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Geomorphology and Stratigraphy of Keppel Bay

South-East Queensland, Australia

David A. Ryan, Helen C. Bostock, Brendan P. Brooke, and Darren Skene

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by

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Executive Summary

A major objective of the Fitzroy Project in the Cooperative Research Centre for Coastal Zone, Estuary and Waterway Management (Coastal CRC) was to determine the spatial distribution and accumulation history of sediments in the Fitzroy River estuary and Keppel Bay. To achieve this involved the analysis of sediment grab samples, vibracores, and 'chirp' sub-bottom profiles. This report describes the datasets that were collected in Keppel Bay and summarises the results of this geoscience research.

Keppel Bay is a large shallow coastal embayment adjacent to the mouth of the Fitzroy River, located on the central coast of Queensland. The geomorphology and distribution of sediment in Keppel Bay is complex due to the influence of Late Quaternary sea-level change, relict topography, a geologically diverse catchment, macrotidal hydrodynamic processes and flood events.

Seabed morphology, sub-bottom profiles and sediment cores reveal the former path of the Fitzroy River across Keppel Bay and the continental shelf. The palaeo-Fitzroy River flowed west across the shelf to the north of Northwest Reef, a position on the shelf that is now under approximately 60 m of water. With the rise in sea level during the early Holocene, the mouth of the Fitzroy River retreated across the continental shelf and by the middle Holocene it was landwards of its present location, near Rockhampton. During the last few thousand years under a relatively stable sea level, much of the shallow inner region of Keppel Bay has been infilled and the coast has prograded several kilometres. Palaeochannels in the inner section of Keppel Bay have mostly been infilled with sediment, which mainly comprises muddy sand from the Fitzroy River. In the outer bay and on the shelf further west many relict channels have not been infilled with marine sediment indicating that the area is relatively starved of sediment. Sediments in outer Keppel Bay are dominantly relict fluvial deposits that are well sorted with only a minor mud component. Subaqueous dunes in the outer southeastern section of Keppel Bay and Centre Bank indicate that tidal currents and currents associated with the predominant southeasterly winds, appear to be transporting marine biogenic sediments and relict coarse terrigenous sediments into Keppel Bay.

Accumulation of fine sediment currently occurs in the mouth of the estuary where muddy sand bars have recently formed, and also adjacent to Long Beach in central Keppel Bay. Some accumulation of fines also occurs within palaeochannels in the bay. The thickest accumulations of sediment occurs in the south of the inner bay, with a sediment wedge thinning to the north away from the mouth of the estuary. The distribution of modern sediments in Keppel Bay indicates that muddy sand is deposited in the mouth of the estuary and in the southern section of the bay. The coarser sediment is rapidly reworked by advection to the north and onshore, and accumulates in nearshore, beach and foredune deposits.

Acknowledgements

The Australian Hydrographic Service provided archived bathymetric data that was included in this study. Many thanks to Drs. Jodie Smith and Michelle Spooner for critical reviews; Cameron Buchanan, Bruce Cotton, John Creasey, Fred Kroh, Melissa Fellows and David Holdway for assistance with GIS and acoustic data analysis; Tony Watson, Alex McLachlan, and Christian Thun for assistance with laboratory work; Bob Noble, Peter Verwey, Kirrod Broadhurst, Tony White, Les Hamilton, Iain Parnum, Malcolm Perry, and Kevin Hooper for field assistance. This study was partly funded by the Cooperative Research Centre for Coastal Zone, Estuary and Waterway Management as part of the Coastal Water Habitat Mapping (CWHM) and Fitzroy Agricultural Contaminants (AC) Projects. Fieldwork was conducted with permission from the Great Barrier Reef Marine Park Authority under permit number G04/12080.1. Published with permission of the Chief Executive Officer, Geoscience Australia.

Contents

Introduction

This report presents the results of sedimentological and geomorphological work undertaken as part of the Fitzroy Agricultural Contaminants (AC) Project in the Cooperative Research Centre for Coastal Zone, Estuary and Waterway Management (Coastal CRC). The main objective of this work was to determine the spatial distribution and accumulation history of sediments in Keppel Bay derived from the Fitzroy River.

Keppel Bay in southeastern Queensland is a large, semi-enclosed and relatively shallow coastal embayment adjacent to the mouth of the Fitzroy River (Fig. 1). The geomorphology and distribution of sediment in Keppel Bay is complex due to the influences of sea-level change, relict topography, a geologically diverse catchment, macrotidal hydrodynamic processes, cyclones, highly episodic flood events, submarine sediment transport, and the accumulation of terrestrial, biogenic and relict sediments (Beach Protection Authority, 1979). Therefore, a range of field and analytical approaches were employed in this study to better understand this sub-tropical coastal sedimentary system.

Field surveys investigating the surface and subsurface sediments of Keppel Bay and the Fitzroy River estuary were undertaken in June and September 2004, and additional sediment data were acquired during a number of related surveys (Brooke et al., submitted; Bostock et al., 2007; Radke et al., 2005; Skene et al., 2004). Sidescan and multibeam sonar data were collected in Keppel Bay and the Fitzroy estuary as part of the Coastal CRC's Coastal Water Benthic Habitat Mapping Project, and much of these data have been published in Ryan et al. (2007a).

STUDY DESIGN

The spatial distribution and accumulation history of sediments in Keppel Bay were assessed through:

1) analysis of a suite of sediment grab samples to ascertain the sedimentological and geochemical characteristics of modern sediments;
2) interpretation of 'chirp' acoustic sub-bottom profiles to determine the stratigraphy of the bay; and
3) analysis of sediment vibracores to determine the sedimentological and geochemical characteristics of subsurface facies, including the shallow units observed in sub-bottom profiles.

The results of this work provide a better understanding of sediment transport in the Fitzroy River estuary and Keppel Bay. The distribution of facies and sediment accumulation rates for the Fitzroy estuary and estuarine floodplain are reported in Bostock et al. (2007).

STUDY PARTICIPANTS

This work benefited from the assistance of Bob Noble, Bob Packett and Peter Verwey of Coastal CRC/Queensland Department of Natural Resources, Mines, and Energy (DNRME) in Rockhampton. The data presented in this report were collected during a number of surveys:

Sediment grab samples

Sediment grab samples were collected during various Coastal CRC surveys in Keppel Bay by Colin Tindall (Geoscience Australia, GA), David Ryan (GA), Darren Skene (GA), and Les Hamilton (Defence Science and Technology Organisation, DSTO).

'Chirp' sub-bottom profiles

This survey was undertaken by Darren Skene (GA), Kevin Hooper (James Cook University, JCU), Franz Villagran (GA) and the skipper and crew of the *Rum Rambler*, Kirrod Broadhurst and Kevin Luck.

Vibracores

This survey was run by Darren Skene, David Ryan and Brendan Brooke (GA), assisted by the skipper, Daniel Toy, and crew of the *Pacific Conquest*. In addition, Lynda Radke, Ian Atkinson and Colin Tindall (GA) collected data for the Fitzroy Contaminants Dynamics subproject. Additional sediment cores were also collected for project partners: 5 PVC cores were collected at Sites 1, 2, 3, 6 and 9 for iron speciation analysis within the sediments and sediment biochemistry (Radke et al., 2005); 2 additional vibracores were collected at Site 20: one core for Rhys Leeming, CSIRO Marine (Hobart) for biomarker analyses, and one core for Vicky Vicente-Beckett (Central Queensland University) to measure hydrocarbons within the bay sediments (Webster et al., 2006).

REGIONAL SETTING

Keppel Bay represents the coastal margin of the Fitzroy River basin, the second largest modern sedimentary basin in Australia. The study area lies on the Tropic of Capricorn and is bounded to the north by Great Keppel Island and to the south by Curtis Island (Fig. 1).

The 144,000 km^2 catchment of the Fitzroy River is topographically and geologically diverse - it comprises over 100 different rock types within the Thompson Fold Belt, the New England Fold Belt, the Bowen Basin, the Surat Basin, and several other minor formations (Douglas et al., 2005; Willmott et al., 1984). Land use in the catchment is dominated by agriculture and coal mining. The catchment was extensively vegetated with Brigalow scrub (*Acacia harpophylla*) before several phases of land clearing during the 19th and 20th century.

Climate and oceanography

Due to the Australasian monsoon, the region experiences highly seasonal rainfall and prevailing easterly winds (Fig. 2). Rainfall is predominantly in the summer and temperatures range between a summer maximum of 32°C (in January) and a winter minimum of 9°C (in July). Large-volume flood events in the Fitzroy basin are produced by intense but short-lived rainfall events linked to summer monsoonal or cyclonic depressions. These floods inundate large areas of the floodplain and take considerable time to discharge through the Fitzroy River system into Keppel Bay (Devlin et al., 2001; Kelly and Wong, 1996).

The tides within Keppel Bay are semi-diurnal, and feature a spring tidal range of 5 m (macrotidal), with a neap tidal range of approximately half this (Hekel, 1980). The oceanography along the adjacent continental shelf is dominated by the southward flowing East Australian Current (EAC). Using sea-surface drifters, Woodhead (1970) showed that the EAC is partly deflected into the Capricorn Channel forming a clockwise gyre (Fig. 2). A time-series dataset of NOAA-9 AVHRR satellite imagery has shown that the EAC follows the 200 m contour until it reaches the Capricorn Channel (Kleypas and Burrage, 1994). Annual variation in regional oceanographic conditions result in the EAC either following the slope contour westward along the shelf, or flowing directly south until it hits the shelf break near Fraser Island (Fig. 2). During periods of southward flow, the current tends to bifurcate, producing a southern current that continues along the coast and a northern component that becomes a cyclonic eddy within the Capricorn Channel. Satellite imagery also shows much cooler waters occur along the shelf edge and possibly the result of upwelling events that bring cooler water from depth onto the shelf, coolest in Hervey Bay (Kleypas and Burrage, 1994). This cold upwelling water is considered to be important source of nutrients to the southern GBR and coastal region (Kleypas and Burrage, 1994). The cool, nutrient-rich water extends as far north as Cape Clinton, and is probably transported by wind-driven longshore currents. In addition, cold water jets have been observed at Cape Clinton heading back into the Capricorn Channel (Kleypas and Burrage, 1994).

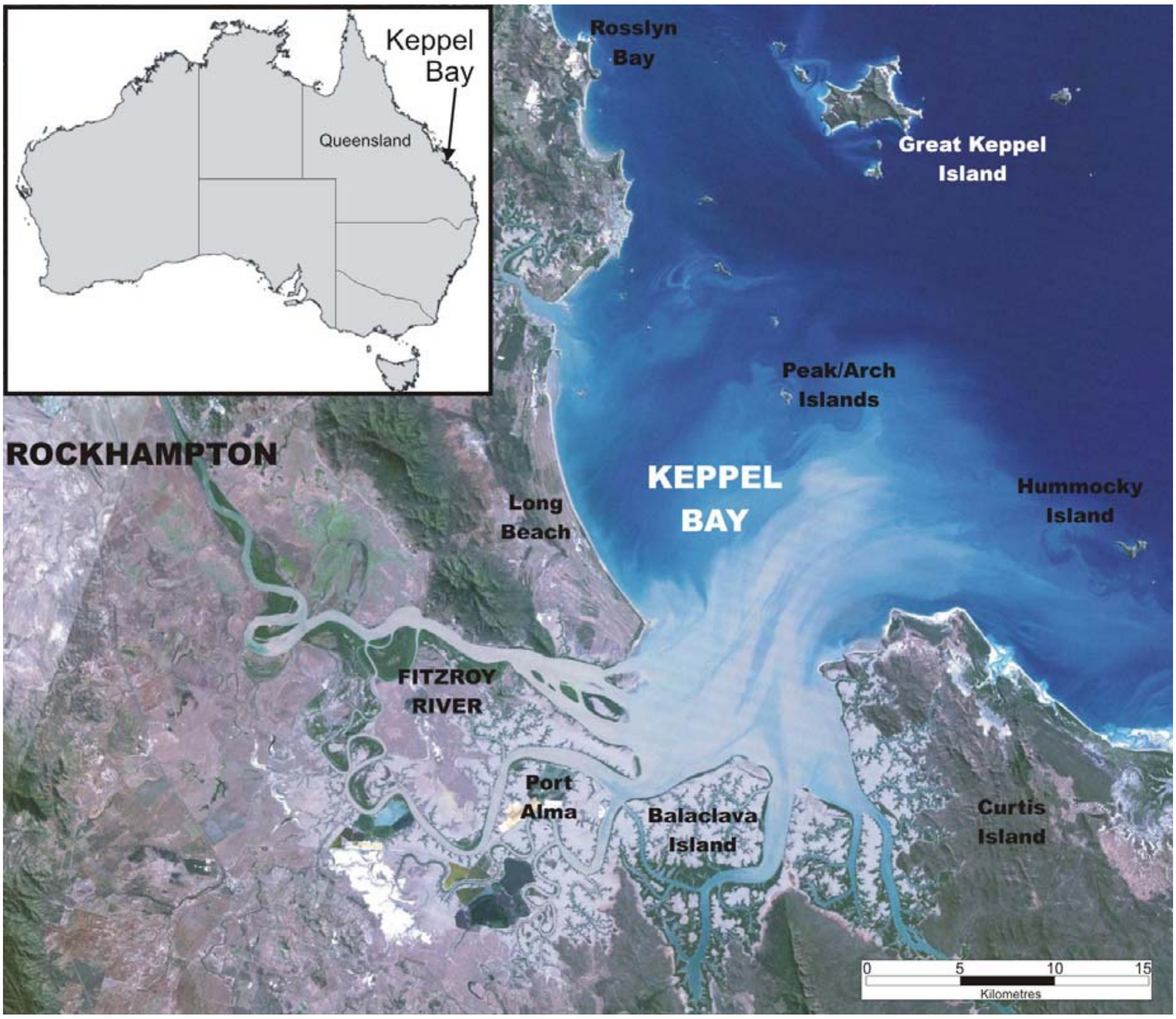


Figure 1: Keppel Bay and the Fitzroy River on the coast of southeast Queensland. The base map is a Landsat ETM+ image, acquired 24/5/2003, Copyright © Commonwealth of Australia, 2003.

The Capricorn Channel and southern Great Barrier Reef

A major survey of the marine geology of the Capricorn Channel and region adjacent to Keppel Bay was undertaken by Marshall (1977), and identified high quartz and feldspar sediments in outer Keppel Bay and to the east of Great Keppel Island. These sediments were classified as terrigenous sands (in the north of Keppel Bay) and mixed marine and terrigenous sands (in the south of Keppel Bay).

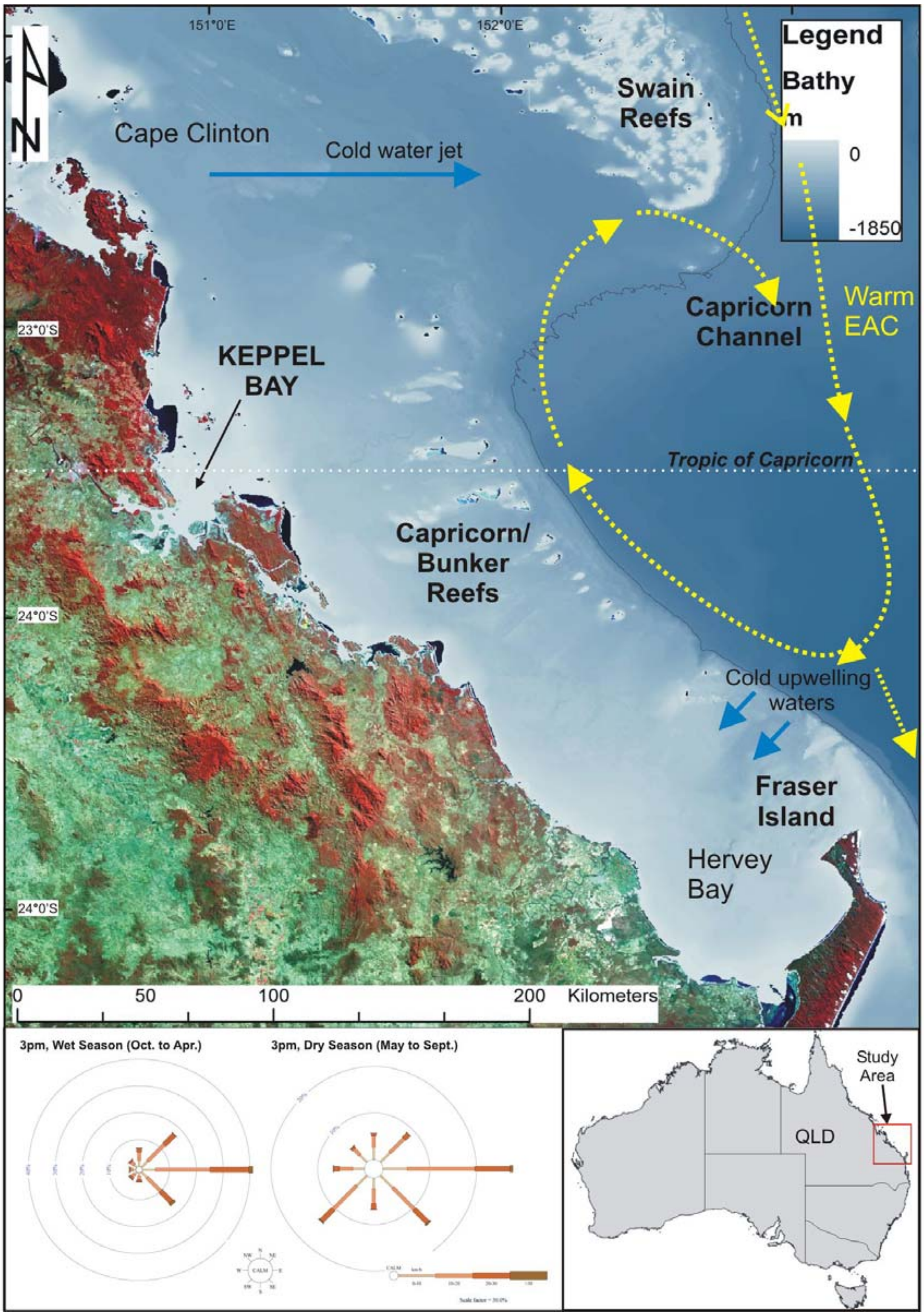


Figure 2: Summary map of bathymetry, water masses and circulation in the study region, with the -120 m isobath indicated (Imagery: Landsat MSS, Copyright © Commonwealth of Australia). The unbroken black line indicates the 120m isobath. Wind frequency analysis are provided for Rockhampton, 1939-2004, for the wet season (October to April, 3pm) and the dry season (May to September, 3pm; Bureau of Meteorology, June 2005). Bathymetry after Webster and Petkovic (2005).

Although the seabed of the Capricorn Channel is mainly flat, both symmetrical and asymmetrical sediment dunes comprising 90% quartz sand occur at a water depth of 60-80 m. These features were probably formed by tidal currents during a period of lower sea level (Marshall, 1977). Evidence of pre-Holocene shorelines with mangrove rootlets, a series of drowned reefal shoals and banks extending northwest from the Capricorn Group of reefs, and ooids (16,800 cal. yrs BP) were also reported from depths of 100-120 m (Marshall and Davies, 1975; Yokoyama et al., 2006). Maxwell (1968) revealed clearly defined drainage patterns around Hervey Bay and north of Fraser Island with channels cut to a base level of 64 m, corresponding to a Pleistocene low sea-level. These are probably the palaeochannels of the Mary, Burrum and Elliott Rivers (Marshall, 1977). Marshall (1977) also suggested that during the glacial lowstand, the Fitzroy River meandered northeast across the shelf before being diverted down the Capricorn Channel.

Geomorphology and bathymetry of Keppel Bay

Keppel Bay is a semi-protected oceanic embayment located south of the widest part of the Queensland continental shelf (Marshall, 1977; Searle, 1978). The Capricorn coastal area bordering Keppel Bay is a drowned landscape, with prominent rocky headlands that divide low-lying stretches of beach dunes and strandplains. A previous geological investigation of Keppel Bay by Searle (1978) using a 'boomer' seismic profiling system suggests that significant quantities of sediment have accumulated in Keppel Bay since the late Tertiary. Evidence of the sub-aerial erosion of the Pleistocene surface was also noted. In addition, a relatively thick Holocene sediment wedge has been deposited adjacent to the Fitzroy River estuary, which becomes thinner to the north. Searle (1977) suggested that fine sediments originating from the Fitzroy River may be advected as far north as Corio Bay (20 km north of Yeppoon).

The southern portion of the study area is bordered by the bedrock hills of Curtis Island and expansive low gradient salt flats, mangroves, and tidal creek networks in the Port Alma region (Fig. 1), which form the Casuarina Basin (Murray, 1980). Significant brine deposits occur below the extensive mudflats and supratidal lowlands near Port Alma, Casuarina Island, and Balaclava Island (Laycock, 1980; Flood and Walbran, 1986). Numerous smaller rocky islands exist within the bay, most notably Humpy, Pelican, Divided and Wedge Islands in the north, and Girt, Quartz, Arch, Peak and Hummocky Islands in the south and south-east. Keppel Bay is bordered to the west by Long Beach, an elongate beach and beach-ridge plain that extends northwards toward a series of rocky headlands.

Methods

FIELD SURVEY

A full description of the field surveys conducted in Keppel Bay is given in Skene et al. (2004), and Radke et al. (2005). The first involved a 'chirp' (swept frequency) acoustic sub-bottom profiling survey in June 2004. The second was a surface sediment sampling and vibracoring programme conducted in August-September 2004, and the third was a sidescan and multibeam sonar survey and associated sampling carried out in September 2004 (Ryan et al., 2007a). Sediment grab samples were acquired throughout Keppel Bay during all Coastal CRC surveys (water column and sediment surveys) using a shipeck grab sampler (Fig. 3). Several box-cores were acquired during the vibracoring survey. Additionally, seabed sediment samples were collected using a small Van-Veen grab from the CSIRO 4.5 m trailer-boat, and using a Hydro-Bios grab (owned by DSTO) during the multibeam sonar survey.

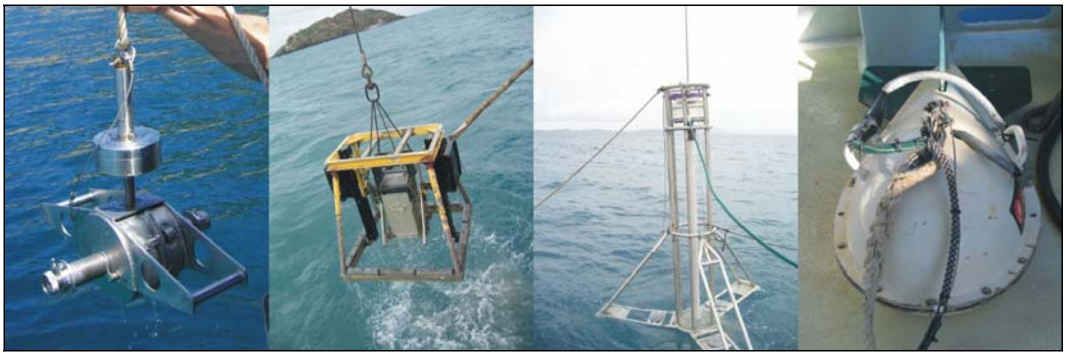


Figure 3: Shipeck sediment grab sampler, box-corer, vibracorer (3 m configuration), the James Cook University Datasonics "Chirp" sub-bottom profiler towfish (Datasonics, 1999).

Twenty vibracore samples were collected in Keppel Bay from the vessel *Pacific Conquest*, during August-September 2004, using a shallow-water vibracoring system (Fig. 3, Appendix 5). Cores were collected in water depths ranging from 6.0 m to 23.5 m and most cores penetrated the full 3 m unless a harder layer was encountered (Skene et al., 2004). Over the same sample sites, a low-powered Datasonics CAP-6600 Chirp II acoustic profiling system (Datasonics, 1999, Fig. 3) was used to collect 275 line kilometres (148 nautical miles) of sub-bottom profiles (Skene et al., 2004). Figure 4 shows the locations of sediment grab samples, vibracore sites and sub-bottom profiles in Keppel Bay.

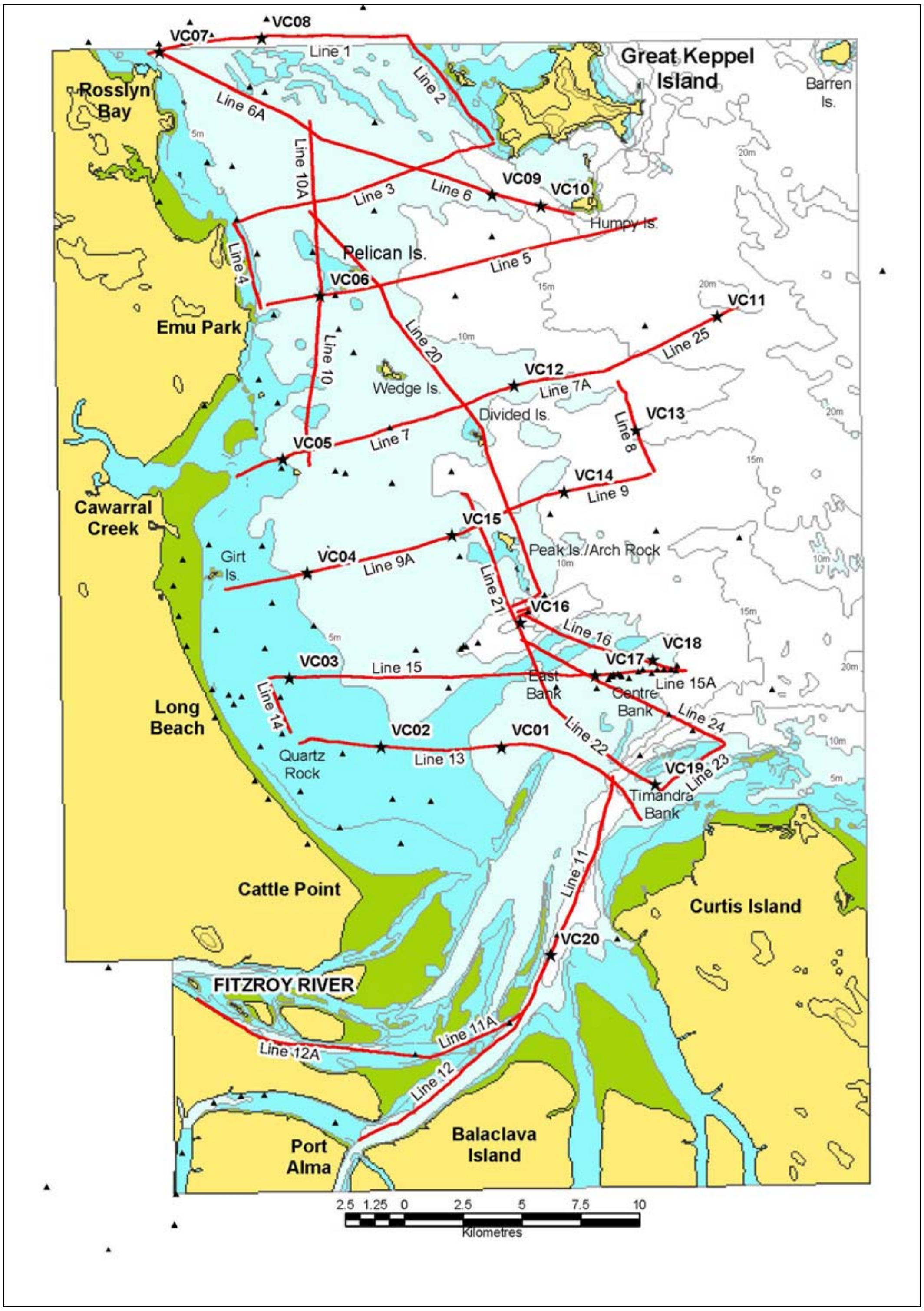


Figure 4: Location of sediment and acoustic samples in Keppel Bay. Stars indicate vibracore sites, triangles indicate grab sample sites, and red lines indicate sub-bottom profiles. Bathymetric contours simplified from Australian Hydrographic Service (2000).

SEDIMENT ANALYSIS

Sediment grab and core sub-samples were analysed for sediment grain-size, proportion of CaCO3, and granular composition (Appendices 1, 2 and 3). Grain size analyses was conducted using standard mesh-sieves, indicating the mud:sand:gravel ratio, and also with a Malvern laser grain size analyser, providing volume-percentage grainsize data. CaCO3 proportions were determined using the CaCO3 'bomb' gas evolution method (Muller and Gastner, 1971). Sediment grainsize data were plotted and converted into ratios of sand:silt:clay using Gradistat software (Blott and Pye, 2001), and cluster analyses was performed using Primer 5 software (Clarke and Gorley, 2001). Selected sediment grab samples and core sub-samples were also analysed for mineralogy using XRD, major oxides and trace elements using XRF/ICP-MS. Total organic carbon (TOC) was determined on finely ground sediments using a LECO combustion furnace (RC412). The samples (1.0 g) were treated with 1:1 HCl to digest the carbonates and were dried at 40oC prior to their combustion in a LECO furnace.

The vibracores were split longitudinally, logged visually (involving estimates of colour, texture and composition of the various lithologic units and notes on any major stratigraphic changes) and photographed prior to sampling. The vibracores were logged in *WinLoG v.4*. Subsamples were taken from different facies within each of the cores and analysed for grainsize and carbonate and the >63 µm fraction described under a binocular microscope. Three of the vibracores (VC05, VC13 and VC20) were sampled in detail for grainsize, carbonate content, organic carbon (TOC), porosity and wet bulk density.

Core VC20, collected in a PVC tube, was analysed using a GEOTEK Multi-Sensor Core Logger (MSCL) to identify the downcore physical properties of the sediment (Appendix 10). The MSCL is an automated non-destructive, high resolution (0.5 cm) system that measures P-wave travel time and amplitude, gamma ray attenuation, and magnetic susceptibility. Cores collected using aluminium barrels were not analysed with the MSCL because of signal interference produced by metals in the core barrel.

GEOCHRONOLOGY

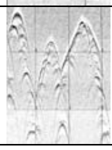
Sediment dating was used to calculate accumulation rates and provide a temporal framework for the stratigraphy of Keppel Bay. The three vibracores that were sampled in detail (VC05, VC13 and VC20) were also sampled for ^{210}Pb, ^{137}Cs and Optically Stimulated Luminescence (OSL) dating. Thirteen samples were taken for ^{210}Pb and ^{137}Cs measurements by gamma spectrometry from each core. These samples were closely spaced at the top of the core in which there may be a record of deposition for the historical period, and further apart at depth. Four OSL samples were also taken from each core, one sample from within the top 1 m of the core to overlap with the ^{210}Pb samples.

SPATIAL ANALYSIS AND DATA PROCESSING

Mapping of sample locations and data interpolation was performed using ESRI™ *ArcGIS 8.3* software. Sub-bottom profile records were acquired as 16-bit SEG-Y format data during the survey. These data were converted to 32-bit floating point SEG-Y format, and imported into Chesapeake Technologies™ *SonarWeb Pro* software for post-processing, interpretation, and report production.

The seabed echo-character in the sub-bottom profiles was interpreted using a modified visual classification based on the scheme developed by Damuth (1975, 1980). The classification used simple echo characteristics of the seafloor to identify three main categories, based on parameters that include the clarity and continuity of surficial and sub-bottom echoes, which show a qualitative relationship with seafloor morphology (Damuth, 1980; Davis et al., 2002). These include distinct echoes, prolonged indistinct echoes, and hyperbolic indistinct echoes (Table 1). Furthermore, seabed geomorphic characteristics such as asymmetric sediment dunes, channels (both modern and infilled), rocky reefs, and sand bars were identified visually in the sub-bottom profiles.

Table 1: Description and examples of echo character types (after Damuth, 1975, 1980).

CLASS	SUB-CLASS	TYPE	EXAMPLE	DESCRIPTION
Distinct		IA		Distinct continuous with no sub-bottom reflectors
		IB		Distinct continuous with numerous parallel sub-bottom reflectors
		IC		Distinct continuous with non-conformable sub-bottom reflectors
Indistinct	Prolonged	IIA		Semi-prolonged with intermittent parallel sub-bottom reflectors
		IIB		Prolonged with no sub-bottom reflectors
	Hyperbolae (not pres ent in chirp data)	IIIA-F		Hyperbolae with varying vertex elevation

The bottom returns of all available survey lines across Keppel Bay were examined to develop a classification system specific to the area. Although qualitative, this method has been effectively used to classify both deep and shallow-water sediments in numerous studies (e.g. Damuth, 1975, Damuth, 1980, Blum and Okamura, 1992, Whitmore and Belton, 1997, Rollet *et al*., 2001). These classes were further sub-divided based on presence or absence of sub-bottom reflectors.

Sub-surface characteristics of Keppel Bay were also identified in the sub-bottom profiles, including parallel and sloping clinoforms, infilled and semi-infilled channels, and antecedent or ravinement surfaces. These features were mapped and their characteristics identified using the interpretation function in *SonarWeb Pro*. Sub-surface characteristics were also related to sediment vibracores where possible, however, poor acoustic penetration into the seabed prevented this in some areas.

Results

The benthic environments of Keppel Bay are initially interpreted in terms of bathymetry (Fig. 5), surficial grainsize and geochemical properties using cluster analyses, ternary diagrams, and spatial interpolation techniques (Figs. 6-10; Table 2). Sub-bottom information, derived from the chirp sub-bottom profiles is then described for both surficial echo character (Table 3; Fig. 11) and subsurface geomorphology (Table 4, Figs. 12-16). Detailed analyses of sediment cores and inferred sub-surface stratigraphic cross-sections are provided to place the Keppel Bay deposits in a Late Quaternary evolutionary context (Figs. 17 to 25, Table 5). A summary of sediment facies in Keppel Bay is also provided (Figs. 26, 27).

BATHYMETRY

The bathymetry of Keppel Bay, derived from the relevant Australian hydrographic chart (Australian Hydrographic Service, 2000), is shown in Figure 4. All depths are corrected to mean low water. Keppel Bay is shallow, with the 20 m isobath lying 25 km offshore from Long Beach (Fig. 4), and typically has a low gradient, with an average slope of 0.05° from Long Beach to Keppel Island. The seabed morphology of Keppel Bay is extremely complex, particularly in the south (Fig. 4). There are numerous deep channel features punctuated by shoals such as Timandra Bank, Centre Bank, and East Bank. A prominent line of bedrock reefs and islands crop out through the centre of Keppel Bay, notably Peak/Arch, Divided, Wedge, and Pelican Islands (Fig. 4). Large-scale longitudinal subaqueous dunes are apparent between Rosslyn Bay and Great Keppel Island.

The inner continental shelf adjacent to Keppel Bay is relatively broad and shallow, as the 120 m isobath lies over 100 km east of the Fitzroy River mouth (Fig. 2). The shelf inboard of the Capricorn/Bunker reefs is also relatively smooth (Fig. 5), however a bathymetric feature corresponding to a major palaeochannel or relict incised valley of the Fitzroy River can be seen offshore from Keppel Bay (Fig. 5). The channel appears to run in a north-easterly direction (between North West Reef and Douglas Shoal) and is of comparable width and sinuosity to the modern day Fitzroy River. The sinuosity ratio of the channel is 1.56, consistent with a stable meandering river system which typically occurs on slopes of <2° (Rosgen, 1994). Cut-off loops (or billabong lakes) are also apparent. The geomorphology of this area of the shelf is investigated in more detail by Ryan et al. (2007b).

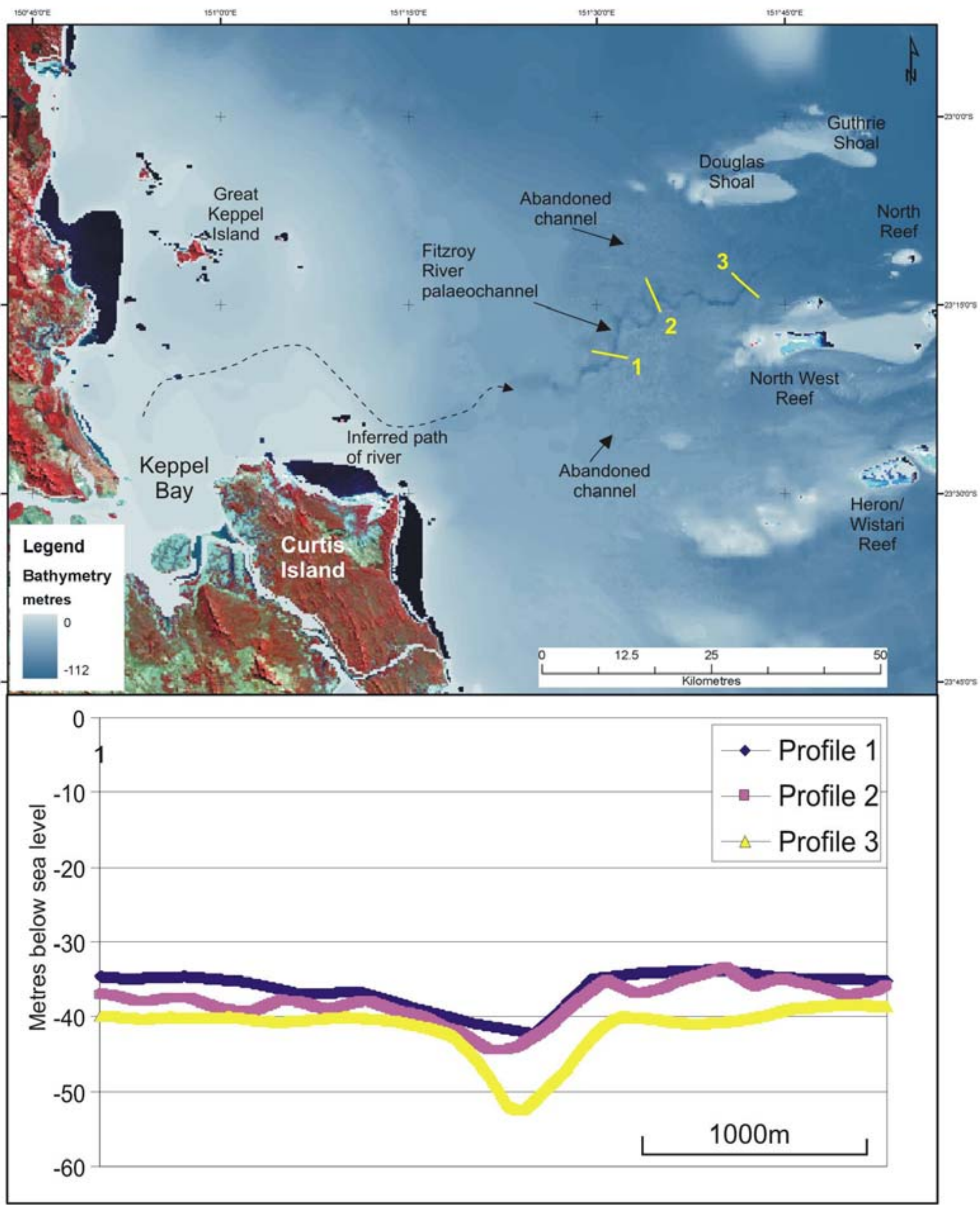


Figure 5: Bathymetry of the continental shelf adjacent to Keppel Bay showing a palaeochannel or incised valley formed by the Fitzroy River during low sea level. Three bathymetric profiles from across the palaeochannel are included. Bathymetry ©Geoscience Australia, 2005.

SURFICIAL SEDIMENT TYPES

Cluster analysis

An initial classification of the 141 surface sediment samples from Keppel Bay was based on laser grainsize data. A normalised Euclidean cluster analysis was performed on the 33 grainsize cumulative frequency distribution 'bins' (ranging from 0.06 µm to 2000 µm, Fig. 6). The grainsize data are provided in Appendix 2.

A visual inspection of the cluster analysis dendrogram suggests that the data may be divided into four major groupings that have a Euclidean dissimilarity value of >6 (Fig. 6). A fifth group of data outliers was also evident. Samples from the five grainsize groups were indexed and their characteristics and spatial distributions were assessed. Figure 7 provides sediment grainsize distributions for each sample in the five cluster groups and corresponding sand:silt:clay ternary diagrams.

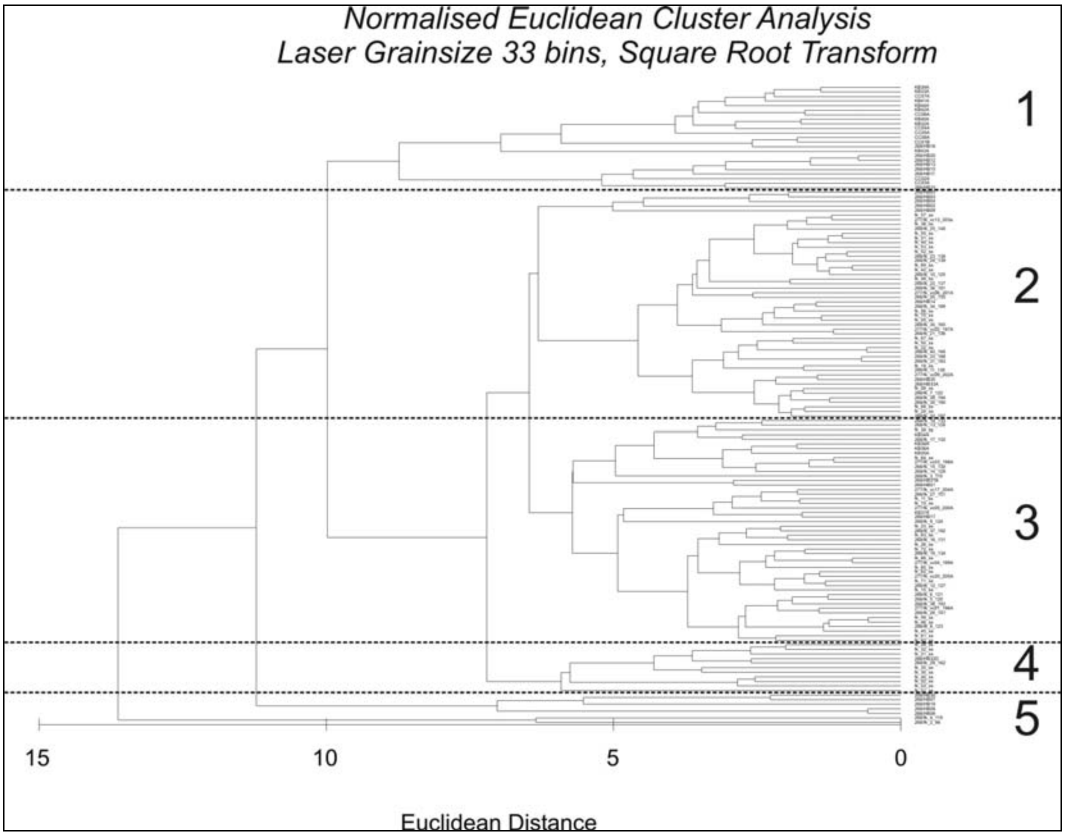


Figure 6: Normalised Euclidean cluster analysis for 141 sediment samples from Keppel Bay, based upon 33 sediment grainsize fractions. Sample names are provided to the right of the dendrogram. Data has been divided into five major groupings, delineated by dashed lines, based on a minimum Euclidean dissimilarity value of >6.

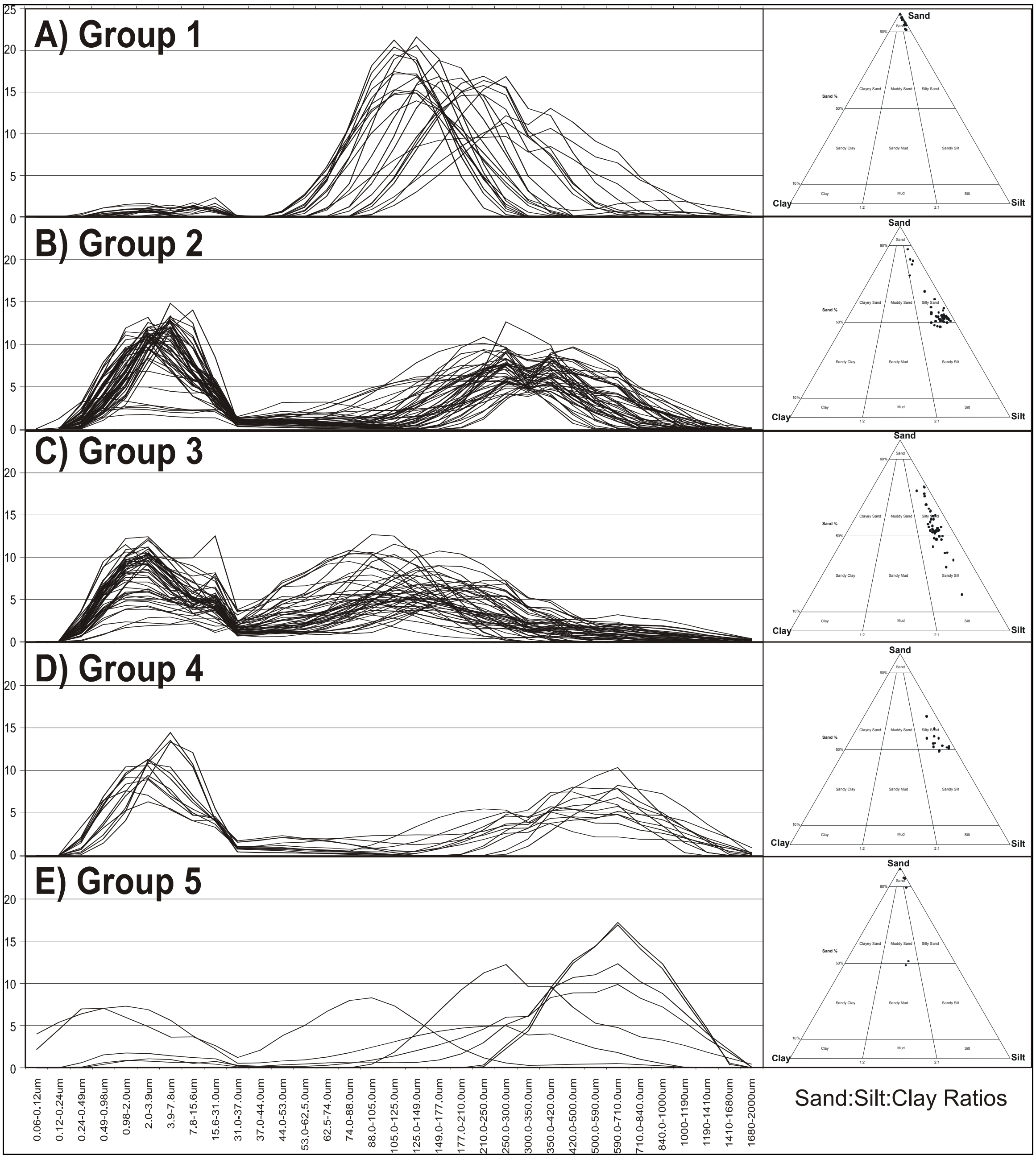


Figure 7: Frequency distribution curves of sediment grainsize, and corresponding ternary diagrams illustrating the ratios of sand:silt:clay, for each of the five groups determined by cluster analysis (Fig. 6). Results derived from Gradistat software (Blott and Pye, 2001).

In terms of grainsize distribution, cluster group 1 (Fig. 7A) is mainly unimodal and leptokurtic and comprises a moderately well-sorted fine sand. Group 2 (Fig. 7B) is strongly bimodal and comprises a very poorly sorted fine sand, with peaks centred on very fine silt (3.9-7.8 µm) and medium sand (300-350 µm). Group 3 (Fig. 7C) is weakly bimodal and fine-skewed, comprising a very poorly sorted fine silt centred on clay (0.98-3.9 µm) and very fine to fine sand (62.5 – 177 µm). Cluster group 4 (Fig. 7D) is strongly bimodal and comprises a poorly sorted fine sand, with peaks centred on very fine silt (3.9-7.8 µm) and medium sand (300-350 µm). Cluster group 5 (Fig. 7E) is polymodal, coarse-skewed, and very poorly sorted. Figure 8 shows the spatial distribution of sediment cluster groups in Keppel Bay (Fig. 6).

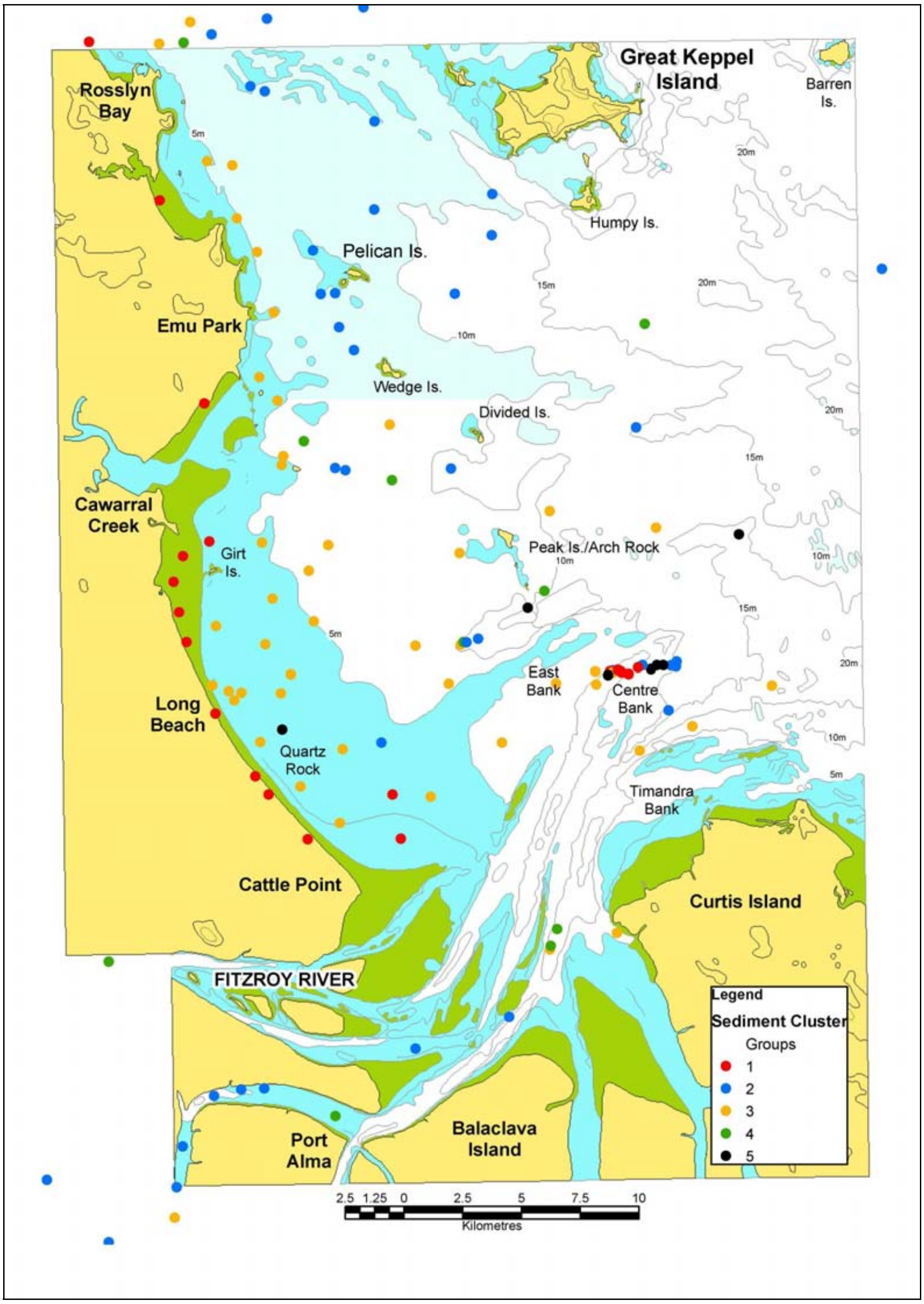


Figure 8: Distribution of the five cluster groups determined by cluster analysis (Fig. 6) in Keppel Bay. Bathymetric contours simplified from Australian Hydrographic Service (2000).

Broad trends in the distribution of sediment types can be seen in Figure 8. Samples belonging to cluster group 1 occur mainly in near sub-littoral environments (e.g. along Long Beach). Cluster group 2 samples mainly occur offshore, and also to the north of Keppel Bay, with some occurrences within the channel system of the estuary (e.g. Casuarina Creek). Samples belonging to cluster group 3 are restricted in distribution to inner and central Keppel Bay. Cluster group 4 occurs mainly in outer and northern Keppel Bay. Outliers (group 5) show no obvious distribution pattern, and are believed to be samples with high bioclastic fragments and clasts. Some of these bioclasts are produced *in-situ* and therefore do not fit into a typical clastic sedimentary scheme.

Distribution of surface sediments

The spatial distribution of sedimentological properties in surface samples is shown in Figure 9. The highest concentrations of mud occur close to the Fitzroy River mouth and Curtis Island (Fig. 9A). Grab samples, however, were not collected on the shallow sandbars but visual inspection suggests that these comprise coarse sediment. There are moderate to high concentrations of mud in the nearshore zone, out from the middle of Long Beach, and in the inner central area of Keppel Bay (Fig. 9A). Gravel (generally bioclastic material) appear to be highest in the outer bay (Fig. 9B), and also occur on sandbars and adjacent to Curtis Island. Sediments are mostly well-sorted adjacent to Long Beach (Fig. 9C) with the exception of the muddy area mentioned above. Well-sorted sediments also occur in the southernmost portion of outer Keppel Bay. In terms of sediment skewness, all samples adjacent to the coastline appear to be coarse skewed, as does material in the southernmost portion of outer Keppel Bay (Fig. 9D).

Figure 10 provides the spatial distributions of important geochemical parameters identified by Radke et al. (2005), including percentage $CaCO_3$ and feldspar, Al_2O_3:K_2O ratio (high ratios indicate greater weathering or an alternative source rock), and concentration of organic carbon (mmol/g). Figure 10A displays the distribution of $CaCO_3$ in the bay which appears to co-vary with percentage gravel (Fig. 9B), and is indicative of bioclastic material. Feldspars appear in highest concentrations within several kilometres of Long Beach (Fig. 10B) and are particularly low in the southernmost portion of outer Keppel Bay. The Al_2O_3:K_2O (or weathering) ratio (Fig. 10C) is low in south-eastern Keppel Bay and grades to high towards the middle of Long Beach and the Fitzroy River mouth. The proportion of organic carbon (Fig. 10D) appears to co-vary with percentage mud (Fig. 9A), with high concentrations out from the middle of Long Beach and in the Fitzroy River mouth.

Table 2 summarises the dominant sedimentological and geochemical parameters for each grainsize cluster group.

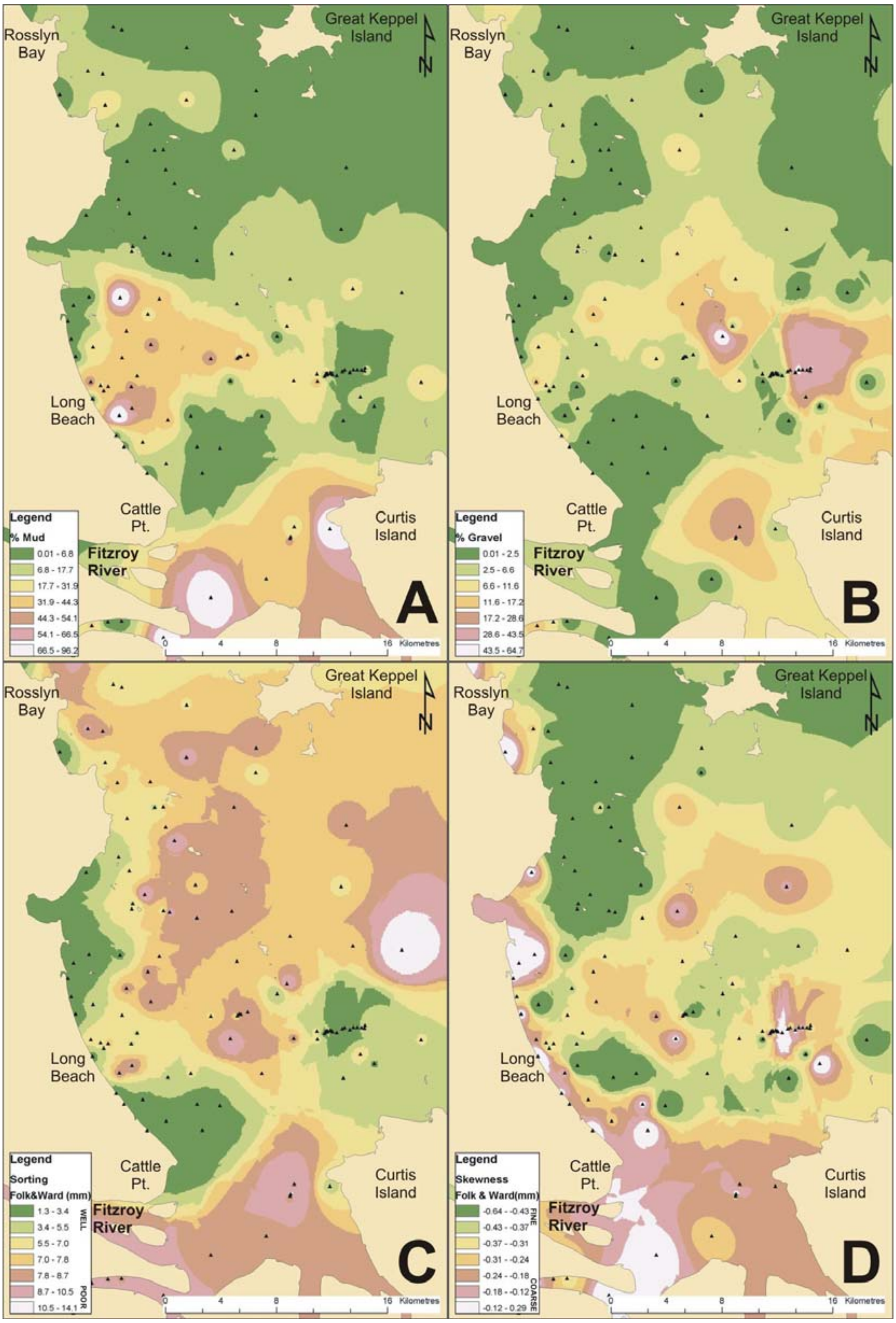


Figure 9: Maps of surface sediment properties in Keppel Bay. A) % mud, B) % gravel, C) sorting coefficient (green is well sorted, white poorly sorted), and D) sediment skewness (green is fine skewed, white is coarse skewed). See Appendix 1 for the Folk & Ward (1957) definitions of sorting and skewness.

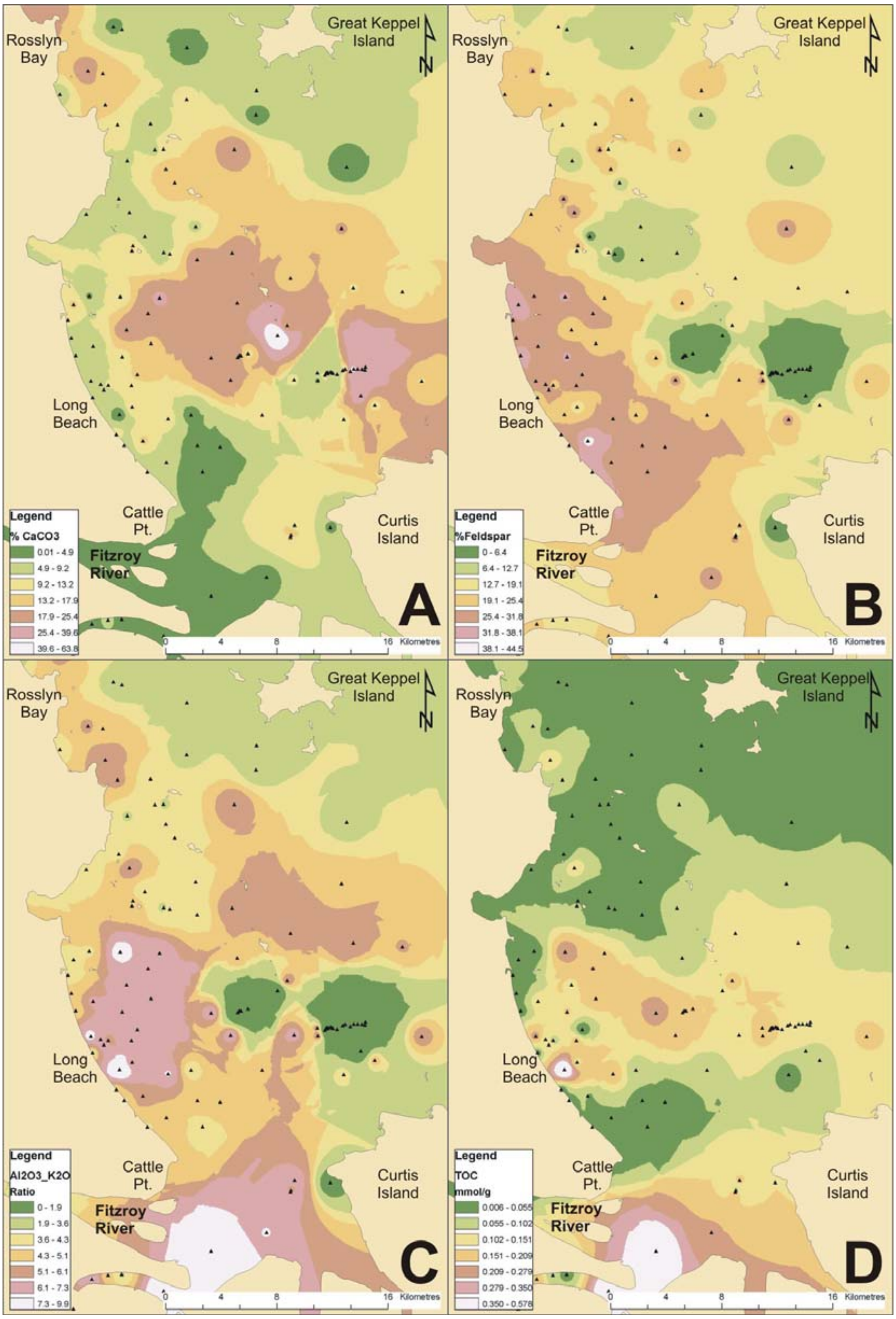


Figure 10: Maps of surface sediment geochemical properties in Keppel Bay. A) % $CaCO_3$, B) % feldspar, C) Al_2O_3:K_2O (high ratio suggests greater degree of weathering), and concentration of organic carbon (mmol/g).

Table 2: Mean and standard deviation for sedimentological characteristics of the five groups determined by cluster analysis (Fig. 6) in Keppel Bay. Sediment descriptions after Folk and Ward (1957).

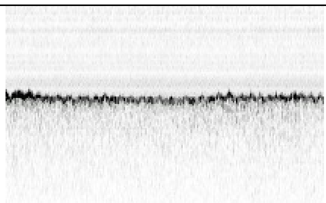
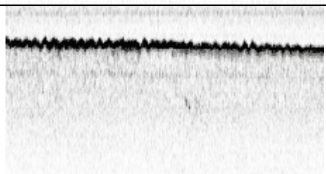
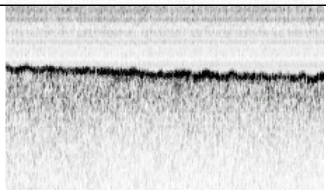
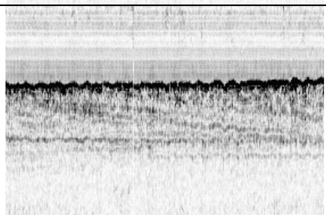
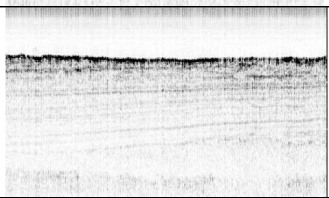
CLUSTER GROUP (FIG. 6)	%MUD	%GRAVEL	SORTING (MM)	% $CACO_3$	AL_2O_3 :K_20	% TOC	% FELD-SPAR	DESCRIPTION	DISTRIBUTION IN KEPPEL BAY
1	1.70 ±1.74	1.62 ±2.60	1.65 ±0.20	7.95 ±4.75	3.97 ±0.52	0.02 ±0.01	25.98 ±8.44	Mostly unimodal, moderately well sorted fine sand.	Near-littoral, inshore
2	11.28 ±18.87	6.30 ±10.95	7.26 ±1.45	10.70 ±9.55	4.36 ±1.76	0.08 ±0.11	16.16 ±6.95	Strongly bimodal, very poorly sorted fine sand.	Offshore and northern Keppel Bay
3	32.09 ±27.72	4.39 ±4.33	6.38 ±1.67	11.52 ±6.77	6.27 ±1.54	0.15 ±0.13	25.16 ±7.88	Weakly Bimodal, very poorly sorted coarse silt.	Central to inner Keppel Bay
4	14.13 ±22.29	7.98 ±11.57	9.50 ±1.15	11.58 ±10.79	4.93 ±1.93	0.09 ±0.14	12.02 ±4.87	Bi-Tri-modal, very poorly sorted fine sand.	Narrow band, central Keppel Bay
5	10.44 ±19.28	27.88 ±27.70	4.80 ±4.84	30.80 ±21.24	6.01 ±1.15	0.11 ±0.03	15.50 ±1.13	Polymodal, very poorly sorted sand-sandy mud.	Various sites with high bioclastic component.

'CHIRP' SUB-BOTTOM PROFILING

Echo character classification of seabed geomorphology

A classification of the sub-bottom profiles acquired in Keppel Bay is presented in Table 3. For each of the five echo character classes identified, example sub-bottom profiles are provided as well as inferences about sediment type and the relationship of this scheme to the original Damuth classification (Table 1). The five classes reflect differences in the echo character, which is largely controlled by the proportion of mud and degree of bedding in the deposits (Table 3), and the surficial geomorphology of the substrate of Keppel Bay. Both distinct and indistinct reflectors are present however hyperbolic reflectors are not evident in the chirp data. The distribution of the five acoustic classes in Keppel Bay is shown in Figure 11.

Table 3: Echo character classification scheme for Keppel Bay, modified from Damuth (1975, 1980).

ECHO CHARACTER	EXAMPLE	DAMUTH CLASSIFICATION (TABLE 1)	INTERPRETATION (FIG. 11 SHOWS THE LOCATION OF THE LINES)
1) Distinct to semi-prolonged with no sub-bottom reflectors		IA, IIB	No penetration, hard-packed sand (e.g. Line 6A).
2) Distinct with single parallel sub-bottom reflector		IB	Shallow single reflector 1-4m depth, fine sandy muds (e.g. Line 5).
3) Semi-prolonged with intermittent sub-bottom reflectors		IIA	Indistinct shallow reflectors, muddy sands (e.g. Line 3).
4) Distinct with non-conformable sub-bottom reflectors		IC	Prograding angled bedding, muddy sands to sandy muds (e.g. Line 24).
5) Semi-prolonged with numerous parallel sub-bottom reflectors		IIA-IB	Thick, well bedded, low density, muds (e.g. Line 11).

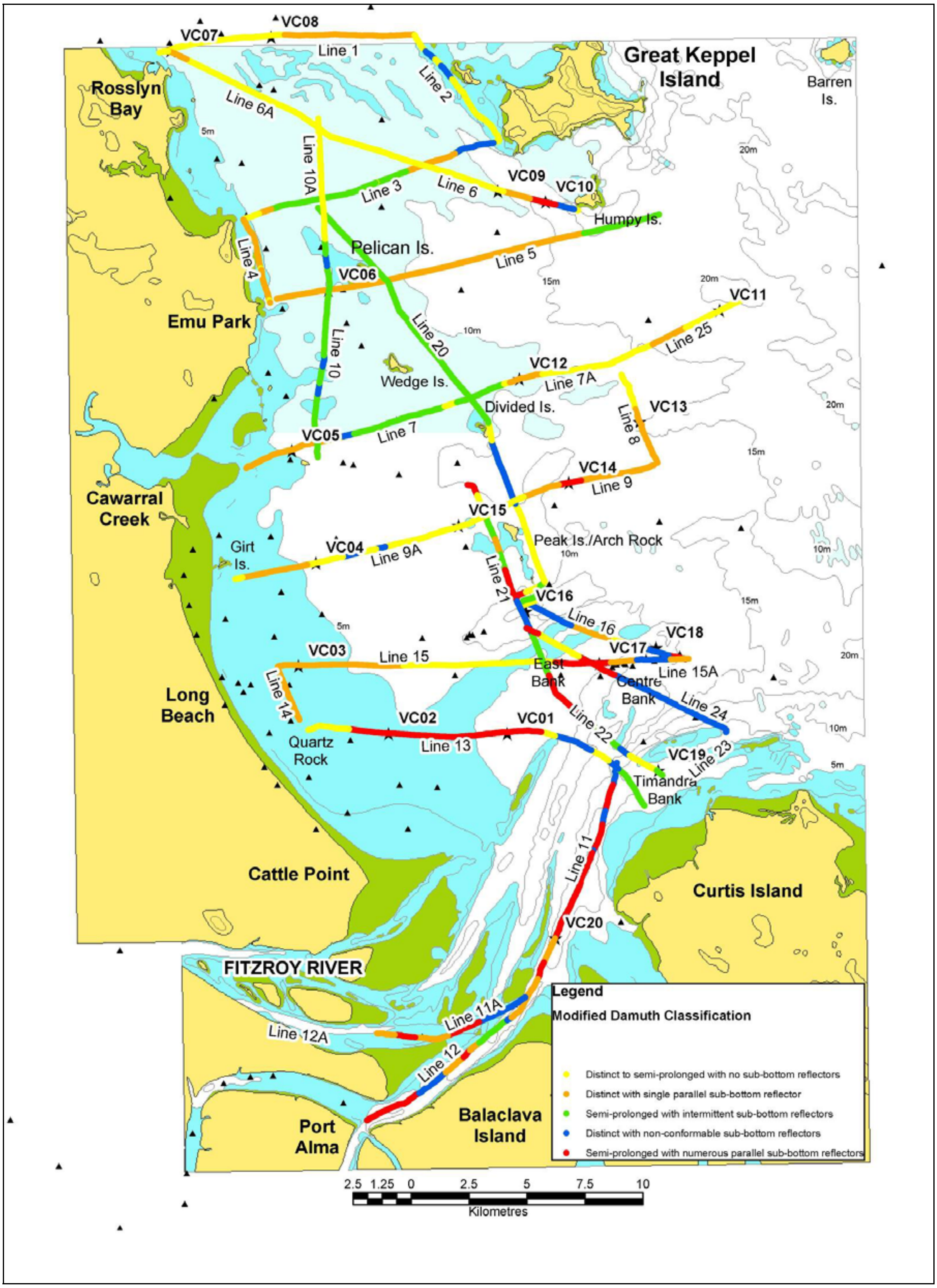


Figure 11: Distribution of echo character 5 acoustic classes in Keppel Bay, based on classes described in Table 3. Bathymetric contours simplified from Australian Hydrographic Service (2000).

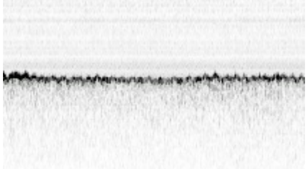
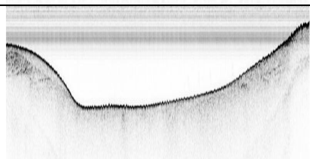
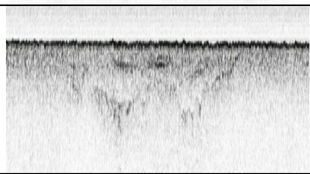
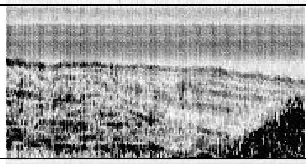
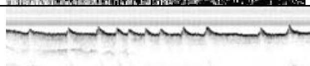
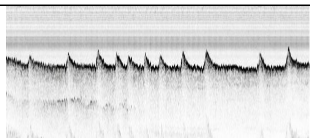
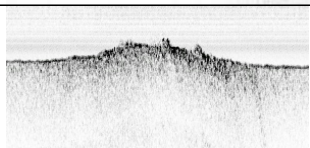
Distinct patterns in the distribution of acoustic classes are apparent in Keppel Bay (Fig. 11). The north and outer areas of the bay and nearshore adjacent to Long Beach exhibit distinct to semi-prolonged echograms with either no sub-bottom reflectors (e.g. hard packed sand; Table 3) or a single sub-bottom reflector. The presence of semi-prolonged echograms with intermittent sub-bottom reflectors also suggests that the sediments are predominantly sand, however, the intermittent nature of the sub-bottom reflectors may also be due to poor data quality. Southern Keppel Bay (south of Peak Island and west of Quartz Rock; Fig. 11) tends to feature echograms that are distinct to semi-prolonged with numerous parallel or non-conformable sub-bottom reflectors (Table 3). These echograms suggest the presence of primarily muddy sediments that can be better penetrated by the acoustic signal.

In general, northern and outer Keppel Bay are characterised by shallow or no sub-surface reflectors, whereas the southern portion of Keppel Bay is highly heterogenous and comprises thick well-bedded deposits. There are, however, some inconsistencies in interpretation between some of the track lines (Fig. 11). These anomalies are likely due to interference generated in the return signal by waves and changes that were made along-track in equipment settings (e.g. acoustic transmission power and gain).

Sub-surface geomorphology

The sub-bottom profiles also provide important information about the geomorphology and stratigraphic architecture of Keppel Bay. These features were determined visually based on the classification scheme presented in Table 4, and their distribution in the bay is shown in Figure 12. The north of Keppel Bay is predominantly featureless, however some large subaqueous dunes were imaged between Great Keppel Island and Rosslyn Bay (Fig. 12). Small infilled channels occur in numerous locations, particularly below the relatively planar substrate between Long Beach and the line of islands that lie across the centre of the bay (Pelican, Divided, Peak and Arch islands). The seabed of the southern area of Keppel Bay is geomorphically complex, and is dominated by extant channel features and sand banks. Subaqueous dunes are a major feature of Centre Bank, while much smaller-scale bedforms also occur within some of the channels. Fluid muds or estuarine sediments are only indicated in the sub-bottom profiles in the vicinity of Port Alma, within the main channels of the Fitzroy River estuary. Detailed examples of selected sub-bottom profiles from Keppel Bay are provided in Figures 13-16 and indicate a range of prominent sub-surface features.

Table 4: Geomorphic classification of sub-bottom profiles for Keppel Bay.

GEOMORPHIC FEATURE	EXAMPLE	DESCRIPTION
1) Gradient < 0.05		Topographically flat with no notable geomorphic features (Line 1).
2) Channel, slope		Modern channel features and associated slopes (Line 21).
3) Channel, infilled		Relict channel features that have been wholly or partially infilled with sediments (Line 15).
4) Fluid muds		Very low density (high water content) estuarine muds associated with large tidal channels (Line 12).
5) Small asymmetric dunes		Low amplitude (<1m) subaqueous sediment dunes (Line 11).
6) Large asymmetric dunes		High amplitude (3-4m) subaqueous sediment dunes (Line 15A).
7) Sand Bank		Bathymetrically high areas with poor acoustic penetration (Line 13).
8) Rock Outcrop		Highly reflective substrate with no acoustic penetration, associated with rocky islands (Line 1).

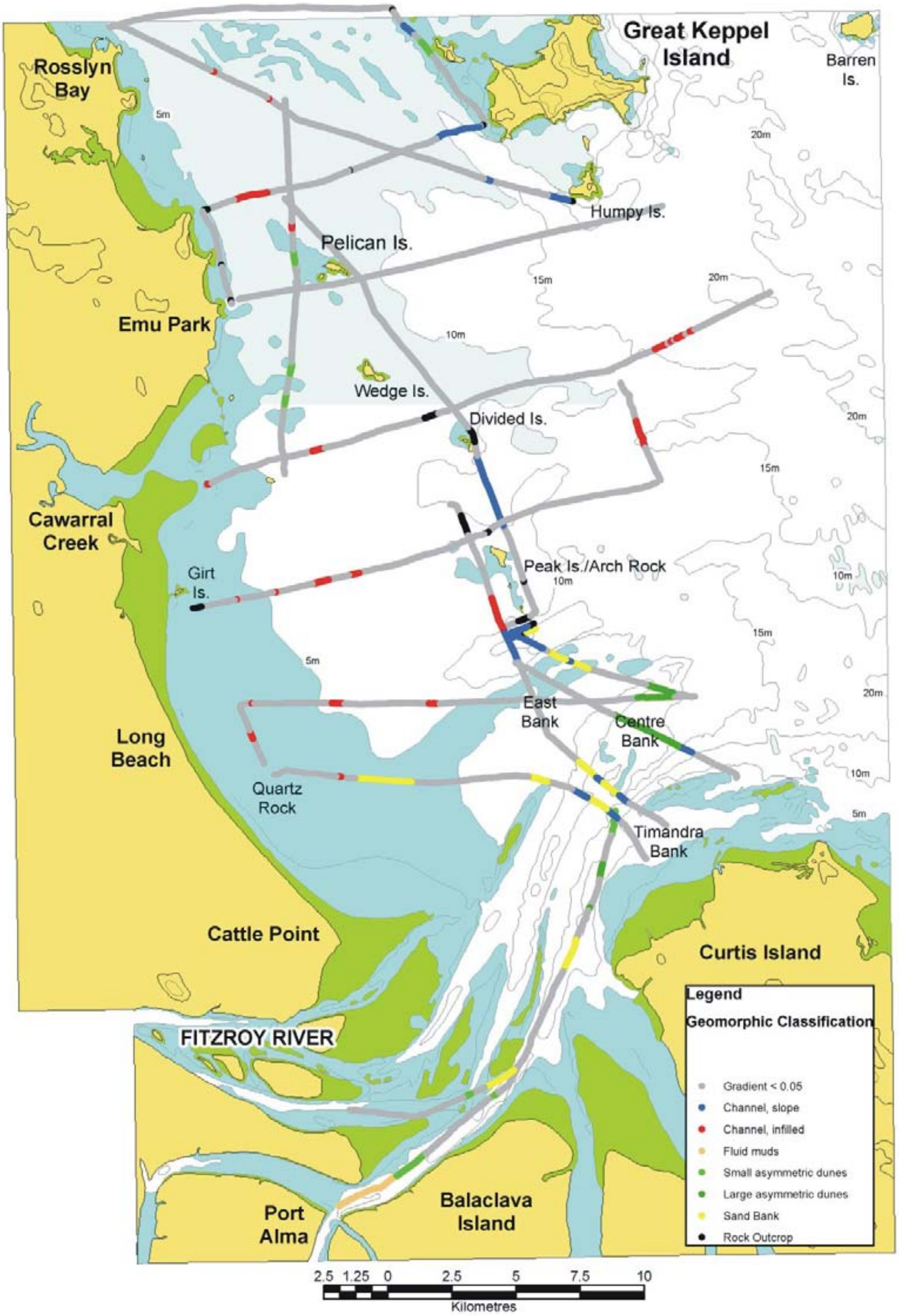


Figure 12: Geomorphic classification map of Keppel Bay. See Table 4 for classification scheme.

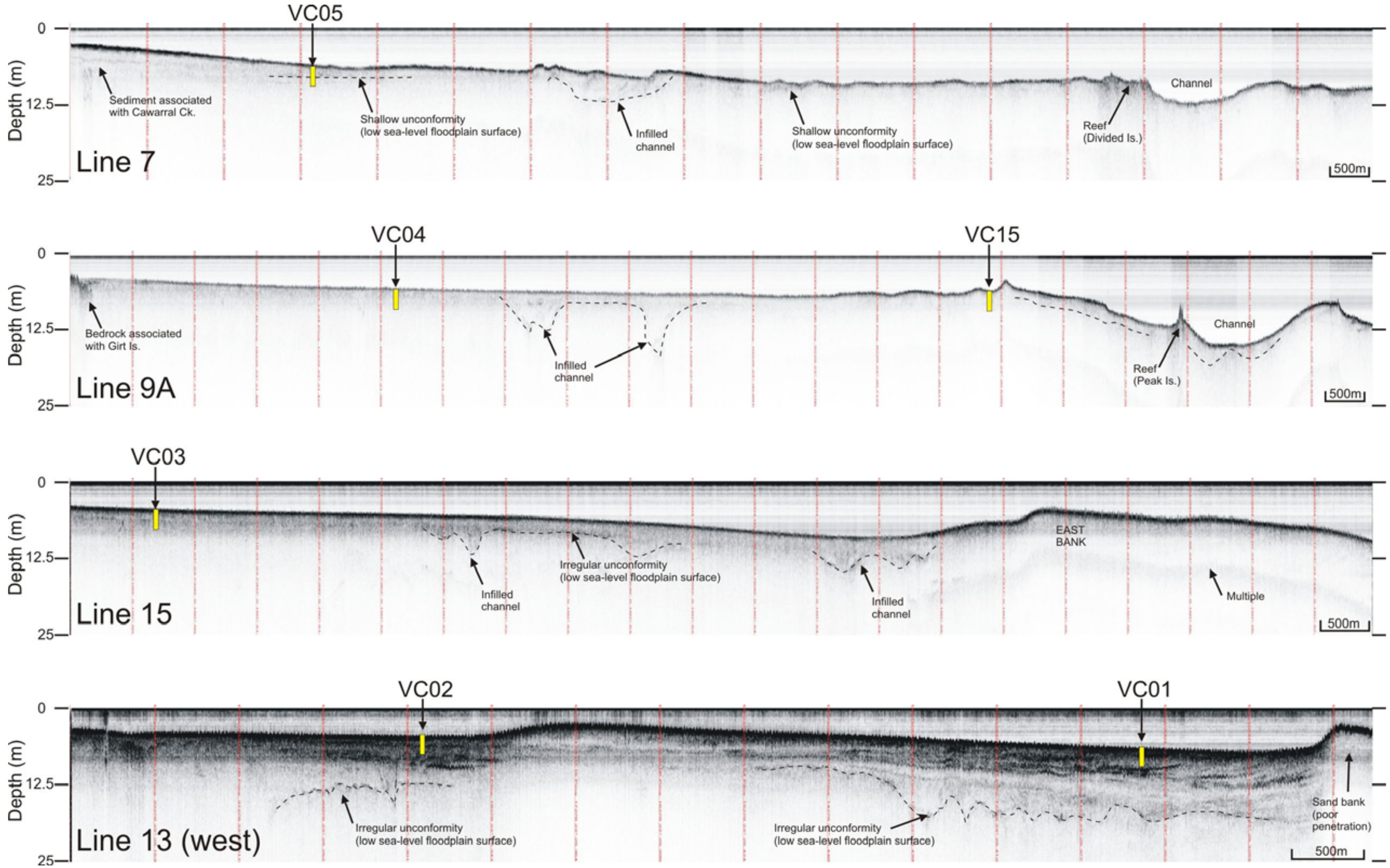


Figure 13: Chirp sub-bottom profiles from the inner and central areas of Keppel Bay. The locations of the profiles are shown in Figure 4. Vibracore locations are also indicated.

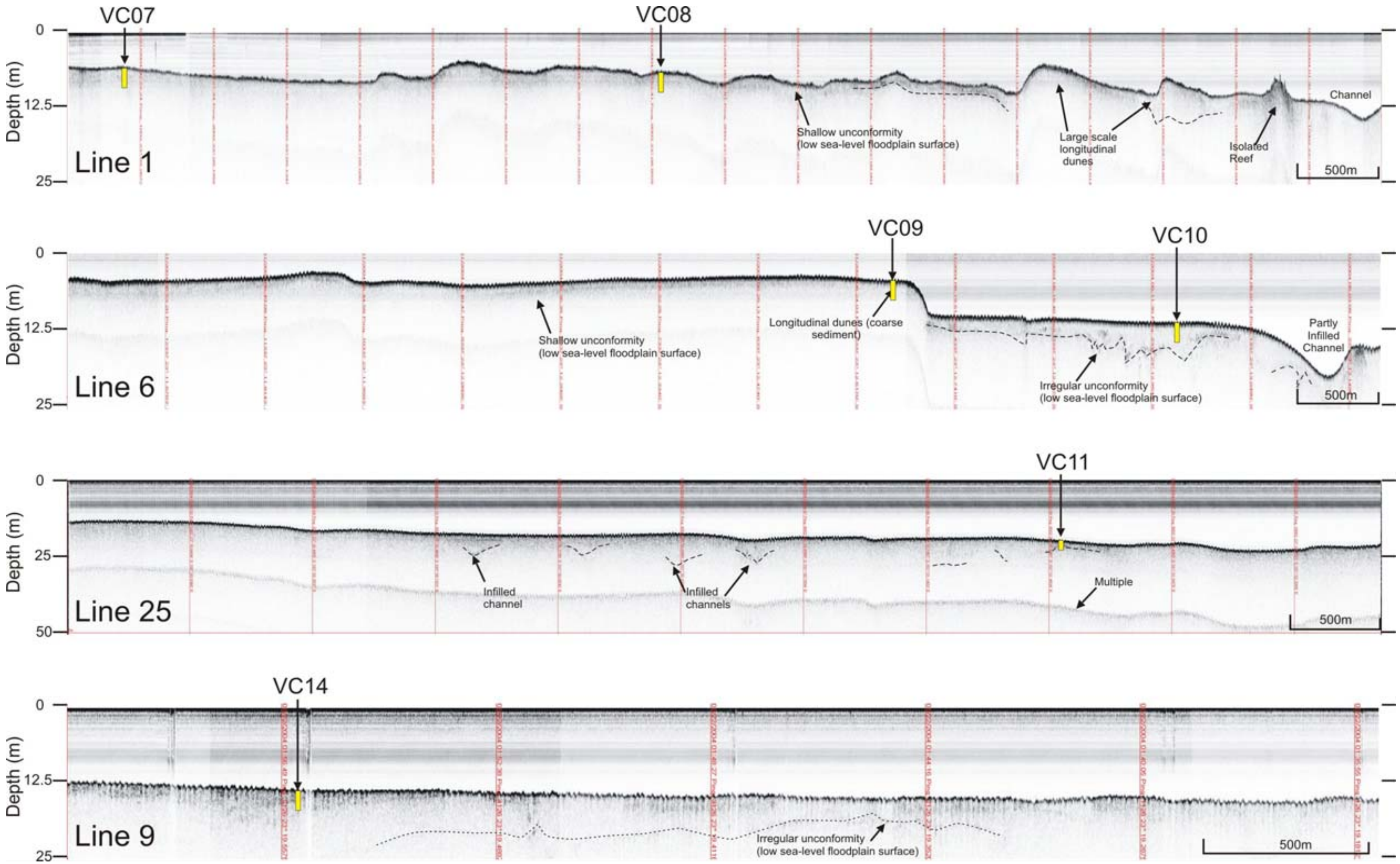


Figure 14: Chirp sub-bottom profiles from the northern and outer areas of Keppel Bay. The locations of profiles are shown in Figure 4. Vibracore locations are also indicated.

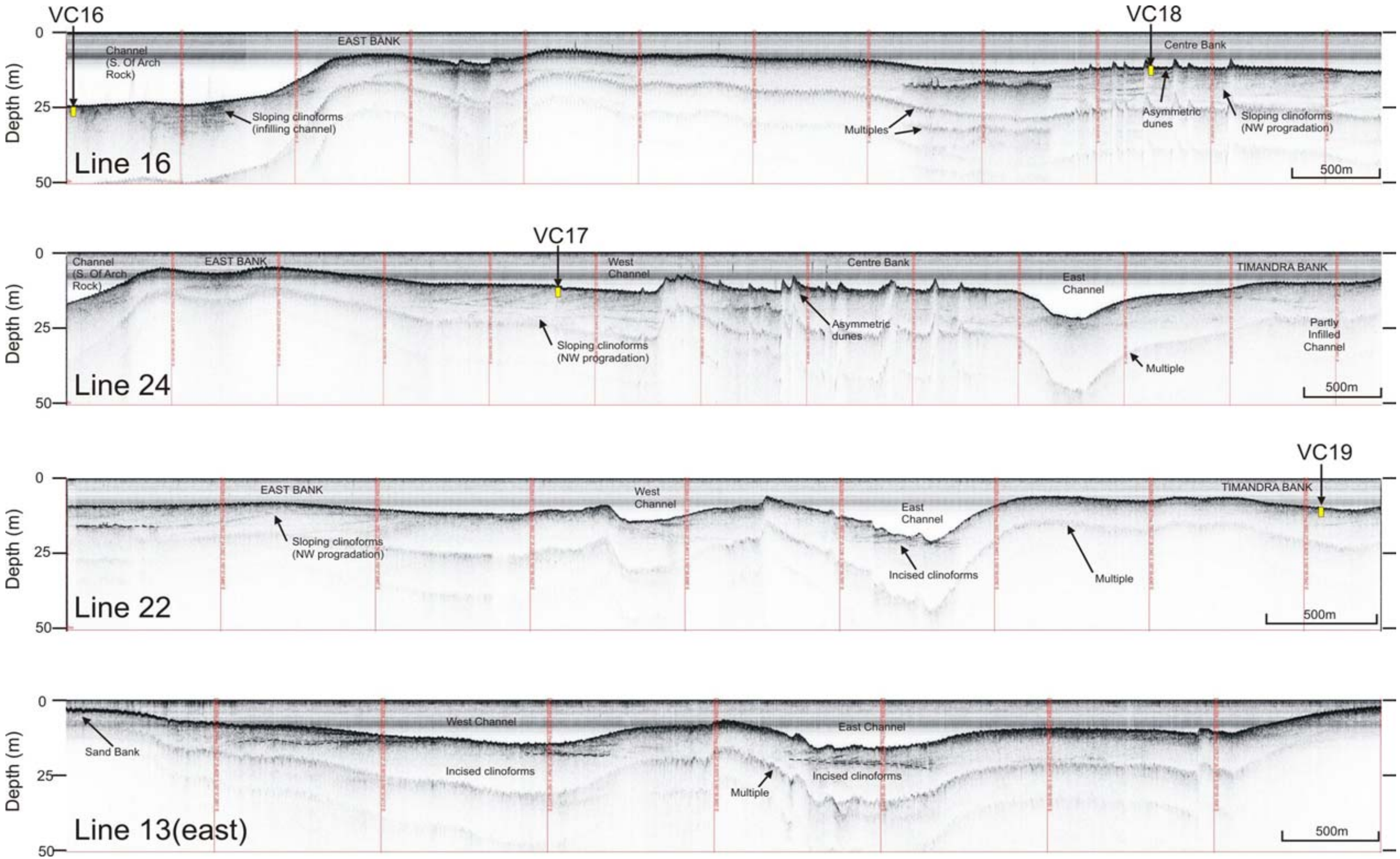


Figure 15: Chirp sub-bottom profiles from the south eastern area of Keppel Bay and Centre Bank. The locations of profiles are shown in Figure 4. Vibracore locations are also indicated.

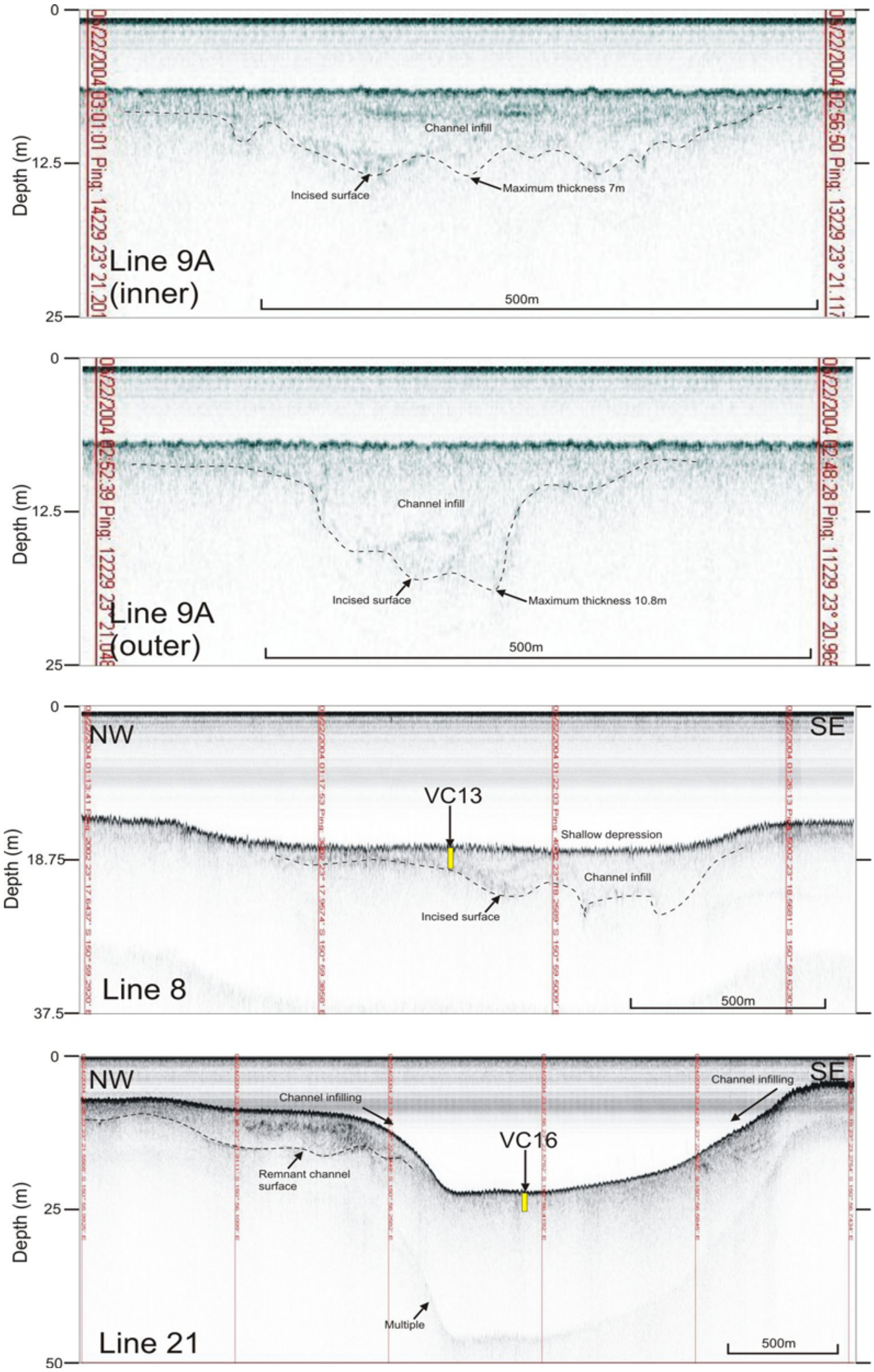


Figure 16: Chirp sub-bottom profiles showing details of both infilled and partially infilled relict channels in Keppel Bay. The locations of the profiles are shown in Figure 4 and Figure 12. Vibracore locations are also indicated.

Figure 13 shows sub-bottom profiles for inner and central Keppel Bay, including chirper lines 7, 9A, 15, and 13 arranged in order from north to south (Fig. 4). Based on the depth of penetration of the acoustic signal, the north of this area (Line 7) features coarser sediments than in the south

(Line 13). An irregular unconformity was detected in most of the sub-bottom profiles of inner Keppel Bay, and is interpreted as a Pleistocene/early Holocene subaerial floodplain unit (see core evidence below). This unit is mostly planar, and thins to the north, ranging from over 10 m thick in the south (Line 13) to 2-3 m thick in the northern lines. Incised features interpreted as relict river channels may be traced through lines 7, 9A and 15. These channels appear to have been completely infilled, and 1-2 m of sediment has accumulated over the channel-fill. The southern inner area of Keppel Bay features a well-bedded Holocene deposit, with clinoforms that suggest progradation in a westerly direction. These features are not apparent further north than Quartz Rock and East Bank.

Figure 14 represents sub-bottom profiles for northern and outer Keppel Bay, including lines 1, 6, 25 and 9 arranged in order from north to south (Fig. 4). Profiles in the north of Keppel Bay (Lines 1 and 6; Fig. 4) display poor sub-bottom penetration and suggest relatively coarse sediments. Irregular dune-like seabed features (up to 5 m relief) are apparent in Line 1 which are consistent with past echosounder evidence of subaqueous dunes in this region, and possibly related to tidal currents (Beach Protection Authority, 1979). Although sub-bottom penetration is poor, visible unconformities suggest that the thickness of Holocene and modern sediment is less than 3 m (Line 1, Fig. 14). A deep, partly infilled channel appears in the west of Line 6 (to the south of Great Keppel Island). This channel appears to be infilling from the east. Lines 25 and 9 (Fig. 14) are from outer Keppel Bay and are mostly featureless. However, a large infilled channel features appear in Line 25, suggesting movement of a river or tidal channel over this area during a period of lower sea level. An irregular unconformity in Line 9 indicates the Holocene sediment is 5-8 m thick.

Figure 15 includes sub-bottom profiles for south-eastern Keppel Bay and the Centre Bank area, with lines 16, 24, 22 and 13 arranged in order from north-east to south-west (Fig. 4). These profiles indicate areas of fine and coarse sediment but generally do not penetrate deep enough to reach the Pleistocene subaerial reflector. These well-bedded fine sediments indicate rapid accumulation and progradation of Holocene marine sediment. The outermost line (Line 16) shows sediment clinoforms that indicate progradation to the north-west, infilling the relict channel that lies south of Arch Rock (Fig. 12). This line also reveals the coarse character of sediments that form East Bank. In the vicinity of Centre Bank, Line 16 and Line 24 feature large asymmetric sediment dunes up to 5 m in relief. The orientation of the dunes suggest the sand is mobilised in a westerly direction. Line 22 and Line 13 feature channels that contain truncated sediment clinoforms that indicate a modern erosional rather than depositional regime in this area.

Figure 16 includes sub-bottom profiles that contain examples of both infilled and partially infilled relict channels. Two examples are provided from Line 9A (locations in Fig. 11). These channels are 7 m and 10.8 m thick respectively, and between 300 m and 500 m wide. Line 8 features a partially infilled channel that appears to have formed in a period when sea level was at least 20 m lower than present. Line 21 (south of Arch Rock) includes a deep, partly infilled channel that was cut into the former floodplain by the palaeo-Fitzroy River.

VIBRACORES

The locations of the 20 vibracores collected during the field survey are shown in Figure 4. The vibracores are distributed throughout Keppel Bay and provide information about geomorphic features, stratigraphy and sediment accumulation in Keppel Bay.

Sub-samples from the vibracores were taken from distinctive sediment types within the cores to provide a means of characterising the major depositional facies in Keppel Bay. These samples also allow a comparison with the modern surface sediment data that were described earlier in this report. Three cores were sub-sampled in detail. These were chosen as they appear to represent distinct depositional regions of the bay. Detailed logs of the vibracores are included in Appendix 5 and simplified logs are shown in Figure 17. The core logs, microscope descriptions of the >63 µm size fraction, and grainsize and carbonate analyses allows the separation of the cores into 6 facies types. The microscope descriptions are provided in Appendix 6 and the grainsize and carbonate analyses in Appendix 7 and 8. The grainsize distributions for the <2 mm fraction are displayed in Figure 18.

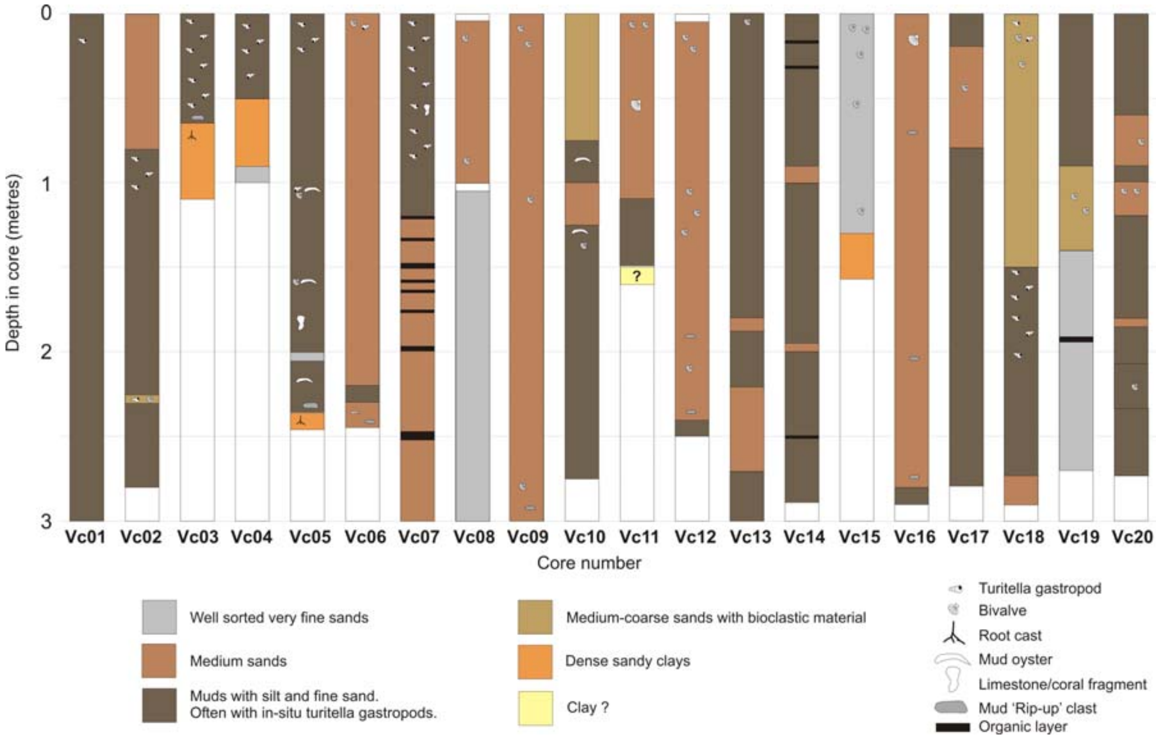
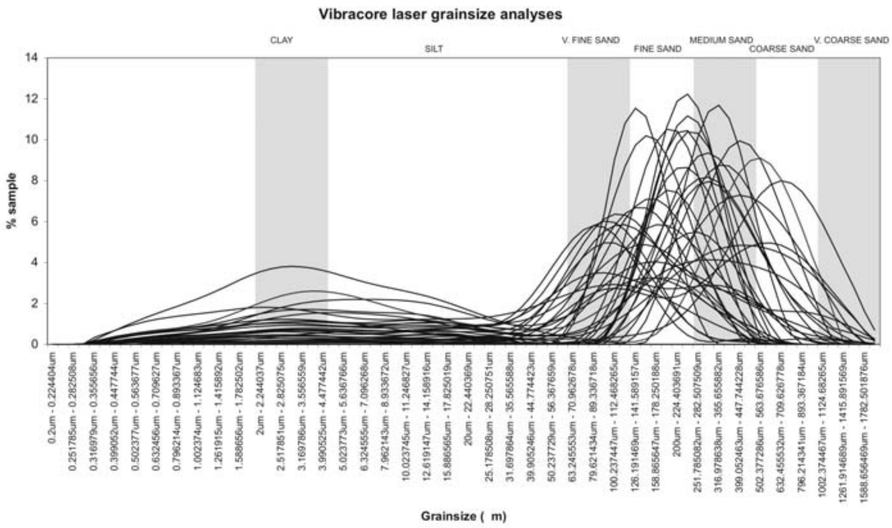
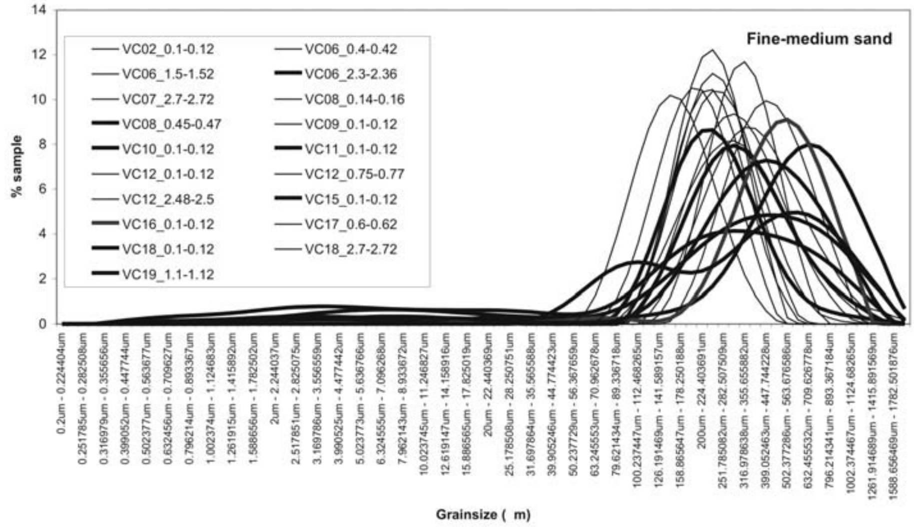
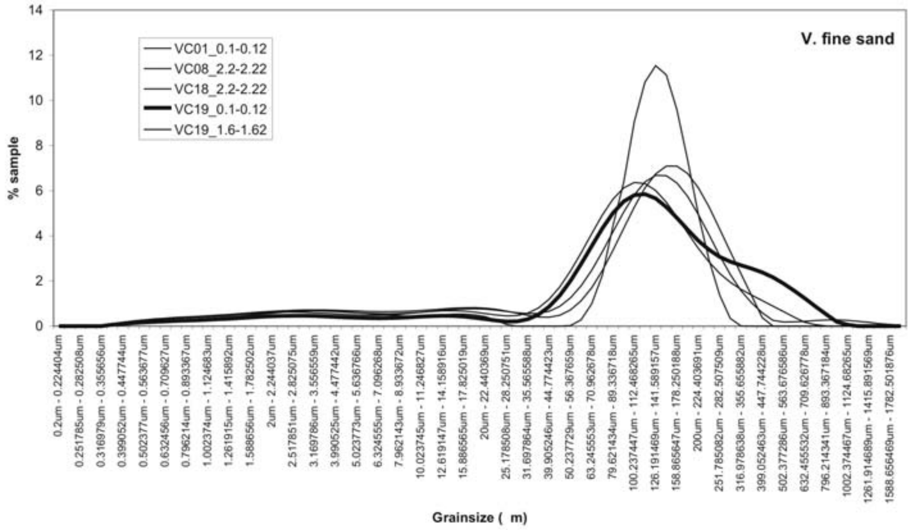


Figure 17: Summary core logs classified into 6 sediment facies. The facies types are based on the visual core logs (Appendix 5), microscope observations, and measurements of grainsize and carbonate content.


Vibracore laser grainsize analyses
CLAY
SILT
V. FINE SAND
FINE SAND
MEDIUM SAND
COARSE SAND
V. COARSE SAND
% sample
Grainsize (m)


Fine-medium sand
VC02_0.1-0.12
VC06_0.4-0.42
VC06_1.5-1.52
VC06_2.3-2.36
VC07_2.7-2.72
VC08_0.14-0.16
VC08_0.45-0.47
VC09_0.1-0.12
VC10_0.1-0.12
VC11_0.1-0.12
VC12_0.1-0.12
VC12_0.75-0.77
VC12_2.48-2.5
VC15_0.1-0.12
VC16_0.1-0.12
VC17_0.6-0.62
VC18_0.1-0.12
VC18_2.7-2.72
VC19_1.1-1.12
% sample
Grainsize (m)


V. fine sand
VC01_0.1-0.12
VC08_2.2-2.22
VC18_2.2-2.22
VC19_0.1-0.12
VC19_1.6-1.62
% sample
Grainsize (m)

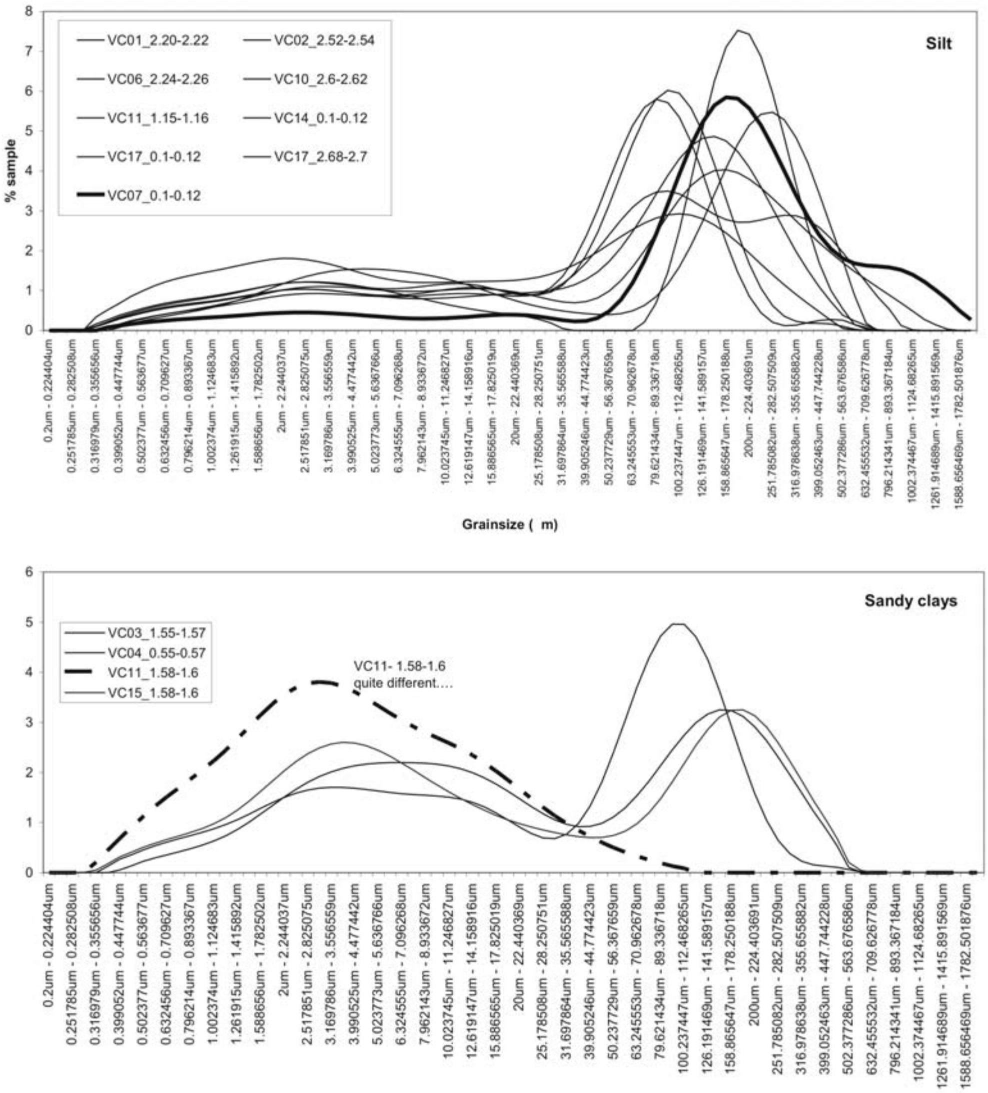


Figure 18 : The graphs show the grainsize distribution of sub-samples from the vibracores. Four different grainsize distributions are shown on the graphs; silt, very fine sand, fine to medium sand and sandy clays. Within the grainsize distributions they can be further separated into facies by $CaCO_3$% - samples with high $CaCO_3$% are highlighted by a thicker line. VC11-1.58-1.6m is highlighted on the graph of sandy clays by a dashed thick line.

Figure 19 : The grainsize distribution and classification for the subsamples are also displayed in this ternary diagram. Sample VC11-1.58-1.6m is highlighted again on the diagram to show its unique character.

Based on the grainsize distribution data four main textural facies are evident; mud and silt, very fine sand, fine to medium sand, and sandy clays. The facies are further distinguished by their carbonate content. Sub-samples with high carbonate content are highlighted by thicker black lines in Figure 18. The samples with high carbonate content often exhibit a bimodal distribution. This is probably related to the *in-situ* biogenic formation of carbonate. The bulk sample carbonate content appears to be loosely related to the percentage of gravel in the vibracore samples (Appendix 7), except for samples from the tops of VC15, VC16 and VC19 which have much higher gravel content than expected from their carbonate content. This suggests that the gravel in these cores may be dominated by terrigenous material. One sample from the base of VC11 (1.58-1.6 m; dashed line Figure 18 and highlighted in Figure 19) has a unique grainsize distribution dominated by clay size material. This is similar to the estuarine mud evident in VC20 and VC13 that is discussed in the more detail in the core analysis section.

A summary of the microscope description of the >63 µm fraction from each of these facies groups is provided below (full details in Appendix 6) and an example photograph of each of these facies is shown in Figure 20.

Well sorted fine sand: These samples comprise predominantly subangular to subrounded quartz grains (Fig. 20A). There are a few benthic foraminifera and occasional fragmented reworked bioclastic material in the gravel fraction.

Silts and muds: This facies group represents the main habitat for the *Turitella* gastropod and a range of other *in-situ* carbonate bioclasts, bivalves, gastropods and benthic foraminifera. The bioclasts are shown in Figure 20B surrounded by a matrix of silt-sized grains. This facies is primarily found in the cores from the nearshore of Keppel Bay and in VC07 from northern Keppel Bay. They are also found in the cores just to the northeast of the Fitzroy Estuary main channels, often in the subsurface sediments (e.g. VC18; Fig. 17).

Medium sands: In the cores these sands are usually massive with little evidence of bedding. They exhibit subrounded to rounded quartz grains, with infrequent gravel content (Fig. 20C). Feldspar grains and lithic fragments are present in the gravel and pebble size fractions. There is a low abundance of bioclasts and carbonate material appears to be highly reworked. Some samples, however, have relatively high concentrations of benthic foraminifera. This facies occurs in outer and northern Keppel Bay, and appears to have infilled palaeochannels in this area.

Medium-coarse sand with bioclastic material: These sands often include a component of lithic gravel. The quartz, feldspar and lithic grains are subangular to subrounded. The bioclasts are quite diverse, relatively large (gravel size) and highly reworked (Fig. 20D). Very few of these bioclasts appear to be *in-situ*, there are occasional benthic forams, but these may also be reworked. This is not a common facies and is primarily found in southern Keppel Bay infilling palaeo-channels and forming dunes on the seabed at the distal end of the tidal channels in the outer bay (VC18). This facies is a mixture of terrigenous and marine sediments.

Dense sandy clays: This sediment is only found in the subsurface of Keppel Bay and is a sticky grey clay with orange mottles, present in the base of cores from the inner bay (Fig. 20E; base of VC05). In many cases this facies prevented the core from penetrating the full 3 m and represents an abrupt facies change. This deposit is believed to represent the land surface prior to the Holocene sea level rise. Evidence to support this interpretation includes the presence of *in-situ* rootlets in some cores (base of VC05). In the overlying sediments there is often clay rip-up clasts of this facies suggesting that there has been some erosion of the surface prior to the deposition of marine sediment.

Clays: These samples could not be usefully observed under the binocular microscope due to their fine particle size. The clay is pale olive with orange mottles throughout and more plastic in texture than the majority of the mud recovered in vibracores.

From the above descriptions and analyses a more comprehensive characterisation of the 6 facies, initially classified on textural features only, is provided in Table 5.

Table 5: Summary of the 6 textural facies found in the vibracores of Keppel Bay.

FACIES	GRAINSIZE (μM)	SORTING	CARBONATE %	GRAVEL %
Fine to medium sand	125-500	Unimodal	<10 %	<5 % (three exceptions)
Medium sand with bioclasts	200-1000	Unimodal to bimodal	>10 %	1-20 %
Very fine sand	63-125	Unimodal	6-12 %	0 (one exception)
Silt and mud	4-63	Bimodal to polymodal	6-17 %	0 (one exception – *Turitella* mud)
Sticky sandy clays	18-27	Bimodal	0	0
Clay (VC11 1.58-1.6m)	~4	Unimodal	0	0

Detailed core analysis

As noted above, vibracores VC05, VC13 and VC20 were chosen for detailed analyses as they represent the major lithostratigraphic zones evident in Keppel Bay. These cores were sampled for grainsize, carbonate, porosity, wet bulk density and total organic carbon. Full data are included in Appendix 9 and a summary of the data and the grainsize distributions is shown in Figures 21, 22 and 23.

VC05 is located in inner Keppel Bay adjacent to Flat Rock (Fig. 4). The top of the core is composed of *Turitella*-rich silts and muds (Fig. 20). It appears to have a higher sand content than expected for this facies with a bimodal distribution of fine sand and medium sand (Fig. 21). This may be the result of *in-situ* carbonate production as indicated by the un-reworked bioclastic material. These sands also exhibit low proportions of organic carbon. Below 0.3 m in the core the grainsize decreases, alternating between silt and mud and very fine sand (Fig. 21b). This is the same type of sand evident in the upper section of core, however, *Turitella* is absent. Organic carbon increases in the finer sediments. At 1.0 m depth, there is a shell-hash layer composed of a mud oyster, other bivalves and *Turitella*. There is an abrupt change to the dense sandy clay facies near the base of the core, with a corresponding dramatic decrease in porosity, absence of carbonate and a distinct change in texture and colour (Fig. 21a).

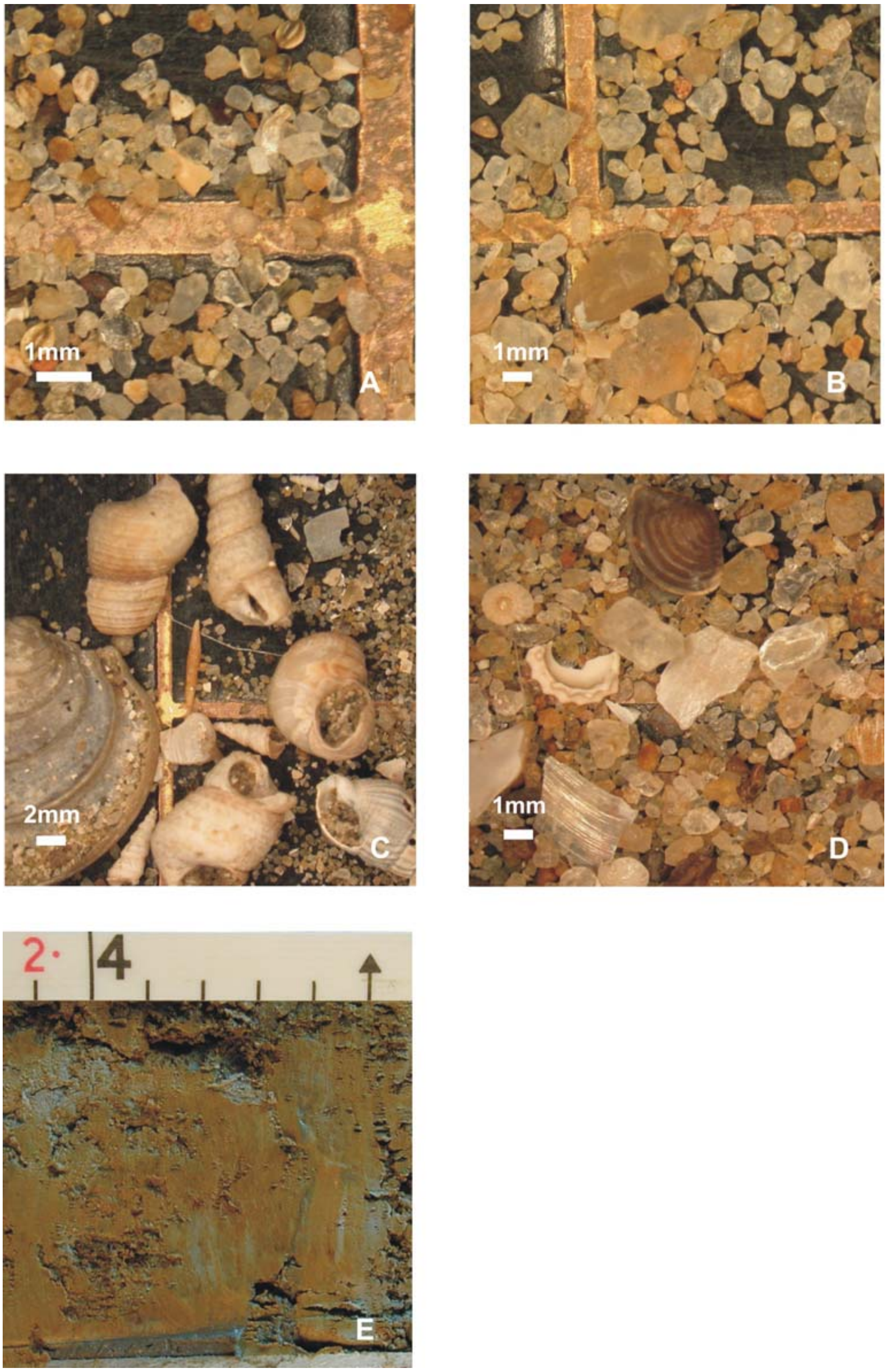


Figure 20: Photos of sediment samples from VC05. A) very fine sands with benthic foraminifera, B) medium sands with some terrigenous gravel component, C) silts and muds with in-situ Turitella gastropods and other bioclasts, D) medium – coarse sands with bioclastic gravel, E) dense sandy clays, likely of terrestrial origin – from the base of VC05.

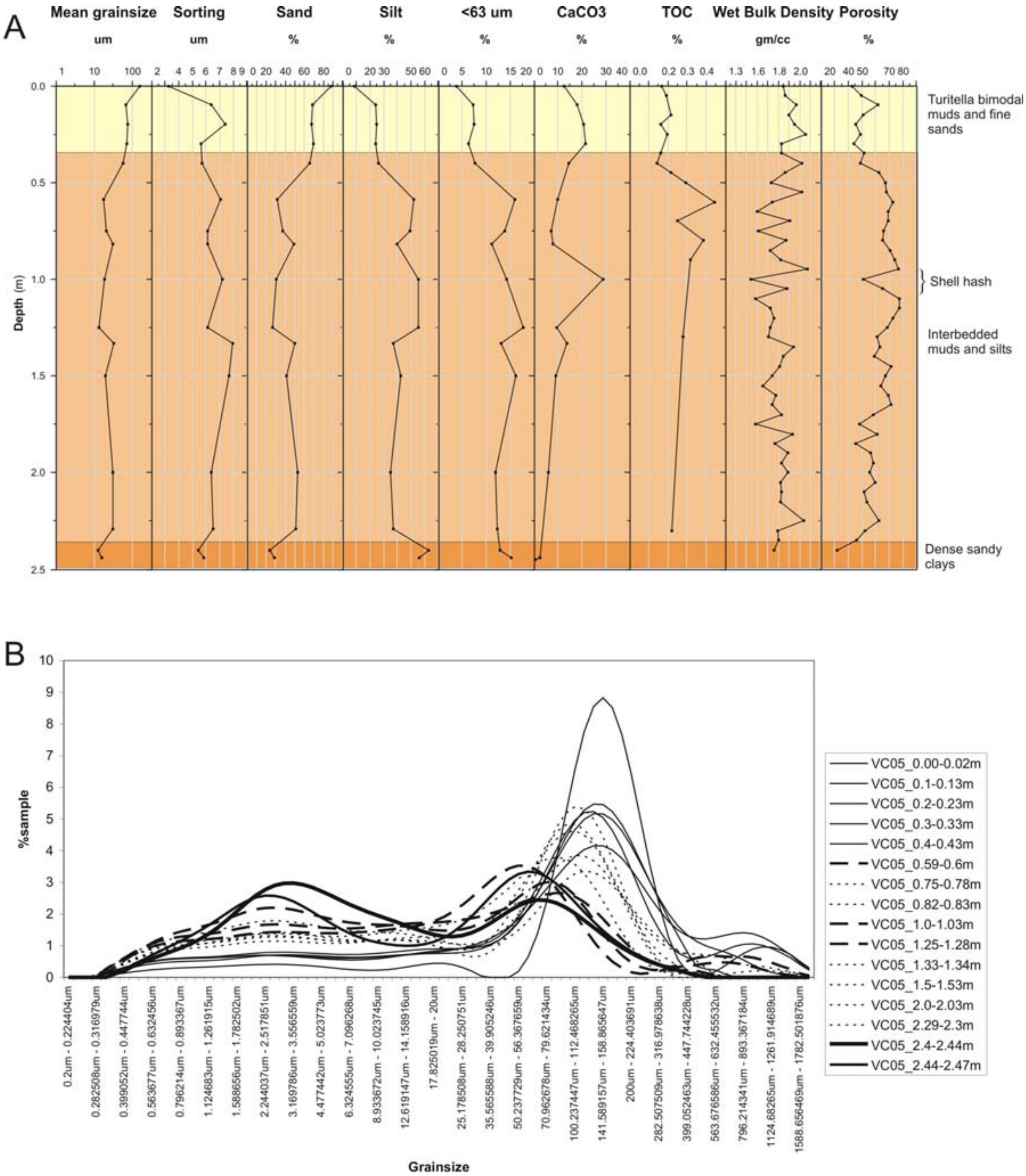
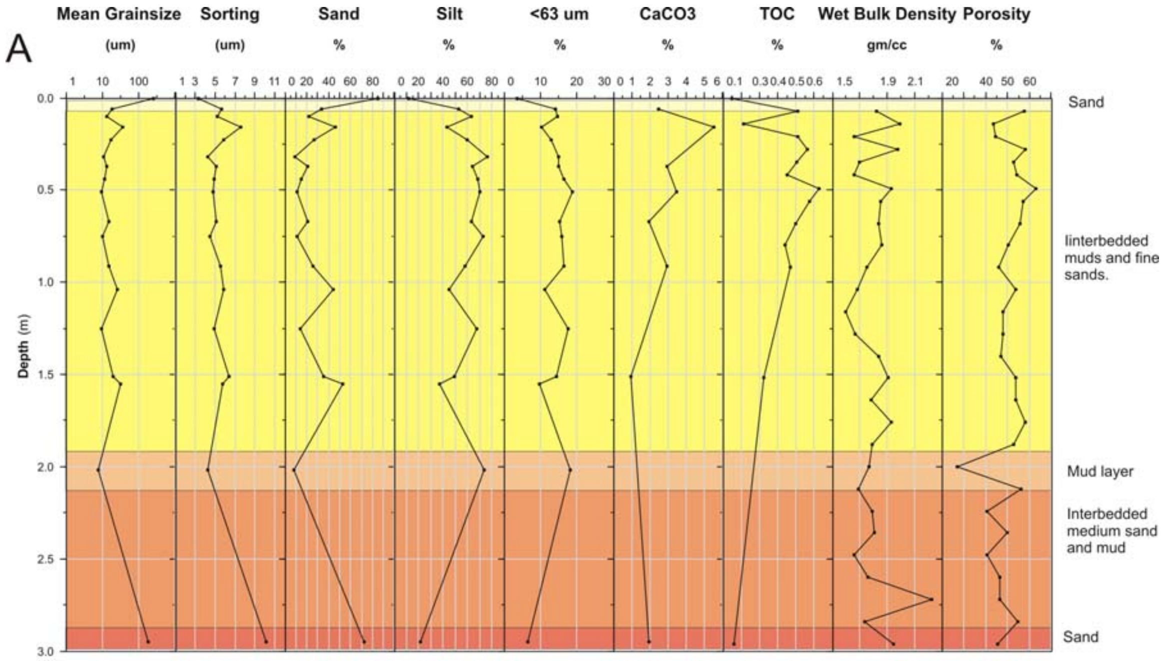


Figure 21 : Physical and geochemical properties of sediment samples from VC05. A) Graphical summary of the data. B) Grainsize distribution curves for sediment samples that show the changes in the grain-size populations with depth. Black thick lines – sandy clay; dashed black lines – silt and mud; dotted lines – fine sand and mud; black lines – fine sand.

VC13 is located in outer Keppel Bay, northeast of Peak Island (Fig. 4). The top of the core includes a large bivalve and pebble but otherwise bioclastic material is a relatively minor component throughout the core. The sediments in the top 2 m of this core are difficult to classify as either silt with mud or fine sand with mud, and it is probably a continuum of the two, becoming coarser down the core. This is evident in the grainsize distribution of samples in this depth range (Fig. 22b). At 2 m depth there is a mud layer, which can be clearly seen in the grainsize data (thick black line; Fig. 22b). Below 2 m the grainsize increases with an increase in sand and corresponding decreases in silt and clay, although the sediment becomes less well sorted. There is also a decrease in organic carbon, probably due to the decrease in clay, and a low carbonate component. The base of the core consists of coarse sand (dashed grey line; Fig. 22b).

VC20 is located in one of the main shipping channels that lead into Port Alma, which is the eastern channel that extends out from the mouth of the Fitzroy Estuary into the southern end of Keppel Bay (Fig. 4). The top 40 cm of the core is made up of mud with lenses of silt and fine sand (Fig. 23a). This is evident in the grainsize distribution graph for this core, with alternating silt and mud (dashed black lines; Fig. 23b) and fine sand and mud (dotted lines; Fig. 23b). These mud-rich sediments also have a relatively high organic carbon content. The carbonate content is highest in the sand layers and generally increases with grainsize. Below 40 cm there is a mud layer 40-50 cm thick (thick black lines; Fig. 22b). A poorly sorted medium sand extends below the mud to a depth of 1.5 m. This facies has the largest grainsize in the core (grey lines; Fig. 23b) and low proportions of organic carbon, which is probably related to the very low proportion of finer sediment. In this bed, some samples have a relatively high carbonate content due to large fragments of bioclastic material. Below the sand is another mud unit, with minimal sand and bioclastic material, which is very similar to the facies in the top of the core. Below a depth of 2 m the mud includes a greater proportion of fine silt and sand and some bioclastic material. At the base of the core the sediment again becomes mud dominated, similar to the top 40 cm (Fig. 23a). The interbedded character of the deposits in this core suggests that in this area of Keppel Bay there have been cycles of sediment accumulation likely related to fluvial discharge from the adjacent Fitzroy River estuary.



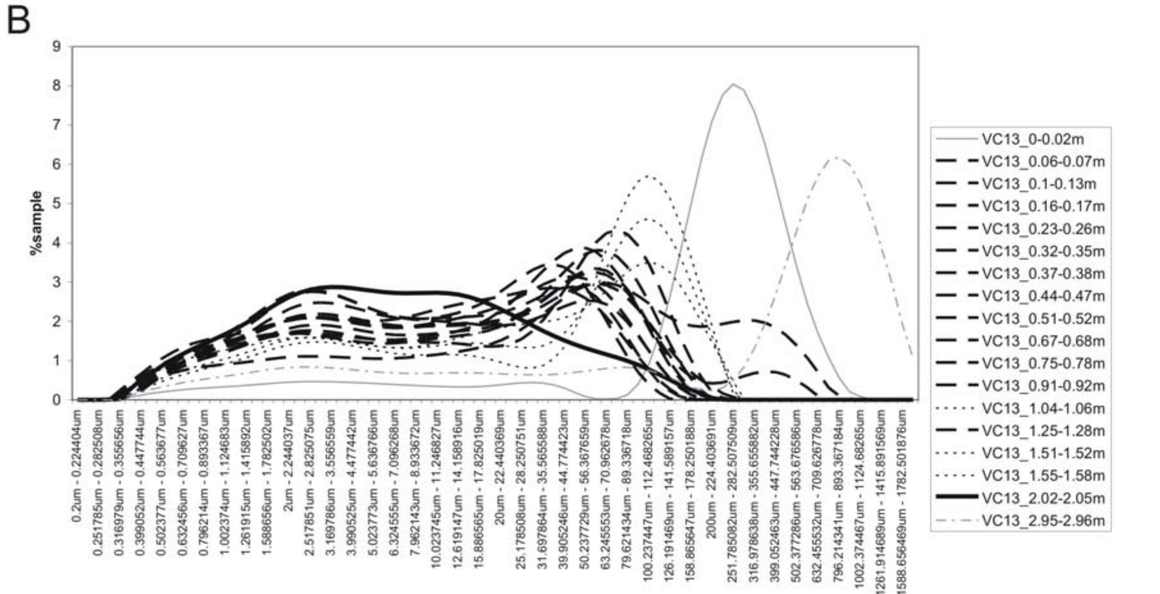


Figure 22: Physical and geochemical properties of sediment samples from VC13. A) Graphical summary of the data. B) Grainsize distribution curves for sediment samples that show the changes in the grain-size populations with depth; black thick line – mud; dashed black line – silt and mud; dotted line – fine sand and mud; grey line – medium sand; dashed grey line – coarse sand.

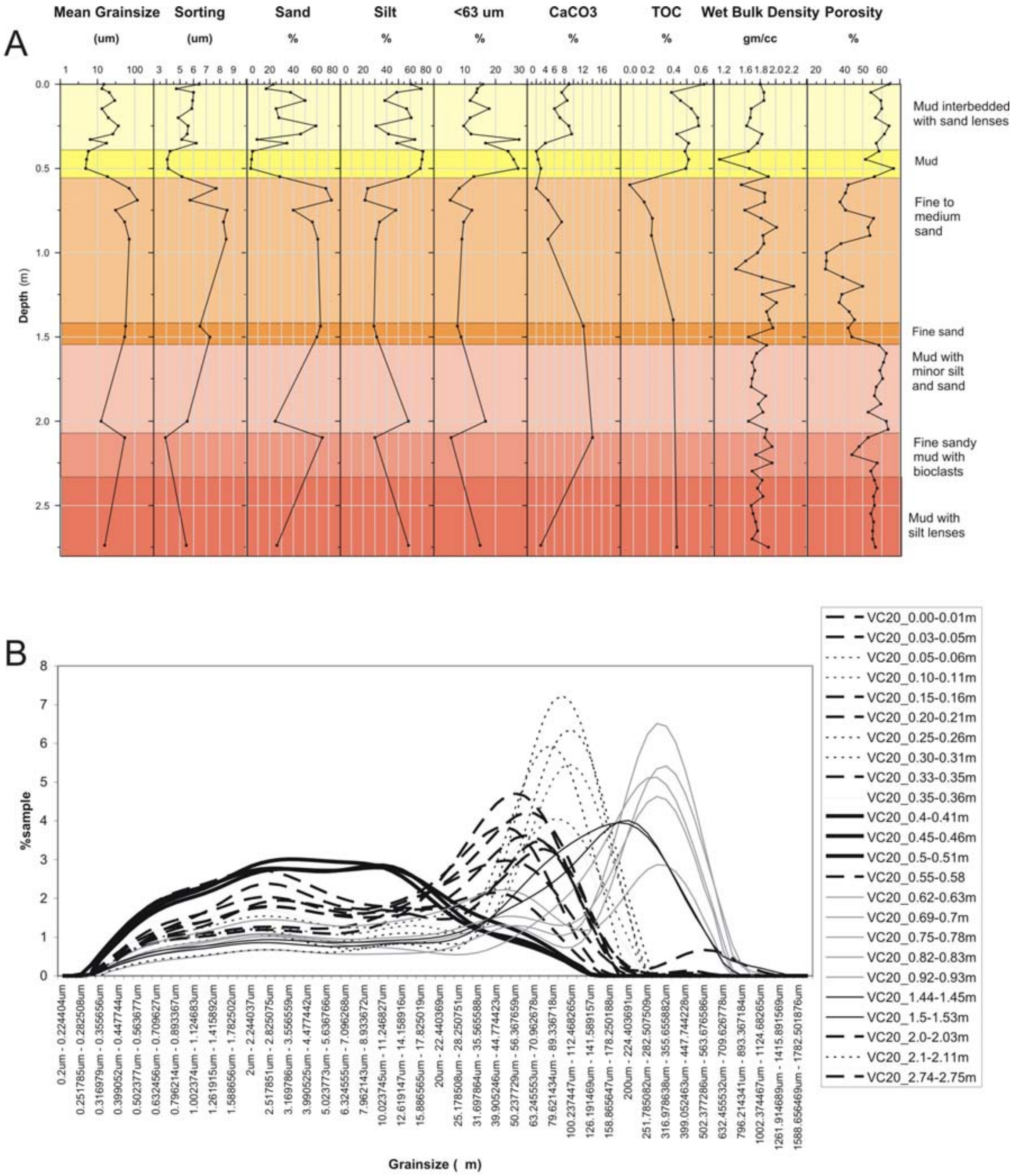


Figure 23: Summary of the sedimentary data for VC20 Physical and geochemical properties of sediment samples from VC20. A) Graphical summary of the data. B) Grainsize distribution curves for sediment samples that show the changes in the grain-size populations with depth. black thick lines – mud; dashed black lines – silt and mud; dotted lines – fine sand and mud; grey line – medium sand; black lines – medium sand; grey line – coarse sand.

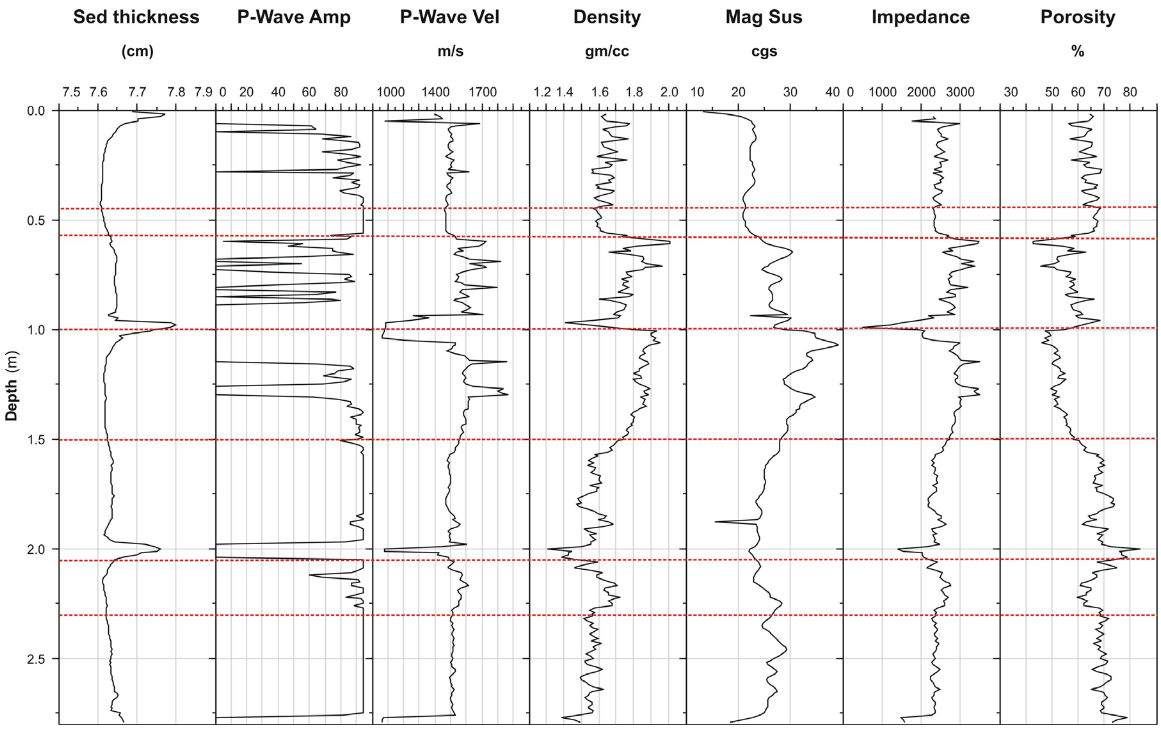
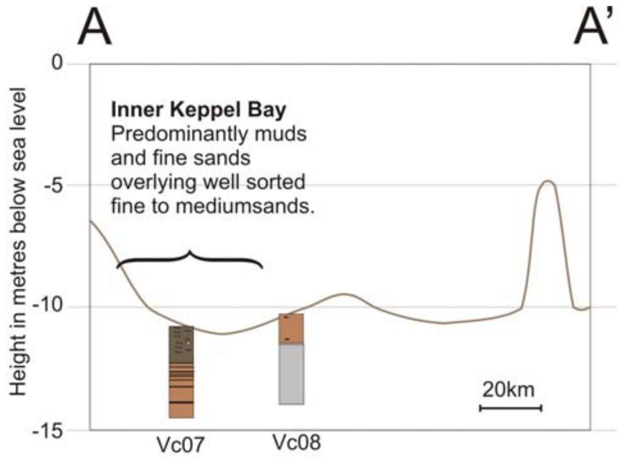


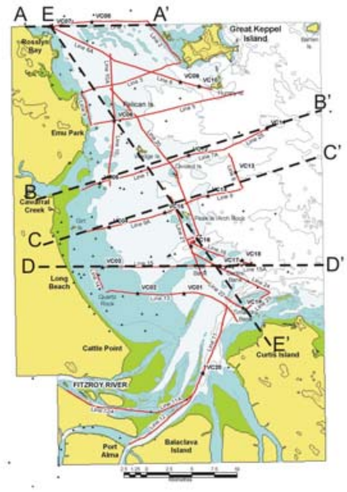
Figure 24: GEOTEK MSCL data for VC20. Sediment thickness, P-Wave Amp (amplitude), P-Wave velocity, wet bulk density, magnetic susceptibility, impedance and fractional porosity. Red dashed lines highlight where changes in sediment character appear to occur.

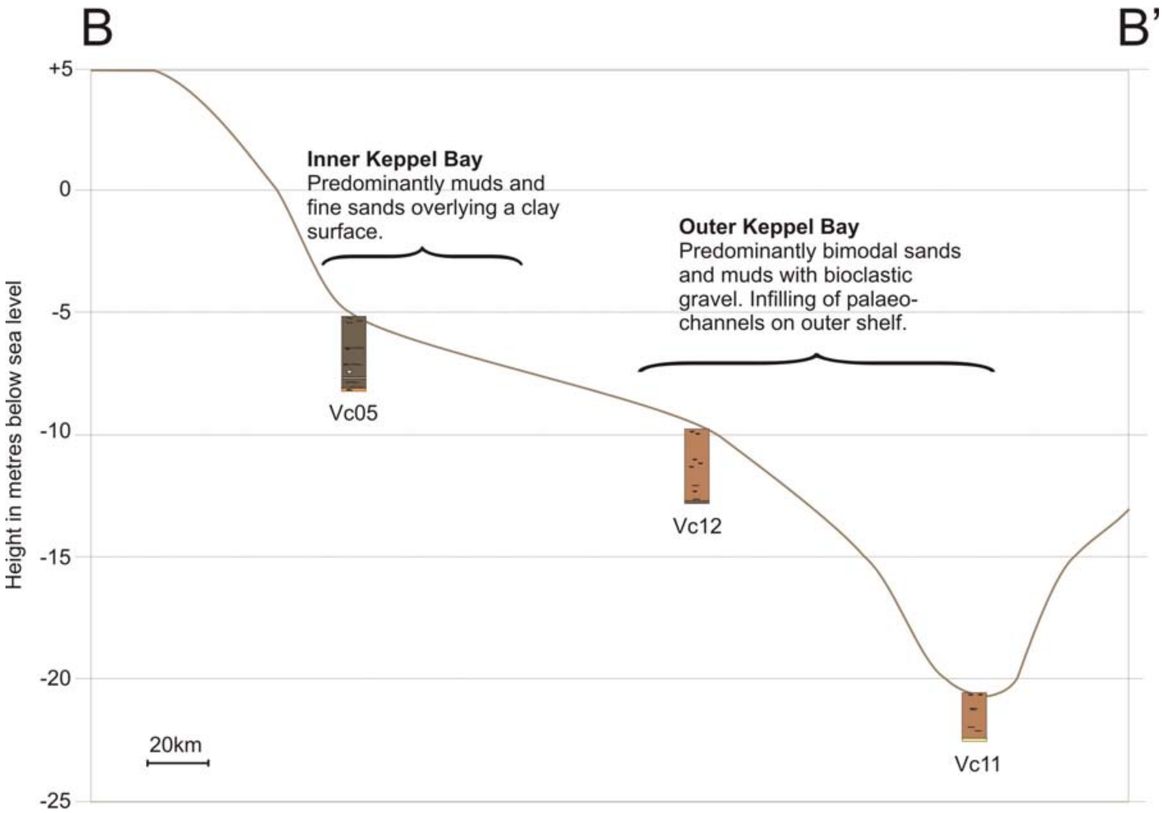
Three sections of core VC20 were run through the MSCL (Fig. 24). Each break between core sections is evident in the sediment thickness graph and as spikes in the P-Wave velocity and impedance

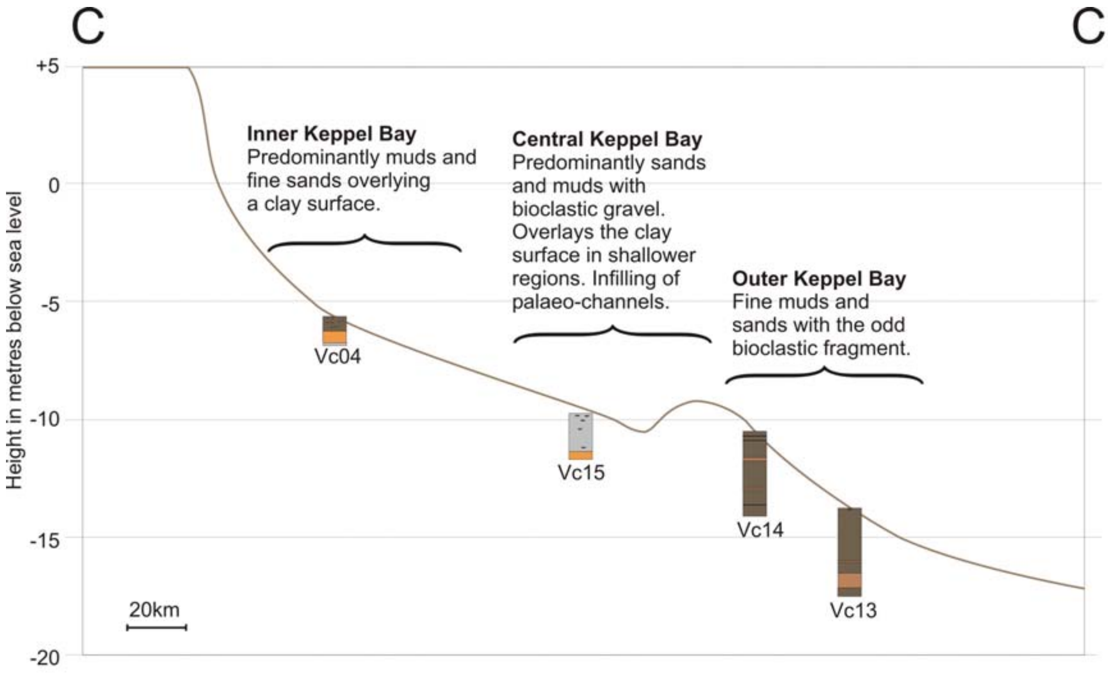
Changes in the sediment character determined from the MSCL data occur at very similar depths to those seen in the laboratory data for VC20 (Fig. 23). At the top of the core the 1 cm thick interbedded muds and sands (Appendix 5 – VC20 core log) are evident in the highly fluctuating porosity and density measurements (Fig. 24). The amplitude of these fluctuations is not very great suggesting there is only a small difference in the sediment type from one layer to the next. The change in sediment type at 0.55 m depth matches an increase in P-wave velocity, density, magnetic susceptibility, impedance and a decrease in porosity. This correlates with an increase in measured mean grainsize and sand content (Fig. 23). The MSCL data for 0.5-1.0 m fluctuates considerably and may reflect the poorly sorted nature of the sediment as seen in grain-size data (Fig. 23), and the thicker bedding evident in the core (Appendix 5). A change is also seen in the MSCL data at ~1 m depth which is not evident in the laboratory data. This may reflect the coarser sampling interval for the laboratory analyses below 1 m. This section of core displays similar P-wave velocity and impedance, decreased porosity with increased density, and less variability than the sediments above (Fig. 24). This reflects much thicker bedding compared with the interbedded sands and muds above (Appendix 5). This section also displays very high magnetic susceptibility suggesting there may have been a change to more Fe-rich sediment related to a change in the sediment source area. Below 1.5 m the P-wave velocity, density, magnetic susceptibility, impedance and porosity return to similar levels as exhibited in the upper section of the core. These parameters have similar values down to the base of the core, with a very slight change over a 25 cm section just below 2 m, which matches an increase in the sand and bioclastic content (Fig. 23).

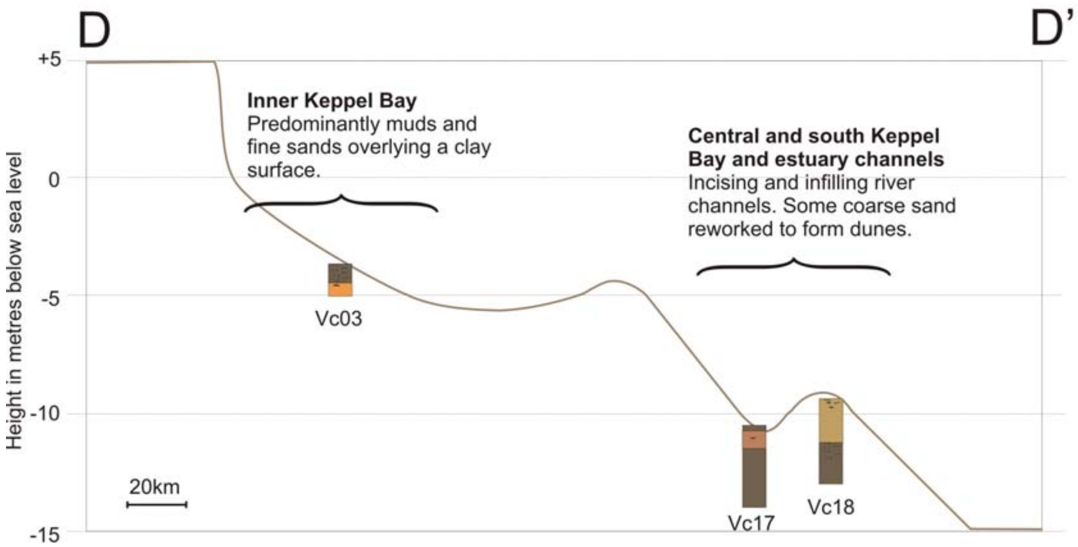
Porosity and wet bulk density were determined by direct measurements of sub-samples in the laboratory and from the MSCL data. A comparison of two sets of analyses is shown in Appendix 10. The MSCL data agrees well with the measurements made on the sub-samples – the two datasets clearly follow similar trends although there is a slight offset between them which may be artefact created by extracting the sediment samples from the core. The data is most similar at the top of the core for both the porosity and wet bulk density values.








C
C'
+5
0
-5
-10
-15
-20
Height in metres below sea level
Inner Keppel Bay
Predominantly muds and fine sands overlying a clay surface.
Central Keppel Bay
Predominantly sands and muds with bioclastic gravel. Overlays the clay surface in shallower regions. Infilling of palaeo-channels.
Outer Keppel Bay
Fine muds and sands with the odd bioclastic fragment.
Vc04
Vc15
Vc14
Vc13
20km


D
D'
+5
0
-5
-10
-15
Height in metres below sea level
Inner Keppel Bay
Predominantly muds and fine sands overlying a clay surface.
Central and south Keppel Bay and estuary channels
Incising and infilling river channels. Some coarse sand reworked to form dunes.
Vc03
Vc17
Vc18
20km

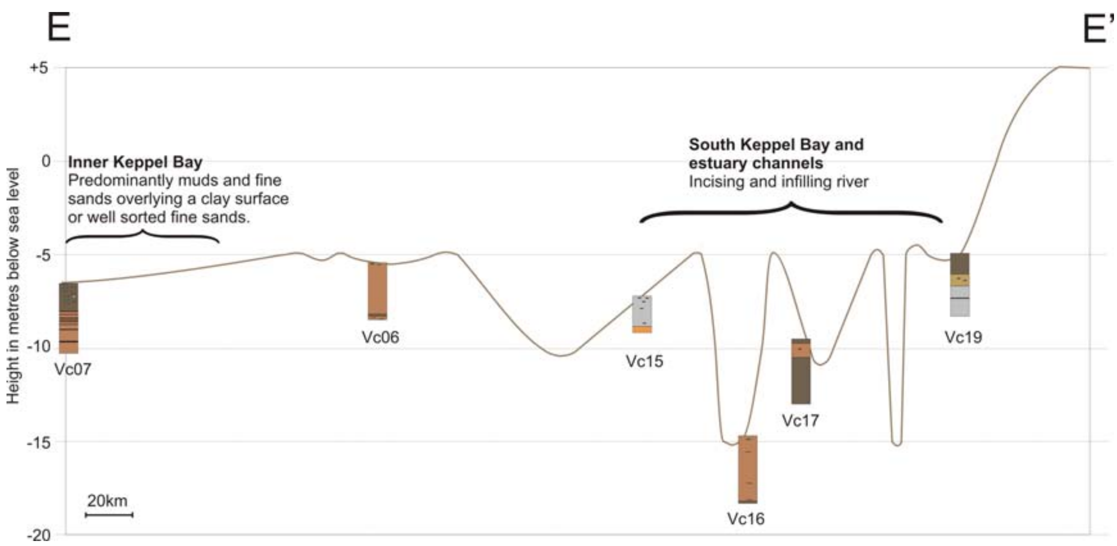


Figure 25: Simplified cross sections of Keppel Bay with the vibracore logs superimposed (NB the very large vertical exaggeration). The location of the cross sections are shown in the inset map.

SUMMARY OF KEPPEL BAY STRATIGRAPHY

A comparison of the surface samples and vibracores with the chirper profiles provides a very useful tool to validate the acoustic data, develop a bay-wide stratigraphic model and to gain insights into the sedimentary evolution of Keppel Bay. A series of cross sections through Keppel Bay (Fig. 25) shows the seabed morphology and the position and stratigraphy of the cores. These cross-sections highlight the significant variability in geomorphology and stratigraphy of the bay. From the variations in the surface sediments (Figs. 8-12), the changes in facies between cores and a comparison with relevant chirper sub-bottom profiles it is clear that there are distinct geomorphic regions in the bay that have characteristic assemblages of marine and terrestrial sediments (Fig. 26). These regions are defined as the nearshore/Long Beach, Inner Bay, Outer and Northern Bay, Central and Southern Bay and Tidal and Estuarine Channels (Fig. 27).

Nearshore/Long Beach

The shallow sublittoral inner Keppel Bay typically comprises well sorted and coarse skewed sandy sediments (mainly cluster group 1; Fig. 5), with low mud and gravel content, low $CaCO_3$ composition, moderate weathering ratio and high feldspar composition. No sub-bottom information or vibracores are available for this region due to the shallow sub-tidal nature of the area.

Inner Keppel Bay

The sediments of this region are poorly sorted, with a high mud and gravel content (mainly cluster group 3; Fig. 5). The area is also enriched in feldspar and organic carbon, with a high weathering ratio. High proportions of $CaCO_3$ suggest the presence of bioclastic material, typically *Turitella* gastropods. The shells appear to be *in-situ* because of the range of shell sizes and lack of any sign of being reworked. This facies is seen down core in cores VC07, VC05, VC04, VC03 for approximately the top 1 m. In cores VC05, VC04 and VC03 this silt and mud *Turitella* facies overlies sticky dense sandy clays. The base of VC15 also comprises this type of clay, indicating that this unit extends to the east as far as the bedrock islands in the centre of the bay. This facies is not exposed in the surface sediments within Keppel Bay and is most similar to the floodplain sediments in the Fitzroy Estuary (Bostock et al., 2007). An indurated surface was seen at the base of the cores in nearby Broad Sound and interpreted as a subaerial soil forming a flat and relatively featureless surface (Cook and Mayo, 1977). Similar heavily oxidised clays and quartz sand basal sediment was found in the South Alligator Estuary, northern Australia (Woodroffe et al., 1989). Therefore this unit most likely represents a palaeo-exposure surface such as a floodplain that formed prior to the sea level rise in the early Holocene. These dense clays in Keppel Bay have no carbonate, but further analyses will be required to confirm their environment of deposition. This unit is discernible in the chirper Lines 15 and 7 (Fig. 13). The base of VC07 (collected offshore Rosslyn Bay) does not include the dense sandy clays, suggesting that this unit is restricted to Keppel Bay.

Remnant infilled channel features are visible on several chirper lines in Keppel Bay (Fig. 13). To the south-east of Quartz Rock, more distinct bedding occurs suggesting the accumulation of river sediment. The area is bordered to the southeast by a bank that extends in a southwest-northeast direction from Cattle Point toward East Bank. The base of core VC07 contains well sorted fine-medium sands with layers of organic matter, which is most similar to deposits sampled in outer Keppel Bay. Core VC02 is also part of the Inner Bay group of cores, although it appears that *Turitella* muds are replaced by slightly coarser sediment, likely related to the formation of a nearby sand bank which is evident in chirper Line 13 (west; Figs. 12 and 13).

Outer and northern Keppel Bay

The northern region of Keppel Bay comprises sandy sediments with low percentages of mud and gravel (mainly cluster group 2; Fig. 5), moderate sorting, low $CaCO_3$, feldspar and organic carbon content and a low weathering ratio. This is likely remnant sand which has been considerably reworked; it is predominantly quartz with minor feldspar and lithics and therefore primarily terrigenous in origin. Cores from this region display fine to medium sands in their upper sections (Fig. 26). These sands include minor bioclastic material, however VC10 and VC06 are the only cores with a large proportion of biogenic carbonate which may be related to their close proximity to Great Keppel Island and Pelican Island respectively. Core VC10 is also situated in a channel which occurs just to the west of Great Keppel Island. The channel appears to be infilling from the east end only, as evident in chirper Line 6 (Figs. 12 and 14), with some sparse subaqueous dune features. It seems likely, therefore, that the silt and mud in the lower sections of VC10 may be of fluvial or estuarine origin. Cores VC13 and VC14 display the same type of silt and mud, interbedded with very fine sands, throughout the cores and are more similar to cores from inner Keppel Bay. Core VC13 sits in a partially infilled palaeo-channel, which is clearly evident in chirper Line 8 (Figs. 12 and 16). Many of the cores from the outer bay have silt and mud facies in their lower sections and it is plausible that these down-core variations in facies reflect depositional events produced by large fluvial discharge events. Some of these deposits may also have been emplaced as point bars in meandering channels that formerly cut across the floodplain during past periods of lower sea level. Core VC11 also shows some unique characteristics down-core, with a high percentage of mud and no carbonate. The grainsize distribution for the base of VC11 (Fig. 18) is most similar to the grainsize distribution in VC13 (2.02-2.05 m; Fig. 22) and VC20 (0.4-0.5 m; Fig. 23). This suggests that the base of core VC11 sits in a palaeo-river channel; a series of these channels is evident in chirper Line 25 (Figs 12 and 14). In the north, core VC08 displays typical well sorted fine to medium sands in the top of the core and in the lower section well sorted very fine sands with no carbonate. It appears that VC08 was extracted from a large dune that formed on the seabed which is evident in chirper Line 1 (Fig. 14).

Central and southern Keppel Bay

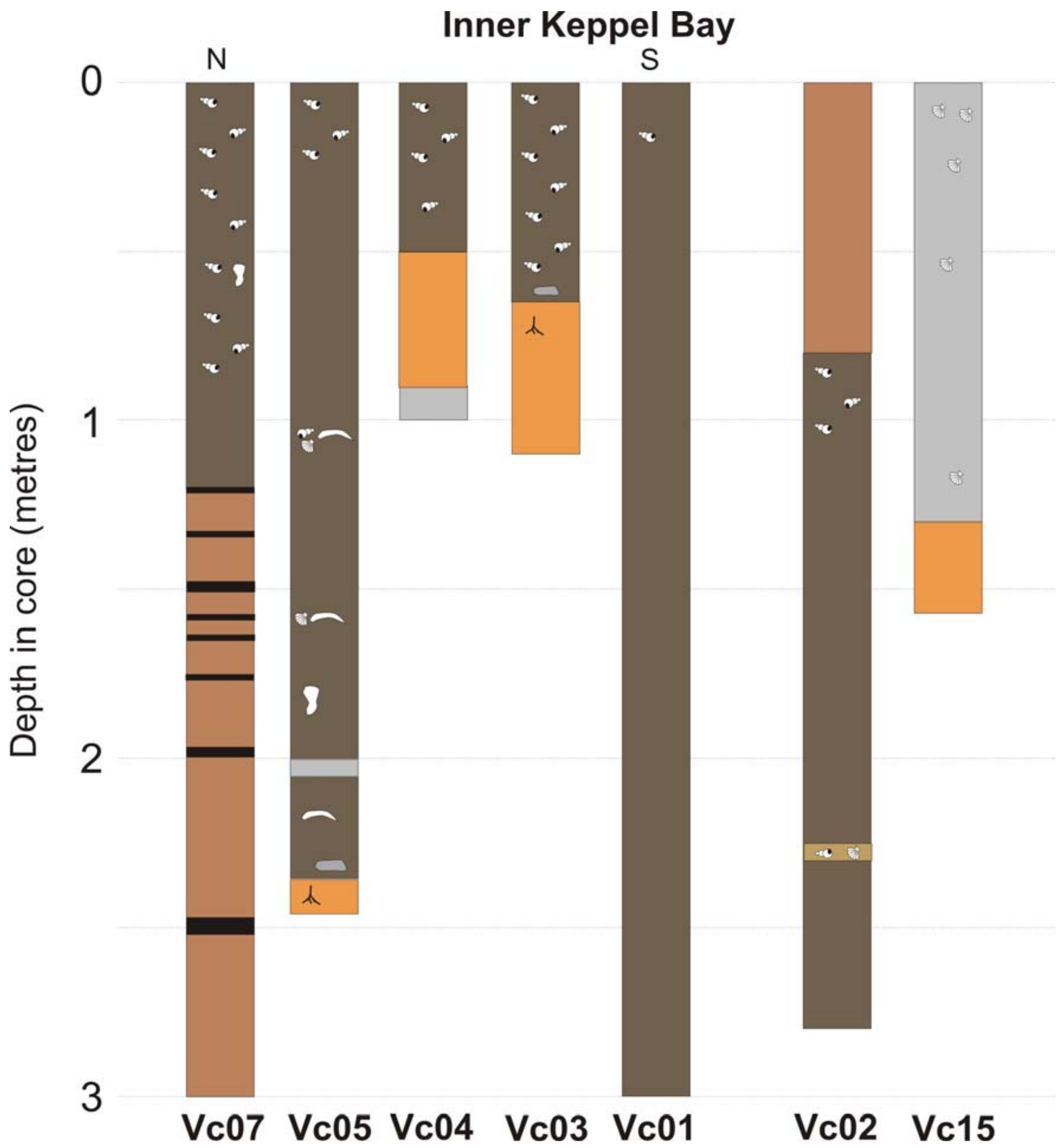
The central and southern parts of Keppel Bay are very dynamic with highly variable bathymetry, much of which is due to the presence of remnant channels (Fig. 25E). These remnant features and deposits explain the wide range of sedimentary facies evident in the vibracores. However, the region is dominated by well sorted, coarse skewed sediments with a large gravel component and low mud content (mainly cluster groups 2, 3 and 5). $CaCO_3$ composition is high (mainly reworked biogenic material), whereas feldspar content and Al_2O_3:K_2O ratios are low. The coarser grainsize and reworked fabric of the biogenic material reflects the highly energetic tidal currents in the region. There is considerable mixing of terrigenous rock fragments and quartz with marine material in this region. Core VC18 displays a medium to coarse sand with bioclasts and was collected in an area of seabed with asymmetric dunes as shown in chirper Line 16 (Figs. 12 and 15).

Cores VC17 and VC19 both comprise silt and mud in the top of the cores apparently derived from the Fitzroy estuary. A similar silt and mud facies is present down-core in VC18 but the upper section of the core comprises coarse bioclastic sand and appears to have been deposited as subaqueous dunes that were mobilised by longshore currents that moving from the south past Curtis Island. VC19, from Timandra Bank (chirper Line 22; Fig. 15) displays a similar coarse bioclastic facies which may also have been deposited as a subaqueous dune. At the base of VC19 there are well sorted very fine sands with organic rich layers, similar to the sands found in the base of VC07.

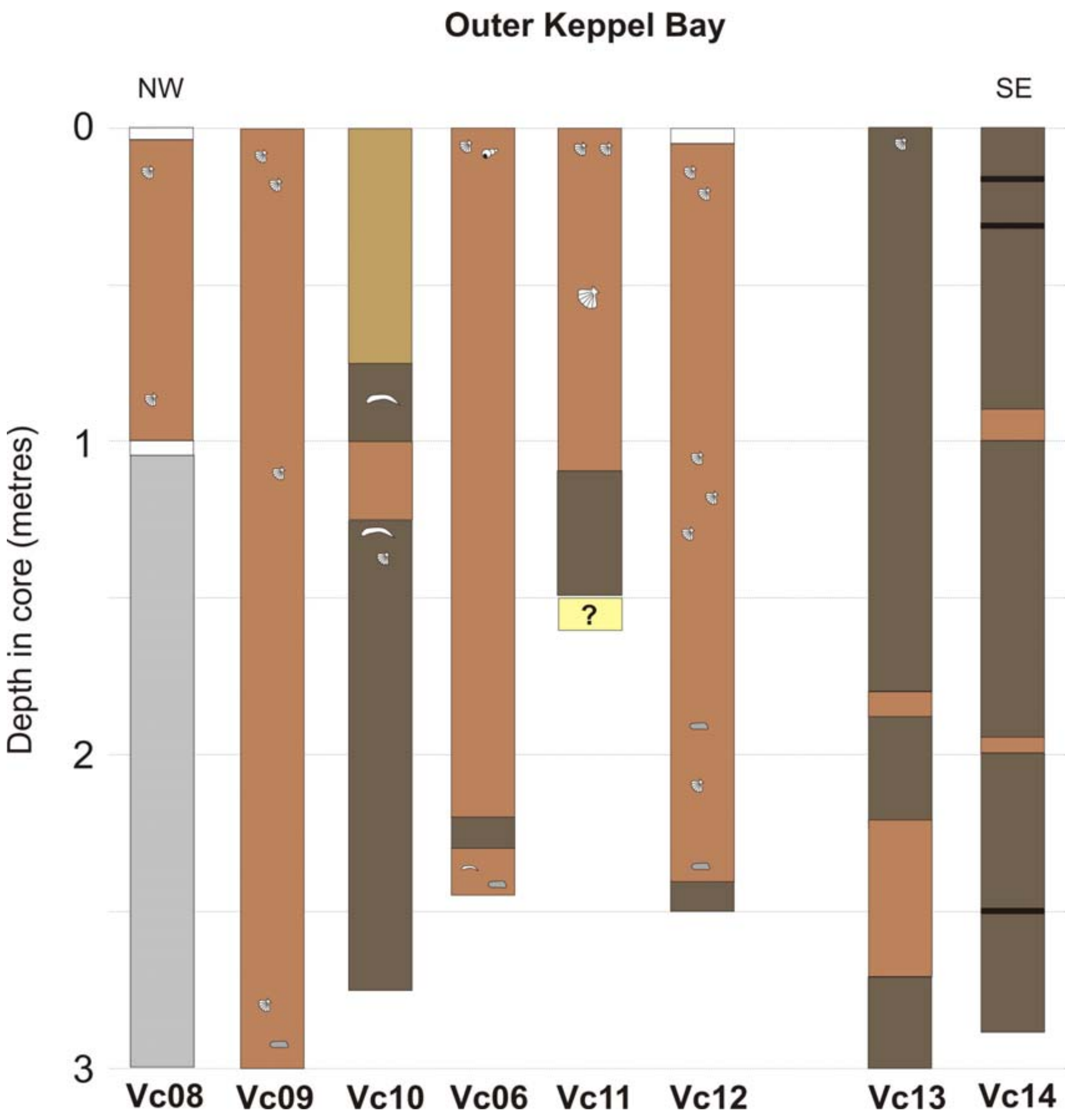
Many of these cores were extracted from channels (e.g. VC10, VC16), some of which have been partially infilled with marine sediment, however, other channels appear to be incising into the seabed. Core VC16 appears to be very coarse and contains little bioclastic material. In the lower section of this core there are gravelly beds with large rounded pebbles. This most probably represents a relict river channel deposit. From the chirper profiles it is evident that this channel is infilling from two different directions (Figs. 12 and 16).

Tidal and estuarine channels

This area of Keppel Bay is bathymetrically complex, but dominated by two major channels. The surface sediments have high mud and variable gravel components and typically feature high weathering ratios, organic carbon and feldspar and low $CaCO_3$. The large sand banks were not sampled but probably comprise sandy sediments given the strong tidal currents. The channels are characterised by thick, well bedded sediments, suggesting that they are the primary areas of sediment accumulation. Core VC20 contains a series of interbedded muds and fine sands in the top 40 cm, probably representing fluvial discharge events. Core VC17 was recovered from the eastern end of the more westerly of the tidal channels (chirper Line 24; Fig. 15), and displays very similar sedimentary facies to VC20, suggesting that VC17 is primarily composed of fluvial material from the Fitzroy River. Fine to medium sands are present at several intervals in both of these cores which also display relatively large proportions of biogenic carbonate material. The carbonate shell material may have been transported into the channel by the strong tidal currents, or may represents remnant deposits emplaced when there was a much reduced tidal flow in the channel. Small (20-30 cm amplitude) asymmetrical sediment dunes are common bedforms within the channels. Near the mouth of the estuary, the bed of the eastern channel appears to be erosional, with little bedding obvious. Very low density sediment, probably estuarine mud, occurs in the vicinity of Port Alma (chirper Line 12; Table 4).



Inner Keppel Bay
N
S
0
1
2
3
Depth in core (metres)
Vc07
Vc05
Vc04
Vc03
Vc01
Vc02
Vc15


Outer Keppel Bay
NW
SE
Depth in core (metres)
0
1
2
3
?
Vc08
Vc09
Vc10
Vc06
Vc11
Vc12
Vc13
Vc14

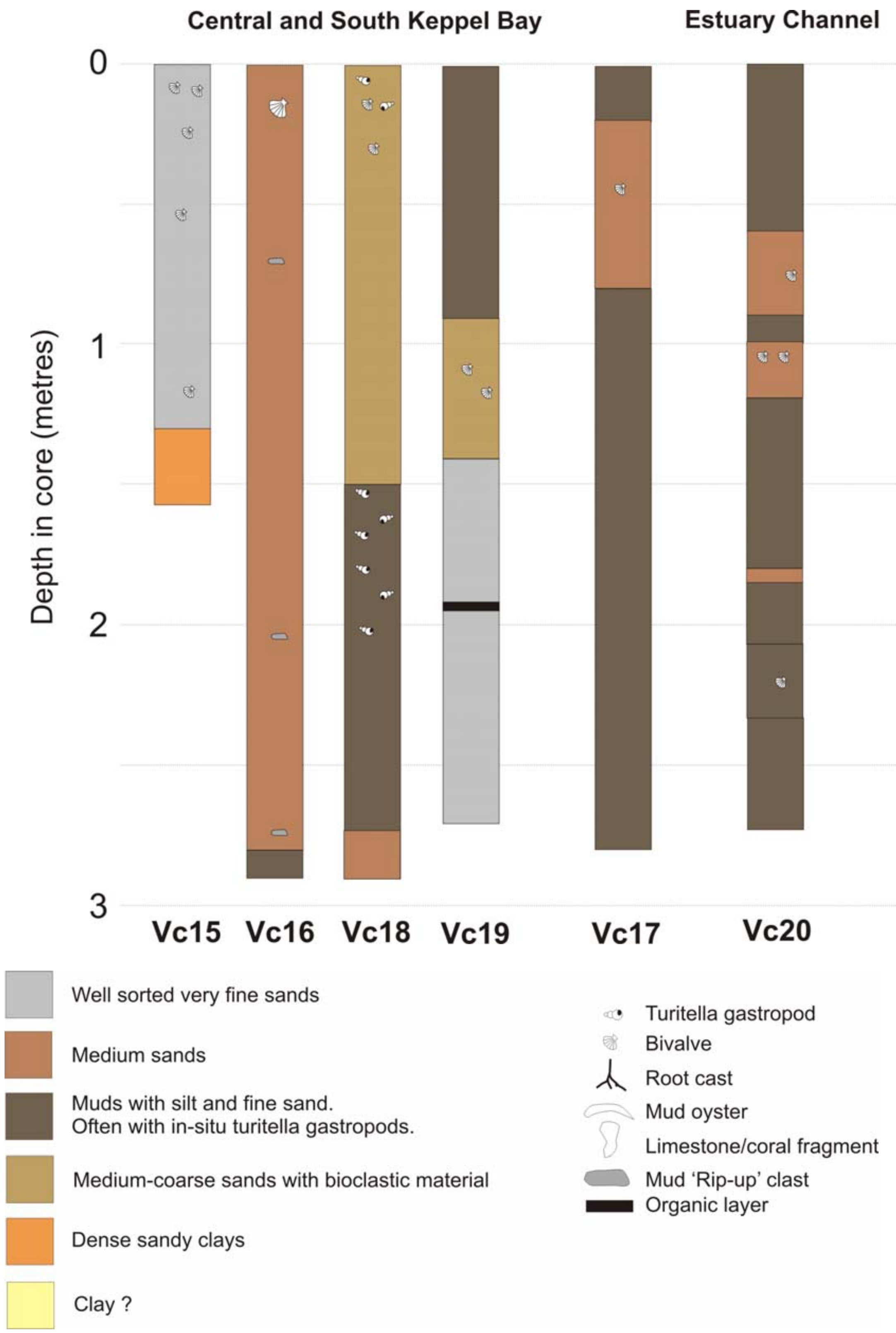


Figure 26: Lithological logs of vibracores collected in the different regions of Keppel Bay showing the similarities and variations in sediment types within and between the different zones. The key is the same as core logs in Figure 17.

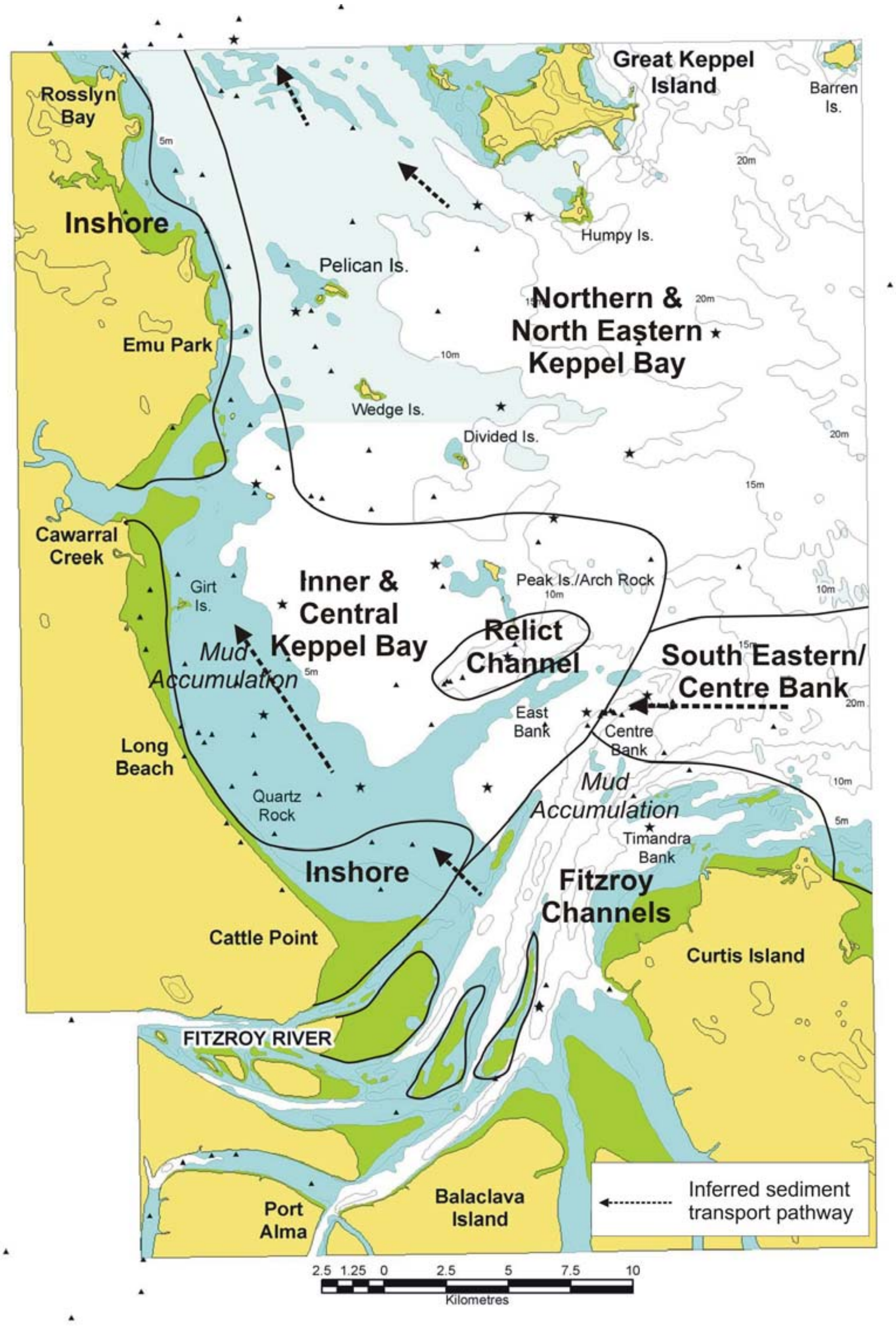


Figure 27: Map of sediment facies and depositional regions in Keppel Bay, showing sediment transport pathways and areas of fine sediment accumulation.

Discussion

RELICT RIVER CHANNELS

The present day seabed morphology of Keppel Bay exhibits many structures inherited from the ancestral Fitzroy River. During the Last Glacial Maximum (LGM), sea level was 120-130 m lower than the present level (Yokoyama et al., 2006), resulting in the Fitzroy River extending out across the exposed shelf. Maxwell (1968) originally suggested that during this last period of low sea level the Fitzroy River may have diverted its course northwards through Broad Sound. However, no evidence was found for this during a detailed stratigraphic study of Broad Sound by Cook and Mayo (1977). The new bathymetric map of Keppel Bay and the adjacent shelf (Webster and Petkovic, 2005) shows that a relatively deeply incised channel enters the Capricorn Channel between the exposed reefs of the Capricorn Bunker Group (Fig. 5). This was likely cut by the palaeo-Fitzroy River during the glacial low sea level period (Ryan et al., 2007b). Although deposits in this channel outside Keppel Bay were not sampled during the present study, Marshall (1977) reported a protuberance of muddy sediment with high proportions of quartz and terrigenous rock fragments bounded by carbonate-rich sediments on this part of the shelf. This deposit probably represents the reworked river channel or estuarine sediment fill associated with the palaeo-Fitzroy River. The bathymetric map of the shelf shows that the palaeo-Fitzroy River was highly sinuous as it flowed across the exposed shelf (Fig. 5) which implies the former coastal plain had a low-gradient of $<2°$ (Rosgen, 1994). The bathymetric expression of the palaeochannel does not extend to the shelf edge and appears to terminate in approximately 60 m water depth. There is no visible evidence to suggest the presence of an estuary at the termination of the channel. The depth of channel termination is very similar to palaeochannels mapped in Hervey Bay, which have cut to a base level of 64 m (Marshall, 1977). A similar phenomenon was noted by Fielding et al. (2003) for the Burdekin River, who suggested that incision into the Pleistocene land surface was less significant on the shelf break, and subsequently the thin river deposits below this level were removed by erosion during the marine transgression.

This study has obtained extensive additional evidence of the path of relict channels of the Fitzroy River further inshore, within the confines of the Keppel Bay study area. Numerous infilled channel features occur in inner Keppel Bay (parallel to the present shoreline), south of Peak Island, and offshore east of Divided Island (Fig. 12). The geometry of these channel features indicates that they probably represent pre- or early-Holocene pathways of the Fitzroy River. Cook and Mayo (1977) found similar palaeo-channels in Broad Sound using shallow seismic data. The channel features that occur in inner Keppel Bay run in a north-south direction and appear to be confined by the bedrock highs in the middle of the bay that presently includes Peak/Arch, Divided, Wedge and Pelican Islands. It is likely that these channel features represent a former reach of the river that ran parallel to the present Long Beach across the floor of a relatively flat bedrock-bounded valley. These channels appear to have extended offshore between East Bank and Centre Bank, or through the deep channel that occurs south of Peak Island and Arch Rock. These deeply scoured and partially infilled channels (e.g. Line 8; Fig. 12) most probably represent incisions made by the river during the LGM and continue to significantly influence the bathymetry and hydrodynamics of present-day Keppel Bay.

CONCEPTUAL MODEL OF HOLOCENE SEDIMENT ACCUMULATION

In Keppel Bay there are numerous bathymetric lows that have been infilled with fluvial sediments. In some cases the fill comprises gravel conglomerates with pebbles up to 2 cm (e.g. VC16; Appendix 5). Gravels were also found infilling palaeo-channels in Broad Sound and likewise interpreted to be fluvial in origin (Cook and Mayo, 1977). In other parts of Keppel Bay palaeo-channels have been filled with marine mud and silt (e.g. VC13). Based on vibracore samples, deposits in outer Keppel Bay contain very little mud as the majority of the sediments are well sorted fine-medium sands, however, mud has accumulated within the palaeo-channels. This suggests that throughout the Holocene a large percentage of the mud discharged by the Fitzroy River is transported back inshore, with the bathymetric depressions formed by palaeochannels representing quiescent sites in the outer bay where mud can be deposited. Many of the relict channels in the outer bay are not completely infilled, which indicates that very little marine sediment has accumulated in the northern and outer sections of Keppel Bay during the Holocene.

In contrast, the majority of palaeo-channels in inner Keppel Bay have been filled and the channel structures and surrounding seabed covered with a veneer of modern sediment. A northward-thinning wedge of modern sediment caps the incised former floodplain surface, ranging from over 10 m thickness in the south (proximal to the mouth of the Fitzroy River) to approximately 2 m in the north (Fig. 13).

In the southeast of Keppel Bay, large scale dune bedforms are evident in the chirper profiles and vibracores. These subaqueous dunes are composed of terrigenous quartz sand and rock fragments mixed with a large proportion of reworked marine carbonate (e.g. VC18; Fig. 26). This type of sediment was originally identified by Marshall (1977) who described it as mixed marine and terrigenous in a sediment classification scheme developed for the shelf in this region. The majority of the sediment appears to be relict and considerably reworked. We suggest that the carbonate content is derived from the mid- to outer continental shelf and reworked by the prevailing southeasterly wind and waves and associated longshore currents. The relatively large dune bedforms in areas such as Centre Bank (Fig. 15; Line 24) indicate that these deposits are being transported into the region and accumulating in the southeast of Keppel Bay. However, sediment dunes may also be relict features, especially in deeper water (>10 m), that were transported onshore from the shelf during a past phase of slightly lower sea level or a past climatic phase in which there was enhanced wind and wave regimes. If this is the case, then at present these bedforms are only being surficially reworked by tidal currents. Another possible transport mechanism is the mobilisation of the large bedforms, especially in the deeper water, during cyclonic storms which pass over or adjacent to this coast on average once every two years (Beach Protection Authority, 1979). Dating the sediment within these dunes (e.g. in VC18), or monitoring the position of the dunes using acoustic methods, is required to better understand longer-term sediment transport and accumulation in this region.

Based on our investigation of the stratigraphy of Keppel Bay and the stratigraphic data obtained from cores recovered from the Fitzroy River lower floodplain (Bostock et al., 2007), we have developed a preliminary conceptual model of the Holocene evolution of Keppel Bay (Figs. 28 - 29).

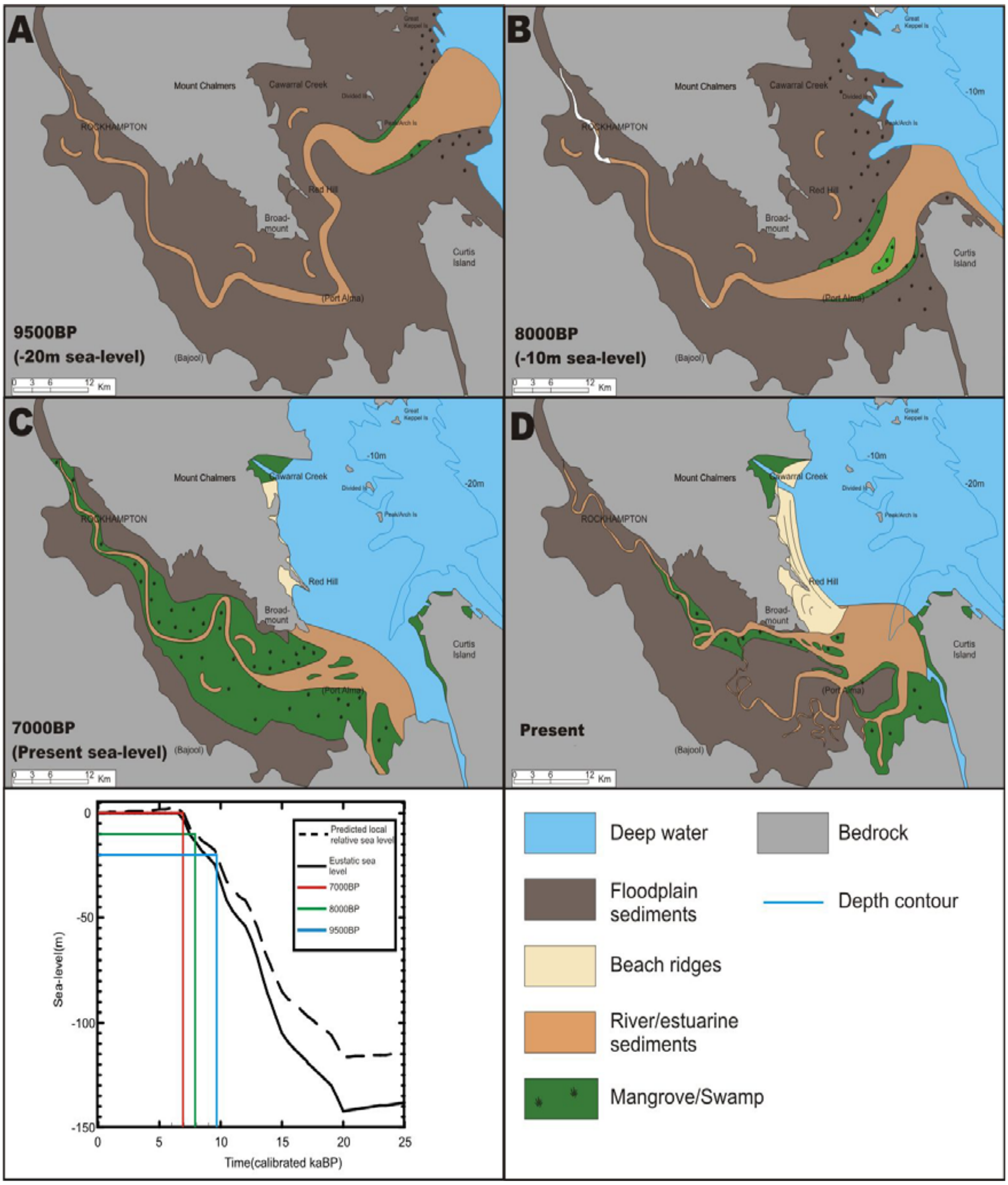


Figure 28: Conceptual model of the Holocene evolution of Keppel Bay. The sea-level curve for Capricorn Channel is from Yokoyama et al. (2006).

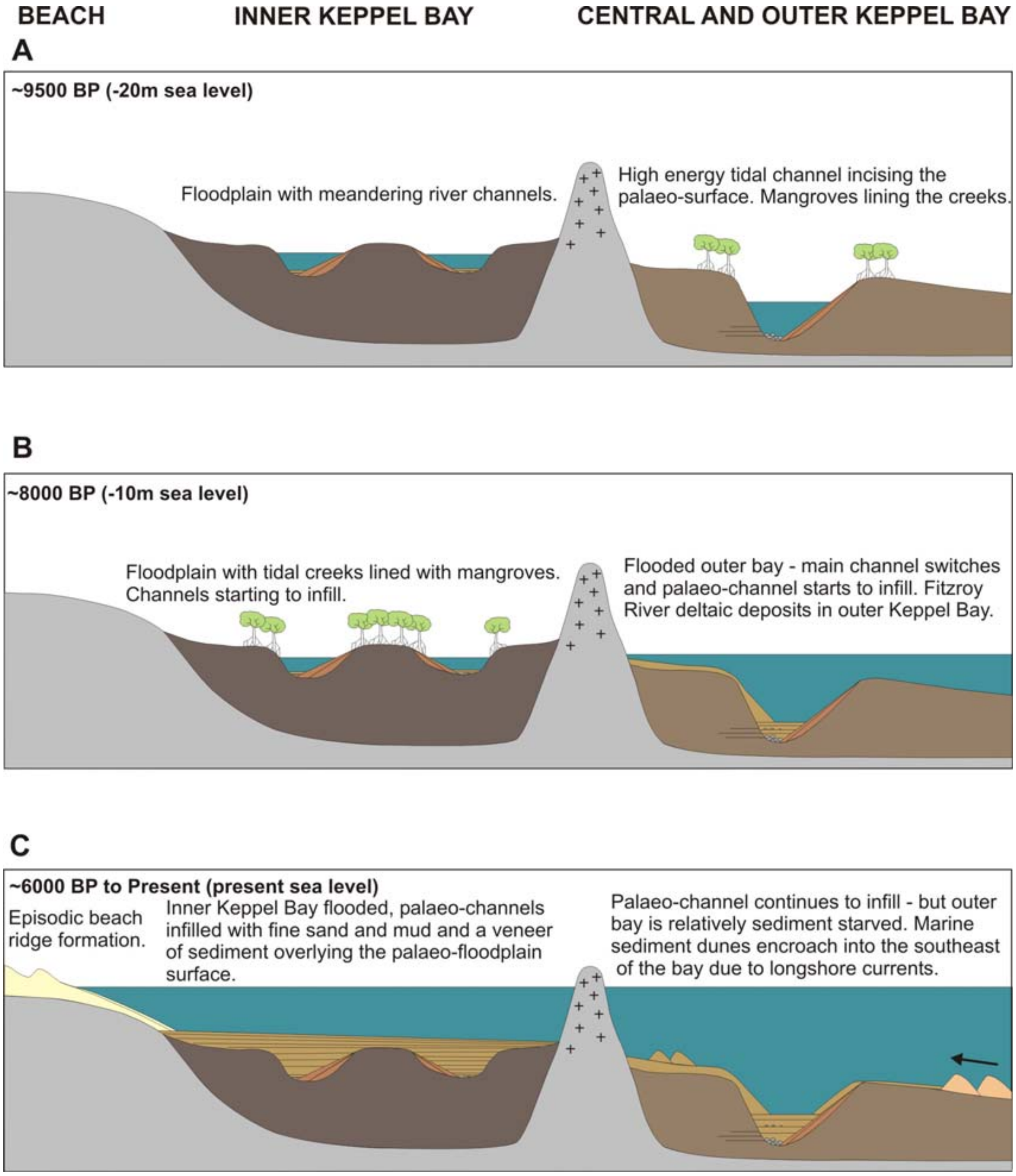


Figure 29: Schematic cross section diagrams that show changes in sedimentation in Keppel Bay during the Holocene, as displayed in plan-form in Figure 28. A) ~9000 yrs BP (-20m sea level) both inner and outer Keppel Bay are exposed and meandering river channels and tidal creeks incise the land surface. B) ~8000 yrs BP (-10m sea level) flooding of outer Keppel Bay, while the inner bay is tidally influenced and colonized by mangroves. C) Sea level at present day levels. The whole of Keppel Bay is flooded and inner Keppel Bay is filled with river muds. There is migration of coarse sediment dunes with high bioclastic content into the southeast of the region by advection. Beach ridges are deposited north of the river mouth and build out the coastline.

Prior to the commencement of the postglacial marine transgression (18,000 – 10,000 yrs ago) the Fitzroy River extended across the continental shelf. The river cut into the older sediments in the area, forming the deep north-east trending channels that are still evident in Keppel Bay south of Peak Island, and between East Bank and Timandra Bank. Figure 28a shows the Fitzroy River and Keppel Bay during the marine transgression at approximately 9500 years before present, when sea level was approximately 20 m below present (Yokoyama et al., 2006). The area occupied by the modern Fitzroy River estuary and floodplain were at this time terrestrial environments where alluvial sediments accumulated. The path of the Fitzroy River probably meandered across the floodplain, including what is now the inner section of Keppel Bay, forming the relict river channels mapped in this study. The estuarine muds in the base of the cores from inner Keppel Bay (e.g. VC13 and VC14; Fig. 26) show that a transgressional estuary (or drowned valley) developed where the river met the rising shoreface.

Approximately 8000 years before present, when sea level reached 10 m below the present level, the mouth of the estuary is likely to have retreated towards its current location, to the south of East Bank (Fig. 28b). Alluvial sedimentation continued on the floodplain, whereas estuarine sedimentation and the development of mangrove environments may have been limited due to the rapid pace of the transgression at this time (Yokoyama et al., 2006). Around 7000 years before present (Figs. 28c and 29c), sea level reached its current level and the formerly exposed inner Keppel Bay was flooded. A large proportion of the modern lower floodplain may also have flooded but then rapidly filled up with extensive estuarine and mangrove deposits (Bostock et al., 2007), similar to the 'Big Swamp' phase of estuary evolution that has been identified for macrotidal estuaries in northern Australia (Woodroffe et al., 1985; Woodroffe et al., 1989; Woodroffe and Chappell, 1993). Estuarine sediments of this age extend slightly inland of the present site of Rockhampton (Bostock et al., 2007). At this time the mouth of the estuary likely retreated to a point inland of its current position.

Between 7000 years ago and the present day (Fig. 28d), rapid vertical accumulation and channel avulsion has occurred, converting much of the former estuarine area into a terrestrial floodplain. The modern Fitzroy River estuary has now evolved towards being a delta rather than estuary because the majority of the 'accommodation space' for sediment has been filled in (e.g. Ryan et al., 2003). During this time, sand deposited in Keppel Bay has also been transported onshore to form an extensive strandplain behind Long Beach (Brooke et al., submitted). These extensive relict coastal deposits indicate that much of the coarser sediment deposited in Keppel Bay by the Fitzroy River is mobilized across and along the bay and into the beach zone, rather than accumulating in the bay or further offshore.

MODERN SEDIMENT TRANSPORT IN KEPPEL BAY

Keppel Bay contains both coarse (bedload) sediment, and a proportion of the fine fraction of material deposited by the Fitzroy River (suspended sediment and nutrient inputs into and out of Keppel Bay have been examined in Radke et al., 2005). A comprehensive study of the modern sediments and hydrodynamics of the southern Queensland coast including Keppel Bay was undertaken by the Queensland Government between 1976 and 1978 (Beach Protection Authority, 1979). The study found that large volumes of quartzose sand eroded from the Fitzroy River catchment are transported into Keppel Bay during flood events, approximately 450,000 m^3 yr^{-1} (median grain size 150 µm). This sediment is reworked northwards and onshore by advection which is the result of the combined effects of local waves and tidal currents on seabed sediments. Cyclones can induce short periods of shoreline erosion from which the coast quickly recovers under normal atmospheric and marine conditions. Extensive beach-ridge deposits indicate there has been a long-term positive sediment supply to the bay from the Fitzroy River (Brooke et al., submitted).

The modern sediment transport pathways from the Fitzroy River identified in this study, inferred from the results of the analyses of surface sediment distribution, bedform geometry and satellite images of bedforms, builds on the work of the Beach Protection Authority (Fig. 27). The river sediments appear to be accumulating rapidly in the mouth of the estuary in the form of muddy channel-fill deposits and sandy islands stabilised by mangroves (Duke et al., 2003; Fig. 30) and in tidal creeks, as seen in core FK413A (Bostock et al., 2007). Sand bars in the mouth of the estuary have grown significantly since 1941 (Fig. 30; Duke et al., 2003). In Keppel Bay, large-scale bedforms in the southeast (e.g. Centre Bank; Fig. 15) and north (east of Great Keppel Island; Fig. 31) indicate the direction of movement of sand into the bay from the southeast and out of the bay to the north.

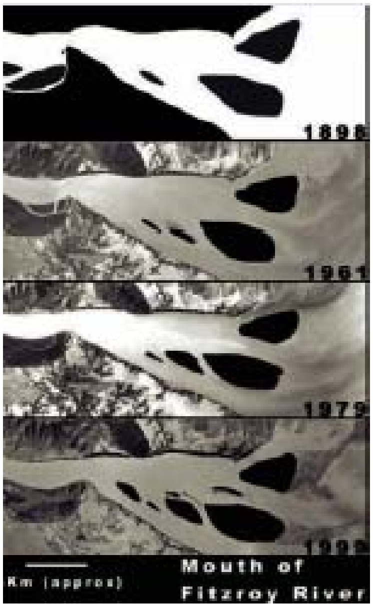


Figure 30: Shallow banks near the mouth of the Fitzroy River have stabilised and grown in the last 50 years to form low islands and stands of mangrove (Duke et al., 2003).

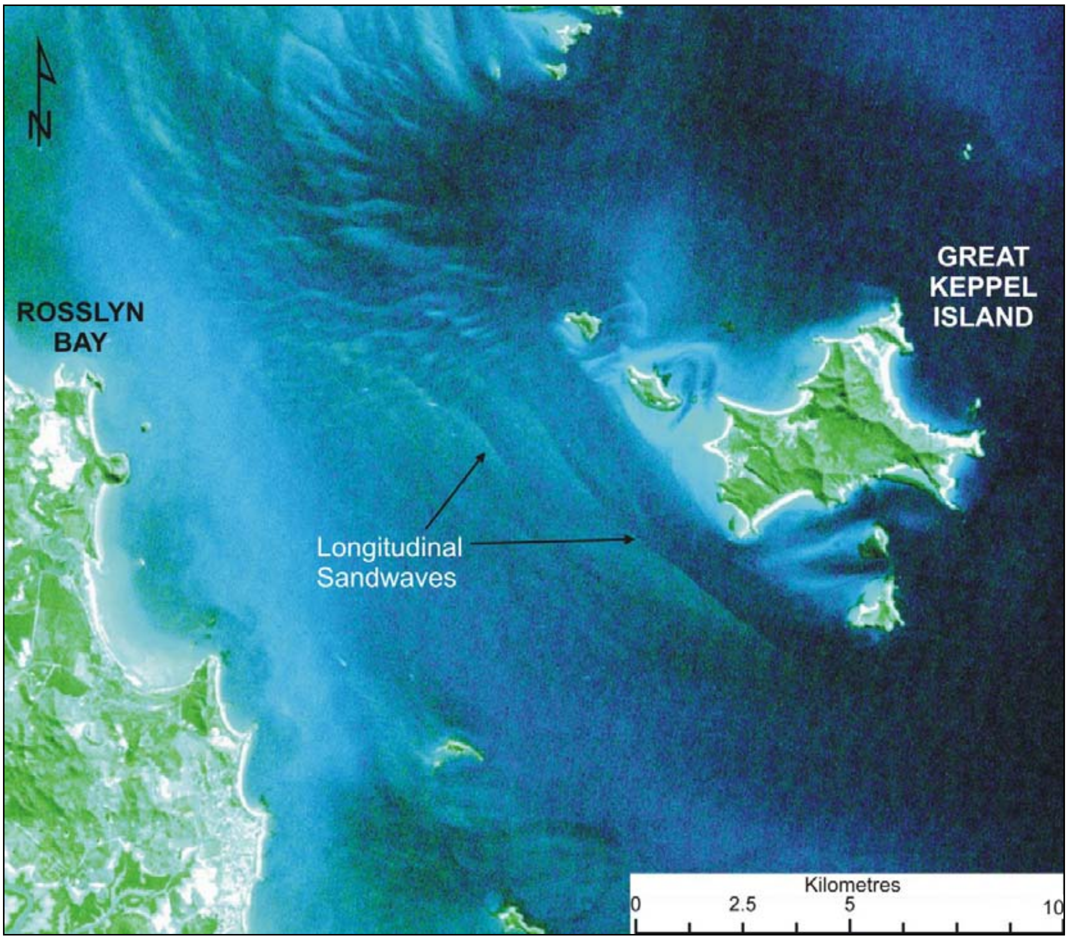


Figure 31: Landsat ETM+ image with blue and green band enhancement, showing longitudinal subaqueous dunes situated to the west of Great Keppel Island, Keppel Bay. The image was acquired 24/5/2003.

The interbedded mud and silt layers in the top of VC20, in the eastern most tidal channel, suggest that there are cycles of sediment deposition, most likely related to flood events. Much of this fine sand and mud is transported northwest into inner Keppel Bay where some of it is has accumulated with marine carbonate sediment (Figs 9 and 26). Fine sand is also being transported and sorted along and onto Long Beach, where it is accumulating in extensive intertidal and shallow subtidal flats and onshore as beach ridges and dunes (Brooke et al., submitted).

Muddy sediments are primarily restricted to inner and southern Keppel Bay and within some channels in the estuary. Terrigenous mud and sand is initially discharged into the bay but a large proportion of the fines are rapidly reworked by tidal currents and waves and transported further along the coast, into beach deposits and out of the northern bay as suspended sediment. This is similar to sedimentary processes in the Burdekin River estuary, whereby sediments in Bowling Green Bay are transported by northward longshore currents into Cleveland Bay (Orpin et al., 1999). In addition to the estuary, significant sites of fine sediment accumulation in Keppel Bay are the muddy zone in the inner-central section of the bay (Fig. 9), and bathymetric lows formed by relict channels in the middle and outer bay.

The outer bay presently appears to be largely sediment starved, and is characterised by well-sorted relict sediments. The low sediment accumulation in this area is also indicated by palaeo-channels that lack any significant accumulations of modern sediment. There may be some influx of mixed marine biogenic-terrigenous sediment into the southeast section of Keppel Bay by longshore transport from the south and east of Cape Keppel. If the dunes mapped in this area are modern bedforms, tidal currents and waves are currently transporting these reworked sediments from the Centre Bank area west towards the inner bay.

The present pattern of sedimentation in the Keppel Bay region fits previously published depositional models for a proximal terrigenous source and an indented depositional mainland coast adjacent to the GBR (Neil et al., 2002). These models depict a terrigenous sediment wedge that is thickest immediately downdrift of the river or major sediment source, with additional accumulations of sediment in northward facing, quiescent embayments further downdrift.

Conclusions

Keppel Bay is a complex depositional environment that is significantly influenced by the Holocene rise in sea level, antecedent geomorphology, relict fluvial deposits and strong tidal currents. With the rise in sea level during the early Holocene the mouth of the Fitzroy River retreated across the shelf and by the middle Holocene it was landwards of its present location, towards Rockhampton. During the last few thousand years under a relatively stable sea level, much of the shallow inner region of Keppel Bay has been infilled and the coast plain has prograded.

Seabed morphology, sub-bottom profiles and sediment cores reveal the former path of the Fitzroy River across Keppel Bay and the adjacent continental shelf. The palaeo-Fitzroy River flowed west across the shelf to the north of Northwest Reef, to a position on the shelf that is now in approximately 60 m of water. Palaeo-channels were mapped in both the outer and inner sections of Keppel Bay. In the outer bay and on the shelf further west many of these relict channels have not been infilled with marine sediment, indicating these areas are relatively starved of sediment. Sediments in outer Keppel Bay are dominantly relict fluvial quartzose sediments that are well sorted with only a minor mud component. Subaqueous dunes in the outer southeastern section of Keppel Bay and Centre Bank indicate that tidal currents and currents generated by the predominant southeasterly winds appear to be transporting marine biogenic sediments and coarse terrigenous sediments into Keppel Bay. Palaeochannels in the inner section of Keppel Bay have mostly been filled in and covered over with beds of muddy sand derived from the Fitzroy River and marine bioclastic sand and gravel.

Fine sediment is presently accumulating in the mouth of the estuary where muddy sand bars have recently formed and have been colonised by mangroves. Accumulation of fine sediment currently occurs within the estuary, in the deep relict channels of southern Keppel Bay, and adjacent to Long Beach in central Keppel Bay. Some accumulation of fines also occurs within palaeo-channel depressions. The thickest accumulation of Holocene and modern sediment occurs in the south of the inner bay, with the sediment wedge thinning to the north away from the mouth of the estuary.

The distribution of modern sediments in Keppel Bay indicates that river sediment is deposited by the Fitzroy River in the mouth of the estuary and in the southern section of the bay. The coarser sediment is subsequently reworked by advection to the north and onshore, where it accumulates in dunes and beach deposits.

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Appendix

APPENDIX 1 – SORTING, SKEWNESS, AND KURTOSIS PARAMETERS

Sorting, skewness and kurtosis parameters, after the modified geometric Folk and Ward (1957) method (Blott & Pye, 2001).

SORTING		SKEWNESS		KURTOSIS	
Very Well Sorted	< 1.27	Very Fine Skewed	-1.0 to -0.3	Very Platykurtic	< 0.67
Well Sorted	1.27 to 1.41	Fine Skewed	-0.3 to -0.1	Platykurtic	0.67 to 0.90
Mod. Well Sorted	1.41 to 1.62	Symmetrical	-0.1 to +0.1	Mesokurtic	0.90 to 1.11
Mod. Sorted	1.62 to 2.00	Coarse Skewed	+0.1 to +0.3	Leptokurtic	1.11 to 1.50
Poorly Sorted	2.00 to 4.00	Very Coarse Skewed	+0.3 to +1.0	Very Leptokurtic	1.50 to 3.00
Very Poorly Sorted	4.00 to 16.00			Extremely Leptokurtic	> 3.00
Extremely Poorly Sorted	>16.00				

Appendix 2 – Geochemical and Sieve Grainsize Data

Sample Data (WGS84)			Geochemistry and Sieve Grainsize Data							
Sample	**LongX**	**LatY**	**%CaCO3**	**Al2O3/K2O**	**TOC (mmol/g)**	**%Feldspar**	**%Quartz**	**%Mud**	**%Gravel**	**%Porosity**
fk_01_ss	150.561917	-23.385933	1.0	4.886	0.051	10.800	85.600	7.803	1.343	40.723
fk_02_ss	150.627483	-23.478117	1.0	3.206	0.006	10.000	88.000	0.070	3.750	38.867
fk_03_ss	150.768150	-23.505350	1.0	3.161	0.006	9.300	87.200	0.192	0.786	41.113
fk_05_ss	150.895367	-23.540700	2.0	8.980	0.452	21.700	63.900	82.379	0.000	76.758
fk_09_ss	151.156250	-23.418350	41.0	4.690	0.063	11.800	60.000	8.614	8.062	52.246
fk_10_ss	151.045950	-23.402700	13.0	5.634	0.160	25.300	60.200	22.445	0.043	59.961
fk_11_ss	150.990600	-23.427033	12.0	4.021	0.030	27.000	59.300	2.744	0.000	59.668
fk_15_ss	150.897833	-23.385550	25.0	7.379	0.234	23.400	42.000	48.446	7.859	76.367
fk_18_ss	151.116900	-23.319850	10.0	3.198	0.018	13.700	77.700	0.312	0.946	45.410
fk_21_ss	150.861583	-23.566183	3.0	9.470	0.478	19.600	61.900	74.809	1.704	53.613
fk_22_ss	150.822433	-23.555467	7.0	4.407	0.060	14.000	78.600	2.305	8.111	54.102
fk_23_ss	150.793900	-23.604483	3.0	9.878	0.501	23.000	63.400	91.777	0.000	65.918
fk_24_ss	150.740950	-23.589083	11.0	9.068	0.392	11.200	63.900	56.166	6.735	67.578
fk_26_ss	150.720700	-23.570750	3.0	8.895	0.425	33.600	55.200	96.249	0.069	80.176
fk_30_ss	150.952300	-23.501833	22.0	5.020	0.047	10.800	64.800	3.911	37.368	48.145
fk_32_ss	150.951767	-23.365117	17.0	5.814	0.154	16.900	66.400	23.262	3.337	62.988
fk_34_ss	150.834567	-23.344933	9.0	7.996	0.253	32.400	53.100	82.373	0.824	57.129
fk_35_ss	150.889017	-23.321592	24.0	3.721	0.020	11.900	68.000	0.906	3.042	45.020
fk_38_ss	150.867900	-23.262300	16.0	3.802	0.019	20.800	58.100	1.731	0.931	55.957
fk_40_ss	150.995083	-23.262683	3.0	3.226	0.018	9.500	88.100	0.493	0.470	50.488
fk_42_ss	151.094017	-23.242717	12.0	3.336	0.029	16.600	75.500	0.891	3.615	48.047
fk_44_ss	150.838533	-23.170950	5.0	3.122	0.019	9.100	76.800	0.326	0.040	45.313
fk_45_ss	150.794967	-23.152017	25.0	5.279	0.057	14.800	56.400	12.988	10.587	58.594
fk_46_ss	150.807967	-23.143800	14.0	5.797	0.102	10.300	75.900	9.033	4.191	57.227
fk_48_ss	150.910967	-23.105067	5.0	3.238	0.012	7.400	88.700	3.211	0.679	41.211
fk_50_ss	151.041150	-23.070967	21.0	3.545	0.023	10.000	74.400	0.654	12.094	39.355
fk_51_ss	150.980983	-23.085483	7.0	3.171	0.015	11.900	83.300	0.375	0.090	48.145
fk_52_ss	150.902783	-23.110000	5.0	3.294	0.014	6.000	88.300	0.326	0.540	51.270
fk_53_ss	150.882033	-23.121667	3.0	3.476	0.013	5.400	90.000	0.232	0.254	43.750
fk_55_ss	150.861500	-23.133833	7.0	3.100	0.012	11.000	79.300	0.239	0.296	44.434
fk_56_ss	150.839850	-23.142983	7.0	3.381	0.025	16.300	75.000	3.097	0.259	52.051
fk_57_ss	150.816733	-23.148700	8.0	3.399	0.019	11.400	83.200	0.994	0.615	49.023
fk_58_ss	150.805150	-23.151800	16.0	5.183	0.068	11.300	71.800	15.319	7.445	54.590
fk_59_ss	150.824583	-23.199367	16.0	4.594	0.035	13.500	67.400	9.707	1.702	61.426
fk_60_ss	150.840850	-23.256350	9.0	3.600	0.014	6.600	84.700	2.074	5.436	40.723
fk_61_ss	150.843267	-23.315183	14.0	5.194	0.065	15.400	73.400	10.573	2.395	53.125
fk_62_ss	150.838567	-23.366633	22.0	6.427	0.140	21.100	52.800	34.261	5.406	57.324
fk_63_ss	150.832683	-23.421567	2.0	9.940	0.579	21.000	58.200	96.081	0.000	78.613
fk_64_ss	150.841450	-23.402967	12.0	6.795	0.176	26.200	49.600	46.746	0.412	68.750
fk_65_ss	150.855667	-23.375633	17.0	7.117	0.182	22.500	60.600	46.599	5.293	64.453
fk_66_ss	150.862117	-23.346233	27.0	6.943	0.151	21.000	50.800	37.934	9.828	74.316
fk_67_ss	150.869767	-23.317567	10.0	4.077	0.025	0.000	0.000	1.553	4.724	41.992
fk_68_ss	150.873983	-23.271250	17.0	3.982	0.018	10.700	74.700	0.910	0.446	43.164
fk_69_ss	150.866550	-23.249267	13.0	3.574	0.010	16.400	73.600	0.138	1.224	42.480
fk_70_ss	150.857550	-23.232533	6.0	3.890	0.030	17.800	78.300	2.902	0.000	48.242
fk_71_ss	150.826083	-23.219767	16.0	5.862	0.131	22.900	59.600	27.397	4.954	58.789
fk_72_ss	150.814183	-23.197550	23.0	5.287	0.077	26.200	49.800	16.386	5.337	69.141
268/fk_1_85	150.852567	-23.306058	6.0	3.677	0.031	2.900	89.400	2.015	5.904	36.098
268/fk_2_98	150.841833	-23.416925	12.1	6.817	0.132	16.300	66.700	52.752	3.500	51.707
268/fk_3_110	151.012667	-23.417892	11.1	4.912	0.094	17.600	74.100	5.280	0.320	51.317
268/fk_4_119	151.033117	-23.344350	10.1	5.195	0.087	14.700	78.400	13.963	0.386	47.902
268/fk_5_120	150.998633	-23.341350	13.1	6.045	0.137	17.900	68.500	18.509	0.600	55.610
268/fk_6_121	150.954483	-23.334467	14.1	5.859	0.125	15.700	71.400	16.915	9.320	57.756
268/fk_7_122	150.913717	-23.317450	19.2	6.102	0.096	10.300	68.800	17.076	10.119	58.244
268/fk_8_123	150.888400	-23.300217	8.5	4.145	0.017	11.000	83.500	1.150	4.166	36.488
268/fk_9_124	150.841917	-23.290350	6.0	5.944	0.136	26.800	69.100	1.451	0.440	49.854
268/fk_10_125	150.931967	-23.227683	3.0	3.059	0.023	9.000	90.600	0.076	2.520	35.805
268/fk_11_126	150.883967	-23.183217	3.5	3.036	0.035	7.200	92.600	0.045	0.842	36.585
268/fk_12_127	150.834350	-23.232875	9.6	5.349	0.068	15.300	74.800	10.358	5.547	55.122

268/fk_13_128	150.834433	-23.281167	7.0	4.047	0.027	25.800	75.300	0.728	0.012	46.439
268/fk_14_129	150.813017	-23.399533	6.0	8.037	0.243	31.200	59.600	53.992	13.854	64.098
268/fk_15_130	150.819833	-23.401833	9.1	6.306	0.117	29.800	66.500	27.664	12.402	55.707
268/fk_16_131	150.825117	-23.402583	10.1	5.667	0.071	21.300	70.900	31.412	4.859	63.122
268/fk_17_132	150.865200	-23.453200	5.0	4.635	0.050	28.900	76.400	12.393	0.000	44.195
268/fk_18_133	150.903233	-23.443700	4.5	4.669	0.029	31.600	73.400	2.703	0.036	48.000
268/fk_19_134	150.911433	-23.400217	19.2	7.312	0.188	28.900	54.200	4.248	1.995	51.902
268/fk_20_135	150.865500	-23.316583	5.5	3.450	0.025	16.200	88.500	0.797	0.213	37.463
268/fk_21_136	150.832533	-23.169000	4.0	3.367	0.025	17.800	86.000	0.328	0.113	37.756
268/fk_22_137	150.880033	-23.139133	12.1	3.405	0.019	12.500	83.300	1.202	0.911	37.366
268/fk_23_138	150.944117	-23.119267	5.5	3.262	0.027	17.700	87.000	0.519	0.103	36.293
268/fk_24_139	151.005917	-23.121267	7.0	3.212	0.031	16.600	85.200	0.931	2.044	38.537
268/fk_25_140	151.005767	-23.137400	10.1	3.534	0.042	20.300	79.500	1.230	0.147	38.927
268/fk_26_141	150.956083	-23.400633	9.6	6.792	0.130	23.700	74.800	21.724	9.220	64.293
268/fk_27_151	150.972833	-23.401317	4.0	6.648	0.166	34.300	71.700	47.476	0.071	55.220
268/fk_29_162	150.955067	-23.495383	12.1	6.877	0.158	19.200	67.900	26.657	22.629	61.561
268/fk_30_165	150.934633	-23.528917	3.0	7.360	0.220	26.500	73.500	33.430	0.076	56.780
268/fk_31_183	150.832067	-23.555117	2.0	3.554	0.033	16.500	87.200	1.063	0.036	39.707
268/fk_32_187	150.811133	-23.557725	2.0	7.399	0.200	21.300	79.700	33.546	16.758	60.390
268/fk_33_188	150.797682	-23.577005	0.9	3.372	0.032	24.200	83.200	1.098	0.053	37.561
268/fk_34_189	150.794912	-23.592707	0.0	7.645	0.255	30.600	72.400	47.245	0.158	62.829
268/fk_35_190	150.766322	-23.613557	19.2	8.861	0.393	19.500	43.500	42.333	25.397	63.122
268/fk_36_191	150.708302	-23.580157	0.0	4.633	0.245	27.600	80.500	4.819	1.082	44.878
268/fk_37_192	150.696380	-23.580758	0.0	9.782	0.500	44.500	58.100	79.146	0.827	72.195
268/fk_38_193	150.916717	-23.350100	22.2	5.053	0.063	22.400	58.800	10.392	14.301	45.951
268/fk_39_194	150.916350	-23.250050	21.7	6.105	0.090	20.000	64.000	7.456	8.973	44.976
268/fk_40_195	150.883300	-23.217200	10.1	3.459	0.032	20.300	80.300	19.476	4.646	39.122
277/fk_vc01_196A	150.933260	-23.423220	9.6	4.906	0.056	24.200	75.500	4.789	2.912	45.854
277/fk_vc02_197A	150.883100	-23.422470	3.5	3.770	0.069	23.500	81.800	0.435	0.000	39.805
277/fk_vc03_198A	150.845700	-23.395750	14.1	6.541	0.011	31.700	60.700	38.267	7.716	60.878
277/fk_vc04_199A	150.853850	-23.356030	24.8	6.909	0.211	29.900	51.300	27.592	14.515	55.512
277/fk_vc05_200A	150.843990	-23.311770	10.1	4.282	0.037	27.500	71.600	6.273	6.275	51.805
277/fk_vc06_201A	150.860500	-23.249450	7.0	3.827	0.019	27.200	79.500	0.081	0.054	40.780
277/fk_vc09_202A	150.932460	-23.211840	8.0	3.319	0.027	24.300	81.600	1.758	2.012	37.268
277/fk_vc13_203a	150.990910	-23.302570	18.2	4.655	0.086	26.400	66.800	4.636	4.089	48.780
277/fk_vc17_204A	150.972520	-23.396450	5.0	6.509	0.163	31.700	72.500	29.691	3.118	50.829
277/fk_vc20_205A	150.951920	-23.503200	4.0	7.873	0.220	34.200	67.100	69.018	1.312	56.195
KB32A	150.887360	-23.442610	4.0	4.597	0.028	29.100	76.800	2.999	0.013	39.317
KB33A	150.851810	-23.459330	5.0	4.299	0.022	36.600	69.900	2.881	0.259	44.000
KB34A	150.849050	-23.439010	14.1	5.555	0.055	39.700	57.000	31.775	0.058	44.585
KB35A	150.866860	-23.424800	10.6	7.435	0.201	30.900	61.500	37.875	2.083	60.976
KB36A	150.822030	-23.405370	7.0	6.955	0.156	33.700	62.300	47.851	1.088	68.878
KB37A	150.814900	-23.376850	6.0	6.321	0.124	28.300	71.900	25.737	11.871	63.805
KB38A	150.835300	-23.384120	12.1	7.116	0.155	32.500	59.300	40.707	5.757	66.244
KB39A	150.812660	-23.344230	4.5	4.238	0.029	27.100	74.900	2.179	0.000	39.512
KB40A	150.801600	-23.349670	14.1	4.080	0.027	35.800	61.200	1.483	0.000	42.146
KB41A	150.890560	-23.459680	3.0	4.029	0.034	28.400	77.300	1.347	0.000	37.756
KB42A	150.835720	-23.441830	5.0	4.218	0.019	26.100	76.600	1.558	1.509	39.512
KB43A	150.814070	-23.410400	8.5	3.763	0.025	19.600	80.500	0.535	2.125	35.610
KB44A	150.799610	-23.371340	6.0	4.695	0.020	29.700	75.200	2.523	0.053	38.927
CC01B	150.752650	-23.105170	9.6	3.095	0.017	7.300	92.500	0.061	0.225	36.098
CC02A	150.764340	-23.077290	5.0	2.987	0.016	13.000	86.500	0.040	0.089	32.976
CC03A	150.765780	-23.150850	26.3	3.290	0.009	15.600	69.400	0.006	4.262	32.195
CC04A	150.794190	-23.212430	7.0	3.913	0.014	23.000	78.700	0.391	0.452	39.220
CC05A	150.811480	-23.290940	8.0	3.692	0.021	25.400	76.500	0.396	0.000	45.756
CC06A	150.830330	-23.434730	11.1	4.556	0.023	32.400	66.800	2.059	10.687	43.707
Sample	**LongX**	**LatY**	**%CaCO3**	**Al2O3/K2O**	**TOC (mmol/g)**	**%Feldspar**	**%Quartz**	**%Mud**	**%Gravel**	**%Porosity**
CC07A	150.802630	-23.382820	6.0	4.352	0.035	34.900	69.600	1.541	0.164	46.244
CC08A	150.797530	-23.359530	10.1	3.702	0.043	31.600	68.800	0.618	0.019	41.463
268/HB01	150.980070	-23.497220	4.5					91.502	2.584	
268/HB02	151.002820	-23.411640	29.3					13.034	27.030	
268/HB03	151.006420	-23.393080	39.5					7.638	47.898	
268/HB04	151.006120	-23.394980	24.3					9.716	29.209	
268/HB05	151.004030	-23.394480	32.4					4.576	41.697	
268/HB06	151.000860	-23.394300	21.2					0.157	19.655	

268/HB07	150.998200	-23.394260	51.7				0.940	66.840	
268/HB08	150.995780	-23.395770	40.5				0.306	39.990	
268/HB09	150.992220	-23.394280	5.5				6.869	25.032	
268/HB10	150.990390	-23.395040	6.5				0.470	1.060	
268/HB11	150.986430	-23.397520	8.0				0.549	2.491	
268/HB12	150.982900	-23.396380	7.0				2.583	2.618	
268/HB13	150.983470	-23.396880	5.0				0.649	1.127	
268/HB14	150.979970	-23.396110	5.0				57.058	1.340	
268/HB15	150.978700	-23.396420	9.1				5.088	2.738	
268/HB16	150.979210	-23.396660	6.0				7.331	0.464	
268/HB17	150.979710	-23.396910	5.5				19.709	5.972	
268/HB19	150.977840	-23.397890	16.2				3.172	5.183	
268/HB20	150.981870	-23.395880	8.0				1.730	6.802	
268/HB30	150.944810	-23.371570	63.8				1.779	59.615	
268/HB31B	150.916630	-23.385510	16.2				62.213	7.766	
268/HB32D	150.917790	-23.384410	32.9						
268/HB33A	150.919040	-23.384540	11.1				41.063	7.580	
268/HB35	150.923910	-23.383240	9.6				37.064	4.979	

Appendix 3 – Malvern Laser Grainsize Data

1-14 of 33 Size Fractions (%)

Sample	Cluster (Fig. 5)	0.06 0.12um	0.12 0.24um	0.24 0.49um	0.49 0.98um	0.98 2um	2 3.9um	3.9 7.8um	7.8 15.6um	15.6 31um	31 37um	37 44um	44 53um	53 62.5um	62.5 74um
fk_01_ss	4	0.000	0.000	0.688	3.563	7.019	9.406	7.796	4.794	4.373	1.740	2.014	2.346	2.014	1.767
fk_02_ss	4	0.000	0.000	0.103	1.467	4.106	9.035	13.348	12.101	5.509	0.829	0.775	0.812	0.665	0.569
fk_03_ss	4	0.000	0.000	0.755	3.863	7.504	10.835	10.419	7.063	4.377	0.981	0.934	0.942	0.738	0.622
fk_05_ss	2	0.000	0.000	1.462	6.507	11.896	13.183	9.106	5.372	3.140	0.604	0.544	0.522	0.412	0.428
fk_09_ss	2	0.000	0.000	0.975	4.237	7.798	10.163	9.258	7.615	5.912	1.244	1.108	1.042	0.765	0.624
fk_10_ss	3	0.000	0.000	1.148	4.886	8.075	9.656	7.903	5.944	4.657	1.320	1.487	1.950	2.491	3.710
fk_11_ss	3	0.000	0.000	0.605	3.360	6.785	10.008	10.039	7.394	3.811	0.860	1.007	1.291	1.463	2.384
fk_15_ss	3	0.000	0.000	1.330	5.698	10.156	12.211	9.344	6.295	3.792	0.667	0.788	1.473	2.196	3.356
fk_18_ss	2	0.000	0.000	0.137	1.365	3.654	7.929	11.786	14.029	8.500	0.866	0.543	0.387	0.248	0.199
fk_21_ss	4	0.000	0.000	1.702	6.041	9.478	11.332	9.668	6.577	4.061	0.761	0.652	0.575	0.369	0.232
fk_22_ss	2	0.000	0.000	1.147	4.855	8.826	11.029	9.455	6.441	4.374	1.005	0.937	0.916	0.691	0.557
fk_23_ss	3	0.000	0.000	2.001	7.188	10.901	11.217	8.406	6.977	6.273	1.615	1.845	2.507	2.845	3.583
fk_24_ss	2	0.000	0.000	2.035	7.438	11.473	11.264	7.515	5.081	3.909	0.949	1.005	1.199	1.165	1.259
fk_26_ss	3	0.000	0.000	1.284	5.746	10.014	11.985	10.016	8.387	7.168	2.041	2.493	3.463	3.822	4.510
fk_30_ss	4	0.000	0.000	1.483	5.857	9.707	11.243	9.042	6.227	4.067	0.884	0.857	0.896	0.737	0.657
fk_32_ss	4	0.000	0.000	2.126	6.922	10.431	10.567	7.343	5.020	3.680	0.787	0.723	0.708	0.545	0.460
fk_34_ss	3	0.000	0.000	0.674	2.785	3.815	3.851	3.559	4.205	5.524	3.151	4.520	6.943	8.091	9.828
fk_35_ss	4	0.000	0.000	0.428	2.430	5.611	10.928	13.528	10.420	4.192	0.417	0.333	0.339	0.305	0.307
fk_38_ss	2	0.000	0.000	1.264	5.078	8.985	11.368	9.609	6.368	3.783	0.645	0.559	0.548	0.450	0.429
fk_40_ss	4	0.000	0.000	0.276	1.969	5.169	11.134	14.450	10.740	4.154	0.444	0.353	0.337	0.275	0.252
fk_42_ss	2	0.000	0.000	0.644	3.288	6.620	10.774	10.927	7.801	5.217	1.041	0.913	0.856	0.638	0.525
fk_44_ss	2	0.000	0.000	0.780	3.507	7.037	11.241	11.334	6.703	3.160	0.752	0.824	0.978	0.901	0.882
fk_45_ss	3	0.000	0.000	1.503	5.628	8.978	10.491	8.236	5.244	3.930	1.002	1.056	1.181	1.029	1.240
fk_46_ss	3	0.000	0.000	1.557	5.619	8.847	9.877	7.764	5.721	4.491	1.074	1.051	1.099	0.897	0.801
fk_48_ss	2	0.000	0.000	0.310	1.906	3.906	8.510	12.760	10.758	5.183	1.027	1.053	1.168	1.000	0.904
fk_50_ss	2	0.000	0.000	0.908	3.674	6.861	10.273	9.921	7.657	5.583	1.134	1.002	0.944	0.702	0.570
fk_51_ss	2	0.000	0.000	0.376	2.228	5.070	10.271	13.324	10.022	4.471	0.746	0.712	0.752	0.624	0.552
fk_52_ss	2	0.000	0.000	0.332	2.005	4.064	8.611	13.192	12.023	5.515	0.777	0.709	0.739	0.615	0.549
fk_53_ss	2	0.000	0.000	0.217	1.571	3.862	9.316	14.820	12.512	4.395	0.498	0.487	0.563	0.509	0.478
fk_55_ss	2	0.000	0.000	0.759	3.230	6.117	10.938	12.640	8.177	3.643	0.749	0.753	0.808	0.668	0.586
fk_56_ss	2	0.000	0.000	1.267	4.869	8.561	11.249	9.579	6.381	4.169	0.827	0.742	0.716	0.546	0.453
fk_57_ss	2	0.000	0.000	0.812	3.478	6.838	11.579	12.060	6.679	2.753	0.786	0.900	1.056	0.924	0.837
fk_58_ss	4	0.000	0.000	1.952	6.395	9.190	9.094	6.972	5.461	4.214	1.057	1.078	1.176	0.996	0.899
fk_59_ss	3	0.000	0.000	1.991	6.429	9.472	9.541	6.866	5.019	4.294	1.110	1.100	1.154	0.939	0.826

fk_60_ss	3	0.000	0.000	0.561	3.157	6.701	9.230	7.103	3.315	2.295	1.450	2.075	2.890	2.884	3.106
fk_61_ss	3	0.000	0.000	1.142	4.804	7.866	8.467	5.911	3.769	4.195	1.842	2.184	2.593	2.261	2.047
fk_62_ss	3	0.000	0.000	2.541	7.326	9.800	8.998	5.967	4.436	3.878	1.128	1.264	1.675	2.113	2.979
fk_63_ss	3	0.000	0.000	3.539	9.480	11.501	9.288	6.112	5.304	4.554	1.380	1.782	2.601	2.997	3.698
fk_64_ss	3	0.000	0.000	0.976	3.726	5.738	6.005	4.708	4.103	2.924	1.617	2.581	4.440	5.446	6.805
fk_65_ss	3	0.000	0.000	1.739	6.196	9.609	10.290	7.617	5.206	3.304	0.872	1.089	1.717	2.141	2.843
fk_66_ss	3	0.000	0.000	1.366	5.105	7.595	7.614	5.158	4.022	3.515	1.498	2.024	3.139	3.732	4.636
fk_67_ss	2	0.000	0.000	1.188	4.964	8.915	11.002	9.036	5.558	3.395	0.881	0.934	1.048	0.902	0.819
fk_68_ss	2	0.000	0.000	1.986	6.245	9.192	9.625	6.911	3.930	2.826	1.064	1.273	1.560	1.430	1.364
fk_69_ss	2	0.000	0.000	0.455	2.847	6.119	10.835	12.463	7.891	3.587	0.881	0.936	1.042	0.882	0.786
fk_70_ss	2	0.000	0.000	1.116	4.940	9.263	12.050	10.399	6.320	3.200	0.572	0.516	0.505	0.389	0.322
fk_71_ss	3	0.000	0.000	1.718	5.831	8.129	7.753	5.627	4.511	5.270	1.775	1.876	2.046	2.207	3.028
fk_72_ss	3	0.000	0.000	1.999	6.468	9.212	9.140	6.705	4.930	4.027	1.108	1.204	1.536	1.916	2.688
268/fk_1_85	4	0.000	0.028	3.327	6.509	7.626	7.081	5.381	4.076	4.193	1.596	1.822	2.123	1.854	1.686
268/fk_2_98	5	2.147	4.541	6.969	7.041	5.940	4.868	3.622	3.650	2.621	1.210	2.063	3.789	5.019	6.688
268/fk_3_110	3	0.000	0.000	0.087	0.822	1.934	2.833	2.912	2.334	1.089	1.837	3.711	6.558	7.851	9.171
268/fk_4_119	5	3.983	5.390	6.380	7.041	7.291	6.884	5.616	3.757	2.215	0.522	0.579	0.798	0.927	1.270
268/fk_5_120	3	0.000	0.000	2.352	5.881	8.589	9.275	6.948	4.878	4.855	1.404	1.521	1.718	1.580	1.967
268/fk_6_121	3	0.000	0.000	2.208	6.241	9.668	10.656	7.667	5.028	4.084	0.980	0.935	0.942	0.949	1.638
268/fk_7_122	2	0.000	0.000	0.759	4.238	8.273	11.726	11.046	6.790	3.681	0.883	0.955	1.084	1.042	1.166
268/fk_8_123	3	0.000	0.000	1.047	4.747	8.574	10.366	8.152	5.214	3.832	1.105	1.202	1.375	1.204	1.113
268/fk_9_124	3	0.000	0.000	2.573	6.615	10.064	11.202	7.771	4.206	2.806	0.764	0.822	1.063	1.798	3.618
268/fk_10_125	2	0.000	0.000	0.178	2.049	4.987	9.559	12.036	9.588	5.652	1.118	1.039	1.046	0.834	0.723
268/fk_11_126	2	0.000	0.000	0.150	1.847	4.555	9.266	13.012	11.005	5.368	0.878	0.810	0.831	0.678	0.599
268/fk_12_127	3	0.000	0.029	3.208	6.392	8.155	8.216	6.021	4.032	4.049	1.474	1.649	1.891	1.831	2.570
268/fk_13_128	3	0.000	0.000	0.927	3.437	5.521	6.250	4.939	3.352	3.912	2.067	2.671	3.468	3.687	5.045
268/fk_14_129	3	0.000	0.000	1.497	3.992	5.223	5.413	4.662	4.715	8.028	3.522	4.231	5.341	5.242	5.577
268/fk_15_130	3	0.000	0.000	1.337	4.042	5.878	5.999	4.795	4.288	5.374	2.439	2.946	3.985	4.280	4.985
268/fk_16_131	3	0.000	0.023	2.917	6.236	7.305	6.580	5.154	4.567	4.792	1.679	1.885	2.493	2.882	3.673
268/fk_17_132	3	0.000	0.000	0.161	0.892	1.663	1.881	1.987	2.134	1.285	2.304	4.366	7.172	8.231	9.600
268/fk_18_133	3	0.000	0.000	0.708	2.530	3.854	4.250	3.464	2.549	1.832	1.922	3.082	4.715	5.730	7.916
268/fk_19_134	3	0.000	0.000	1.574	5.608	8.829	9.987	8.491	7.113	5.004	1.038	1.049	1.460	1.819	2.516
268/fk_20_135	2	0.000	0.000	0.436	2.645	5.758	8.369	7.185	3.903	2.454	1.515	2.224	3.160	3.190	3.208
268/fk_21_136	2	0.000	0.000	0.330	2.544	5.866	10.462	11.892	7.563	3.582	0.990	1.123	1.330	1.192	1.118
268/fk_22_137	2	0.000	0.000	0.377	2.728	5.998	10.520	11.911	8.148	4.267	0.911	0.913	0.995	0.853	0.789
268/fk_23_138	2	0.000	0.000	0.244	2.241	5.317	10.143	12.815	9.526	4.311	0.826	0.842	0.935	0.805	0.736
268/fk_24_139	2	0.000	0.000	0.482	2.967	6.290	10.111	10.370	7.397	5.068	1.195	1.160	1.203	0.978	0.865
268/fk_25_140	2	0.000	0.000	0.423	3.001	6.861	10.743	10.625	7.474	4.885	1.099	1.055	1.080	0.863	0.742
268/fk_26_141	3	0.000	0.000	1.892	6.068	9.490	10.086	7.180	4.752	4.571	1.225	1.246	1.342	1.122	1.281

268/fk_27_151	3	0.000	0.000	2.588	6.575	9.000	9.111	6.738	5.234	4.884	1.171	1.157	1.206	1.206	1.842
268/fk_29_162	4	0.000	0.000	1.961	5.561	8.394	8.940	6.741	4.733	4.602	1.563	1.775	2.140	2.007	2.035
268/fk_30_165	2	0.000	0.000	3.047	7.884	11.092	10.494	6.852	4.598	3.754	0.776	0.721	0.816	0.894	1.232
268/fk_31_183	2	0.000	0.000	0.693	4.038	8.731	12.565	11.592	7.823	3.373	0.366	0.263	0.213	0.142	0.106
268/fk_32_187	2	0.000	0.012	2.883	7.274	10.541	10.879	7.941	5.269	3.766	0.875	0.833	0.814	0.580	0.419
268/fk_33_188	2	0.000	0.000	0.913	3.925	7.498	11.995	12.743	8.231	2.982	0.321	0.264	0.260	0.216	0.200
268/fk_34_189	2	0.000	0.000	2.085	6.555	9.501	9.623	7.448	5.724	5.009	1.206	1.096	1.040	0.819	0.804
268/fk_35_190	2	0.000	0.000	1.897	6.314	9.636	10.508	8.774	7.003	5.201	1.078	0.973	0.940	0.730	0.666
268/fk_36_191	2	0.000	0.000	1.460	5.517	8.630	9.383	7.697	5.849	4.588	1.146	1.146	1.221	1.013	0.900
268/fk_37_192	3	0.000	0.000	1.687	6.239	9.151	10.244	9.692	8.981	7.484	1.643	1.629	1.915	1.968	2.378
268/fk_38_193	3	0.000	0.000	1.060	4.801	8.421	9.934	7.607	5.125	4.315	1.340	1.534	1.829	2.059	2.679
268/fk_39_194	2	0.000	0.000	1.252	5.163	9.215	10.969	8.786	6.358	4.911	1.052	0.885	0.842	0.644	0.554
268/fk_40_195	2	0.000	0.000	1.297	5.345	9.346	10.981	8.223	5.190	3.914	0.962	0.957	1.017	0.842	0.745
277/fk_vc01_196A	3	0.000	0.000	1.009	4.896	9.133	10.964	8.370	5.072	3.747	1.056	1.133	1.288	1.127	1.060
277/fk_vc02_197A	2	0.000	0.000	0.202	2.034	5.784	10.933	11.577	6.441	2.673	0.960	1.284	1.742	1.718	1.703
277/fk_vc03_198A	3	0.000	0.000	1.055	3.599	4.843	4.730	4.004	3.306	3.738	2.188	3.100	4.836	5.565	6.637
277/fk_vc04_199A	3	0.000	0.000	1.331	5.449	8.287	8.581	6.501	5.267	4.579	1.655	2.118	3.138	3.557	4.283
277/fk_vc05_200A	3	0.000	0.000	0.999	3.903	5.706	5.861	4.885	3.940	5.226	2.444	2.923	3.512	3.135	3.436
277/fk_vc06_201A	2	0.000	0.000	0.070	1.064	2.894	7.150	11.511	9.637	4.903	1.399	1.677	2.109	1.988	1.932
277/fk_vc09_202A	2	0.000	0.000	0.749	4.053	7.388	9.387	8.154	5.942	4.612	1.300	1.410	1.629	1.452	1.373
277/fk_vc13_203a	2	0.000	0.000	0.466	3.225	7.589	11.958	11.818	7.659	4.651	1.007	0.893	0.848	0.666	0.563
277/fk_vc17_204A	3	0.000	0.000	1.532	5.766	9.356	10.366	8.206	6.409	5.229	1.067	1.023	1.049	1.046	1.520
277/fk_vc20_205A	3	0.000	0.000	2.471	6.845	9.208	9.229	7.254	6.391	5.387	1.217	1.402	2.095	2.648	3.655
KB32A	1	0.000	0.000	0.092	0.645	0.974	1.092	0.553	1.026	0.527	0.000	0.000	0.590	2.271	5.102
KB33A	1	0.000	0.000	0.003	0.430	0.664	0.810	0.223	0.000	0.000	0.000	0.000	0.590	2.575	6.089
KB34A	3	0.000	0.000	0.696	2.024	2.349	2.218	2.074	2.714	2.702	2.285	3.909	6.473	7.726	9.422
KB35A	3	0.000	0.000	2.174	5.482	6.410	6.161	5.208	5.359	4.283	1.402	2.199	3.814	4.965	6.643
KB36A	3	0.000	0.000	1.312	4.400	5.468	5.122	4.966	5.714	7.719	3.788	4.906	6.537	6.603	7.084
KB37A	3	0.000	0.000	1.157	3.722	4.799	4.925	4.364	4.317	5.753	1.494	1.344	1.389	1.414	2.016
KB38A	3	0.000	0.000	1.723	5.461	7.076	7.065	6.071	5.979	6.472	2.502	3.208	4.438	4.782	5.542
KB39A	1	0.000	0.000	0.000	0.296	0.595	0.811	0.163	0.000	0.000	0.000	0.000	0.149	1.460	4.950
KB40A	1	0.000	0.000	0.004	0.439	0.645	0.768	0.218	0.000	0.000	0.000	0.000	0.757	2.751	5.754
KB41A	1	0.000	0.000	0.000	0.195	0.564	0.872	0.313	0.000	0.000	0.000	0.000	0.001	0.447	2.535
KB42A	1	0.000	0.000	0.087	0.655	0.925	1.049	0.530	1.274	0.708	0.000	0.000	0.234	1.600	4.603
KB43A	1	0.000	0.000	0.000	0.196	0.499	0.695	0.252	0.000	0.000	0.000	0.000	0.002	0.727	3.095
KB44A	1	0.000	0.000	0.264	1.123	1.538	1.673	0.941	1.728	0.875	0.000	0.000	0.096	1.175	4.339
CC01B	1	0.000	0.000	0.000	0.000	0.139	0.808	1.030	1.325	2.339	0.072	0.000	0.000	0.002	0.118
CC02A	1	0.000	0.000	0.000	0.000	0.000	0.233	0.480	0.961	1.295	0.000	0.000	0.007	0.088	1.146
CC03A	1	0.000	0.000	0.000	0.000	0.000	0.050	0.414	0.375	0.819	0.236	0.040	0.000	0.000	0.000

CC04A	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.842	3.302
CC05A	1	0.000	0.000	0.000	0.000	0.261	1.096	1.136	1.143	1.046	0.000	0.000	0.000	0.041	1.039
CC06A	1	0.000	0.000	0.005	0.591	0.888	1.047	0.532	1.346	0.635	0.000	0.000	0.689	2.611	5.772
CC07A	1	0.000	0.000	0.000	0.000	0.332	0.826	0.540	1.417	0.762	0.000	0.000	0.114	1.230	4.469
CC08A	1	0.000	0.000	0.000	0.000	0.260	1.174	1.455	1.047	0.993	0.000	0.000	0.000	0.021	0.864
268/HB01	3	0.000	0.033	3.591	8.796	12.222	12.425	9.887	9.912	12.509	3.696	3.752	4.067	3.495	3.313
268/HB02	2	0.070	1.236	3.185	3.773	3.318	2.912	2.364	2.306	2.339	0.790	1.084	1.725	2.202	3.041
268/HB03	2	0.000	0.000	0.732	2.086	2.544	2.553	2.214	2.221	2.262	0.638	0.824	1.318	1.752	2.542
268/HB04	2	0.000	0.174	1.654	2.468	2.654	2.859	2.586	2.244	2.057	0.593	0.784	1.276	1.724	2.540
268/HB05	2	0.000	0.000	0.682	1.436	1.691	1.766	1.534	1.381	1.369	0.345	0.421	0.687	0.982	1.556
268/HB06	5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
268/HB07	5	0.000	0.000	0.075	0.596	0.860	0.785	0.641	0.621	0.413	0.114	0.190	0.342	0.444	0.572
268/HB08	5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
268/HB09	2	0.000	0.033	1.356	2.295	2.418	2.311	2.022	1.905	2.356	0.601	0.578	0.721	0.935	1.564
268/HB10	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
268/HB11	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
268/HB12	1	0.000	0.000	0.000	0.142	0.476	0.559	0.540	0.037	0.000	0.000	0.000	0.000	0.000	0.000
268/HB13	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
268/HB14	2	0.000	0.000	2.391	6.169	8.139	8.167	6.622	5.758	5.604	1.129	0.827	0.573	0.352	0.484
268/HB15	1	0.000	0.000	0.100	0.670	0.920	0.973	0.823	0.465	1.291	0.190	0.016	0.000	0.000	0.028
268/HB16	1	0.000	0.000	0.413	1.124	1.353	1.366	1.073	0.720	1.673	0.101	0.000	0.000	0.002	0.111
268/HB17	3	0.000	0.000	1.733	3.724	4.281	4.129	3.381	3.035	3.728	0.749	0.565	0.605	0.901	1.821
268/HB19	5	0.000	0.000	0.001	0.392	0.813	1.054	0.969	0.502	0.740	0.278	0.175	0.014	0.000	0.000
268/HB20	1	0.000	0.000	0.000	0.109	0.469	0.568	0.556	0.040	0.000	0.000	0.000	0.000	0.000	0.000
268/HB30	5	0.000	0.000	0.584	1.531	1.741	1.688	1.431	1.200	1.059	0.209	0.169	0.163	0.175	0.287
268/HB31B	3	0.000	0.000	3.489	8.858	10.615	10.427	8.561	7.777	8.153	2.494	2.727	3.246	3.093	3.267
268/HB32D	4	0.000	0.000	0.888	3.247	5.286	6.320	5.516	4.087	3.329	0.986	1.145	1.492	1.579	1.863
268/HB33A	2	0.000	0.000	1.528	4.123	4.998	4.977	4.481	4.266	4.469	1.365	1.501	1.814	1.773	1.948
268/HB35	2	0.000	0.000	1.874	5.118	6.663	6.855	6.262	5.894	4.993	1.298	1.361	1.563	1.435	1.460

14-33 of 33 Size Fractions (%)

Sample	74	88	105	125	149	177	210	250	300	350	420	500	590	710	840	1000	1190	1410	1680
	88um	105um	125um	149um	177um	210um	250um	300um	350um	420um	500um	590um	710um	840um	1000um	1190um	1410um	1680um	2000um
fk_01_ss	1.332	0.813	0.317	0.016	0.000	0.000	0.000	0.154	1.109	2.888	4.745	6.208	8.263	7.771	7.266	5.663	3.695	2.073	0.165
fk_02_ss	0.411	0.229	0.042	0.001	0.000	0.000	0.016	0.639	1.956	5.070	7.901	9.326	10.351	7.408	4.775	2.193	0.354	0.010	0.000
fk_03_ss	0.473	0.310	0.154	0.030	0.001	0.145	0.884	2.217	3.212	5.484	6.685	7.086	7.878	6.287	5.039	3.298	1.662	0.122	0.000
fk_05_ss	0.601	1.056	1.884	3.155	4.534	5.823	6.829	7.274	5.550	5.195	3.265	1.597	0.059	0.000	0.000	0.000	0.000	0.000	0.000
fk_09_ss	0.515	0.531	0.694	1.255	2.089	3.107	4.265	5.459	5.108	6.147	5.515	4.569	4.128	2.777	1.932	1.044	0.122	0.000	0.000
fk_10_ss	5.313	6.918	7.789	7.851	6.871	5.334	3.627	2.049	0.748	0.265	0.011	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

fk_11_ss	3.883	5.793	7.413	8.458	8.201	7.105	5.370	3.372	1.246	0.152	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
fk_15_ss	4.641	5.717	6.109	5.896	5.047	3.902	2.727	1.673	0.754	0.497	0.400	0.505	0.790	0.882	0.961	0.868	0.663	0.454	0.207
fk_18_ss	0.157	0.113	0.061	0.245	1.063	2.322	3.980	5.912	6.092	7.806	7.231	5.939	5.043	2.939	1.351	0.106	0.000	0.000	0.000
fk_21_ss	0.142	0.063	0.096	0.556	1.291	2.254	3.398	4.638	4.555	5.747	5.462	4.854	4.810	3.656	2.991	2.132	1.235	0.510	0.162
fk_22_ss	0.395	0.232	0.066	0.048	0.563	1.700	3.481	5.815	6.425	8.530	7.922	6.291	4.950	2.540	0.778	0.032	0.000	0.000	0.000
fk_23_ss	4.299	4.779	4.792	4.621	4.081	3.439	2.798	2.157	1.266	0.957	0.520	0.275	0.191	0.138	0.128	0.106	0.061	0.026	0.009
fk_24_ss	1.309	1.329	1.324	1.486	1.850	2.411	3.183	4.140	4.048	5.169	4.963	4.368	4.137	2.854	1.982	1.038	0.115	0.000	0.000
fk_26_ss	4.899	4.759	3.972	2.963	1.888	1.095	0.634	0.499	0.506	0.832	1.043	1.145	1.330	1.126	0.978	0.723	0.453	0.209	0.020
fk_30_ss	0.547	0.442	0.412	0.505	0.817	1.281	1.884	2.634	2.743	3.809	4.158	4.353	5.201	4.803	4.715	4.052	3.026	2.050	0.913
fk_32_ss	0.503	1.257	2.207	3.424	4.476	5.177	5.480	5.350	3.899	3.739	2.802	2.189	2.193	1.911	1.900	1.681	1.281	0.837	0.379
fk_34_ss	10.812	10.417	8.513	5.685	3.483	1.769	0.672	0.143	0.012	0.059	0.176	0.272	0.357	0.296	0.226	0.117	0.044	0.002	0.000
fk_35_ss	0.284	0.227	0.155	0.269	0.774	1.527	2.526	3.711	3.888	5.258	5.431	5.282	5.773	4.820	4.201	3.084	2.044	1.202	0.305
fk_38_ss	0.593	1.544	2.721	4.174	5.380	6.249	6.669	6.560	4.768	4.437	3.014	1.917	1.357	0.750	0.463	0.238	0.071	0.008	0.000
fk_40_ss	0.208	0.148	0.075	0.017	0.000	0.171	1.135	2.928	4.223	6.994	8.053	7.880	7.842	5.376	3.506	1.496	0.372	0.025	0.000
fk_42_ss	0.395	0.261	0.134	0.449	1.568	3.246	5.337	7.487	7.165	8.313	6.732	4.700	3.236	1.362	0.358	0.014	0.000	0.000	0.000
fk_44_ss	0.778	0.593	0.445	1.034	2.545	4.928	7.545	9.579	8.064	7.867	4.982	2.525	0.948	0.069	0.000	0.000	0.000	0.000	0.000
fk_45_ss	1.580	2.133	2.821	3.650	4.407	4.985	5.321	5.352	4.048	4.006	3.008	2.218	1.956	1.451	1.253	0.993	0.700	0.445	0.156
fk_46_ss	1.139	2.012	3.194	4.544	5.672	6.316	6.454	6.044	4.162	3.639	2.308	1.417	1.085	0.789	0.742	0.656	0.509	0.355	0.164
fk_48_ss	0.727	0.511	0.615	1.599	3.232	5.124	6.828	7.867	6.271	6.055	4.072	2.503	1.786	1.155	1.003	0.864	0.665	0.450	0.191
fk_50_ss	0.417	0.259	0.086	0.095	0.438	1.101	2.177	3.739	4.417	6.521	7.047	6.765	6.844	4.957	3.566	2.018	0.325	0.000	0.000
fk_51_ss	0.433	0.288	0.196	0.770	2.229	4.417	6.959	9.168	8.052	8.272	5.601	3.068	1.334	0.067	0.000	0.000	0.000	0.000	0.000
fk_52_ss	0.434	0.296	0.276	1.141	2.738	4.741	6.772	8.336	7.075	7.272	5.175	3.212	2.026	0.883	0.383	0.097	0.012	0.000	0.000
fk_53_ss	0.388	0.264	0.105	0.167	1.098	3.060	5.923	8.998	8.672	9.486	6.718	3.795	1.846	0.251	0.000	0.000	0.000	0.000	0.000
fk_55_ss	0.456	0.305	0.167	0.430	1.725	3.861	6.533	9.030	8.195	8.647	6.032	3.448	1.717	0.320	0.066	0.001	0.000	0.000	0.000
fk_56_ss	0.363	0.839	2.264	4.675	7.184	8.900	9.287	8.114	4.747	3.096	1.116	0.056	0.000	0.000	0.000	0.000	0.000	0.000	0.000
fk_57_ss	0.670	0.802	1.507	2.881	4.558	6.091	7.210	7.644	5.800	5.464	3.632	2.179	1.406	0.700	0.408	0.222	0.099	0.025	0.000
fk_58_ss	0.748	0.811	1.087	1.652	2.512	3.444	4.350	5.131	4.485	5.125	4.491	3.816	3.775	2.991	2.623	2.049	1.401	0.833	0.193
fk_59_ss	1.115	2.149	3.508	4.994	6.148	6.685	6.609	5.930	3.893	3.230	1.938	1.148	0.891	0.688	0.683	0.626	0.498	0.355	0.171
fk_60_ss	3.613	4.229	4.900	5.641	6.210	6.410	6.088	5.300	3.417	2.824	1.724	1.068	0.879	0.698	0.683	0.608	0.471	0.324	0.147
fk_61_ss	2.387	3.114	4.257	5.636	6.727	7.164	6.940	6.081	3.873	3.054	1.646	0.783	0.411	0.213	0.188	0.172	0.136	0.094	0.043
fk_62_ss	4.026	5.051	5.665	5.894	5.548	4.824	3.892	2.895	1.654	1.321	0.942	0.839	1.020	1.009	1.041	0.916	0.688	0.467	0.205
fk_63_ss	4.250	4.482	4.200	3.853	3.233	2.615	2.115	1.769	1.295	1.462	1.434	1.414	1.579	1.322	1.143	0.839	0.518	0.232	0.005
fk_64_ss	7.725	7.901	7.148	5.975	4.769	3.956	3.204	2.548	1.642	1.497	1.117	0.868	0.816	0.618	0.507	0.353	0.211	0.071	0.004
fk_65_ss	3.531	4.046	4.175	4.140	3.963	3.668	3.384	3.164	2.426	2.641	2.339	2.069	2.133	1.729	1.514	1.161	0.772	0.450	0.070
fk_66_ss	5.336	5.662	5.438	5.008	4.345	3.676	2.979	2.371	1.594	1.673	1.617	1.675	2.041	1.896	1.824	1.501	1.061	0.670	0.228
fk_67_ss	0.661	0.443	0.234	0.019	0.050	0.711	2.095	4.269	5.365	7.951	8.242	7.331	6.634	4.128	2.434	0.775	0.015	0.000	0.000
fk_68_ss	1.153	0.833	0.754	1.338	2.321	3.601	4.920	6.103	5.474	6.276	5.361	4.285	3.819	2.621	1.951	1.232	0.503	0.050	0.000
fk_69_ss	0.621	0.410	0.241	0.521	1.728	3.468	5.551	7.589	7.100	8.069	6.423	4.452	3.133	1.412	0.495	0.062	0.000	0.000	0.000

fk_70_ss	0.239	0.207	0.851	2.517	4.876	7.261	8.996	9.415	6.659	5.454	2.809	1.018	0.106	0.000	0.000	0.000	0.000	0.000	0.000
fk_71_ss	4.167	5.412	6.311	6.756	6.556	5.760	4.624	3.329	1.750	1.168	0.609	0.431	0.535	0.592	0.666	0.615	0.473	0.325	0.152
fk_72_ss	3.594	4.433	4.850	4.971	4.556	4.004	3.338	2.676	1.759	1.766	1.659	1.724	2.122	1.973	1.887	1.557	1.082	0.746	0.367
268/fk_1_85	1.347	0.911	0.582	0.464	0.899	1.746	3.036	4.809	5.353	7.444	7.484	6.598	5.971	3.679	2.039	0.333	0.000	0.000	0.000
268/fk_2_98	7.957	8.288	7.336	5.594	3.762	2.245	1.172	0.557	0.271	0.322	0.400	0.447	0.489	0.348	0.220	0.064	0.006	0.000	0.000
268/fk_3_110	9.510	8.907	7.609	6.482	5.215	4.159	3.021	2.022	1.109	1.013	1.031	1.250	1.719	1.674	1.582	1.224	0.785	0.441	0.108
268/fk_4_119	1.768	2.427	3.069	3.767	4.314	4.682	4.906	4.971	3.873	4.002	3.121	2.276	1.786	1.001	0.483	0.047	0.000	0.000	0.000
268/fk_5_120	2.621	3.543	4.504	5.419	6.015	6.093	5.732	4.977	3.217	2.663	1.603	0.928	0.645	0.398	0.306	0.209	0.121	0.038	0.002
268/fk_6_121	2.730	4.125	5.343	6.341	6.568	6.168	5.346	4.241	2.506	1.913	1.096	0.665	0.556	0.436	0.394	0.299	0.197	0.078	0.005
268/fk_7_122	1.347	1.594	1.880	2.221	2.660	3.098	3.604	4.219	3.869	4.780	4.539	4.023	3.902	2.813	2.100	1.276	0.420	0.011	0.000
268/fk_8_123	0.923	1.073	1.999	3.443	5.031	6.411	7.244	7.290	5.230	4.624	2.866	1.652	1.149	0.776	0.722	0.645	0.500	0.340	0.151
268/fk_9_124	6.718	9.450	10.334	8.988	5.974	3.038	1.062	0.186	0.000	0.000	0.000	0.000	0.074	0.192	0.232	0.199	0.139	0.080	0.031
268/fk_10_125	0.570	0.385	0.242	0.540	1.769	3.538	5.665	7.760	7.273	8.271	6.562	4.490	3.018	1.057	0.050	0.000	0.000	0.000	0.000
268/fk_11_126	0.476	0.321	0.163	0.040	0.286	1.271	2.944	5.270	6.103	8.456	8.227	6.875	5.761	3.197	1.461	0.151	0.000	0.000	0.000
268/fk_12_127	3.646	4.937	6.009	6.710	6.788	6.193	5.155	3.847	2.083	1.397	0.670	0.380	0.405	0.450	0.526	0.500	0.391	0.271	0.126
268/fk_13_128	7.409	10.178	11.557	10.765	7.874	4.636	1.994	0.312	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
268/fk_14_129	5.575	5.150	4.120	3.341	2.755	2.289	2.085	2.190	2.018	2.621	2.621	2.385	2.298	1.573	1.053	0.450	0.032	0.000	0.000
268/fk_15_130	5.518	5.732	5.415	4.885	4.478	3.938	3.418	3.001	2.195	2.320	2.013	1.738	1.713	1.286	1.010	0.656	0.314	0.022	0.000
268/fk_16_131	4.485	5.126	5.316	5.197	4.805	4.246	3.658	3.142	2.235	2.315	2.002	1.756	1.780	1.383	1.123	0.761	0.417	0.064	0.001
268/fk_17_132	10.371	10.565	10.036	9.071	7.528	5.494	3.347	1.612	0.291	0.011	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
268/fk_18_133	10.578	12.681	12.518	10.152	6.282	3.234	1.148	0.171	0.000	0.000	0.000	0.000	0.011	0.160	0.200	0.162	0.102	0.036	0.014
268/fk_19_134	3.228	3.705	3.637	3.286	2.711	2.206	1.931	1.954	1.794	2.430	2.658	2.756	3.187	2.790	2.567	2.050	1.420	0.876	0.325
268/fk_20_135	2.777	2.271	2.177	2.551	3.765	5.206	6.554	7.568	6.322	6.615	4.906	3.175	1.835	0.233	0.000	0.000	0.000	0.000	0.000
268/fk_21_136	0.945	0.922	1.856	3.681	6.145	8.277	9.387	8.977	5.771	4.167	1.724	0.154	0.002	0.000	0.000	0.000	0.000	0.000	0.000
268/fk_22_137	0.667	0.490	0.407	0.938	2.102	3.829	5.797	7.615	6.902	7.607	5.849	3.918	2.677	1.293	0.640	0.330	0.270	0.184	0.077
268/fk_23_138	0.600	0.432	0.519	1.339	2.761	4.518	6.308	7.765	6.718	7.178	5.437	3.645	2.491	1.150	0.369	0.030	0.000	0.000	0.000
268/fk_24_139	0.702	0.513	0.618	1.637	3.210	5.105	6.945	8.250	6.830	6.895	4.858	3.030	1.948	0.876	0.394	0.095	0.009	0.000	0.000
268/fk_25_140	0.578	0.758	1.633	2.934	4.500	5.943	7.085	7.704	6.073	5.999	4.194	2.552	1.197	0.000	0.000	0.000	0.000	0.000	0.000
268/fk_26_141	1.668	2.310	3.098	3.980	4.763	5.257	5.484	5.418	4.055	3.979	2.938	2.085	1.704	1.129	0.864	0.594	0.348	0.070	0.002
268/fk_27_151	3.042	4.752	6.377	7.708	7.966	7.229	5.786	3.925	1.788	0.698	0.017	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
268/fk_29_162	1.931	1.704	1.436	1.278	1.441	1.822	2.400	3.186	3.236	4.373	4.556	4.449	4.834	3.984	3.472	2.632	1.729	0.993	0.089
268/fk_30_165	1.764	2.479	3.215	4.024	4.686	5.221	5.639	5.835	4.526	4.475	3.149	1.921	0.905	0.000	0.000	0.000	0.000	0.000	0.000
268/fk_31_183	0.067	0.028	0.000	0.000	0.000	0.247	1.416	3.819	5.574	8.977	9.588	8.301	6.847	3.555	1.518	0.156	0.000	0.000	0.000
268/fk_32_187	0.309	0.209	0.345	0.866	1.746	2.875	4.171	5.513	5.250	6.377	5.742	4.744	4.239	2.788	1.867	0.796	0.079	0.000	0.000
268/fk_33_188	0.173	0.133	0.082	0.045	0.017	0.166	1.198	3.474	5.291	8.814	9.701	8.611	7.248	3.794	1.552	0.151	0.000	0.000	0.000
268/fk_34_189	0.997	1.624	2.715	4.320	5.924	7.135	7.699	7.371	4.963	3.966	1.958	0.416	0.002	0.000	0.000	0.000	0.000	0.000	0.000
268/fk_35_190	0.671	0.858	1.205	1.949	2.850	3.807	4.755	5.561	4.798	5.328	4.394	3.369	2.840	1.811	1.213	0.631	0.230	0.012	0.000
268/fk_36_191	0.716	0.474	0.241	0.035	0.481	2.693	7.070	12.641	11.355	9.928	4.445	1.207	0.162	0.000	0.000	0.000	0.000	0.000	0.000

268/fk_37_192	2.867	3.316	3.557	3.736	3.626	3.393	3.131	2.861	2.090	2.115	1.699	1.345	1.215	0.843	0.619	0.362	0.147	0.046	0.020
268/fk_38_193	3.443	4.231	4.782	5.127	5.147	4.895	4.448	3.889	2.679	2.554	1.966	1.554	1.466	1.102	0.900	0.629	0.373	0.103	0.005
268/fk_39_194	0.707	1.140	1.862	2.910	4.004	5.009	5.814	6.287	5.032	5.181	3.939	2.791	2.172	1.278	0.806	0.394	0.041	0.000	0.000
268/fk_40_195	0.590	0.387	0.192	0.014	0.396	1.570	3.456	5.945	6.636	8.822	8.168	6.463	5.081	2.628	0.808	0.026	0.000	0.000	0.000
277/fk_vc01_196A	1.188	1.670	2.469	3.602	4.816	5.883	6.619	6.842	5.152	4.864	3.250	1.952	1.256	0.638	0.413	0.277	0.180	0.056	0.020
277/fk_vc02_197A	1.447	1.080	1.522	3.397	6.648	9.602	10.854	9.568	5.231	2.876	0.713	0.011	0.000	0.000	0.000	0.000	0.000	0.000	0.000
277/fk_vc03_198A	7.257	7.198	6.385	5.237	4.340	3.777	3.303	2.937	2.147	2.216	1.836	1.509	1.431	1.055	0.839	0.567	0.297	0.066	0.003
277/fk_vc04_199A	4.816	5.001	4.712	4.236	3.617	2.966	2.379	1.935	1.376	1.547	1.576	1.669	2.049	1.914	1.854	1.539	1.100	0.706	0.260
277/fk_vc05_200A	4.291	5.821	7.432	8.741	9.019	7.877	5.822	3.442	1.237	0.343	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
277/fk_vc06_201A	1.646	1.360	1.814	2.944	4.634	6.417	7.775	8.341	6.313	5.811	3.629	1.906	0.913	0.153	0.008	0.000	0.000	0.000	0.000
277/fk_vc09_202A	1.163	0.830	0.489	0.371	1.089	2.259	3.818	5.646	5.814	7.466	6.968	5.822	5.129	3.223	1.998	0.461	0.005	0.000	0.000
277/fk_vc13_203a	0.441	0.644	1.285	2.642	4.267	5.822	7.040	7.601	5.825	5.476	3.562	2.026	1.169	0.475	0.212	0.087	0.045	0.028	0.011
277/fk_vc17_204A	2.457	3.868	5.315	6.700	7.252	6.951	5.960	4.452	2.304	1.344	0.414	0.052	0.016	0.034	0.068	0.085	0.078	0.055	0.025
277/fk_vc20_205A	4.723	5.577	5.744	5.583	4.809	3.812	2.833	1.984	1.120	0.948	0.744	0.682	0.787	0.720	0.697	0.584	0.428	0.290	0.134
KB32A	8.859	12.646	14.812	15.233	13.220	10.090	6.773	3.778	1.401	0.310	0.007	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
KB33A	10.795	15.350	17.460	16.946	13.396	8.873	4.759	1.036	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
KB34A	10.431	10.360	8.991	7.211	5.157	3.518	2.428	1.816	1.259	1.333	1.123	0.863	0.654	0.240	0.026	0.000	0.000	0.000	0.000
KB35A	8.080	8.779	8.238	7.001	5.112	3.323	1.935	1.034	0.522	0.547	0.563	0.486	0.281	0.000	0.000	0.000	0.000	0.000	0.000
KB36A	7.048	6.427	5.253	4.094	2.967	2.168	1.703	1.497	1.167	1.302	1.112	0.844	0.602	0.179	0.018	0.000	0.000	0.000	0.000
KB37A	3.164	4.840	6.581	8.226	8.980	8.912	8.151	6.763	4.071	2.896	0.716	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000
KB38A	6.027	6.057	5.471	4.703	3.716	2.876	2.280	1.929	1.436	1.580	1.386	1.108	0.842	0.255	0.012	0.000	0.000	0.000	0.000
KB39A	10.834	17.302	20.423	19.102	13.473	7.283	2.838	0.321	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
KB40A	9.437	12.906	14.689	14.884	12.915	10.015	6.971	4.189	1.728	0.786	0.138	0.007	0.000	0.000	0.000	0.000	0.000	0.000	0.000
KB41A	7.136	13.687	18.917	20.603	17.028	10.998	5.363	1.296	0.044	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
KB42A	9.238	14.299	17.185	17.185	13.664	8.879	4.545	1.557	0.180	0.000	0.000	0.093	0.285	0.342	0.340	0.260	0.166	0.090	0.027
KB43A	6.419	10.097	12.704	13.952	12.936	10.587	7.699	4.814	2.120	1.225	0.793	0.972	1.591	1.832	2.025	1.852	1.435	1.003	0.476
KB44A	11.074	18.158	21.244	18.415	11.357	4.871	1.104	0.026	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CC01B	1.261	4.877	9.705	15.922	18.816	17.902	13.913	8.055	3.196	0.520	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CC02A	2.787	4.890	6.824	8.460	9.213	9.459	9.567	9.688	7.797	8.475	6.950	5.193	3.994	1.987	0.507	0.000	0.000	0.000	0.000
CC03A	0.078	0.927	2.449	4.493	6.573	8.470	10.107	11.357	9.585	10.647	9.011	7.244	6.507	4.459	3.262	2.019	0.832	0.044	0.000
CC04A	7.199	11.772	15.169	16.812	15.545	12.552	8.887	5.245	1.991	0.661	0.018	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CC05A	4.021	10.878	17.657	21.617	19.036	12.548	6.382	1.958	0.138	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CC06A	9.811	13.592	15.284	14.883	12.010	8.314	4.864	2.212	0.600	0.181	0.157	0.362	0.719	0.828	0.832	0.636	0.399	0.173	0.026
CC07A	9.612	16.281	19.500	18.834	13.918	8.005	3.421	0.739	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CC08A	3.249	7.349	11.943	15.832	16.851	15.190	11.740	7.492	3.108	1.322	0.109	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
268/HB01	2.950	2.400	1.716	1.132	0.681	0.438	0.366	0.425	0.446	0.615	0.574	0.407	0.151	0.000	0.000	0.000	0.000	0.000	0.000
268/HB02	3.992	4.904	5.483	5.918	5.939	5.819	5.690	5.565	4.344	4.682	4.012	3.390	3.298	2.486	1.989	1.338	0.717	0.092	0.000
268/HB03	3.500	4.479	5.161	5.675	5.742	5.651	5.592	5.662	4.700	5.528	5.261	4.884	5.124	4.071	3.371	2.333	1.354	0.220	0.004

268/HB04	3.559	4.649	5.475	6.151	6.339	6.303	6.221	6.160	4.909	5.453	4.841	4.202	4.143	3.113	2.448	1.594	0.774	0.054	0.000
268/HB05	2.354	3.319	4.214	5.108	5.690	6.129	6.562	7.046	6.014	7.075	6.598	5.959	6.101	4.788	3.980	2.852	1.713	0.638	0.010
268/HB06	0.000	0.000	0.000	0.000	0.000	0.000	0.111	2.257	4.367	8.959	12.380	14.374	17.215	14.616	12.316	8.377	4.647	0.382	0.000
268/HB07	0.651	0.649	0.589	0.629	0.916	1.642	2.980	5.089	6.135	9.383	10.693	11.020	12.316	10.218	8.796	6.462	4.059	2.071	0.053
268/HB08	0.000	0.000	0.000	0.000	0.000	0.005	0.319	2.664	4.815	9.472	12.705	14.416	16.921	14.119	11.742	7.962	4.316	0.542	0.001
268/HB09	2.650	4.220	5.958	7.830	9.148	9.909	10.120	9.665	6.863	6.198	3.989	2.307	1.375	0.542	0.120	0.011	0.000	0.000	0.000
268/HB10	0.027	0.339	1.413	3.031	5.083	7.377	9.814	12.176	11.106	13.053	11.399	9.126	7.824	4.820	2.888	0.523	0.000	0.000	0.000
268/HB11	0.000	0.276	1.966	4.859	8.534	12.242	15.299	16.865	13.036	12.199	7.736	4.150	2.109	0.604	0.124	0.000	0.000	0.000	0.000
268/HB12	0.138	1.691	4.667	8.714	12.446	14.967	15.803	14.650	9.579	7.566	3.996	1.834	0.900	0.403	0.301	0.248	0.185	0.111	0.046
268/HB13	0.087	1.627	4.774	9.174	13.284	16.060	16.911	15.462	9.821	7.330	3.425	1.214	0.322	0.043	0.058	0.116	0.136	0.106	0.050
268/HB14	1.060	2.201	3.717	5.457	6.773	7.499	7.582	6.958	4.640	3.849	2.201	1.119	0.358	0.181	0.117	0.064	0.008	0.000	0.000
268/HB15	0.722	2.692	5.757	9.601	12.788	14.589	14.681	12.918	7.962	5.833	2.770	1.144	0.600	0.439	0.533	0.567	0.470	0.327	0.135
268/HB16	1.229	4.016	8.245	13.093	16.218	16.686	14.557	10.475	4.895	2.471	0.179	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
268/HB17	3.451	5.717	7.982	9.985	10.745	10.378	9.100	7.080	3.872	2.491	0.546	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
268/HB19	0.000	0.416	1.830	4.101	6.740	9.245	11.217	12.223	9.602	9.588	7.160	5.277	4.750	3.659	3.268	2.625	1.830	1.132	0.406
268/HB20	0.076	1.283	4.071	8.083	12.067	15.047	16.399	15.618	10.386	8.201	4.169	1.692	0.595	0.141	0.107	0.118	0.105	0.072	0.029
268/HB30	0.518	0.895	1.383	2.022	2.711	3.526	4.582	5.990	6.073	8.317	8.874	8.890	9.877	8.258	7.207	5.378	3.416	1.797	0.047
268/HB31B	3.303	3.149	2.760	2.366	1.938	1.641	1.521	1.597	1.464	1.908	1.907	1.672	1.401	0.571	0.095	0.000	0.000	0.000	0.000
268/HB32D	2.132	2.335	2.389	2.437	2.423	2.522	2.864	3.566	3.668	5.245	5.871	6.077	6.834	5.639	4.738	3.286	1.891	0.336	0.009
268/HB33A	2.097	2.207	2.250	2.404	2.624	3.051	3.775	4.841	4.846	6.479	6.600	6.155	6.145	4.408	3.102	1.600	0.174	0.000	0.000
268/HB35	1.433	1.380	1.360	1.558	1.990	2.738	3.830	5.240	5.313	6.946	6.727	5.852	5.316	3.328	1.896	0.317	0.000	0.000	0.000

Appendix 4 – Gradistat Sediment Analysis Results (after Folk & Ward, 1957)

Sample	Sample Type	Textural Group	Mean (µm)	Sorting (µm)	Skewness (µm)	Kurtosis (µm)
fk_01_ss	Polymodal, Very Poorly Sorted	Muddy Sand	121.088	10.037	-0.515	0.618
fk_02_ss	Trimodal, Very Poorly Sorted	Muddy Sand	119.721	7.523	-0.484	0.591
fk_03_ss	Polymodal, Very Poorly Sorted	Muddy Sand	96.146	9.463	-0.453	0.598
fk_05_ss	Trimodal, Very Poorly Sorted	Sandy Mud	33.877	7.863	-0.065	0.596
fk_09_ss	Polymodal, Very Poorly Sorted	Muddy Sand	57.982	8.348	-0.159	0.647
fk_10_ss	Trimodal, Very Poorly Sorted	Muddy Sand	40.069	5.503	-0.502	0.721
fk_11_ss	Trimodal, Very Poorly Sorted	Muddy Sand	48.180	5.237	-0.526	0.708
fk_15_ss	Polymodal, Very Poorly Sorted	Sandy Mud	33.221	6.879	-0.220	0.768
fk_18_ss	Trimodal, Very Poorly Sorted	Muddy Sand	93.529	6.362	-0.362	0.647
fk_21_ss	Polymodal, Very Poorly Sorted	Sandy Mud	49.635	10.240	-0.026	0.620
fk_22_ss	Polymodal, Very Poorly Sorted	Muddy Sand	58.175	8.654	-0.234	0.604
fk_23_ss	Trimodal, Very Poorly Sorted	Sandy Mud	26.401	6.355	-0.186	0.706
fk_24_ss	Polymodal, Very Poorly Sorted	Sandy Mud	42.513	10.010	-0.076	0.606
fk_26_ss	Polymodal, Very Poorly Sorted	Sandy Mud	25.946	6.334	-0.099	0.892
fk_30_ss	Polymodal, Very Poorly Sorted	Sandy Mud	59.111	11.461	-0.035	0.601
fk_32_ss	Polymodal, Very Poorly Sorted	Muddy Sand	54.482	9.769	-0.357	0.677
fk_34_ss	Bimodal, Poorly Sorted	Muddy Sand	59.654	3.172	-0.482	1.572
fk_35_ss	Polymodal, Very Poorly Sorted	Muddy Sand	93.915	8.707	-0.322	0.622
fk_38_ss	Trimodal, Very Poorly Sorted	Muddy Sand	54.403	7.481	-0.445	0.647
fk_40_ss	Polymodal, Very Poorly Sorted	Muddy Sand	96.001	7.941	-0.396	0.595
fk_42_ss	Polymodal, Very Poorly Sorted	Muddy Sand	73.620	7.400	-0.442	0.631
fk_44_ss	Polymodal, Very Poorly Sorted	Muddy Sand	69.318	6.986	-0.530	0.626
fk_45_ss	Polymodal, Very Poorly Sorted	Muddy Sand	53.385	8.415	-0.328	0.686
fk_46_ss	Polymodal, Very Poorly Sorted	Muddy Sand	52.322	7.700	-0.435	0.685
fk_48_ss	Polymodal, Very Poorly Sorted	Muddy Sand	80.249	6.241	-0.376	0.696
fk_50_ss	Polymodal, Very Poorly Sorted	Muddy Sand	84.122	8.819	-0.368	0.624
fk_51_ss	Polymodal, Very Poorly Sorted	Muddy Sand	75.173	6.380	-0.461	0.633
fk_52_ss	Polymodal, Very Poorly Sorted	Muddy Sand	79.734	6.119	-0.410	0.662
fk_53_ss	Polymodal, Very Poorly Sorted	Muddy Sand	83.445	6.029	-0.448	0.614
fk_55_ss	Polymodal, Very Poorly Sorted	Muddy Sand	72.882	7.009	-0.495	0.627
fk_56_ss	Polymodal, Very Poorly Sorted	Muddy Sand	52.425	6.700	-0.526	0.633
fk_57_ss	Trimodal, Very Poorly Sorted	Muddy Sand	62.906	6.916	-0.442	0.645
fk_58_ss	Polymodal, Very Poorly Sorted	Muddy Sand	65.148	10.200	-0.354	0.658
fk_59_ss	Polymodal, Very Poorly Sorted	Muddy Sand	49.442	7.893	-0.467	0.675
fk_60_ss	Polymodal, Very Poorly Sorted	Muddy Sand	59.679	6.278	-0.441	0.777
fk_61_ss	Polymodal, Very Poorly Sorted	Muddy Sand	53.610	6.631	-0.491	0.735
fk_62_ss	Polymodal, Very Poorly Sorted	Muddy Sand	39.504	8.030	-0.375	0.755
fk_63_ss	Polymodal, Very Poorly Sorted	Sandy Mud	27.734	8.506	-0.145	0.745
fk_64_ss	Trimodal, Very Poorly Sorted	Muddy Sand	52.997	5.341	-0.426	1.308
fk_65_ss	Polymodal, Very Poorly Sorted	Muddy Sand	46.636	8.607	-0.266	0.733
fk_66_ss	Polymodal, Very Poorly Sorted	Muddy Sand	52.419	7.795	-0.309	0.931
fk_67_ss	Trimodal, Very Poorly Sorted	Muddy Sand	79.053	9.290	-0.475	0.598
fk_68_ss	Polymodal, Very Poorly Sorted	Muddy Sand	65.805	9.522	-0.446	0.640
fk_69_ss	Polymodal, Very Poorly Sorted	Muddy Sand	76.225	7.175	-0.452	0.631
fk_70_ss	Trimodal, Very Poorly Sorted	Muddy Sand	55.630	7.166	-0.516	0.609
fk_71_ss	Trimodal, Very Poorly Sorted	Muddy Sand	44.347	6.670	-0.469	0.786
fk_72_ss	Polymodal, Very Poorly Sorted	Muddy Sand	47.477	8.844	-0.295	0.779
268/fk_1_85	Polymodal, Very Poorly Sorted	Muddy Sand	67.679	10.067	-0.439	0.657
268/fk_2_98	Trimodal, Very Poorly Sorted	Muddy Sand	22.914	8.803	-0.629	0.729
268/fk_3_110	Bimodal, Poorly Sorted	Muddy Sand	110.482	3.219	-0.003	1.895
268/fk_4_119	Polymodal, Very Poorly Sorted	Sandy Mud	26.447	14.104	-0.348	0.673
268/fk_5_120	Polymodal, Very Poorly Sorted	Muddy Sand	44.176	7.265	-0.405	0.701
268/fk_6_121	Trimodal, Very Poorly Sorted	Muddy Sand	41.365	7.172	-0.426	0.677
268/fk_7_122	Polymodal, Very Poorly Sorted	Muddy Sand	55.998	8.428	-0.138	0.640
268/fk_8_123	Polymodal, Very Poorly Sorted	Muddy Sand	59.446	7.506	-0.472	0.664
268/fk_9_124	Trimodal, Very Poorly Sorted	Muddy Sand	33.658	5.815	-0.602	0.654
268/fk_10_125	Polymodal, Very Poorly Sorted	Muddy Sand	81.298	6.539	-0.435	0.645
268/fk_11_126	Polymodal, Very Poorly Sorted	Muddy Sand	94.955	6.934	-0.438	0.622
268/fk_12_127	Polymodal, Very Poorly Sorted	Muddy Sand	42.437	7.164	-0.497	0.727
268/fk_13_128	Bimodal, Very Poorly Sorted	Muddy Sand	50.846	4.411	-0.640	1.227
268/fk_14_129	Polymodal, Very Poorly Sorted	Muddy Sand	55.948	6.333	-0.195	1.377
268/fk_15_130	Polymodal, Very Poorly Sorted	Muddy Sand	56.293	6.373	-0.318	1.173
268/fk_16_131	Polymodal, Very Poorly Sorted	Muddy Sand	46.795	7.992	-0.375	0.866

268/fk_17_132	Unimodal, Poorly Sorted	Muddy Sand	99.109	2.288	-0.252	1.539
268/fk_18_133	Unimodal, Poorly Sorted	Muddy Sand	70.596	3.217	-0.581	1.865
268/fk_19_134	Polymodal, Very Poorly Sorted	Sandy Mud	52.040	9.595	-0.107	0.736
268/fk_20_135	Polymodal, Very Poorly Sorted	Muddy Sand	74.092	6.402	-0.445	0.757
268/fk_21_136	Trimodal, Very Poorly Sorted	Muddy Sand	63.853	5.848	-0.519	0.653
268/fk_22_137	Polymodal, Very Poorly Sorted	Muddy Sand	76.742	7.083	-0.450	0.645
268/fk_23_138	Polymodal, Very Poorly Sorted	Muddy Sand	75.468	6.622	-0.414	0.649
268/fk_24_139	Polymodal, Very Poorly Sorted	Muddy Sand	73.604	6.855	-0.490	0.664
268/fk_25_140	Polymodal, Very Poorly Sorted	Muddy Sand	64.366	6.640	-0.437	0.652
268/fk_26_141	Polymodal, Very Poorly Sorted	Muddy Sand	48.413	8.233	-0.342	0.675
268/fk_27_151	Polymodal, Very Poorly Sorted	Muddy Sand	39.661	6.643	-0.514	0.676
268/fk_29_162	Polymodal, Very Poorly Sorted	Muddy Sand	63.053	10.338	-0.188	0.656
268/fk_30_165	Polymodal, Very Poorly Sorted	Sandy Mud	38.570	8.447	-0.298	0.624
268/fk_31_183	Trimodal, Very Poorly Sorted	Muddy Sand	71.452	8.654	-0.351	0.574
268/fk_32_187	Polymodal, Very Poorly Sorted	Sandy Mud	43.371	10.131	-0.106	0.606
268/fk_33_188	Trimodal, Very Poorly Sorted	Muddy Sand	87.508	8.560	-0.534	0.586
268/fk_34_189	Trimodal, Very Poorly Sorted	Muddy Sand	42.557	7.512	-0.362	0.643
268/fk_35_190	Polymodal, Very Poorly Sorted	Sandy Mud	40.672	8.966	-0.038	0.647
268/fk_36_191	Trimodal, Very Poorly Sorted	Muddy Sand	64.935	7.702	-0.599	0.620
268/fk_37_192	Polymodal, Very Poorly Sorted	Sandy Mud	31.618	7.195	-0.056	0.764
268/fk_38_193	Polymodal, Very Poorly Sorted	Muddy Sand	48.825	7.166	-0.341	0.744
268/fk_39_194	Polymodal, Very Poorly Sorted	Muddy Sand	49.879	8.047	-0.246	0.648
268/fk_40_195	Polymodal, Very Poorly Sorted	Muddy Sand	73.635	8.937	-0.520	0.599
277/fk_vc01_196A	Polymodal, Very Poorly Sorted	Muddy Sand	54.603	7.443	-0.419	0.642
277/fk_vc02_197A	Polymodal, Very Poorly Sorted	Muddy Sand	64.207	5.603	-0.553	0.642
277/fk_vc03_198A	Polymodal, Very Poorly Sorted	Muddy Sand	65.369	5.415	-0.324	1.441
277/fk_vc04_199A	Polymodal, Very Poorly Sorted	Muddy Sand	46.894	8.010	-0.237	0.873
277/fk_vc05_200A	Polymodal, Very Poorly Sorted	Muddy Sand	55.500	5.002	-0.563	1.110
277/fk_vc06_201A	Polymodal, Very Poorly Sorted	Muddy Sand	80.735	5.106	-0.420	0.700
277/fk_vc09_202A	Polymodal, Very Poorly Sorted	Muddy Sand	78.207	8.229	-0.427	0.647
277/fk_vc13_203a	Trimodal, Very Poorly Sorted	Sandy Mud	49.351	6.795	-0.172	0.633
277/fk_vc17_204A	Polymodal, Very Poorly Sorted	Sandy Mud	38.377	6.473	-0.361	0.664
277/fk_vc20_205A	Trimodal, Very Poorly Sorted	Sandy Mud	33.490	7.009	-0.313	0.769
KB32A	Unimodal, Moderately Sorted	Sand	148.897	1.634	-0.105	1.154
KB33A	Unimodal, Moderately Well Sorted	Sand	140.551	1.472	-0.044	0.981
KB34A	Bimodal, Poorly Sorted	Muddy Sand	90.888	2.955	-0.261	1.988
KB35A	Trimodal, Very Poorly Sorted	Muddy Sand	40.060	5.339	-0.560	0.959
KB36A	Polymodal, Very Poorly Sorted	Muddy Sand	42.151	4.808	-0.364	1.383
KB37A	Trimodal, Very Poorly Sorted	Muddy Sand	74.063	5.189	-0.602	1.086
KB38A	Polymodal, Very Poorly Sorted	Muddy Sand	37.947	5.953	-0.361	0.950
KB39A	Unimodal, Well Sorted	Sand	139.831	1.403	-0.031	1.010
KB40A	Unimodal, Moderately Well Sorted	Sand	151.963	1.580	-0.001	0.993
KB41A	Unimodal, Well Sorted	Sand	154.816	1.397	-0.032	0.991
KB42A	Unimodal, Moderately Sorted	Sand	143.636	1.676	-0.207	1.581
KB43A	Unimodal, Moderately Sorted	Sand	190.911	1.961	0.293	1.489
KB44A	Unimodal, Moderately Sorted	Sand	129.720	1.878	-0.382	2.768
CC01B	Unimodal, Moderately Sorted	Sand	196.269	1.700	-0.279	1.897
CC02A	Trimodal, Moderately Sorted	Sand	271.519	1.923	-0.007	0.905
CC03A	Bimodal, Moderately Sorted	Sand	384.546	1.853	0.053	0.966
CC04A	Unimodal, Moderately Well Sorted	Sand	168.719	1.491	0.023	0.949
CC05A	Unimodal, Moderately Well Sorted	Sand	162.256	1.431	-0.105	1.184
CC06A	Unimodal, Moderately Sorted	Sand	144.522	1.773	-0.107	1.508
CC07A	Unimodal, Moderately Well Sorted	Sand	141.244	1.438	-0.073	1.062
CC08A	Unimodal, Moderately Well Sorted	Sand	187.153	1.550	-0.106	1.138
268/HB01	Trimodal, Very Poorly Sorted	Sandy Mud	15.042	4.948	-0.189	0.812
268/HB02	Polymodal, Very Poorly Sorted	Muddy Sand	103.639	7.165	-0.456	1.551
268/HB03	Polymodal, Very Poorly Sorted	Muddy Sand	206.957	4.616	-0.303	1.456
268/HB04	Polymodal, Very Poorly Sorted	Muddy Sand	163.962	5.076	-0.377	1.599
268/HB05	Polymodal, Poorly Sorted	Muddy Sand	296.974	3.697	-0.300	1.580
268/HB06	Unimodal, Moderately Well Sorted	Sand	760.718	1.494	-0.031	0.909
268/HB07	Bimodal, Poorly Sorted	Sand	612.497	2.158	-0.279	1.541
268/HB08	Unimodal, Moderately Well Sorted	Sand	746.629	1.507	-0.032	0.917
268/HB09	Trimodal, Poorly Sorted	Muddy Sand	167.729	3.681	-0.497	2.145

268/HB10	Bimodal, Moderately Sorted	Sand	416.011	1.684	-0.016	0.951
268/HB11	Unimodal, Moderately Well Sorted	Sand	321.053	1.519	0.024	0.954
268/HB12	Unimodal, Moderately Well Sorted	Sand	268.260	1.552	0.026	1.040
268/HB13	Unimodal, Moderately Well Sorted	Sand	264.775	1.485	0.021	0.981
268/HB14	Polymodal, Very Poorly Sorted	Muddy Sand	53.479	7.477	-0.569	0.689
268/HB15	Bimodal, Moderately Sorted	Sand	244.502	1.920	-0.203	1.817
268/HB16	Unimodal, Poorly Sorted	Sand	204.471	2.073	-0.354	2.477
268/HB17	Bimodal, Very Poorly Sorted	Muddy Sand	82.304	4.965	-0.652	1.346
268/HB19	Bimodal, Poorly Sorted	Sand	373.547	2.025	0.110	1.183
268/HB20	Unimodal, Moderately Well Sorted	Sand	272.207	1.522	-0.002	1.024
268/HB30	Trimodal, Poorly Sorted	Sand	472.254	3.499	-0.431	2.048
268/HB31B	Polymodal, Very Poorly Sorted	Sandy Mud	23.873	7.336	-0.136	0.815
268/HB32D	Polymodal, Very Poorly Sorted	Muddy Sand	119.126	8.302	-0.488	0.828
268/HB33A	Polymodal, Very Poorly Sorted	Muddy Sand	109.008	7.901	-0.509	0.914
268/HB35	Polymodal, Very Poorly Sorted	Muddy Sand	79.330	8.694	-0.474	0.718

Appendix 5 – Vibracore Logs

CORE: VC01	**DRILL METHOD:** Vibracore	**PENETRATION (m):** 2.92 m
LOCATION: Keppel Bay	**WATER DEPTH (m):** 9.8 mbsl	**RECOVERY (m):** 3.03 m
DATE: 31/08/2004	**COORDINATES (WGS84):** 23.42326 S, 150.93318 E	

Depth (m)	Core Photo / Graphic Log	Core Description
0.00		Very dark grey (5Y3/1) laminated muds with layers of fine sand and mud (1-2 cm up to 5cm). Bioclastic material present. Sample taken (0.1-0.12 m) - very fine sand, very poorly sorted, 10% $CaCO_3$ Shell accummulation in muddy sand. Predominantly turitella shells. Organic plant material - flaky woody appearance.
1.00		Dark grey (5Y3/1) mud with sand layers. Turitella in sandy layer from 1.15-1.16 m. Thicker mud layers of dark olive grey (5Y3/2). Organic blob. Sediment becoming sandier to a muddy medium sand.
2.00		Dark grey (5Y3/1) muddy medium sand, with minor mud layers. Bioclastic material present in layers. Sample taken (2.2-2.22 m) silt and mud, trimodal, very poorly sorted, 9% $CaCO_3$
3.00		EOH @ 3.03 m

COMMENTS:

CORE: VC02	**DRILL METHOD:** Vibracore	**PENETRATION (m):** 3.04 m
LOCATION: Keppel Bay	**WATER DEPTH (m):** 8 mbsl	**RECOVERY (m):** 2.72 m
DATE: 31/08/2004	**COORDINATES (WGS84):** 23.42254 S, 150.88315 E	

Depth (m) | **Core Photo** | **Graphic Log** | **Core Description**

0.00

Olive (5Y4/3) poorly sorted massive medium sand with bioclastic material. Bioturbation evident.

Sample taken (0.1-0.12 m) fine-medium sand, moderately well sorted, 6% CaCO3

Sharp contact to dark grey (5Y3/1) muddy fine sand with turitella scattered throughout and other bioclastic material (bivalves etc.) Also fairly uniform with no laminations evident.

1.00

Dark grey (5Y3/1) muddy fine sand with common turitella.

Sandier sections with medium sand between 1.15 and 1.24 m.

Gets slightly muddier, but still with sandy layers of fine sand.

2.00

Dark grey (5Y3/1) muddy fine sand, slightly sandier than above.

Bioclastic rich layer with gravelly medium sand between 2.29-2.33 m. Bioclasts are fragmented and reworkd bivalves and turitella.

Muddier section, but still with fine sand layers.

Sample taken (2.5-2.52 m) silt and mud, bimodal, very poorly sorted, 12.6% CaCO3

Organic blobs present at 2.6 and 2.68 m.

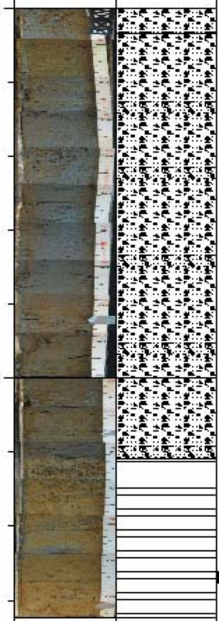
EOH @ 2.73 m.

3.00

COMMENTS:

CORE: VC03	**DRILL METHOD: Vibracore**	**PENETRATION (m): 2.03 m**
LOCATION: Keppel Bay	**WATER DEPTH (m): 8.3 mbsl**	**RECOVERY (m): 1.65 m**
DATE: 31/08/2004	**COORDINATES (WGS84): 23.3957 S, 150.84548 E**	

Depth (m)	Core Photo	Graphic Log	Core Description



0.00

Olive grey (5Y4/2) muddy fine sand with top 3-4 cm full of turitella shells. Grades into olive grey sandy mud between 0.04-0.2 m.

Interbedded sandy mud and muddy sand. Indistinct laminations and sparse turitella shells.

Black organic flecks dispersed throughout the sediment.

Coarser shell fragments.

1.00

Whole bivalve of approximately 2.5 cm.

Clay rip up clast in sandy mud sediment.

Erosional contact at 1.22 m to a pale olive (5Y6/3) to olive grey (5Y5/2) sandy clay. Mottles of strong brown (7.5YR5/8). No evidence of fossils.

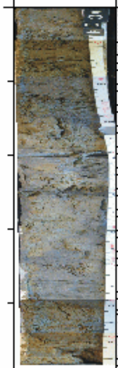
Sample taken (1.55-1.57 m) dense sandy clay, bimodal, very poorly sorted, 0% CaCO3
EOH @ 1.65 m

2.00

3.00

COMMENTS:

CORE: VC04	**DRILL METHOD: Vibracore**	**PENETRATION (m): 3.0 m**
LOCATION: Keppel Bay	**WATER DEPTH (m): 9.4 mbsl**	**RECOVERY (m): 0.97 m**
DATE: 31/08/2004	**COORDINATES (WGS84): 23.35567 S, 150.8535 E**	

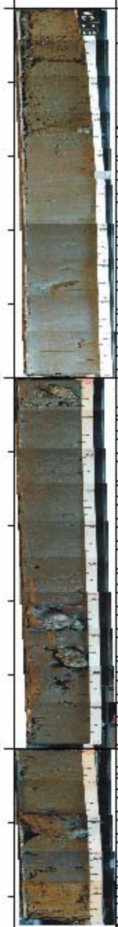
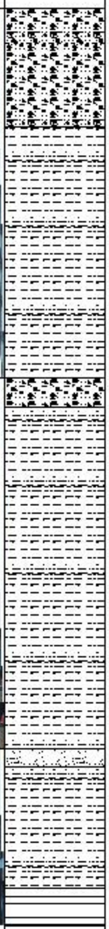
Depth (m)	Core Photo	Graphic Log	Core Description
0.00			Core was severely bent and was therefore cut at 0.4 m. Dark grey (5Y4/1) shelly muddy sand with abundant turitella and other shell fragments. Gradational change to clay from 0.27 m onwards. Olive (5Y5/3) stiff, sandy clay with orange mottles. Inclusions of muddy sand with turitella. Sample taken (0.55-0.57 m) dense sandy clay, bimodal, very poorly sorted, 0% $CaCO_3$ Sharp contact to massive medium sand bedding. EOH @ 0.97 m
1.00			
2.00			
3.00			

COMMENTS:

CORE: VC05 | **DRILL METHOD:** Vibracore | **PENETRATION (m):** 2.99 m

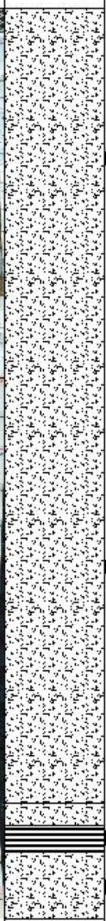
LOCATION: Keppel Bay | **WATER DEPTH (m):** 8.2 mbsl | **RECOVERY (m):** 2.47 m

DATE: 31/08/2004 | **COORDINATES (WGS84):** 23.31181 S, 150.84401 E

Depth (m)	Core Photo	Graphic Log	Core Description
0.00			Olive (5Y5/3) muddy fine sand with sparse shell fragments and turitella. Indistinct sandy bedding. Samples taken - fine sands, unimodal, 12-20% CaCO3 Becoming muddier between 0.33 - 0.44 m grading into olive grey (5Y4/2) sticky sandy mud with fine bedding of 1-2 cm. Very little carbonate. Samples - silt and mud, bimodal, ~10% CaCO3
1.00			Sand hash, oysters and other bioclastic material between 1.0 - 1.08 m. Olive grey (5Y4/2) fine sandy mud. No bioclastic material. Faint sandier bedding. Large oyster and shall hash present between 1.62 - 1.68 m. Large cemented coral chunk present between 1.74 - 1.78 m. Olive grey (5Y4/2) sandy mud with faint sandy bedding.
2.00			Sandy layer, no carbonate present. Large oyster. Clay rip-up clasts in the sandy mud. Distinct change to pale olive (5Y6/4) hard dry sandy clay with burrows/root casts and orange mottles. EOH @ 2.48 m
3.00			

COMMENTS:

CORE: VC06	**DRILL METHOD: Vibracore**	**PENETRATION (m): 2.07 m**
LOCATION: Keppel Bay	**WATER DEPTH (m): 7.2 mbsl**	**RECOVERY (m): 2.46 m**
DATE: 31/08/2004	**COORDINATES (WGS84): 23.24946 S, 150.8605 E**	

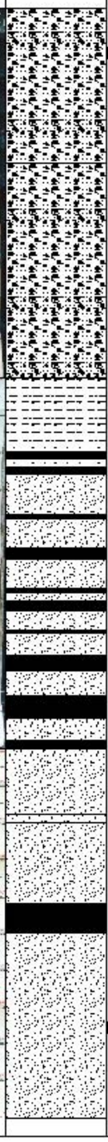
Depth (m)	Core Photo	Graphic Log	Core Description
0.00			Dark greyish brown (2.5Y4/2) medium to coarse sand. Moderately sorted and sub-angular. Massive - no obvious bedding. Very high shell hash content. Occasional larger shell fragments up to 1.5 cm of bivalves and rare whole gastropods.
			Sample taken (0.4-0.42 m) fine-medium sand, unimodal, moderately sorted, 18% CaCO3
1.00			
			Slightly darker in colour and increase in mud content at 1.25 m. Smaller bioclastic fragments.
			Sample taken (1.5-1.52 m) fine-medium sand, unimodal, moderately sorted, 20% CaCO3
			Distinct increase in mud at 1.65 m.
2.00			
			Mud blob within the sand at 2.17 m.
			Very dark greyish brown (2.5Y3/2) mud layer - mangrove?
			Sample taken (2.24-2.26 m) silt and mud, bimodal, very poorly sorted, 6%
			Sharp contact back to coarse gravelly sand with coarser shell fagments and pebbles. Some mud rip up clasts also present.
			Sample taken (2.34-2.36 m) medium-coarse sand, unimodal, moderately sorted, 42.5% CaCO3
			EOH @ 2.46 m
3.00			

COMMENTS:

CORE: VC07 | **DRILL METHOD:** Vibracore | **PENETRATION (m):** 3.08 m

LOCATION: Keppel Bay | **WATER DEPTH (m):** 6.0 mbsl | **RECOVERY (m):** 3.04 m

DATE: 31/08/2004 | **COORDINATES (WGS84):** 23.15529 S, 150.79537 E

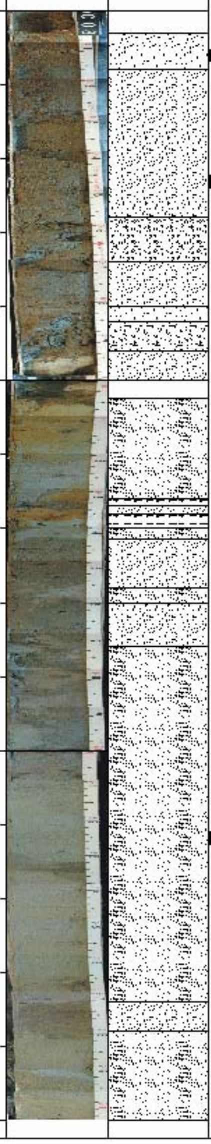
Depth (m)	Core Photo	Graphic Log	Core Description
0.00 1.00 2.00 3.00			Dark grey (2.5Y4/1) muddy medium to coarse sand with abundant turitella gastropods and other shell hash. Shells up to 2.5 cm. No obvious bedding. Sample taken (0.1-0.12 m) silt and mud, bimodal, very poorly sorted, 27.3% $CaCO_3$ Becoming muddier. Orange clay inclusions (0.55 m), Large carbonate lump (0.6 m). Woody debris, organic material (0.72 m). Turitella becoming less abundant. Dark grey (2.5Y4/1) muddy medium sand, slightly finer than above and with rare teritula. Dark organic bands of 1-2 cm thick, interbedded with sandy mud from 1.2-1.3 m. Medium sand interbedded with organic bands. Small inclusions of clay (rip up clasts?) Organic material in medium sands. Mud clasts and fragments of bivalves. Coarser sands in thin layer. Woody organic bed. Medium sands, moderately sorted with mud clasts, and bivalve fragments. Sample taken (2.72-2.74 m) fine-medium sand, unimodal, moderately sorted, 2.5% $CaCO_3$ Articulated bivalve shell. EOH @ 3.0 m

COMMENTS:

CORE: VC08	**DRILL METHOD: Vibracore**	**PENETRATION (m): 3.065 m**
LOCATION: Keppel Bay	**WATER DEPTH (m): 7.3 mbsl**	**RECOVERY (m): 3.02 m**
DATE: 31/08/2004	**COORDINATES (WGS84): 23.15053 S, 150.83736 E**	

Depth (m)	Core Photo	Graphic Log	Core Description

0.00



Top 6 cm of core lost.
Brown (10YR5/3) coarse to very coarse sand with coarse fragments.
Sample taken (0.14-0.16 m) fine - medium sand, unimodal, moderately well sorted, 8% CaCO3
Change in colour to dark grey (2.5Y4/1) medium sand with shell fragments.

Sample taken (0.45-0.47 m) fine-medium sand, unimodal, poorly sorted, 12% CaCO3
Gravel clasts and rock material in coarse sand and gravel matrix.

Medium sands.

Gravel clasts and Pectin? fragment - in coarse sand matrix.

Facies change to light grey (2.5Y7/1) medium sand.
Top 5 cm of section lost.

1.00

Olive yellow (2.5Y6/9) to brownish yellow (10YR6/8) fine sand, well sorted and subrounded. Burrows evident in sediment.
Change in colour to olive grey (5Y5/2).

Clay rich layer.
Medium sand.
Clay rich layer.
Dark grey (5Y4/1) medium sand, moderately sorted and sub angular.

Fine sand.
Dark grey (5Y4/1) medium sand, dark mottling in this layer and the medium sand above. Indistinct bedding.

Olive grey to light grey (5Y5/2 to 2.5Y7/1) fine sand. Indistinct beds, dark grey bands, burrows and bioturbation.

2.00

Light grey to grey (2.5Y7/1 to 6/1) fine-medium sand. Very well sorted and moderately well rounded. No fossils.
Sample taken (2.2-2.22 m) very fine sand, unimodal, poorly sorted, 0.5% CaCO3

Grey (2.5Y5/1) medium sand, moderately well sorted in subhorizontal layer/discontinuous layer.

Faint bedding at base of core, sand a pale yellow (2.5Y7/3).
EOH @ 3.04 m

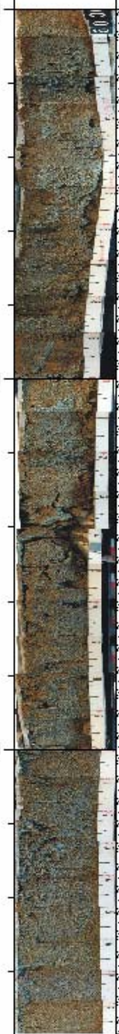
3.00

COMMENTS:

CORE: VC09 | **DRILL METHOD:** Vibracore | **PENETRATION (m):** 3.01 m

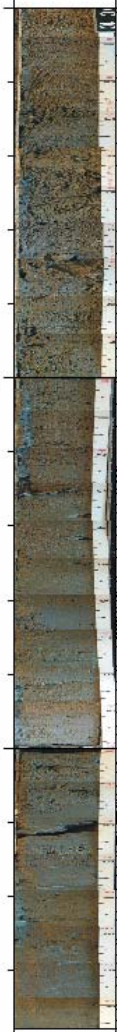
LOCATION: Keppel Bay | **WATER DEPTH (m):** 10.2 mbsl | **RECOVERY (m):** 2.85m

DATE: 01/09/2004 | **COORDINATES (WGS84):** 23.21184 S, 150.93247 E

Depth (m)	Core Photo	Graphic Log	Core Description
0.00			Dark greyish brown (2.5Y4/2) medium-coarse sand, moderately sorted, subangular. Abundant bioclastic fragments, predominantly bivalves up to 4 mm. Sample taken (0.1-0.12 m) medium sand, unimodal, moderately well sorted, 5.5% CaCO3
			Well sorted medium-coarse sand slightly lighter in colour - light olive brown (2.5Y5/4).
			Dark greyish brown (2.5Y4/2) medium coarse sand, moderately sorted and subangular.
			Light olive brown (2.5Y5/4) with dark greyish brown mottles and burrows.
1.00			Dark greyish brown medium-coarse sand, moderately sorted and subangular with lots of gragmented bioclastic material.
			Light olive brown (2.5Y5/4).
			Partial sample loss. Core slightly bent and therefore some of the sediment was lost during splitting.
			Mottled light olive brown with dark greyish brown and bioturbation.
2.00			Very abundant large bioclastic fragments. Medium to coarse sand moderately sorted and subangular.
			Bioclasts smaller and more uniform and several mud rip up clasts present at the base of the core.
			EOH @ 2.77 m
3.00			

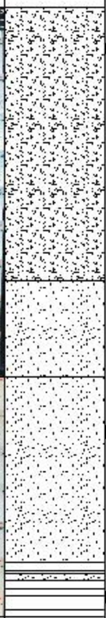
COMMENTS:

CORE: VC10	**DRILL METHOD: Vibracore**	**PENETRATION (m): 3.05 m**
LOCATION: Keppel Bay	**WATER DEPTH (m): 19 mbsl**	**RECOVERY (m): 2.76 m**
DATE: 01/09/2004	**COORDINATES (WGS84): 23.21632 S,150.9526 E**	

Depth (m)	**Core Photo**	**Graphic Log**	**Core Description**
0.00			Dark grey (5Y4/1) fine to medium sand with abundant broken bioclastic material and organic matter throughout
			Sample taken (2.6-2.62 m) silt and mud, polymodal, very poorly sorted, 43% CaCO3
			Organic matter.
			Cemented carbonate nodules between 0.64 and 0.74 m.
			Increasing mud content, to muddy sand.
			Broken oyster shell.
1.00			Dark grey (5Y4/1) fine to medium sand.
			Muddy layer. Oyster shell.
			Bivalves found at 1.39 and 1.46 m.
			Increasing mud content with depth.
			Muddy layers with fine sands. Less bioclastic material below 1.6 m.
2.00			Gap at top of core.
			Organic layer in mud.
			Organic and bioclastic layer.
			Lots of little twigs like organic matter predominantly in the muddy layers. Some fine sand lenses.
			Sample taken (2.6-2.62 m) silt and mud, polymodal, very poorly sorted, 8% CaCO3 EOH @ 2.76 m
3.00			

COMMENTS:

CORE: VC11	**DRILL METHOD:** Vibracore	**PENETRATION (m):** 2.01 m
LOCATION: Keppel Bay	**WATER DEPTH (m):** ~ 17 mbsl	**RECOVERY (m):** 1.64 m
DATE: 01/09/2004	**COORDINATES (WGS84):** 23.25946 S, 151.02531 E	

Depth (m)	Core Photo	Graphic Log	Core Description
0.00			Olive grey (5Y4/2) massive medium sand, moderately sorted, subangular, with abundant reworked fragmented bioclasts Sample taken (0.1-0.12 m) fine-medium sand, unimodal, poorly sorted, 12% CaCO3 Large Pecten. Large chunks of clay inthe sand matrix from 0.74-0.75, 0.76-0.94 and 0.96-1.0 m. No sand present in the clay. Clay has orange mottles and organic matter.
1.00			Olive grey (5Y4/2) massive medium sand, with mottles of olive brown (2.5Y4/4). Mud clasts in matrix. Sample taken (1.15-1.17 m) silt and mud, bimodal, poorly sorted, 0% CaCO3 Large clay chunks of dark greenish grey (gley1 4/1) from 1.21-1.25 and 1.27-1.33 m. Coarse-medium sand with layers of light olive brown (2.5Y5/3) sand. Clay layer from 1.5-1.53 m. Coarse sand layer. Greenish grey (gley1 5/1) clay at base of the core. Sample taken (1.58-1.6 m) clay, unimodal, poorly sorted, 1% CaCO3 EOH @ 1.65 m
2.00			
3.00			

COMMENTS:

CORE: VC12	**DRILL METHOD: Vibracore**	**PENETRATION (m): 2.73 m**
LOCATION: Keppel Bay	**WATER DEPTH (m): 14 mbsl**	**RECOVERY (m): 2.5 m**
DATE: 01/09/2004	**COORDINATES (WGS84): 23.28507 S, 150.94053 E**	

Depth (m)	**Core Photo**	**Graphic Log**	**Core Description**
0.00			Top of core missing. Olive brown (2.5Y4/4) medium sand, moderately sorted with abundant fragmented bioclastic material. Much less bioclastic material. Sample taken (0.1-0.12 m) medium sand, unimodal, moderately well sorted, 6% CaCO3 Olive (5Y4/3) coarser sands with abundant bioclasts. Olive grey (5Y4/2) medium sand with less abundant bioclastic material. Coarse gravel layer. Uniform massive medium sand with less abundant bioclasts. Burrows evident. Sample taken (0.75-0.77 m) fine - medium sand, unimodal, moderately well sorted, 3% CaCO3 Coarse gravel sand with abundant bioclastic material. Bioclasts are less fragmented than above. Complete bivalve shells.
1.00			Dark grey (5Y4/1) massive medium sand with bioclastic material. Organic woody fragment. Muddy clump from 1.77-1.79 m within the sediment matrix.
2.00			Olive grey (5Y4/1) fine sand with common bioclastic material. Uniform sediment with no bedding evident. Small mud rip up clasts in the sediment. Increasing mud content of the sediment from 2.44 m down to the base of the Sample taken (2.48-2.5 m) fine sand, unimodal, poorly sorted, 5% CaCO3 EOH @ 2.53 m
3.00			

COMMENTS:

CORE: VC13	**DRILL METHOD:** Vibracore	**PENETRATION (m):** 3.04 m
LOCATION: Keppel Bay	**WATER DEPTH (m):** 19 m	**RECOVERY (m):** 3.01 m
DATE: 01/09/2004	**COORDINATES (WGS84):** 23.30257 S, 150.99091 E	

Depth (m) | **Core Photo** | **Graphic Log** | **Core Description**

Depth (m)	Core Description
0.00	Dark grey (5Y4/1) mud with sandy lenses. Large bivalve and pebble at top of core, but bioclastic material is rare throughout the rest of the core. Some organic streaks and blobs. Bedding is evident from organic layers and sandy layers.
	Black organic streak.
1.00	Dark grey (5Y4/1) mud with fine sandy lenses throughout. No obvious bioclastic material. Organic streaks and layers. Very similar to top of core.
	Samples taken (0-2.0 m) interbedded muds and fine sands, <6% $CaCO_3$
	Fine sand layer.
2.00	Mud with sandy lenses. Similar to above.
	Olive grey (5Y4/2) sandy layers with medium to coarse sand and gravel dominate the core, interbedded with muddy sand. Lithic fragments. Poorly sorted with very minor bioclastic material evident in sandy layers.
	Samples taken (2.96 m) interbedded medium sand and mud, 2% $CaCO_3$
	Some sandy layers are not horizontal/complete - more like pockets of sand.
	Base of core predominantly mud with medium to coarse sand throughout. Very poorly sorted.
3.00	EOH @ 3.03 m

COMMENTS:

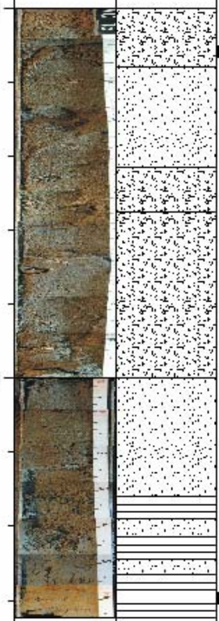
CORE: VC14	**DRILL METHOD: Vibracore**	**PENETRATION (m): 3.03 m**
LOCATION: Keppel Bay	**WATER DEPTH (m): 16 mbsl**	**RECOVERY (m): 2.9 m**
DATE: 01/09/2004	**COORDINATES (WGS84): 23.32588 S, 150.96065 E**	

Depth (m)	**Core Photo**	**Graphic Log**	**Core Description**
0.00			Dark grey (5Y4/1) fine sandy mud, interbedded muds and fine sand. Some bioclasts present.
			Sample taken (0.1-0.12 m) silt and mud, trimodal, very poorly sorted, 17%
			Layer of organic debris.
			Woody debris.
			Mud and sand layers 1-5cm thick. Bedding evident from these layers. Organic debris evident throughout.
			Sandier layer at base of section.
1.00			Dark grey (5Y4/1) fine sandy mud, layers alternating between fine sand and mud.
			Little evidence of bioclastic material.
			Organic blobs and streaks from 1.2-1.3 m.
			Organic layer and organic blobs at 1.55 m. Organic matter throughout but concentrated in some areas.
			Organic matter. Cemented sand at base of section - break up on pressure?
2.00			Fine mud layer. Organic layers and streaks from 2.08 to 2.14 m.
			Fine sandy mud throughout the rest of the section. No bioclastic material evident and lots of organic matter.
			Organic blobs at 2.44 and 2.7 m.
			EOH @ 2.92 m
3.00			

COMMENTS:

CORE: VC15	**DRILL METHOD: Vibracore**	**PENETRATION (m): 2.4 m**
LOCATION: Keppel Bay	**WATER DEPTH (m): 8 mbsl**	**RECOVERY (m): 1.65 m**
DATE: 01/09/2004	**COORDINATES (WGS84): 23.34196 S, 150.91397 E**	

Depth (m)	**Core Photo**	**Graphic Log**	**Core Description**
0.00			Poorly sorted bioclastic layer in sand matrix. Lithic pebbles within the gravel. Slight increase in mud from 0.05-0.15 m
			Sample taken (0.1-0.12 m) very fine sand, bimodal, very poorly sorted, 26% $CaCO_3$
			Medium to fine sand with lots of bioclastic material but smaller and more reworked. Some less fragmented bioclasts.
			Layer of coarser material with lots of bioclastic fragments.
			Lots of bioclastic material throughout, but less fragmented and reworked. Bioclastic material predominantly bivalves.
1.00			Large encrusted pebble at base of section.
			Dark grey (5Y4/1) fine sand with abundant bioclastic material. Some whole bivalve shells.
			Whole bivalve shell.
			Mud/clay layers with sand layers in between.
			Olive to light olive brown (5Y5/4 to 2.5Y5/6) clay, becoming sandier at the base
			Sample taken (1.58-1.6 m) dense sandy clay, bimodal, very poorly sorted, 0% $CaCO_3$
			EOH @ 1.65 m
2.00			
3.00			

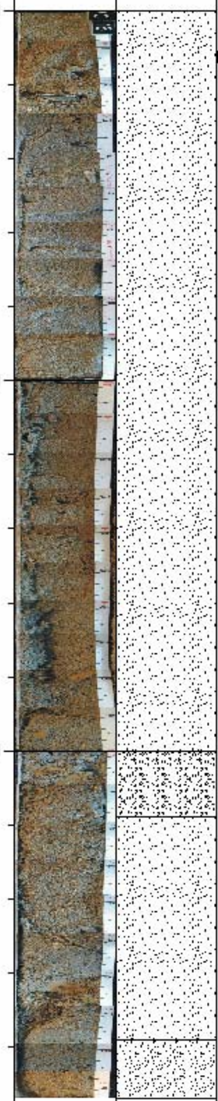


COMMENTS:

CORE: VC16	**DRILL METHOD: Vibracore**	**PENETRATION (m): 3.04 m**
LOCATION: Keppel Bay	**WATER DEPTH (m): 23.5 mbsl**	**RECOVERY (m): 2.99 m**
DATE: 01/09/2004	**COORDINATES (WGS84): 23.37575 S, 150.94177 E**	

Depth (m)	Core Photo	Graphic Log	Core Description

0.00



Olive grey (5Y5/2) coarse gravelly sands with large pebbles, and mud rip up clasts up to 2 cm in diameter. Massive sands, no bedding evident. Sub-rounded to well rounded grains throughout.

Sample taken (0.1-0.12 m) medium sand, unimodal, moderately sorted, 1% CaCO3

Large pecten shell (0.22 m)

Large pebbles and mud rip up clasts throughout.

1.00

Sands becoming coarser and more gravelly.

2.00

Gravelly and very coarse with large pebbles and mud rip up clasts between 2 - 2.18 m.

Olive grey (5Y5/2) coarse gravelly sand with rounded grains. Some large pebbles present.

Large brown (10Y4/3) mud rip up clast.

Becoming muddier at the base of the core. Olive grey (5Y5/2) in colour. Still coarse sands.

EOH @ 2.94 m

3.00

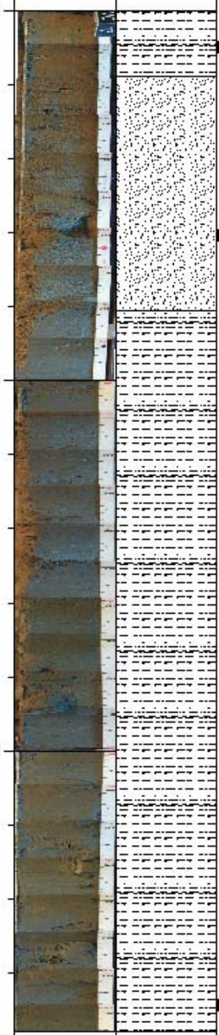
COMMENTS:

CORE: VC17 | **DRILL METHOD:** Vibracore | **PENETRATION (m):** 3.02 m

LOCATION: Keppel Bay | **WATER DEPTH (m):** 11 mbsl | **RECOVERY (m):** 2.76 m

DATE: 01/09/2004 | **COORDINATES (WGS84):** 23.39645 S, 150.97252 E

Depth (m)	Core Photo	Graphic Log	Core Description



0.00

Dark greyish brown (2.5Y4/2) fine sandy mud. Fine bedding and bioclastic material present

Sample taken (0.1-0.12 m) silt and mud, bimodal, very poorly sorted, 10.6% CaCO3

Poorly sorted, massive, fine to medium sand with organic matter and shells present.

Reworked, fragmented bioclastic material.

Sample taken (0.6-0.62 m) fine sand, unimodal, moderately well sorted, 6% CaCO3

Muddy layer.

Muddy sand, increasing in mud content towards the base of the section to sandy mud. Bits of organic matter.

1.00

Dark grey fine sandy mud with burrows infilled with fine sand. Lots of bits of organics throughout. Very little bioclastic material.

2.00

Sample taken (2.68-2.7 m) silt and mud, trimodal, very poortly sorted, 8% CaCO3

EOH @ 2.76 m

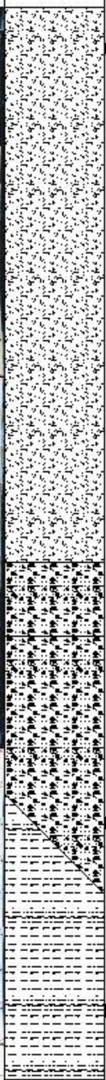
3.00

COMMENTS:

CORE: VC18 | DRILL METHOD: Vibracore | PENETRATION (m): 3.04 m

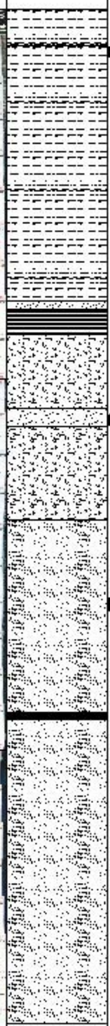
LOCATION: Keppel Bay | WATER DEPTH (m): ~ 10 mbsl | RECOVERY (m): 2.9 m

DATE: 01/09/2004 | COORDINATES (WGS84): 23.39068 S, 150.99653 E

Depth (m)	Core Photo	Graphic Log	Core Description
0.00			Massive coarse sands with abundant bioclastic material. Poorly sorted angular to subrounded grains. Lithic gravel present. Turitella present throughout. No bedding apparent.
			Sample taken (0.1-0.12 m) medium sand, unimodal, moderately sorted, 18.7% CaCO3
1.00			
			Very dark grey (5Y3/1) muddy sand with turitella and rare other bioclastic material. Organic matter also present. Becoming more sandy mud with depth. No bedding evident.
2.00			
			Sample taken (2.2-2.22 m) very fine sand, unimodal, very poorly sorted, 6% CaCO3
			Gradational change and decreasing abundance of turitella to very dark greyish brown (5Y3/2) muddy fine sand with muddy lenses. Occasional bioclastic material but mostly reworked and fragmented.
			Sample taken (2.7-2.72 m) fine sand, unimodal, moderately sorted, 4% CaCO3
			EOH @ 2.9 m.
3.00			

COMMENTS:

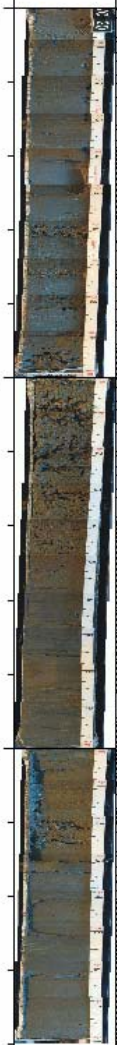
CORE: VC19	**DRILL METHOD:** Vibracore	**PENETRATION (m):** 2.81 m
LOCATION: Keppel Bay	**WATER DEPTH (m):** ~ 7 mbsl	**RECOVERY (m):** 2.70 m
DATE: 01/09/2004	**COORDINATES (WGS84):** 23.43846 S, 150.99675 E	

Depth (m)	Core Photo	Graphic Log	Core Description
0.00 – 3.00			Dark grey (5Y4/1) muddy medium to fine sand. Gradational change from 0.1-0.25 m with lots of organic matter present. Sample taken (0.1-0.12 m) very fine sand, unimodal, very poorly sorted, 12% CaCO3 Very dark grey (5Y3/1) fine sandy mud with lots of organic streats and the odd bioclast. Faint bedding evident. Organic matter. Coarse-medium sand layer. Muddy layer. Reworked shell material with muddy sections. Sandier section. Sample taken (1.1-1.12 m) fine to medium sand, bimodal, poorly sorted, 45.6% CaCO3 Muddier section. Abrupt change to very dark greenish grey (gley1 3/1) fine sand with very little mud. Fairly uniform with lots of organic matter in specific layers. Sample taken (1.6-1.62 m) very fine sand, unimodal, very poorly sorted, 9% CaCO3 Organic matter. Poorly sorted fine very dark greenish grey (gley1 3/1) sand. No obvious bedding. Muddy inclusions and becoming more muddy with depth down the core to fine muddy sand. Muddier inclusions from 2.45-2.48 m. Organic streak. EOH @ 2.74 m

Depth scale: 0.00, 1.00, 2.00, 3.00

COMMENTS:

CORE: VC20	**DRILL METHOD: Vibracore**	**PENETRATION (m): 2.79 m**
LOCATION: Keppel Bay	**WATER DEPTH (m): 13.8 mbsl**	**RECOVERY (m): 2.79 m**
DATE: 01/09/2004	**COORDINATES (WGS84): 23.50329 S, 150.95235 E**	

Depth (m)	**Core Photo**	**Graphic Log**	**Core Description**
0.00			Dark greenish grey (gley13/10Y) mud with sandy lenses of 0.5-1 cm from 0-0.38 m. Organic matter present in the sandy lenses. Samples taken (0-0.4 m) interbedded fine sands and silts and muds, high TOC % and <10% CaCO3 Uniform muddy section from 0.38-0.57 m. Samples taken (0.4-0.5 m) mud, 0.5% TOC, 2% CaCO3 Fine to medium sandy lenses with bioclastic material present, interbedded with mud. Sandy lenses start to dominate and are much thicker and coarser than in the upper section of the core. Some coarse sand/gravel in sandy lenses.
1.00			Fine sandy mud matrix with medium sand present. Poorly sorted and massive. Lots of bioclastic material - some large fragments. Samples taken (0.55-1.5 m) fine to medium sand, <10% CaCO3 More muddy and less bioclastic material. More organic matter present. Some sandy lenses present. Fine sand in section with evidence of burrows.
2.00			Sand and organic filled burrows in mud. Sandy mud with organic matter. Fine sandy mud with fragmented reworked bioclastic material. Very fine sandy lenses. Sample taken (2.75 m) silt and mud, 0.4% TOC, 2% CaCO3 Burrows infilled with sand present in the mud. Well bioturbated throughout. Large burrows infilled with sand at the base of the core.
3.00			EOH @ 2.8 m

COMMENTS:

Appendix 6 – Microscope descriptions of the >63µm fraction

SAMPLE ID	MUNSELL	COLOUR	VISUAL MINERALOGY	VISUAL FOSSIL CONTENT
277/VC01_0.1-0.12m	5Y4/2	Dark grey		
277/VC01_2.2-2.22m	5Y4/3	Dark grey		
277/VC02_0.1-0.12m	2.5Y5/3	Light olive brown	Quartz 80%, Feldspar 10%, Lithics 2%	Sponge spicules, gastropods, bivalves, benthic forams
277/VC02_2.52-2.54m	5Y4/4	Dark grey		
277/VC03_1.55-1.57m	10YR4/3	Brown		
277/VC04_0.55-0.57m	2.5Y4/2	Dark greyish brown		
277/VC06_0.4-0.42m	2.5Y5/3	Light olive brown	Quartz 70%, Feldspar 5%, Lithics 2%	Broken bivalves, sponge spicules, gastropods, benthic forams.
277/VC06_1.5-1.52m	2.5Y5/3	Light olive brown	Quartz 80%, Feldspar 5%, Lithics 1%	Broken bivalves, bryozoa, benthic forams.
277/VC06_2.24-2.26m	5Y4/1	Dark grey		
277/VC06_2.34-2.36m	2.5Y4/2	Dark greyish brown	Quartz 60%, Feldspar 5%, Lithics 2%	Bivalves, gastropods, bryozoa, benthic forams.
277/VC07_0.1-0.12m	2.5Y4/2	Dark greyish brown	Quartz 60%, lithics.	Turitella gastropods, bivalves, benthic foraminifera.
277/VC07_2.7-2.72m	2.575/1	Grey	Quartz 80%, Feldspar 1%, Lithics 1%	Bivalves, gastropods, bryozoa.
277/VC08_0.14-0.16m	2.5Y5/3	Light olive brown	Quartz 70%, Feldspar 5%, Lithics 1%	Gastropods, broken bivalves, sponge spicules, benthic forams.
277/VC08_0.45-0.47m	2.5Y5/3	Light olive brown	Quartz 70%, Feldspar 2%, Lithics 5%	Broken bivalves, sponge spicules, echinoid spine, benthic forams.
277/VC08_2.2-2.22m	2.5Y7/1	Light grey	Quartz 80%, Feldspar 20%	
277/VC09_0.1-0.12m	2.5Y6/3	Light yellowish brown	Quartz 80%, Feldspar 5%, Lithics 2%	Fragment of coral (1cm) bivalves, gastropods, benthic forams.
277/VC10_0.1-0.12m	2.5Y5/2	Greyish brown	Quartz 50%,	Broken bivalves, echinoid spines, coral, bryozoa, lots of benthic forams.
277/VC10_2.6-2.62m	5Y4/1	Dark grey		Organics and odd bioclast
277/VC11_0.1-0.12m	2.5Y5/3	Light olive brown	Quartz 80%, Feldspar 2%, Lithics 2%	Bivalves, benthic forams, gastropods.
277/VC11_1.15-1.17m	2.5Y5/2	Greyish brown	Quartz 80%, Feldspar 20%	
277/VC11_1.58-1.6m	5Y4/2	Olive grey		
277/VC12_0.1-0.12m	2.5Y6/4	Light yellowish brown	Quartz 90%, Feldspar 1%, Lithics 5%	Bivalves, bryozoa and benthic forams.
277/VC12_0.75-0.77m	2.5Y5/3	Light olive brown	Quartz 90%, Feldspar 5%, Lithics 2%	Gastropods, bivalves, benthic forams.
277/VC12_2.48-2.5m	2.5Y5/2	Greyish brown	Quartz 70%, Feldspar 5%, Lithics 1%	Bivlaves, gastropods, bryozoa and lots of benthic forams.
277/VC14_0.1-0.12m	5Y4/1	Dark grey		Organics and odd bioclast
277/VC15_0.1-0.12m	2.5Y4/2	Dark greyish brown	Quartz 30%, Feldspar 5%, Lithics 20%	Broken bivalves, echinoid spines, sponge spicules, benthic forams.
277/VC15_1.58-1.6m	2.5Y4/3	Olive brown		
277/VC16_0.1-0.12m	2.5Y6/3	Light yellowish brown	Quartz 80%, Feldspar 10%, Lithics 1%, Mica	Benthic forams, very minor bioclasts.
277/VC17_0.1-0.12m	2.5Y4/2	dark greyish brown		
277/VC17_0.6-0.62m	2.5Y5/2	Greyish brown	Quartz 70%, Feldspar 2%, Lithics 1%	Bivalves, benthic forams, bryozoa, sponge spicules, echinoid fragments.
277/VC17_2.68-2.7m	5Y4/1	Dark grey		

277/VC18_0.1-0.12m	2.5Y5/3	Light olive brown	Quartz 60%, Feldspar 1%, Lithics 2%	Turitella gastropods, bivalves, gastropods, bryozoa, benthic forams.
277/VC18_2.2-2.22m	5Y4/1	Dark grey		
277/VC18_2.7-2.72m	2.5Y5/2	Greyish brown	Quartz 70%, Feldspar 10%, Lithics 1%	Bivalves, ostracods, benthic forams, sponge spicules, echinoid spines, fish vertebrae, bryozoa
277/VC19_0.1-0.12m	2.5Y4/1	Dark grey		
277/VC19_1.1-1.12m	2.5Y4/2	Dark greyish brown	Quartz 50%, Lithics 5%	Bivalves,gastropods, bryozoa, sponge spicules, echinoid fragments, benthic forams.
277/VC19_1.6-1.62m	2.5Y4/2	Dark greyish brown	Quartz 70%, Feldspar 2%, Lithics, Mica 1%	Bivalves, sponge spicules, gastropods, bryozoa, echinoid spines, benthic forams.

Appendix 7 – Sieved grainsize and CaCO3% for vibracore subsamples

SAMPLE ID	% GRAVEL:	% SAND:	% MUD:	CaCO3%
277/VC01_0.1-0.12m				10.1
277/VC01_2.2-2.22m				9.1
277/VC02_0.1-0.12m				6.0
277/VC02_2.52-2.54m				12.6
277/VC03_1.55-1.57m				0.9
277/VC04_0.55-0.57m				0.9
277/VC06_0.4-0.42m	1.52	96.93	1.55	18.2
277/VC06_1.5-1.52m	1.52	98.05	0.43	20.2
277/VC06_2.24-2.26m				6.0
277/VC06_2.34-2.36m	17.71	81.29	0.99	42.5
277/VC07_0.1-0.12m				27.3
277/VC07_2.7-2.72m	1.36	96.11	2.53	2.5
277/VC08_0.14-0.16m	0.42	97.95	1.63	8.0
277/VC08_0.45-0.47m	1.67	95.06	3.27	12.1
277/VC08_2.2-2.22m				0.4
277/VC09_0.1-0.12m	2.44	96.63	0.93	5.5
277/VC10_0.1-0.12m	4.63	88.36	7.00	43.6
277/VC10_2.6-2.62m				8.0
277/VC11_0.1-0.12m	1.00	96.59	2.41	12.1
277/VC11_1.15-1.17m				0
277/VC11_1.58-1.6m				0.9
277/VC12_0.1-0.12m	2.26	97.30	0.44	6.0
277/VC12_0.75-0.77m	0.69	98.57	0.74	3.0
277/VC12_2.48-2.5m				5.0
277/VC14_0.1-0.12m				17.2
277/VC15_0.1-0.12m	42.09	51.80	6.11	26.3
277/VC15_1.58-1.6m				0
277/VC16_0.1-0.12m	7.92	89.95	2.14	0.9
277/VC17_0.1-0.12m				10.6
277/VC17_0.6-0.62m				6.0
277/VC17_2.68-2.7m				8.5
277/VC18_0.1-0.12m	8.89	90.33	0.79	18.7
277/VC18_2.2-2.22m				6.0
277/VC18_2.7-2.72m				4.0
277/VC19_0.1-0.12m	10.58	70.99	18.43	12.1
277/VC19_1.1-1.12m	27.61	67.09	5.30	45.6
277/VC19_1.6-1.62m				9.1

Appendix 8 – Gradistat sediment analysis results for vibracore subsamples (after Folk and Ward, 1957)

SAMPLE ID:	SAMPLE TYPE:	TEXTURAL GROUP:	SEDIMENT NAME:	MEAN	SORTING	SKEWNESS	KURTOSIS	% SAND:	% SILT:	% CLAY:
VC01_0.1-0.12	Unimodal, Very Poorly Sorted	Muddy Sand	Very Coarse Silty Very Fine Sand	69.03	4.221	-0.483	1.964	71.1%	23.4%	5.5%
VC01_2.20-2.22	Trimodal, Very Poorly Sorted	Sandy Mud	Very Fine Sandy Very Coarse Silt	28.06	5.382	-0.581	0.861	46.5%	42.8%	10.7%
VC02_0.1-0.12	Unimodal, Moderately Well Sorted	Sand	Moderately Well Sorted Fine Sand	230.8	1.436	-0.020	0.958	98.7%	1.1%	0.2%
VC02_2.52-2.54	Bimodal, Very Poorly Sorted	Muddy Sand	Very Coarse Silty Fine Sand	44.12	6.384	-0.553	0.947	60.1%	30.6%	9.2%
VC03_1.55-1.57	Bimodal, Very Poorly Sorted	Sandy Mud	Very Fine Sandy Very Coarse Silt	26.54	5.749	-0.496	0.710	45.1%	43.9%	11.0%
VC04_0.55-0.57	Bimodal, Very Poorly Sorted	Sandy Mud	Fine Sandy Fine Silt	24.33	6.151	0.001	0.681	40.8%	51.3%	8.0%
VC06_0.4-0.42	Unimodal, Moderately Sorted	Sand	Moderately Sorted Medium Sand	301.5	1.743	0.033	0.987	98.7%	1.2%	0.1%
VC06_1.5-1.52	Unimodal, Moderately Sorted	Sand	Moderately Sorted Medium Sand	375.8	1.680	0.069	0.984	100.0%	0.0%	0.0%
VC06_2.24-2.26	Bimodal, Very Poorly Sorted	Muddy Sand	Muddy Fine Sand	51.00	7.617	-0.732	0.735	69.3%	19.4%	11.3%
VC06_2.3-2.36	Unimodal, Moderately Sorted	Sand	Moderately Sorted Coarse Sand	609.3	1.841	-0.154	1.095	98.1%	1.8%	0.1%
VC07_0.1-0.12	Unimodal, Very Poorly Sorted	Muddy Sand	Very Fine Silty Fine Sand	179.2	4.067	-0.222	2.162	84.7%	11.2%	4.1%
VC07_2.7-2.72	Unimodal, Moderately Sorted	Sand	Moderately Sorted Medium Sand	314.3	1.770	-0.287	1.881	94.7%	4.8%	0.5%
VC08_0.14-0.16	Unimodal, Moderately Well Sorted	Sand	Moderately Well Sorted Fine Sand	235.9	1.506	-0.050	1.010	96.8%	3.1%	0.1%
VC08_0.45-0.47	Unimodal, Poorly Sorted	Sand	Poorly Sorted Fine Sand	221.9	2.654	-0.311	2.607	91.2%	6.5%	2.3%
VC08_2.2-2.22	Unimodal, Poorly Sorted	Muddy Sand	Very Fine Silty Fine Sand	78.50	3.437	-0.703	3.233	83.2%	12.4%	4.4%
VC09_0.1-0.12	Unimodal, Moderately Well Sorted	Sand	Moderately Well Sorted Medium Sand	427.5	1.562	-0.020	0.961	97.9%	2.1%	0.0%
VC10_0.1-0.12	Unimodal, Very Poorly Sorted	Muddy Sand	Fine Silty Medium Sand	265.8	4.337	-0.437	1.668	84.2%	14.0%	1.8%
VC10_2.6-2.62	Polymodal, Very Poorly Sorted	Muddy Sand	Very Coarse Silty Very Fine Sand	56.09	6.667	-0.367	0.991	59.9%	32.9%	7.2%
VC11_0.1-0.12	Unimodal, Poorly Sorted	Sand	Poorly Sorted Medium Sand	298.9	2.443	-0.246	2.037	92.6%	7.1%	0.3%
VC11_1.15-1.16	Bimodal, Very Poorly Sorted	Muddy Sand	Fine Silty Medium Sand	58.78	7.113	-0.620	0.668	61.0%	31.8%	7.1%
VC11_1.58-1.6	Unimodal, Poorly Sorted	Mud	Very Fine Silt	4.128	3.351	0.077	0.942	1.0%	71.1%	27.9%
VC12_0.1-0.12	Unimodal, Moderately Well Sorted	Sand	Moderately Well Sorted Medium Sand	307.8	1.606	0.040	0.956	100.0%	0.0%	0.0%
VC12_0.75-0.77	Unimodal, Moderately Well Sorted	Sand	Moderately Well Sorted Medium Sand	256.9	1.534	0.036	0.964	100.0%	0.0%	0.0%
VC12_2.48-2.5	Unimodal, Poorly Sorted	Muddy Sand	Very Fine Silty Fine Sand	206.9	2.616	-0.424	3.210	88.3%	8.7%	3.1%
VC14_0.1-0.12	Trimodal, Very Poorly Sorted	Muddy Sand	Very Fine Silty Fine Sand	57.24	7.277	-0.468	0.869	63.0%	29.5%	7.5%
VC15_0.1-0.12	Bimodal, Very Poorly Sorted	Muddy Sand	Very Fine Silty Medium Sand	115.2	7.303	-0.532	1.313	75.3%	19.2%	5.6%
VC15_1.58-1.6	Bimodal, Very Poorly Sorted	Sandy Mud	Fine Sandy Fine Silt	18.88	7.334	0.127	0.639	38.9%	48.2%	12.9%

VC16_0.1-0.12	Unimodal, Moderately Sorted	Sand	Moderately Sorted Coarse Sand	473.2	1.980	-0.288	1.674	94.9%	4.7%	0.4%
VC17_0.1-0.12	Bimodal, Very Poorly Sorted	Sandy Mud	Very Fine Sandy Very Coarse Silt	17.48	7.561	-0.216	0.685	35.6%	45.1%	19.3%
VC17_0.6-0.62	Unimodal, Moderately Well Sorted	Sand	Moderately Well Sorted Fine Sand	151.0	1.592	-0.062	1.067	95.1%	4.2%	0.7%
VC17_2.68-2.7	Trimodal, Very Poorly Sorted	Muddy Sand	Very Coarse Silty Very Fine Sand	33.57	5.304	-0.597	0.965	53.3%	37.2%	9.5%
VC18_0.1-0.12	Unimodal, Moderately Sorted	Sand	Moderately Sorted Medium Sand	420.6	1.820	-0.027	0.943	99.6%	0.4%	0.0%
VC18_2.2-2.22	Unimodal, Very Poorly Sorted	Muddy Sand	Very Coarse Silty Fine Sand	69.01	4.535	-0.577	1.789	72.9%	21.3%	5.8%
VC18_2.7-2.72	Unimodal, Moderately Sorted	Sand	Moderately Sorted Fine Sand	185.9	1.906	-0.303	1.946	93.7%	5.1%	1.2%
VC19_0.1-0.12	Unimodal, Poorly Sorted	Muddy Sand	Very Coarse Silty Very Fine Sand	125.8	3.528	-0.210	1.885	79.6%	16.8%	3.6%
VC19_1.1-1.12	Bimodal, Poorly Sorted	Muddy Sand	Very Coarse Silty Coarse Sand	293.9	3.391	-0.351	1.050	89.7%	9.4%	0.9%
VC19_1.6-1.62	Unimodal, Very Poorly Sorted	Muddy Sand	Coarse Silty Fine Sand	70.05	4.578	-0.633	1.724	74.1%	20.4%	5.4%

Appendix 9 – Data for VC05, VC13 and VC20

VC05

Sample	Depth	Mean grainsize (um)	Sorting	% Sand	% Silt	% Clay	CaCO3%	TOC %	Wet bulk density g/cc	Porosity %
277/VC05_0.00-0.03m	0.00	156.4	3.273	87.5	8.7	3.7	12.61	0.17	1.85	42.90
277/VC05_0.05-0.08m	0.05							0.19	1.86	49.36
277/VC05_0.1-0.13m	0.10	68.01	6.360	68.5	24.2	7.3	18.19		1.97	61.52
277/VC05_0.15-0.18m	0.15							0.22	1.90	50.56
277/VC05_0.2-0.23m	0.20	77.10	7.371	67.7	24.8	7.5	20.72	0.16	1.95	45.77
277/VC05_0.25-0.28m	0.25							0.20	2.06	48.65
277/VC05_0.30-0.33m	0.30	71.39	5.632	69.8	23.8	6.3	21.74		1.83	43.93
277/VC05_0.35-0.38m	0.35							0.16	1.83	51.72
277/VC05_0.40-0.43m	0.40	56.62	5.728	65.9	26.4	7.7	14.64	0.14	2.02	49.24
277/VC05_0.45-0.48m	0.45							0.22	1.86	62.68
277/VC05_0.50-0.53m	0.50							0.29	1.73	67.38
277/VC05_0.55-0.58m	0.55								2.02	67.70
277/VC05_0.59-0.6m	0.59	17.53	7.089	31.9	52.1	16.0	10.07			
277/VC05_0.60-0.62m	0.60							0.44	1.74	72.60
277/VC05_0.65-0.68m	0.65								1.60	69.29
277/VC05_0.70-0.72m	0.70							0.25	1.91	69.61
277/VC05_0.75-0.78m	0.75	21.52	6.123	36.9	49.3	13.8	7.03		1.61	65.56
277/VC05_0.80-0.83m	0.80							0.38	1.87	65.49
277/VC05_0.82-0.83m	0.82	30.99	6.132	48.8	40.0	11.2	8.04			
277/VC05_0.85-0.88m	0.85								1.72	70.91
277/VC05_0.90-0.92m	0.90							0.32	1.82	74.16
277/VC05_0.95-0.98m	0.95								2.07	76.86
277/VC05_1.00-1.03m	1.00	19.00	7.173	30.1	55.7	14.3	28.84		1.54	51.08
277/VC05_1.05-1.08m	1.05								1.88	65.14
277/VC05_1.10-1.13m	1.10								1.58	77.53
277/VC05_1.15-1.18m	1.15								1.72	77.64
277/VC05_1.20-1.23m	1.20								1.76	72.51

277/VC05_1.25-1.28m	1.25	13.15	6.098	26.8	55.4	17.8	9.56		1.72	68.73
277/VC05_1.30-1.33m	1.30							0.28	1.71	61.32
277/VC05_1.33-1.34m	1.33	32.14	7.957	50.2	36.7	13.1	13.62			
277/VC05_1.35-1.38m	1.35								1.94	63.18
277/VC05_1.40-1.43m	1.40								1.85	59.26
277/VC05_1.45-1.48m	1.45								1.81	71.36
277/VC05_1.50-1.53m	1.50	20.38	7.673	41.2	42.5	16.3	9.06		1.74	67.29
277/VC05_1.55-1.58m	1.55								1.65	63.50
277/VC05_1.60-1.63m	1.60								1.78	69.47
277/VC05_1.65-1.68m	1.65								1.74	71.01
277/VC05_1.70-1.73m	1.70								1.83	58.52
277/VC05_1.75-1.78m	1.75								1.58	47.86
277/VC05_1.80-1.83m	1.80								1.93	60.75
277/VC05_1.85-1.88m	1.85								1.77	45.56
277/VC05_1.90-1.93m	1.90								1.89	56.26
277/VC05_1.95-1.98m	1.95								1.83	58.18
277/VC05_2.00-2.03m	2.00	31.60	6.392	52.8	35.3	12.0	6.01		1.89	55.36
277/VC05_2.05-2.08m	2.05								1.82	59.74
277/VC05_2.10-2.13m	2.10								1.83	51.93
277/VC05_2.15-2.18m	2.15								1.82	53.92
277/VC05_2.25-2.28m	2.25								2.04	62.15
277/VC05_2.29-2.3m	2.29	30.37	6.504	50.7	36.9	12.3				
277/VC05_2.30-2.33m	2.30							0.22	1.79	52.05
277/VC05_2.35-2.38m	2.35								1.80	46.48
277/VC05_2.40-2.43m	2.40	12.74	5.461	23.9	63.1	13.0			1.76	31.73
277/VC05_2.44-2.47m	2.44	15.83	5.834	28.8	56.0	15.2	2.35			
277/VC05_2.45-2.48m	2.45						0.43			

VC13

Sample	Depth	Mean Grainsize (um)	Sorting	Sand %	Silt %	<63um %	CaCO3%	TOC%	Wet bulk density g/cc	Porosity %
277/VC13_0-0.02m	0.00	248.41	3.30	84.75	11.53	3.72		0.15		

277/VC13_0.06-0.07m	0.06	18.48	5.61	33.08	52.80	14.12	2.46			
277/VC13_0.07-0.09m	0.07							0.51	1.82	57.52
277/VC13_0.1-0.13m	0.10	13.37	5.23	21.48	63.71	14.81				
277/VC13_0.14-0.16m	0.14							0.21	1.99	43.55
277/VC13_0.16-0.17m	0.16	36.84	7.59	46.05	43.51	10.44	5.50			
277/VC13_0.21-0.23m	0.21							0.51	1.66	44.64
277/VC13_0.23-0.26m	0.23	16.90	5.84	26.86	60.12	13.02				
277/VC13_0.28-0.3m	0.28							0.56	1.98	57.93
277/VC13_0.32-0.35m	0.32	10.50	4.24	8.75	76.35	14.89				
277/VC13_0.35-0.37m	0.35							0.50	1.70	52.72
277/VC13_0.37-0.38m	0.37	13.34	5.07	20.62	64.42	14.96	2.97			
277/VC13_0.42-0.44m	0.42							0.45	1.66	53.96
277/VC13_0.44-0.47m	0.44	11.61	4.92	15.23	68.24	16.53				
277/VC13_0.49-0.51m	0.49							0.63	1.93	62.98
277/VC13_0.51-0.52m	0.51	9.73	4.81	10.77	70.52	18.71	3.47			
277/VC13_0.56-0.58m	0.56							0.57	1.85	57.06
277/VC13_0.67-0.68m	0.67	14.70	5.14	20.86	63.73	15.40	1.95			
277/VC13_0.68-0.70m	0.68							0.50	1.84	55.85
277/VC13_0.75-0.78m	0.75	9.99	4.48	11.53	72.63	15.84				
277/VC13_0.80-0.82m	0.80							0.44	1.86	50.18
277/VC13_0.91-0.92m	0.91	15.20	5.58	25.64	57.82	16.54	2.97			
277/VC13_0.92-0.94m	0.92							0.47	1.75	46.18
277/VC13_1.04-1.06m	1.04	25.85	5.90	43.98	44.70	11.32			1.68	53.77
277/VC13_1.16-1.18m	1.16								1.60	48.00
277/VC13_1.25-1.28m	1.25	9.63	4.86	14.20	68.14	17.66				
277/VC13_1.28-1.3m	1.28								1.67	47.81
277/VC13_1.4-1.42m	1.40								1.84	47.00
277/VC13_1.51-1.52m	1.51	20.09	6.35	35.77	49.78	14.45	0.94			
277/VC13_1.52-1.54m	1.52							0.32	1.91	53.56
277/VC13_1.55-1.58m	1.55	32.26	5.75	52.63	37.44	9.93				
277/VC13_1.64-1.66m	1.64								1.78	53.93

277/VC13_1.76-1.78m	1.76								1.93	57.90
277/VC13_1.88-1.9m	1.88								1.79	52.55
277/VC13_2.00-2.02m	2.00								1.77	27.01
277/VC13_2.02-2.05m	2.02	7.64	4.29	8.27	73.39	18.34				
277/VC13_2.12-2.14m	2.12								1.69	55.97
277/VC13_2.24-2.26m	2.24								1.79	40.67
277/VC13_2.36-2.38m	2.36								1.81	50.01
277/VC13_2.48-2.5m	2.48								1.66	40.70
277/VC13_2.60-2.62m	2.60								1.76	46.27
277/VC13_2.72-2.74m	2.72								2.23	46.38
277/VC13_2.84-2.86m	2.84								1.74	54.50
277/VC13_2.95-2.96m	2.95	181.39	10.18	71.92	21.51	6.58	1.95			
277/VC13_2.96-2.98m	2.96							0.16	1.95	45.43

VC20

Sample	Depth	Mean Grainsize (um)	Sorting	Sand %	Silt %	<63um%	CaCO3%	%TOC	Wet bulk density g/cc	Porosity %
277/VC20_0.00-0.03m	0.00	14.66	6.43	22.90	61.21	15.90	9.06	0.63	1.80	63.90
277/VC20_0.03-0.05m	0.03	13.75	4.71	16.41	69.50	14.09				
277/VC20_0.05-0.08m	0.05	21.48	6.02	37.70	48.55	13.74	7.53	0.39	1.85	54.10
277/VC20_0.10-0.13m	0.10	29.85	5.98	50.07	38.18	11.74	8.55	0.45	1.85	59.64
277/VC20_0.15-0.18m	0.15	13.18	5.87	25.26	56.76	17.97	6.01	0.53	1.68	60.29
277/VC20_0.20-0.23m	0.20	20.35	4.84	27.30	60.94	11.76	7.03	0.58	1.67	56.60
277/VC20_0.25-0.28m	0.25	36.66	5.62	59.46	30.68	9.86	9.06	0.59	1.62	63.76
277/VC20_0.30-0.33m	0.30	26.59	5.53	46.24	41.61	12.15	9.56	0.43	1.82	61.67
277/VC20_0.33-0.35m	0.33	6.36	5.15	8.75	63.87	27.37				
277/VC20_0.35-0.38m	0.35	18.28	6.23	34.91	48.44	16.65	3.98	0.51	1.76	57.20
277/VC20_0.40-0.43m	0.40	5.89	4.23	4.79	71.15	24.06	1.95	0.49	1.65	58.63
277/VC20_0.45-0.48m	0.45	5.12	4.02	3.89	70.42	25.69	2.46	0.51	1.28	51.51
277/VC20_0.50-0.53m	0.50	5.04	4.13	3.72	69.13	27.16	2.97	0.49	1.66	66.19
277/VC20_0.55-0.58m	0.55	19.06	5.16	28.22	58.82	12.96			1.90	56.40
277/VC20_0.60-0.63m	0.60							0.07	1.56	41.85

277/VC20_0.62-0.63m	0.62	70.08	7.69	67.98	23.71	8.30	1.95			
277/VC20_0.65-0.68m	0.65								1.86	40.46
277/VC20_0.69-0.7m	0.69	118.55	5.77	73.00	21.61	5.39	4.49			
277/VC20_0.70-0.73m	0.70							0.18	1.86	37.80
277/VC20_0.75-0.78m	0.75	31.08	8.55	40.14	47.39	12.47			1.60	40.83
277/VC20_0.80-0.83m	0.80							0.24	1.81	55.56
277/VC20_0.82-0.83m	0.82	54.37	8.26	56.61	33.52	9.87	7.53			
277/VC20_0.85-0.88m	0.85								2.01	52.85
277/VC20_0.90-0.93m	0.90							0.24	1.84	53.94
277/VC20_0.92-0.93m	0.92	71.40	8.45	60.56	30.27	9.17	4.49			
277/VC20_0.95-0.98m	0.95								1.85	38.18
277/VC20_1.00-1.03m	1.00								1.77	30.34
277/VC20_1.05-1.08m	1.05								1.61	30.66
277/VC20_1.10-1.13m	1.10								1.48	29.91
277/VC20_1.15-1.18m	1.15								1.82	39.33
277/VC20_1.20-1.23m	1.20								2.23	50.04
277/VC20_1.25-1.28m	1.25								1.82	38.45
277/VC20_1.30-1.33m	1.30								2.01	37.43
277/VC20_1.35-1.38m	1.35								1.88	42.44
277/VC20_1.40-1.43m	1.40							0.40	1.92	45.37
277/VC20_1.44-1.45m	1.44	58.49	6.51	62.97	29.19	7.83	12.10			
277/VC20_1.45-1.48m	1.45								1.96	41.94
277/VC20_1.50-1.53m	1.50	54.34	7.22	59.92	31.23	8.84			1.65	44.08
277/VC20_1.55-1.58m	1.55								1.88	58.39
277/VC20_1.60-1.63m	1.60								1.75	62.27
277/VC20_1.65-1.68m	1.65								1.70	61.03
277/VC20_1.70-1.73m	1.70								1.73	59.01
277/VC20_1.75-1.78m	1.75								1.69	60.72
277/VC20_1.80-1.83m	1.80								1.68	57.25
277/VC20_1.85-1.88m	1.85								1.87	55.97
277/VC20_1.90-1.93m	1.90								1.78	59.80

277/VC20_1.95-1.98m	1.95								1.83	52.97
277/VC20_2.00-2.03m	2.00	12.65	5.53	24.53	58.73	16.74			1.65	62.69
277/VC20_2.05-2.08m	2.05								1.88	63.61
277/VC20_2.10-2.13m	2.10	52.93	3.90	64.62	29.59	5.79	14.13		1.86	52.96
277/VC20_2.15-2.18m	2.15								1.95	47.80
277/VC20_2.20-2.23m	2.20								1.74	44.23
277/VC20_2.25-2.28m	2.25								1.95	57.39
277/VC20_2.30-2.33m	2.30								1.70	54.46
277/VC20_2.35-2.38m	2.35								1.82	56.07
277/VC20_2.40-2.43m	2.40								1.76	57.46
277/VC20_2.45-2.48m	2.45								1.84	55.84
277/VC20_2.50-2.53m	2.50								1.68	55.97
277/VC20_2.55-2.58m	2.55								1.71	54.26
277/VC20_2.60-2.63m	2.60								1.74	55.92
277/VC20_2.65-2.68m	2.65								1.77	55.17
277/VC20_2.70-2.73m	2.70								1.69	54.97
277/VC20_2.74-2.75m	2.74	16.09	5.49	26.27	58.80	14.92	2.97			
277/VC20_2.75-2.78m	2.75							0.43	1.91	56.76

Appendix 10 – comparison of porosity and wet bulk density from sediment analyses and GEOTEK Multi Sensing Core Logger (MSCL)