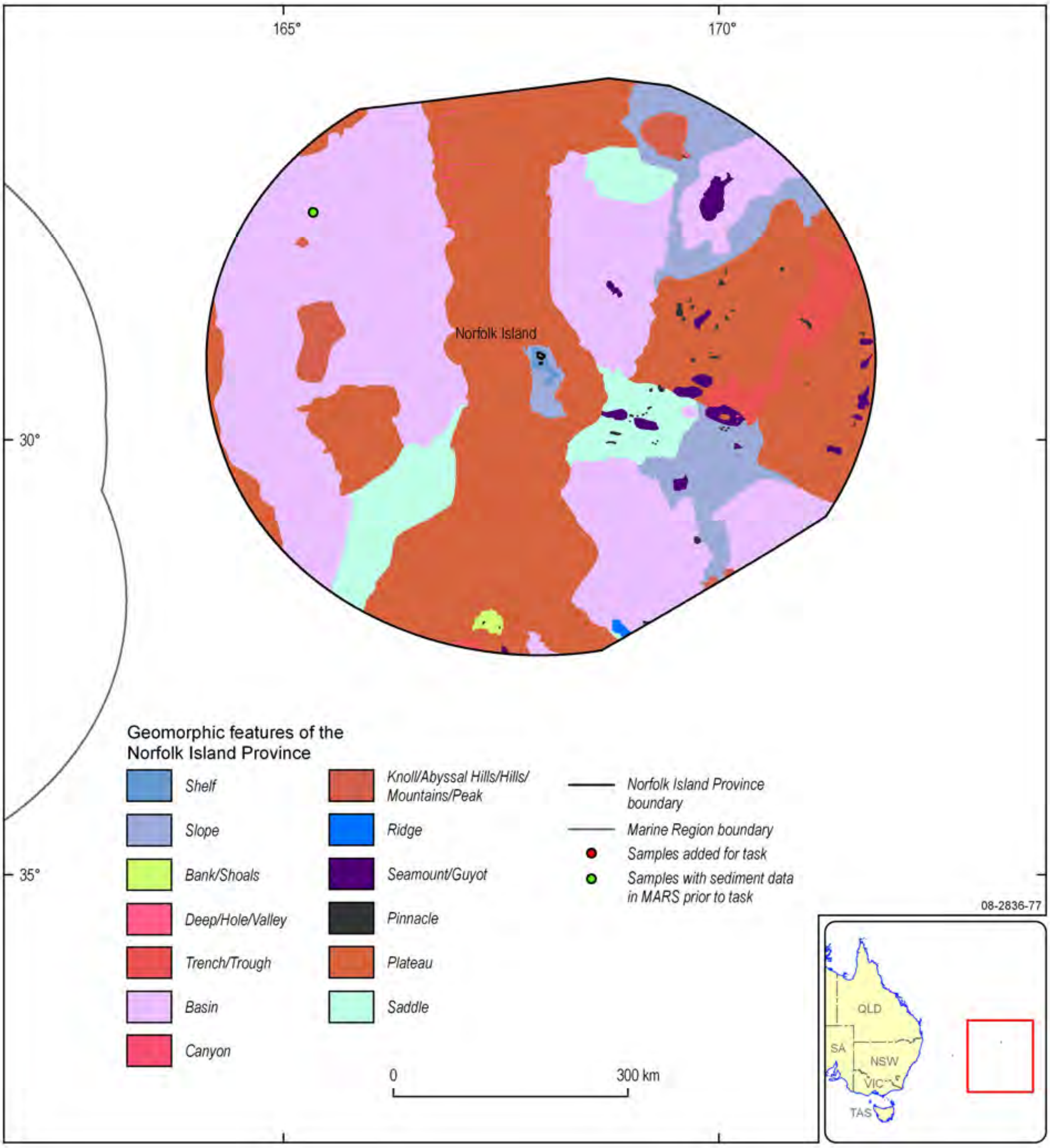
Water depths in the NIP range from 0 – 4,920 m with an average depth of 2,775 m (Table 5.17). Approximately 80% of the NIP occurs in water depths of 2,000 – 5,000 m (Fig. 5.37). Water depths on the shelf range from 0 – 205 m. Water depths on the slope range from 15 – 4,475 m with an average depth of 3,015 m. Bank/shoals generally occur in relatively shallow areas of the slope (average depth 915 m) while other features occur at significantly greater depths: plateaus average 2,120 m, seamount/guyots 2,170 m, pinnacles 2,550 m, saddles 2,760 m, knoll/abyssal hills/hills/mountains/peaks 2,810 m, trench/troughs 3,225 m and basins 3,430 m. Unassigned areas are dominantly located in deeper areas of the slope with average water depths of 3,015 m.

5.10.2. Sample Coverage

The NIP contains one sample with quantitative compositional data. This sample is located on the New Caledonia Basin in 3,525 m water depth. Bulk carbonate content of this sample is 86%, but beyond this no quantitative assessment of sedimentology is possible for the NIP.

Average sample density for the bioregion is the lowest of all bioregions in the EMR at 1:430,790 km². Despite being identified as a significant data gap in the EMR, no samples from the NIP were available from either Australian or international data repositories. Additional samples for this region were collected by GA during September/October 2007. These will be analysed and added to the MARS database during 2008. The NIP contains one carbonate assay.

a)


165°
170°
30°
35°
Norfolk Island
Geomorphic features of the Norfolk Island Province
Shelf
Slope
Bank/Shoals
Deep/Hole/Valley
Trench/Trough
Basin
Canyon
Knoll/Abyssal Hills/Hills/ Mountains/Peak
Ridge
Seamount/Guyot
Pinnacle
Plateau
Saddle
Norfolk Island Province boundary
Marine Region boundary
Samples added for task
Samples with sediment data in MARS prior to task
0
300 km
08-2836-77
QLD
SA
NSW
VIC
TAS

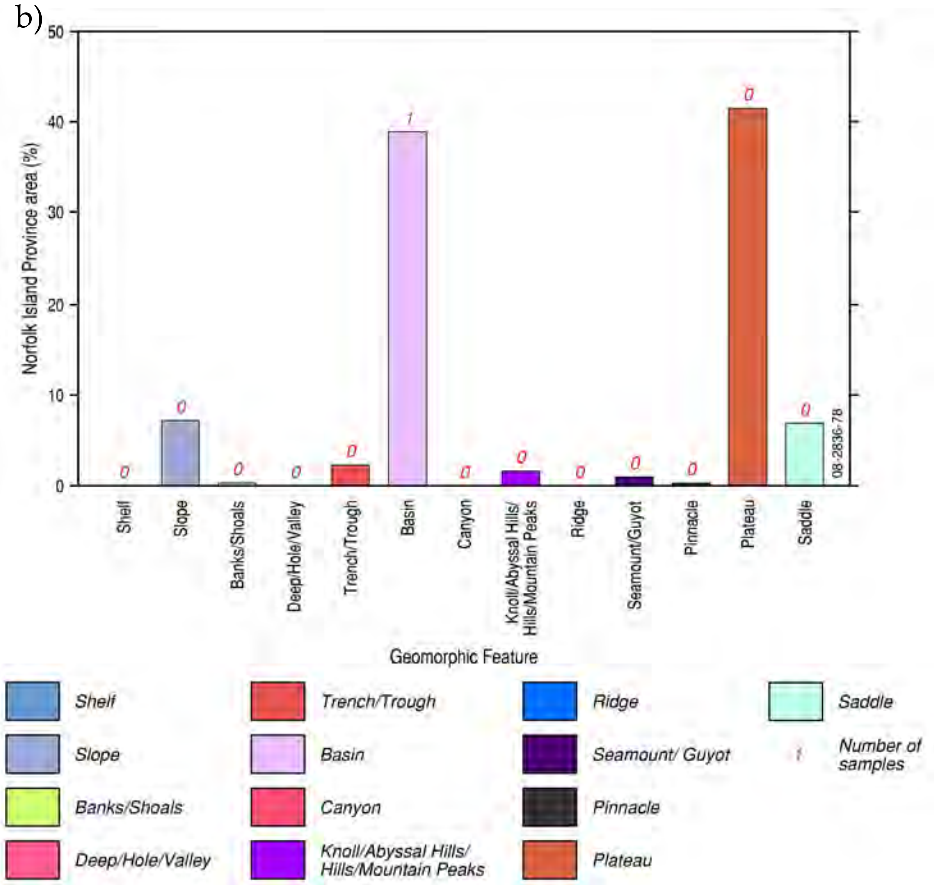


Figure 5.36. a) Geomorphology of the Norfolk Island Province (NIP) with location of sediment samples; and b) Percentage area of each geomorphic feature within the NIP with number of corresponding sediment samples (on top of columns).

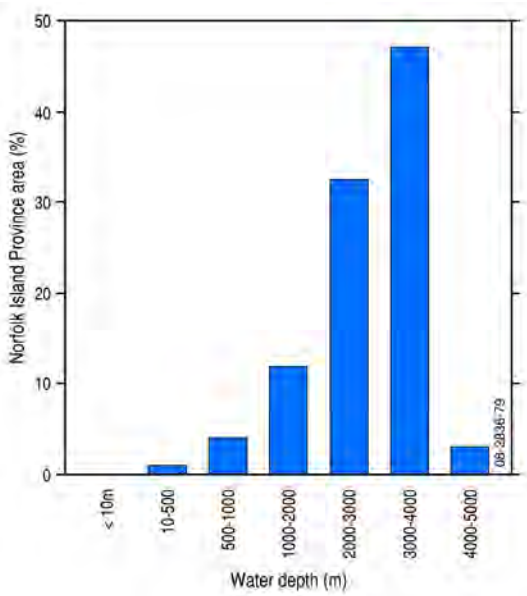


Figure 5.37. Distribution of water depth classes by percentage area within the NIP.

Table 5.16. The percentage area of geomorphic units found in the Norfolk Island Province.

Feature	% of bioregion area covered	% of EMR area this unit lies within this bioregion	% of EEZ area this unit lies within this bioregion
Geomorphic Province			
Shelf	0.15	1.67	0.02
Slope	99.85	23.41	11.33
Geomorphic Feature			
Shelf (unassigned)	0.15	1.87	0.05
Slope (unassigned)	7.27	14.11	2.28
Banks/shoals	0.16	99.57	1.39
Deep/hole/valley	<0.01	0.05	<0.01
Trench/trough	2.28	11.96	5.65
Basin	38.87	45.73	25.21
Canyon	0.14	6.34	0.58
Knoll/abyssal hills/hills/mountains/peak	1.58	70.04	5.72
Ridge	0.06	24.88	0.25
Seamount/guyot	1.06	10.86	4.54
Pinnacle	0.18	32.05	15.43
Plateau	41.32	17.32	11.90
Saddle	6.92	31.49	20.34

Table 5.17. The water depth of geomorphic units found in the Norfolk Island Province.

Feature	Depth Range (m)	Mean Depth (m)
Geomorphic Province		
Shelf	0 – 205	55
Slope	15 – 4,955	2,775
Geomorphic Feature		
Shelf (unassigned)	0 – 205	55
Slope (unassigned)	15 – 4,475	3,015
Banks/shoals	240 – 1,420	915
Deep/hole/valley	1,625 – 2,305	1,870
Trench/trough	880 – 3,900	3,225
Basin	1,375 – 4,955	3,430
Canyon	945 – 3,540	2,755
Knoll/abyssal hills/hills/mountains/peak	1,315 – 4,045	2,810
Ridge	960 – 3,810	2,390
Seamount/guyot	205 – 3,965	2,170
Pinnacle	225 – 3,950	2,550
Plateau	50 – 3,900	2,120
Saddle	1,510 – 3,620	2,760

5.11. NORTHEAST PROVINCE (NEP)

5.11.1. Geomorphology and bathymetry

The Northeast Province (NEP) covers an area of 422,290 km^2 and represents 17% of the EMR. The NEP occurs on the slope and abyssal plain/deep ocean floor to the east of the Great Barrier Reef. It is bordered by the Great Barrier Reef Marine Park to the west, the NET to the north, the KT and EEZ boundary to the east, and the CET to the south.

The NEP is dominated by slope (351,505 km^2 or 85% of the total NEP area) but includes a significant area of abyssal plain/deep ocean floor (68,510 km^2 or 16%) and a small area of rise (2,440 km^2 or >1%) (Table 5.18). Thirteen geomorphic features are identified within these: deep/hole/valley (475 km^2, >1%); trench/trough (48,835 km^2, 12%); basin (68,230 km^2, 16%); reef (18,405 km^2, 4%); canyon (2,575 km^2, >1%); knoll/abyssal hills/hills/mountains/peak (305 km^2, >1%); seamount/guyot (1,310 km^2, >1%); pinnacle (365 km^2, >1%); plateau (176,095 km^2, 42%); apron/fan (1,499 km^2, >1%); and terrace (39,105 km^2, 9%) (Fig. 5.38 & Table 5.18). No geomorphic features are identified for 63,060 km^2 or 18% of the area of the slope and 2,195 km^2 or 90% of the rise. All of the area of abyssal plain/deep ocean floor occurs in Coral Sea Basin of which part occurs in the north of the NEP.

Ten significant features are identified within the NEP, reflecting the complex geomorphology of the region. These include, slope (unassigned); trench/trough basin; reef; canyon; knoll/abyssal hills/hills/mountains/peak; pinnacle; plateau; apron/fan and terrace features. The NEP contains the largest area of reefs in any bioregion in the EMR and include the Willis, Lihou, Coringa, and Tregrosse Reefs. Although this feature covers only 4% of the bioregion, this represents 92% of the total area of reefs in the EMR and 40% of reefs in the EEZ. Trench/trough, terrace, and apron/fan features in the NEP also represent large proportions of the total area of these features in the EMR (60%, 67% and 57% respectively). Pinnacles within the NEP are clustered on the Queensland and Marion Plateau and occupy an area of <1% of the total area of the NEP, however they represent 15% of pinnacles within the EMR. The Townsville Trough separates the Queensland and Marion Plateaus and is the largest single area of this feature type in the EMR. The Coral Sea Basin is situated adjacent to the EEZ boundary in the north of the NEP and represents 18% of the total area of basins in the EMR.

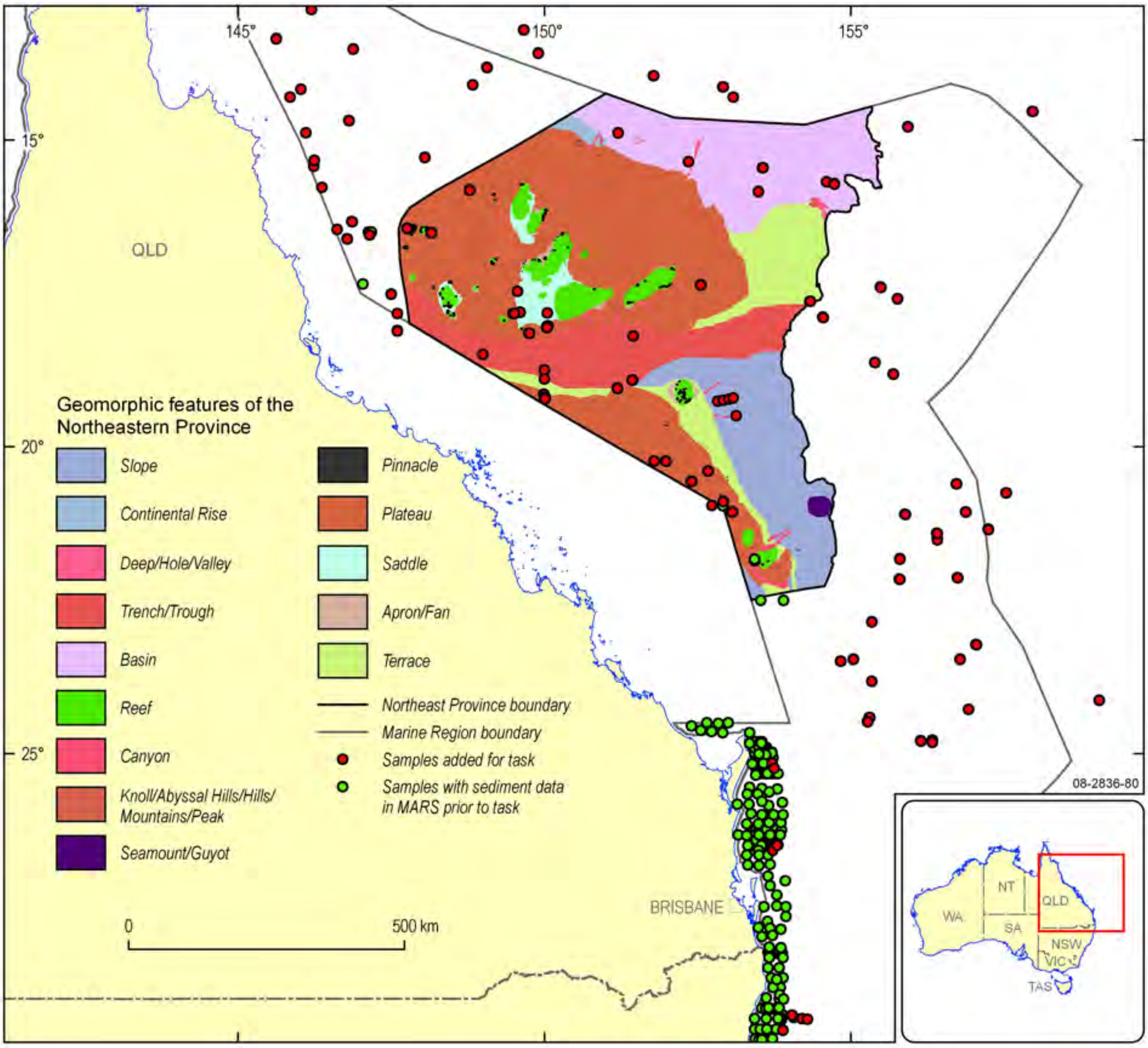
Water depths in the NEP range from 0 – 4,915 m with an average depth of 1,755 m (Table 5.19). Approximately 65% of the area in the NEP lies in water depths of 10 – 2,000 m (Fig. 5.39) Significant geomorphic features occur over a large range of water depths.: A total 13% of the area lies in water depths between 4,000 – 5,000 m in the Coral Sea Basin. Rise (unassigned), deep/hole/valley, basin and knoll/abyssal hills/hills/mountains/peak occur at mean water depths of 3,485 m, 8,865 m, 4,305 m, and 3,725 m respectively. Apron/fan, reef, saddle and plateau occur in shallower areas of the NEP, with mean water depths of 435 m, 130 m, 435 m, and 985 m respectively.

5.11.2. Sample Coverage

The NEP contains 50 sample points with either quantitative grainsize and/or carbonate data. Samples occur in water depths of 285 – 4,650 m within slope (unassigned) (6 samples, 12%); trench/trough (7 samples, 14%); basin (6 samples, 12%); canyon (1 sample, 2%); plateau (24 samples, 48%); saddle (3 samples, 6%); and terrace (3 samples, 6%) geomorphic features. A total of 44 of the 50 samples were procured for the task, significantly improving the data coverage of the NEP. New samples have particularly improved coverage of trench/trough, terrace, canyon and basin features for which there were no quantitative sediment data prior to this task.

Average sample density in the NEP is 1:8,450 km. Sample coverage is sufficient to assess the sedimentology of the slope (unassigned), basins, plateaus and trench/troughs. Sample density remains too low to assess the sedimentology of saddles, terraces and canyons. Despite targeted sample addition, no data is available for reef, knoll/abyssal hills/hills/mountains/peak, pinnacle, and apron/fan features.

a)



b)

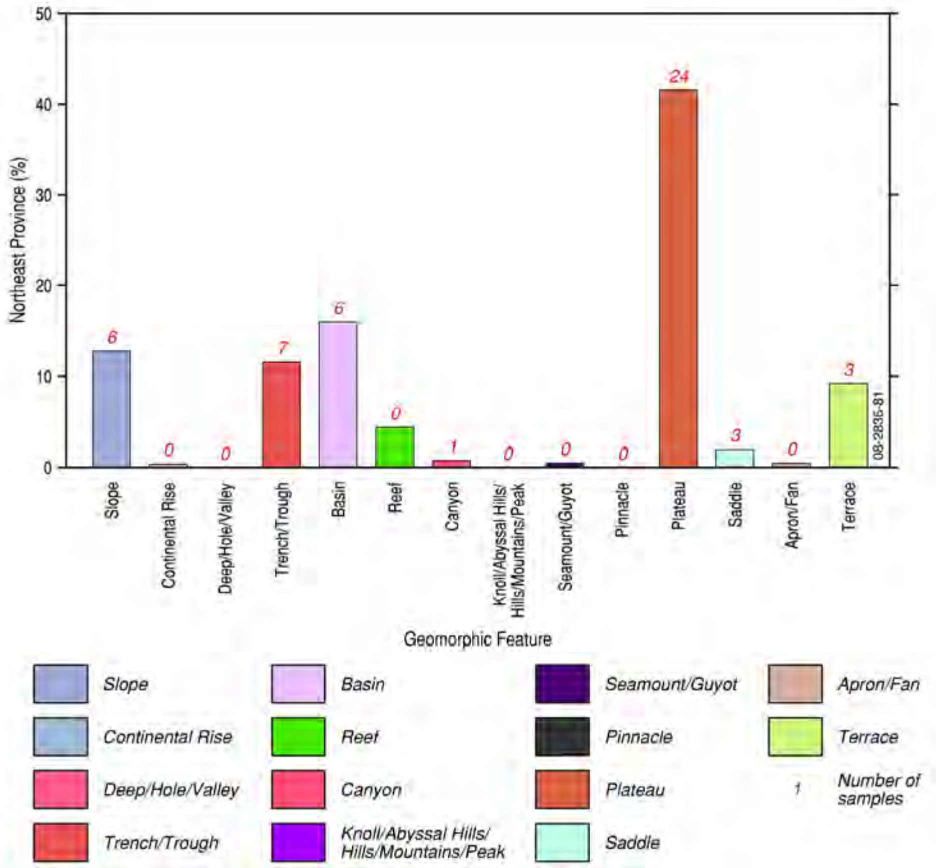


Figure 5.38. a) Geomorphology of the Northeast Province (NEP) with location of sediment samples; and b) Percentage area of each geomorphic feature within the NEP with number of corresponding sediment samples (on top of columns).

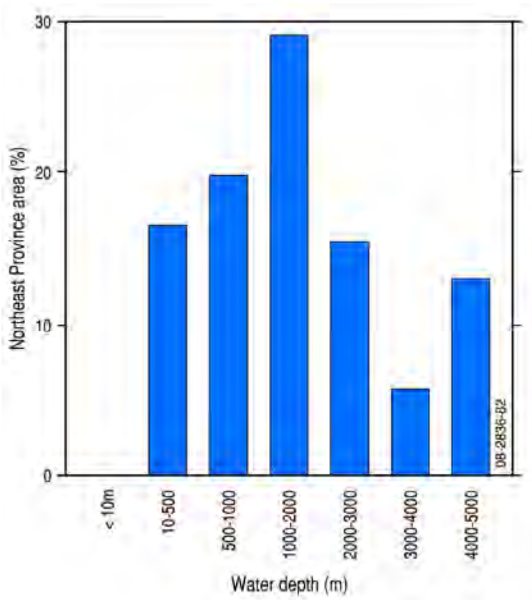


Figure 5.39. Distribution of water depth classes by percentage area within the NEP.

Table 5.18. The percentage area of geomorphic units found in the Northeast Province.

Feature	% of bioregion area covered	% of EMR area this unit lies within this bioregion	% of EEZ area this unit lies within this bioregion
Geomorphic Province			
Slope	83.20	19.07	9.25
Rise	0.58	9.65	2.42
AP/DOF	16.22	14.11	2.84
Geomorphic Feature			
Slope (unassigned)	14.92	33.68	4.59
Rise (unassigned)	0.52	7.52	2.29
Deep/hole/valley	0.11	2.53	0.28
Trench/trough	11.56	59.44	28.10
Basin	16.16	18.63	10.27
Reef	4.36	91.98	39.50
Canyon	0.61	26.22	2.41
Knoll/abyssal hills/mountains/peak	0.07	3.14	0.27
Seamount/guyot	0.31	3.11	1.30
Pinnacle	0.09	14.76	7.12
Plateau	41.70	17.13	11.77
Saddle	2.05	9.15	5.92
Apron/fan	0.35	56.53	12.79
Terrace	9.26	67.04	6.75

Table 5.19. The water depth of geomorphic units found in the Northeast Province.

Feature	Depth Range (m)	Mean Depth (m)
Geomorphic Province		
Slope	0 – 4,540	1,255
Rise	1,975 – 4,290	3,455
AP/DOF	2,540 – 4,915	4,305
Geomorphic Feature		
Slope (unassigned)	150 – 3,295	1,890
Rise (unassigned)	2,485 – 4,290	3,485
Deep/hole/valley	3,245 – 4,445	3,865
Trench/trough	500 – 2,905	1,590
Basin	2,540 – 4,915	4,305
Reef	30 – 1,105	130
Canyon	305 – 4,610	1,240
Knoll/abyssal hills/mountains/peak	3,020 – 4,325	3,725
Seamount/guyot	15 – 3,210	1,775
Pinnacle	40 – 2,720	755

Plateau	35 – 4,120	985
Saddle	45 – 3,500	3,455
Apron/fan	5 – 1,090	435
Terrace	50 – 4,540	1,855

5.11.3. Sedimentology of the Northeast Province

The NEP contains 49 grain size and 50 carbonate assays (Fig. 5.40). Sand content of samples ranges from 1 – 93% and decreases with increasing water depth. Mud content ranges from 0 – 99% and increases with increasing water depth. Gravel content is low throughout the entire NEP with 41 (83%) samples containing <10% gravel. Bulk carbonate content of sediments in the NEP is high, exceeding 90% in 46 (92%) samples. Carbonate content is highest adjacent to the Great Barrier Reef and reduces with distance from the reef and increasing water depth.

5.11.4. Sedimentology of Significant Geomorphic Features

5.11.4.1. Slope (unassigned)

A total of six samples with quantitative grain size and carbonate data were obtained from the slope (unassigned). Mud is the dominant sediment fraction with contents ranging from 26 - 80% and five (83%) samples containing >55% mud (Fig. 5.40). Sand is also relatively abundant and contents range from 20 - 72% and are <45% in five (83%) samples. Gravel content does not exceed 42%. Bulk carbonate content is high for all samples, ranging from 83 - 87% (Fig. 5.41). Where analysed, the carbonate content of all textural fractions is also high, ranging from 82 - 86% for mud, 95 - 96% for sand, and 100% for gravel.

5.11.4.2. Trenches/troughs

A total of seven samples with bulk carbonate assays and five samples with grain size assays were obtained from trench/troughs within the NEP. Mud is the dominant sediment fraction and ranges from 33 - 71% with three (60%) samples containing <50% mud (Fig. 5.40). Sand ranges from 28 – 65% and three (60%) samples lie between 50 – 65% sand content. Gravel formed less than 2% of sediment in all samples. Bulk carbonate content ranges from 85 - 91% in all samples (Fig. 5.41). Carbonate content is high for all textural fractions: 88 – 90% for mud, 93 – 97% for sand and 100% for gravel.

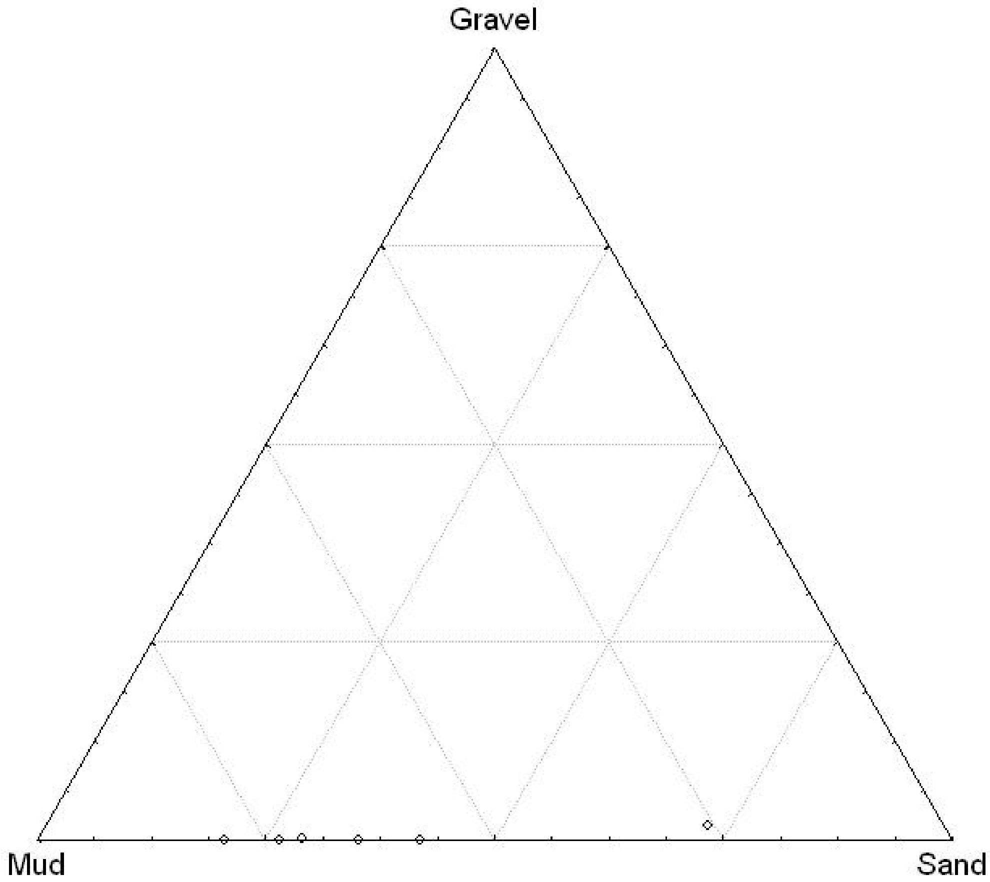
5.11.4.3. Basins

Two samples with quantitative grainsize and six samples with quantitative carbonate values are available for basins in the NEP. These two samples are dominated by a mud content of 89% and >99% and a sand content of 11% and <1% respectively. No gravel is present in either of the samples. Bulk carbonate assays are available for six samples and carbonate contents ranges from 16 - 86% and six (67%) samples contain <60% bulk carbonate (Fig. 5.41). Carbonate content of the mud fraction ranges from 58 - 89%. No carbonate analyses were performed on sand and gravel fractions.

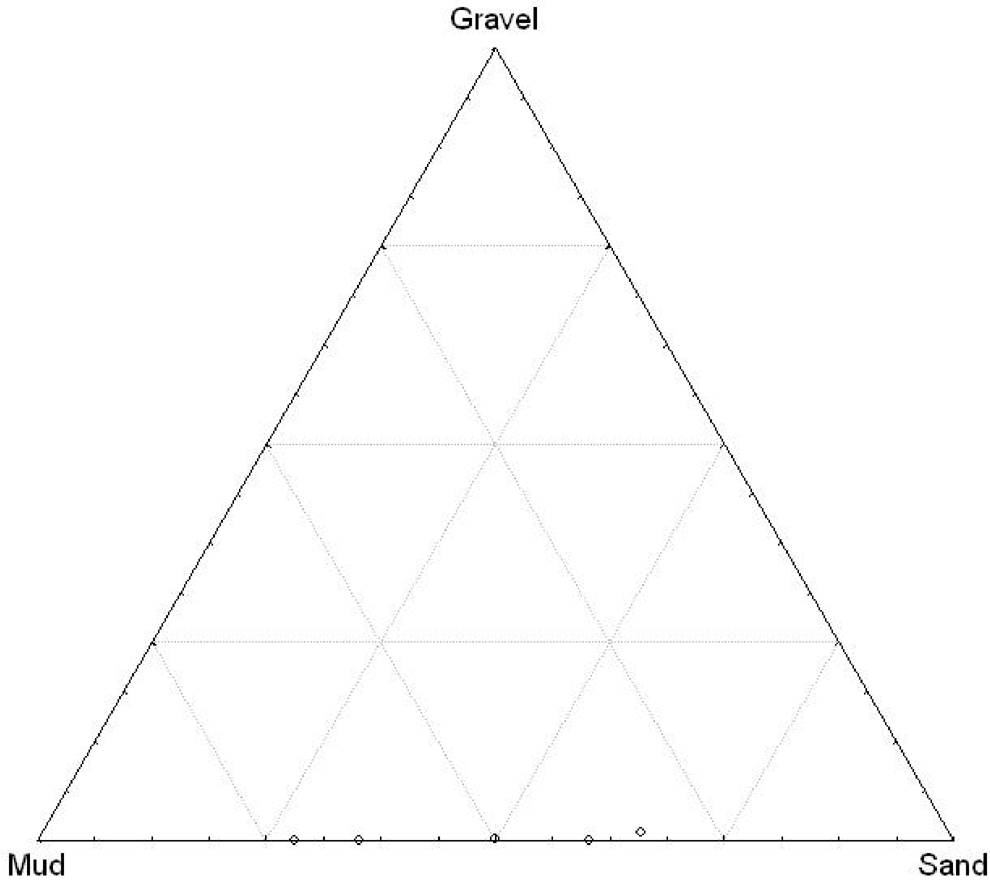
5.11.4.4. Plateau

A total of 24 samples occur on plateaus in the NEP. A total of 20 of these samples have grain size assays and 24 have bulk carbonate assays. Sand is the dominant textural fraction with contents ranging from 7 - 93% and is less than 55% in 14 (67%) samples (Fig. 5.40). Mud is the next abundant fraction with contents ranging from 6 - 93% and <75% in 18 (85%) samples. Gravel content is bimodal, being <3% in 16 (67%) samples and from 72 - 82% in three (12%) samples. Bulk carbonate content is consistently high, ranging from 84 - 97% (Fig. 5.41). Carbonate contents of all textural size fractions are high ranging from 86 – 96% for mud and 93 – 98% for sand. Where analysed, gravel was entirely composed of carbonate.

a)



b)



c)

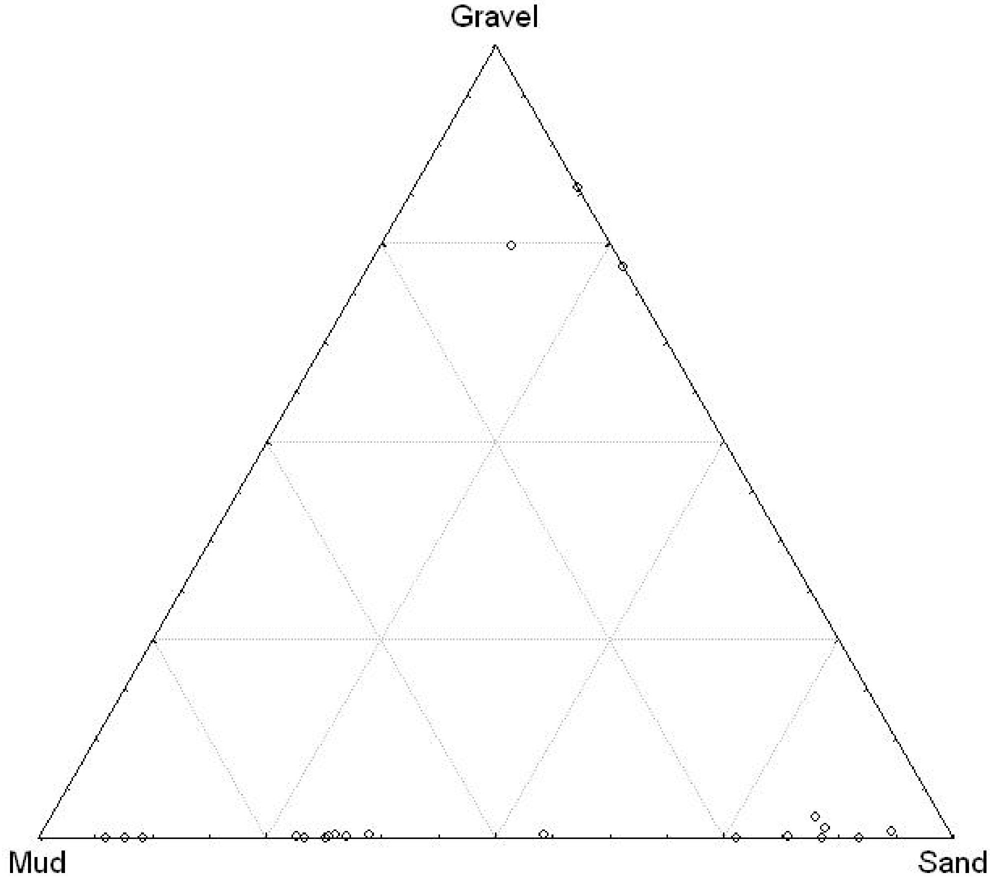


Figure 5.40. Textural composition (mud:sand:gravel ratio) of a) slope; b) trench/trough; and c) plateau sediments within the NEP.

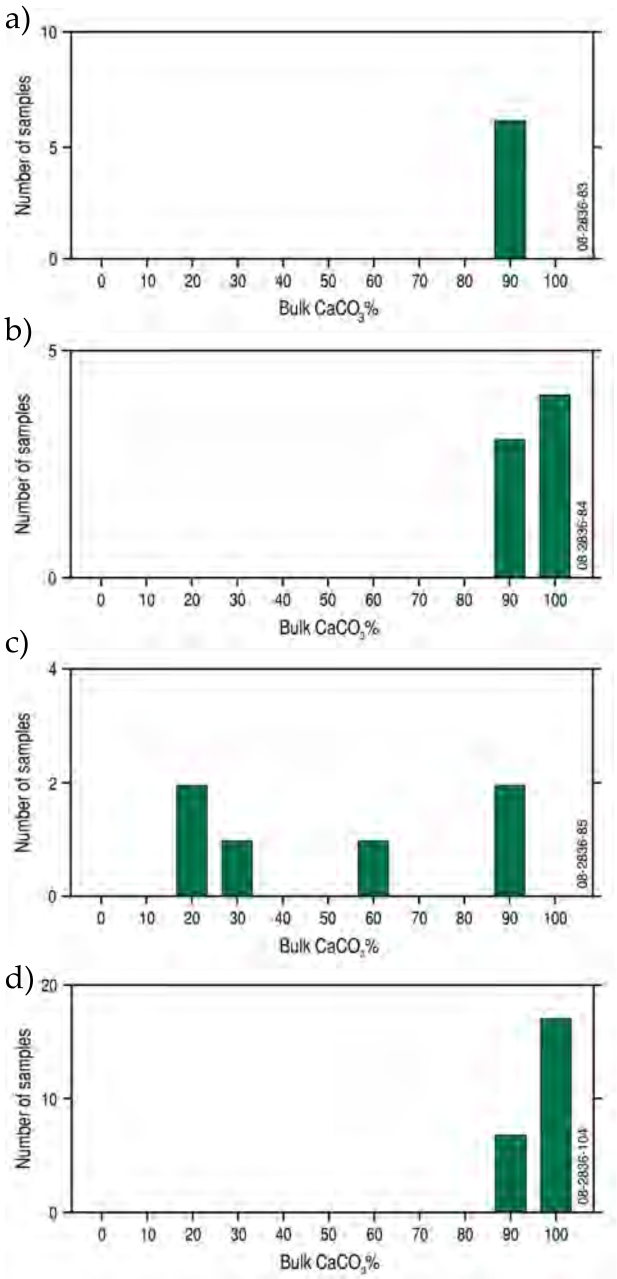


Figure 5.41. Carbonate content of a) slope; b) trench/trough; c) basin; and d) plateau sediments within the NEP.

5.12. LORD HOWE PROVINCE (LHP)

5.12.1. Geomorphology and bathymetry

The Lord Howe Province (LHP) covers an area of 484,880 km^2, which represents 20% of the EMR. The LHP is situated on the slope surrounding Lord Howe Island. This bioregion is separated from the NSW coast to the east by the TBP, CEP and CESP, and extends to the KT in the north and the EEZ boundary in the west.

The entire LHP occurs on the slope and contains eight geomorphic features types. These include deep/hole/valleys (410 km^2 or <1% of total LHP area); basin (65,100 km^2, 13%); knoll/abyssal hills/hills/mountains/peak (795 km^2, <1%); ridge (224 km^2, <1%); seamount/guyot (5,454 km^2, 1%); plateau (389,387 km^2, 80%); and saddle (23,467 km^2, 5%) (Fig. 5.42 & Table 5.20). Basin within the LHP is separated into the Lord Howe and Middleton Basins. Areas of seamount include, Gifford Guyot located to the north of the bioregion; and Middleton and Elizabeth Reefs located within the saddle in the centre of the bioregion.

Five significant features are identified for the LHP: Basins, ridges, seamount/guyots, plateaus and saddles. Plateaus cover the greatest area of any feature in the LHP. Basins cover >13% of the LHP, and this represents 18% of the area of basins in the EMR and 10% of the area of basins in the EEZ. While ridge, seamount/guyot and saddle features cover relatively small areas of the LHP (<5%), the area of these features in the LHP represents a significant proportion of the total area for each feature in the EMR. For example, ridges in LHP represent 20% of the total area of ridges in the EMR, and saddles represent 25% of the area of saddles in the EMR and 16% of the area of saddles in the EEZ.

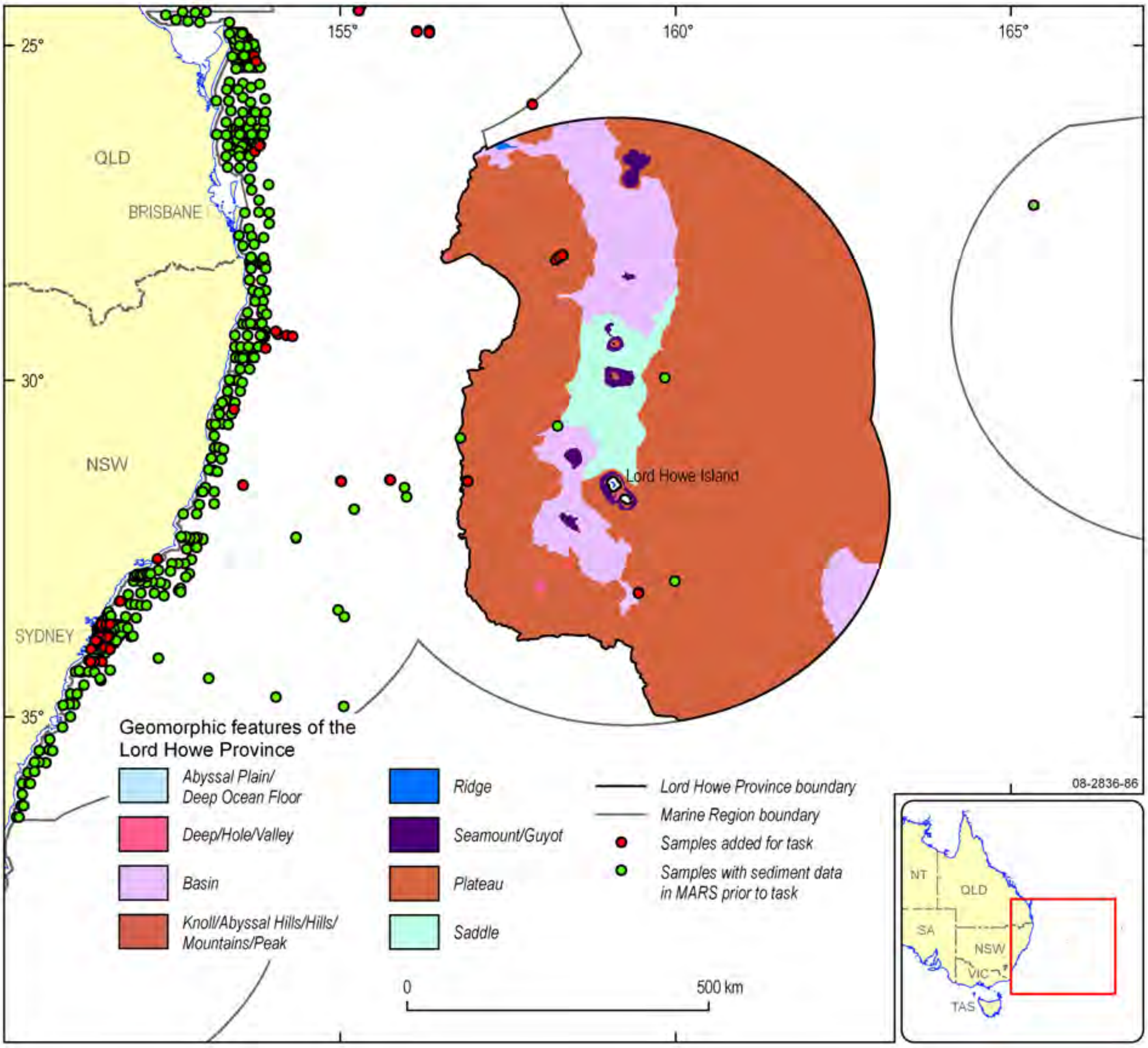
Water depths in the LHP range from 0 – 5,135 m with an average depth of 2,335 m (Fig. 5.43). Approximately 90% of the total area in the LHP occurs in water depths between 1,000 – 4,000 m (Table 5.21).

5.12.2. Sample Coverage

The LHP contains nine samples with quantitative textural and/or compositional data, resulting in an average sample density of 1:53,875 km^2. Five of these samples were procured and analysed for this task, significantly improving data coverage in the region.

All samples in the LHP are located on the Lord Howe Rise in water depths of 1,660 – 4,500 m. Samples achieve sufficient coverage to assess the sedimentology of plateau features within the LHP. Despite targeted sample addition, no samples were procured for other significant geomorphic features.

a)


25°
30°
35°
155°
160°
165°
QLD
BRISBANE
NSW
SYDNEY
Lord Howe Island
Geomorphic features of the Lord Howe Province
Abyssal Plain/ Deep Ocean Floor
Deep/Hole/Valley
Basin
Knoll/Abyssal Hills/Hills/ Mountains/Peak
Ridge
Seamount/Guyot
Plateau
Saddle
Lord Howe Province boundary
Marine Region boundary
Samples added for task
Samples with sediment data in MARS prior to task
0
500 km
08-2836-86
NT
QLD
SA
NSW
VIC
TAS

b)

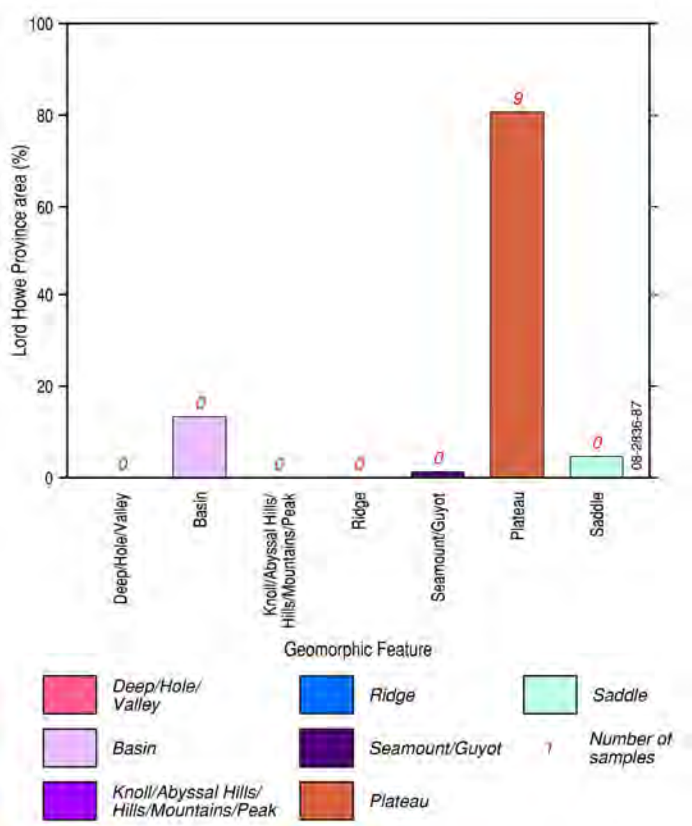


Figure 5.42. a) Geomorphology of the Lord Howe Province (LHP) with location of sediment samples; and b) Percentage area of each geomorphic feature within the LHP with number of corresponding sediment samples (on top of columns).

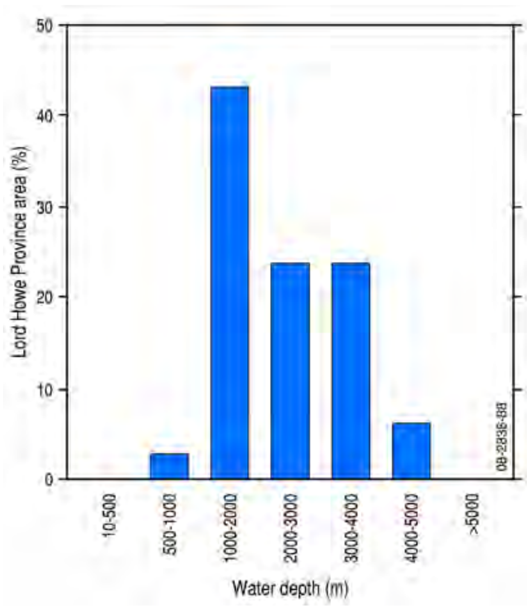


Figure 5.43. Distribution of water depth classes by percentage area within the LHP.

Table 5.20. The percentage area of geomorphic units found in the Lord Howe Province.

Feature	% of bioregion area covered	% of EMR area this unit lies within this bioregion	% of EEZ area this unit lies within this bioregion
Geomorphic Province			
Slope	100	26.30	12.77
Geomorphic Feature			
Deep/hole/valley	0.08	2.18	0.24
Basin	13.41	17.77	9.80
Knoll/abyssal hills/mountains/peak	0.16	8.21	1.09
Ridge	0.05	20.25	0.20
Seamount/guyot	1.13	12.95	5.42
Plateau	80.31	37.88	26.02
Saddle	4.84	24.80	16.02

Table 5.21. The water depth of geomorphic units found in the Lord Howe Province.

Feature	Depth Range (m)	Mean Depth (m)
Geomorphic Province		
Slope	0 – 5,140	2,335
Geomorphic Feature		
Deep/hole/valley	450 – 4,015	2,570
Basin	260 – 4,750	3,245
Knoll/abyssal hills/mountains/peak	0 – 4,480	570
Ridge	2,750 – 3,980	3,215
Seamount/guyot	75 – 4,070	1,890
Plateau	805 – 5,140	2,170
Saddle	335 – 3,875	2,760

5.12.3. Sedimentology of the Lord Howe Province

A total of five grain size and nine carbonate assays are available for the LHP. LHP sediments are dominated by mud, and become finer with increasing water depth. Mud content ranges from 66 - 98% and exceeds 70% in three (60%) samples. Sand content ranges from 2 - 34%, and exceeds 20% in five (83%) samples. No gravel was detected in any samples from the LHP.

Bulk carbonate content ranges from 31 – 86% and exceeds 50% in 8 (89%) samples. Carbonate content of mud ranges from 34 - 83%. One carbonate sand assay is available and this equals 92%.

5.12.4. Sedimentology of significant geomorphic features

5.12.4.1. Plateau

A total of nine samples were obtained from plateaus. Five have grain size data and nine have bulk carbonate data. Mud is the dominant fraction with contents ranging from 65 – 98% (Fig. 5.44). Sand is the next most abundant fraction with contents ranging from 1 - 34%. Gravel was not present in any of the samples. Bulk carbonate content ranges from 31 - 86% and seven (78%) samples contain >60% carbonate content (Fig. 5.45). Carbonate content of mud was analysed for 5 samples and ranges from 34 - 83%. Carbonate content of sand was 92% in the one sample analysed.

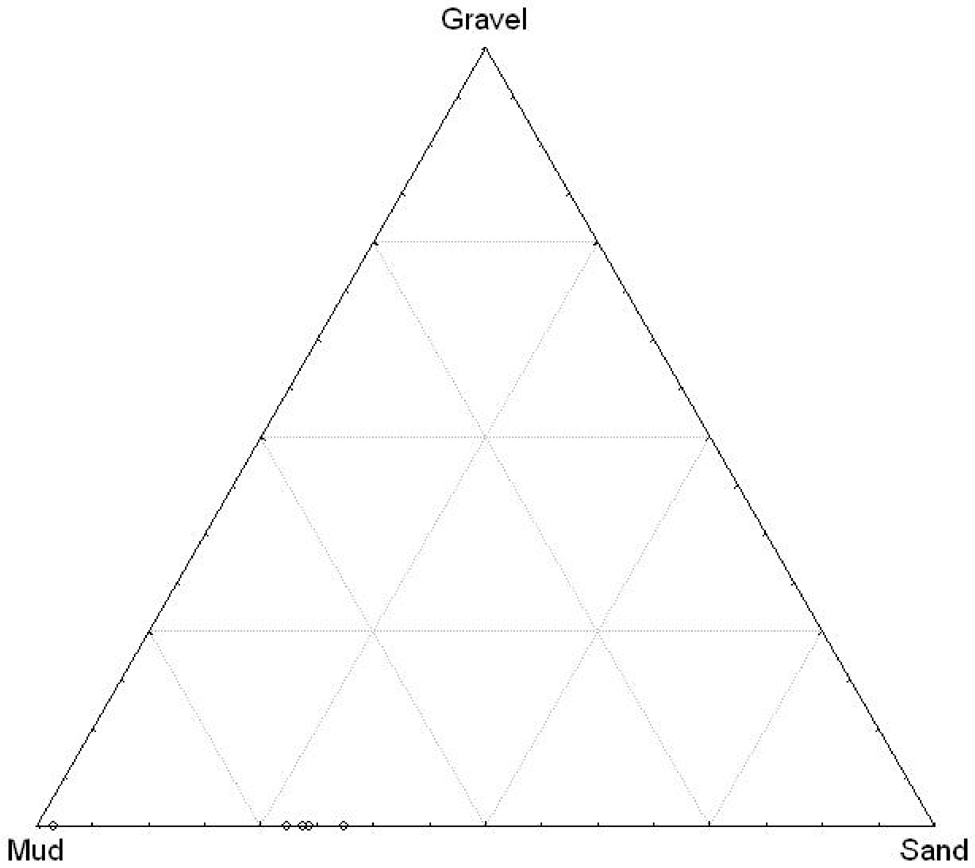


Figure 5.44. Textural composition (mud:sand:gravel ratio) of plateau sediments within the LHP.

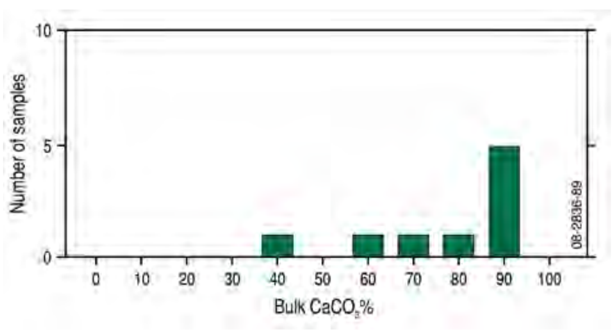


Figure 5.45. Carbonate content of plateau sediments within the LHP.

5.13. NORTHEAST TRANSTION (NET)

5.13.1. Geomorphology and bathymetry

The Northeast Transition (NET) covers an area of 132,490 km^2 which represents 5% of the EMR. The NET is located off the shelf between Cape Sydmouth and Cardwell and is bound north by the CP, to the south by the CEP, and to the east by the EEZ boundary.

More than 99,830 km^2 or 75% of the NET is located on the slope with a small area of rise (12,990 km^2, 10 %) and contains a complex geomorphology. Geomorphic features covering significant areas of the slope include, trench/trough (15,580 km^2, 12%); basin (19,680 km^2, 15%); and plateau (82,260 km^2, 62%) (Fig. 5.46. & Table 5.22). Geomorphic features covering minor areas (<1%) of the bioregion include, apron/fans (790 km^2); canyons (750 km^2); reefs (570 km^2) and ridges (440 km^2) (Fig. 5.46. & Table 5.22). No features are identified on 11,970 km^2 (12%) of the slope and 10,600 km (82%) of the rise.

The rise in the NET separates the plateau from the adjacent Coral Sea Basin and is cut by a series of ridges and canyons. A large trench/trough, the Queensland Trough occurs in the west of the bioregion and extends south east offshore to Cairns. Reefs in the NET include the Osprey Reef, located on the plateau and surrounded by apron/fans.

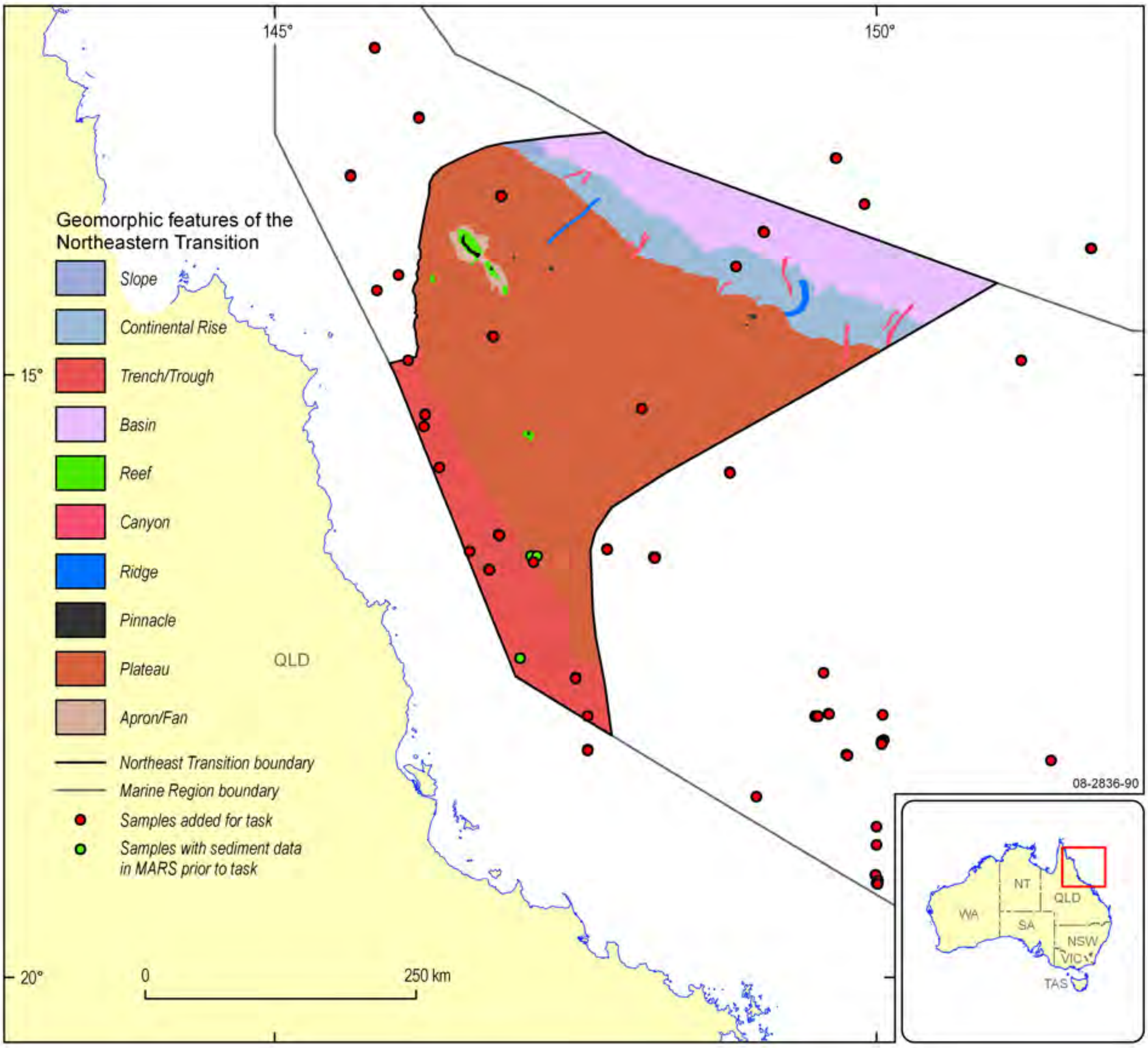
Six significant geomorphic features are identified for the NET: rise (unassigned), trench/trough, deepwater basins, pinnacles, plateaus, apron/fans, and ridges. The NET contains the largest area of rise of any bioregion in the EMR and represents 41% of the total area of rise in the EMR and 13% of rise in the EMR. Apron/fan, ridge and trench/trough features in the NET represent 30%, 40% and 19% respectively and are significant due to the total area these features represent in the EMR. Rise, deepwater basins, pinnacles, canyons, reefs and plateaus represent <10% of area in each feature in the EMR

Water depths in the NET range from 0 – 4,230 m water depth, with an average depth of 2,275 m (Table 5.23). More than 99% of the total area of the NET occurs in water depths >1,000 m, and 55% occurs in depths of 1,000 – 2,000 m (Fig. 5.47). Reefs occur in shallower areas of the bioregion (average depth 595 m) and basins form the deepest areas of the region (average 4,415 m).

5.13.2. Sample Coverage

The NET contains 18 samples with either quantitative grain size and/or carbonate data. Sixteen of these were procured and analysed for the task, resulting in significant improvement in data coverage. The average sample density in the NET is 1:7,360 km^2. Due to the small sample volumes provided by external institutions, only 6 of the new samples were sieved for weight % mud/sand/gravel. Six of these samples are located on the plateau and 10 are located on trench/trough. One sample is situated on the rise and basin. Of the samples that have grainsize data, one (13%) sample is located on the plateau and seven (88%) samples are located on trench/troughs. These samples achieve sufficient coverage to assess the sedimentology in two of the six significant features: trench/troughs and plateaus. Sample coverage is inadequate to assess sedimentology of the rise (unassigned), deepwater basins, pinnacles, apron/fans, and ridges.

a)



b)

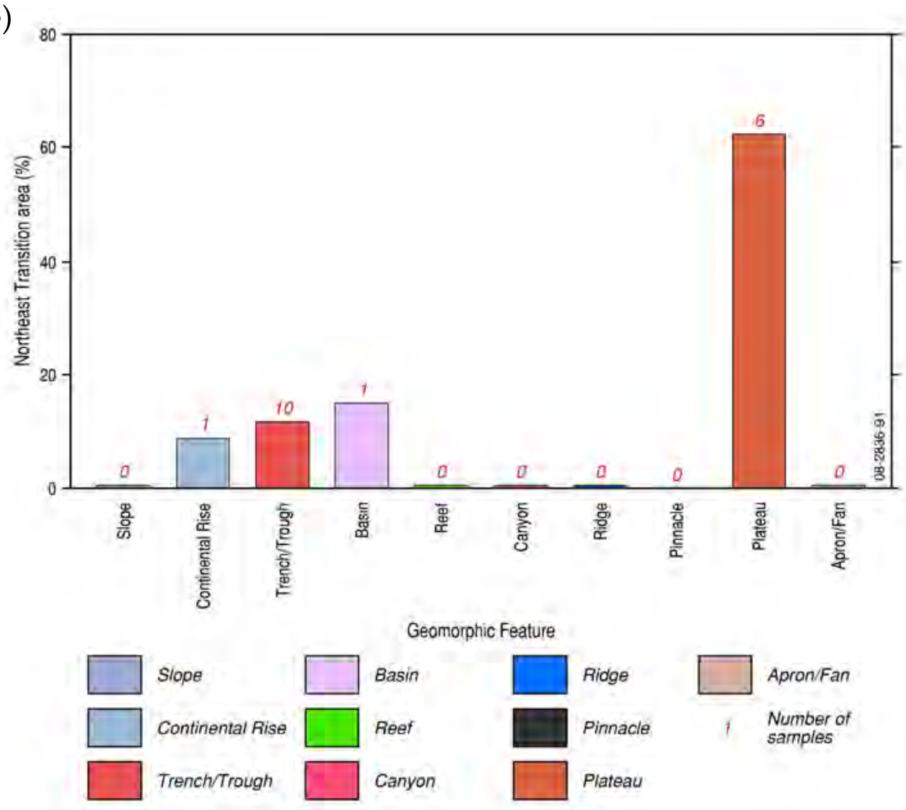


Figure 5.46. a) Geomorphology of the Northeast Transition (NET) with location of sediment samples; and b) Percentage area of each geomorphic feature within the NET with number of corresponding sediment samples (on top of columns).

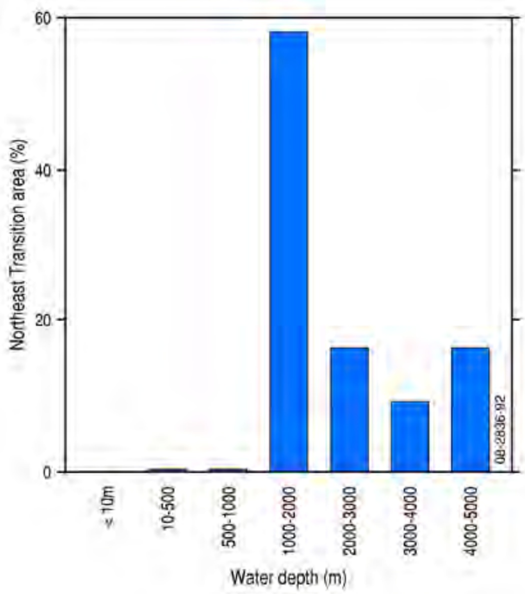


Figure 5.47. Distribution of water depth classes by percentage area within the NET.

Table 5.22. The percentage area of geomorphic units found in the Northeast Transition.

Feature	% of bioregion area covered	% of EMR area this unit lies within this bioregion	% of EEZ area this unit lies within this bioregion
Geomorphic Province			
Slope	75.35	5.42	2.63
Rise	9.80	51.28	12.86
AP/DOF*	14.86	4.05	0.82
Geomorphic Feature			
Slope (unassigned)	0.29	0.17	0.03
Rise (unassigned)	9.04	41.03	12.50
Trench/trough	11.76	18.96	8.96
Basin	14.86	5.37	2.96
Reef	0.43	2.87	1.23
Canyon	0.57	7.65	0.70
Ridge	0.33	39.67	0.39
Pinnacle	0.04	2.38	1.15
Plateau	62.10	8.00	5.50
Apron/fan	0.59	29.71	6.72

Table 5.23. The water depth of geomorphic units found in the Northeast Transition.

Feature	Depth Range (m)	Mean Depth (m)
Geomorphic Province		
Slope	0 – 4,030	1,670
Rise	1,925 – 4,665	3,655
AP/DOF	3,740 – 4,830	4,420
Geomorphic Feature		
Slope (unassigned)	2,875 – 4,030	3,400
Rise (unassigned)	2,785 – 4,410	3,660
Trench/trough	1,135 – 2,560	1,680
Basin	3,740 – 4,835	4,420
Reef	0 – 2,295	595
Canyon	1,925 – 4,665	3,630
Ridge	1,670 – 4,065	3,090
Pinnacle	1,490 – 2,905	2,110
Plateau	190 – 3,510	1,670
Apron/fan	420 – 2,585	1,505

5.13.3. Sedimentology the Northeast Transition

A total of 16 mean grain size, 8 weight % of textural fraction and 18 carbonate assays occur in the NET. Mud is the dominant textural fraction with contents ranging from 15 – 97% with five out of eight samples attaining >84%. Sand contents range from 2 – 85% with a majority (62%) samples attaining

<16%. Gravel forms <1% of all samples. Samples with the highest mud contents occur in trench/trough features.

Carbonate content exceeds 50% in 15 (83%) samples, and exceed 80% in 5 (28%) samples. Three samples contain carbonate ranging from 21 - 37%. Samples with carbonate contents of <80% occur on the abyssal plain/deep ocean floor and rise. Where analysed, the carbonate content of mud consistently exceeds 50% with three (38%) samples attaining >75%. The carbonate content of sand is more variable, ranging from 28 to 95%. Where present, gravel is entirely composed of carbonate.

5.13.4. Sedimentology of significant geomorphic features

5.13.4.1. Trench/Trough

Ten samples were collected from trench/troughs in the NEP. Mud is the dominant textural fraction with contents ranging from 21 - 97% with five out of seven samples (71%) attaining >84%. (Fig. 5.48). Sand is the next most abundant fraction, ranging from 3 - 78% with six out of seven samples (86%) attaining <35%. Gravel content is <1% in all samples. Bulk carbonate content data is available for all ten samples and ranges from 37 - 94% and exceeds 50% in 90% of samples (Fig. 5.49).

5.13.4.2. Plateau

Six samples were obtained from plateaus. Due to small sample volumes, weight % data for textural fractions was only generated for one sample. This sample is composed of 14% mud, 86% sand and <1% gravel. Mud in this sample is composed of 91% carbonate, sand 95%, and gravel 100%. Bulk carbonate data is available for all six samples and ranges from 29 – 91% and exceeds 75% in four (67%) samples (Fig. 5.49).

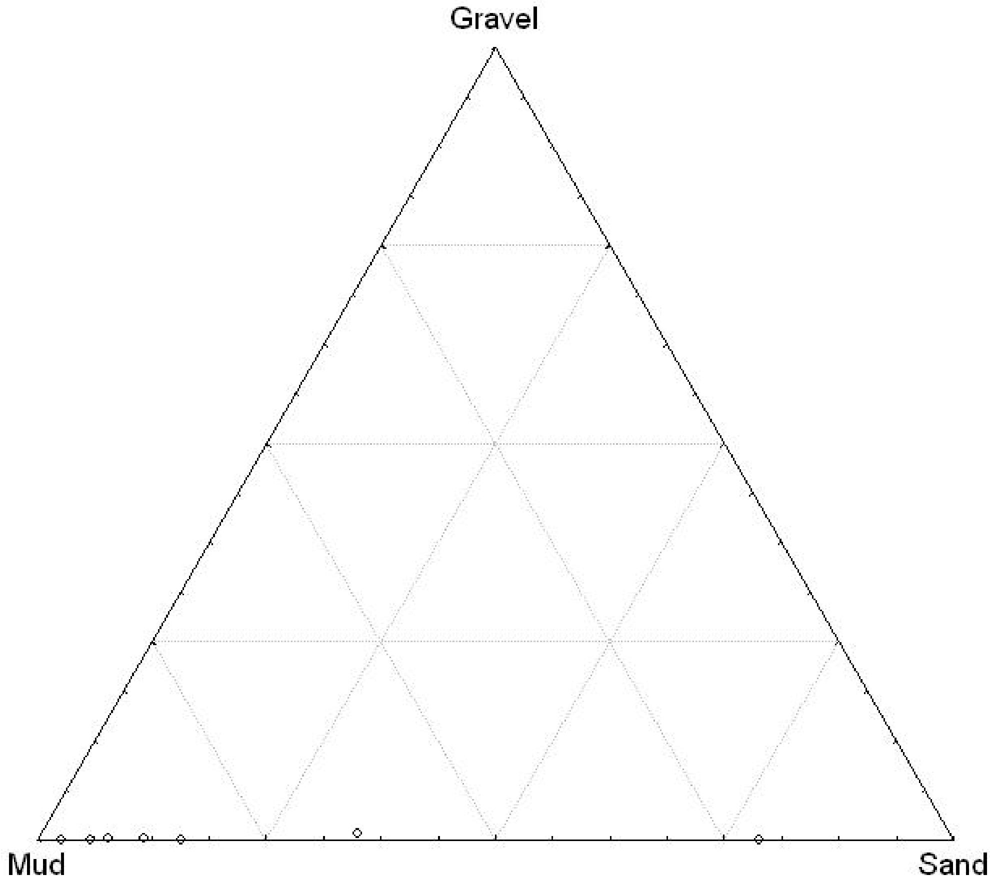


Figure 5.48. Textural composition (mud:sand:gravel ratio) of trench/trough sediments within the NET.

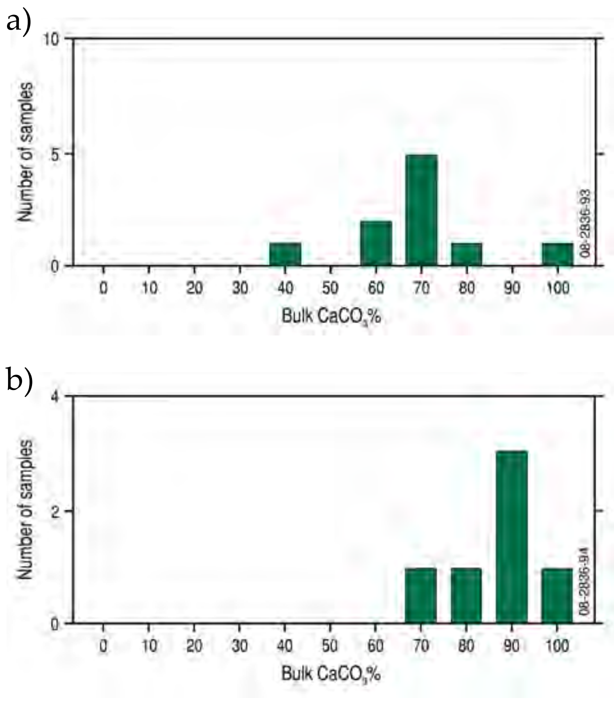


Figure 5.49. Carbonate content of a) trench/trough and b) plateau sediments within the NET.

5.14. SOUTHEAST TRANSITION (SET)

5.14.1. Geomorphology and bathymetry

The SET covers a total area of 241,910 km^2 of which 8,800 km^2 (4%) is located within the EMR. The SET represents <1% of the total area of the EMR. The SET is located on the offshore between Ulladulla and Bermagui. In the EMR, the SET is bounded to the northeast by the CEP to the west by the CEST, and to the south and southeast by the EMR boundary.

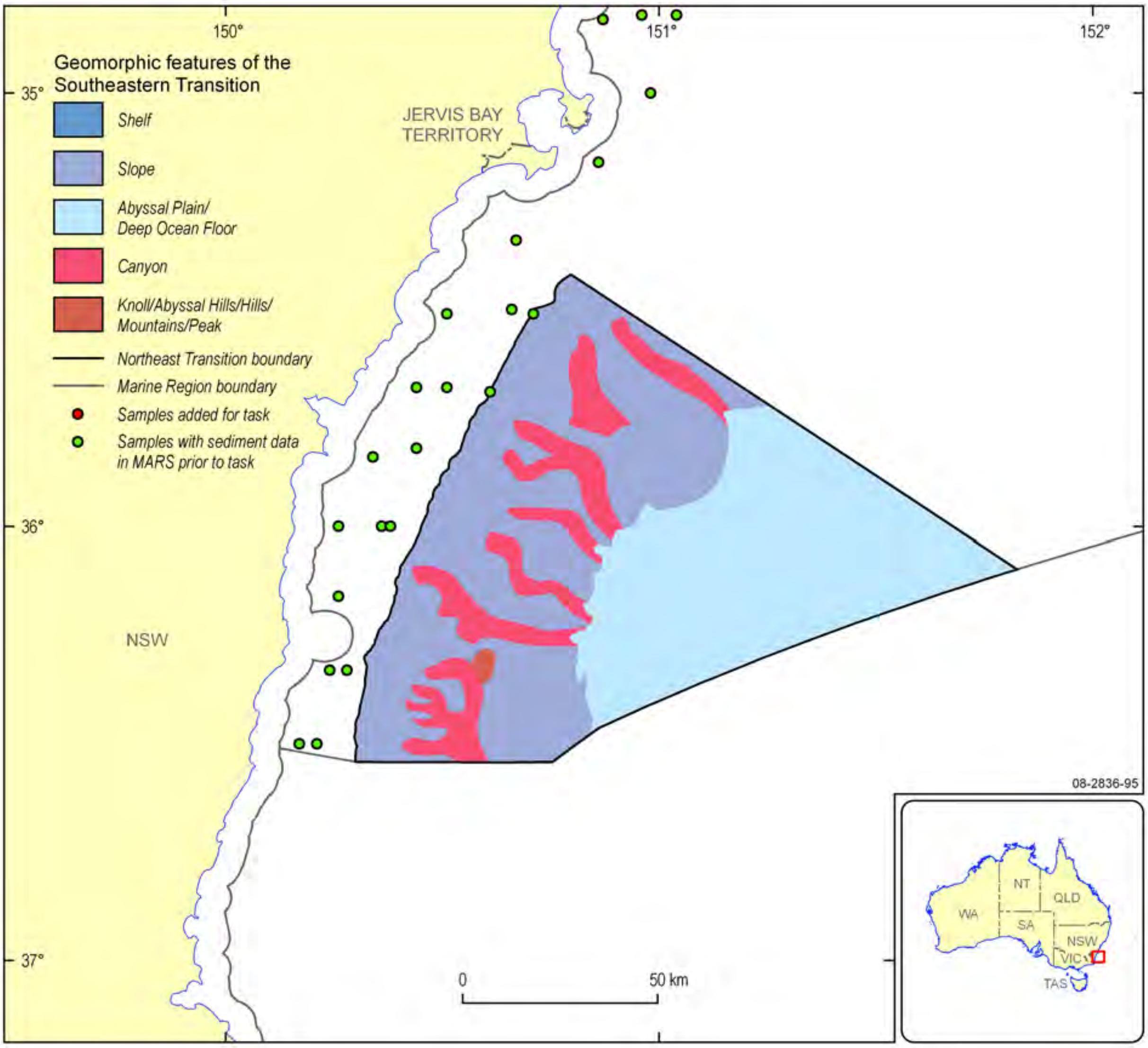
The area of the SET in the EMR occurs on the slope (5,190 km^2, 59%) and abyssal plain/deep ocean floor (3,595 km^2, 41%). Two geomorphic features are identified within the area of the slope: canyons (1,255 km^2, 14%); and knoll/abyssal hills/hills/mountains/peak in the south of the region (30 km^2, >1%) (Fig. 5.50. & Table 5.24). No geomorphic features were identified on 3,910 km^2 (75%) of the slope. No features occur on the abyssal plain/deep ocean floor.

Water depths in the area of the SET included in the EMR range from 125 m near the shelf break to 5,265 m on the abyssal plain/deep ocean floor with an average depth of 3,485 m (Table 5.25). More than 82% of the region lies in water depths >2,000 m (Fig. 5.51). Canyons occur in water depths from 405 – 4,845 with an average depth of 2,980 m. Knoll/abyssal hills/hills/mountains/peaks occur in water depths of 1,595 – 2,490 with an average depth of 4,810 m.

5.14.2. Sample Coverage

The area of the SET within the EMR contains no textural and/or compositional data. Although this bioregion was identified as a significant data gap, no samples were available for this area either at GA or from external repositories.

a)


150°
151°
152°
35°
36°
37°
Geomorphic features of the Southeastern Transition
Shelf
Slope
Abyssal Plain/ Deep Ocean Floor
Canyon
Knoll/Abyssal Hills/Hills/ Mountains/Peak
Northeast Transition boundary
Marine Region boundary
Samples added for task
Samples with sediment data in MARS prior to task
JERVIS BAY TERRITORY
NSW
0
50 km
08-2836-95
NT
QLD
WA
SA
NSW
VIC
TAS

b)

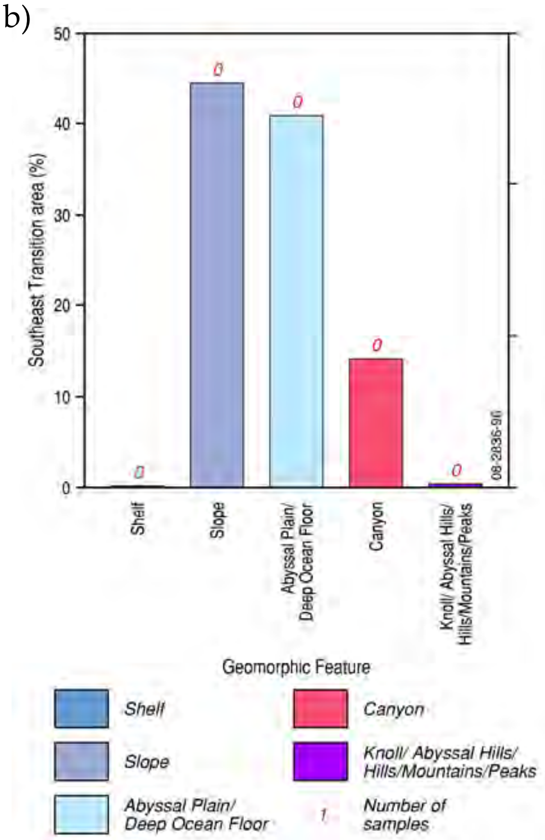


Figure 5.50. a) Geomorphology of the Southeast Transition (SET) with location of sediment samples; and b) Percentage area of each geomorphic feature within the SET with number of corresponding sediment samples (on top of columns).

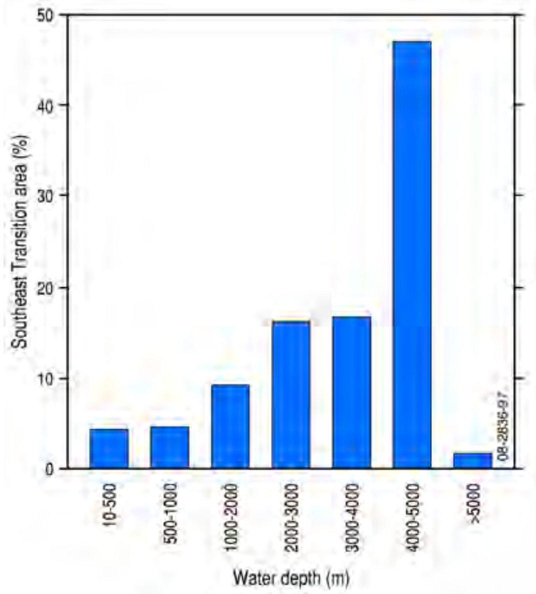


Figure 5.51. Distribution of water depth classes by percentage area within the SET.

Table 5.24. The percentage area of geomorphic units found in the Southeast Transition.

Feature	% of bioregion area covered	% of EMR area this unit lies within this bioregion	% of EEZ area this unit lies within this bioregion
Geomorphic Province			
Slope	59.03	0.28	0.14
AP/DOF	40.85	0.74	0.15
Geomorphic Feature			
Slope (unassigned)	44.44	1.76	0.28
AP/DOF (unassigned)	40.85	0.97	0.15
Canyon	14.25	12.76	1.17
Knoll/abyssal hills/hills/mountains/peak	0.34	0.31	0.03

Table 5.25. The water depth of geomorphic units found in the Southeast Transition.

Feature	Depth Range (m)	Mean Depth (m)
Geomorphic Province		
Slope	140 – 5,270	2,505
AP/DOF	4,170 – 5,270	4,810
Geomorphic Feature		
Slope (unassigned)	140 – 5,270	2,360
AP/DOF (unassigned)	4,170 – 5,270	4,810
Canyon	405 – 4,845	2,980
Knoll/abyssal hills/hills/mountains/peak	1,595 – 2,490	1,880

5.15. TASMAN BASIN PROVINCE (TBP)

5.15.1. Geomorphology and bathymetry

The TBP covers 156,420 km² which represents 6% of the total area of the EMR. The TBP is located on abyssal plain/deep ocean floor offshore between North Stradbroke Island and Sussex Inlet, and comprises seabed from the abyssal plain of the Tasman Basin to Dampier Ridge (located in the LHP). It includes the Tasman Basin and the Tasmantid Seamount Chain, a chain of volcanic seamounts. The seamounts are flat topped and include the Brisbane Guyot, Queensland Guyot, the Brittania Guyots, Stradbroke Seamount, Derwent-Hunter Guyot, Barcoo Bank and Taupo Bank. The TBP is bounded to the east by the LHP, to the east by the CEP and CEST, and to the north by the KT.

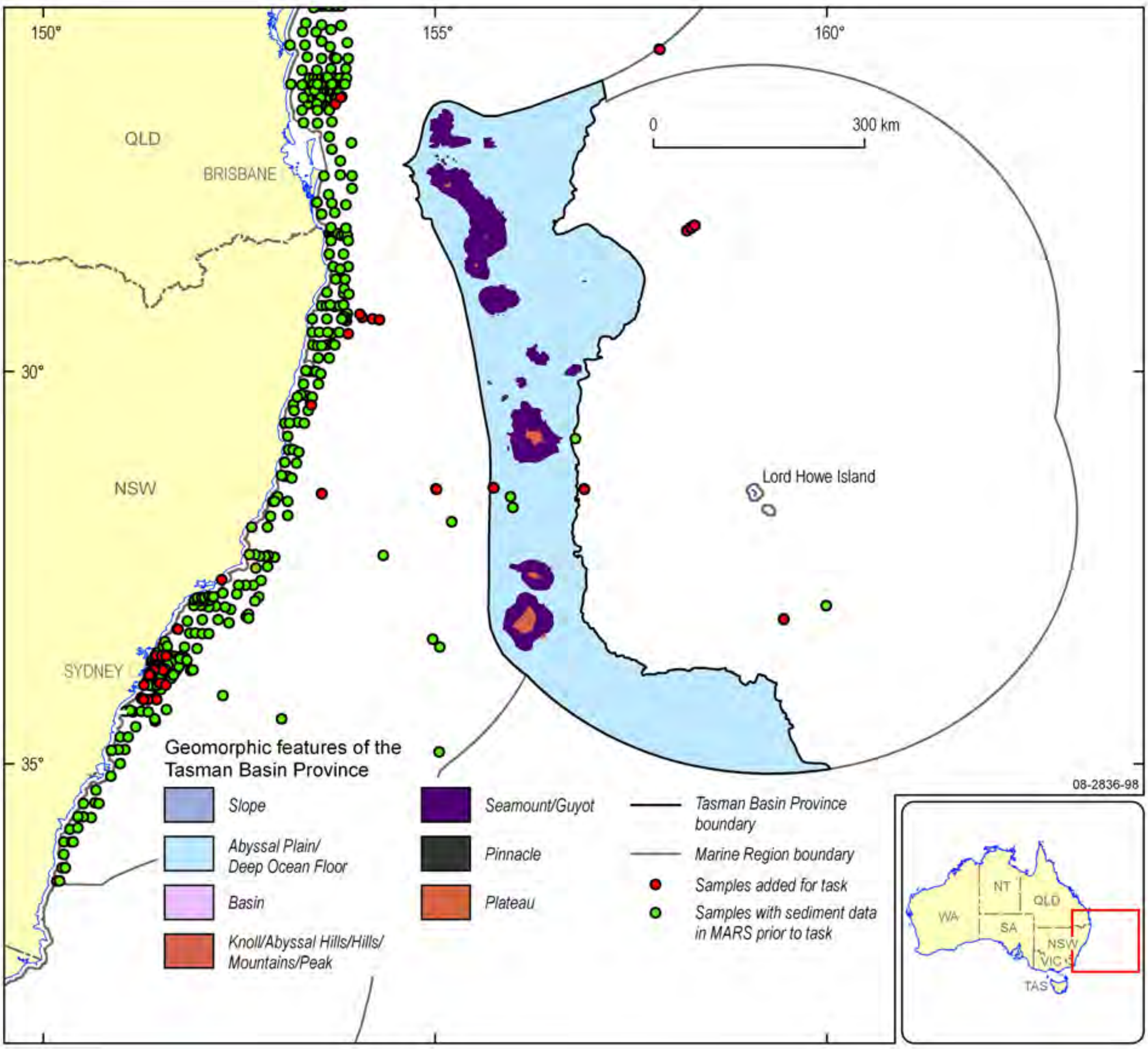
More than 136,090 km² or 87% of the TBP occurs on the abyssal plain/deep ocean floor. Within this area, three geomorphic features are identified: knolls/abyssal hills/hills/mountains/peaks (1,120 km², 1%); seamounts/guyots (18,480 km², 12%); and pinnacles (210 km², <1%) (Fig. 5.52). No geomorphic features are identified on 136,610 km² (87%) of the abyssal plain/ deep ocean floor. All geomorphic features that occur in the TBP are considered significant due to the unique features positioned adjacent to the western edge of the province and the relatively large percentage (>10% with the exception of pinnacles which occupy 8% of the total area of pinnacles in the EMR) of area of each feature within the EMR (Table 5.26).

Water depths in the area of the TBP included in the EMR range from 125 m to 5,180 m on the abyssal plain/deep ocean floor with an average depth of 4,670 m (Table 5.27). More than 83% of the region lies in water depths >4,000 m (Fig. 5.53).

5.15.2. Sample Coverage

The TBP contains three samples with quantitative grain size and/or carbonate data. All three of the samples occur on the abyssal plain/deep ocean floor (unassigned) in water depths >4,700 m. The average sample density in the TBP is 1:7,800 km², and samples do not achieve sufficient coverage to describe sedimentology of individual feature types. Despite targeted sample selection, only one sample from the TBP was procured and analysed for this task, and no other samples were found to be available at GA or in external repositories.

a)



b)

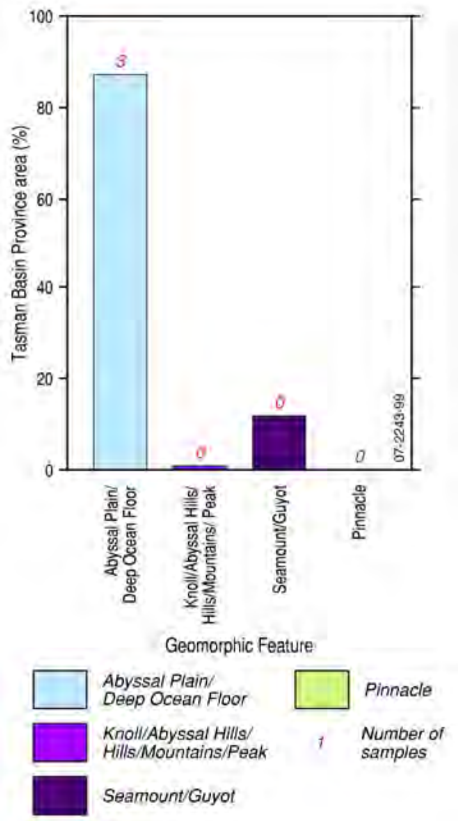


Figure 5.52. a) Geomorphology of the Tasman Basin Province (TBP) with location of sediment samples; and b) Percentage area of each geomorphic feature within the TBP with number of corresponding sediment samples (on top of columns).

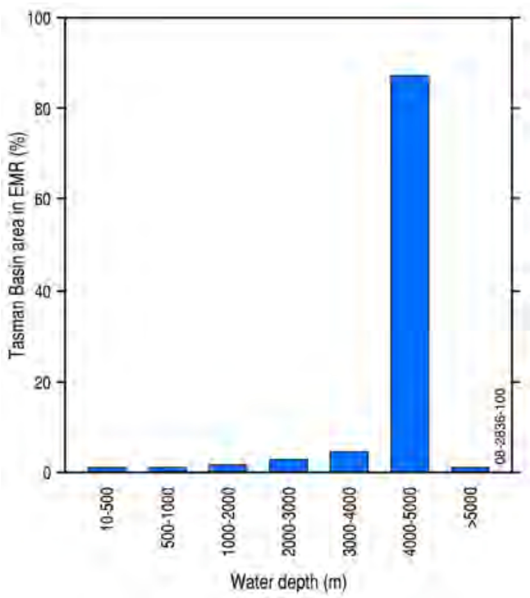


Figure 5.53. Distribution of water depth classes by percentage area within the TBP.

Table 5.26. The percentage area of geomorphic units found in the Tasman Basin Province.

Feature	% of bioregion area covered	% of EMR area this unit lies within this bioregion	% of EEZ area this unit lies within this bioregion
Geomorphic Province			
AP/DOF*	100	32.21	6.49
Geomorphic Feature			
AP/DOF (unassigned)	87.34	36.91	5.54
Knoll/abyssal hills/hills/mountains/peak	0.71	11.53	0.94
Seamount/guyot	11.81	43.86	18.36
Pinnacle	0.13	8.41	4.05

Table 5.27. The water depth of geomorphic units found in the Tasman Basin Province.

Feature	Depth Range (m)	Mean Depth (m)
Geomorphic Province		
Slope	4,005 – 5,105	4,600
AP/DOF	125 – 5,180	4,425
Geomorphic Feature		
Slope (unassigned)	4,590 – 4,765	4,690
AP/DOF (unassigned)	1,585 – 5,180	4,670
Basin	4,560 – 4,750	4,660
Knoll/abyssal hills/hills/mountains/peak	125 – 3,975	395
Seamount/guyot	200 – 5,150	2,835
Pinnacle	3,300 – 5,055	4,640
Plateau	4,005 – 5,105	4,595

5.15.3. Sedimentology of the Tasman Basin Province

One grain size and three bulk carbonate assays are available for the TBP. The sample with grainsize data occurs on the abyssal plain/deep ocean floor (unassigned) and comprises >99% mud with the remainder of sediment composed of sand. Carbonate content of the mud in this sample is 51%. Sediments in this sample are similar to those found at >4000 m depths in the adjacent LHP. Bulk carbonate contents for all samples range from 24 – 55% (Fig. 5.54).

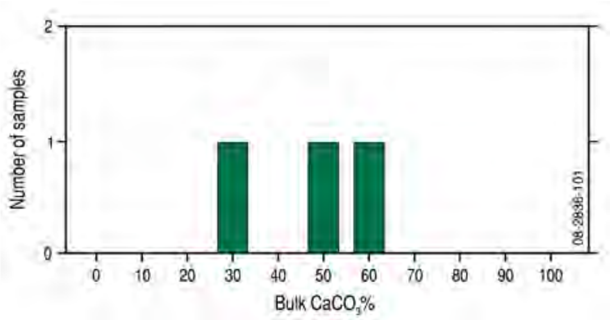


Figure 5.54. Carbonate content of abyssal plain/deep ocean floor sediments within the TBP.

6. Summary and Discussion

Textural and compositional data generated for the EMR permits a quantitative comparison of the sedimentology for Australia's East Margin. The data build on the predominantly qualitative studies that currently exist for the region. The following provides a comprehensive description of the sedimentology and geomorphology of the EMR, including information from previous studies (Section 3) and new results (Sections 4 & 5). The implications of seabed sediment distribution for marine habitat mapping are also discussed.

6.1. SUMMARY OF THE SEDIMENTOLOGY AND GEOMORPHOLOGY OF THE EMR AS DESCRIBED FROM EXISTING LITERATURE

The shelf in the EMR is subject to relatively high wave and current energy and has had a low sediment supply since sea level reached its present position some 6,000 years ago. This has had a profound effect on the geomorphology of the sea floor and on the texture and composition of sediments found on the shelf. The shelf is shaped by the topography that was drowned as sea level rose. A wedge of sediment of varying width and thickness has accumulated during the late Cainozoic and characterises the shape of the outer shelf and upper slope (Davies, 1979; Roy and Thom, 1991).

The inner shelf is shaped by the submarine extension of coastal headlands and rock outcrop and rock debris are common on the sea floor. Quartz sand ridges abut this outcrop in many places and some are modified relict shorelines. Ripples and dunes in the sand and scours around rock outcrops are common on the shelf and are evidence for mobile sediment on the sea floor. This is particularly so north of Fraser Island where the quartz sands that are moving north by longshore drift form the Breaksea Spit that extends across the shelf to the shelf edge (Boyd et al., 2008).

The mid-shelf is characterised by the deposition of fine sediments that have been able to accumulate below fair weather base, inboard from the effects of the EAC. The only significant accumulations of mud in the sand occur where the shelf is wider south of Sugarloaf Point at three locations: offshore of Newcastle, north of Sydney and Wollongong (Matthai and Birch, 2000a). North of Sugarloaf Point there is evidence that the EAC has affected sediments at all depths except in the larger embayments (Jones and Kudrass, 1982; Rule et al., 2007).

The outer shelf is generally a flat plain that is dominated by carbonate sediments, much of it relict (Marshall and Davies, 1978). Winnowing by the EAC has led to the accumulation of shelly and ferruginous gravels on the outer shelf in many places. Off Queensland significant carbonate banks have formed on the outer shelf with rhodolith gravels and carbonate hardgrounds on the sea floor.

The slope in the EMR is characterised by being relatively steep and having a relatively low rate of sediment accumulation. On the slope there are the competing processes of erosion and deposition to modify the topography inherited from plate tectonics. Canyons and scars from gravity slumping are a major feature of the NSW-Queensland slope in the EMR. They occur 50 to 100 km apart, generally off major drainage systems on land. The canyons are smaller on the Queensland section of the slope. The erosion of canyons has exposed a variety of rock types (Heggie et al., 1992; Packham et al., 2006). The canyons are also important as conduits for nutrient-rich water to reach the shelf. Nowhere are canyon heads incised into the shelf break but in 13 cases they have incised to the 150-300 m isobath. In general, the upper slope down to 1,500 m is a smooth surface of unconsolidated sediments. These sediments are the seaward face of the sediment wedge that underlies the shelf edge. Slide scars and evidence of creep are present in the toe of this sediment wedge below 1,000 m. Most of the large canyons form from tributaries coalescing on the mid-slope where large slope failures have occurred.

From north of Brisbane to Breaksea Spit on the northern tip of Fraser Island small canyons and gullies have incised the upper slope to water depths of 150 m. Above this depth the upper slope is very steep due to outcrop of limestone platforms (Marshall et al., 1998). This is the only area where significant amounts of sediment are reaching the heads of canyons. Quartz and carbonate sand from the inner shelf is found in canyons down this slope (Boyd et al., 2008). Elsewhere the canyons are considered inactive and would have a floor draped in hemipelagic mud.

A prominent geomorphic feature of the lower slope is the major scarps, up to 2,000 m high and extending for 10s of kilometers along the base of slope where it has an abrupt contact with the abyssal plain/deep ocean floor. These scarps represent fault surfaces that were formed during breakup of the continental crust along this margin 70 to 60 million years ago. Rock and rubble are exposed on these scarps. The base of the continental slope is at 5,000 m in the south and 4,600 m in the north off Fraser Island.

At all water depths throughout the EMR the sea floor sediments are well oxygenated. This reflects the relatively low productivity in the surface waters, and hence the oxygen minimum zone in the water column between 1,000 and 2,000 m is poorly developed and benthic communities are not affected where it impinges on the slope. Both rock and sediment form the substrate on the slope. Most rock outcrops are in water depths >1,500 m on the sides of canyons, igneous pinnacles and domes and on fault scarps. The only rocks on the upper slope are cemented hardgrounds off northern NSW, volcanic ridges off Wollongong and Port Macquarie, a seamount off Sydney and a limestone platform off Fraser Island. In general, the sediment is muddy sands and sandy muds, composed of about half carbonate and half terrigenous particles (Troedson and Davies, 2001). Scours around rock outcrops indicate that the EAC can winnow the sediment down to 1,000 m water depth. The sediment becomes more mud rich below this depth. The carbonate fraction is dominated by the calcite remains of foraminifers (sand size) and coccoliths (mud size). Minor amounts of pteropods, echinoids and sponge spicules (both silica and calcite) are also present. The terrigenous fraction is fine quartz and clay minerals. The two exceptions to this distribution of sediment texture and composition are sands on the upper slope off Queensland, where bottom sediment has been transported over the shelf edge, and off northern NSW where phosphate, glauconite and ferruginous gravels and slabs occur on the sea floor.

The abyssal sea floor of the Tasman Sea receives very little sediment today because: plankton productivity is low in the surface waters; its depth of 4,800-5,100 m leads to dissolution of carbonate particles, and little sediment is supplied from land because all except one canyon system are inactive. In the north of the basin the sea floor is shallower because there has been more sedimentation in the past, from turbidity currents generated by a greater supply of sediments to the slope. The abyssal plain extends approximately 200-250 km out from the base of slope. It was formed by deposits from turbidity currents filling the underlying volcanic topography on the oceanic crust. East of the abyssal plain are abyssal hills where the volcanic topography is draped by pelagic sediments. There are no fans or large debris aprons at the base of slope. This is unusual and probably due to bottom currents redistributing the sediments. Scours in the sediments, sediment drift deposits and moats are all evidence of strong bottom current activity along both the east and west margins of the basin and around seamounts (Jenkins, 1984). Sediments on the abyssal sea floor are slowly accumulating brown clays or calcareous muds overlying turbidite deposits. Manganese nodules occur in the abyssal hills region.

Seamounts are a major feature of the EMR. They vary in size from 2 to 50 km wide at their base and range in height from 10s of meters to ~5,000 m. They occur all over the Tasman abyssal sea floor, on the plateaus and ridges and in the Norfolk Island region. Some were formed during sea floor spreading, others were formed by the plate moving over hot-spots in the mantle. The youngest discovered to date are on Lord Howe Rise and Norfolk Island (~2 Ma). Two major seamount chains run north-south with the younger seamounts (~7 Ma) in the south and seamounts of Oligocene age (~30 Ma) in the north (McDougall and Duncan, 1988). Many reach the surface to form island and carbonate reefs, others have subsided below sea level and are capped with limestone, and have a flat summit within 500 m of the sea surface. The seamounts are composed of basalt which is coated with manganese crust where it has been exposed on the sea floor for a long time. They shed carbonate and volcanic debris to the sea floor below by gravity slumping.

The Dampier Ridge and Lord Howe Rise are plateaus mostly 1,000 to 2,000 m below sea level that are blanketed in pelagic ooze consisting of foraminifers and coccoliths. They have steep sides, along some margins the scarps have over 1,000 m of relief. Slumping, gullying and small canyons occur on all slopes. Volcanic activity has formed some of the scarps on both plateaus. There is also evidence of relatively recent volcanic activity forming small seamounts on the LHR itself. Moats around seamounts on LHR suggest the presence of relatively strong bottom currents.

The Marion and Queensland Plateaus dominate the northern part of the EMR. They have a similar origin due to subsidence of continental crust attached to Australia to form marginal plateaus, followed by a period of carbonate platform construction in the Miocene (Davies and McKenzie, 1993). Reef growth on these platforms has led to carbonate platforms/atolls at the sea surface being major geomorphic features today. These atolls have very steep upper slopes where limestone is exposed. Scalloped morphology on their margins indicates mass slumping of material into the adjacent deeper water (Francis et al., in press). The platforms/atolls shed shallow water carbonate sediments to the surrounding sea floor. Many smaller platforms and pinnacles are drowned features. Limestone outcrops on the sea floor occur on both plateaus. Elsewhere, pelagic carbonate is the dominant sediment with the terrigenous mud content greater in the troughs between the plateaus and the shelf. There is strong evidence of bottom currents eroding the sediment and modifying the sea floor on the plateaus (Exon et al., 2005). Both plateaus have steep sides with small canyons and gullies leading into the adjacent basins and troughs.

East of the marginal plateaus is an area with complex geomorphology that is poorly surveyed. There is evidence for extensive volcanism in the Cato Basin area and around Mellish Reef (Exon et al., 2006a). Narrow ridges and basins characterise the area. Turbidites have formed a smooth floor in the basins whereas the ridges are rugged. Erosion and sediment movement on the ridges is confirmed by sand waves and scours. Slumping and small canyons occur on the slopes and channels have been eroded in the sediment in the troughs. Pelagic carbonate sediments drape the highs and have been redeposited into the lows. In the northeast of the EMR the presence of diatoms in the sediment from the Coral Sea Basin suggests higher surface water productivity due to the Southern Equatorial Current. In the narrow northwest section of the EMR there is a greater supply of terrigenous sediment than in other areas, as it is sourced from the rivers flowing into the Gulf of Papua.

The area around Norfolk Island in the EMR is divided in two by the N-S Norfolk Ridge. To the west the Fairway Basin floor is quite rugged compared to the smooth flat floor of the New Caledonia Basin. They are separated by a steep-sided rugged ridge with scarps of up to 1,000 m. Norfolk Ridge itself has a relatively flat top <2,000 m deep with three large areas in less than 500 m of water. Wanganella Bank at the boundary of the EMR in the south is less than 100 m water depth. East of Norfolk Ridge is a complex topography of basins, ridges and plateaus with numerous seamounts and submarine escarpments. At least four large seamounts come to within 1,000 m of the sea surface (DiCaprio et al., in press). Rock outcrop is abundant in this region. Sediments in the area are pelagic carbonates with a minor contribution from radiolarians, diatoms and volcanic ash. There is some evidence of bottom currents affecting the sediments on the tops of seamounts and ridges.

6.2. SUMMARY OF SEDIMENTOLOGY AS DERIVED FROM SEDIMENT DATA FOR THE EMR

New consistent quantitative data for the EMR have revealed regional scale patterns in sediment distribution not apparent in previous studies, and forms a framework within which local scale patterns can be understood in a regional context. New data reveals some of the seabed complexity. At a regional scale our data show that the seabed sediments generally become finer with increasing water depth. Variation in sediment texture and composition generally decreases with increasing water depth, with sediments on the rise and abyssal plain/deep ocean floor being relatively homogeneous compared to those on the shelf and adjacent slope.

The shelf is predominantly composed of sand and the abyssal plain/deep ocean floor composed of mud. This trend is reported in reports by Geoscience Australia for other areas of the Australian margin (Potter et al, in press). Areas of gravel are localised and occur mainly on the inner, mid and outer shelf/slope, and are generally absent from the abyssal plain/deep ocean floor. Calcium carbonate concentrations are highest on the shelf and upper slope, and lowest on the lower slope rise and abyssal plain/deep ocean floor. Calcium carbonate content increases adjacent to the Great Barrier Reef Marine Park where calcium production is high.

At a regional scale our results agree with previous sedimentological work on the shelf, slope and abyssal plain/deep ocean floor. Our data indicate distinct variations in the sediment characteristics for the shelf, slope and abyssal plain/deep ocean floor. Our data also provides an analysis of the sediment texture of the rise within the EMR.

Our data indicate distinct variations in sediment characteristics along the inner and outer shelf, and mid to upper slope, due to high current and wave energy. These sediment characteristics were reported at local scales by (Gordon and Hoffman, 1986; Short and Trenaman, 1992; Roy et al., 1994a; Middleton et al., 1997). New data have allowed us to more accurately map the extent, and recognise the regional significance of these sedimentary characteristics.

High resolution data for the seabed in the EEZ indicate that geomorphic features are characterised by a combination of several environments with zones of transition between the features. For some geomorphic features, the new data allow us to more accurately predict and distinguish between the range of environments present and, where data are adequate, estimate the relative proportions of these. Distinct sedimentary environments occurred in some geomorphic features and these include: abyssal plain/deep ocean floor, basin, shallow and deep water terrace, slope, plateau, and trench/trough.

6.2.1. Shelf

Seabed sediments of the shelf are sand dominated, with a large carbonate component with >50% of samples containing between 50 and 100%. Bulk carbonate content increases with sand content and sand content decreases with water depth. Our data indicate that localised deposits of mud occur in the vicinity of Newcastle. This pattern corresponds to the high mud content found off the Hunter River as observed by Matthai and Birch (2000a). Our data also detected additional comparable areas of gravel (~40-80%) present locally offshore of Stradbroke Island, within Hervey Bay, north of Brisbane and offshore of Wollongong. Our results are consistent with Marshall and Davies (1978) description of the carbonate dominated outer shelf sediments. Associations between our sediment data and previous facies models for some areas of the inner shelf are difficult to resolve due to local areas of sparse data. Our data show that the regional trend for the shelf appears to be dominated by carbonate sand with localized accumulations of gravel and mud as seen by Marshall and Davies (1978).

6.2.2. Slope

At a regional scale, sediments of the inner slope mostly comprise sand, while seabed sediments of the outer slope are dominated by mud. Further, mud content increases with water depth on the abyssal plain/deep ocean floor and rise. Sediment data for this province are relatively scarce, however the available data provide significantly higher coverage for this area than was previously available. Carbonate content increases with sand content with localised concentrations of bulk carbonate ranging between 40 and 100% offshore outside Hervey Bay, Stradbroke Island and to the south of Wollongong. Gravel content is generally low, however localised aggregations occur in large quantities offshore Hervey Bay, Mackay and to the south of Cairns. Smaller localised concentrations of gravel occur offshore Coffs Harbour, Byron Bay and to the north of Brisbane. Mud content on the upper slope is low, however localised clusters occur offshore Wollongong, Newcastle, Port Macquarie and north of Coffs Harbour.

Our results reveal that at a regional scale the greatest variety of sediments occur in areas containing several geomorphic features and between bioregions (i.e., features adjacent to seamounts with higher gravel amounts although there were low sample numbers taken from seamounts). This is particularly evident where features with a distinct sedimentology are interspersed with other features with a distinct sedimentology (i.e., gravel dominated pinnacles located within the homogenous, sand dominated shelf).

Addition of data in geomorphic features occurring on the shelf and inner slope have resulted in the first quantitative analysis of the sedimentology of features occurring at these water depths in the EMR, including trenches, plateaus and terraces. Sediment data show that some features in this zone are characterised by a distinct sedimentology that differentiates each feature from one another. These features include: plateaus, terraces, trench/troughs, shelf and slope.

Our data provide further evidence for extensive carbonate deposits on the outer shelf with localized deposits of rhodolith gravels on the sea floor (Marshall and Davies, 1978). The outer slope contains a higher proportion of mud (20-90%) than found on the adjacent shelf.

6.2.3. Abyssal Plain/Deep Ocean Floor

Sediment samples procured for this task from the abyssal plain/deep ocean floor have significantly increased the sample coverage and understanding of the sediment properties. The abyssal plain/deep ocean floor is a relatively homogenous sedimentary environment dominated by calcareous mud containing foraminifers and coccoliths with small inclusions of sand and gravel. Our data concurs with the findings of Jenkins (1984) who described the sedimentology of the abyssal plain/deep ocean floor as brown clays or calcareous muds. The bulk carbonate content of sediments in deep water areas of the EMR provides further evidence that content range between 5 and 55% (Eade & van der Linden, 1970).

6.3. IMPLICATIONS FOR MARINE HABITAT MAPPING

Conservation of benthic marine habitats requires information on the geomorphology, sedimentology and oceanography of an area. The use of sediment properties as physical surrogates for benthic biological data that can be measured with ease, (Bax, 2001), may provide a greater understanding of marine ecosystems (Post, 2006). Relationships are recognised to exist between the texture and composition of seabed sediments and biota (Day & Roff, 2000; Roff et al., 2003; Roff & Taylor, 2000). For this reason, sediment properties as measured in this study are an important input into statistical models used to approximate the nature and extent of seabed marine habitats (see the seascapes of Day and Roff, 2000 and Whiteway et al., 2007). The accuracy of the seascapes in representing seabed habitats is directly related to the quality and resolution of underlying sediment data. Major sources of spatial error in sediment data used to characterise habitats are the result of low data density and inadequate interpolation methodologies. Addition of new data helps reduce these sources of error and allows recognition of relationships between physical datasets that are useful in developing more effective interpolation techniques.

Benthic biota have been shown to have measurable relationships with the gravel and mud content of seabed sediments (Post, 2006; Bax and Williams, 2001). Our data show that where the sedimentology is relatively diverse, such as on the inner shelf and on the slope, the sediment properties including gravel and mud content varies greatly over relatively small distances. A higher sample density is required in these environments to more accurately map the spatial distribution properties (and by association benthic biota), however the complexity of the seabed is beginning to be resolved. Our data have improved sample coverage in these areas, however additional coverage will further increase the reliability with which this can be mapped. In areas where seabed environments are relatively uniform, such as over most of the abyssal plain/deep ocean floor, sediment properties are more constant over larger distances, and the physical characteristics can be accurately mapped from fewer samples.

Our synthesis of sedimentology and geomorphology has;-

a) provided a more improved understanding of the range of seabed sedimentary environments present in the EMR,

b) allowed comparison between sedimentary environments occurring in different areas culminating in the identification of rare or unique areas of seabed that may be of particular interest for conservation; and

c) described relationships between physical datasets providing full coverage of the EMR, such as bathymetry and geomorphology, and sediment distribution; and

d) provided the first most up-to-date synthesis of all data and studies for the EMR. These can be used to help predict the sedimentary environments that occur in areas where sediment data points are relatively scarce. New data on the abyssal plain/deep ocean floor, plateaus and terraces have allowed characterisation at a higher confidence.

6.4. LIMITATIONS

Although we have added significant detail to the regional sedimentology of the east margin, including better defined local and regional trends, the data are still relatively sparse in deep water areas, which limits the degree to which we can fully describe the sedimentology. It is important to recognise some of the limitations of the data.

Data in the EMR is clustered on the shelf, with a paucity of data for the outer slope and abyssal plain/deep ocean floor. This means that sediments present in areas with most data are likely to be over-represented in statistics at a regional scale. Uneven distribution of data also makes it difficult to statistically quantify relationships that are observed visually in data, and means that existing relationships may not be detected and utilised when interpolating data to rasters for input into seascapes. While this may cause some inaccuracy or bias at a regional scale, the structure of our analysis with observations and statistics generated for individual bioregions, provinces and features means that sedimentology at these scales is not significantly affected. Because data density is greatest on the shelf we place more confidence in the sediment patterns. However, complexity elsewhere may not have been detected due to relatively low sample density.

In this study we have used the inverse distance weighted method, with a fixed interpolation parameter, which has been used by Geoscience Australia to interpolate all of its point data across Australia's marine jurisdiction. This provides for a comparable and consistent dataset. The maximum distance that any data were extrapolated was 45 km. This method is adequate, where large ranges in data density occur, to produce maps that allow identification of trends in sediment distribution occurring at a regional scale, but may not necessarily represent sediment distribution at finer scales.

The key question in modelling studies is *"How much simplification is acceptable?"* A linear inverse distance weighted method (with a fixed interpolation parameter) does not necessarily represent all trends in sediment distribution. However, no interpolation method is able to pick up such trends if sample density is inadequate. Trends in sediment distribution in the EMR are known to occur on scales from centimeters to hundreds of kilometers. Without knowing at what scale variations in sediment characteristics are significant in mapping distribution of species, it is difficult to comment on how much uncertainty in interpolated data affects results generated for seabed habitat mapping.

Sample density for the EMR is 15:1,000 km^2 on the shelf, >1:1,000 km^2 on the slope, >1:1,000 km^2 on the rise and >1:1,000 km^2 on the abyssal plain/deep ocean floor. This provides the minimum distances over which variations in the sediment properties can be detected. Interpolation images must be used with caution when drawing comparison between seabed composition in different areas of the EMR as they do not necessarily represent: 1) the relative proportions of environments present in an area; or 2) the way sedimentary environments are interspersed spatially, as resolution of the interpolation is more a reflection of sample density than diverse sedimentology.

6.5. RECOMMENDATIONS

To improve interpolated data sets and confidence in representing the true characteristics of the seafloor, it is important to improve sample densities in areas of the seabed that contain significant variations in sediment characteristics over relatively small distances. As collecting sediment samples from the seabed is highly time consuming and costly, information about distribution of seabed complexity and the relationship to geomorphology can be used to target areas where data coverage is likely to be inadequate. New data generated for the NWMR and the SWMR (Potter, in press) allows recognition of relationships between relatively diverse seabed sedimentology and geomorphic features such as seamounts and surrounding plateaus and basins. In the EMR, sample densities in these features remain relatively low. New data for the EMR also indicates that although sediments are more homogenous in deep water areas (e.g., abyssal plain/deep ocean floor), greater variation may be captured in these areas than is captured in the current data. Data generated for this study have significantly improved sample densities for these areas and this work should be continued, particularly for the abyssal plain/deep ocean floor, slope and rise.

Data collection, advances in interpolation methods, and improved understanding of relationships between geomorphic features and sediment type, will improve the accuracy of future sedimentology work conducted at a Regional Marine Planning area scale. An improved understanding of geomorphic features such as the abyssal plain/deep ocean floor is required to more accurately map sediment distribution. Where sample coverage is sparse, the inclusion of secondary datasets in the interpolation process will allow the prediction of sediment type. Secondary datasets such as energy level, tidal regime, sediment transport pathways, and previous sediment models will improve the accuracy of future seabed sediment mapping. Our study has shown that future sampling in the EMR should focus on areas with poor sample coverage such as the abyssal plain/deep ocean floor, pinnacles, deep/hole/valleys, reefs, bank/shoals, knoll/abyssal hill/hill/peaks, ridge, outer shelf, lower slope and rise.

Geoscience Australia has a program to asses the accuracy and precision of interpolation techniques, and is investigating the usefulness of secondary datasets during interpolation.

6.6. SUMMARY

The EMR is characterised by a variable geomorphology and sedimentology. Sediment texture and composition displays a zoning with depth and bioregion, and sand and gravel dominate the shelf area whilst mud dominates the lower slope and abyssal plain/deep ocean floor. Calcium carbonate concentrations throughout the region are generally highest along the shelf to the shelf edge and are associated with reefs. Significant geomorphic features of the EMR with sedimentological information include; shelf (unassigned), slope (unassigned), AP/DOF (unassigned), basins, deep water trench/troughs, shallow and deep water terraces and plateaus.

Geoscience data plays a vital role in the management of Australia's ocean resources because we may never have a full inventory of all biota found on the seabed. Geomorphology and sedimentological data can be mapped relatively easily and this can be used as a surrogate between the distribution and abundance of benthic biota and seabed habitats. The relationship(s) between geomorphology and sediment/substrate type and biota is a key priority for future marine research.

7. References

Albani, A.D., Tayton, J.W., Rickwood, P.C., Gordon, A.D. and Hoffman, J.G., 1988. Cainozoic morphology of the inner continental shelf near Sydney. *Journal and Proceedings of the Royal Society of NSW* **121**, 11-28.

Albani, A.D. and Rickwood, P.C., 2000. Marine aggregates near Sydney. In: McNally, G.H. and Franklin, B.J. (Eds.), *Sandstone City – Sydney's dimension stone and other sandstone geomaterials.* Geological Society of Australia, EEHSG Monograph 5, 260-266.

Alcock, M.B., Stagg, H.M.J., Colwell, J.B. Borissova, I., Symonds, P.A. and Bernardel, G., 2006. *Seismic Transects of Australia's Frontier Continental Margins*. Geoscience Australia Record **2006/04**, 131p.

Andrews, J.E., Packham, G. *et al*., 1975. *Initial Reports of the Deep Sea Drilling Project*, Volume 30. Washington (U.S. Govt. Printing Office).

Anselmetti, F.S., Isern, A.R., Blum, P. and Betzler, C., (Eds.), 2006. Constraining Miocene sea level change from carbonate platform evolution, Marion Plateau, northeast Australia, Leg 194. *Proceedings of the Ocean Drilling Program, Scientific Results,* Volume 194. College Station, TX (Ocean Drilling Program).

Ashley, G.M, Boothroyd, J.C., Bridge, J.S., Clifton, H.E., Dalrymple, R.W., Elliot, T., Fleming, B.W., Harms, J.C., Harris, P. T., Hunter, R.E., Kreisa, R.D., Lancaster, N., Middleton, G.V., Paola, C., Rubin, D.M., Smith, J.D., Southard, J.B., Terwindt, J.H.I & Twitchell, D.C., 1990. Classification of large-scale subaqueous bedforms: a new look at an old problem. *Journal of Sedimentary Petroleum* **60**, 160-172

Auzende, J.M., Van de Beuque, S., Dickens, G., Francois, C., Lafoy, Y., Voutay, O. and Exon, N., 2000. Deep sea diapirs and bottom simulating reflector in Fairway Basin (SW Pacific). *Marine Geophysical Researches* **21(6)**, 579-587.

Baker, C., Potter, A. and Tran, M., 2008. Sedimentology and Geomorphology of the North West Region: A Spatial Analysis. Geoscience Australia Record **2008/07**. Geoscience Australia, Canberra, 220p.

Baker, E.K., Harris, P.T., Hubble, T.C.T., Jenkins, C.J., Keene, J.B., Manning, P.B., Packham, G.H., Pritchard, T.R., Schneider, P.M. and Tate, P.M., 1988a. *Geophysical and geological results of the*

HMAS 'Cook' Seamap cruise 1-86: north Tasman Sea and Polynesia. University of Sydney Ocean Sciences Institute Report 30, 33p.

Baker, E.K., Harris, P.T. and Packham, G.H., 1988b. *Physical properties of sediment sub-samples from cores collected in the Tasman Sea and Polynesia during the 'Seamap' program, 1985-87*. University of Sydney Ocean Sciences Institute Report 31, 23p.

Bax, N.J. and Williams, A., 2001. Seabed habitat on the southeast Australian continental shelf - context, vulnerability and monitoring. Marine and Freshwater Research, 52: 491-512.

Beaufort, L. and shipboard scientists, 2005. *MD148 – PECTEN IMAGES XII Cruise Report.* Past Equatorial Climate: tracking El Nino. Institut Polaire Francais. 58p.

Beiersdorf, H., 1989. Provenance and accumulation rates of Pliocene and Quaternary sediments from the western Coral Sea. *Geologische Rundschau* **78**, 987-998.

Bernardel, G., Carson, L., Meffre, S, Symonds, P. and Mauffret, A., 2002. *Geological and morphological framework of the Norfolk Ridge and Three Kings Ridge region*. Geoscience Australia Record **2002/08**. Geoscience Australia, Canberra.

Betzler, C., Brachert, T.C. and Kroon, D.,1995. Role of climate in partial drowning of the Queensland Plateau carbonate platform (northeastern Australia). *Marine Geology* **123**, 11-32.

Birch, G.F. and Davey, S., 1995. Accumulation of metallic contaminants in surficial sediments on a high energy continental shelf (Sydney, Australia). *The Science of the Total Environment* **170**, 81-93.

Blakeway, D., 1991. *Sedimentary sources and processes in outer shelf, slope and submarine canyon environments, Northern Ribbon Reefs, Great Barrier Reef, Australia*. Bachelor of Science (Honours) Thesis, James Cook University, Townsville, Australia, unpublished.

B.M.R. 1972-1977. *Marine Geophysical Survey of the Australian Continental Margin 1971-1972*. Deep seismic "Sparker" sections. Bureau of Mineral Resources, Geology and Geophysics, Canberra.

Boland, F.M. and Church, J.A., 1981. The East Australian Current 1978. *Deep-Sea Research* **28**, 937–957.

Boland, F.M. and Hamon, B.V., 1970. The East Australian Current, 1965-1968. *Deep-Sea Research* **17**, 777-794.

Bolton, B.R., Exon, N.F. and Ostwald J., 1990. Thick ferromanganese deposits from the Dampier Ridge and the Lord Howe Rise off eastern Australia. *BMR Journal of Australian Geology and Geophysics* **11(4)**, 421-427.

Boyd, R., Ruming, K. and Roberts, J.J., 2004a. Geomorphology and surficial sediments on the southeast Australian continental margin. *Australian Journal of Earth Sciences* **51**, 743-764.

Boyd, R., Ruming, K., Davies, S., Payenberg, T. and Lang, S., 2004b. Fraser Island and Hervey Bay – a classic modern sedimentary environment. In: Boult, P.J., Johns, D.R. and Lang, S.C. (Eds.), *Eastern Australasian Basins Symposium II*, Petroleum Exploration Society of Australia, Special Publication, 511-521.

Boyd, R., Ruming, K., Goodwin, I., Sandstrom, M. and Schroder-Adams, M., (2008). Highstand transport of coastal sand to the deep ocean: a case study from Fraser Island, southeast Australia. *Geology* **36**, 15-18.

Brachert, T.C. and Dullo, W.-C., 2000. Shallow burial diagenesis of skeletal carbonates: selective loss of aragonite shell material (Miocene to Recent, Queensland Plateau and Queensland Trough, NE Australia) – implications for shallow cool-water carbonates. *Sedimentary Geology* **136**, 169-187.

Browne, I., 1994. Seismic stratigraphy and relict coastal sediments off the east coast of Australia. *Marine Geology* **122**, 81-107.

Brunskill, G.J., Woolfe, K.J. and Zagorskis, I., 1995. Distribution of riverine sediment chemistry on the shelf, slope, and rise of the Gulf of Papua. *Geo-Marine Letters* **15**, 160-165.

Bryan, S.E., Constantine, A.E., Stephens, C.J., Ewart, A., Schon, R.W. and Parianos, J., 1997. Early Cretaceous volcano-sedimentary successions along the eastern Australian continental margin: implications for the break-up of eastern Gondwana. *Earth and Planetary Science Letters* **153**, 85-102.

Burns, R.E., Andrews, J.E., et al., 1973. *Initial Reports of the Deep Sea Drilling Project*, Volume 21. Washington (U.S. Govt. Printing Office).

Burrage, D.M., Steinberg, C.R., Skirving, W.J. and Kleypas, J.A., 1996. Mesoscale circulation features of the Great Barrier Reef region inferred from NOAA satellite imagery. *Remote Sensing of Environment* **56**, 21-41.

Church, J.A., 1987. East Australian Current adjacent to the Great Barrier Reef. *Australian Journal of Marine and Freshwater Research* **38**, 671-683.

Church, J.A. and Craig, P.D., 1998. Australia's shelf seas: diversity and complexity. In: Robinson, A.R. and Brink, K.H. (Eds.), *The Sea, Volume 11: The global ocean regional studies and synthesis.* Chapter 11.

Cochran, J.K. and Osmond, J.K., 1976. Sedimentation patterns and accumulation rates in the Tasman Basin. *Deep-Sea Research* **23**, 193-210.

Colwell, J. B. and Roy, P. S., 1983. *Description of subsurface sediments from the east Australian continental shelf ("Sonne" cruise SO-15).* Bureau of Mineral Resources, Geology and Geophysics Record **1983/21**, Canberra, 65pp.

Colwell, J.B. and Coffin, M.F., 1987. *Rig Seismic Research Cruise 13: Structure and stratigraphy of the northeast Gippsland Basin and southern New South Wales margin initial report.* BMR Report **283**, 76p.

Colwell, J.B., Coffin, M.F. and Spencer, R.A., 1993. Structure of the southern New South Wales continental margin, southeastern Australia. *BMR Journal of Australian Geology and Geophysics* **13**, 333-343.

Colwell, J.B., Foucher, J-P. and shipboard scientific party, 2006. *MD153 Programme Ausfair Cruise Report*. Institut Polaire Francais, 144p.

Conolly, J.R., 1968. Submarine canyons of the continental margin, East Bass Strait (Australia). *Marine Geology* **6**, 449-461.

Conolly, J.R., 1969. Western Tasman Sea Floor. *New Zealand Journal of Geology and Geophysics* **12**, 310-343.

Cotillon, P., Rousselle, B., Courtinat, B. and Crumiere, J-P., 1994. Evolution of sediment fluxes from the middle Miocene to present at ODP Site 817 (Townsville Basin, northeastern Australia) as a record of regional paleogeographic events. *Marine Geology* **121**, 265-291.

Cowell, P. and Nielson, P., 1984. *Predictions of sand movement on the south Sydney inner-continental shelf, south east Australia.* Ocean Sciences Institute Report 9, University of Sydney.

Crawford, A.J., Meffre, S. and Symonds, P.A., 2004. 120 to 0 Ma tectonic evolution of the southwest Pacific and analogous geological evolution of the 600 to 220 Ma Tasman Fold Belt System. In: Hillis, R.R. and Muller, R.D. (Eds.), *Evolution and Dynamics of the Australian Plate*. Geological Society of Australia Special Publication 22 and Geological Society of America Special Paper **372**, 377-397.

Creswell, G.R., Ellyett, C., Legeckis, R. and Pearce, A.F., 1983. Nearshore features of the East Australian Current system. *Australian Journal of Marine and Freshwater Research* **34**, 105-114.

David, T.W.E., 1932. *Explanatory notes to accompany a new geological map of the Commonwealth of Australia, based on the maps already published by the geological surveys of the various states*. Australasian Medical Publishing. 177p.

Davies, P.J., 1975. Shallow seismic structure of the continental shelf, southeast Australia. *Journal Geological Society of Australia* **22**, 345-359.

Davies, P.J., 1979. Marine geology of the continental shelf off southeastern Australia. *BMR Bulletin* **195**, 51pp.

Davies, P.J., 1988. Evolution of the Great Barrier Reef - reductionist dream or expansionist nightmare. In: Choat, J.H. *et al*., (Eds.), *Proceedings* of the *6th International Coral Reef Symposium*, Townsville, Australia, vol. **1**, 9-17.

Davies, P.J., Symonds, P.A., Feary, D.A., Pigram, C.J., 1988. Facies models in exploration - the carbonate platforms of north-east Australia. *APEA Journal* **28(1)**, 123-143.

Davies, P.J., Symonds, P.A., Feary, D.A., Pigram, C.J., 1989. The evolution of the carbonate platforms of northeast Australia. In: Crevello, P.D., Wilson, J.L., Sarg, J.F. and Read, J.F. (Eds.), *Controls on Carbonate Platform and Basin Development*. Society of Economic Paleontologists and Mineralogists, Tulsa, U.S.A., Special Publication **44**, pp. 233-258.

Davies, P.J., McKenzie, J.A., *et al*., 1991a. *Proceedings ODP, Initial Reports, 133.* College Station, TX (Ocean Drilling Program).

Davies, P.J., Symonds, P.A., Feary, D.A. and Pigram, C.J., 1991b. The evolution of the carbonate platforms of northeast Australia. In: Williams, M.A.J., Kershaw, A.P. and De Deckker, P. (Eds.), *The Cainozoic in Australia: a reappraisal of the evidence*, Geological Society of Australia Special Publication **18**, pp. 44-78.

Davies, P.J. and McKenzie, J.A., 1993. Controls on Pliocene-Pleistocene evolution of the northeastern Australian continental margin. *Proceedings of the Ocean Drilling Program, Scientific Results* **133**, 755-762.

Davies, P.J. and Peerdeman, F.M., 1998. The origin of the Great Barrier Reef - the impact of Leg 133 drilling. In: Camoin, G.F. and Davies, P.J. (Eds.), *Reefs and Carbonate Platforms in the Pacific and Indian Oceans*. Blackwell Science, Oxford, U.K. Intl Assoc of Sedimentologists, Special Publication **25**, pp. 23-38.

Day, J.C. and Roff, J.C., 2000. Planning for Representative Marine Protected Areas: A Framework for Canada's Oceans. World Wildlife Fund, Toronto.

de Garidel-Thoron, T., Beaufort, L., Bassinot, F. and Henry P., 2004. Evidence for large methane releases to the atmosphere from deep-sea gas-hydrate dissociation during the last glacial episode. *Proceedings of the National Academy of Science* **101(25)**, 9187-9192.

DEH (Department of Environment and Heritage), 2005. *Marine Bioregional Planning*. Media release by the Department of Environment and Heritage. Internet document from http://www.environment.gov.au/, accessed 05/08/07.

DiCaprio, L.J., Muller, D., Gurnis, M. and Goncharov A., *in press*. The structure and history of the Norfolk Basin, SW Pacific. *Geochemistry Geophysics Geosystems*.

Dickens, G., Exon, N., Holdway, D., Lafoy, Y., Auzende, J-M., Dunbar, G. and Summons, R., 2001. *Quaternary sediment cores from the southern Fairway Basin on the northern Lord Howe Rise (Tasman Sea)*. AGSO Record **2001/031**. Australian Geological Survey Organisation, Canberra.

Division of National Mapping, 1976. *National Bathymetric Map Series 1:250,000*.

Done, T.J., 1982. Patterns in the distribution of coral communities across the central Great Barrier Reef. *Coral Reefs* **1**, 95-107.

Dunbar, G.B., 2000. *Late Quaternary Evolution of the Northeast Australian Continental Margin.* Doctor of Philosophy Thesis, James Cook University, Townsville, Australia, unpublished.

Dunbar, G.B., Dickens, G.R. and Carter, R.M., 2000. Sediment flux across the Great Barrier Reef Shelf to the Queensland Trough over the last 300 ky. *Sedimentary Geology* **133**, 49-92.

Dunbar, G.B. and Dickens, G.R., 2003a. Late Quaternary shedding of shallow-marine carbonate along a tropical mixed siliciclastic-carbonate shelf: Great Barrier Reef, Australia. *Sedimentology* **50**, 1061-1077.

Dunbar, G.B. and Dickens, G.R., 2003b. Massive siliciclastic discharge to slopes of the Great Barrier Reef Platform during sea-level transgression: constraint from sediment cores between 15°S and 16°S latitude and possible explanations. *Sedimentary Geology* **162**, 141-158.

Eade, J.V., 1988. The Norfolk Ridge system and its margins. In: Nairn, A., Stehli, F. and Uyeda, S. (Eds.), *The Pacific Ocean, basins and margins*. Vol. **7B**, ch. 7, 303-324.

Eade, J. and van der Linden, W.J.M., 1970. Sediments and stratigraphy of deep-sea cores from the Tasman Basin. *New Zealand Journal of Geology and Geophysics* **13**, 228-268.

Earl, K., Holm, O. and Powell, T.G., 2002. *Outline of geologic studies in the Great Barrier Reef and adjacent regions: Industry, Commonwealth Government and International*. Geoscience Australia Record **2002/22**. Geoscience Australia, Canberra.

Ehrenberg, S.N., McArthur, J.M. and Thirlwall, M.F., 2006. Growth, demise, and dolomitization of Miocene carbonate platforms on the Marion Plateau, offshore NE Australia. *Journal of Sedimentary Research* **76**, 91-116.

Ennyu, A., Arthur, M.A. and Pagani, M., 2002. Fine-fraction carbonate stable isotopes as indicators of seasonal shallow mixed-layer paleohydrography. *Marine Micropaleontology* **46**, 317-342.

Etheridge, M.A., Symonds, P.A. and Lister, G.S., 1989. Application of the detachment model to reconstruction of conjugate passive margins. In: Tankard, A.J. and Balkwill, H.R. (Eds), *Extensional tectonics and stratigraphy of the North Atlantic margins*. AAPG Memoir **46**, 23-40.

Ewart, A., Schon, R.W. and Chappell, B.W., 1992. The Cretaceous volcanic-plutonic province of the central Queensland (Australia) coast – a rift related 'calc-alkaline' province. *Transactions of the Royal Society of Edinburgh: Earth Sciences* **83**, 327-345.

Exon, N.F., Moreton, D. and Hicks, G., 1980. Manganese nodules from the Tasman Sea off Sydney. *BMR Journal of Australian Geology and Geophysics* **5(1)**, 67-68.

Exon, N.F., Brinkhuis, H., Rober, C., Kennett, J.P., Hill, P.J. and Macphail, M.K., 2004a. Tectono-sedimentary history of uppermost Cretaceous through Oligocene sequences from the Tasmanian region, a temperate Antarctic margin. In: Exon, N.F., Kennett, J.P. and Malone, M.J. (Eds.), *The Cenozoic Southern Ocean: Tectonics, Sedimentation and Climate Change between Australia and Antarctica.* American Geophysical Union Geophysical Monograph Series **151**, 319-344.

Exon, N.F., Dickens, G.R., Auzende, J-M., Lafoy, Y., Symonds, P.A. and Van De Beuque, S., 1998. Gas hydrates and free gas on the Lord Howe Rise, Tasman Sea. *Petroleum Exploration Society of Australia Journal* **26**, 148-58.

Exon, N., Quilty, P.J., Lafoy, Y., Crawford, A. and Auzende, J.M., 2004b Miocene volcanic seamounts on northern Lord Howe Rise: lithology, age and origin. *Australian Journal of Earth Sciences* **51(2)**, 291-300.

Exon, N., Hill, P., Lafoy, Y., Fellows, M., Perry, K., Mitts, P., Howe, R., Chaproniere, G., Dickens, G., Ussler, W. and Paull, C., 2004c. *Geology of the Fairway and New Caledonia Basins in the Tasman Sea: sediment, pore water, diapirs and bottom simulating reflectors (Franklin Cruise FR9/01 and Geoscience Australia Survey 232)*. Geoscience Australia Record **2004/26**, 112p.

Exon, N., Hill, P., Lafoy, Y., Burch, G., Post, A., Heine, C., Quilty, P., Howe, R. and Taylor, L., 2005. *The geology of the Kenn Plateau off northeast Australia: results of Southern Surveyor Cruise SS5/2004 (Geoscience Australia Cruise 270)*. Geoscience Australia Record **2005/04**, 172p.

Exon, N., Bernardel, G., Brown, J., Cortese, A., Finlay, C., Hoffmann, K., Howe, R. and Quilty, P., 2006a. *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.* Geoscience Australia Record **2006/08**, 204p.

Exon, N., Hill, P., Lafoy, Y., Heine, C. and Bernardel, G., 2006b. Kenn Plateau off northeast Australia: a continental fragment in the southwest Pacific jigsaw. *Australian Journal of Earth Sciences* **53**, 541-564.

Exon, N. F., Lafoy, Y., Hill, P.J., Dickens, G.R. and Pecher, I., 2007. Geology and petroleum potential of the Fairway Basin in the Tasman Sea. *Australian Journal of Earth Sciences* **54**, 629-645.

Ferland, M.A., 1991. *Shelf sand bodies in southeastern Australia*. PhD thesis, University of Sydney, unpublished.

Ferland, M.A., Roy, P.S. and Murray-Wallace, C.V., 1995. Glacial lowstand deposits on the outer continental shelf of southeastern Australia. *Quaternary Research* **44**, 294-299.

Ferland, M.A. and Roy, P.S., 1997. Southeastern Australia: sea-level dependent, cool-water carbonate margin. In: James, N.P. and Clarke, J.D.A. (Eds.), *Cool Water Carbonates*, SEPM Special Publication **56**, 37-52.

Field, M.E. and Roy, P.S., 1984. Offshore transport and sand body formation: evidence from a steep high energy shoreface, southeastern Australia. *Journal of Sedimentary Petrolog*y **54**, 1292-1302.

Folk, R.L., 1954. The distinction between grain size and mineral composition in sedimentary rock nomenclature. *Journal of Geology* **62 (4)**, 344-359.

Francis, J.M., Dunbar, G.B., Dickens, G.R., Sutherland, I.A. and Droxler, A.W., 2007. Siliciclastic sediment across the north Queensland margin (Australia): a Holocene perspective on reciprocal versus coeval deposition in tropical mixed siliciclastic-carbonate systems. *Journal of Sedimentary Research* **77**, 572-586.

Francis, J.M., Daniell, J., Droxler, A.W., Dickens, G.R., Bentley, S.J., Peterson, L.C., Opdyke, B.N. and Beaufort, L., in press. Deepwater geomorphology and sediment pathways of the mixed siliciclastic/carbonate system, Gulf of Papua. *Journal of Geophysical Research – Earth Surface*.

Gaina, C., Roest, W.R., Muller, R.D. and Symonds, P., 1998a. The Opening of the Tasman Sea: a gravity anomaly animation. *Earth Interactions* **2**, 1-23.

Gaina, C., Muller, D.R., Royer, J-Y., Stock, J., Hardebeck, J. and Symonds, P., 1998b. The tectonic history of the Tasman Sea: a puzzle with 13 pieces. *Journal of Geophysical Research* **103(B6)**, 12413-12433.

Gaina, C., Muller, D.R., Royer, J.-Y. and Symonds, P., 1999. Evolution of the Louisiade Triple Junction. *Journal of Geophysical Research* **104(B6)**, 12927-12939.

Game, P.M., 1970. Petrology of Lord Howe Island, Part 1: the younger volcanics. *Bulletin of the British Museum (Natural History) Mineralogy* **2**, 223-284.

Gardner, J.V., 1970. Submarine geology of the Western Coral Sea. *Geological Society of America Bulletin* **81**, 2599-2614.

Gibbs, M.T., Marchesiello, P. and Middleton, J.H., 2000. Observations and simulations of a transient shelfbreak front over the narrow shelf at Sydney, southeastern Australia. *Continental Shelf Research* **20**, 763-784.

Glasby, G.P., Stoffers, P., Grapes, R.H., Pluger, W.L., McKnight, D.G. and Main, W. deL., 1986. Manganese nodule occurrence in the Tasman Sea. *New Zealand Journal of Marine and Freshwater Research* **20**, 489-494.

Glenn, K.C., Post, A., Keene, J., Boyd, R., Fountain, L., Potter, A., Osuchowski, M., Dando, N. and Shipboard Party, 2007. *Geoscience Australia Marine Survey Post-Cruise Report – NSW Continental Slope Survey*. Geoscience Australia Record 2007/. Geoscience Australia, Canberra.

Godfrey, J.S., Cresswell, G.R., Boyd, R., Golding, T.J. and Pearce, A.F., 1980. The separation of the East Australian Current. *Journal of Physical Oceanography* **10**, 430-440.

Gordon, A.D., Lord, D.B. and Nolan, M.W., 1979. *Byron Bay–Hastings Point erosion study*. NSW Department of Public Works Record **PWD78026**.

Gordon, A.D. and Hoffman, J.G., 1986. Sediment features and processes of the Sydney continental shelf. In: Frankel, E., Keene, J.B. and Waltho, A.E. (Eds.), *Recent Sediments in Eastern Australia: Marine through Terrestrial*, Geological Society of Australia, NSW Division, pp 29-51.

Gordon, A.D. and Hoffman, J.G., 1989. *Seabed Information*, 1:25,000 Sheets: Bate Bay, Sydney Heads, Broken Bay, Gosford. Public Works Department New South Wales Coast and Rivers Branch.

Harris, P.T., Baker, E.K. and Cole, A.R., 1991. *Physical sedimentology of the Australian continental shelf: with emphasis on late Quaternary deposits in major shipping channels, port approaches and choke points*. University of Sydney Ocean Sciences Institute Report **51**, 505p.

Harris, P.T., Davies, P.J. and Marshall, J.F., 1990. Late Quaternary sedimentation on the Great Barrier Reef continental shelf and slope east of Townsville, Australia. *Marine Geology* **94**, 55-77.

Harris, P.T., Heap, A., Passlow, V., Hughes, M., Daniell, J., Hemer, M. and Anderson, O., 2005b. Tidally incised valleys on tropical carbonate shelves: an example from the northern Great Barrier Reef, Australia. *Marine Geology* **220**, 181-204.

Harris, P., Heap, A., Passlow, V., Sbaffi, L., Fellows, M., Porter-Smith, R., Buchanan, C. and Daniell, J., 2005a. *Geomorphic Features of the Continental Margin of Australia*. Geoscience Australia Record **2003/30**, 142p.

Harris, P.T., Jenkins, C. J., Packham, G.H., Baker, E.K., Pritchard, T.R., Schneider, P.M. and Manning, P.B., 1987. *Geophysical and geological results of the HMAS 'Cook' Seamap Cruise 12-87: Tasman Sea and Polynesia*. University of Sydney Ocean Sciences Institute Report **26**, 30p.

Harris, P.T., Pattiaratchi, C.B., Keene, J.B., Dalrymple, R.W., Gardner, J.V., Baker, E.K, Cole, A.R., Mitchell, D., Gibbs, P. and Schroeder, W.W., 1996b. Late Quaternary deltaic and carbonate sedimentation in the Gulf of Papua foreland basin: Response to sea level change. *Journal of Sedimentary Research* **66(4)**, 801-819.

Harris, P.T., Tsuji, Y., Marshall, J.F., Davies, P.J., Honda, N. and Matsuda, H., 1996. Sand and rhodolith-gravel entrainment on the mid- to outer-shelf under a western boundary current: Fraser Island continental shelf, eastern Australia. *Marine Geology* **129**, 313-330.

Hayes, D.E. and Ringis, J., 1973. Seafloor spreading in the Tasman Sea. *Nature* **243**, 454-458.

Hayes, D.E. et al., 1972-1977. *Preliminary report of volumes 22-26, USNS Eltanin cruises 28-50, March 1967 – January 1972*. Lamont-Doherty Geological Observatory of Columbia University, N.Y.

Heap, A. and Harris, P., in press. Geomorphology of the Australian margin and adjacent sea floor. *Australian Journal of Earth Sciences.*

Heck, P.R., Anselmetti, F.S., and Isern, A.R., 2004. Data report: late Pleistocene and Holocene sedimentation on the Marion Plateau: data from precruise ODP Leg 194 site survey gravity cores. In: Anselmetti, F.S., Isern, A.R., Blum, P., and Betzler, C. (Eds.), *Proc. ODP Science Results,* 194: College Station, TX (Ocean Drilling Program), 1–13.

Heck, P.R., Frank, M., Anselmetti, F.S., and Kubik, P.W., 2007. Origin and age of submarine ferromanganese hardgrounds from the Marion Plateau, offshore northeast Australia. In: Anselmetti, F.S., Isern, A.R., Blum, P., and Betzler, C. (Eds.), *Proc. ODP Science Results,* 194: College Station, TX (Ocean Drilling Program), 1–22.

Heggie, D. and shipboard scientist, 1992. *Preliminary results of AGSO RV Rig Seismic Survey 112: Offshore Sydney Basin continental shelf and slope geochemistry, sedimentology and geology*. AGSO Record **1993/5**, 121p.

Heggie, D., Lane, J., and Herczeg, A., 1993. *Geochemistry of sediments from the north east Australian continental margin, including the Great Barrier Reef slope, Queensland Plateau and trough and the Osprey Embayment*. AGSO Record **1993/33**. Australian Geological Survey Organisation, Canberra.

Herzer, R.H., Chaproniere, G.C.H., Edwards, A.R., Hollis, C.J.., Pelletier, B., Raine, J.I., Scott, G.H., Stagpoole, V., Strong, C.P., Wilson, G.J. and Zhu, H., 1997. Seismic stratigraphy and structural history of the Reinga Basin and its margins, southern Norfolk Ridge system. *New Zealand Journal of Geology and Geophysics* **40**, 425-451.

Hill, P.J., 1991. Maryborough and Capricorn Basins – new geophysical data. In: Draper, J. (Ed.), *Queensland 1991 – Exploration and Development*, 13th PESA(Qld.)-ODCAA-SPE Petroleum Symposium, Brisbane, 70-82.

Hill, P.J., 1992. Capricorn and northern Tasman Basins: structure and depositional systems. *Exploration Geophysics* **23(1/2)**, 153-162.

Hill, P.J., 1994. *Geology and geophysics of the offshore Maryborough, Capricorn and northern Tasman Basins: results of AGSO Survey 91*. AGSO Record **1994/1**, 71p.

Hill, P.J. and Cranfield, L.C., 1992. Offshore Maryborough Basin, southeast Queensland: extent, structure and petroleum potential from new geophysical survey data. *AAPG Bulletin* **76(7)**, 1107-1108.

Hill, P.J., Rollet, N., Rowland, D., Calver, C.R. and Bathgate, J., 2000. *AUSTREA-1 cruise report: Lord Howe Island, south-east Australian margin and central Great Australian Bight.* AGSO Record **2000/6**, 138pp.

Hill, P.J. and Exon, N.F., 2004. Tectonics and basin development of the offshore Tasmanian area incorporating results from deep ocean drilling. In: Exon, N.F., Kennett, J.P. and Malone, M.J. (Eds.), *The Cenozoic Southern Ocean: Tectonics, Sedimentation and Climate Change between Australia and Antarctica.* Geophysical Monograph **151**, 19-42.

Howard, J., 1993. *A study of special variations and temporal cycles in Late Quaternary sediments from the continental slope east of Sydney, NSW.* Honours thesis, University of Sydney, Australia, unpublished.

Hubble, T.C.T. and Jenkins, C.J., 1984a. *Sediment cores from the NSW continental slope of Port Stephens, Port Macquarie and Coffs Harbour.* Ocean Sciences Institute Report, **6**, 40p.

Hubble, T.C.T. and Jenkins, C.J., 1984b. *Sediment samples and cores from the southern New South Wales upper continental slope.* University of Sydney Ocean Sciences Institute Report, **8**. 34p.

Hubble, T.C.T., Robson, A.D., Jenkins, C.J., Garces, J. and Packham, G.H., 1987. *Geophysical and geological results of the Cook 17-86 (Seamap 4) cruise: Sydney to Cook Strait*. University of Sydney Ocean Sciences Institute Report **24**, 60p.

Hubble, T.C.T., Packham, G.H., Hendry, D.A.F. and McDougall, I., 1992. Granitic and monzonitic rocks dredged from the southeast Australian continental margin. *Australian Journal of Earth Sciences* **39**, 619-630.

Huyer, A., Smith, R.L., Stabeno, P.J., Church, J.A. and White, N.J., 1988. Currents off south-eastern Australia: results from the Australian Coastal Experiment. *Australian Journal of Marine and Freshwater Research* **39**, 245-288.

Isern, A.R., Pigram, C.J., Muller, D. and Anselmetti, F., 1998. Sea-level magnitudes and variations recorded by continental margin sequences on the Marion Plateau, northeast Australia. AGSO Record **1998/005**. Australian Geological Survey Organisation, Canberra.

Isern, A.R., Anselmetti, F.S. and Blum, P., 2001. ODP Leg 194; sea level magnitudes recorded by continental margin sequences on the Marion Plateau, Northeast Australia. *JOIDES Journal* **27(2)**, 7-11.

Isern, A.R., Anselmetti, F.S. and Blum, P. and Shipboard Scientific Party, 2002. *Proceedings Ocean Drilling Program, Initial Reports 194 (Constraining Miocene sea level change from carbonate platform evolution, Marion Plateau, northeast Australia).* College Station, TX (Ocean Drilling Program).

Isern, A.R., Anselmetti, F.S. and Blum, P., 2004. A Neogene carbonate platform, slope, and shelf edifice shaped by sea level and ocean currents, Marion Plateau (northeast Australia). In: Eberli, G.P., Masaferro, J.L. and Sarg, J.F.R. (Eds.), *Seismic imaging of carbonate reservoirs and systems*, AAPG Memoir **81**, 291-307.

Jenkins, C.J., 1984. *Erosion and deposition at abyssal depths in the Tasman Sea. A seismic stratigraphic study of the bottom-current patterns.* University of Sydney Ocean Sciences Institute Report, **4**, 53p.

Jenkins, C.J., 1991. *Research Cruise Summary, RV Franklin, FR5/91.* CSIRO National Facility, Hobart.

Jenkins, C.J., 1992a. Abyssal sediment drifts, erosion and history of bottom water flow in the Tasman Sea southwest of New Zealand. *Australian Journal of Earth Sciences* **39**, 195-210.

Jenkins, C.J., 1992b. GLORIA imagery and geological structure of the NSW continental margin (offshore Sydney Basin). In: Diessel, C.F.K. (Ed.), *Advances in the study of the Sydney Basin*. Proceedings of the 26th symposium, University of Newcastle, NSW, 9-14.

Jenkins, C.J., Keene, J.B., Pritchard, T.R. and Schneider, P.M., 1986. *Seafloor photography in the Tasman Sea: results of the 1985 Sydney University/HMAS Cook program*. University of Sydney Ocean Sciences Institute Report, **18**, 62p.

Jenkins, C.J. and Keene, J.B., 1992. Submarine slope failures of the southwest Australian continental slope: a thinly sedimented margin. *Deep-Sea Research* **39**, 121-136.

Johnson, D.P., 2004. *The Geology of Australia*. Cambridge University Press.

Jones, H.A., Davies, P.J. and Marshall, J.M., 1975. Origin of the shelf-break off southeast Australia. *Journal of the Geological Society of Australia* **22**, 71-78.

Jones, H.A. and Kudrass, H.R., 1982. Sonne cruise (SO-15 1980) off the east coast of Australia bathymetry and sea floor morphology. *Geologisches Jahrbuch.* Reihe D56, 55-68.

Jones, H.A., Lean, J. and Schlüter, H.-U., 1982. Seismic reflection profiling off the east coast of Australia, Newcastle to Cape Hawke. *Geologisches Jahrbuch*. Reihe D56, 69-75.

Jones, J.G. and McDougall, I., 1973. Geological history of Norfolk and Phillip Islands, southwest Pacific Ocean. *Journal of the Geological Society of Australia* **20**, 239-254.

Jongsma, D. and Mutter, J.C., 1978. Nonaxial breaking of a rift valley: evidence from the Lord Howe Rise and the southeastern Australian margin. *Earth and Planetary Science Letters* **39**, 226-234.

Kawagata, S., 2001. Tasman Front shifts and associated paleoceanographic changes during the last 250,000 years: foraminiferal evidence from the Lord Howe Rise. *Marine Micropaleontology* **41**, 167-191.

Kawahata, H., 2002. Shifts in oceanic and atmospheric boundaries in the Tasman Sea (southwest Pacific) during the Late Pleistocene: evidence from organic carbon and lithogenic fluxes. *Palaeogeography Palaeoclimatology Palaeoecology* **184**, 225-249.

Kawahata, H., Ohkushi, K. and Hatakeyama, Y., 1999. Comparative late Pleistocene paleoceanographic changes in the mid latitude boreal and austral western Pacific. *Journal Oceanography* **55**, 747-761.

Keen, T.R., Ko, D.S., Slingerland, R.L. and Riedlinger, S., 2006. Potential transport pathways of terrigenous material in the Gulf of Papua. *Geophysical Research Letters*, **33**, **L04608**, 4p.

Kennedy, D. M., Woodroffe, C. D., Jones, B. G., Dickson, M. E. and Phipps, C. V. G., 2002. Carbonate sedimentation on tropical shelves around Lord Howe Island and Balls Pyramid, southwest Pacific. *Marine Geology* **188**, 333-349.

Kennedy, D.M. and Woodroffe, C.D., 2004. Carbonate sediments of Elizabeth and Middleton Reefs close to the southern limits of reef growth in the southwest Pacific. *Australian Journal of Earth Sciences* **51**, 847-857.

Kennett, J.P., Houtz, R.E., *et al*., 1974. *Initial Reports of the Deep Sea Drilling Project*, Volume **29**. Washington (U.S. Govt. Printing Office).

Kennett, J.P., von der Borch, C.C., *et al*., 1986. *Initial Reports of the Deep Sea Drilling Project*, Volume **90**. Washington (U.S. Govt. Printing Office).

Kennett, J.P. and von der Borch, C.C., 1986. Southwest Pacific Cenozoic paleoceanography. In: *Initial Reports of the Deep Sea Drilling Project*, Volume **90**, 1493-1517. Washington (U.S. Govt. Printing Office).

Kress, A.G. and Veeh, H.H., 1980. Geochemistry and radiometric ages of phosphatic nodules from the continental margin of northern New South Wales, Australia. *Marine Geology* **36**, 143-157.

Kroenke, L.W., Jouannic, C. and Woodward, P., 1983. *Bathymetry of the Southwest Pacific*. CCOP/SOPAC Map, 2 Sheets, scale 1:6,442,192.

Kroh, F., Morse, M.P. and Hashimoto, T., 2007. New data on Capel and Faust Basins. October, 2007, *Preview*, Geoscience Australia, 22-24.

Lane, J. and Heggie, D., 1993. *Physical properties and bulk chemical composition of continental shelf and slope sediments of Australia*. AGSO Record **1993/7**, 86pp. Australian Geological Survey Organisation, Canberra.

Launay, J., Dupont, J., Lapoville, A., Ravenne, C. and De Broin, C.E., 1976. Seismic traverses across the northern Lord Howe Rise and comparison with the southern part (southwest Pacific). *Intl. Symp. on Geodynamics in South-West Pacific*, Noumea, New Caledonia, 91-104.

Lawford, Geoff., 2000. *Data Standards and validation in AGSO: Geographic information officer's handbook*. Australian Geological Survey Organisation, Information Management Branch, Canberra, Australia, 150p.

Lea, D.W., Martin, P. A., Pak, D.K. and Spero, H.J., 2002. Reconstructing a 350 ky history of sea level using planktonic Mg/Ca and oxygen isotope records from a Cocos ridge core. *Quaternary Science Reveiws* **21**, 283-293.

Liu, K., Pigram, C.J., Paterson, L. and Kendall, C.G., 1998. Computer simulation of a Cainozoic carbonate platform, Marion Plateau, north-east Australia. *Spec. Publs int. Ass. Sediment* **25**, 145-161.

Luick, J.L., Mason, L., Hardy, T. and Furnas, M.J., 2007. Circulation in the Great Barrier Reef lagoon using numerical tracers and *in situ* data. *Continental Shelf Research* **27**, 757-778.

Marchesiello, P. and Middleton, J.H., 2000. Modelling the East Australian Current in the Western Tasman Sea. *Journal of Physical Oceanography* **30**, 2956-2971.

Marshall, J.F., 1977. *Marine geology of the Capricorn Channel area*. BMR Bulletin **163**. 81pp.

Marshall, J.F., 1978. *Morphology and shallow structure of the continental shelf of southern Queensland and northern New South Wales.* BMR Record **1978/100**, 25p.

Marshall, J.F., 1979. The development of the continental shelf of northern New South Wales. *BMR Journal of Australian Geology and Geophysics* **4**, 281-288.

Marshall, J. F., 1980. *Continental shelf sediments: southern Queensland and northern New South Wales*. BMR Bulletin **207**, 39pp.

Marshall, J.F., 1983. Geochemistry of iron-rich sediments on the outer continental shelf off northern New South Wales. *Marine Geology* **51**, 163-175.

Marshall, J.F., 1984. Geochemistry of iron-rich sediments on the outer continental shelf off northern New South Wales – Reply. *Marine Geology* **59**, 321-322.

Marshall, J.F. and Cook, P.J., 1980. Petrology of iron- and phosphorous-rich nodules from the E. Australian continental shelf. *Journal of the Geological Society of London* **137**, 765-771.

Marshall, J.F. and Davies, P.J., 1978. Skeletal carbonate variation on the continental shelf of eastern Australia. *BMR Journal* **3**, 85-92.

Marshall, J.F., Tsuji, Y., Matsuda, H., Davies, P.J., Iryu, Y., Honda, N., and Satoh, Y., 1998. Quaternary and Tertiary subtropical carbonate platform development on the continental margin of southern, Queensland, Australia. In: Camoin, G.F. and Davies, P.J. (Eds.), *Reefs and Carbonate Platforms in the Pacific and Indian Oceans*. Blackwell Science, Oxford, U.K. Intl Assoc of Sedimentologists, Special Publication 25, 163-195.

Martinez, I. J., 1994a. Late Pleistocene palaeoceanography of the Tasman Sea: implications for the dynamics of the warm pool in the western Pacific. *Palaeogeography Palaeoclimatology Palaeoecology* **112**, 19-62.

Martinez, I. J., 1994b. Late Pleistocene carbonate dissolution patterns in the Tasman Sea. In: van der Lingen, G. J., Swanson, K. and Muir R. J. (Eds.), *Evolution of the Tasman Sea Basin*. Balkema, Rotterdam, 215-228.

Matthai, C. and Birch, G.F., 2000a. Effect of coastal cities on surficial sediments mantling and adjacent high-energy continental margin – central New South Wales, Australia. *Marine and Freshwater Research* **51**, 565-576.

Matthai, C. and Birch, G.F., 2000b. Dispersion of dredge spoil dumped on a high energy continental margin (southeastern Australia). *Journal Marine Environmental Engineering* **6**, 1-32.

Matthai, C., Birch, G.F., Jenkins, A. and Heijnis, H., 2000. Physical resuspension and vertical mixing of sediments on a high energy continental margin (Sydney, Australia). *Journal of Environmental Radioactivity* **52**, 67-89.

Maung, T. U., Alder, D., Shaw, R. and Hawley, S., 1997. *Offshore Sydney Basin*. Bureau of Resource Sciences, Petroleum Prospectivity Bulletin **1997/1**. Canberra.

McDougall, I. and Duncan, R.A., 1988. Age progressive volcanism in the Tasmantid Seamounts. *Earth and Planetary Science Letters* **89**, 207-220.

McDougall, I., Embleton, B.J.J. and Stone, D.B., 1981. Origin and evolution of the Lord Howe Island, Southwest Pacific. *Journal of the Geological Society of Australia* **28**, 155-176.

McDougall, I., Maboko, M.A.H., Symonds, P.A., Mc Culloch, M.T., Williams, I.S. and Kudrass, H.R., 1994. Dampier Ridge, Tasman Sea as a stranded continental fragment. *Australian Journal of Earth Sciences* **41**, 395-406.

McDougall, I. and van der Lingen, G.J., 1974. Age of the rhyolites on the Lord Howe Rise and the evolution of the southwest Pacific Ocean. *Earth and Planetary Science Letters* **21**, 117-126.

McKenzie, J.A., Davies, P.J., Palmer-Julson, A. et al., 1993. *Proceedings of the Ocean Drilling Program, Scientific Results*, Volume **133**. College Station, Texas, 902p.

McKenzie, J.A. and Davies, P.J., 1993. Cenozoic evolution of carbonate platforms on the northeastern Australian margin: synthesis of Leg 133 drilling results. In: McKenzie, J.A., Davies, P.J., Palmer-Julson, A. et al., 1993. *Proceedings of the Ocean Drilling Program, Scientific Results*, Volume **133**. College Station, Texas, 763-770.

McNeill, D.F., 2005. Accumulation rates from well-dated late Neogene carbonate platforms and margins. *Sedimentary Geology* **175**, 73-87.

Middleton, J.H., Cox, D. and Tate, P., 1997. The oceanography of the Sydney region. *Marine Pollution Bulletin* **33**, 124-131.

Mortimer, N., Herzer, R.H., Gans, P.B., Parkinson, D.L. and Seward, D., 1998. Basement geology from Three Kings Ridge to West Norfolk Ridge, southwest Pacific Ocean: evidence from petrology, geochemistry and isotopic dating of dredge samples. *Marine Geology* **148**, 135-162.

Mulhearn, P.J., 1983. Deep currents of the northern Tasman Sea basin. *Deep-Sea Research* **30**, 1119-1126.

Muller, D.R., Gaina, C. and Clark, S., 2000. Seafloor spreading around Australia. In: Veevers, J.J. (Ed.), *Billion-year Earth history of Australia and neighbours in Gondwanaland*. Pp.18-28. GEMOC Press, Sydney.

Murray-Wallace, C.V., Ferland, M.A. and Roy, P.S., 2005. Further amino acid racemisation evidence for glacial age, multiple lowstand deposition on the New South Wales outer continental shelf, southeastern Australia. *Marine Geology* **214**, 235-250.

Mutter, J.C., 1977. *The Queensland Plateau*. Bureau of Mineral Resources Bulletin **179**, 55p.

Mutter, J.C. and Karner, G.D., 1980. The continental margin off northeast Australia. In: Henderson, R.A. and Stephenson, P.J., (Eds.), *The Geology and Geophysics of Northeastern Australia*, Geological Society of Australia, Queensland, 47-69.

National Bathymetric Map Series, 1976, 1:250,000, Canberra.

Nees, S., 1997. Late Quaternary palaeoceanography of the Tasman Sea: the benthic foraminiferal view. *Palaeogeography Palaeoclimatology Palaeoecology*, 131, 365-389.

Nelson, C.S., Hendy, C.H. and Cuthbertson, A.M., 1994. Oxygen isotope evidence for climatic contrasts between Tasman Sea and Southwest Pacific Ocean during the late Quaternary. In: van der Lingen, G.J., Swanson, K.M. and Muir, R.J. (Eds.), *Evolution of the Tasman Sea Basin,* 181-196.

Norvick, M.S., Smith, M.A. and Power, M.R., 2001. The plate tectonic evolution of eastern Australasia guided by the stratigraphy of the Gippsland Basin. In: Hill, K.C. and Benecker, T. (Eds.), *Eastern Australasian Basins Symposium*. Melbourne, PESA Special Publication, vol. **1**, 15-23.

O'Brien, G.W., Harris, J.R., Milnes, A.R. and Veeh, H.H., 1981. Bacterial origin of East Australian continental margin phosphorites. *Nature* **294**, 442-444.

O'Brien, G. W. and Heggie, D. T., 1990. *Organic carbon cycling and Quaternary phosphorite formation - East Australian continental margin (28 degrees-32 degrees S). Project 9131.03 sample locations and solid phase geochemical results.* Bureau of Mineral Resources, Geology and Geophysics Record **1990/45**, Canberra. 109pp.

O'Brien, P.E., Powell, T.G., and Wells, A.T., 1994. Petroleum Potential of the Clarence-Moreton Basin. In: Wells, A.T., and O'Brien, P.E. (Editors). *Geology and petroleum potential of the Clarence-Moreton Basin, New South Walees and Queensland*. Bureau of Mineral Resources, Australia, Bulletin **241**, 277-290.

O'Brien, G.W. and Veeh, H.H., 1980. Holocene phosphorite on the East Australian continental margin. *Nature* **288**, 690-692.

O'Halloran, G.J. and Johnstone, E,M., 2001. Late Cretaceous Rift Volcanics of the Gippsland Basin, SE Australia – new insights from 3D seismic , In: Hill, K.C. and Benecker, T. (Eds.), *Eastern Australasian Basins Symposium*. Melbourne, PESA Special Publication, vol. **1**, 353-361.

Orme, G.R., 1977. The Coral Sea Plateau – a major reef province. In: Jones, O.A. and Endean, R., (Eds.), *Biology and Geology of Coral Reefs*, Vol. **4**. Academic Press, NY. p. 267-306.

Packham, G.H., 1983. *Morphology and acoustic properties of the N.S.W. slope with special references to the Coffs Harbour-Point Plommer and Montague Island-Green Cape area.* University of Sydney Ocean Sciences Institute Report **1**. 48p.

Packham, G.H., Philip, G.M. and Hubble, T.C.T., 2006. Late Silurian or Early Devonian corals from the continental slope off southern New South Wales. *Alcheringa* **30(1)**, 33-42.

Page, M.C., Dickens, G.R. and Dunbar, G.B., 2003. Tropical view of Quaternary sequence stratigraphy: siliciclastic accumulation on slopes east of the Great Barrier Reef since the Last Glacial Maximum. *Geology* **31(11)**, 1013-1016.

Page, M.C. and Dickens, G.R., 2005. Sediment fluxes to Marion Plateau (southern Great Barrier Reef province) over the last 130 ky: New constraints on 'transgressive-shedding' off northeastern Australia. *Marine Geology* **219**, 27-45.

Payenberg, T.H.D., Boyd, R., Beaudoin, J., Ruming, K., Davies, S., Roberts, J.J. and Lang, S.C., 2006. The filling of an incised valley by shelf dunes - an example from Hervey Bay, east coast of Australia. In: Dalrymple, R. and Leckie, D. (Eds.), *Incised Valley Systems*, SEPM Special Publication **85**, Tulsa, 87-98.

Pelejero, C., Calvo, E., McCulloch, M., Marshall, J.F., Gagan, M., Lough, J. and Opdyke, B.N., 2005. Preindustrial to modern interdecadal variability in coral reef pH. *Science* **309**, 2204-2207.

Petkovic, P. and Buchanan, C., 2002. *Australian Bathymetry and Topography Grid - digital dataset*. GeoCat No. 38713. Geoscience Australia, Canberra, Australia.

Phipps, C.V.G., 1966. Evidence of Pleistocene warping of the New South Wales continental shelf. *Geol. Survey Canada Paper* **66-15**, 280-293.

Phipps, C.V.G., 1967. The character and evolution of the Australian continental shelf. *APEA Journal* **7(2)**, 44-49.

Pickard, G.L., Donguy, J.R., Henin, C. and Rougerie, R., 1977. *A review of the physical oceanography of the Great Barrier Reef and western Coral Sea.* Australian Institute of Marine Science, Monograph Series, **2**, 134p.

Pigram, C.J., 1993. *Carbonate Platform Growth, Demise and Sea Level Record: Marion Plateau, Northeast Australia.* PhD thesis, Australian National University, 316pp.

Post, A.L., 2006. Physical surrogates for benthic organisms in the southern Gulf of Carpentaria, Australia: Testing and application to the Northern Planning area. Geoscience Australia Record 2006/09: 46.

Potter, A. & Southby, C., et al, in press. Sedimentology and Geomorphology of the South West Planning Region of Australia, A spatial analysis. Geoscience Australia, Record **2006**. Geoscience Australia, Canberra.

Quilty, P.G., 1993. Tasmantid and Lord Howe Seamounts: biostratigraphy and palaeoceanographic significance. *Alcheringa* **17**, 27-53.

Quilty, P.G., Shafik, S., Jenkins, C.J. and Keene, J.B., 1997. An Early Cainozoic (Paleocene) foraminiferal fauna with *Fabiania* from offshore eastern Australia. *Alcheringa* **21**, 299-315.

Quilty, P.G. and Packham, G.H., 2006. Late Paleocene foraminiferal faunas with Chapmanina and Reticulophragmium from offshore southeastern Australia: a Tethyan influence. *Alcheringa* **30**, 315-341.

Richardson L., Mathews, E. and Heap, A., 2005. Geomorphology and sedimentology of the South Western Planning Area of Australia. Geoscience Australia, Record **2005/17**. 123p.

Ringis, J., 1972. *The Structure and History of the Tasman Sea and Southwest Australian Margin*. PhD thesis, University of NSW, 338pp.

Roberts, J.J. and Boyd, R., 2004. Late Quaternary core stratigraphy of the northern New South Wales continental shelf. *Australian Journal of Earth Sciences* **51**, 141-156.

Roeser, H. and Shipboard Party, 1985. *Geophysical, geological and geochemical studies on the Lord Howe Rise. Final Report on the R/V Sonne Cruise, SO-36*. Bundesanstalt fur Geowissenschaften und Rohstoffe Cruise Report, 193p.

Roff, J.C., Taylor, M.E. and Laughran, J., 2003. Geophysical approaches to the classificatopn, delineation and monitoring or marine habitats and their communities. Aquatic Conservation: Marine and Freshwater Ecosystems, 13: 77-90.

Roy, P.S., 1998. Cainozoic geology of the New South Wales coast and shelf. In: Scheibner, E. and Basden, H. (Eds.), *Geology of New South Wales: Synthesis, Vol. 2 Geological Evolution*, Geological Survey of NSW Memoir **13(2)**, 361-385.

Roy, P.S. and Thom, B.G., 1981. Late Quaternary marine deposition in New South Wales and southern Queensland – an evolutionary model. *Journal of the Geological Society of Australia* **28**, 471-189.

Roy, P.S. and Hudson, J., 1987. *The marine placer minerals project – seismic results from the continental shelf, southern NSW: Narooma-Montague Island-Bermagui area.* Geological Survey of New South Wales Report **1987/094**, 65p.

Roy, P.S. and Thom, B.G., 1991. Cainozoic shelf sedimentation model for the Tasman Sea margin of southeastern Australia. In: Williams M.A.J., Kershaw, A.P. and De Deckker, P. (Eds.), *The Cainozoic in Australia: a reappraisal of the evidence*, pp. 119-136. Geological Society of Australia Special Publication **18**.

Roy, P.S., Cowell, P.J., Ferland, M.A. and Thom, B.G., 1994a. Wave-dominated coasts. In: Carter, R.W.G. and Woodroffe, C.D. (Eds.), *Coastal Evolution*, Cambridge University Press, pp. 121-186.

Roy, P.S., Zhuang, W-Y., Birch, G.F. and Cowell, P.J.M., 1994b. *Quaternary geology and placer mineral potential of the Forster-Tuncurry shelf, southeastern Australia*. Department of Mineral Resources, NSW Geological Survey Report, 164p.

Rule, M., Jordan, A. and McIlgorm, A., 2007. *The marine environment of northern New South Wales, a review of current knowledge and existing datasets*. Northern Rivers Catchment Management Authority, 335p.

Scott, D.L., 1993. Architecture of the Queensland Trough: implications for the structure and tectonics of the Northeastern Australian margin. *AGSO Journal of Geology and Geophysics* **14**, 21-34.

Sdrolias, M., Muller, R.D. and Gaina, C., 2001. Plate tectonic evolution of eastern Australian marginal ocean basins. In: Hill, K.C. and Benecker, T. (Eds.), *Eastern Australasian Basins Symposium*. Melbourne, PESA Special Publication, vol. **1**, 227-237.

Sdrolias, M., Muller, R.D. and Gaina, C., 2003. Tectonic evolution of the southwest Pacific using constraints from backarc basins. In: Hillis, R.R. and Muller, R.D. (Eds.), *Evolution and Dynamics* *of the Australian Plate*. Geological Society of Australia Special Publication 22 and Geological Society of America Special Paper **372**, 343-359.

Sdrolias, M., Muller, R.D., Mauffret, A. and Bernardel, G., 2004. Enigmatic formation of the Norfolk Basin, SW Pacific, a plume influence on back-arc extension. *Geochemistry Geophysics Geosystems* **5**

Shaw, R.D., 1979. *On the evolution of the Tasman Sea and adjacent continental margins.* PhD thesis, University of Sydney, Australia, unpublished.

Shirley, J., 1964. An investigation of the sediments on the continental shelf of New South Wales, Australia. *Journal of the Geological Society of Australia* **11**, 331-341.

Short, A.D. and Wright, D., 1981. Beach systems of the Sydney region. *Australian Geographer* **15**, 8-15.

Short, A.D. and Trenaman, N.L., 1992. Wave climate of the Sydney region, an energetic and highly variable ocean wave regime. *Australian Journal of Marine and Freshwater Research* **43**, 765-791.

Skene, D.L., 1988. *The Quaternary geology and evolution of the coast and inner continental shelf at Wooli, northern New South Wales*. MSc thesis, University of Sydney, unpublished.

Slater, R.A. and Goodwin, R.H., 1973. Tasman Sea guyots. *Marine Geology* **14**, 81-99.

Smith, W. H. F. and Sandwell, D. T., 1997. Global seafloor topography from satellite altimetry and ship depth soundings, *Science* **277**, 1957-1962.

Stagg, H.M.J., Borissova, I., Alcock, M. and Moore, A.M.G., 1999a. Tectonic provinces of the Lord Howe Rise. *AGSO Research Newsletter*, November 1999 **31**, 31-32.

Stagg, H.M.J., Willcox, J., Symonds, P., O'Brian, G., Colwell, J., Hill, P., Lee, C-S., Moore, A. and Struckmeyer, H., 1999b. Architecture and evolution of the Australian continental margin. *AGSO Journal* **17(5/6)**, 17-33.

Stagg, H.M.J., Alcock, M.B., Borissova, I., and Moore, A.M.G., 2002. *Geological framework of the southern Lord Howe Rise and adjacent areas*. Geoscience Australia Record **2002/25**. 104pp.

Standard, J.C., 1961. Submarine geology of the Tasman Sea. *Geological Society of America Bulletin* **72**, 1777-1788.

Stephenson, A.E. & Burch, G.J., 2004. Preliminary evaluation of the petroleum potential of Australia's central eastern margin. BMR Record **2004/006**.

Struckmeyer, H.I.M., Symonds, P.A., Fellows, M.E. and Scott, D.L., 1994. *Structure and stratigraphic evolution of the Townsville Basin, Townsville Trough, offshore northeastern Australia*. BMR Record **1994/50**. 71pp.

Struckmeyer, H.I.M. and Symonds, P.A., 1997. Tectonostratigraphic evolution of the Townsville Basin, Townsville Trough, offshore northeastern Australia. *Australian Journal of Earth Sciences* **44(6)**, 799-817.

Sutherland, L., 1998. Origin of north Queensland Cenozoic volcanism: relationship to long lava flow basaltic fields, Australia. *Journal of Geophysical Research* **103**, B11, 27,347-27,358.

Symonds, P.A., Davies, P.J. and Parisi, A., 1983. Structure and stratigraphy of the central Great Barrier Reef. *BMR Journal of Australian Geology and Geophysics* **8**, 277-291.

Symonds, P.A. *et al*., 1992. *Northeast Australia : Torres Shelf – Pandora Trough*. Continental Margins Program. Map Folio 4. Bureau of Mineral Resources.

Taylor, L.W.H., 1977. *The western Coral Sea: sedimentation and tectonics*. PhD thesis, University of Sydney, Sydney, unpublished.

Taylor, L.W.H. and Falvey, D.A., 1977. Queensland Plateau and Coral Sea Basin: stratigraphy, structure and tectonics. *APEA Journal* **17**, 13-29.

Terrill, A., 1975. *Submarine geology of the northern Lord Howe Rise – Mellish Rise area.* M.Sc. University of Sydney, unpublished.

Tomczak, M. and Godfrey, J. S., 1994. *Regional Oceanography: an introduction.* Pergamon. 422p.

Troedson, A.L., 1997. *Late Quaternary sedimentation on the East Australian continental slope: responses to palaeoenvironmental change*. PhD thesis, University of Sydney, 305p.

Troedson, A.L. and Davies, P.J., 2001. Contrasting facies patterns in subtropical and temperature continental slope sediments: inferences from east Australian late Quaternary records. *Marine Geology* **172**, 265-285.

Tsuji, Y., Marshall, J.F., Honda, N., Davies, P.J. and Matsuda, H., 1997. *Facies relationships of subtropical and warm temperate carbonate environments: southern Queensland continental shelf, Australia*: *a joint program between the Marine Geoscience and Petroleum Geology Program, AGSO, and the Technology Research Center, Japan National Oil Corporation.* AGSO Final Report, 2 volumes.

Van de Beuque, S., Stagg, H.M.J., Sayers, J., Willcox, J.B. and Symonds, P.A., 2003. *Geological framework of the Northern Lord Howe Rise and adjacent areas*. Geoscience Australia Record **2003/01**, 64p.

Vogt, P.R. and Conolly, J.R., 1971. Tasmantid Guyots, the age of the Tasman Basin, and motion between the Australian plate and the mantle. *Geological Society of America Bulletin* **82,** 2577-2584.

von der Borch, C.C., 1970. Phosphatic concretions and nodules from the upper continental slope, northern New South Wales. *Journal Geological Society of Australia* **16**, 755-759.

von Stackelberg, U. (Ed.), 1982a. Heavy-mineral exploration of the east Australian shelf, Sonne cruise SO-15, 1980. *Geologisches Jahrbuch,* Reihe **D56**, 215p.

von Stackelberg, U. and Jones, H.A., 1982b. Outline of Sonne cruise SO-15 on the east Australian shelf between Newcastle and Fraser Island. *Geologisches Jahrbuch,* Reihe **D56**, 5-23.

Walker, B., 1992. *Evolution of the Cato Trough – Kenn Plateau region, offshore Queensland.* Honours thesis, University of Sydney, Australia, unpublished.

Walsh, J.P. and Nittrouer, C.A., 2003. Contrasting styles of off-shelf sediment accumulation in New Guinea. *Marine Geology* **196**, 105-125.

Watts, K.F., Varga, L.L. and Feary, D.A., 1993. Origins, timing, and implications of Miocene to Pleistocene turbidites, debris flows, and slump deposits of the Queensland Trough, northeastern Australia (Site 823). In: McKenzie, J.A., Davies, P.J., Palmer-Julson, A. et al., 1993. *Proceedings of the Ocean Drilling Program, Scientific Results*, Volume **133**. College Station, Texas, 379-406.

Webster, M.A. and Petkovic, P., 2005. *Australian Bathymetry and Topography - digital dataset*. Geoscience Australia Record **2005/12**. Geoscience Australia, Canberra.

Weissel, J.K. and Hayes, D.E., 1977. Evolution of the Tasman Sea reappraised. *Earth and Planetary Science Letters* **36**, 77-84.

Weissel, J.K. and Watts, A.B., 1979. Tectonic evolution of the Coral Sea basin. *Journal of Geophysical Research* **84**, 4572.

Wellman, P. and McDougall, I., 1974. Cainozoic igneous activity in eastern Australia. *Tectonophysics* **23**, 49-65.

Wellman, P., Struckmeyer, H.I.M., Symonds, P.A., Fellows, M.E., Scott, D.L. and Draper, J.J., 1997. Coral Sea Region. In: Bain, J.H.C. and Draper, J.J. (Eds.), *North Queensland Geology*. AGSO Bulletin **240**, 409-418.

Whiteway, T., A. Heap, et al. (2007). "Seascapes of the Australian margin and adjacent sea floor : methodology and results. Geoscience Australia Record **2007/011**. Geoscience Australia, Canberra.

Willcox, J.B., 1981. Petroleum prospectivity of Australian marginal plateaus. In: Halbouty, M.T. (Ed.), *Energy Resources of the Pacific Region*, AAPG Studies in Geology, **12**, 245-271.

Willcox, J.B., Symonds, P.A., Hinz, K. and Bennett, D., 1980. Lord Howe Rise, Tasman Sea – preliminary geophysical results and petroleum prospects. *BMR Journal* **5**, 225-236.

Willcox, J.B., Symonds, P.A., Bennett, D. and Hinz, K., 1981. *Lord Howe Rise area, offshore Australia: preliminary results of a co-operative Federal Republic of Germany/Australia geophysical survey*. Bureau of Mineral Resources Australia Report, **228**. 56p.

Willcox, J.B. and Sayers, J., 2001. Gower Basin, Lord Howe Rise. In: Hill, K.C. and Benecker, T. (Eds.) *Eastern Australasian Basins Symposium*. Melbourne, PESA Special Publication, vol. **1**, 189-200.

Willcox, J.B. and Sayers, J., 2002. *Geological framework of the central Lord Howe Rise (Gower Basin) region.* Geoscience Australia Record 2002/11. Geoscience Australia, Canberra.

Winterer, E.L., 1970. Submarine valley systems around the Coral Sea Basin (Australia). *Marine Geology* **8**, 229-244.

Wolanski, E., Pickard, G.L. and Jupp, D.L.B., 1984. River plumes, coral reefs and mixing in the Gulf of Papua and the Northern Great Barrier Reef. *Estuarine, Coastal and Shelf Science* **18**, 291-314.

Wolanski, E., Norro, A. and King, B., 1995. Water circulation in the Gulf of Papua. *Continental Shelf Research* **15**, 185-212.

Woodroffe, C.D., Dickson, M.E., Brooke, B.P. and Kennedy, D.M., 2005. Episodes of reef growth at Lord Howe Island, the southernmost reef in the southwest Pacific. *Global and Planetary Change* **49**, 222-237.

Zhu, H. and Symonds, P.A., 1994. Seismic interpretation, gravity modeling and petroleum potential of the southern Lord Howe Rise region. New Zealand Petroleum Conference Proceedings, 223-230.

8. Appendices

8.1. APPENDIX A: PROJECT STAFF

Name	Substantive Role
Dr Andrew Heap	Project Manager/Geomorphologist/Sedimentologist
Dr Jock Keene	Project Scientist/Geomorphologist/Sedimentologist
Anna Potter	Project Scientist/Sedimentologist
Christina Baker	Project Scientist/Sedimentologist (DEWHA funded)
Maggie Tran	Project Scientist/Sedimentologist (DEWHA funded)
Stuart McEwen	Laboratory Manager
Christian Thun	Senior Laboratory Officer
Tony Watson	Senior Laboratory Officer
Alex Mclachlan	Senior Laboratory Officer
Keith Henderson	Laboratory Officer
Billie Poignand	Laboratory Officer
Kylia Wall	Laboratory Officer (DEWHA funded)

8.2. APPENDIX B: MAPPING PARAMETERS

8.2.1. Gravel, Sand, Mud and Carbonate Maps

- data imported to ArcGIS in csv format
- interpolate to raster using:
  - i) inverse distance weighted interpolator
  - ii) cell size of 0.01 decimal degrees (dd) – about 1 kilometre
  - iii) optimal parameters: search radius of 12 points and power parameter of 1 (Ruddick, 2006).
  - iv) maximum extrapolation distance of 0.45 dd – about 45 kilometres
- raster image clipped to Australian Economic Exclusive Zone limit and the National Mapping 1:250,000 coastline from the National GIS.
- additional clip areas were added where interpolator extrapolation produced
- artefacts that were not consistent with the surrounding data points.

8.2.2. Sedbed Sediment Type – Folk Classification

- rasters for fractions were created as in #.2.1 but with a cell size of 0.05dd.
- rasters were exported as 0.05 dd grids of points
- samples were allocated to one of 15 Folk sediment type classifications based on gravel/sand/mud percentages using pearl script.
- classified data was imported into ArcGIS in .csv format
- point data was converted to raster with folk class number as the cell value

8.2.3. Sediment Texture – Red/Green/Blue Image

- rasters for fractions (#.2.1) were imported into ENVI
- grids were loaded into the bands of a RGB image (Gravel – red, Sand – green, Mud – blue)
- image was saved as a geotiff and imported to ArcGIS

8.3. APPENDIX C: EXPLANATION OF TABLE FIELDS

8.3.1. Chapter 3 Tables

Table 3.1. Location of Deep Sea Drilling sites in the Tasman and Coral Seas

Location	Water Depth (m)	Data	Reference
32^{0} 01′S; 165^{0} 27′E New Caledonia Basin	3196	DSDP Leg 21 Site 206	Burns et al., 1973
36^{0} 58′S; 165^{0} 26′E Southern LHR	1389	DSDP Leg 21 Site 207	Burns et al., 1973
26^{0} 07′S; 161^{0} 13′E Northern LHR	1545	DSDP Leg 21 Site 208	Burns et al., 1973
15^{0} 56′S; 152^{0} 11′E Queensland Plateau	1428	DSDP Leg 21 Site 209	Burns et al., 1973 Davies et al., 1991
13^{0} 46′S; 152^{0} 54′E Coral Sea Basin	4643	DSDP Leg 21 Site 210	Burns et al., 1973
43^{0} 55′S; 154^{0} 17′E Central Tasman Sea	4729	DSDP Leg 29 Site 283	Kennett et al., 1974
13^{0} 55′S; 153^{0} 16′E Coral Sea Basin	4632	DSDP Leg 30 Site 287	Andrews et al., 1975
21^{0} 11′S; 161^{0} 20′E Chesterfield Plateau	1111	DSDP Leg 90 Site 587	Kennett et al., 1986
26^{0} 07′S; 161^{0} 14′E LHR Faust Basin	1533	DSDP Leg 90 Site 588	Kennett et al., 1986
30^{0} 43′S; 163^{0} 38′E Lord Howe Rise	1391	DSDP Leg 90 Site 589	Kennett et al., 1986
31^{0} 10′S; 163^{0} 21′E S Lord Howe Rise	1299	DSDP Leg 90 Site 590	Kennett et al., 1986
31^{0} 35′S; 164^{0} 27′E S Lord Howe Rise	2131	DSDP Leg 90 Site 591	Kennett et al., 1986
36^{0} 28′S; 165^{0} 27′E S Lord Howe Rise	1088	DSDP Leg 90 Site 592	Kennett et al., 1986
16^{0} 31′S; 148^{0} 09′E 3.5nm E of Holmes Reef, W Queensland Plateau	937	ODP Leg 133 Site 811	Davies et al., 1991a ; McKenzie et al., 1993 ; Davies et al., 1993 Betzler et al., 1995 Brachert and Dullo, 2000
17^{0} 49′S; 149^{0} 36′E Tregrosse Reef Queensland Plateau slope	462	ODP Leg 133 Site 812	Davies et al., 1991a ; McKenzie et al., 1993 ; Davies et al., 1993 Betzler et al., 1995 McNeill, 2005

			Brachert and Dullo, 2000
17^0 50′S; 149^0 30′E Tregrosse Reef Queensland Plateau slope	539	ODP Leg 133 Site 813	Davies et al., 1991a ; McKenzie et al., 1993 ; Davies et al., 1993 Betzler et al., 1995 McNeill, 2005 Brachert and Dullo, 2000
17^0 50′S; 149^0 31′E Tregrosse Reef Queensland Plateau slope	520	ODP Leg 133 Site 814	Davies et al., 1991a ; McKenzie et al., 1993 ; Davies et al., 1993 Betzler et al., 1995 McNeill, 2005 Brachert and Dullo, 2000
19^0 09′S; 150^0 00′E Marion Plateau	466	ODP Leg 133 Site 815	Davies et al., 1991a ; McKenzie et al., 1993 ;
19^0 12′S; 150^0 01′E Marion Plateau	438	ODP Leg 133 Site 816	Davies et al., 1991a ; McKenzie et al., 1993 ;
18^0 09′S; 149^0 46′E Queensland Plateau/Townsville Trough slope	1016	ODP Leg 133 Site 817	Davies et al., 1991a ; McKenzie et al., 1993 ; Davies et al., 1993 Cotillon et al., 1994a McNeill, 2005
18^0 04′S; 150^0 03′E Queensland Plateau/Townsville Trough slope	749	ODP Leg 133 Site 818	Davies et al., 1991a ; McKenzie et al., 1993 ; Davies et al., 1993 McNeill, 2005
16^0 37′S; 146^0 19′E Great Barrier Reef	565	ODP Leg 133 Sites 819	Davies et al., 1991a ; McKenzie et al., 1993 ; Davies et al., 1993 Davies and Peerdeman, 1998
16^0 38′S; 146^0 18′E Great Barrier Reef	279	ODP Leg 133 Site 820	Davies et al., 1991a ; McKenzie et al., 1993 ;
16^0 39′S; 146^0 17′E Great Barrier Reef	213	ODP Leg 133 Site 821	Davies et al., 1991a ; McKenzie et al., 1993 ;
16^0 25′S; 149^0 13′E Great Barrier Reef	955	ODP Leg 133 Site 822	Davies et al., 1991a ; McKenzie et al., 1993 ;
16^0 37′S; 149^0 36′E Queensland Trough	1638	ODP Leg 133 Site 823	Davies et al., 1991 ; McKenzie et al., 1993 ;
16^0 27′S; 147^0 46′E W of Holmes Reef, W Queensland Plateau	1001	ODP Leg 133 Sites 824	Davies et al., 1991a ; McKenzie et al., 1993 ; Davies et al., 1993 Betzler et al., 1995

			Brachert and Dullo, 2000
16^0 31′S; 148^0 09′E 3.5nm E of Holmes Reef, W Queensland Plateau	939	ODP Leg 133 Site 825	Davies et al., 1991a ; McKenzie et al., 1993 ;
19^0 14′S; 150^0 01′E Marion Plateau	425	ODP Leg 133 Site 826	Davies et al., 1991a ; McKenzie et al., 1993 ;
20^0 34′S; 152^0 24′E Marion Plateau	374	ODP Leg 194 Site 1192	Isern et al., 2002 ; Anselmetti et al., 2006 Isern et al., 2001 Ehrenberg et al., 2006
20^0 14′S; 151^0 48′E Marion Plateau	348	ODP Leg 194 Site 1193	Isern et al., 2002 ; Anselmetti et al., 2006
20^0 15′S; 151^0 59′E Marion Plateau	374	ODP Leg 194 Site 1194	Isern et al., 2002 ; Anselmetti et al., 2006
20^0 24′S; 152^0 40′E Marion Plateau	419	ODP Leg 194 Site 1195	Isern et al., 2002 ; Anselmetti et al., 2006
21^0 00′S; 152^0 52′E Marion Plateau	304	ODP Leg 194 Site 1196	Isern et al., 2002 ; Anselmetti et al., 2006
21^0 05′S; 153^0 04′E	348	ODP Leg 194 Site 1197	Isern et al., 2002 ; Anselmetti et al., 2006
20^0 58′S; 152^0 44′E Marion Plateau	320	ODP Leg 194 Site 1198	Isern et al., 2002 ; Anselmetti et al., 2006
20^0 59′S; 152^0 55′E Marion Plateau	316	ODP Leg 194 Site 1199	Isern et al., 2002 ; Anselmetti et al., 2006

Table 3.2. Cores and other samples on the continental shelf off NSW and southern Queensland: general location and reference.

Location	**Water Depth (m)**	**Data**	**Reference**
Off Fraser Island Surface samples		Sedimentology, ^{14}C	Marshall et al., 1998
Off Fraser Island Surface samples		Sedimentology	Boyd et al., 2004b, Boyd et al., 2008
Off southern Queensland and NSW Surface sediments		Sedimentology	Davies, 1979
Off central NSW Cores		Sedimentology, ^{14}C, amino acid racemisation	Freland and Roy, 1997 Ferland et al., 1995 Murray-Wallace et al., 2005

Off central NSW Cores		Sedimentology, trace metals	Matthai and Birch, 2000
Off central NSW Surface sediments		Sedimentology	Boyd et al., 2004a
Off Sydney Surface samples		Sedimentology, heavy metals	Birch and Davey, 1995
Off Newcastle Surface samples		Sedimentology, trace metals	Matthai and Birch, 2000
Off Sydney Surface sediments		Sedimentology	Albani and Rickwood, 2000
Off northern NSW Surface sediments		Sedimentology	Boyd et al., 2004a
Off northern NSW Cores		Sedimentology	Roberts and Boyd, 2004
Off NSW Surface samples		Sedimentology	Shirley, 1964

Table 3.3. Bottom photography of the continental shelf off NSW and southern Queensland.

Location	Water Depth (m)	Data	Reference
33^0 52′S; 151^0 22′E Off Sydney	~ 75	Muddy bottom, pit, mounds, tracks, trails	Conolly, 1969
34^0 10′S; 151^0 08′E Off Sydney	~ 45	Sand with ripples	Conolly, 1969
34^0 13′S; 151^0 14′E Off Sydney	~ 120	Muddy bottom, tracks, trails, epifauna	Conolly, 1969
Off Fraser Island	Outer shelf	Rhodoliths and corals	Marshall et al., 1998; Davies and Peerdeman, 1998.
Off Evans Head and Cape Byron	40-68	Calcareous gravel, sand, rock, sea urchins, sponges	Jones and Kudras, 1982

Table 3.4. Sea floor photography of continental slope off NSW and southern Queensland: location, data collected and reference.

Location	Water Depth (m)	Data	Reference
34^0 04′S; 151^0 37′E Off Sydney	~280	Muddy bottom, pits, mounds,	Conolly, 1969

		tracks, trails	
Off Sydney			Glenn et al., 2007
28^0S to 32^0S Evans Head to Yamba Cores and dredges	100-3955 m	Iron-rich glauconite foraminifer sands. Phosphate and iron hardgrounds	O'Brien and Heggie, 1990.

Table 3.5. Cores and surface samples analysed from the east Australian continental slope.

Location	Water Depth (m)	Data	Reference
26^0 30'S; 153^0 53'E Off Noosa	842	58% carbonate, 70% mud, ^{14}C, ^{18}O.	Troedson and Davies, 2001
26^0 35'S; 153^0 51'E Off Noosa	1022	53% carbonate, 82% mud, ^{14}C, ^{18}O	Troedson and Davies, 2001
33^0 57'S; 151^0 55'E Off Sydney	1467	46% carbonate, 55% mud, ^{14}C, ^{18}O	Troedson and Davies, 2001
33^0 59'S; 152^0 00'E Off Sydney	2007	47% carbonate, 82% mud, ^{14}C, ^{18}O	Troedson and Davies, 2001
Upper continental slope, central NSW		11 cores, carbonate, mud, ^{14}C	Glenn et al., 2007
33^0 55.5'S; 151^0 51.5'E Off Sydney	977	Grain size, carbonate, magsus.	Howard, 1993
34^0 00.5'S; 152^0 04.0'E Off Sydney	2445	Grain size, carbonate, mag sus.	Howard, 1993
34^0 06.5'S; 152^0 08.5'E Off Sydney	3017	Grain size, carbonate, mag sus.	Howard, 1993
Upper continental slope between 31^0 to 33^0 S.	200-1600	8 cores described	Hubble and Jenkins, 1984.
Upper continental slope between 36^0 and 37^0 15'S.	392-1200	5 cores described	Hubble and Jenkins, 1984.
31^0 34'S; 153^0 33'E Off Smoky Cape	3768	46% carbonate, silty mud	Eade and van der Linden, 1970
Off Breaksea Spit Surface samples	50 – 3500	Sedimentology, luminescence	Boyd et al., 2008

Off northern NSW One core	125	Biogenic muddy gravel (sponge spicules, bryozoa)	Roberts and Boyd, 2004
Off Fraser Island Surface samples	105 – 250	Foraminifer, molluscs, bryozoans, coralline algae	Marshall et al., 1998
Off Evans Head, NSW Two cores	1000-2000	48,56% carbonate, 59,84% mud	Lane and Heggie, 1993.
Off central NSW Four cores	167-238	90,70,64,59% carbonate, 10-20% mud, <10% biogenic gravel, C14.	Ferland and Roy, 1997. Heggie et al., 1993.
28^0S to 32^0S Evans Head to Yamba Cores and dredges	100-3955 m	Iron-rich glauconite foraminifer sands. Phosphate and iron hardgrounds	O'Brien and Heggie, 1990.

Table 3.6. Dredge Samples from the east Australian continental slope: Location and Reference

Location	**Water Depth (m)**	**Data**	**Reference**
29^0 23'S; 153^0 50'E	385	Phosphate concretions	Von der Borch, 1970. Kress and Veeh, 1980.
30^0 41'S; 153^0 18'E	210	Nodules ferruginised and phosphatised with bones and teeth.	Von der Borch, 1970. Kress and Veeh, 1980.
30^0 40'S; 153^0 20'E	265	As above	Von der Borch, 1970.
30^0 01'S; 153^0 18'E	290	As above	Von der Borch, 1970.
34^0 22'S; 151^0 58'E	4219	Metasediments, metavolcanics, ?Palaeozoic	Heggie et al., 1992
34^0 14'S; 152^0 08'E	3967	Mudstone, sandstone, mid to late Campanian	Heggie et al., 1992
34^0 16'S; 152^0 09'E	4612	Sandstone, Triassic. Mudstone, ?late Mesozoic	Heggie et al., 1992

34^0 09'S; 152^0 15'E	4818	Basaltic andesite. Mudstone, ?late Mesozoic.	Heggie et al., 1992
34^0 09'S; 152^0 14'E	4290	Volcanic sandstone, mudstone, late Cretaceous. Mn/Fe nodules and crusts	Heggie et al., 1992
33^0 59'S; 152^0 16'E	3533	Sandstone, mudstone, glauconitic calcareniter, early Paleocene - Eocene	Heggie et al., 1992
33^0 49'S; 152^0 04'E	1606	Mudstone, lithic sandstone, ?late Mesozoic. Living corals, sponges, annelids, echinoderms, brachiopods, bivalves, gastropods	Heggie et al., 1992
33^0 45'S; 152^0 06'E	1745	Mudstone, early Eocene. Glauconitic calcarenite, ?Paleocene	Heggie et al., 1992
33^0 32'S; 152^0 25'E	3082	Sandstone, siltstone, mid to late Campanian	Heggie et al., 1992
33^0 12'S; 152^0 46'E	3470	Vesicular basalt, hyaloclastite. Sandstone	Heggie et al., 1992
33^0 34'S; 152^0 21'E	2876	Volcanic breccia of basalt and ?rhyolite. Lithic sandstone, mudstone mid to late Campanian	Heggie et al., 1992
34^0 02'S; 151^0 39'E	420	Ferruginised/phosphatised basaltic breccia	Jenkins, 1991.
33^0 59.1'S; 152^0 16.5'E 112/DR008	3533-3306	Glauconitic calcarenite, early Paleocene.	Quilty et al., 1997
37^0 12'S; 150^0 45'E	3750	Granodiorite, Middle Devonian	Hubble et al., 1992
37^{0}14'S; 150^0 42' E	4000	Granodiorite, Middle Devonian	Hubble et al., 1992
36^0 06'S; 150^0 39'E	2610-2155	Limestone, latest Silurian-Early Devonian. Fe/Mn coated shale and siltstone	Packham et al., 2006
36^0 10'S; 150^0 34'E	1700	Leuco-quartz monzodiorite, Early Cretaceous, 101 Ma	Hubble et al., 1992
36^0 32'S; 150^0 48'E	4500	Serpentinite, mudstone	Hubble et al., 1992
36^0 38'S; 150^0 48'E	4500	Serpentinite, mudstone	Hubble et al., 1992
37^0 07'S; 150^0 46'E	4000-4500	Lithic sandstone	Packham et al., 2006

37^{0} 13′S; 150^{0} 44′E	4000-4500	Meta-basalt	Hubble et al., 1992
37^{0} 17′S; 150^{0} 46′E	4000-4500	Meta-basalt, marble	Hubble et al., 1992
36^{0} 17′S; 150^{0} 35′ E	1750	Schist, slate, limestone. Fe/Mn coated scoriaceous basalt lava blocks in late Paleocene limestone	Quilty and Packham, 2006
35^{0} 57.5′S; 151^{0} 39.2′E	~ 200	Green foraminiferal sand	Conolly, 1969
34^{0} 00.2′S; 151^{0} 44.2′E	~ 500	Green sand	Conolly, 1969
34^{0} 3.2′S; 151^{0} 51.5′E	~ 1200	Calcareous green mud	Conolly, 1969
34^{0} 08′S; 152^{0} 00′E	~ 1700	Calcareous green mud	Conolly, 1969
34^{0} 09′S; 151^{0} 55′E	~ 2000	Calcareous green mud	Conolly, 1969
34^{0} 13′S; 151^{0} 38′E	~ 700	Calcareous green mud	Conolly, 1969
Off Fraser Island	270-600	Shallow water limestone, dolomitic limestone (Oligocene-middle Miocene). Stable isotopes.	Marshall et al., 1998

Table 3.7. Sea floor photography of the Tasman Basin: Location and Reference

Location	**Water Depth (m)**	**Data**	**Reference**
34^{0} 35.7′S; 152^{0} 02.5′E Abyssal plain at foot of continental slope E of Nowra	4820	Pebbles and blocks in bioturbated mud. Current indicators	Jenkins et al., 1986
30^{0} 45.5′S; 153^{0} 46.8′E Abyssal plain at foot of continental slope E of Coffs Harbour	4515-4585	Strong current indicators in bioturbated mud	Jenkins et al. 1986
30^{0} 40.6′S; 154^{0} 21.4′E E of Coffs Harbour	4365-4432	Crest of linear sediment drift. Current indicators	Jenkins et al., 1986
30^{0} 43.8′S; 154^{0} 29.2′E E of Coffs Harbour	4640	E flank of sediment drift	Jenkins et al., 1986
33^{0} 22′S; 156^{0} 45′E	4800-4811	Between Taupo Smt and Dampier Ridge	Baker et al., 1988a

31° 41'S; 155° 51'E Abyssal hills	4705-4750		Baker et al., 1988a
32° 20'S; 154° 20'E Abyssal plain	4730-4735		Baker et al., 1988a
35° 33.3'S; 155° 40.4'E	4408-4418	Mn nodules and bioturbated sediment	Glasby et al., 1986

Table 3.8. Cores and dredge samples from the Tasman Basin: Location and Reference

Location	Water Depth (m)	Data	Reference
36° 15'S; 155° 35'E	4300	Mn nodules, greenish grey calcareous mud	Exon et al., 1980
35° 48.6'S; 156° 31.8'E	4714-4548	Mn nodules	Glasby et al., 1986
34° 50'S; 155° 28'E	~ 4500	Red clay	Conolly, 1969
36° 41'S; 158° 29'E	~ 4500	Red clay	Conolly, 1969
31° 37'S; 154° 14'E	4565	40% carbonate, sandy mud	Eade and van der Linden, 1970
31° 31'S; 155° 01'E	4654	43% carbonate, silty mud	Eade and van der Linden, 1970
31° 29'S; 155° 45'E	4838	55% carbonate, clay	Eade and van der Linden, 1970
31° 29'S; 156° 13'E	4689	55% carbonate, silty mud	Eade and van der Linden, 1970
31° 31'S; 156° 54'E	4283	42% carbonate, silty mud	Eade and van der Linden, 1970
Numerous cores in Tasman Basin	4082-4830	Carbonate dissolution	Martinez, 1994b

Table 3.9. Size of erosion scours at base of Tasmantid Seamounts in the EMR deduced from Eltanin seismic records (from Jenkins, 1984)

Seamount Location	Seamount height (m)	Seamount width at base (Km)	Moat width (Km)	Moat depth (m)
33° 36'S; 153° 54'E Unnamed seamount	664	10.8	12-23 east and west side	30-48
28° 12'S; 155° 48'E Britannia Seamount	4270	43	>29 east side	332

25^0 48′S; 154^0 30′E Recorder Seamount	3567	43	6 west side	18

Table 3.10. Sea floor photography of Tasmantid seamounts: location, data collected and reference.

Location	Water Depth (m)	Data	Reference
36^0 37.8′S; 155^0 31.0′E Gascoyne Smt South of EMR	4840-4880	Eroded scoured moat at W foot. Gravel and boulder lag.	Jenkins et al., 1986
30^0 50′S; 156^0 42′E Derwent Hunter Seamount	4614-4592	Eroded scoured moat	Baker et al., 1988a

Table 3.11. Cores and Dredge Samples from the Tasmantid and Lord Howe Seamount chains: Location and Reference

Location	Water Depth (m)	Data	Reference
36^0 39′S; 156^0 14′E Gascoyne Smt	600-900	Basalt. Petrography and K-Ar	McDougall and Duncan, 1988
33^0 06′S; 156^0 17′E Taupo Bk	500-750	Basalt and limestone Petrography and K-Ar	McDougall and Duncan, 1988; Slater & Goodwin, 1973
32^0 59′S; 156^0 14′E Taupo Bk	500-750	Petrography and K-Ar	McDougall and Duncan, 1988
30^0 56′S; 156^0 14′E Derwent Hunter G	600-1000	Petrography and K-Ar	McDougall and Duncan, 1988
30^0 47′S; 155^0 21′E Derwent Hunter G	1150-1250	Basalt, limestone and phosphorite. Petrography and K-Ar	McDougall and Duncan, 1988; Slater & Goodwin, 1973
28^0 38′S; 155^0 27′E Britannia G	1100-1400	Petrography and K-Ar	McDougall and Duncan, 1988
27^0 29′S; 155^0 18′E Queensland G	1500-1900	Petrography and K-Ar	McDougall and Duncan, 1988
Barcoo	300-350	Basalt and limestone	Slater & Goodwin, 1973
Gifford	300-350	Limestone and phosphorite	Slater & Goodwin, 1973
Lord Howe	50-350	Limestone	Slater & Goodwin, 1973

Table 3.12. Cores samples from the plateaus and rises in the Tasman Sea: Location and Reference

Location	Water Depth (m)	Data	Reference
33^0 10′S; 159^0 27′E Lord Howe Rise	3609	85% carbonate, very sandy mud	Eade and van der Linden, 1970
33^0 23′S; 161^0 37′E Lord Howe Rise	1448	93% carbonate, sandy mud	Eade and van der Linden, 1970
33^0 31′S; 164^0 03′E Lord Howe Rise	1834	94% carbonate, sandy mud	Eade and van der Linden, 1970
33^0 30′S; 165^0 02′E New Caledonia Basin	3045	93% carbonate, sandy mud	Eade and van der Linden, 1970
Numerous core on Lord Howe Rise and New Caledonia Basin	1500-3000	Carbonate dissolution	Martinez, 1994b
Lord Howe Rise		^{18}O	Nelson et al., 1994
30^0 33′S; 161^0 26′E Lord Howe Rise	1340	Benthic forams ^{18}O	Nees, 1997
33^0 23′S; 161^0 37′E Lord Howe Rise	1448	Benthic forams ^{18}O	Nees, 1997
25^0 16′S; 162^0 00′E Lord Howe Rise	1299	^{18}O, foram-nanno ooze, primary production, dust	Kawahata, 2002, Kawahata et al., 1999 Kawagata, 2001
30^0 00′S; 162^0 00′E Lord Howe Rise	1158	^{18}O, foram-nanno ooze, primary production, dust	Kawahata, 2002, Kawahata et al., 1999 Kawagata, 2001
35^0 00′S; 162^0 31′E Lord Howe Rise	1338	^{18}O, foram-nanno ooze, primary production, dust	Kawahata, 2002, Kawahata et al., 1999 Kawagata, 2001
35^0 30′S; 161^0 00′E Lord Howe Rise	3166	^{18}O, coccolith ooze, primary production, dust	Kawahata, 2002, Kawahata et al., 1999 Kawagata, 2001
27^0 46′S; 160^0 13′E W LHR Capel Basin Core MD06-3036	2505	Geochemical studies	Colwell et al., 2006
27^0 47′S; 160^0 11′E W LHR Capel Basin Core MD06-3037	2584	Geochemical studies	Colwell et al., 2006
27^0 47′S; 160^0 11′E W LHR Capel Basin Core MD06-3038	2585	Geochemical studies	Colwell et al., 2006

Table 3.13. Dredge samples from the plateaus and rises in the Tasman Sea: Location and Reference

Location	Water Depth (m)	Data	Reference
28^{0} 34′S; 163^{0} 00′E Central LHR, Vening-Meinesz FZ			Roeser et al., 1985
28^{0} 38′S; 163^{0} 04′E Central LHR, Vening-Meinesz FZ	1650	Mn crust, breccia, conglomerate	Colwell et al., 2006
28^{0} 33′S; 163^{0} 00′E Central LHR, Vening-Meinesz FZ	1600	Mn crust, volcaniclastic, limestone breccia	Colwell et al., 2006
28^{0} 25′S; 162^{0} 47′E Central LHR, Vening-Meinesz FZ	1700-1450	Mn crusts, nodules, volcanics, breccia and epifauna.	Colwell et al., 2006
E flank of southern Lord Howe Rise		Basalt, hyaloclastic breccia	Launay et al., 1976 Willcox et al., 1981
Dampier Ridge		Granite, ?andesite, 250-270 Ma	McDougall et al., 1994

Table 3.14. Bottom photography from the Lord Howe Rise, Dampier Ridge, Cato Trough, Kenn Plateau and Mellish Rise: Location and Reference

Location	Water Depth (m)	Data	Reference
23^{0} 15′S; 154^{0} 55′E	3000-3200	BC1	Walker, 1992
22^{0} 37′S; 155^{0} 03′E	3380	BC2	Walker, 1992
22^{0} 34′S; 155^{0} 30′E	3068	BC3	Walker, 1992
32^{0} 59′S; 160^{0} 01′E W flank LHR	1552-1560		Baker et al., 1988a
28^{0} 34′S; 162^{0} 52′E Channel LHR	1698-1700		Baker et al,. 1988a
29^{0} 59′S; 159^{0} 52′E W slope LHR	1992-200		Baker et al., 1988a
30^{0} 52′S; 156^{0} 47′E Base of Dampier Ridge	4556-4374		Baker et al., 1988a

Table 3.15. Cores samples from the Cato Trough, Kenn Plateaus and Mellish Rise: Location and Reference

Location	Water Depth (m)	Data	Reference
22^{0} 37.7′S; 155^{0} 03.5′E	3380	Calcareous sandy mud	Walker, 1992

22^0 34.3'S; 155^0 30.5'E	3068	Calcareous sandy mud	Walker, 1992
19^0 43.3'S; 154^0 59.3'E	3152	Calcareous sandy mud	Walker, 1992

Table 3.16. Dredge samples from the Cato Trough, Kenn Plateau and Mellish Rise: Location and Reference

Location	Water Depth (m)	Data	Reference
Numerous dredges from Kenn Plateau		Petrography and age	Exon et al., 2006

Table 3.17. Cores and other Samples from the Marion Plateau: Location and Reference

Location	Water Depth (m)	Data	Reference
20.8^0S; 152.3^0E Marion Plateau cores	320	Carbonate, Sr sedimentology, ^{18}O	Page and Dickens, 2005

Table 3.18. Cores and other Samples from the Queensland Plateau, Townsville and Queensland Troughs: Location and Reference

Location	Water Depth (m)	Data	Reference
Queensland Trough 154 surface samples and cores		Carbonate %, mineralogy, Sr	Dunbar and Dickens, 2003a; Francis et al., 2007
Queensland Trough and Plateau cores		Carbonate, stratigraphy, ^{14}C	Dunbar et al., 2000
Queensland Trough cores		Carbonate, sedimentology, ^{18}O	Dunbar and Dickens, 2003b
Queensland Trough cores		Carbonate, sedimentology, ^{14}C	Page et al., 2003
Queensland Trough cores		Carbonate, Sr sedimentology, ^{18}O	Page and Dickens, 2005
Townsville Trough		Carbonate, sedimentology, ^{14}C	Harris et al., 1990
Queensland Plateau Surface samples		Sediment type	Gardner, 1970

Table 3.19. Cores and other Samples from the Eastern Plateau and Reefs: Location and Reference

Location	Water Depth(m)	Data	Reference
9^0 54'S; 144^0 39'E Ashmore Trough	760	Dark grey calcareous mud, ^{14}C, ^{13}C, ^{18}O	de Garidel-Thoron et al., 2004
At shelf edge	100-120	3 cores, ^{14}C	Harris et al., 1996b.
Ashmore Trough Cores MD05		Core for palaeoclimate studies IMAGES	Beaufort et al., 2005

Table 3.20. Cores and other Samples from the Coral Sea Basin, Louisiade Plateau and Louisiade Trough: Location and Reference

Location	Water Depth (m)	Data	Reference
Coral Sea Basin Surface samples		Sediment type	Gardner, 1970

Table 3.21. Cores and other Samples from the Norfolk Island ridges and basins: Location and Reference

Location	Water Depth (m)	Data	Reference
79 dredge locations Norfolk Basin	various	Rock petrography, K-Ar dating.	Various authors listed in DiCaprio et al., 2007. Mortimer, 1998.
32^0 01'S; 165^0 28'E New Caledonia Basin Core MD97-2123		Paleoclimate, IMAGES	Marion Dufresne MD106, 1997
26^0 46'S; 163^0 38'E W Fairway Basin Core MD97-2124		Paleoclimate, IMAGES	Marion Dufresne MD106, 1997
30^0 26'S; 165^0 56'E E Fairway Basin seamount dredge	2704-2456	Foram nanno-ooze	Colwell et al., 2006
27^0 43'S; 165^0 17'E E Fairway Basin seamount dredge	2900	Volcaniclastic breccia, sandstone, Mn crust	Colwell et al., 2006
26^0 33'S; 165^0 01'E E Fairway Basin Core MD06-3029	2889	Geochemical studies	Colwell et al., 2006

26^0 35′S; 164^0 46′E E Fairway Basin Core MD06-3030	2928	Geochemical studies	Colwell et al., 2006
26^0 35′S; 164^0 46′E E Fairway Basin Core MD06-3032	2930	Geochemical studies	Colwell et al., 2006E

8.3.2. Chapter 4 Tables

E.g. Table 4.1

Feature	Area in EMR	% total* EMR Area	% EEZ Area	% Total EEZ area located in EMR	Water Depth Range** in EMR (m)

Area in EMR: Area in km² covered by this feature within the EMR.

% total* EMR Area: Percent of the total area of the EMR (not including areas with water depths <10 m) which is allocated to this feature.

% EEZ Area: Percent of the total area of the EEZ which is allocated to this feature.

% Total EEZ area located in EMR: The proportion of the EEZ area allocated to this feature that lies within the EMR.

Water Depth Range in EMR (m):** Range of water depths occurring in the EMR area (not including areas with water depths <10m) allocated to this feature. To reduce error, depths were determined from the point data underpinning the bathymetry grid rather than the interpolated data. Values are rounded to the nearest 10 m.

E.g. Table 4.2

PROVINCE/ # Feature	No. sample points	% EMR Area	Average sample density

PROVINCE/ # Feature: Features are nested within Provinces. Shelf, Slope, Rise and Abyssal Plain/Deep Ocean Floor Provinces are capitalised. Statistics for Provinces include the area of all features occurring within them. Feature names are not capitalised. Shelf, slope, rise and AP/DOF features comprise the area of these provinces with no other features identified within them.

No. sample points: The total number of samples used in this study that are located within the area allocated to this province or feature. Some samples included in this figure have only textural or compositional data.

%EMR Area: As in Table 4.1.

Average sample density (samples per km²): The average sample density across all occurrences of the feature in the EMR. This is calculated by dividing the total area of the feature by the number of sample points within it. Results have been rounded to the nearest 100 km².

8.3.3. Chapter 5 Tables

E.g. Table 5.1

Bioregion	No. sample points (no. added for task)	% EMR Area*	Average sample density (km²)

No. sample points (no. added for task): The number of sample points occurring in the bioregion including both data existing before this task and new assays generated for this task. The number of samples added to this bioregion for this task is given in brackets.
%EMR Area: Percentage of the total area of the NWMR allocated to this bioregion. Percentages are calculated from the NWMR including the area not assigned to any bioregion.
Average sample density (km²): As for Table 4.2.

E.g. Table 5.2

Feature	% of bioregion area covered	% of EMR area this unit lies within this bioregion	% of EEZ area this unit lies within this bioregion

% of bioregion area covered: The percentage of the total area of the bioregion that is included in the NWMR that falls within this feature. Calculations do not include areas with water depths <10 m.

% of EMR area this unit lies within this bioregion: The percentage of the total area covered by this feature in the EMR that lies within the area of this bioregion included in the EMR.

% of EEZ area this unit lies within this bioregion: The percentage of the total area covered by this feature in the EEZ that lies within the area of this bioregion included in the EMR.

E.g. Table 5.3

Feature	Depth Range (m)	Mean Depth (m)

Depth Range (m): Range of water depths occurring in the area of this feature within the bioregion(not including areas with water depths <10 m). To reduce error, depths were determined from the point data underpinning the bathymetry grid rather than the interpolated data. Values are rounded to the nearest 10 m.

Mean Depth (m): The mean water depth occurring in the area of this feature within the bioregion. To reduce error, depths were determined from the point data underpinning the bathymetry grid rather than the interpolated data. Areas with water depths <10 m were removed prior to calculations. Values are rounded to the nearest 10 m.

8.4. APPENDIX D: METADATA

(To be included with GIS files in final report DVD)

8.5. APPENDIX E: DATA GENERATED

See excel workbook "EMR Task 2007 Assays".

8.6. APPENDIX F: LASER GRAINSIZE DISTRIBUTIONS

See PDF file "Appendix F EMR Laser Reports".

8.7. APPENDIX G: WEB ACCESSIBLE DIGITAL MAPS FOR DATA COVERAGE AND SEDIMENT PROPERTIES

(To be included in final report DVD)

Instructions for the DVD

Sedimentology and Geomorphology of the East Marine Region: A Spatial Analysis

This DVD contains the above-titled Report as Record 2008/10.pdf

View this .pdf document using Adobe Acrobat Reader (Click Adobe.txt for information on readers)

Click on: Record 2008/10.pdf to launch the document.

Directories on this DVD:

Appendix D: Metadata File with electronic documents as .txt files

Appendix E: Data Generated (Refer to EMR_Task_2007_Assays.xls)

Appendix F: Laser grainsize distributions (Refer to Appendix_F_EMR_Laser_Reports.pdf)

Appendix G: Web Accessible Digital Maps for Data Coverage and Sediment Properties

Within the directory of GIS Files, sub-directories include: boundaries, georef image files, layer files, polygons, rasters and sample points. All these subdirectories can be viewd using ARC GIS Catelogue and ARC MAP. Sub-directories of figures include three different formats of all figures found in the report: JPEG, GIF and TIFF.