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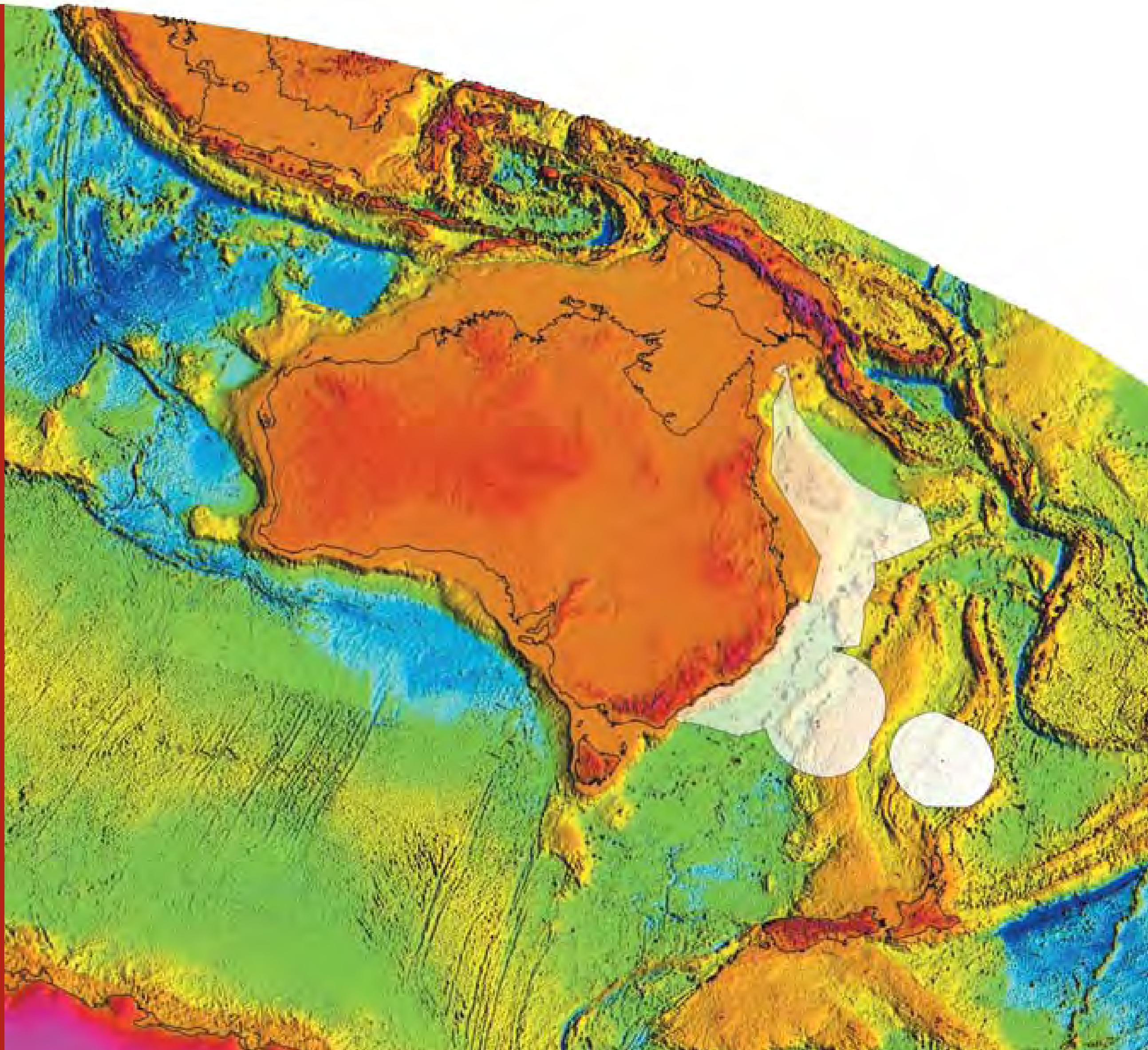
Sedimentology and Geomorphology of the East Marine region of Australia

A Spatial Analysis

Jock Keene, Christina Baker, Maggie Tran and Anna Potter

Record
2008/10



APPLYING GEOSCIENCE TO AUSTRALIA'S MOST IMPORTANT CHALLENGES

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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

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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.

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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).

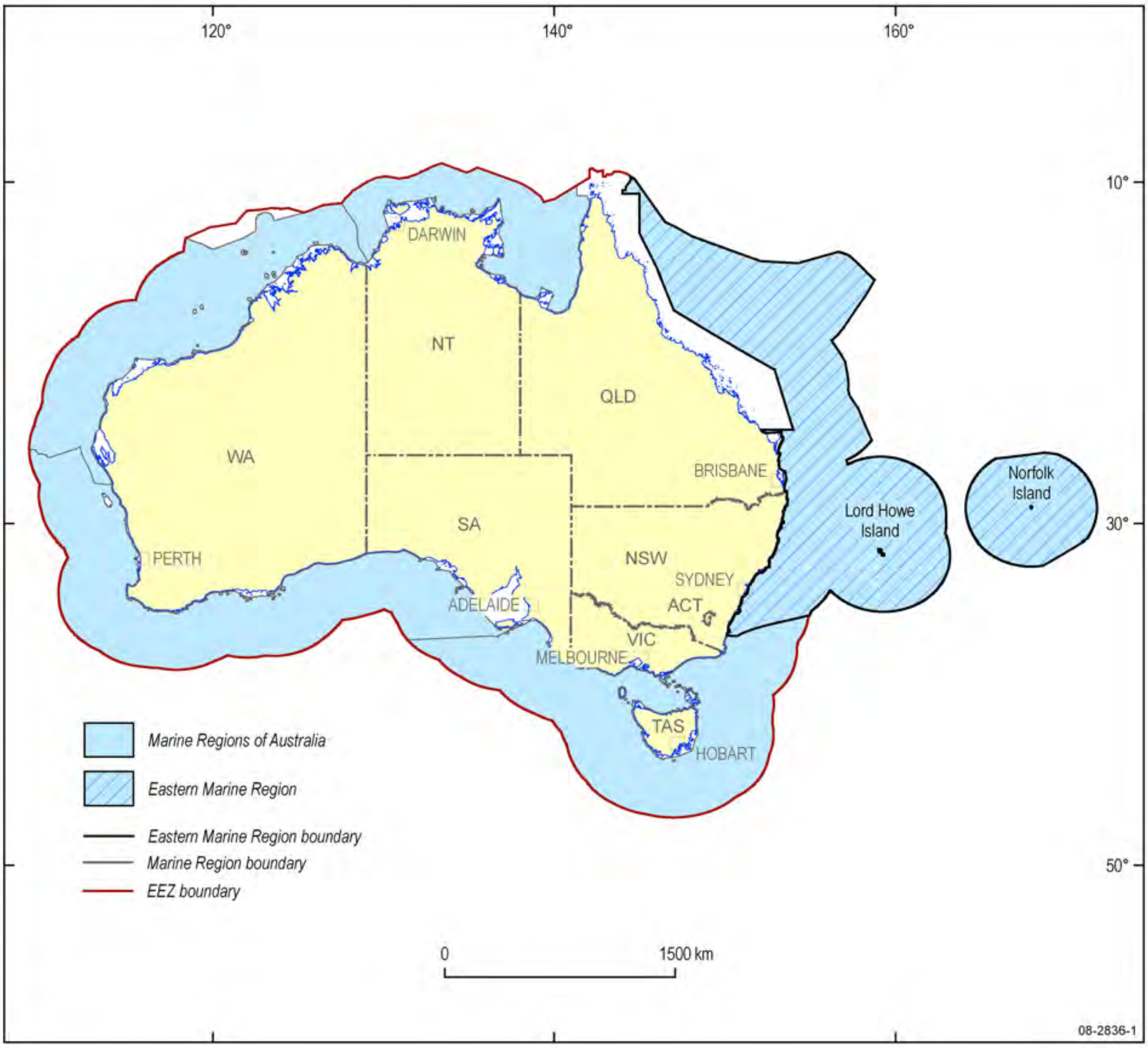

Figure 1.1. Map showing the boundaries of the East Marine Planning Area as defined by the Department of the Environment, Water, Heritage and the Arts. The boundaries extend from the Torres Strait in the north to Montague Island in the south excluding the Great Barrier Reef Marine Park but including other 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).

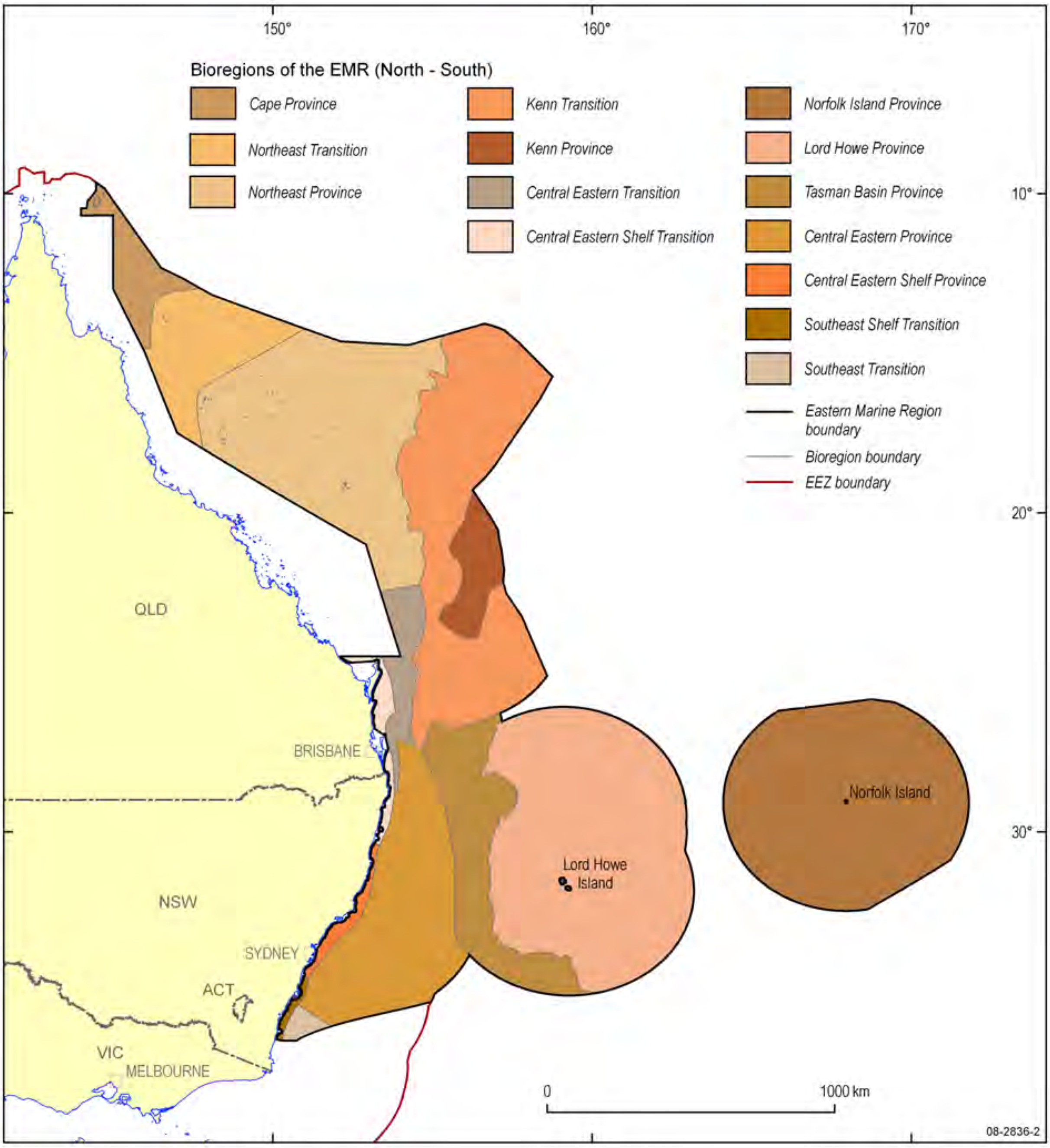

Figure 1.2. Map showing the bioregions of the East Marine Region as defined by the Department of the Environment, Water, Heritage and the Arts.

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.

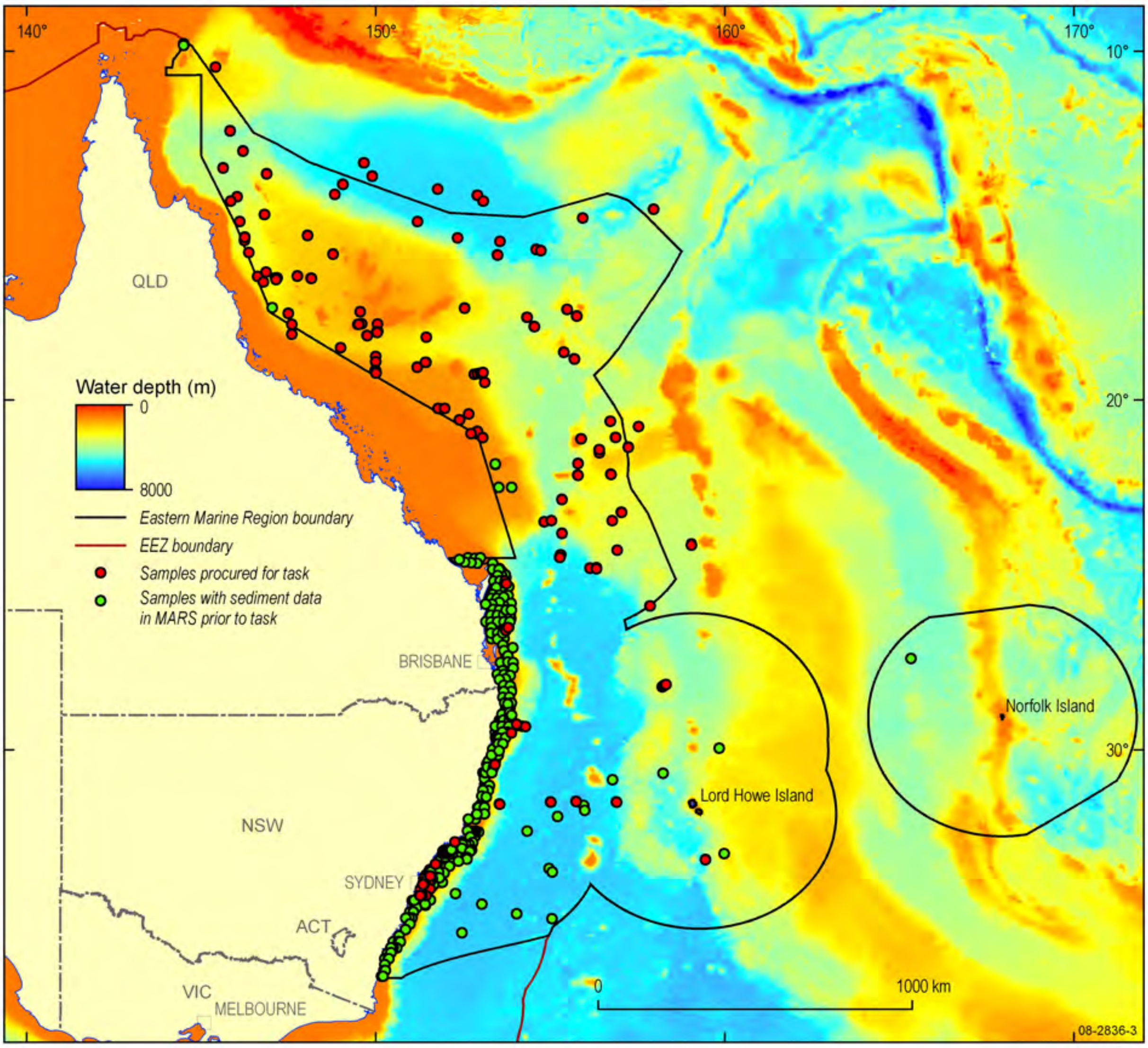

Figure 2.1. The location of all quantitative textural and compositional data for the EMR stored in MARS prior to, and following, the MOU.

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.