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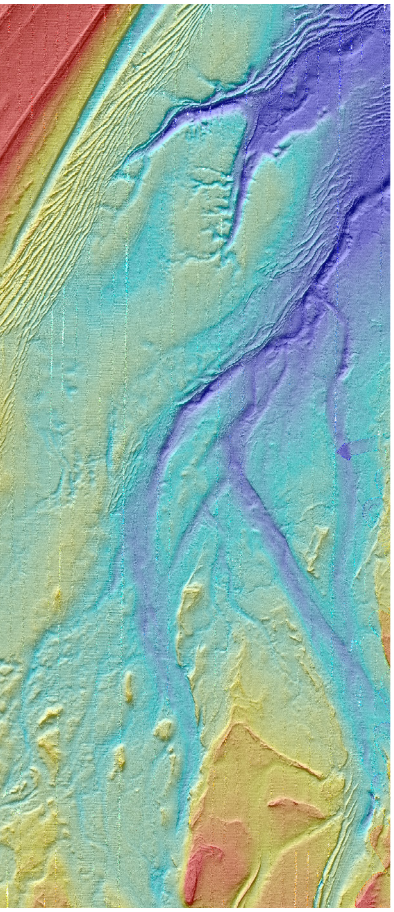

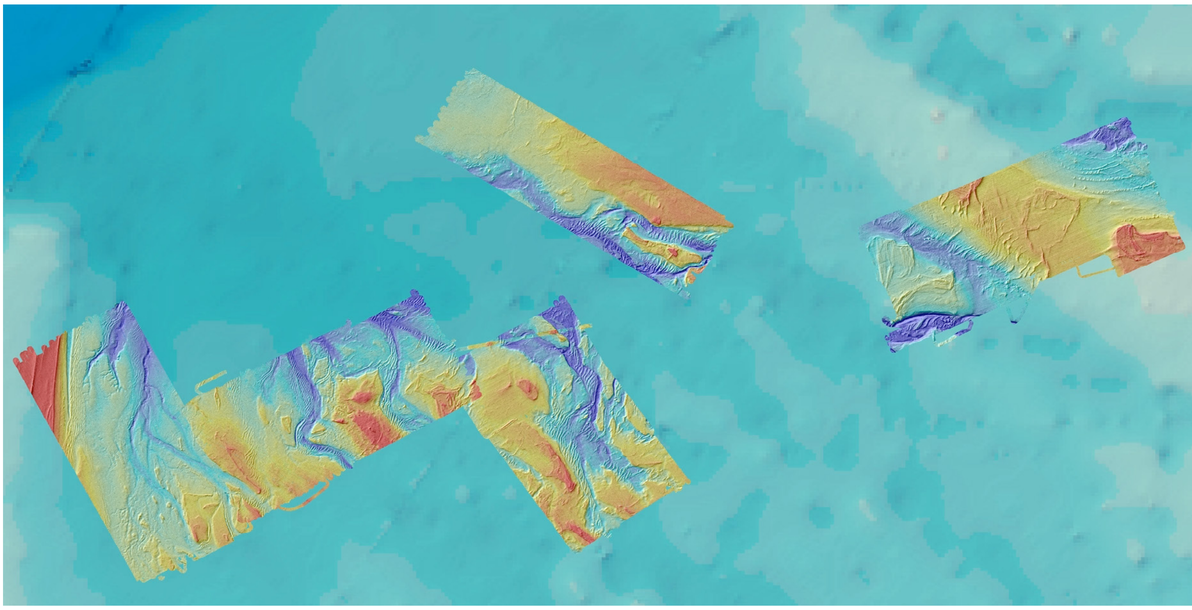

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GA0340/SOL5754 – Post-survey report

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Australian Government
Geoscience Australia

1. Geoscience Australia, GPO Box 378, Canberra, ACT 2601
2. Australian Institute of Marine Science, PMB 3, Townsville MC, Qld 4810

Department of Industry

Minister for Industry: The Hon Ian Macfarlane MP
Parliamentary Secretary: The Hon Bob Baldwin MP
Secretary: Ms Glenys Beauchamp PSM

Geoscience Australia
Chief Executive Officer: Dr Chris Pigram
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Executive Summary

In May 2013, Geoscience Australia (GA) and the Australian Institute of Marine Science (AIMS) undertook a collaborative seabed environmental mapping survey (GA0340/ SOL5754) on the Leveque Shelf, a distinct geological province within the Browse Basin, offshore Western Australia. The purpose of the survey was to acquire geophysical and biophysical data on seabed environments over a previously identified potential CO_2 injection site to better understand the overlying seabed habitats and to assess potential for fluid containment or migration. A total of six areas were investigated using multibeam and single beam echosounders, sub-bottom profilers, sidescan sonar, underwater towed-video, gas sensors, water column profiler, grab samplers, and vibrocorer.

Over 1070 km^2 of seabed and water column was mapped using the multibeam and single beam echosounder, in water depths ranging between 40 and 120 m. The sub-surface was investigated using the multichannel and the parametric sub-bottom profilers along lines totalling 730 km and 1547 km in length respectively. Specific seabed features were investigated over 44 line km using the sidescan sonar and physically and visually inspected using a variety of instrumentation at 58 stations.

Key observations from the survey are as follows:

- The seabed is characterised by a more complex network of geomorphic features than is evident in the national map of seabed features (Harris et al., 2003). Banks and terraces interspersed with a large network of valleys dominate the seabed. Valleys are populated mainly by bedforms and small depressions, while ridges overlay banks and terraces.
- The survey area is dominated by coarse-grained, carbonate sediment, which is cemented in places. This interpretation is supported by the limited acoustic penetration (< 5 m) achieved with the parametric sub-bottom profiler. The limited cover of mobile sediments also suggests a sediment-starved environment.
- Internal waves, observed in the single beam echograms, and highly turbid waters, observed in the towed-videos, support previously-known observations stating that strong tidal energy influences this region of the shelf.
- Bioturbated habitats and mixed patches of octocorals and sponges dominate the area. Infauna assemblages are dominated by crustaceans and polychaetes, and to a lesser extent echinoderms and molluscs.
- Seabed and water column features investigated did not show strong signs of active seepage; only two geochemical samples with higher oxygen demand might be indicative of seepage. However, many seabed features show potential relationships with basin geology.

Integration of this newly acquired data with existing seismic data will provide new insights into the geology of the Leveque Shelf. This work will contribute to the Australian Government's National CO_2 Infrastructure Plan (NCIP) by providing key seabed environmental and geological data to better inform the assessment of the CO_2 storage potential in this area of the Browse Basin.

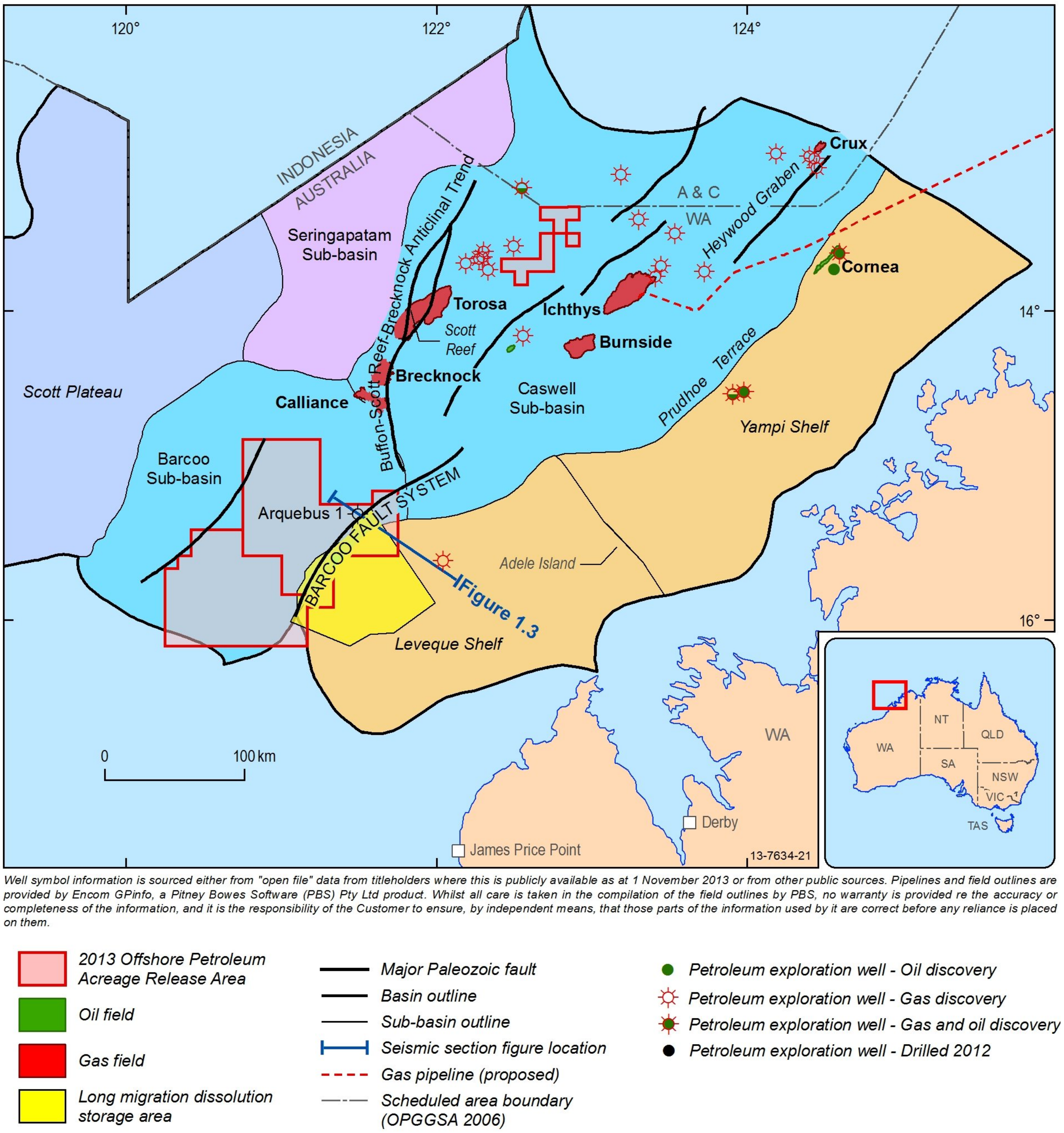
1 Introduction

This report outlines the activities undertaken during a conjoint Geoscience Australia (GA) and Australian Institute of Marine Science (AIMS) seabed mapping survey (GA0340/ SOL5754) of the Browse Basin, offshore Western Australia (Figure 1.1). The purpose of the survey was to acquire geophysical and biophysical data on shallow (<150 m water depth) seabed environments over a previously identified potential CO_2 injection site to better understand the overlying seabed habitats and to assess the potential for fluid containment or migration. The survey was conducted over two legs between 1 and 31 May 2013 aboard the AIMS research vessel RV *Solander*. Six targeted areas located on the Leveque Shelf, a geological province within the Browse Basin, were investigated. The survey included scientists and technical staff from GA and AIMS (Appendix A). This report provides the context for the survey activities, describes the geophysical data acquisition and processing methods, and describes the techniques used for sedimentological, geochemical and biological seabed sampling. The report also outlines preliminary observations derived from the various datasets collected.

1.1 Background

The Browse Basin, offshore Western Australia (Figure 1.1), was identified in the 2009 Carbon Storage Taskforce Report (Carbon Storage Taskforce, 2009) as potentially suitable for offshore geological storage of CO_2 because of its favourable geological setting and proximity to offshore gas resources that tend to naturally contain high amounts of CO_2 (~10%, Chirinos et al., 2008). As part of the Australian Government's National CO_2 Infrastructure Plan (NCIP), Geoscience Australia has been tasked to deliver pre-competitive data and information to support the regional assessment of CO_2 storage prospectivity in four offshore basins, which include the Browse Basin (Carbon Storage taskforce, 2009). To address key knowledge gaps in CO_2 storage potential and seal integrity, Geoscience Australia will compile and reinterpret existing data, and acquire, process and interpret new pre-competitive data. Previous interpretations will be integrated with new findings to produce a comprehensive interdisciplinary assessment of the CO_2 geological storage prospectivity of targeted areas within the basins.

Collection and analysis of marine environmental data (consisting of geophysical, geochemical and biological information) is essential to assess the potential for fluid containment or migration and to determine the distribution and representativeness of marine habitats and their associated ecological communities. Bathymetric data provide information on the presence or absence of physical seabed features that may be associated with seepage; sub-bottom profiles provide insight into links between the seabed and the deeper subsurface geology; and biological and geochemical data may also help to indicate seepage. Additionally, the combined environmental datasets provide valuable baseline information that may be used as a benchmark for future monitoring and impact prediction associated with the development of marine infrastructures. These datasets also provide information about potential geohazards that may hinder such development.



Well symbol information is sourced either from "open file" data from titleholders where this is publicly available as at 1 November 2013 or from other public sources. Pipelines and field outlines are provided by Encom GPinfo, a Pitney Bowes Software (PBS) Pty Ltd product. Whilst all care is taken in the compilation of the field outlines by PBS, no warranty is provided re the accuracy or completeness of the information, and it is the responsibility of the Customer to ensure, by independent means, that those parts of the information used by it are correct before any reliance is placed on them.

Figure 1.1 Location map showing the distinct geological provinces that make up the Browse Basin, along with petroleum exploration and production leases (red and green polygons), major gas fields (red-filled polygons) and major faults (black lines).

1.1.1 Regional geology

The Browse Basin is a large northeast-trending sedimentary basin (140,000 km^2) that developed over 320 million years and was shaped by six major tectonic phases (Blevin et al., 1998):

- Late Carboniferous to Early Permian extension;
- Late Permian to Triassic thermal subsidence;
- Late Triassic to Early Jurassic inversion;
- Early to Middle Jurassic extension;

- Late Jurassic to Cenozoic thermal subsidence; and
- Middle Miocene inversion

Initial extension of the basin resulted in half-graben geometries and the formation of two distinct depocentres which are referred to as the Caswell and Barcoo Sub-basins (Figure 1.1 and Figure 1.2). These depocentres contain in excess of 15 km of sediments and are found at water depths of 100 to 1500 m. The outer Browse Basin underlies the deeper waters (1,500–4,000 m) of the Scott Plateau. The southeastern margin of the Browse Basin is underlain by shallow basement, which is typically highly eroded with a distinct, rugose palaeotopographic relief, and is onlapped by Permian to Mesozoic sediments (Struckmeyer et al., 1998). This area is termed the Yampi Shelf in the central and northern parts of the basin, and the Leveque Shelf to the south (Figure 1.1) (Hocking et al., 1994). The basinward (offshore) boundary of the Leveque and Yampi shelves is defined by a 'hinge' where the dip of the basement changes from relatively flat lying to gently basinward-dipping (Figure 1.3). The thick sedimentary section of the Browse Basin is composed of a succession of fluvio-deltaic, coastal, and marine clastic sediments, transitioning during the Turonian (90 M yr) into a major progradational clastic-to-carbonate sequence.

The Browse Basin is a proven hydrocarbon province that is covered by a large number of exploration leases, some of which cover major undeveloped gas/condensate fields and minor oil discoveries (Department of Resources, Energy, and Tourism, 2013) (Figure 1.1). The gas in these fields tends to be high in CO_2 (up to ~10%, Chirinos et al., 2008).

Previous studies have identified several suitable sites for CO_2 injection and storage in the Browse Basin (Bradshaw and Rigg, 2001; Spencer, 2005; Chirinos et al., 2008). Amongst them are two large anticline structures identified around Lyhner Bank, and a potential long migration dissolution storage site identified on the Leveque Shelf. The shelf stretches across the low angle continental slope, over approximately 10,000 km^2. The reservoir occupies the Late Jurassic and earliest Cretaceous basal sedimentary section (Figure 1.2). The reservoir is composed of transgressive sands (Lower Vulcan Formation) and lies at depths between 2,549 and 849 m below the seafloor. The reservoir thickness varies between 170 m at the base of the ramp and about 65 m where it pinches out against the Leveque High (Figure 1.3). This storage site is regionally sealed by the Heywood Formation (Aptian to Turonian), the lateral equivalent of the Jamieson Formation found elsewhere in the Browse Basin. The formation is composed of a thick (up to ~ 1 km) progradational unit, mainly characterised by semi-lithified to unconsolidated claystones and marls, that extends from about 50 to 100 km from the coastline out into the Barcoo and Caswell Sub-basins, the deepest parts of the basin (Figure 1.3).

Prior to declaring a site suitable for CO_2 storage, many points need to be addressed. Amongst these is the identification of potential leakage that could compromise the integrity of the seal. Leakage can originate from many types of structures, including shallow faulting, volcanics, basement pinchouts, stacking of buried valleys, etc. For the migration dissolution storage site on the Leveque Shelf, basement pinchout around the Leveque High and reservoir thickness variations in other areas are of concern (Figure 1.3), as well as shallow faulting and structures associated with high seismicity in the south of the region.

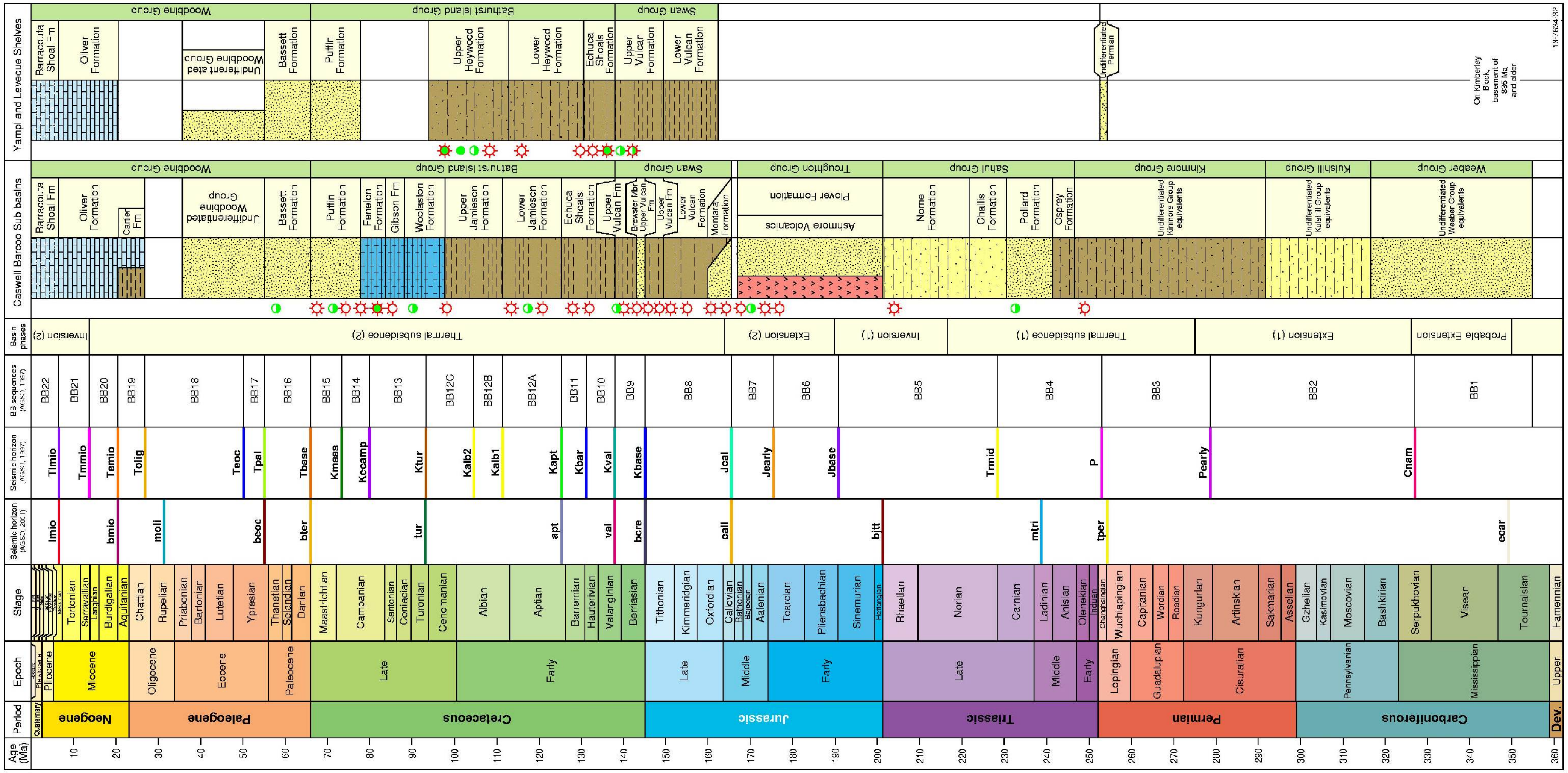


Figure 1.2 Stratigraphy of the Leveque and Yampi Shelves, and the Barcoo and Caswell Sub-basins, geological provinces within the offshore Browse Basin. The Lower Vulcan Formation represents the potential CO_2 reservoir with the Heywood/Jamieson Formations its associated seal (Chirinos et al., 2008).The stratigraphy is based on the Browse Biozonation and Stratigraphy Chart (Nicoll et al., 2009). Geological Time Scale after Gradstein et al. (2012). Seismic horizons used to defined BB sequences (AGSO Browse Basin Project Team, 1997) and AGSO regional seismic horizons (AGSO, 2001) shown.

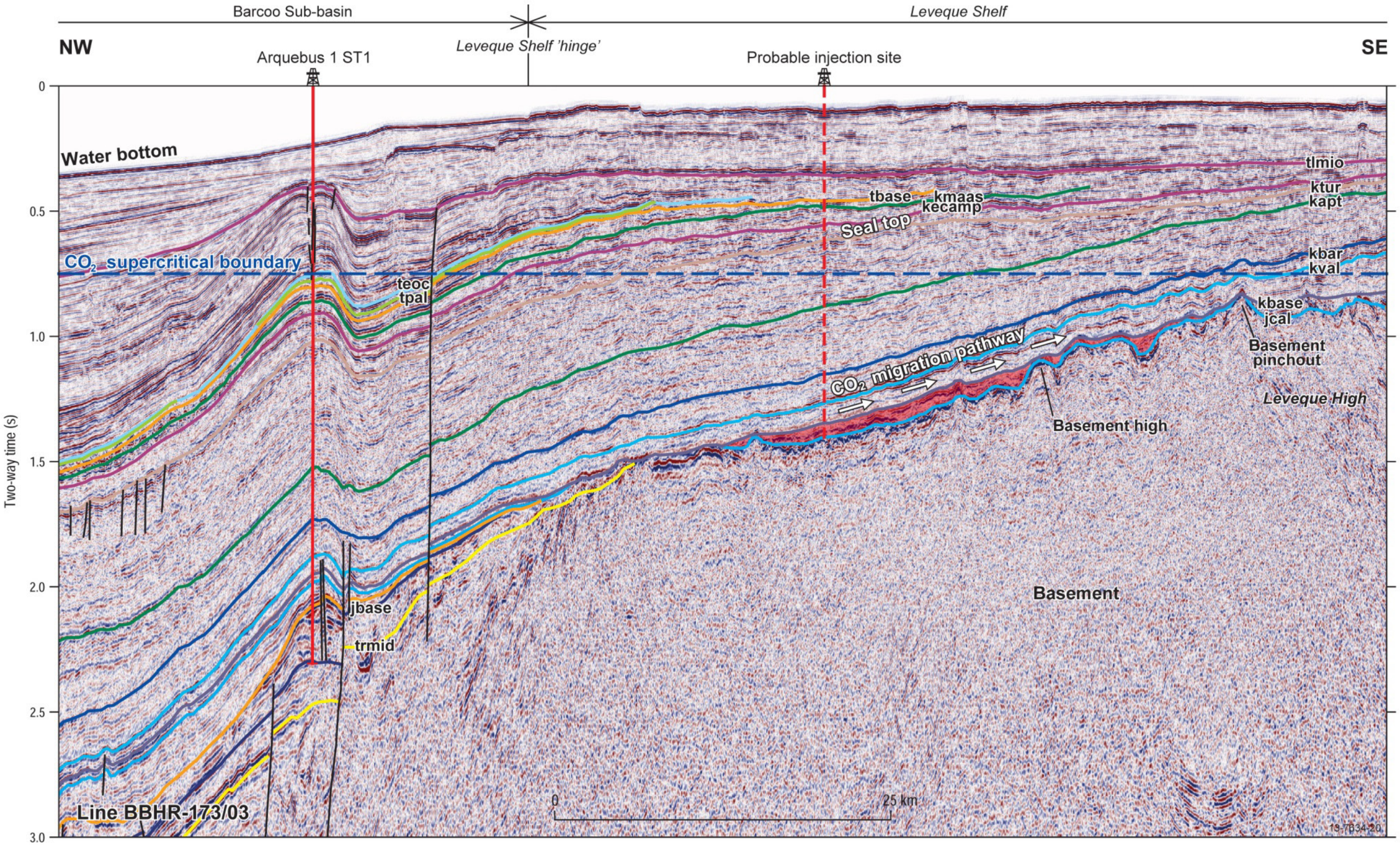


Figure 1.3 Regional seismic line across the Leveque Shelf area showing proposed CO_2 storage reservoir (red-shaded polygon) and overlying seal (up to ktur), as well as the point at which CO_2 would revert from a supercritical phase to gas, where it can more easily migrate through the sediments overlying the storage reservoir. Examples of structures targeted during the survey, such as basement pinchout where evidence of disturbance might be detected at the seafloor, are also marked.

1.1.2 Geomorphology and sedimentology

At the seafloor, the Browse Basin extends from the inner shelf to the base of the continental slope. The continental shelf, which includes part of the Northwest and Sahul Shelves, is broad (100–250 km) with relatively low relief and transitions into the upper slope at between 100-150 m water depths (Figure 1.4). The seabed topography of the basin is highly variable. Significant geomorphic features include plateaus and terraces (Scott, Rowley), banks and shoals (Lynher, Heywood), reefs (Scott, Seringapatam, Beagle), slope, canyons, and valleys, (Harris et al., 2003; Figure 1.5). The most prominent bathymetric high is Lynher Bank, which extends along the southwestern boundary of the basin. Along the shelf break, the bank reaches depths as shallow as 65 m. Within the Leveque Shelf, intermittent large calcarenite ridges and sand waves overlaying otherwise flat seabed areas have been observed (Woodside, 2011). The sand waves can be up to 9 m high and with slopes of up to 7 degrees. Emergent reef systems are absent.

Throughout the Pleistocene, the Leveque Shelf has been subject to long periods of sub-aerial exposure due to low sea-level stands. During the Last Glacial Maximum and until about 20 ka BP, sea-level in the Northwest shelf region was 120 m to 130 m lower than present, and most of the Leveque Shelf would have been emergent until about 10 ka BP (Yokoyama et al., 2001; Lewis et al., 2013). The prolonged low-stand conditions during the Last Glacial Maximum (LGM) appears to have formed a shelf-wide terrace backed by a 30 m high escarpment 125 m below present sea-level (James et al., 2004). This terrace (ancient coastline) has been identified as a key ecological feature of this region (DEWHA, 2008).

Modern sedimentary processes are dominated by high tidal energy and low sedimentation rates. Coastal areas bordering the Leveque Shelf host the largest tides in Australia, with King Sound recording a maximum astronomical tide range at Derby of 11 m (Australian Hydrographic Service, 2009).The tide range on the shelf area is more modest, but still macrotidal (e.g. Adele Island records a mean spring tide of 6.2 m) (Australian Hydrographic Service, 2009). In the vicinity of the coast, tidal currents are considerable, reaching speeds of up to 1.5 m s^{-1} (Great Britain Hydrographic Department, 1972). Further offshore and away from raised topographic features, maximum tidal current speeds are ~1 m s^{-1} (Holloway, 1983; Cresswell and Badcock, 2000). On the open shelf, the flooding tide is directed to the southeast and the ebbing tide to the northwest (Great Britain Hydrographic Department, 1972).

During summer, the upper 50 m of the water column over the shelf-slope is well stratified, which combined with the large tides in the region, leads to internal waves (Holloway, 1994; Pelinovsky et al., 1995; Rayson et al., 2011). Internal waves are most pronounced over the upper shelf-slope and have peak-to-trough heights of 25 m and a semi-diurnal period which is consistent with the barotropic tide in the region (Holloway and Pelinovsky, 2001). The internal waves propagate shoreward onto the shelf and evolve into undular bores as they move into shallower water (Holloway et al., 1997). Numerical model results indicate that nearly all of the internal wave energy is dissipated after crossing the outer shelf (Condie and Andrewartha, 2008).

The Fitzroy River flows into King Sound at Derby and is the closest river system to the shelf area (Figure 1.4). However, terrigenous sediment contribution to this offshore region is minimal as fine grains are mainly absent. Sediments originate from a mixture of relict, stranded and Holocene grains, and vary between high carbonate content sands and gravels (James et al., 2004). The combination between high tidal energy and internal waves, as well as cyclonic storms and long period swells, which are common in the area, result in sediments being highly mobile and resuspended within the water column (DEWHA, 2008). Hard substrates, likely associated with relict landforms, are also present throughout the area (DEWHA, 2008).

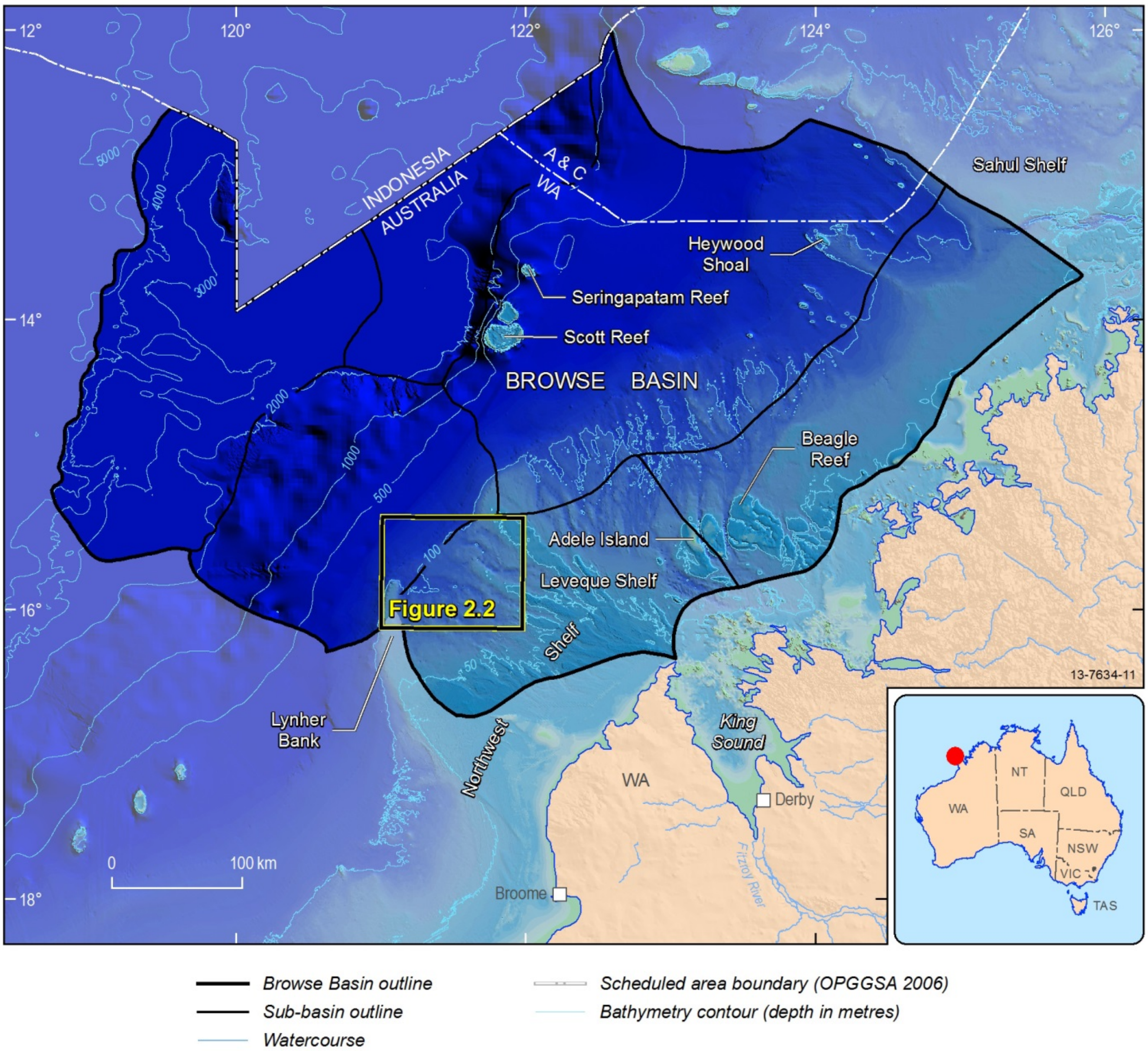


Figure 1.4 General seabed topography of the Browse Basin. The inset box highlights the location of Figure 2.2.

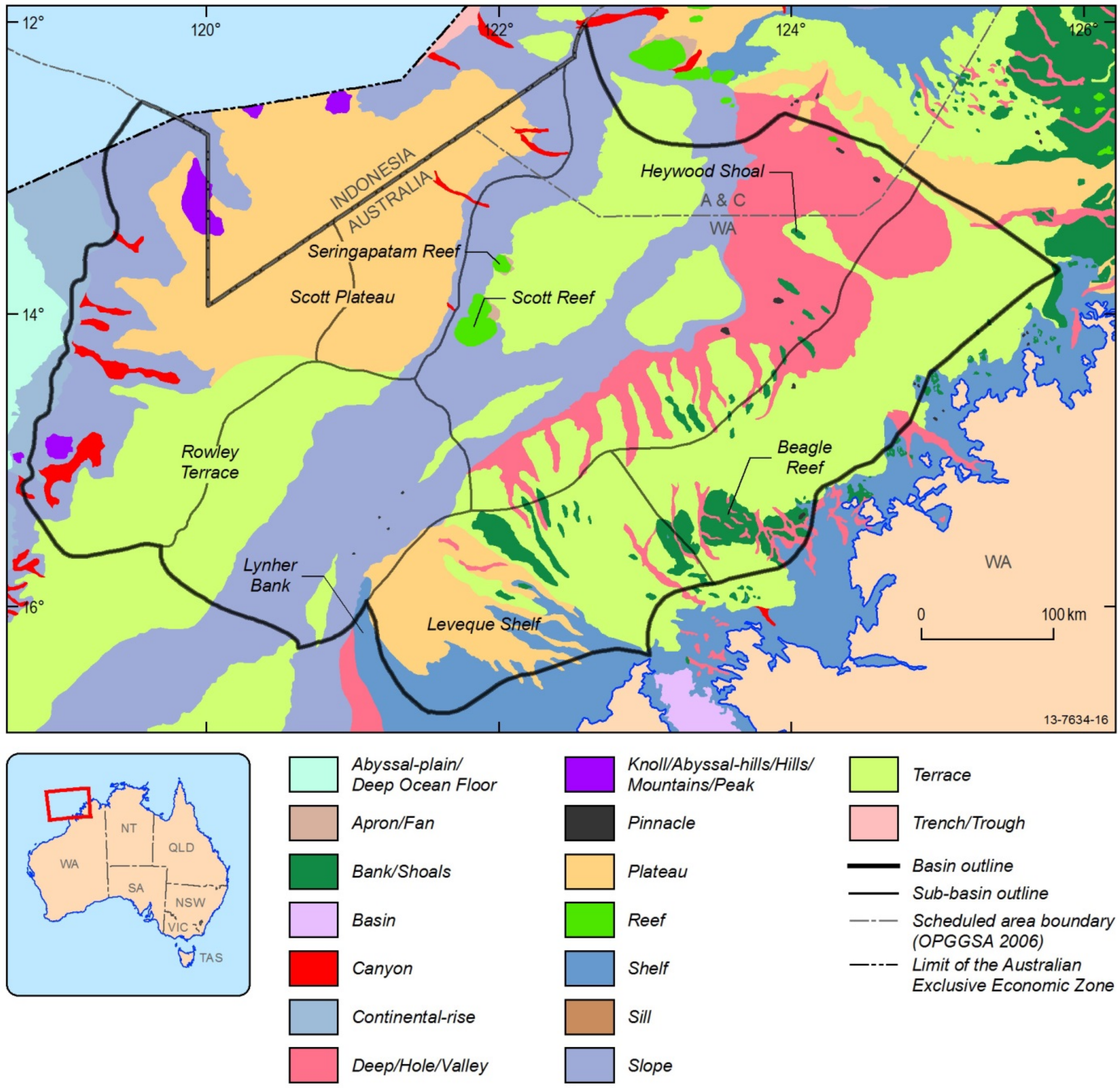


Figure 1.5 Distribution of the regional geomorphic features present in the Browse Basin.

1.2 Survey aims

The study area for the marine survey lies in the Northwest Shelf Province of the Northwest Marine Region (DEWHA, 2008), approximately 106 km northwest of Cape Leveque (WA), 45 km west of Adele Island (WA) and 73 km south-east of Scott Reef South (WA), in water depths between 30 and 150 m (Figure 1.4). The study area is located within the Leveque Shelf, a distinct geological province at the southeastern edge of the Browse Basin.

The main aim of the survey was to build upon existing seismic data to develop a greater understanding of the CO_2 storage potential of the Browse Basin; more specifically focusing on the long-migration dissolution storage on the Leveque Shelf proposed by Chirinos et al. (2008). The specific objectives were to determine:

- The presence or absence of seabed structures that may be surficial expressions of fault and fracture systems, reservoir pinch-out, basement highs, volcanics, and other geological features that may be indicative of pathways for CO_2 migration out of the proposed storage reservoir;
- The presence or absence of reefal seabed structures that may be indicative of potential or actual natural fluid escape (hydrocarbon, CO_2 or otherwise);
- Characteristics of the seabed and associated biota over the proposed storage site and across the boundary where CO_2 would be in its supercritical form, particularly in relation to the location and character of banks, ridges and pockmarks. These characteristics will also provide baseline information on the potential effects of CO_2 storage development;
- Location and internal stratigraphy of palaeo-channels in the vicinity of potential CO_2 migration pathways.

2 Methods

2.1 Survey Overview

The Browse Marine Survey SOL5754 (GA0340) was undertaken as two operational legs: Leg 1 (1-15 May 2013) and Leg 2 (15-31 May 2013). Operations undertaken during both legs included: geophysical data acquisition (multibeam and single beam echosounders, and parametric and sparker sub-bottom profilers), deployment of oceanographic instruments (conductivity, temperature and depth (CTD) probes and methane and carbon dioxide sensors), seabed sampling (grabs) and imaging (underwater towed-video). Due to deck space limitations, sidescan sonar data was only acquired during Leg 1, and vibrocoring was only undertaken during Leg 2. For a detail account of the survey activities, refer to the survey leader's daily log (Appendix J).

2.1.1 Planning rationale

High-resolution seabed mapping was undertaken to enable geomorphic mapping and to identify seabed features related to seepage (e.g. fault scarps, vents, carbonate hard grounds, and rock exposures). Simultaneous water column acoustic imaging using multibeam and single beam echosounders was undertaken to identify potential fluid seepage throughout the water column.

Prior to the survey, a total of seven areas were selected based on the distribution and density of seismic features indicative of potential migration of fluids to the seabed (Table 2.1). These features included basement volcanics that may disrupt the reservoir and force CO_2 out into overlying sediments; and reservoir pinchout or shallow faulting where migrating CO_2 may escape into overlying sediments (Figure 2.1). The environmental context was also considered when determining the size of the survey areas.

Table 2.1 Main motives for selecting each area during pre-survey planning phases (Areas ultimately not surveyed)*

Area	Motives
1	Shallow faults
2	Volcanic basement; Seabed pockmarks; Outboard fault anticline
3	Reservoir pinchout; Volcanic basement
4	Shallow faults
5	Shallow faults
6*	Seabed pockmarks
7*	Seabed pockmarks

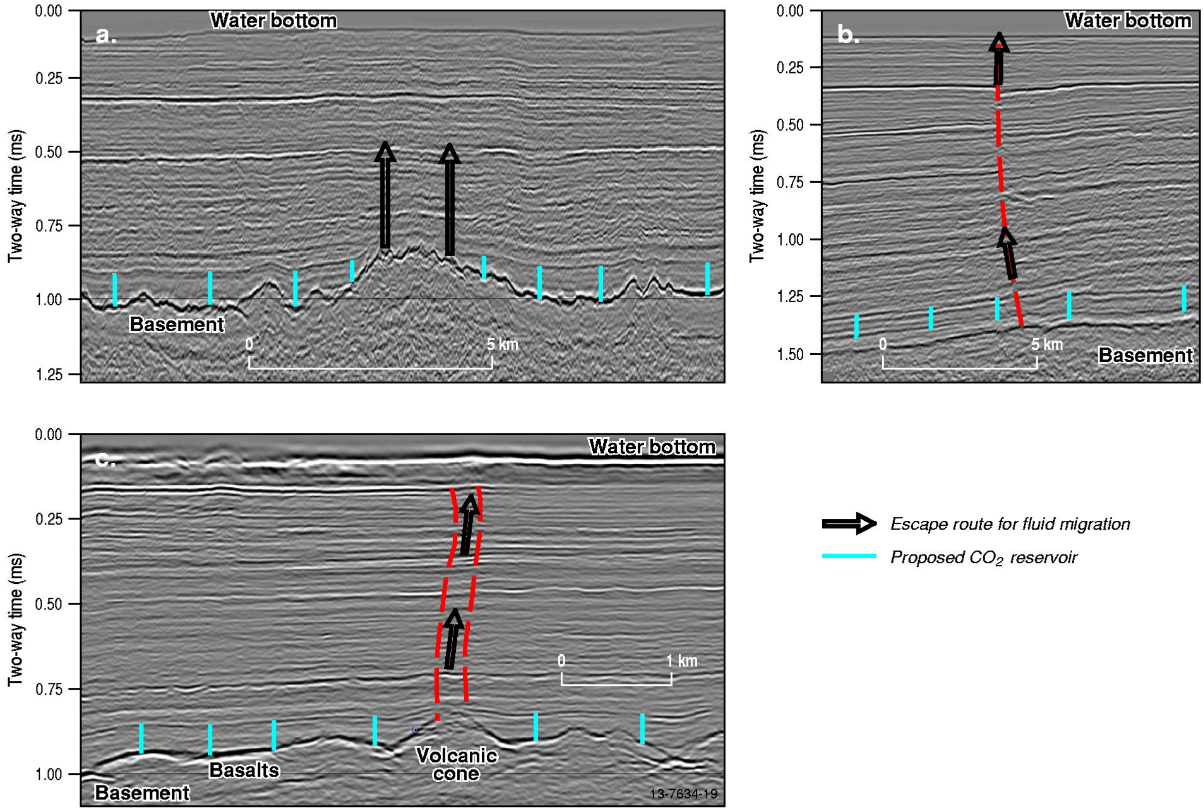


Figure 2.1 Example for each type of seismic anomalies and features targeted for the survey; a) basement pinchout (line Cockatoo 94-3667) b) shallow faulting (line Cockatoo 94-3607) c) basement volcanics (line w01wy_0022P).

Five of the pre-planned areas were investigated (Areas 1 to 5). Areas 1, 2, 4, and 5, representing a subset of the western side of the survey area, targeted multiple seismic features that have potential to compromise the integrity of the CO_2 reservoir seal. These features include shallow faults, volcanic basement, seabed pockmarks, and outboard fault anticline. Area 3 was selected to investigate two types of seismic anomalies, i.e. reservoir pinchout and volcanic basement. Note that Areas 6 and 7 were ranked last priority during pre-survey planning and thus, due to the lack of time, were not surveyed. Note also that Areas 8 and 9 do not exist because they were deemed unnecessary during pre-survey planning. Finally, Area 10 was selected during the survey, and given high priority, to investigate an area of possible basement reactivation due to recent tectonic and shallow volcanic activity.

Seabed and water column mapping methods provided the initial basis to guide the selection of sampling sites during the survey. Sub-bottom profiler survey lines were selected based on the location and density of pre-existing seismic lines in each of the selected areas.

2.1.2 Sampling overview

Seabed samples and oceanographic measurements were collected at 58 stations within the six survey areas (Figure 2.2; Table 2.2). A range of sampling operations was completed at each station, including a combination of underwater towed-video and stills photography, CTD casts, vibrocores, sidescan sonograms, and sediment grabs. The combination of operations was determined on a station-by-station basis and depended on the nature of the seabed environment and prevailing weather conditions (Table 2.2). Physical sampling (grabs or vibrocores) was always preceded by visual inspection using the underwater towed-video and thus, occurred in close proximity to the video transect. Sub-surface profiling was also collected throughout the survey areas (Figure 2.2). The acquisition and processing parameters of the different datasets recorded during the survey are outlined in the following sections.

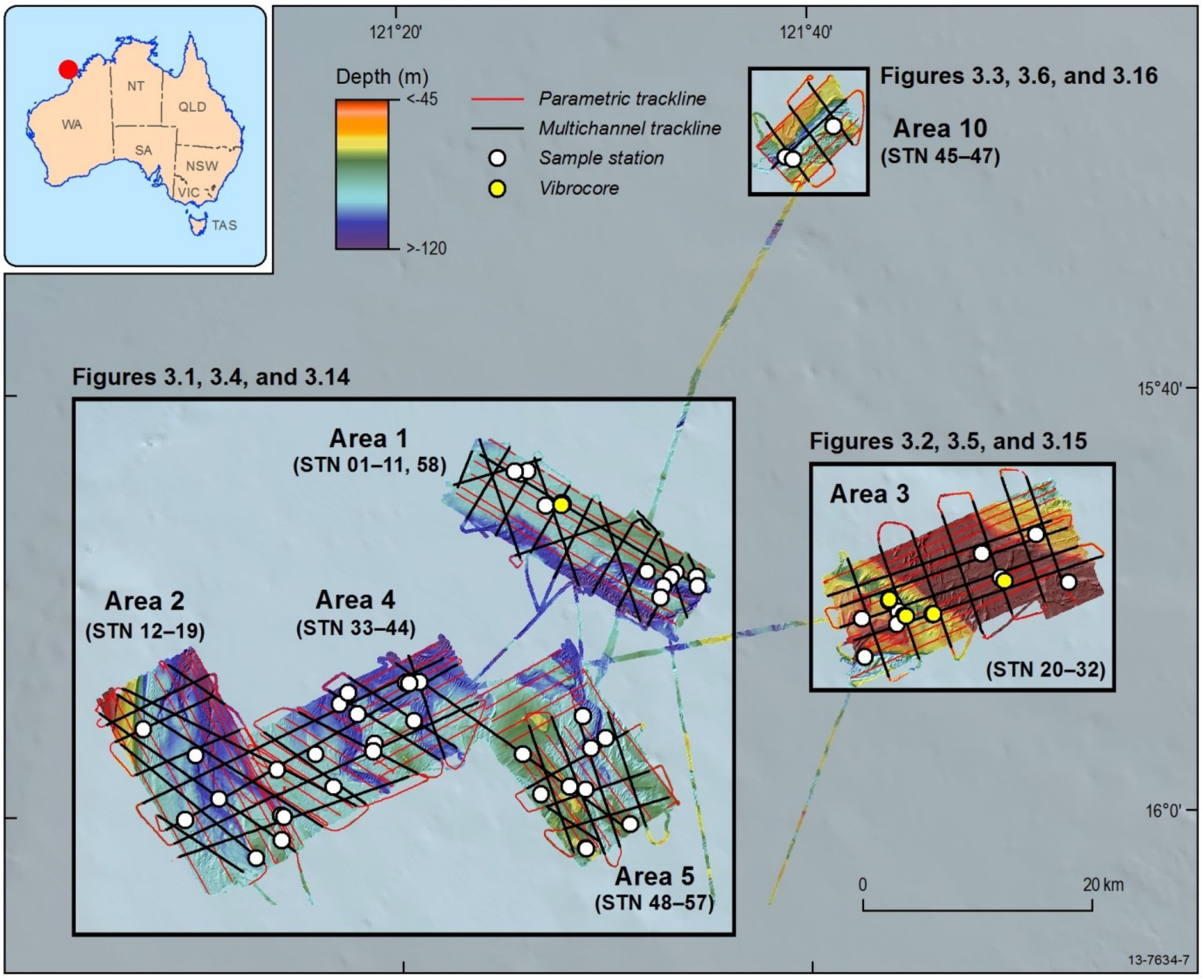


Figure 2.2 Map showing the multibeam bathymetry of the surveyed areas, including a transit line as well as the locations of all sampling stations and sub-surface profiles. Reference and details for each stations and profiles can be found in the figures presented in Section 3.

Table 2.2 List of physical samples and towed-videos by station (STN). Reference numbers of stations and individual operations can be found in figures of Section 3.

STN	Area	Towed-video	Sediment grab	CTD	CO_2 /CH_4	Vibrocore	STN	Area	Towed-video	Sediment grab	CTD	CO_2 /CH_4	Vibrocore
01	1	01	01, 02, 03	01	on	-	23	3	18	66, 67, 68	18	on	-
02	1	-	04, 05, 06	-	-	-	24	3	19	69, 70, 71	19	on	-
03	1	-	07, 08, 09	-	-	-	25	3	20	72, 73, 74	20	on	-
04	1	02	10, 11, 12	-	-	-	26	3	21	75, 76, 77	21	on	-
05	1	-	-	02	-	-	27	3	22	78, 79, 80	22	on	-
06	1	03	13, 14, 15	03	on	-	28	3	23	81, 82, 83	23	on	03
07	1	-	16, 17, 18	-	-	-	29	3	24	84, 85, 86	24	-	04
08	1	04	19, 20, 21	04	on	-	30	3	-	-	-	-	05
09	1	05	22, 23, 24	05	on	-	31	3	25	87, 88, 89	25	-	-
10	1	06	25, 26, 27	06	on	-	32	3	26	90, 91, 92	26	-	-
11	1	07	28, 29, 30	07	on	-	33	4	-	-	27	-	-
12	2	08	31, 32, 33	08	on	-	34	4	27	93, 94, 95	28	-	-
13	2	09	34, 35, 36	09	on	-	35	4	28	96, 96_D1, 97	29	-	-
14	2	-	37, 38, 39	-	-	-	36	4	29	98, 99, 100	30	-	-
15	2	10	40, 41, 42, 43	10	on	-	37	4	30	101, 102, 103	31	-	-
16	2	11	44, 45, 46	11	on	-	38	4	31	104, 105, 106	32	-	-
17	2	12	47, 48, 49	12	on	-	39	4	32	107, 108, 109	33	-	-
18	2	13	50, 51, 52, 53	13	on	-	40	4	33	110, 111, 112	34	-	-
19	2	14	54, 55, 56	14	on	-	41	4	34	113, 114, 115	35	-	-
20	3	15	57, 58, 59	15	on	-	42	4	35	116, 117, 118	36	-	-
21	3	16	60, 61, 62	16	on	-	43	4	36	119, 120, 121	37	-	-
22	3	17	63, 64, 65	17	on	01, 02	44	4	37	122, 123, 124	38	-	-

STN	Area	Towed-video	Sediment grab	CTD	CO_2 /CH_4	Vibrocore
45	10	38	125, 126, 127	39	-	-
46	10	39	128, 129, 130, 131	40	-	-
47	10	40	132, 133, 134	41	-	-
48	5	41	135, 136, 137	42	-	-
49	5	42	138, 139, 140	43	-	-
50	5	-	141, 142, 143	44	-	-
51	5	43	144, 145, 146	45	-	-
52	5	44	147, 148, 149	46	-	-
53	5	48	150, 151, 152	47	-	-
54	5	46	153, 154, 155	48	-	-
55	5	47	156, 157, 158	49	-	-
56	5	48	159, 160, 161	50	-	-
57	1	-	162, 163, 164	51	-	06, 07, 08
58	5	49	165, 166, 167	52	-	-

2.2 Geophysical data

2.2.1 Seabed Mapping

2.2.1.1 Multibeam Echosounder

2.2.1.1.1 Bathymetry

High-resolution multibeam bathymetry data were collected using GA's Kongsberg EM3002 multibeam echosounder system, mounted in the moon pool of the RV *Solander* (Figure 2.3). Technical details of the multibeam operations can be found in Appendix B. The multibeam bathymetry data were processed using Caris HIPS/SIPS v7.1 SP1 software, and included:

- applying algorithms that corrected for tide and vessel pitch, roll and heave; and
- software filters and visual inspection of each swath line to remove any remaining artefacts and noisy data (e.g. nadir noise and data outliers).

During the survey, a co-tidal solution was adopted to minimise tidal bursts. This solution used average tide from multiple tide stations weighted inversely to distance between the tide station and the point of interest available in Caris (Appendix B). Transit lines and study areas were divided into closed zones with designated primary and secondary tide stations of known locations, all defined in a Zone Definition File (.zdf) in Caris. The predicted tides were calculated using tidal constituents requested for predefined locations from the National Tidal Centre, Bureau of Meteorology. Final bathymetry surfaces at 2 m horizontal resolution were created within Caris and then exported as a surface grid (bathymetric map) for display and analysis. Final processing to correct for tidal variations was completed post-survey using a modified GPS tide in Caris.

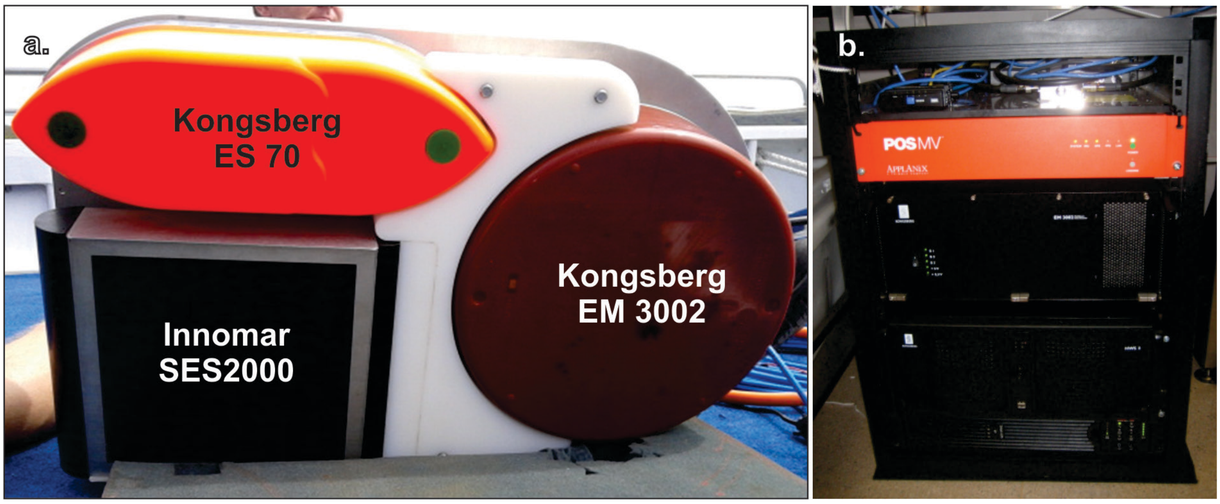


Figure 2.3 Acoustic instrumentation used on the survey. a) Sonar heads fitted to one mounting device and deployed through the moon pool of the RV Solander. Top Left: Kongsberg ES70 dual-frequency single beam; Bottom Left: Innomar SES-2000 parametric sub-bottom profiler; Right: Kongsberg EM3002 multibeam echosounder b) Multibeam echosounder processing unit, including Applanix POSMV motion reference system.

2.2.1.1.2 Backscatter Strength

Along with bathymetric data, the Kongsberg EM3002 multibeam system also co-registered backscatter data. These data were processed using the multibeam backscatter *CMST-GA MB Process* v12.05.07.0 (×64) toolbox software co-developed by the Centre for Marine Science and Technology (CMST) at Curtin University of Technology and GA (described in Gavrilov et al., 2005; Parnum and Gavrilov 2011). The process within the toolbox involved removal of the system transmission loss, removal of the system model, calculation of the incidence angle, correction of the beam pattern, calculation of the angular backscatter response within a sliding window of 25 pings with a 50% overlap in a 1° bin, removal of the angular dependence, and restoration to the backscatter strength at an angle of 25° (Daniell et al., 2010). The final processed backscatter data were then gridded to 2 m horizontal resolution and exported for display and analysis.

2.2.1.2 Sidescan Sonar

Following mapping with the multibeam and single beam echosounders, sidescan sonograms were collected in three targeted areas using an Edgetech 4200 dual-frequencies (100 and 400 kHz) (Figure 2.4). The areas were selected onsite to investigate seabed and water column features suspected to relate to seabed seepage. The objectives were to improve the mapped resolution of the features and image the potential associated features, such as flares, present in the water column. The data were post-processed using Chesapeake Technology SonarWiz v.5.0 software. The data were slant range corrected, georeferenced using features present on the newly acquired multibeam data, and mosaicked.

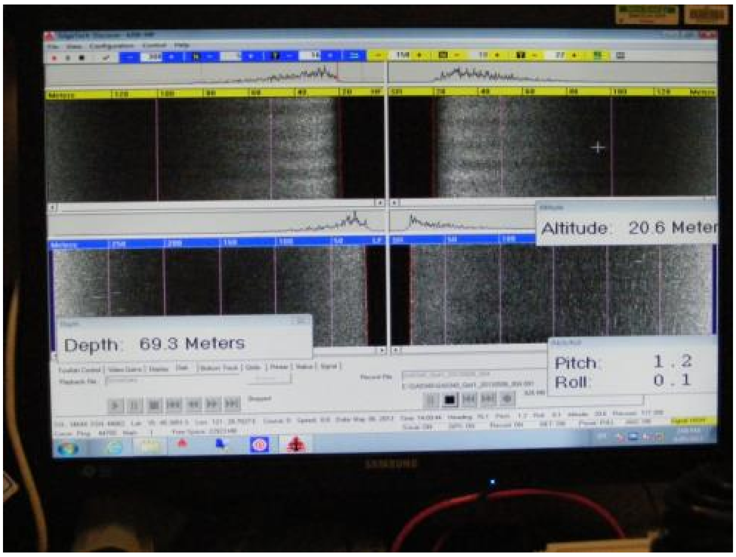


Figure 2.4 Edgetech 4200 dual-frequencies sidescan sonar acquisition system. Top screen: High Frequency data; Bottom screen: Low Frequency data

2.2.2 Sub-Surface Reflection

Sub-bottom data were acquired at two different scales using two different systems. A multichannel sparker sub-bottom profiling system was used to map the first 100 ms TWT of sediment, while a parametric system was used to map the first 50 ms TWT of sediment at higher resolution.

2.2.2.1 Multichannel Sub-Bottom Profiler

Multichannel imaging of sub-bottom sediments was performed with an Applied Acoustics Squid 2000 sparker source and a 24 channel Geometrics MicroEel streamer, with a Geometrics Seismodule PC based acquisition system (Figure 2.5). The sparker was powered by a CSP-D generator, initially run on a setting of 2,000 joules (Hi 10). Firing on position at 6.25 m intervals, in conjunction with the MicroEel group interval of 3.125 m, allowed six fold Common Depth Point (CDP) stacked data. In line offset of the sparker from the starboard stern was initially 25 m, subsequently reduced to 20 m to try to reduce the movement of the sparker in the water. In line offset of the streamer was 45 m (port stern to centre of first group), with a lateral offset from the sparker of 6.5 m. The sparker and streamer were towed at a speed through water of 5 knots (9 km hr^{-1}), in seas ranging from 1 to 4 on the Beaufort Sea States Scale. Source depth was a nominal 0.5 m and the streamer depth a nominal 2.5 m ('average' of Star Oddi pressure sensor readings).

During acquisition, data quality was monitored by displaying each successive shot record and a progressive near trace (second channel) gather on the acquisition PC. Shot records were output on disk in SEG-Y format with 0.5 second record length, and usually 0.125 ms sample interval. Only times, not coordinates, were input into the SEG-Y trace headers. Separate navigation log files contained GPS position and UTC time for each shot record. At the start of each acquisition session, the PC clock was synchronised with UTC to within one second. Several problems, which are listed in Appendix C, occurred during the survey. Complete details on acquisition and issues can be found in the Observers Logs in Geoscience Australia data store (note that Area 4 will be referred to as Area 4/6 in the sub-bottom profile observer logs).

Multichannel seismic reflection processing was carried out with Paradigm Geophysical's Focus 5.4 software. Brute stack processing was carried out on board the RV *Solander* for loading into Kingdom interpretation software, and final stack processing was undertaken at Geoscience Australia for data delivery and archiving (Figure 2.6). Use of shell scripts and job templates expedited the handling of such a large number of lines which had to be processed on an individual basis (For detailed description of the methods, see Jones, in prep). The final processing stream is documented in the Extended Binary Coded Decimal Interchange Code (EBCDIC) text header of each final processed SEG-Y file (Appendix C).

Final stack processing included geometry definition, with correction to actual source receiver offsets to accommodate lateral offset and effects of yaw, mute of leaked timing pulse and first arrivals, band pass frequency filtering, and surface related multiple elimination (SRME) on shot records. After sorting into CDP gathers, velocity analysis was carried out on representative lines for each area to develop interval velocity models so that stacking velocity could be calculated below digitised water bottom. Non-surface consistent trim statics were used to correct for time shifts due to the relative motion of the sparker and streamer, particularly in the rougher seas (Carroll et al., 2012; Jones, 2013). For the Browse Basin, features such as bedforms and valleys present on the seabed made it impractical to use the water bottom reflection as the reference for statics calculation. Therefore, the strongest reflector band in the sediments was digitised to feed into the calculation of the statics reference gates. The effect of both stacking velocity and statics can be seen in the comparison of the on board brute stack with the much improved final stack for line GA0340-061 (Figure 2.6).

The final step involved the application of datum statics to adjust to mean sea level, correcting for source and streamer depth, and tidal variations of up to +/- 3 m, which could lead to significant mis-ties in intersecting lines. Tidal statics were calculated from the change in elevation of the CNAV GPS antenna at known UTC times. The final processed data set consists of SEG-Y stack data with all relevant trace headers populated and a full EBCDIC header with metadata on acquisition and processing for each line, a P190 navigation file for the CDP coordinates, and stacking velocity file in Disco HANDVEL format.

Figure 2.5 Sparker sub-bottom profiler. a-c) Preparation, operation and retrieval of the Applied Acoustics Squid 2000. d-e) Preparation and retrieval of 24 channel Geometrics MicroEel

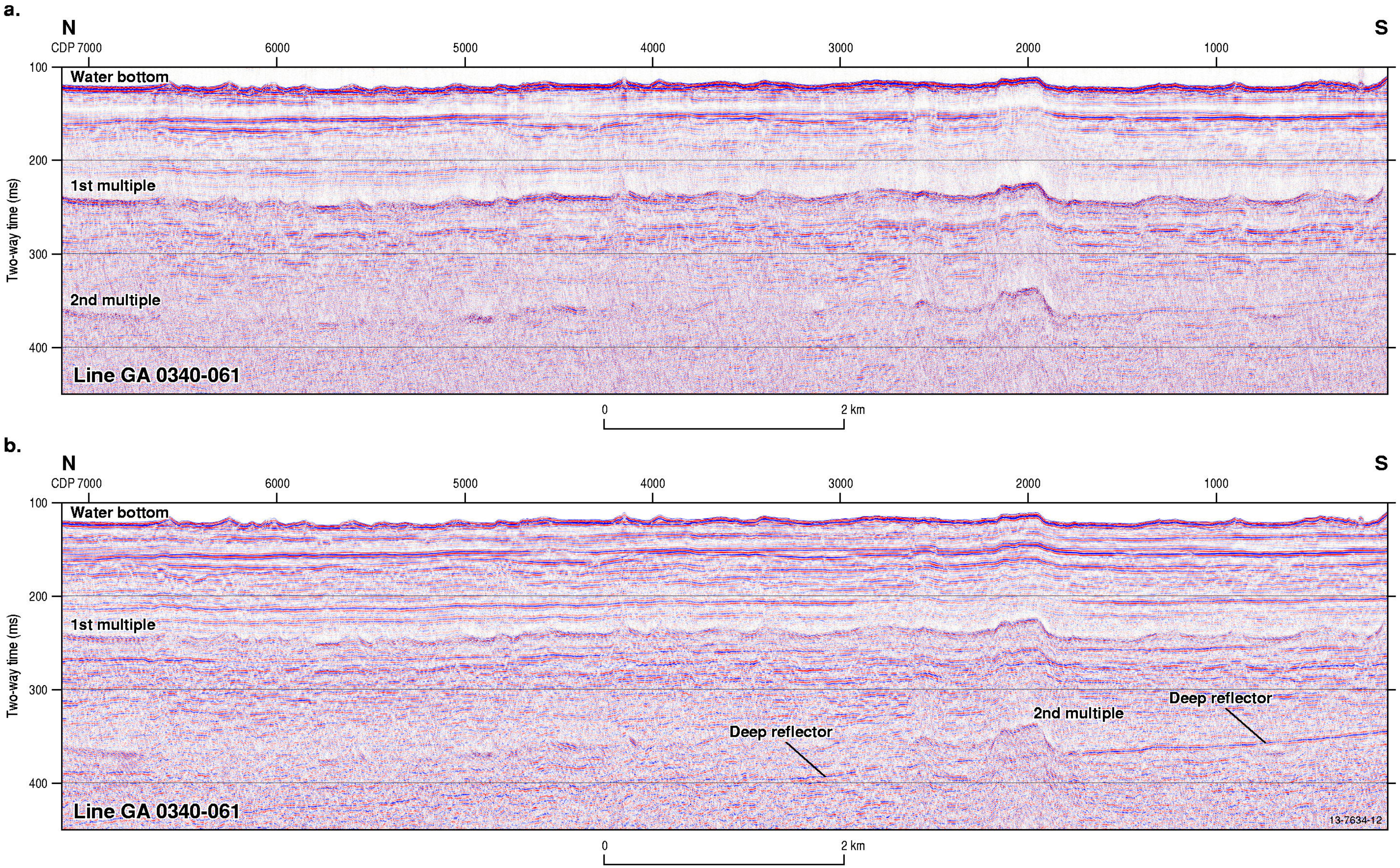


Figure 2.6 Stack section of sub-bottom profile line GA0340-061 in Area 5 (approximately 100 m of sediment lies between water bottom and the first multiple). (a) Brute stack processed on board, stacked with water velocity and no trim statics. (b) Final stack showing significant improvement due to better velocity function and non-surface consistent trim statics. Water bottom multiple suppression is also improved, due to a combination of factors. Note the deep primary reflector dipping to the left through the second water bottom multiple. The vertical exaggeration is approximately 9:1, using a P wave interval velocity of 1,800 m s^{-1} in the sediments.

2.2.2.2 Parametric Sub-Bottom Profiler

An Innomar SES-2000 compact parametric sub-bottom profiler was used to image the upper 50 ms of sub-surface sediments. The system's transducer was mounted in the moon pool alongside the multibeam and single beam transducers (Figure 2.3). The system was run simultaneously with the acquisition of multibeam echosounder data and thus, synched externally to the latter. However, due to residual interference with the multibeam echosounder, affecting mainly the outer beams, the data was collected approximately every fifth line (~ 1 km spacing) (Appendix D). During rough weather conditions, the acquisition was coordinated with the downwind survey lines. Data was also acquired together with the multichannel sparker sub-bottom profiler. Innomar proprietary acquisition software SESWin was used to record the data. The system was set up using the sub-bottom single-frequency mode with the low frequency (LF) set to 4 kHz. The data was position- and heave-corrected using POSMV values, and depth-corrected using a constant value for sound velocity of 1,545 m s^{-1}. The latter estimate was based on the average surface water velocities measured from a haul probe.

2.3 Physical data

Seabed samples were acquired for sedimentological, geochemical, and biological analyses. This information will be used to provide general descriptions of benthic habitats and to identify unique, rare and/or potentially vulnerable biological communities, and those found in association with geophysical indicators of fluid seepage.

2.3.1 Grabs

Unconsolidated seabed sediments were collected using a Smith-McIntyre (SM) (10 L, 0.1 m^2 opening) grab sampler. A Shipek (20 X 21 cm; 10 cm deep) grab sampler was also deployed at two stations (16 and 17, refer to Section 3 Figure 3.1), due to a temporary malfunction of the SM grab sampler. The grab samplers were deployed from the starboard side winch of the RV *Solander*. The SM grab sampler is mounted on a sturdy, weighted, steel frame, with springs to force the two-jaw bucket into the sediment substrate when released (Figure 2.7). Tripping pads, positioned below the square-based frame on which the bucket is suspended, make first contact with the seabed and are pushed upward to release two latches holding the spring-loaded bucket jaws. Tension from the winch wires keeps the grab closed during retrieval. The Shipek grab sampler is engaged by rewinding the deployment wire, which exerts tension on cables connected to the end of each bucket-jaw arm causing the jaws to pivot tightly shut. Upon contact with the seabed, wire tension is released closing the jaws.

In the majority of cases, three SM grabs were taken at each station. Generally, the first and second grabs were sub-sampled for sedimentology (mainly grain-size analysis) and infauna and the third grab was sub-sampled for geochemistry.

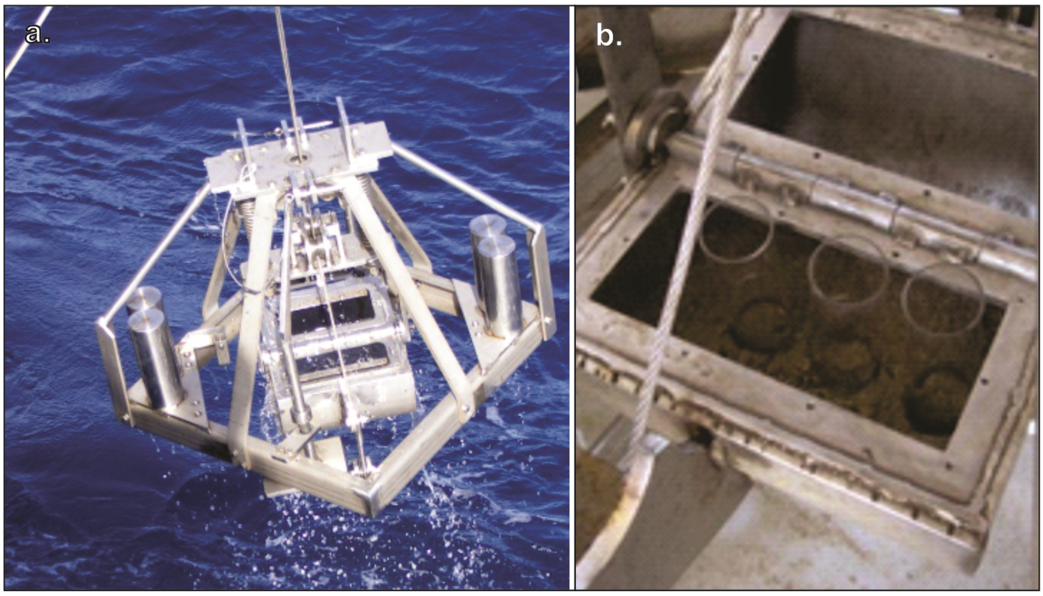


Figure 2.7 Images of sediment sampling devices used on this survey. a) Smith McIntyre grab full of sediment during recovery; b) Extraction of sediment cores from the Smith McIntyre grab sampler.

2.3.1.1 Sedimentology

The principal aim of the sedimentology component of the survey was to determine the texture and composition of the surface sediments for seabed characterisation. Up to 100 g of bulk sediment was sub-sampled from the top 2 cm of the grabs. Samples were submitted to the GA sedimentology laboratory for grain-size analysis using sieve separation and particle size distributions (including mean, median, standard deviation, skewness, and kurtosis analysis) by laser diffraction using the Malvern Mastersizer 2000 particle size analyser. Separate sample splits were submitted for measurement of carbon content using the carbonate digestion method (Müller and Gastner, 1971).

2.3.1.2 Geochemistry

The principal aims of the geochemistry component of the survey were to:

- determine the geochemical composition of surface sediment for seabed characterisation; and
- quantify the levels of reactive organic matter in the sediments that were due to pigments and bulk organic matter. The grabs were sub-sampled and processed aboard following the method described in Table 2.3, which provides a detailed list of the shipboard laboratory processing undertaken for each station.

Table 2.3 Details of shipboard laboratory processing used to prepare and analyse the geochemistry sub-samples. Sub-sample codes (C_B1, etc.) correspond to the file extension assigned to the sub-sample types in the shipboard database.

Sub-sample	Shipboard processing	Parameters measured
C_B1	7.5 ml samples of surface sediment (0-2 cm) were syringed into plastic container. The samples were wrapped in Al foil and frozen.	Porosity and wet/dry bulk densities (0.0-2.0cm) Total chlorins and chlorin indices Mineralogy
C_B2	4 ml samples of surface sediment (0-0.5 cm) were syringed into plastic bags. The samples were wrapped in Al foil and frozen.	Chlorophyll a,b,c and phaeophytin
C_B3	4 ml samples of surface sediment (0-0.5 cm) were syringed into plastic bags. Samples were frozen.	Porosity and wet/dry bulk densities (0-0.5cm)
C_C1	Bulk sub-sample (6.5 ml) of surface sediment (0-2 cm) incubated in BOD bottles for ~24 hrs in the dark at sea surface temperature (SST). Dissolved oxygen concentrations (and saturation values) were measured at the start and finish of each incubation.	Sediment oxygen demand
C_C2	Salinity, temperature and pH were measured on pore waters extracted from sub-samples C_D1. These pore waters were then filtered (0.45 µm) into 3 ml gas-tight vials (pre-charged with 0.025 $HgCl_2$) within 1 hr of collection (T=0). The procedure was repeated on pore waters from an additional bulk sample collected as per C_D1 and incubated for ~24 hrs at SST (T=1). All samples were refrigerated prior to laboratory analysis.	CO_2 production rates
C_C3	A 4.5 cm diameter core of surface sediment overlain by 0.118L of local seawater was incubated in the dark for ~4 hrs at ~26^{o}C after a ~3 hrs pre-incubation period. Dissolved oxygen levels were measured at ~30 minute intervals. Samples for DIC analysis were taken at the start and finish of the incubation. Blank cores (local seawater only) accompanied all incubations.	CO_2 production/consumption rates/ total oxygen consumption/production rates
C_D1	Surface sediment (0-2 cm) was syringed into falcon vials. Pore waters were removed within 20 minutes of collection. Residual sediment was frozen for transport to the laboratory.	Major, minor, trace and rare earth elements Bulk carbonate Particle surface area TOC, TN and C & N isotopes
C_E1	Spare sample. Surface sediment (~0-2 cm) was scooped into plastic bag. Samples were immediately frozen.	TBD
C_E2	~0-2 cm of surface sediment was transferred to metal container using a metal spoon. The sample was frozen for transport to GA laboratories.	Biomarkers
C_S1	Carbonate specimens were bagged and refrigerated.	TBD

2.3.1.3 Infaunal Sampling

The sediments captured in the relevant grab samplers (including those that remained after the sedimentology sub-sampling) were released into a 52 L nally bin (Figure 2.8a). Excess water was passed through a 500 µm sieve, and the samples were weighed (including nally bin). The sediments were then sampled for infauna by elutriating for approximately five minutes through a 500 µm sieve. Following elutriation, excess water was passed through the sieve to collect animals lighter than the sediments (Figure 2.8b). The elutriated material was carefully removed from the sieve and preserved in ethanol to be sent to GA for sorting (Figure 2.8c). To account for heavier animals such as molluscs, which may not be collected during elutriation, the coarse fraction was sorted by hand. Elutriated samples were preserved in ethanol (most taxa) or formalin (polychaete worms) for laboratory processing of microscopic animals. In addition, ~ 25 ml of un-sieved sediment was retained to confirm that elutriation did not fail to collect significant numbers of heavy-bodied organisms (e.g. molluscs, hermit crabs).

In the GA marine laboratory, elutriated samples and sub-sampled whole fractions were examined under a dissecting microscope and all intact animals were separated. Animals are currently being identified to operational taxonomic unit (OTU) by GA ecologists, with voucher specimens photographed and separated in a reference library. Polychaetes and echinoderms will be lodged at the Museum of Victoria where taxonomists will archive and identify the specimens to species level. All other taxa will be sent to appropriate institutions pending agreements.

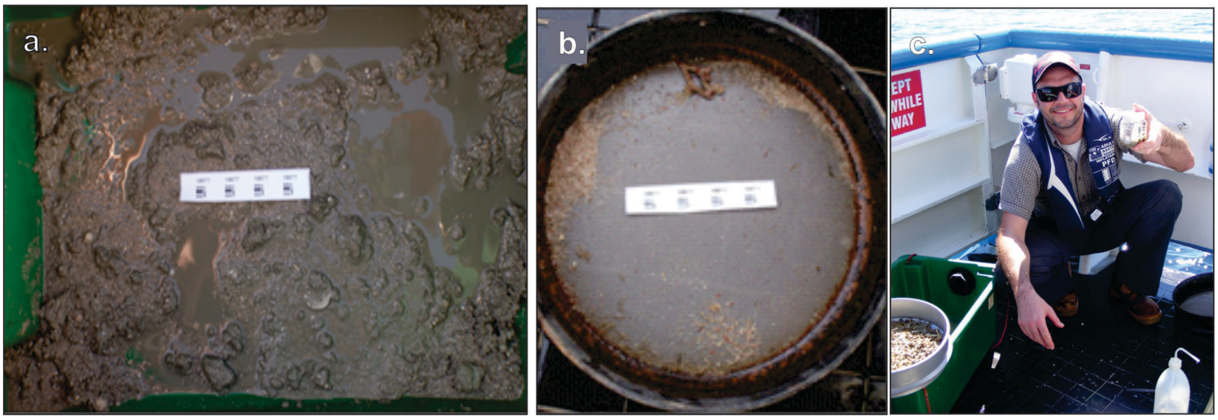


Figure 2.8 Images of the elutriating process used for infaunal sampling. a) Sediment collected from a grab sample in nally bin prior to elutriating. b) Organisms collected with a 500 µm sieve after 5 minutes of elutriation. c) Scientist holding the organisms resulting from elutriation and stored in an ethanol-filled container.

2.3.2 Vibrocore

Sediment cores for sedimentology and geochemistry were collected using a vibrocorer fitted with an aluminium core barrel. The vibrocorer was deployed and retrieved from the RV *Solander* stern A-frame, with GA's hydraulically-operated JADIN vibrocore winch and SEA's 450 vibrocorer (head and tower) (Figure 2.9). The 136 kg vibrocore head was vibrated for one minute at each deployment. A 6 m core barrel was used, giving variable penetration depending on substrate type, with very limited penetration in sandy sediments. The stations were selected based on features of interest identified with the multibeam echosounder and the parametric sub-bottom profiler.

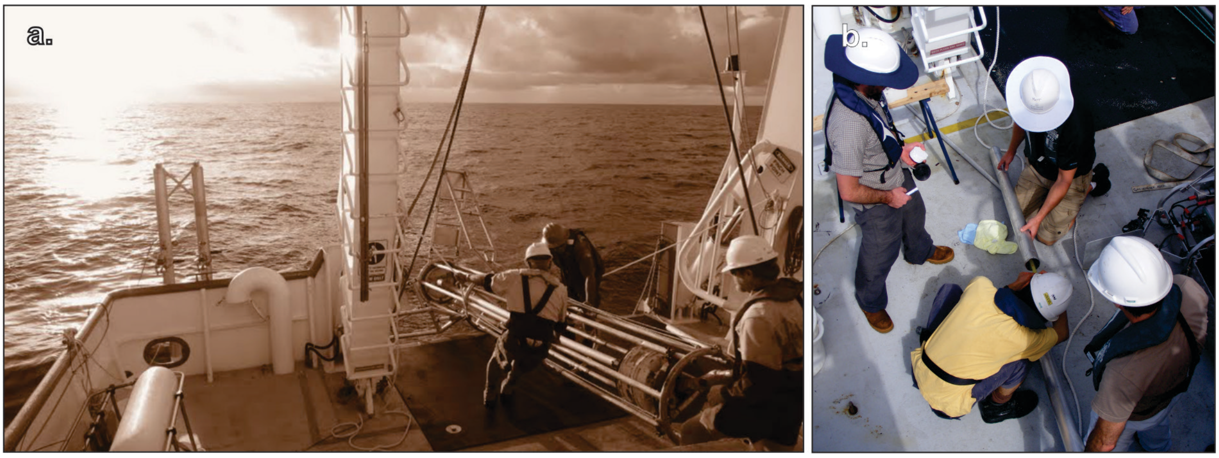


Figure 2.9 a) Vibrocore retrieved from the stern of the RV Solander; b) Measurement of the core sample length retrieved in the barrel.

2.3.3 Underwater Towed-Video

Seabed habitats and associated benthic macro-organisms were surveyed using the AIMS towed-video system (Figure 2.10). This system was fitted with a single forward-facing video camera (Watec colour D250 model, 4 mm lens) and two high-resolution still cameras (Sea&Sea DX2G 12 mega pixel: one forward-facing and one downward-facing) and their associated lights. At each station, the towed-video system was deployed from the stern of the RV *Solander* and towed at 0.5 to 1.5 knots at an altitude of 0.5 to 2 m above the seabed for a distance of approximately 1 km. High-resolution still photographs (captured every five seconds along each towed-video transect) were used in conjunction with the video footage to assist identification of biota. To accurately correlate the position of seabed video and images with physical features in the multibeam bathymetry, the position of the towed-video system was tracked using a USBL (Ultra-short Baseline) acoustic tracking system. Video footage was transmitted in real-time to the surface via a coaxial cable to enable operators to characterise the seabed environment and allow the winch operator to regulate the altitude of the towed-camera system. Live video feed to the surface was monitored and broadly characterised according to AIMS's classification scheme (Figure 2.10b). Upon retrieval of the camera system, video and still images were downloaded and renamed by station and a sequential image number. Images of representative habitat and biota were identified for further analysis and description.

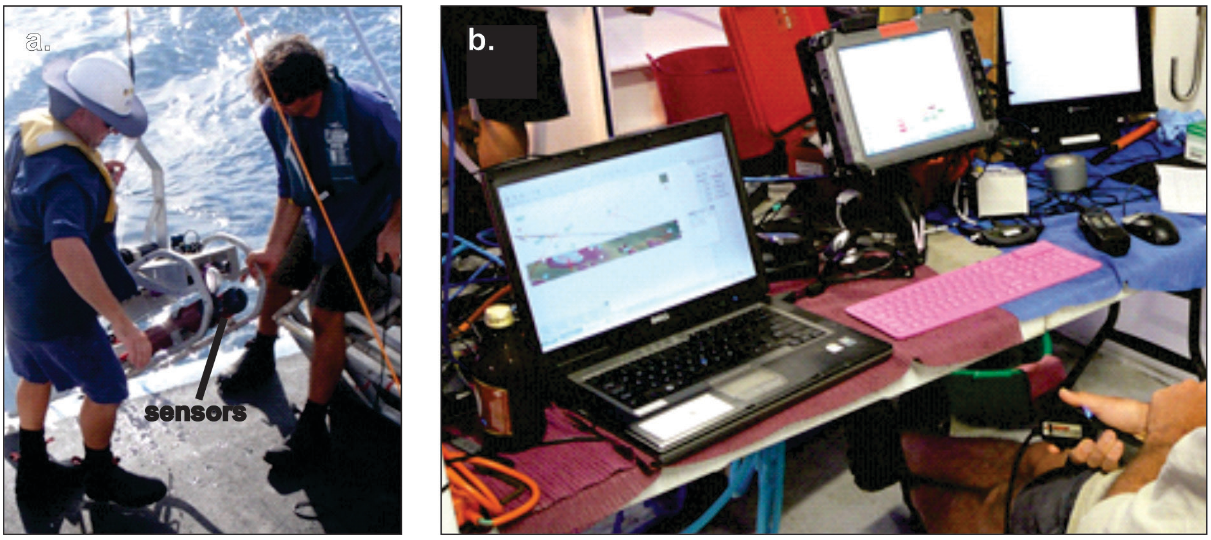


Figure 2.10 Images of the AIMS towed-video system. a) Deployment of AIMS towed-video system of the stern of the RV Solander. Note the red methane and CO_2 sensors mounted below the video camera b) Monitoring station with USBL acoustic tracking system and video feed.

2.4 Oceanographic data

2.4.1 Water Column Imaging

2.4.1.1 Single Beam Echosounder

A Kongsberg ES70 single beam echosounder was used to collect acoustic returns from the water column down to the seafloor (Figure 2.3). The system operated at dual frequencies of 38 kHz and 200 kHz and was mounted in the moon pool of the ship alongside the multibeam transducer. The echosounder was run simultaneously with the acquisition of multibeam echosounder and thus, synched externally to the latter. The data was visualised and processed onboard using Echoview v5.4.40.22725 (Figure 2.11). The software assumed a constant speed of sound of 1,500 m s^{-1} in the seawater.

2.4.1.2 Multibeam Echosounder

Multibeam water column data were collected using the Kongsberg EM3002 multibeam system. The returns were analysed using Echoview v5.4.40.22725 (Figure 2.11). The software assumed a constant speed of sound of 1,500 m s^{-1} in the seawater and applied a straight line ray tracing. The tool allows for viewing water column cross-section per ping and allows for manual selection of the water column backscatter range. While on board, visual inspection of the water column cross-sections from both systems was conducted to identify water column features potentially related to seepage.

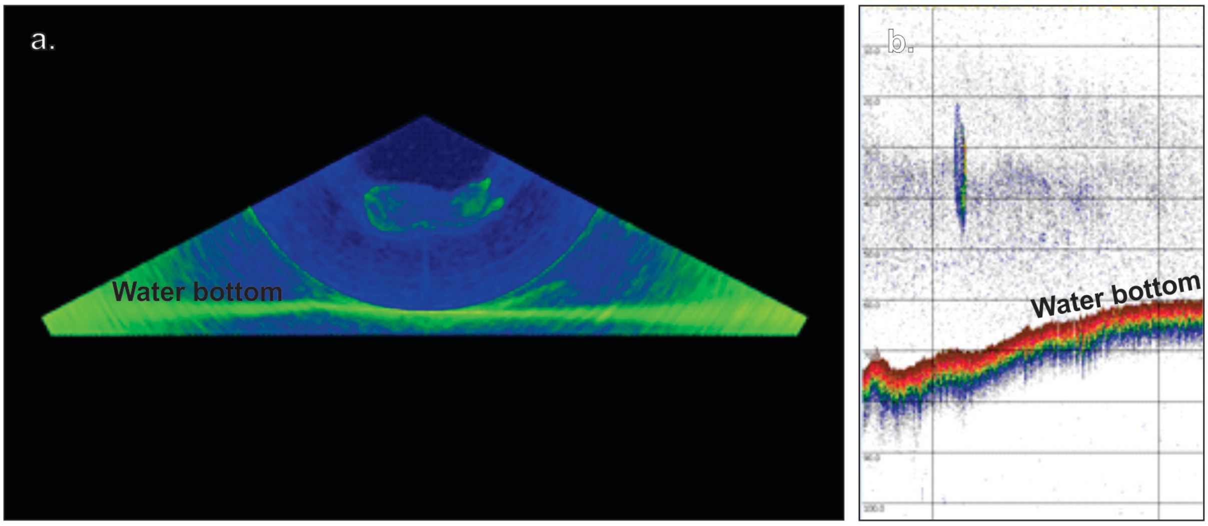


Figure 2.11 Water column acoustic imagery from a) multibeam and b) single beam echosounders. Both images are captured at the same time and location.

2.4.2 Water Column Measurements and Sampling

2.4.2.1 CTD

Conductivity, temperature and depth (CTD) casts were collected with a live-wire Seabird 911 deployed using a hydrographic wire from the starboard side of the RV *Solander* (Figure 2.12). This system comprised additional fluorometer, transmissometer, altimeter, and surface Photosynthetically Active Radiation (PAR) sensors. Temperature, conductivity (≈salinity), fluorescence, and turbidity readings of the surface water (<5 m below the sea surface) were recorded at 10 second intervals using the ship's Seabird Electronics SBE-21 thermosalinograph in conjunction with a WetLabs ECO FLNTU meter. A list of the 52 CTD stations is included in Appendix F, with data readily available on the AIMS data centre using the trip number (SOL5754) (AIMS data centre).

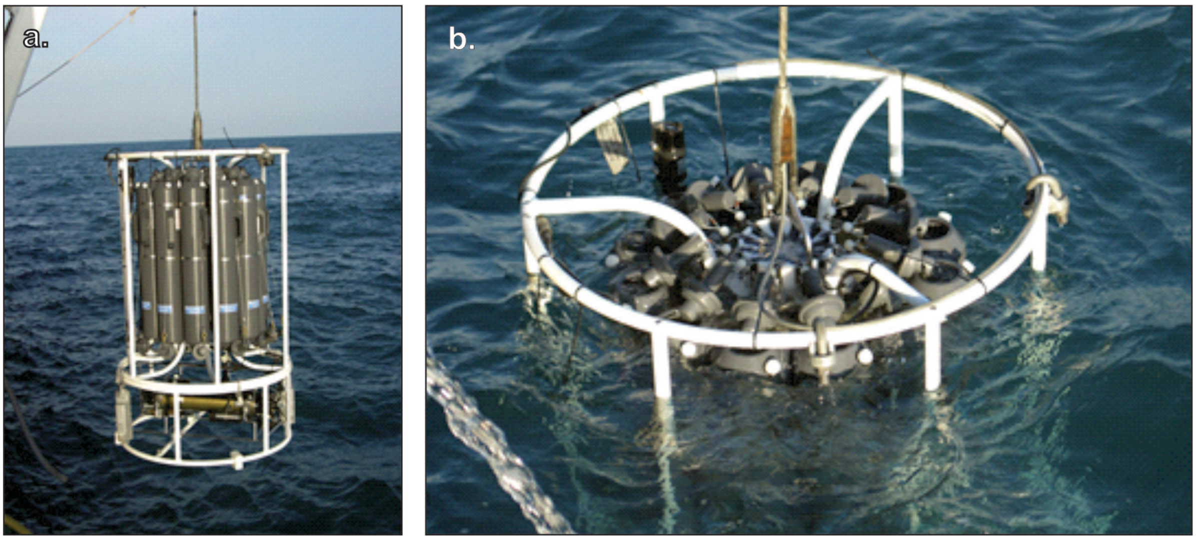


Figure 2.12 Deployment of Seabird Electronics SBE-911plus Livewire CTD

2.4.2.2 Methane and CO_2 Sensors

Contros HydroC – methane (CH_4) and carbon dioxide (CO_2) sensor data were collected along with underwater towed-videos to detect possible traces of CH_4 or CO_2 gases within areas of potential seepage. The instruments, designed for either towed/ROV applications (generating the water flow over the sensor) or moored applications (used in conjunction with a small pump to pass water over the membrane), were attached to the underwater towed-video body frame enabling a simultaneous visual record of the sampled environment (Figure 2.10). The sensors function following the same principles. The respective type of dissolved gas within the water column diffuses through a silicon membrane located at the front of the instrument, and then passes through a Non-Dispersive Infrared Spectrometry (NDIR) chamber where precise concentrations are measured. The sensors were towed in close proximity to the seafloor (between 0–1 m) along transects of interest. The tow durations varied, but averaged between 30 and 60 minutes, and covered a distance of approximately 1 km. Measurements were taken once a second with readings averaged over a 5 second interval and logged to an internal memory. Precise time and position of the sensors were recorded via a USBL system mounted to the tow body frame. Data were downloaded, converted and viewed after each deployment to look for elevated readings and highlight possible areas of interest.

3 Preliminary results

3.1 Survey summary

Six areas, covering over 1,070 km^2 of seabed, in water depths ranging between 40 and 120 m, were mapped using the multibeam echosounder (Figure 2.2; Table 3.1). Water column (multibeam and single beam) data were also collected over the whole mapped area. The sub-surface was investigated using the multichannel and parametric sub-bottom profilers along lines totalling 725 km and 1,547 km in length respectively. Specific seabed features and their association with water column features were investigated using the sidescan sonar on profiles totalling 44 km in length. Targeted physical and visual investigations using a variety of instrumentation were achieved over 58 stations (Table 2.3; Figure 2.2). Preliminary results and observations for each dataset are presented in this section.

Table 3.1 Summary of data acquired during GA0340 survey. Refer to Figure 2.2 for overall location. (SBP = Sub-bottom profiler)

Data Type	Units	Total Amount	Comment
Multibeam	km^2	1,070	Area 1 = 176 km^2; Area 2 = 191 km^2; Area 3 = 216 km^2; Area 4 = 250 km^2; Area 5 = 192 km^2; Area 10 = 44 km^2
SBP Multichannel	km	730	Area 1 = 139 km; Area 2 = 171 km; Area 3 = 164 km; Area 4 = 132 km; Area 5 = 92 km; Area 10 = 27 km
SBP Parametric	km	1,547	Area 1 = 176 km; Area 2 = 413 km; Area 3 = 450 km; Area 4 = 215 km; Area 5 = 224 km; Area 10 = 69 km
Side Scan	km	44	Area 1 = 18.9 km; Area 2 = 18 km; Area 3 = 7 km
Sediment grab	no.	167	Area 1 = 36; Area 2 = 26; Area 3 = 36; Area 4 = 32; Area 5 = 27; Area 10 = 10
Towed-video	no.	49	Area 1 = 8; Area 2 = 7; Area 3 =12; Area 4 = 11; Area 5 = 8; Area 10 = 3
CTD casts	no.	52	Area 1 = 9; Area 2 = 7; Area 3 = 12; Area 4 = 12; Area 5 = 9; Area 10 = 3
Vibrocores	no.	8	Area 1 = 3; Area 3 = 5

3.2 Geophysical data

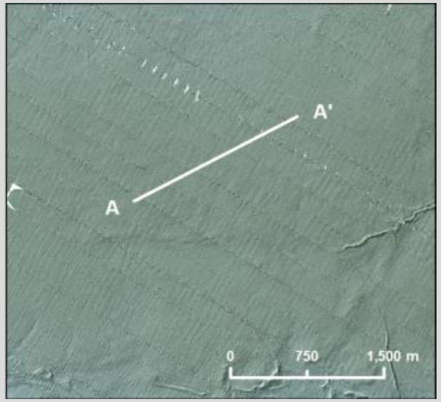
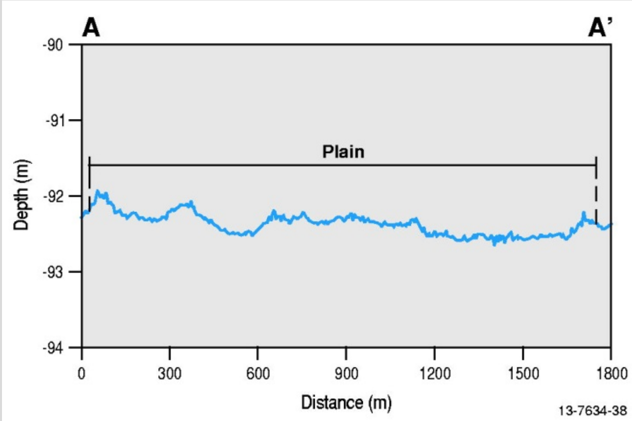
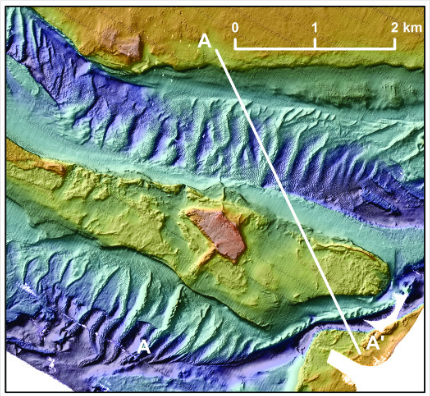
3.2.1 Seabed Mapping

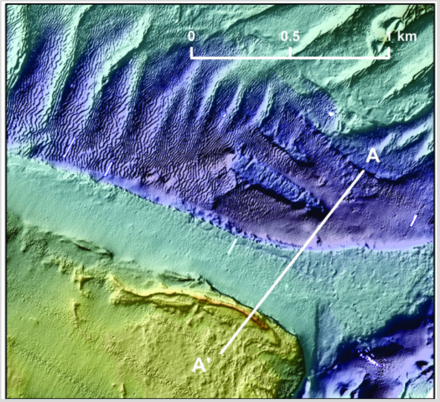
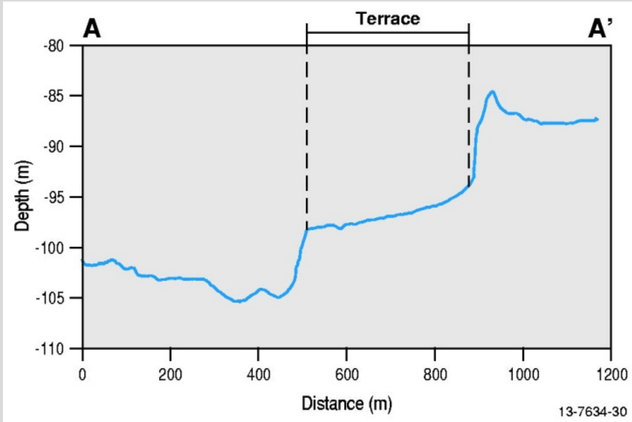
3.2.1.1 Multibeam Echosounder

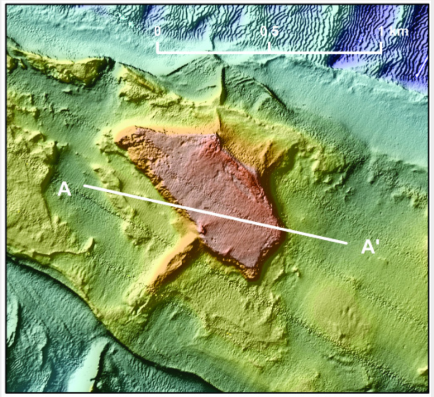
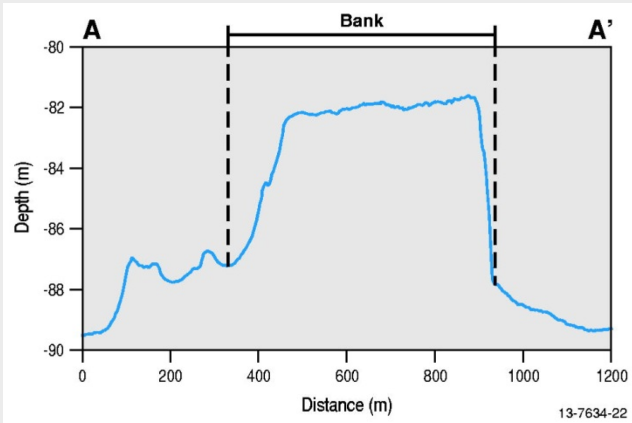
3.2.1.1.1 Bathymetry

A total of 15 key geomorphic features were identified in the multibeam bathymetry (Table 3.2). These include plain, valley, terrace, bank, scarps, hummock fields, bedforms (Type I and II), depression clusters (Type I and II), and ridges (Type I to V). Table 3.2 presents the description and general distribution of each feature. However, their extent and specific distribution have yet to be determined

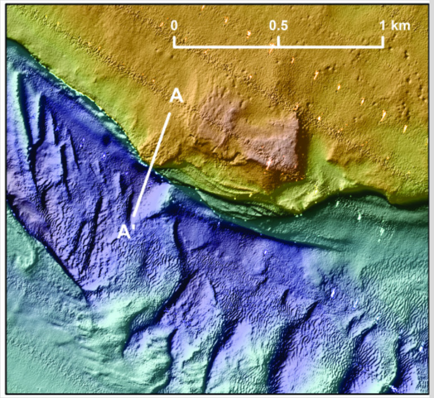
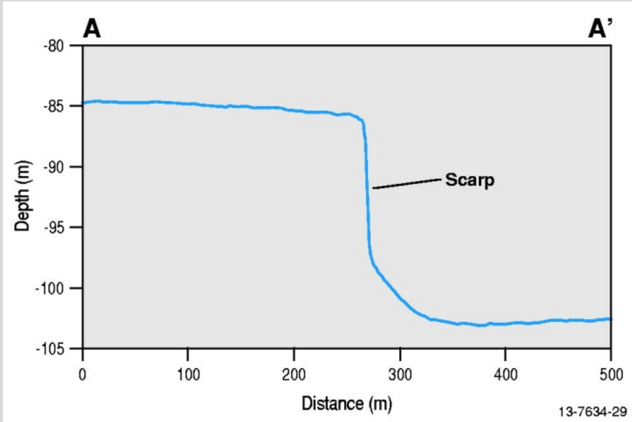
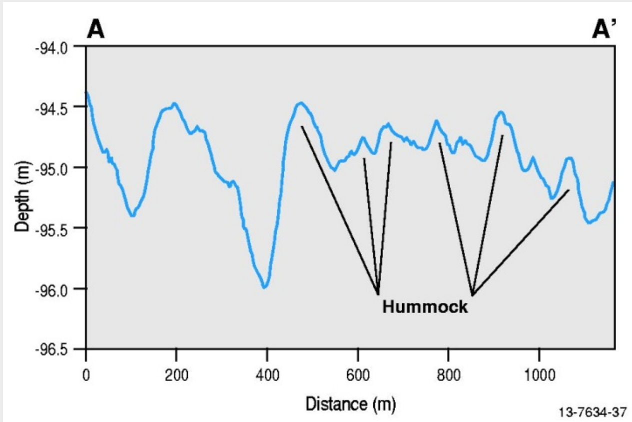
Table 3.2 Description and representative examples of key geomorphic features identified from hillshaded multibeam bathymetry and cross-sectional profiles from all survey areas. Examples of these features presented throughout Figure 3.1 to Figure 3.3

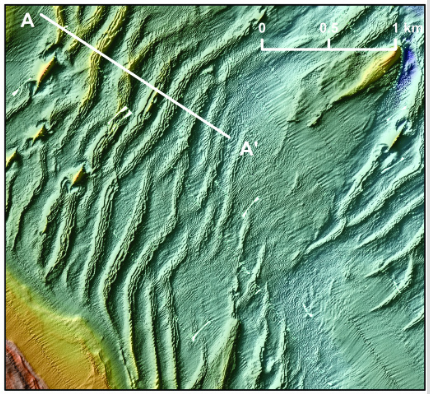
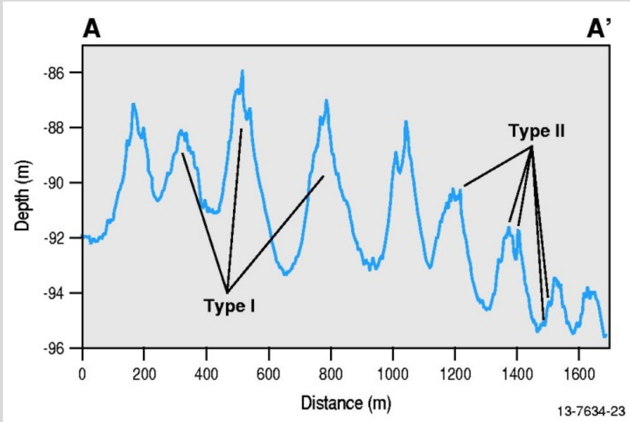
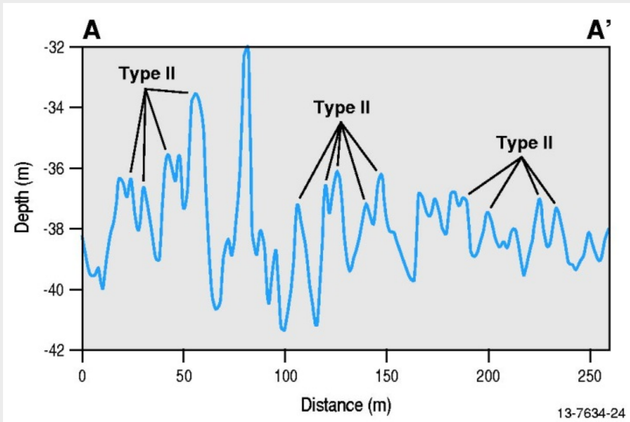
Name	Bathymetry	Representative Profile	Description
Plain			**Definition:** Extensive, flat or gently sloping (<2°) generally featureless areas **Area(s):** 1,2,4 and 5
Valleys			**Definition:** Elongate, locally deeper areas with moderately-sloping to steep rises on either side. **Area(s):** All areas

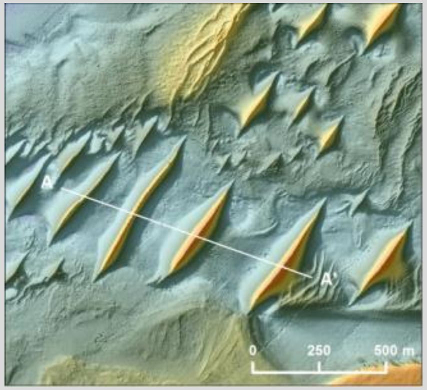
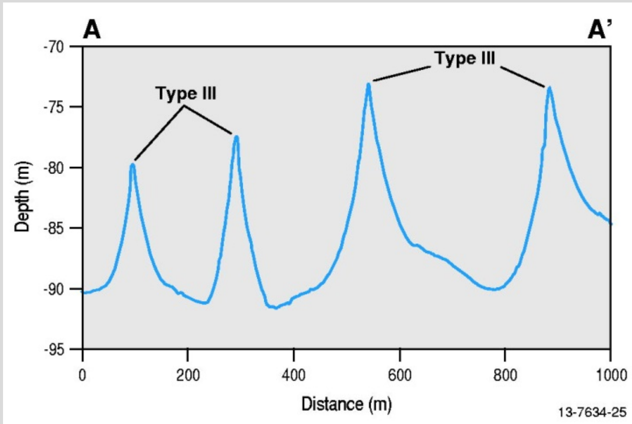
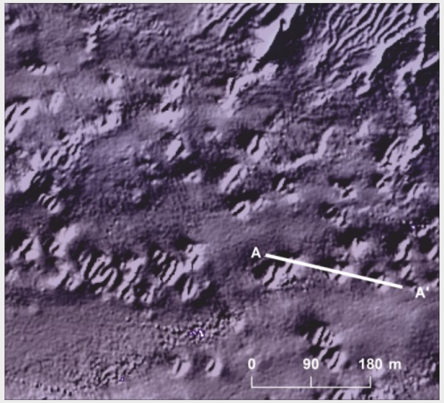
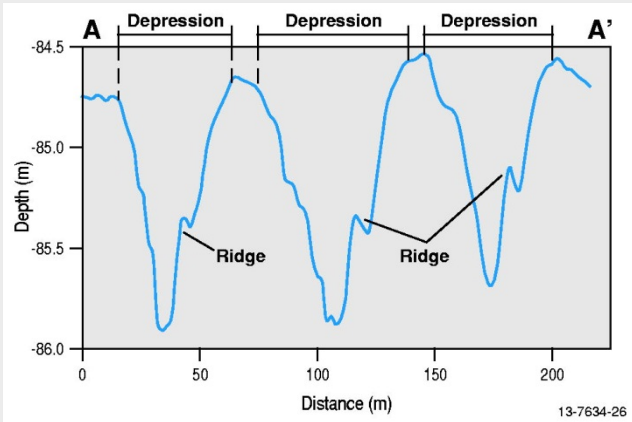
<table>
<tr><th>Name</th><th>Bathymetry</th><th>Representative Profile</th><th>Description</th></tr>
<tr><td>Terraces</td><td>
</td><td>
</td><td>Definition: Relatively flat or gently-sloping areas of the seafloor with a moderately-sloping to steep rise on one side and a moderately-sloping to steep drop on the other side.

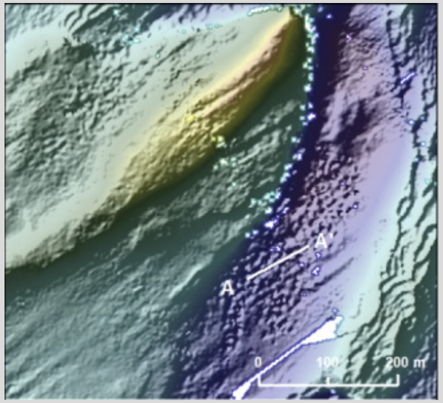
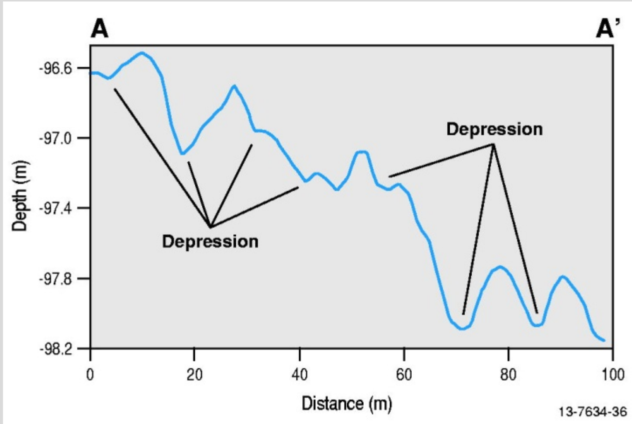
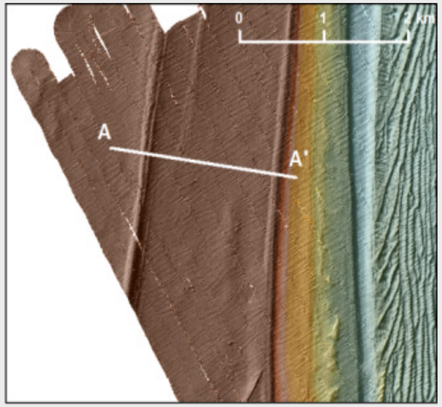
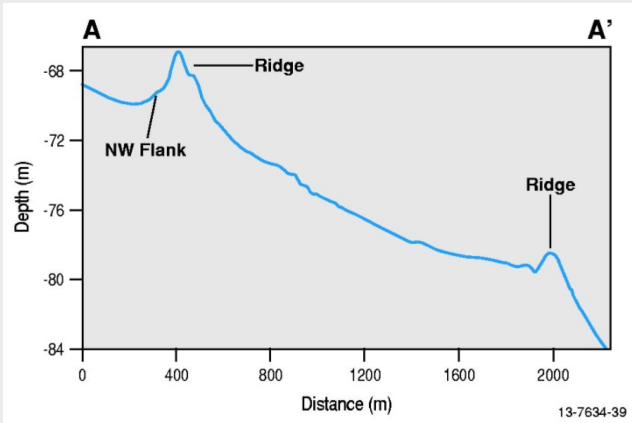
Area(s): 1,2,3, 5, and 10</td></tr>
<tr><td>Banks</td><td>
</td><td>
</td><td>Definition: Areas of elevated seafloor with a relatively flat top and one or more steep sides.

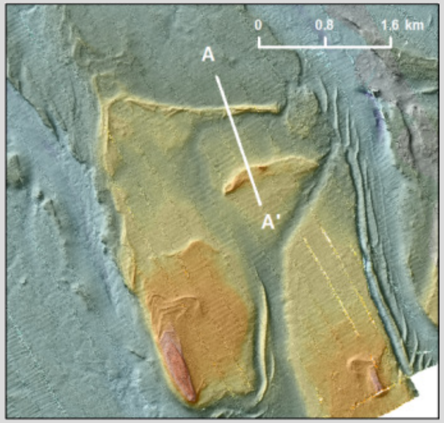
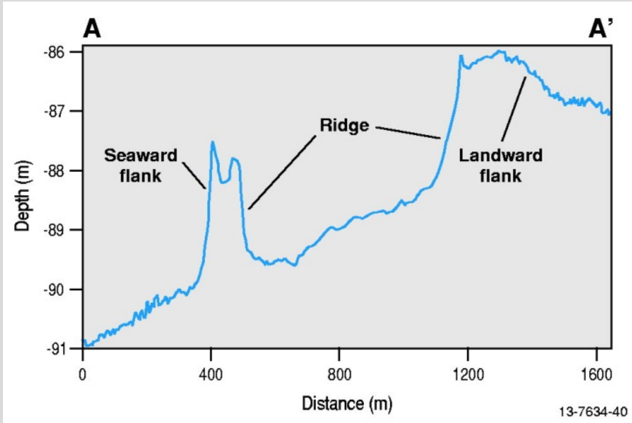
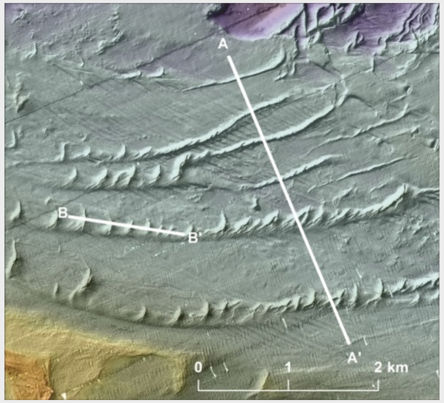
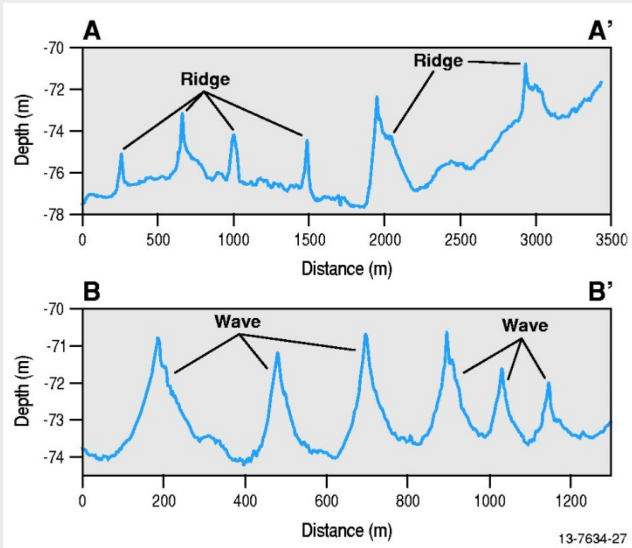
Area(s): 1, 2, 3, 5 and 10</td></tr>
</table>

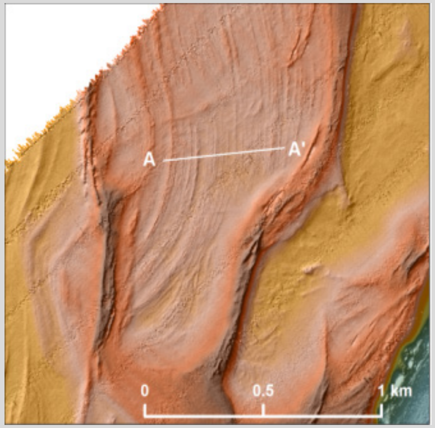
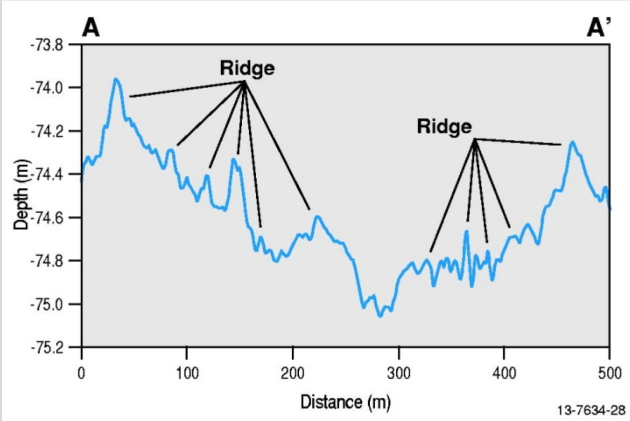
Name	Bathymetry	Representative Profile	Description
Scarps			**Definition:** Elongated and comparatively steep (≥10°) slopes separating more gently sloping areas. **Area(s):** 1, 2, 3, 5 and 10
Hummock fields			**Definition:** Flat areas with rounded, irregular mounds generally rising less than one metre over a few hundred metres. **Other Characteristics:** Smooth appearance in bathymetry. **Area(s):** 1, 2, 3 , 4 and 5

Name	Bathymetry	Representative Profile	Description
Bedform Type I			**Definition:** Semi-parallel fields of sinusoidal, bifurcated ridges. **Height:** 2-10 m **Length:** Variable **Wavelength:** 200-250 m **Orientation:** 26°±7 (but deflect around bathymetric highs) **Other Characteristics:** Found in bathymetric lows and on the flanks of plains, banks, and terraces with gentle slopes. Wavelength shortens with decreasing ridge height. Superimposed by bedform type II. **Area(s):** All areas
Bedform Type II			**Definition:** Smaller, less organised ridges that bifurcate more frequently than bedform type I. **Height:** 10-80 cm **Length:** Variable **Wavelength:** ~10 m **Orientation:** 34°±16 **Other Characteristics:** Often (but not always) superimposed on bedform type I. **Area(s):** All Areas

<table>
<tr><th>Name</th><th>Bathymetry</th><th>Representative Profile</th><th>Description</th></tr>
<tr><td>Bedform Type III</td><td>
</td><td>
</td><td>Definition: Prominent steep elevated ridges with a concave profile that is steepest near the crest. Features can be found either individually, in small clusters of 3-5, or in extensive fields with dozens of individuals.
Height: Up to 18 m
Length: 50-650 m
Wavelength (in field): Up to 200 m
Orientation: 19-36°
Other Characteristics: Generally symmetrical in cross-section, but some features have asymmetric profiles across their widest point with no clear trend in asymmetry. Longer features tend to be taller than shorter features.
Area(s): 1, 3, 4, 5 and 10</td></tr>
<tr><td>Depression Cluster Type I</td><td>
</td><td>
</td><td>Definition: Clusters of overlapping or adjacent circular to elliptical bathymetric lows. Within each depression is a shallow ridge.
Depth: 50-180 cm
Diameter: 35-50 m
Height (ridge): Slightly less than half the depression's depth.
Orientation (ridge): 18-35°
Other Characteristics: Found only within valleys at water depths between 79-86 m. The NW flank of the ridges is steeper than their SE flank.
Area(s): 3</td></tr>
</table>

<table>
<tr><th>Name</th><th>Bathymetry</th><th>Representative Profile</th><th>Description</th></tr>
<tr><td>Depression Cluster Type II</td><td>
</td><td>
</td><td>Definition: Dense clusters (n≥50) of overlapping or adjacent circular bathymetric lows.
Depth: 40-90 cm
Diameter: 8-15 m
Other Characteristics: Found adjacent to or on the flanks of ridges, banks, or in hollows between ridges of bedform type I
Area(s): All Areas</td></tr>
<tr><td>Ridge Type I</td><td>
</td><td>
</td><td>Definition: Narrow, elongated, elevated features with moderately sloping drops on either side.
Height: 1-2 m
Length: >3 km
Orientation: ~6°
Other Characteristics: Their NW flank is steeper than their SE flank.
Area(s): 2</td></tr>
</table>

<table>
<tr><th>Name</th><th>Bathymetry</th><th>Representative Profile</th><th>Description</th></tr>
<tr>
<td>Ridge
Type II</td>
<td>
</td>
<td>
</td>
<td>Definition: Linear to curvilinear, elevated features without a preferential orientation along their crest, but a tendency to form complexes of intersecting or continuous features.
Height: Up to 4 m
Orientation: Converge/curve-acutely on their seaward margin.
Other Characteristics: Complexes only found on local bathymetric highs. Features have a steeper seaward flank than landward flank.
Area(s): All Areas</td>
</tr>
<tr>
<td>Ridge
Type III</td>
<td>
</td>
<td>
</td>
<td>Definition: Elongated, curvilinear, elevated features that are sub-parallel to one another and converge on their western ends.
Height: 1-2 m
Length: Up to 4 km
Other Characteristics: Spacing between features increases with increasing slope. In some cases, these ridges are superimposed along sections of their length by en-echelon waves.
Height (wave): 2-3 m
Wavelength (wave): 100-200 m
Orientation (wave): Sub-orthogonal to the ridge
Area(s): 3</td>
</tr>
</table>

Name	Bathymetry	Representative Profile	Description
Ridge Type IV			**Definition:** Small, nested, semi-parallel features separated by shallow swales. **Height:** 5-40 cm **Wavelength:** 5-20 m **Other Characteristics:** Only found on other relatively flat elevated features. Crests occur at uneven depths. **Area(s):** All areas

Areas 1, 2, 4 and 5 cover a total area of 809 km^2 and range in depth from 60–110 m (Figure 3.1). This region is dominated by braided valleys, which dissect a broad plain, and gently slope towards the continental shelf break to the northwest. Valleys reach depths of 12 m and range in width from >3 km to ~120 m. The narrower valleys tend to exhibit dendritic plan form morphologies. Extensive fields of bedform type I and II are found along the northern boundary of the valleys and plains, often against more prominent features such as banks. Type III bedforms are scattered throughout the valleys, where they existed independently or in small clusters. Banks are widespread throughout the area, and are cut by numerous smaller terrace features. Prominent banks are generally orientated in a NW-SE direction, with the exception of Lynher Bank, which extends in a N-S direction. Two type I ridges are observed running parallel to the south-western margin of Lynher Bank. Type II ridges and ridge complexes are found on larger bathymetric highs, such as banks and terraces, while hummock fields overprint some of the flatter plain regions. Finally, type II depression clusters are found scattered throughout the study areas. They mostly exist at the base or flanks of ridges or in swales of type I bedforms.

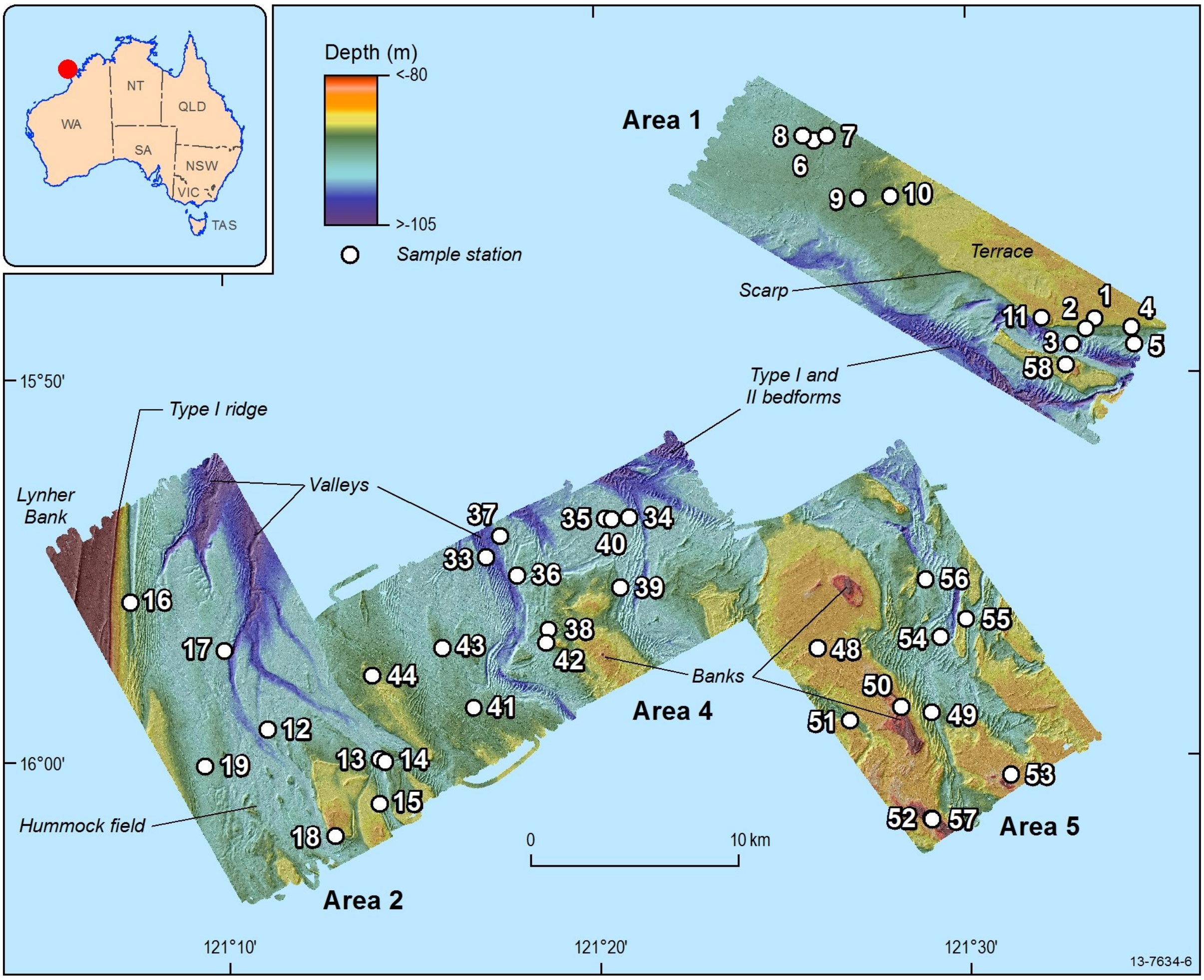


Figure 3.1 False colour bathymetry image of Area 1, 2, 4, and 5 showing the location of sampling stations as well as examples of key geomorphic features found in the area (Table 3.2).

Area 3 covers a total area of 216 km^2 and range in depth from 43-105 m (Figure 3.2). It is dominated by two banks, at 71 and 49 m water depth. The shallower bank sits on a large terrace found at 58 m water depth, which is surrounded by a deeper terrace (75 m). The long axis of both terraces has a NW-SE trend. Type I and II bedforms occur on the south-western slope of the 58 m water depth terrace. The north-eastern 75 m water depth terrace contains an extensive complex of type III ridges. These curvilinear ridges run slightly oblique to the long axis of the terrace and get more widely spaced as the slope of the terrace increases. Complexes of type II and IV ridges are found on top of the two banks, while type II ridges are found on the large terrace at 58 m water depth. Three valleys, overprinted by large fields of type I and II bedforms, dissect the banks. Type III bedforms are found individually or in small clusters throughout the valleys. The central valley, which is the shallowest at ~82 m water depth, contains regions of hummock fields. The only examples of type 1 depression clusters surveyed are found along the deepest parts of the valley.

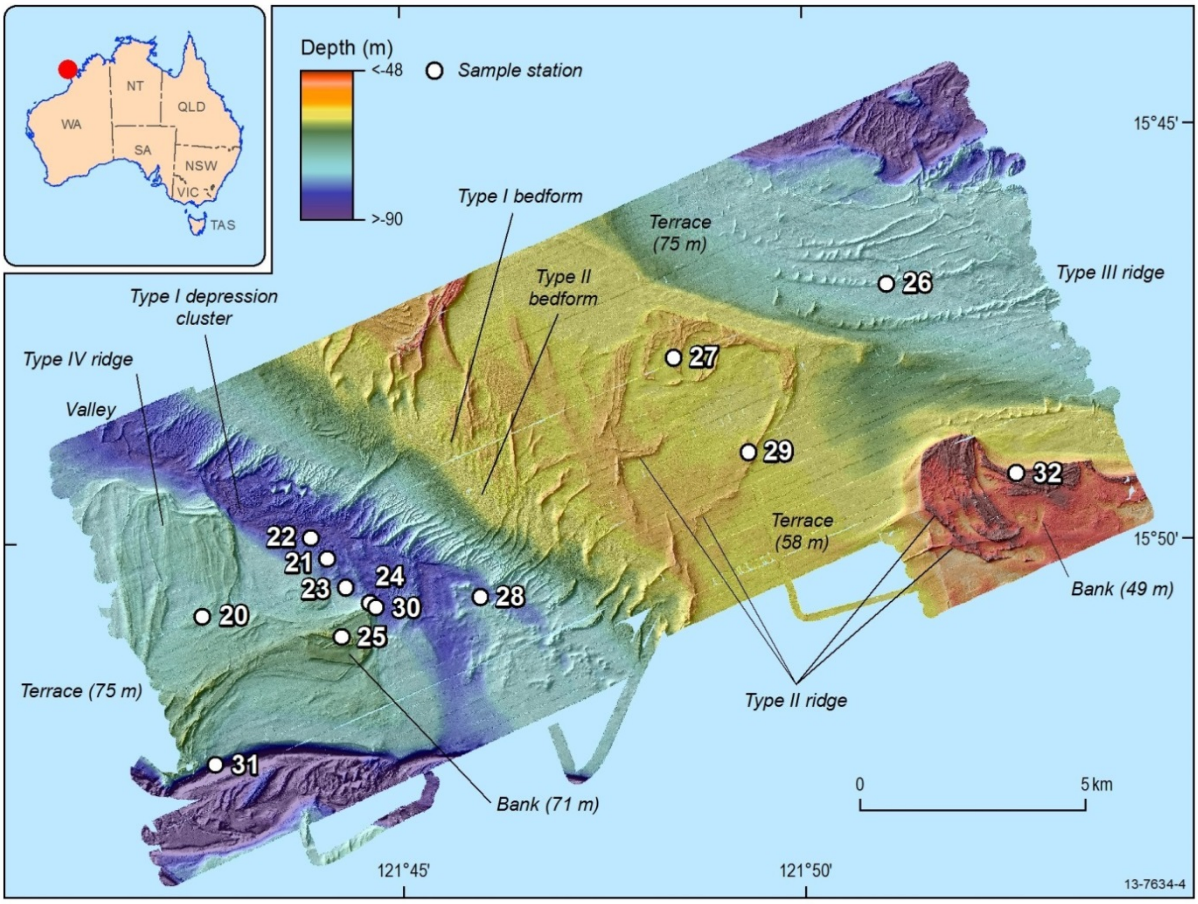


Figure 3.2 False colour bathymetry image of Area 3 showing the location of sampling stations as well as examples of key geomorphic features found in the area (Table 3.2).

Area 10 covers a total area of 44 km^2 and ranges in depth from 70-110 m (Figure 3.3). The area is characterised by 3 prominent banks (75, 78, and 80 m water depth) onto which type II and IV ridges are superimposed. These banks, which are undercut by several terraces, are separated by large valleys which are up to 3 km wide and 20 m deep. Unique to Area 10 is a large field of type III bedforms which are generally confined to the valleys. These bedforms vary considerably in size. The largest examples are up to 18 m high and have crest lengths of 600 m, while the smallest examples are only 1 m high and have crest lengths of 50 m. Type I and II bedforms are present in the valleys, though in lower numbers than the other areas. Type II depression clusters are abundant at the base of the northern-most bank, while two type III ridges are present in the valley surrounding the bank near station 47.

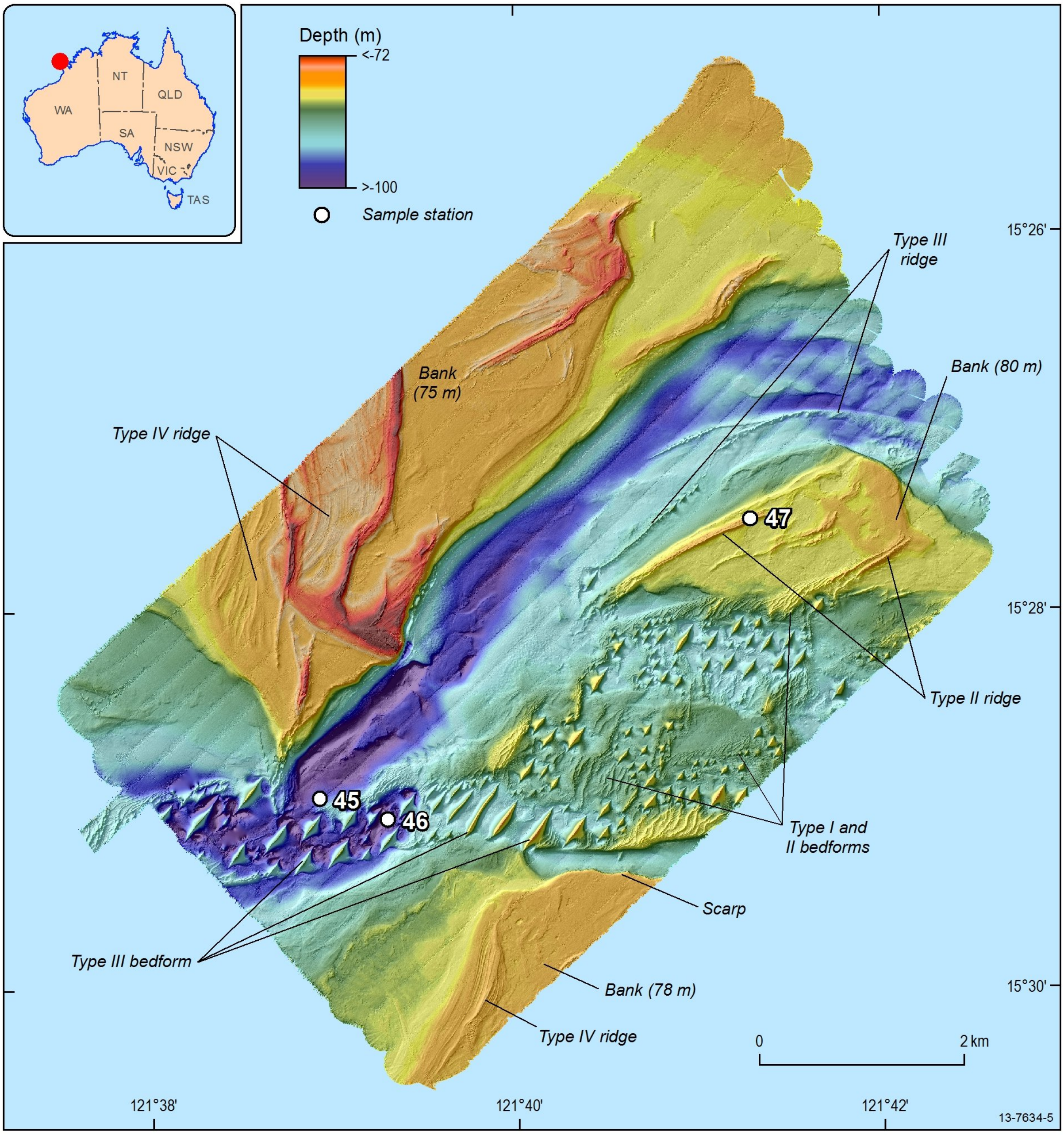


Figure 3.3 False colour bathymetry image of Area 10 showing the location of sampling stations as well as examples of key geomorphic features found in the area (Table 3.2).

3.2.1.1.2 Backscatter Strength

Backscatter strength varies between the study areas and the geomorphic features (Figure 3.4 to Figure 3.6). High backscatter strength is typically associated with elevated features including shallow reefs and banks, while low backscatter is associated with soft sediments e.g. within valleys and depressions. The backscatter values are highest in Areas 3 and 10, followed by Areas 1 and 5 and 2 and 4 (Figure 3.7a). Terraces have higher backscatter values (e.g. mean -26.94 dB; range -27.68 to -

26.45 dB along sparker lines 029, 037, and 056) than valleys (e.g. mean -31.87 dB; range -32.10 to -31.64 dB along sparker lines 029 and 037) (Figure 3.7b). In addition, the difference in backscatter strength between terraces and valleys in area 10 is half of what is observed elsewhere (e.g. 2.41 dB along sparker line 056 in area 10 versus 5.16 dB along sparker line 37 in area 3; Figure 3.7b). This suggests that sediment properties in Area 10 are more homogeneous.

Theoretically, backscatter strength increases with the sediment grain size. However, this is not evident here. In some cases, finer grain sizes are observed in association with higher backscatter strength (Figure 3.14 to Figure 3.16 in Section 3.3), sometime even as high as the terrace strength (e.g. grabs 122 from station 44 respectively, and grabs 141 and 142 from station 50 in Figure 3.14 in Section 3.3). The range of the backscatter strength for each individual grain size group is also large (around 10 dB). This is likely caused by the presence of a sand veneer over cemented sediment, which was observed in the underwater video footage. The observed cemented sediment is associated with high backscatter strength, which is consistent with the current state of knowledge on geoacoustics where the most "acoustically hard" substrates are dominated by hard, compacted substrates. The cemented sediment has, on average, slightly higher backscatter values and narrower backscatter ranges than the loose sediment.

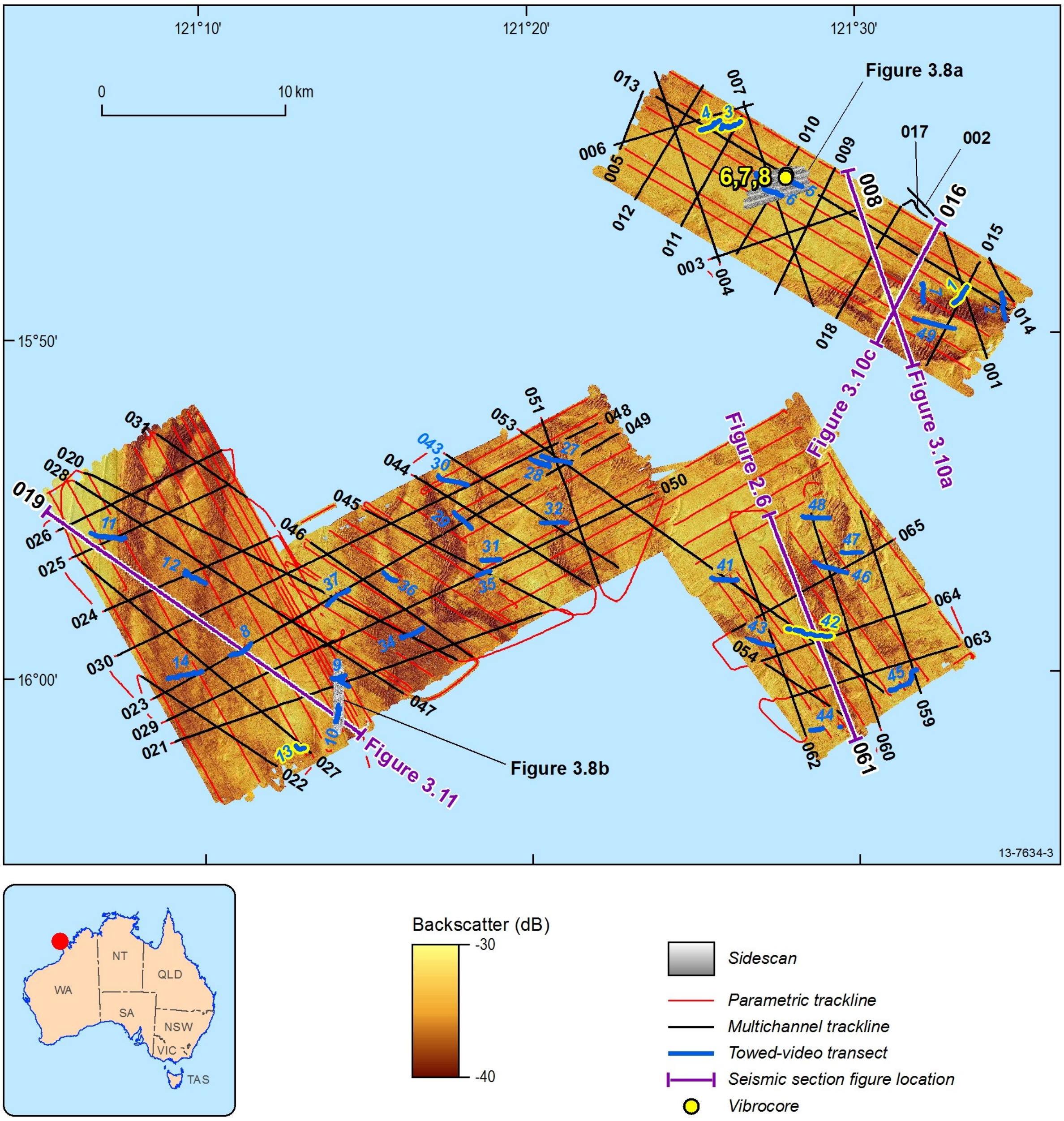


Figure 3.4 False colour backscatter image of Area 1, 2, 4, and 5 showing the location of sub-bottom profiles, towed-video transects, vibrocores, and sidescan sonar mosaic. Note that the line numbers are assigned to the multichannel sub-bottom profiler lines. The parametric sub-bottom line numbers can be found in Appendix D. Locations of sub-bottom profiler sections in Figure 2.6 (061), Figure 3.10 (008, 016) and Figure 3.11 (019) are indicated.

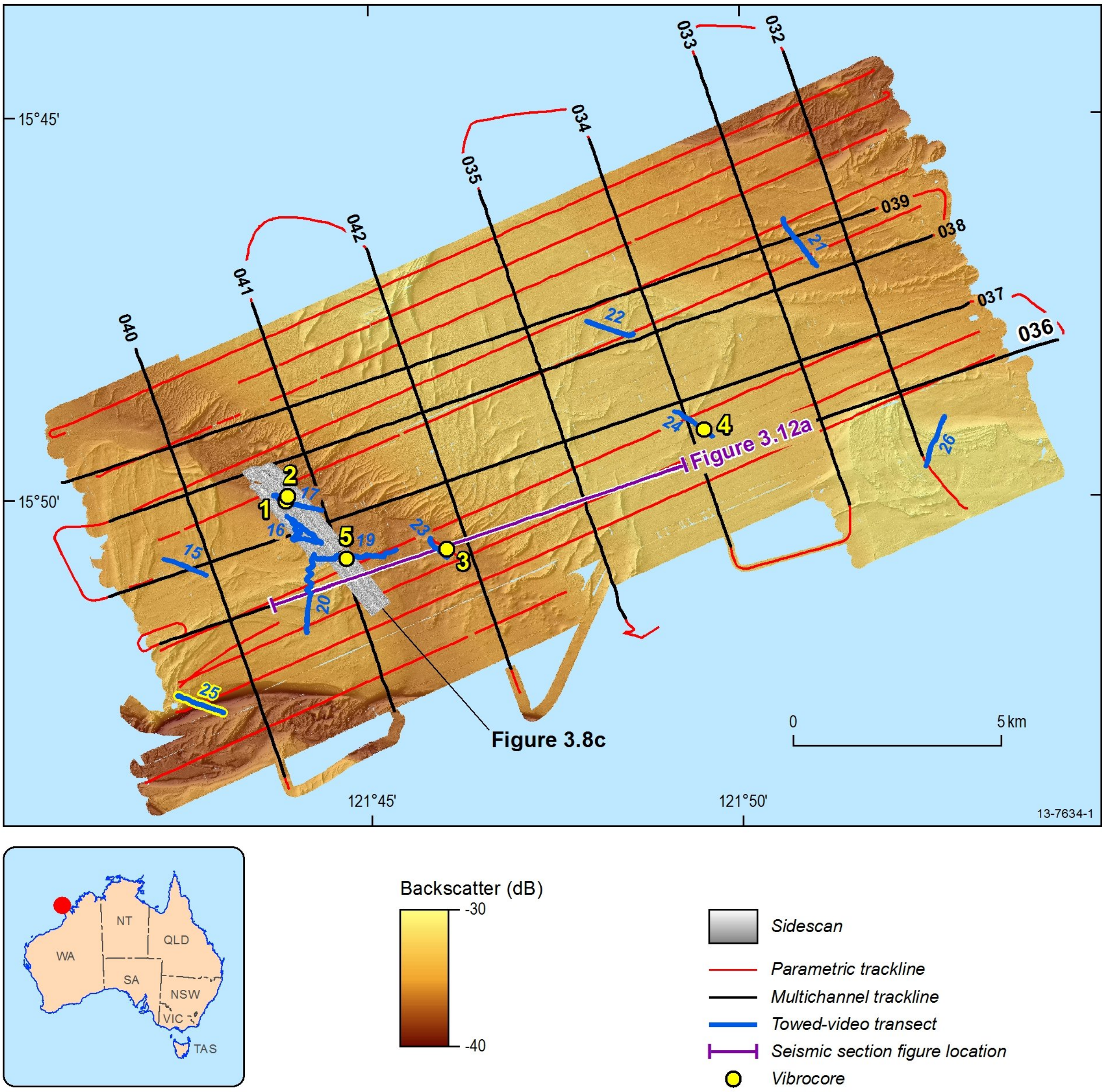


Figure 3.5 False colour backscatter image of Area 3 showing the location of sub-bottom profiles, towed-video transects, and vibrocores, Note that the line numbers are assigned to the multichannel sub-bottom profiler lines. The parametric sub-bottom line numbers can be found in Appendix D. Location of sub-bottom profiler section in Figure 3.12 (036) is indicated.

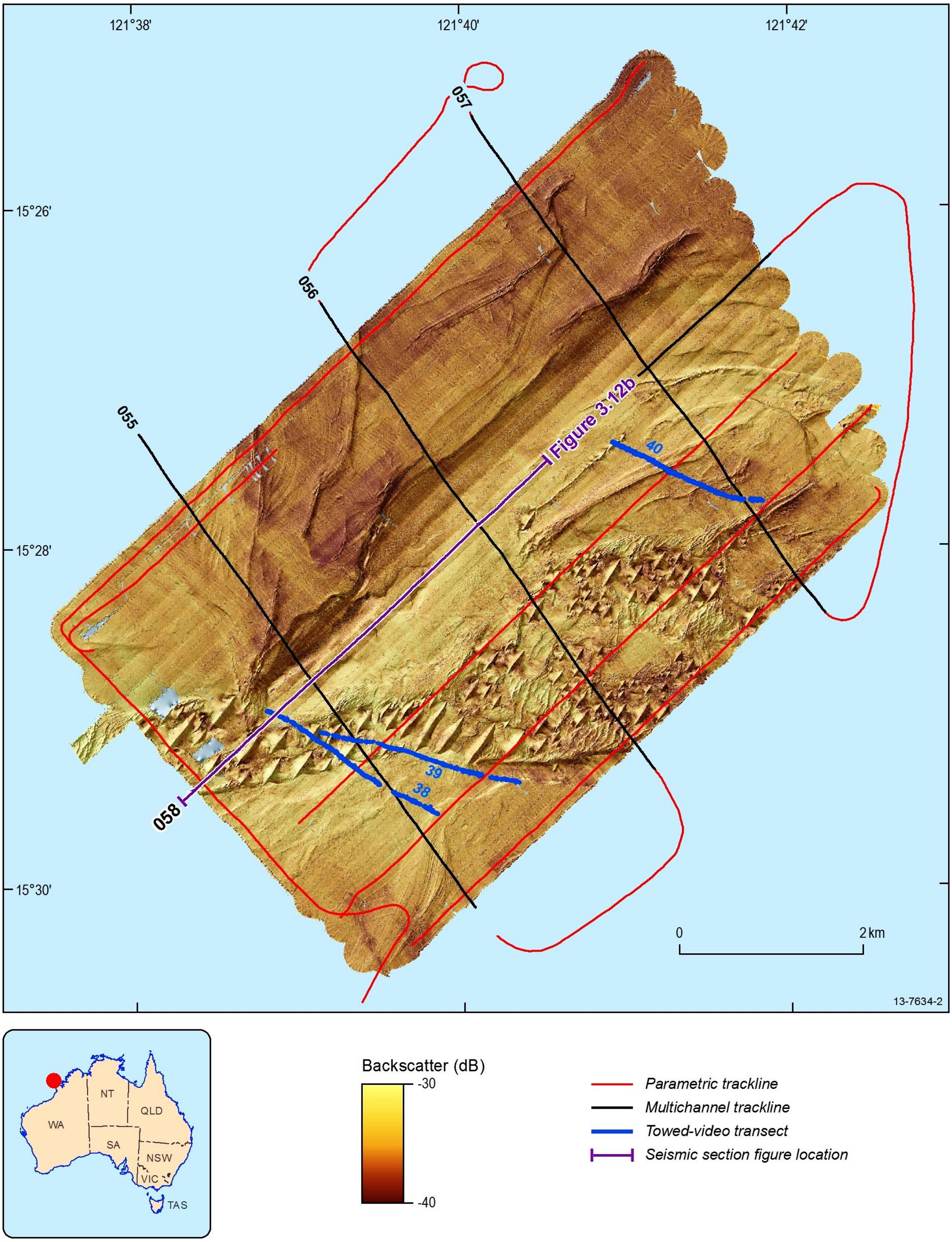


Figure 3.6 False colour backscatter image of Area 10 showing the location of sub-bottom profiles and towed-video transects. Note that the line numbers are assigned to the multichannel sub-bottom profiler lines. The parametric sub-bottom line numbers can be found in Appendix D. Location of sub-bottom profiler section in Figure 3.12 (058) is indicated.

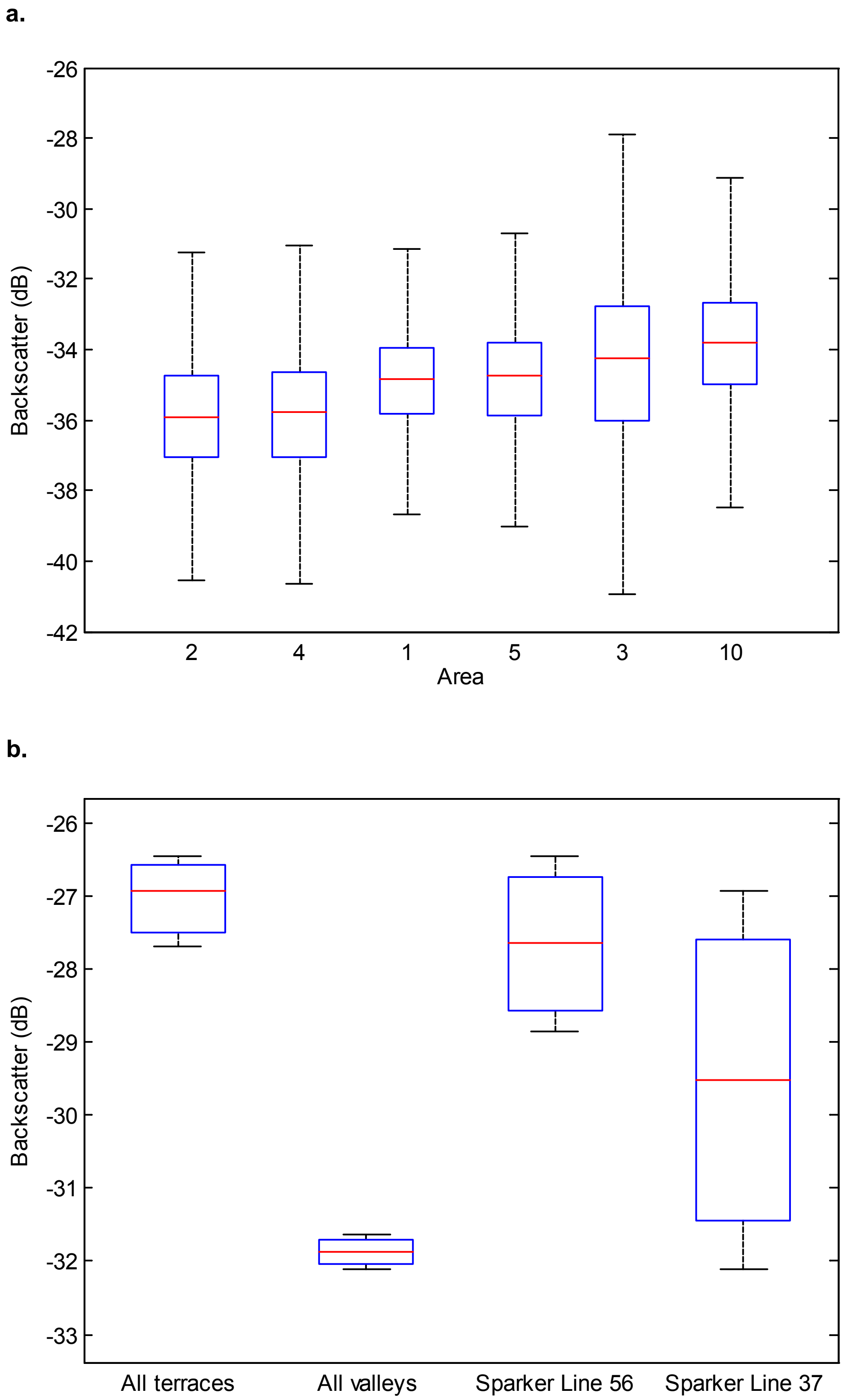


Figure 3.7 Box plots showing the relationship between backscatter strength and a) survey areas and b) terraces and valleys; the left side of the graph compares backscatter strength averaged from terraces identified along sparker lines 029, 037, and 056 and valleys identified along lines 029 and 037 with the ones specifically observed across sparker line 037 from area 3 and line 056 from area 10.

3.2.1.1.3 Sidescan Sonar

Sidescan sonograms were collected in areas 1, 2, and 3 over targeted seabed features potentially linked to seepage that were observed on the multibeam data (Figure 3.8). The sidescan sonograms revealed more seabed details than the multibeam grids due to its higher resolution, but no active seepage was identified. In some cases, anomalous acoustic features were detected in the water column, but after cross-checking with single beam and multibeam water column data, these were interpreted as fish schools (Figure 3.9).

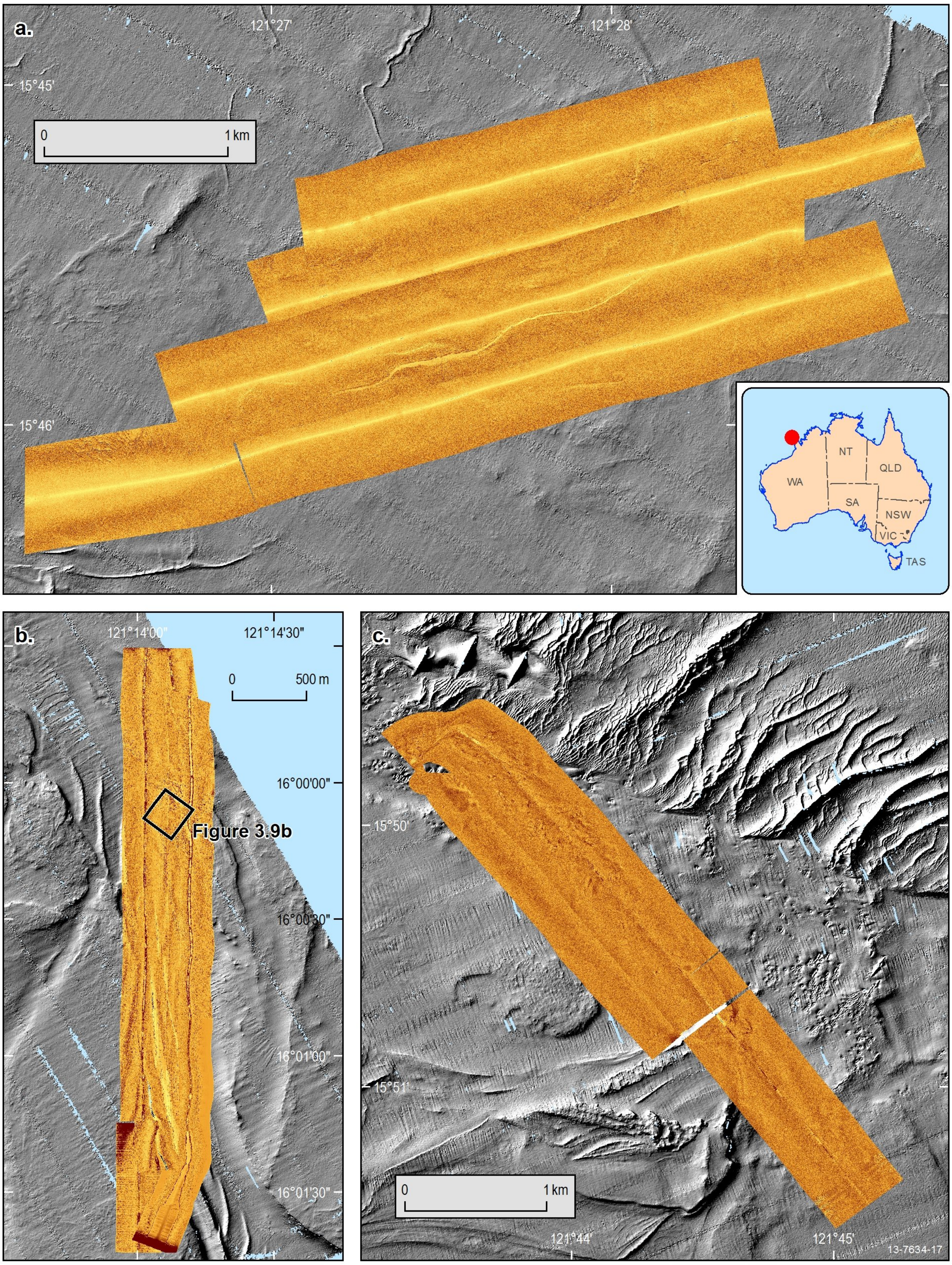
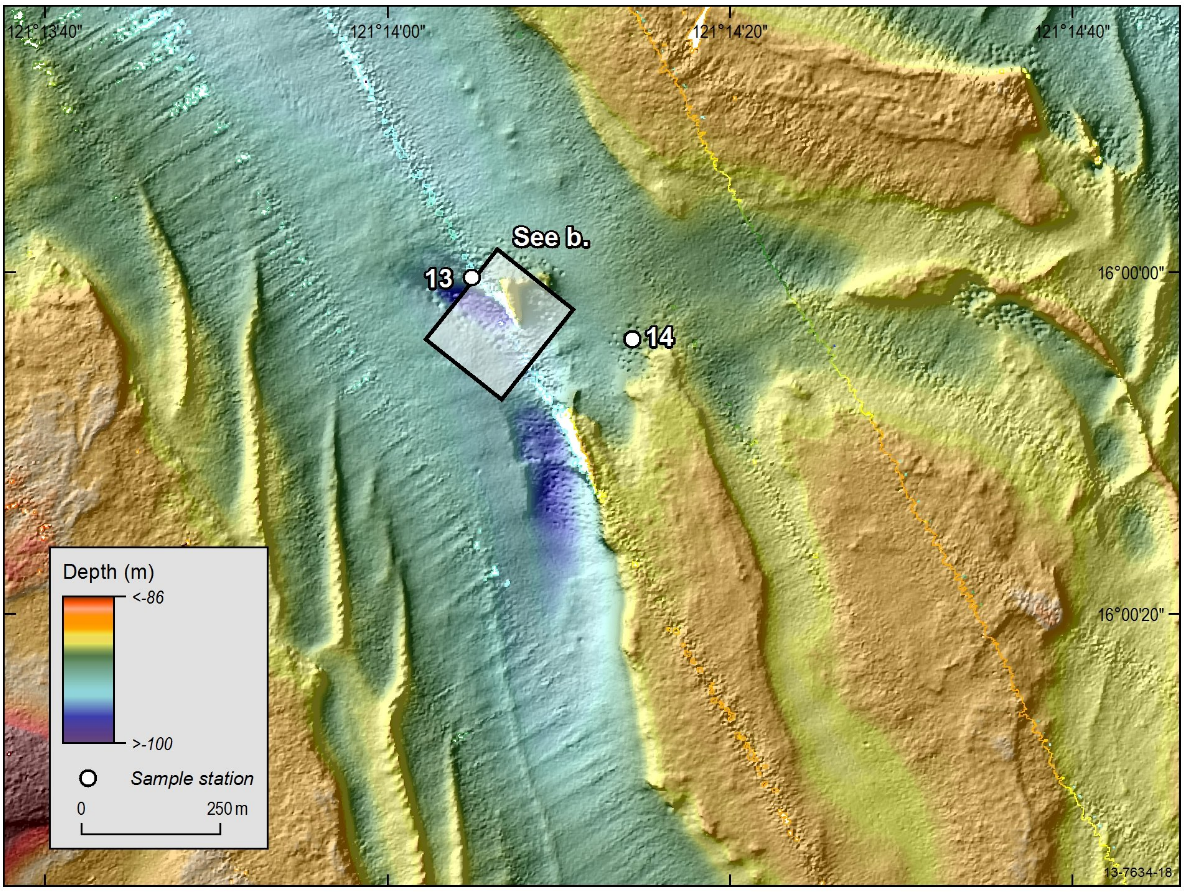
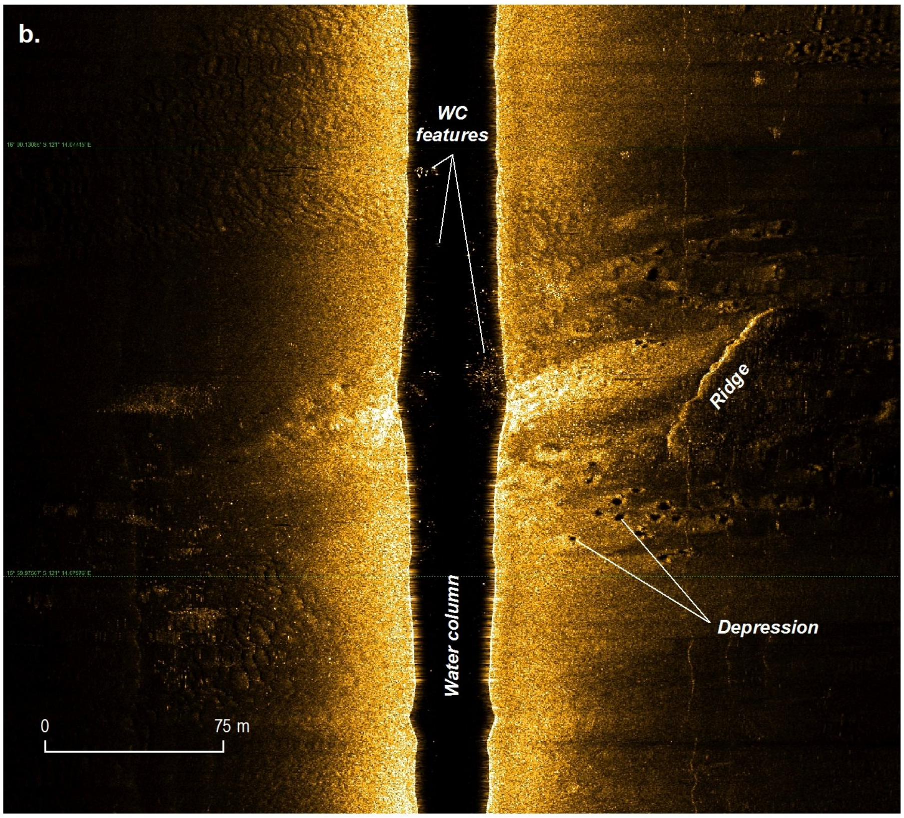


Figure 3.8 Sidescan sonar mosaics of Area a) 1; b) 2; and c) 3. The locations of these mosaics are shown in Figure 3.4 and Figure 3.5. The mosaics are overlain on top of sun-illuminated multibeam bathymetry. Dark shades represent high reflectivity, while lighter shades represent low reflectivity. The black rectangle indicates the location of Figure 3.9.


121°13'40"
121°14'00"
121°14'20"
121°14'40"
16°00'00"
16°00'20"
See b.
13
14
Depth (m)
<-86
>-100
Sample station
0
250 m
13-7634-18


b.
WC features
Ridge
Depression
Water column
0
75 m


NT
QLD
WA
SA
NSW
VIC
TAS

Figure 3.9 a) False colour bathymetry showing the location in Area 2 of b) acoustic features detected with the sidescan sonar 100 kHz frequency channel (Line GA0340_grid2_20130510_008). Dark shades represent high reflectivity, whereas lighter shades represent low reflectivity. Locations of near sampling stations noted in a.

3.2.2 Sub-Surface Reflection

3.2.2.1 Multichannel Sub-Bottom Profiler

Multichannel sub-bottom profiling was carried out along 65 discrete lines over 725 km of seabed (Figure 2.2; Appendix C). The processed final stacks of the multichannel sub-bottom profiler data revealed the upper ~100 m of sediment below the seafloor. In most cases, the best imaging is restricted to the region before the first water bottom multiple. However, in some instances, deep reflections are observed below the second water bottom multiple (Figure 2.6). As expected, compared to the industry seismic sections, the sub-bottom profiles show much better resolution, although the secondary bubble pulse results in a pronounced 'doublet' (Figure 3.10a). In addition to the 'doublet' present in most profiles, a few other artefacts remain after processing. A 'boudinage' effect appears in the water bottom reflection and is due to remnant effects of offset errors caused by vessel yaw (Figure 3.10a). Apparent faulting beneath the steep sides of the channel, as seen on line GA0340-016 is caused by a velocity pull-up/pull-down effect (Figure 3.10c).

Features, such as bedforms, appear in the sub-bottom profiles on the edge of the high (Figure 3.11). Buried valleys/channels are infilled with distinctive prograding sediments (Figure 3.12b). A diffraction hyperbola observed on the southwest end of the profile presented in Figure 3.12b results from a seafloor feature and tends to mask the edge of a channel.

In comparison with the Petrel GA0335 processed data set where the processing was able to compensate for many of the limitations of sparker acquisition (Carroll et al., 2012, Jones, 2013), the Browse survey results were less satisfactory. It appears that the higher frequency component of the source signal was lost in transmission at the sea floor, thereby limiting resolution of deeper layers. This is likely the result of the difference between the shallow geology of the two areas. The Bonaparte Gulf is known as a depocentre for relatively recent sediments, whereas the seafloor sediment recovered on the Leveque Shelf supports a high-energy relict environment (James et al., 2004). These results agree with other sub-bottom profiler surveys in the Browse Basin, which have generally also obtained poor data (McGiveron, pers. comm.). Considering this anecdotal evidence, the final stacks are of reasonable quality, medium but not high resolution, and indicate a considerable depth of penetration.

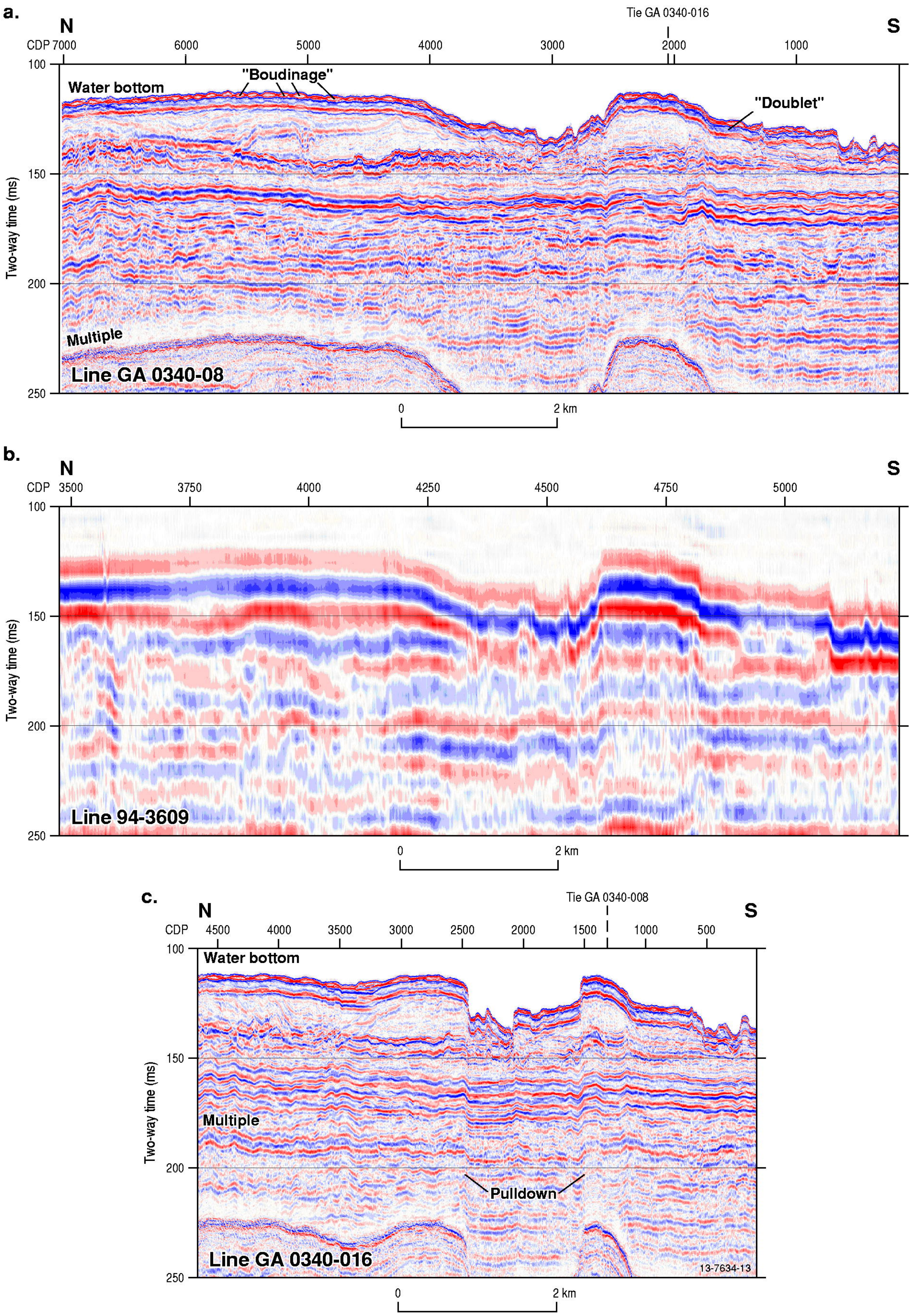


Figure 3.10 Examples of profiles in Area 1. (a) Final stack for sub-bottom profile line GA0340-008. (b) Migrated section for part of seismic line 94-3609 from the 1994 Cockatoo 2D Survey (WA-242-P), which is coincident with

line GA0340-008. (c) Final stack for sub-bottom profile line GA0340-016. The vertical exaggeration for all sections is about 28:1 (using a P wave interval velocity of 2,000 m s^{-1} in the sediments).

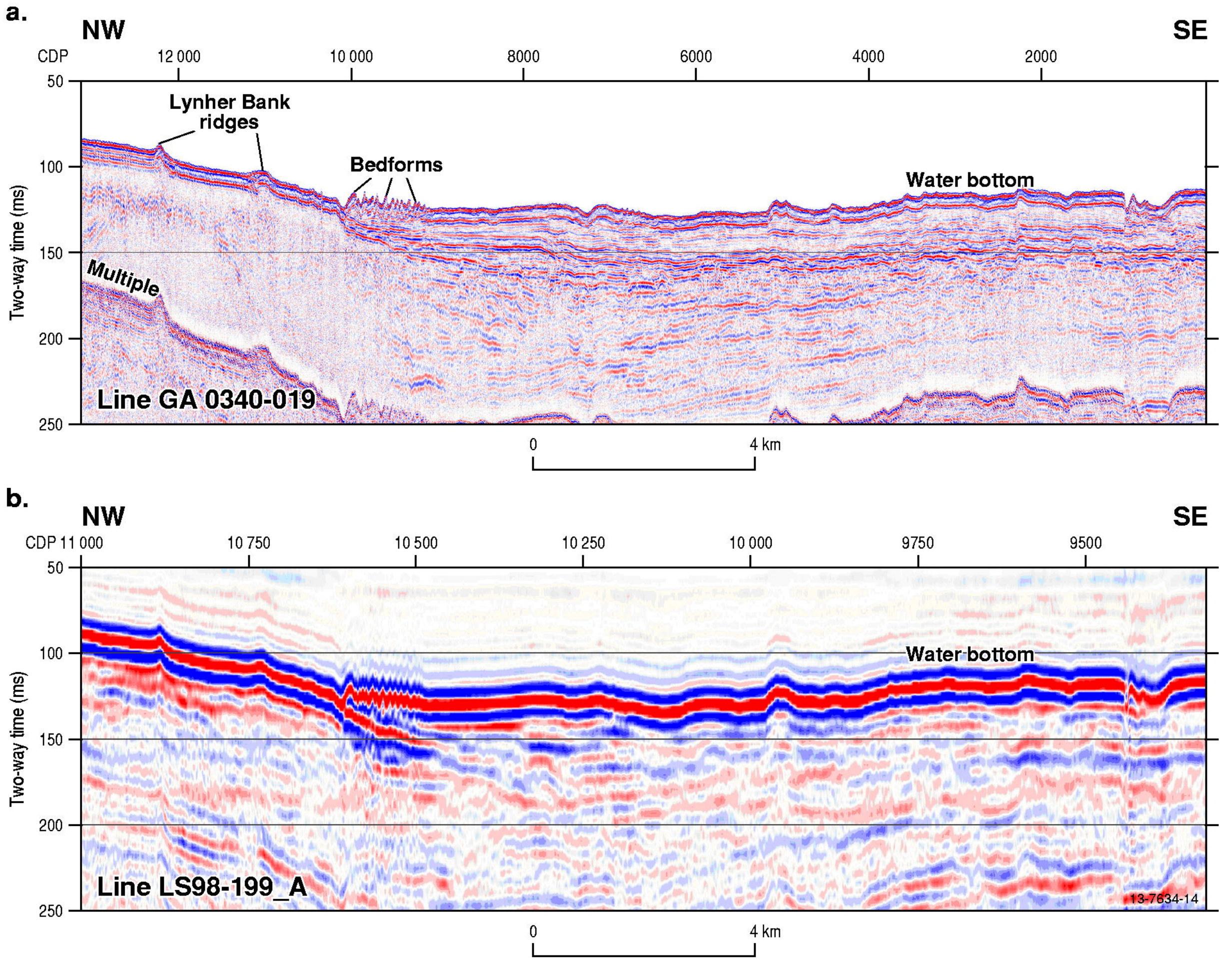


Figure 3.11 Examples of profiles in Area 2 (about 100 m of sediment lies between the water bottom and its first multiple). (a) Final stack for sub-bottom profile line GA0340-019. (b) Migrated section for part of seismic line LS98-199_A from the Leveque Shelf 1998 survey, which is coincident with line GA0340-019. The vertical exaggeration is approximately 35:1 (using a P wave interval velocity of 1,800 m s^{-1} in the sediments).

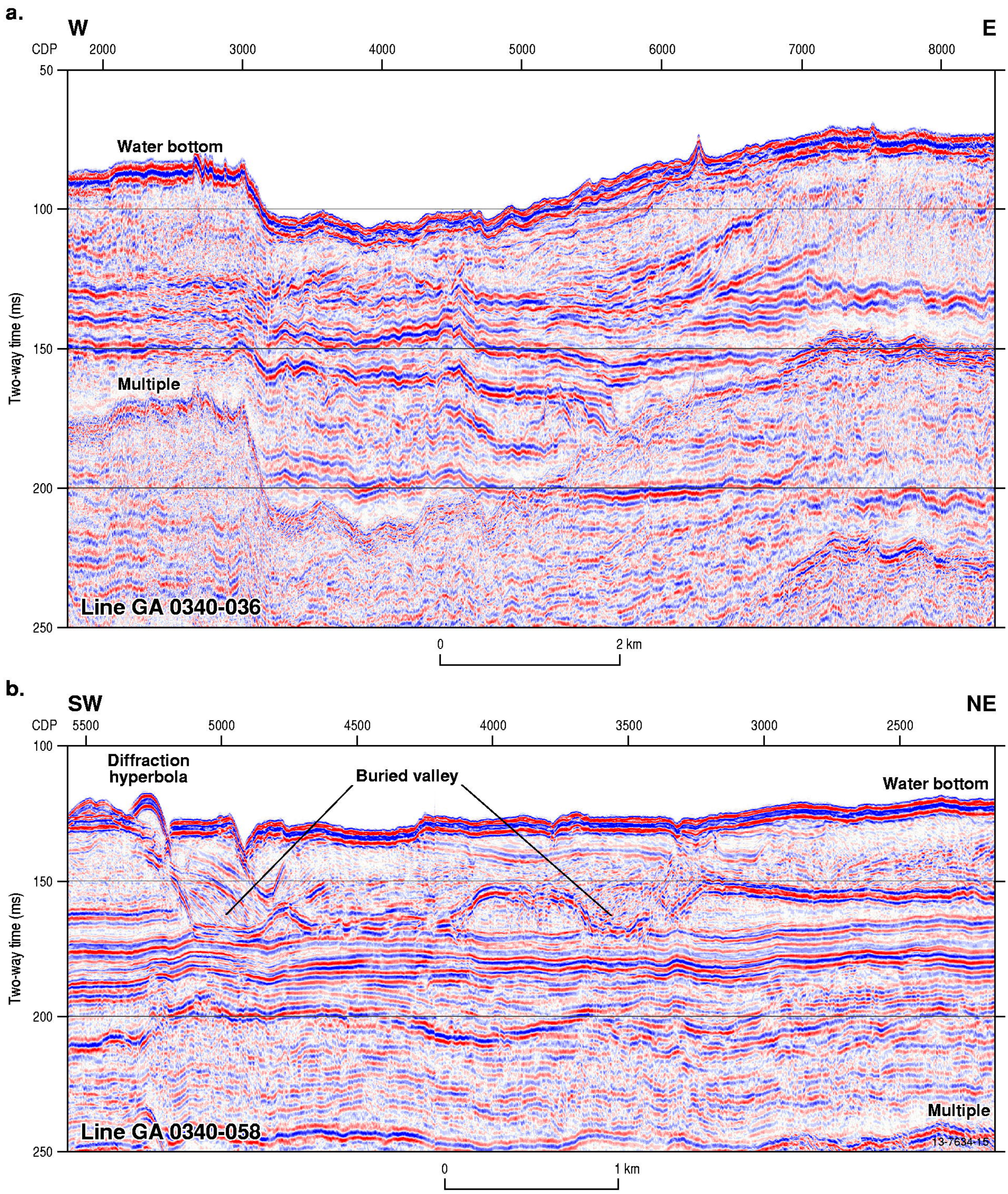


Figure 3.12 Examples of sub-bottom profiler data in Areas 3 and 10. (a) Part of the final stack for sub-bottom profile line GA0340-036 in Area 3. The vertical exaggeration is about 35:1, using a P wave interval velocity of 1,800 m s^{-1} in the sediments. Note deeper reflectors cutting through the first water bottom multiple. (b) Part of the final stack for sub-bottom profile line GA0340-058 in Area 10. The vertical exaggeration is about 18:1 (using a P wave interval velocity of 1,700 m s^{-1} in the sediments).

3.2.2.2 Parametric Sub-Bottom Profiler

Profiles collected using the parametric sub-bottom profiler show limited penetration (i.e. <5 ms) (Appendix D). This suggests that mobile sediments are rarely available and/or present only as very coarse-grained layers that are impenetrable with the relatively high-frequency (4 kHz) of the parametric sub-bottom profiler utilised across the survey area. In places where penetration occurred, it often corresponds to lower backscatter values and is generally geographically limited (Figure 3.13). High noise levels are present throughout the data. This is likely caused by a combination of two factors, i.e. the ship survey speed and the low transmit frequency used. As the multibeam echosounder dataset was the primary dataset to be collected, the survey speed averaged 8 to 9 knots. However, according to Innomar system specification, the maximum speed to ensure quality of sub-bottom profiler data should be around 6 knots. Secondly, the use of 4 kHz as the low transmit frequency (LF) is considered to be within the outer spectrum of frequencies produced by the Innomar system and is thus not likely to be optimal. In addition, lower frequencies use broader bandwidths, increasing the noise ratio, and thus recording higher levels of noise. Therefore, to optimise the data quality of the Innomar system during future acquisition, it is recommended that a higher low transmit frequency of about 8 kHz and slower survey speeds should be considered.

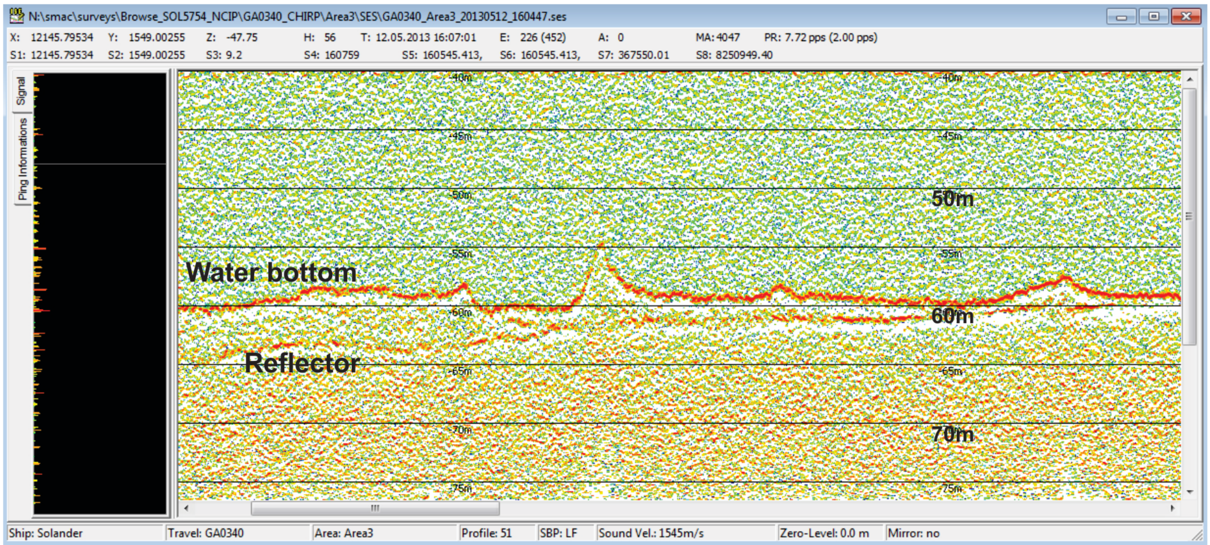


Figure 3.13 Unprocessed Innomar parametric sub-bottom profile section from Area 3 (line GA0340_Area3_20130512_160447) as viewed in the ISE v2.94 post-processing software.

3.3 Physical data

3.3.1 Grabs

Unconsolidated sediments were collected at 55 stations (Figure 2.2), for a total of 167 grab samples (Table 2.2). Each station included three grab samples, with the exception of stations 15, 18, and 46, which had four grab samples taken.

3.3.1.1 Sedimentology

Sediments across all survey areas were predominantly sandy in texture, with modal grain sizes ranging from fine to coarse sand (Figure 3.14 to Figure 3.16; Appendix G). Approximately half of the samples (55) contained a mud fraction, usually as a trace (<5 %), with the exception of grabs GR60, GR81, and GR82 from Area 3 (Figure 3.15). All three of these samples were taken from a hummock field within a channel.

Five sediment samples contained a gravel or ‘clast’ fraction: GR04, GR05, GR20 from Area 1 and GR47, GR51 from Area 2 (Figure 3.14). These grabs were taken from a wide range of geomorphic features including terraces, plains, ridges, and depression clusters. However, gravel fraction was not found in valleys.

All sediment samples were largely carbonate in composition with angular, gravel to sand-sized fragments of shell, bryozoan and coral very common (Appendix G). Additionally, 20 samples included cemented sand grains. Cemented sand grains were largely found in sediments taken from, or in close proximity to, fields of type II depression clusters or ridges. Possible exceptions to this trend were GR88 in Area 3 (Figure 3.15), which was located on the steep flank of a bank, and GR104 and GR105 from Area 4 (Figure 3.14), which were taken in a hummock field containing more widely spaced depressions.

These sediment descriptions are based on preliminary shipboard observations and subject to change after the application of further analytical procedures.

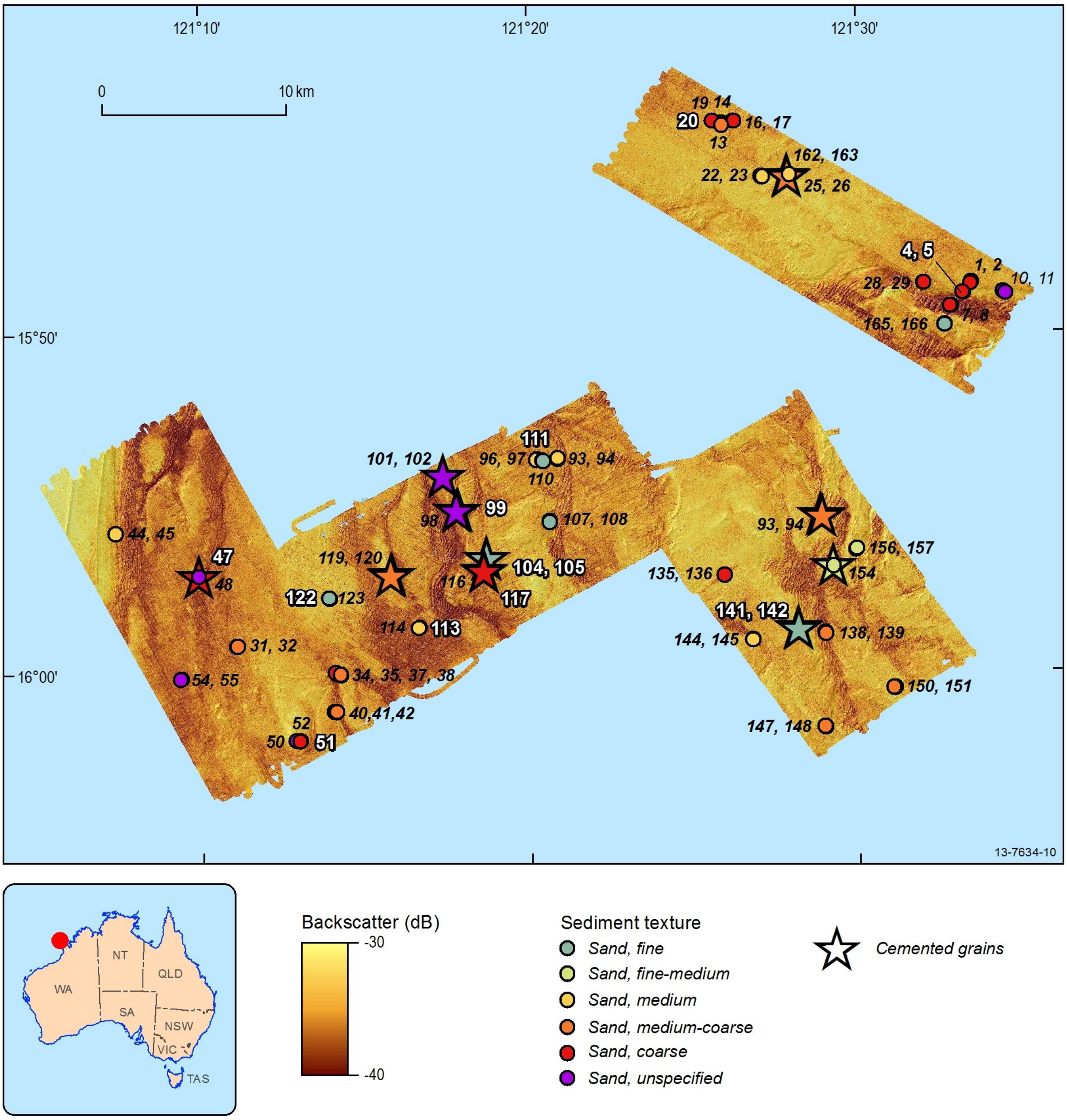


Figure 3.14 Map showing the distribution of the dominant sediment texture for each grab in Areas 1, 2, 4 and 5 over a hillshaded multibeam backscatter image. Numbers refer to grab samples discussed in the text.

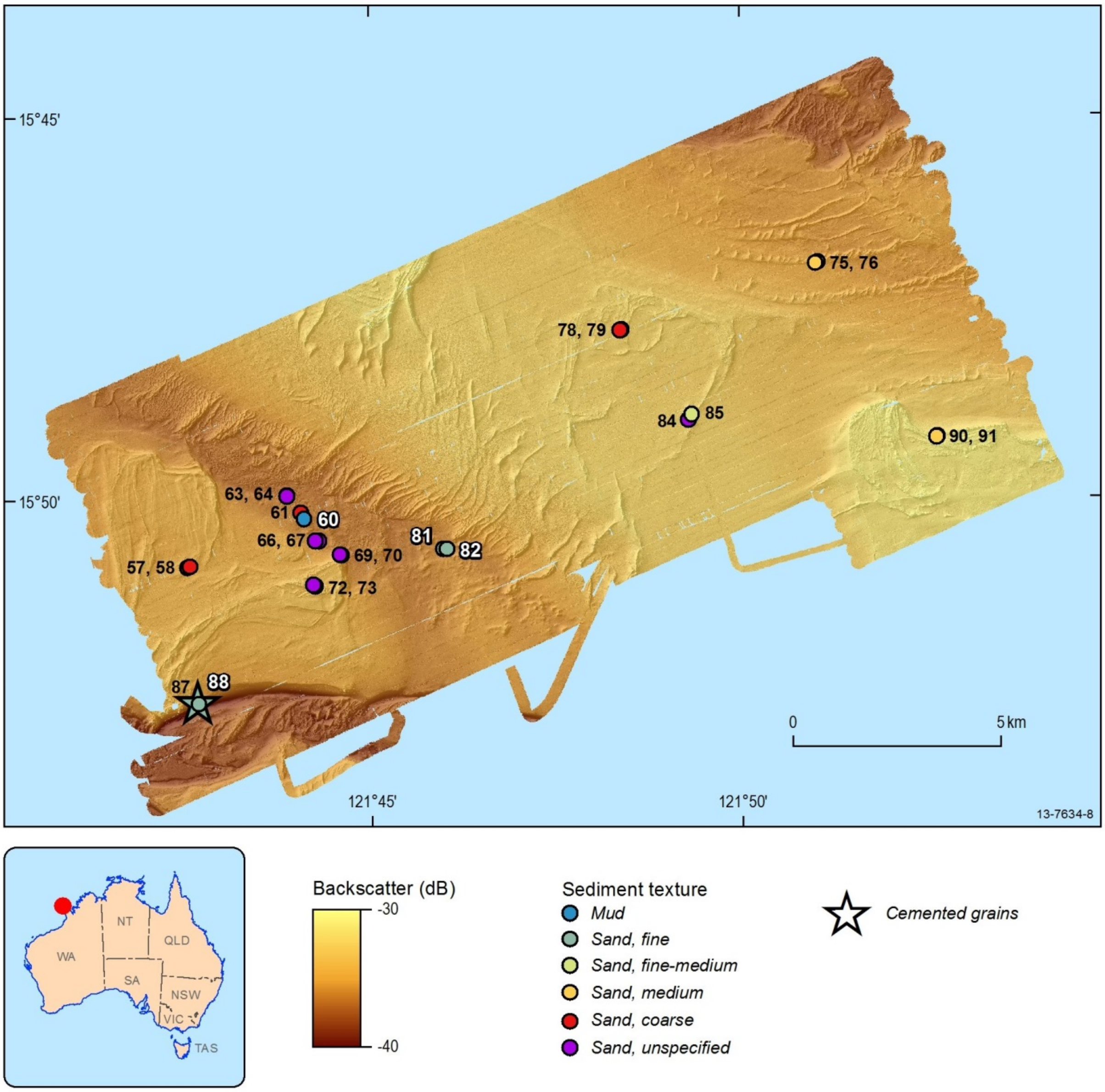


Figure 3.15 Map showing the distribution of the dominant sediment texture for each grab in Area 3 over a hillshaded multibeam backscatter image. Numbers refer to grab samples discussed in the text.

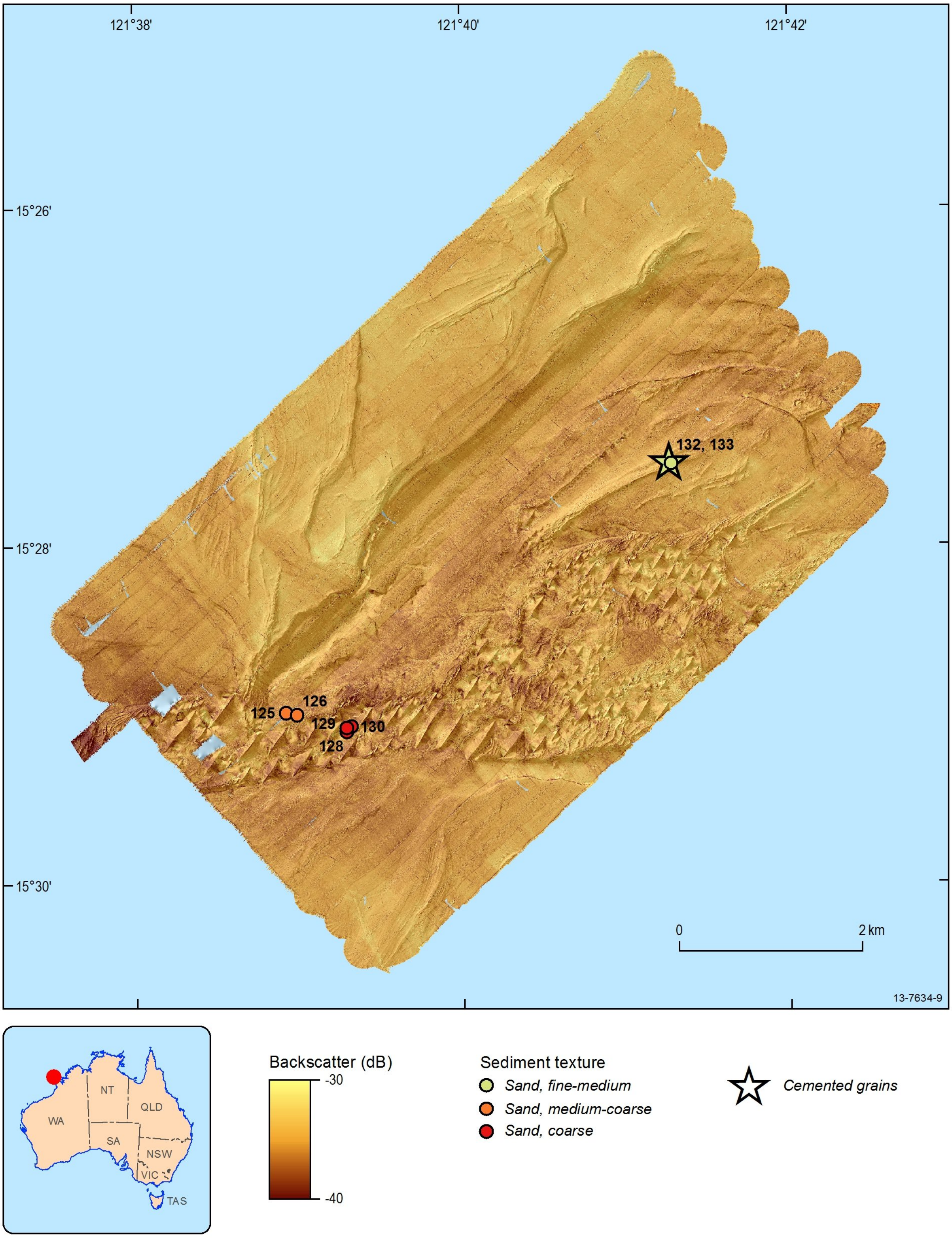


Figure 3.16 Map showing the distribution of the dominant sediment texture for each grab in Area 10 over a hillshaded multibeam backscatter image. Numbers refer to grab samples discussed in the text.

3.3.1.2 Geochemistry

From the 55 samples collected for geochemical analysis (Appendix E), anomalous sediment oxygen demand (SOD) values were observed at two stations, 06 and 12 (Figure 3.1). Samples 06/GR15 from Area 1 and 12/GR33 from Area 2 had oxygen consumption levels of 96 % day^{-1} and 86.1 % day^{-1} respectively, compared to the overall average of 12.8 ± 10.8 % day^{-1} for the entire dataset (Stations 06 and 12 excluded). Elevated oxygen demand values such as these could be caused by abundant labile organic matter in the sediment (e.g. infauna that are large relative to the sample), or by chemical oxidation of ammonia, ferrous iron or sulphides. Elevated chemical oxidation demand, especially of ferrous iron, could potentially indicate subsurface seepage. The high SOD at station 12 was not matched by high oxygen consumption measured by the core incubation method. Indeed oxygen consumption in cores at this station was -4.9 ± 2.8 mmol m^{-2} day^{-1} and was lowest for the dataset. However, O_2:CO_2 flux ratios at this station exceeded the ratio expected from aerobic degradation with complete nitrification which also points to chemical oxidation. Unfortunately, core incubations were not undertaken at station 06.

3.3.1.3 Infaunal Sampling

Preliminary sorting of infaunal specimens sampled from seabed sediments indicate that assemblages are dominated by crustaceans and polychaetes, and to a lesser extent echinoderms and molluscs (Figure 3.17). The observed infauna are similar to assemblages described in other areas of northwestern Australia, including the Joseph Bonaparte Gulf (e.g. Przeslawski et al., 2011; Carroll et al., 2012). Further analysis will include investigation of the relationships between environmental factors and infauna, particularly in relation to gas or fluid seeps. The species matrix generated by the current collection will contribute to a broader understanding of biodiversity patterns at a regional and national scale.

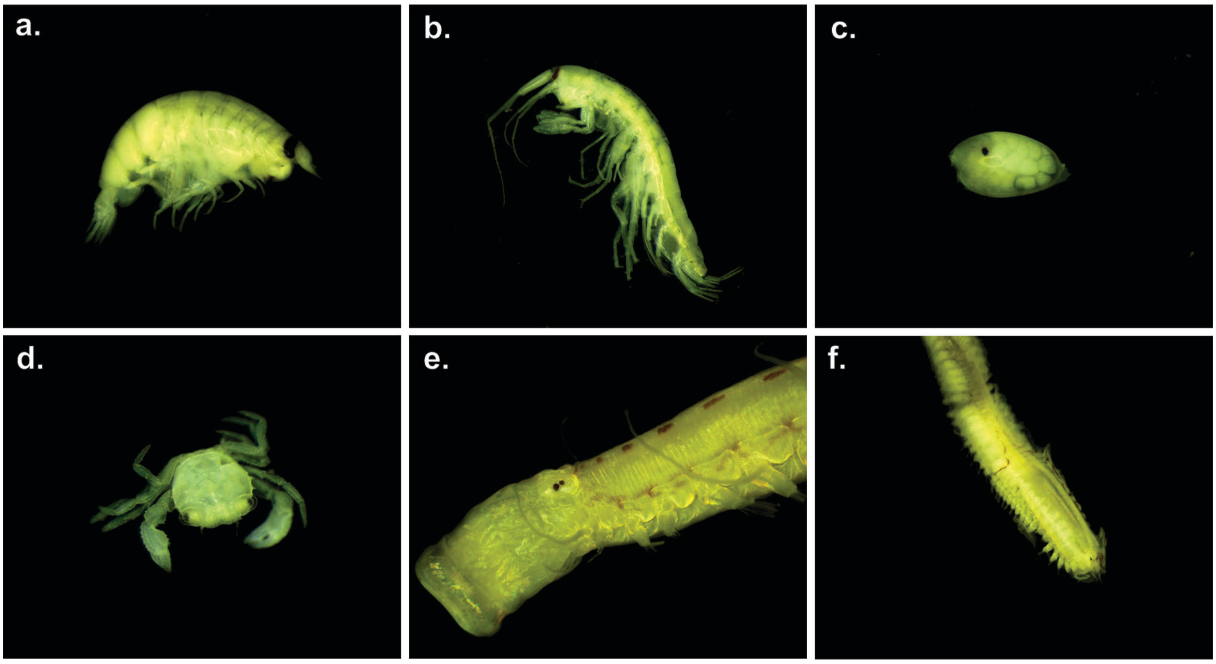


Figure 3.17 Representative infauna from grab samples 36GR99, 40GR111 and 42GR117 (Figure 3.14): (a, b) gammarid spp.; (c) ostracod sp.; (d) decapod sp., and (e, f) polychaete spp.

3.3.1.4 Vibrocores

Eight cores were recovered in water depths of 58 to 90 m from the six survey areas (Figure 3.4 to Figure 3.6; Appendix H). The recovery length of the cores ranged between 0.26 and 2.52 m. Preliminary inspection noted a generally sandy to gravelly carbonate composition of sediments in all cores. The carbonate was observed to be dominantly derived from carbonate secreting organisms (e.g. bryozoans, echinoids, bivalve molluscs, gastropods, etc). Non-carbonate biogenic material was not noted (e.g. mangrove or other organic-rich muds) nor was evidence for basement material present in these initial observations (i.e. volcanics, metamorphic rocks). Sediment samples have been submitted to the PalSed Laboratories at Geoscience Australia for grain-size analyses and carbonate content measurement.

3.3.2 Biology

3.3.2.1 Underwater Towed-Video

A total of 50 video transects and 15,606 usable still images were collected in the six survey areas, in water depths of 47 to 102 m (Table 2.2; Figure 3.4 to Figure 3.6). Benthic habitats throughout the surveyed areas were broadly classified, based on video observations, into four main categories (see Appendix I; Przeslawski et al., 2011; Carroll et al., 2012):

1. Barren sediments: Sediment is flat with little evidence of infaunal (bioturbation) or epifaunal activity (<20 individual epifauna over the entire transect).
2. Bioturbated sediments: Sediment shows at least a moderate level of infaunal and epifaunal activity with characteristic trails and burrows (lebensspurren) and low cover of epifauna (>20 individuals over the transect; up to 15 individuals per 15 seconds estimated over the course of the video).
3. Mixed patches (octocorals and sponges): Patchy rocky outcrops supporting locally abundant patches of octocorals and sponges (that occupy a proportion of at least 20% of the transect - up to 25 individuals per 15 seconds), interspersed with areas of soft sediment and low epifaunal cover. Rocky outcrops may be covered with a thin veneer of sediment; however, epibenthic growth of sessile organisms indicates that a hard substratum is present.
4. Mixed gardens (octocorals and sponges): rocky outcrops comprising diverse and locally abundant octocoral and sponge gardens (that occupy a proportion >50 % of the transect).

Preliminary classifications of benthic habitats consisted predominantly of bioturbated habitats (23 stations) and mixed patches of octocorals and sponges (22 stations) (Figure 3.18a-c). Bioturbated sediments with lebensspurren, which included pits and mounds, were observed at depths of 58 to 100 m (Appendix I). Mixed patches had localised areas of highly diverse epifaunal communities, often interspersed with areas of rippled or flat sediments (Figure 3.18d-h). Relatively dense and diverse mixed gardens of octocorals and sponges (e.g. soft corals, gorgonians, whips) were recorded at stations 18, 31, and 49 at depths ranging between 70 to 101 m (Figure 3.1 and Figure 3.2). Relatively flat expanses of barren sediments with few epifauna and little bioturbation were observed at station 53 (Figure 3.1).

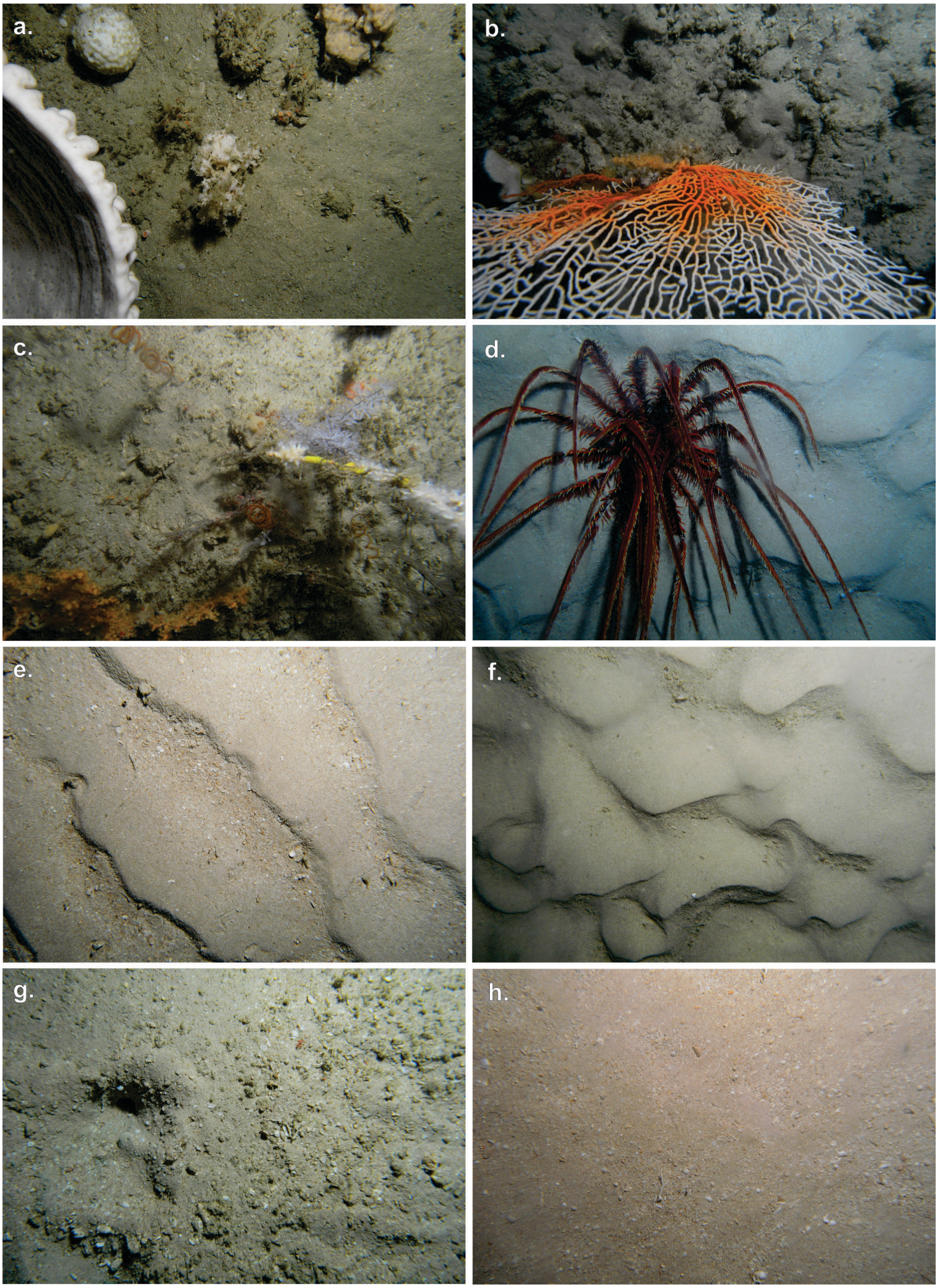


Figure 3.18 Still underwater photographs showing benthic habitats: (a-c) mixed gardens/patches of octocoral and sponges (a-STN01cam01, Figure 3.4; b-STN31cam25, Figure 3.5; c-STN18cam13, Figure 3.4); (d) crinoid on rippled sediments (STN49cam42, Figure 3.4); (e) 2D sand ripples (STN06cam03, Figure 3.4); (f) 3D sand ripples (STN49cam42); (g) bioturbated sediments (STN08cam04, Figure 3.4), and (h) barren sediments (STN49cam42).

3.4 Oceanographic data

3.4.1 Water Column Imaging

The total data acquired for the survey amounted to 730 Gb of raw multibeam water column data in 1,128 multibeam swath lines and 90 Gb of raw single beam water column data in 770 single beam lines. A multibeam swath line contained 8400 pings on average. Using Echoview, the analysis was first conducted on the single beam data and resulted in 275 anomalous features ranging from a few metres to 70 m high. The features were found as individuals or groups of individuals present over various geomorphic features. Using the synchronisation tool in Echoview, these 275 anomalies were cross-correlated with the multibeam data, which provided a 3D perspective. Various types of water column returns were observed. These include pelagic school of fish, demersal school of fish, internal waves, and possible seep-like objects (Figure 3.19). Most features were interpreted as pelagic and demersal fish school, either stationary or on the move. The presence of seepage in the study areas remains inconclusive and requires further processing as well as cross-correlation with other datasets.

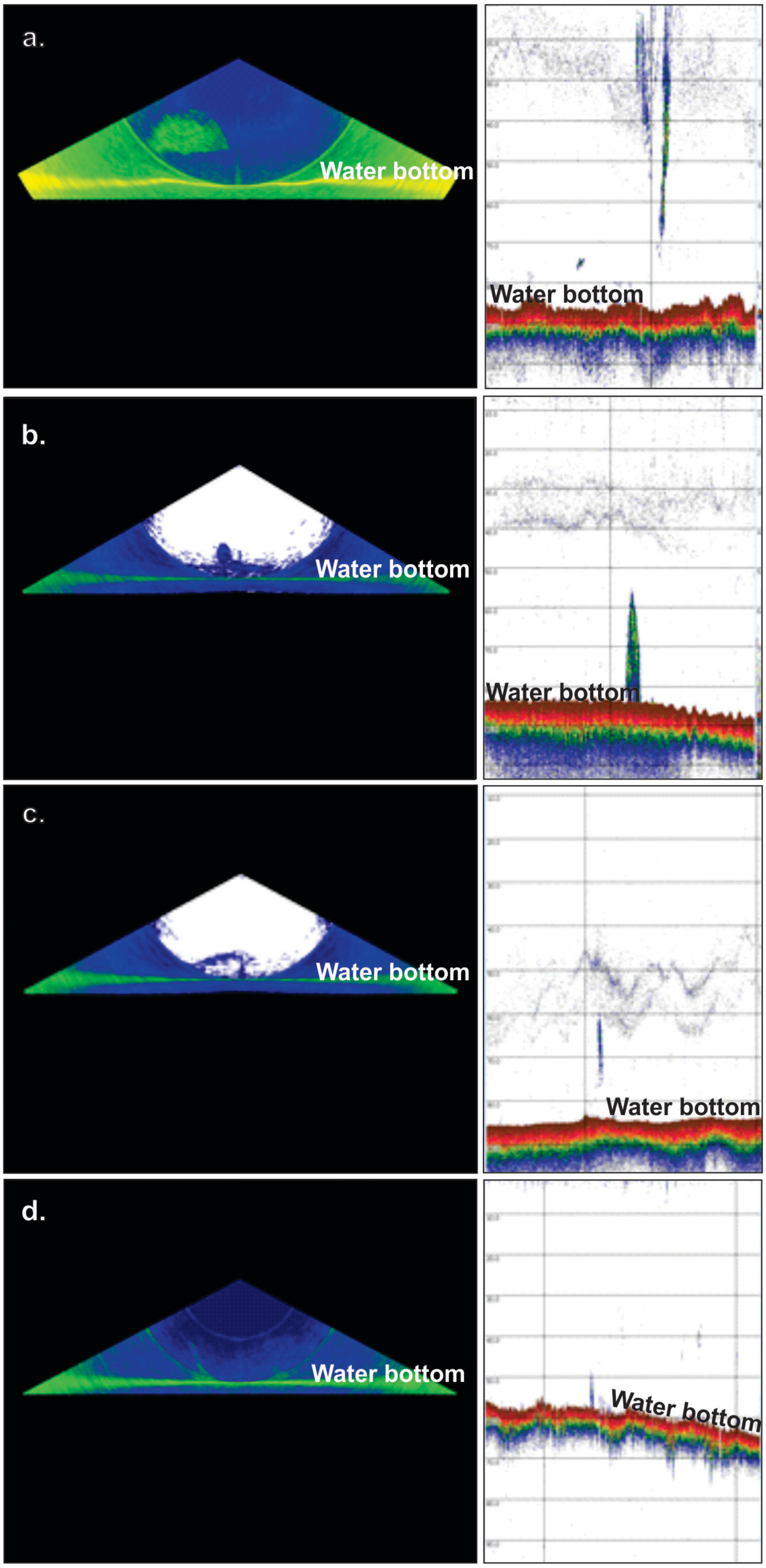


Figure 3.19 Image of multibeam (left panel) and single beam (right panel) water column data showing examples of water column features observed. These include a) pelagic school of fish; b) demersal school of fish; c) internal waves; and d) possible seep-like feature.

4 Summary of observations

4.1 Relict coastal landscape

The high resolution bathymetry reveals a range of geomorphic features that are indicative of a relict coastal landscape probably carved during the low sea-level periods of the Pleistocene (Table 3.2). The preservation of these relict features is possible due to the low sedimentation rates observed in this offshore region (Collins, 2011). At a broad scale, a network of valleys, banks, and terraces dominates the seabed landscape. The morphology of the valleys, especially throughout the western side of the survey area (Figure 3.1), strongly resembles the modern tidal estuarine complex present along the Kimberley coastline (Figure 4.1). At a smaller scale, the Type IV ridges observed in Areas 3 and 10 on a terrace and a bank (Figure 3.2 and Figure 3.3 respectively) are morphologically similar to shorelines, more specifically beach ridge plains as observed on the NE coast of Australia (Nott, 2010).

Preliminary observations of the grab samples suggest that coarse carbonate grain-size, from sand to gravel, and often cemented, overlay most of the survey areas (Figure 3.14 to Figure 3.16). The elevated and limited range of the backscatter strength, as well as the shallow sub-seabed penetration observed in both the vibrocore samples and the sub-bottom profiles (Figure 3.4 to Figure 3.6, and Figure 3.13) support this interpretation. These observations are in accordance with previous interpretations suggesting that this area of the Northwest Shelf is dominated by palimpsest sediments of mostly relict origin (James et al., 2004; Collins, 2011).

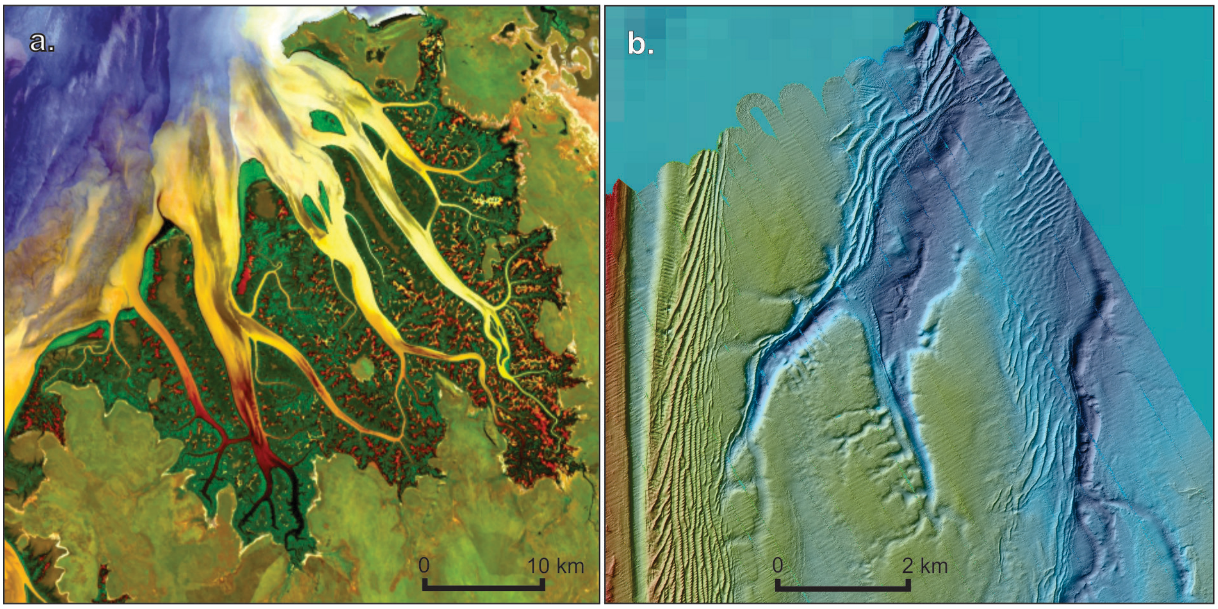


Figure 4.1 Comparison between the valleys observed in a) processed satellite image of the modern Kimberley coastline (Ord River area, NT) and b) the multibeam bathymetry.

4.2 High energy modern environment

The range of data collected during the survey supports previous work showing that this area of the shelf is subjected to a highly-dynamic modern oceanographic regime (James et al., 2004; DEWHA, 2008; Rayson, 2011). The high resolution bathymetry reveals multiple types of bedforms mainly on valley floors and terraces (Table 3.2). Based on the sub-bottom profiles, these areas are generally characterised by a thin accumulation of unconsolidated sediments (< 5 m), which is contrary to most other areas where no acoustic penetration suggests a certain degree of consolidation of the seabed. The high and narrow range of the backscatter strength (Figure 3.4 to Figure 3.6), supported by the sub-surface observations, suggest that the coarse-grained and cemented nature of the seabed noted from grab and vibrocore samples (Figure 3.14 to Figure 3.16) is common to the whole area and consistent with a sediment-starved environment.

The dynamic character of this environment is also indicated by the presence of internal waves visible throughout the water column acoustic data. Internal waves were particularly evident in Areas 1, 2, and 3, but are known to exist over the entire Northwest Shelf (Rayson et al., 2011). Finally, the location (upper 50 ms TWT of the sub-surface) of the truncated, hummocky, and cross-cutting reflectors observed in the multichannel sub-bottom profiles suggests a depositional environment characterised by dynamic surface processes (Figure 3.12).

4.3 Basement controls on seabed morphology

High resolution bathymetry revealed many small depressions suggestive of gas or fluid escape. Preliminary observations of the sub-bottom profiles suggest that sub-surface reflectors are undisturbed, which suggests a relatively shallow source for any gas or fluid that contributed to the formation of the depressions. The shallow stratigraphy of the area is generally characterised by flat-lying, parallel, and continuous reflectors, which suggests a relatively stable depositional history involving vertical sediment accumulation (Figure 3.10). There are examples of buried valleys and channels observed locally throughout the surveyed areas (Figure 3.12). However, these valleys mainly coincide with the valleys observed on the high-resolution bathymetry and are usually confined to the upper part of the sub-surface stratigraphy (<50 ms).

Although many features were observed in the water column acoustic data, none showed a clear correlation with active seepage (with many anomalies likely to be schools of fish). Amongst the geochemistry samples collected, only two, located in Areas 1 and 2, reported preliminary anomalous sediment oxygen demand (SOD) readings. These could potentially indicate subsurface seepage, but could also be related to the presence of degraded organic matter. Preliminary observations thus suggest that there is little evidence for gas/fluid migration pathways that link the proposed CO_2 storage reservoir to the seabed.

Many seabed features, however, show potential relationships with basin geology. These included Type I ridges observed on Lynher Bank and Lynher Bank itself of Area 2 (Figure 3.1), which coincide with a major structural basement fault (Barcoo system fault, Figure 1.1). In some cases, these major structures might still have an impact on the suitability of the area for CO_2 storage and will be further investigated.

5 Summary and Concluding remarks

The primary objectives of this survey were to target seabed or shallow sub-surface structures that may reflect pathways along which CO_2 could migrate out of the storage reservoir and to characterise the seabed and associated biota in order to provide baseline information in an area that may be developed for CO_2 storage in the future. The survey provided insight into the Leveque Shelf area, a region where limited seabed information was previously available. Six areas were targeted where features in seismic data suggested possible reduction in the integrity of the CO_2 reservoir seal. These areas covered a total of 1,070 km^2 and were mapped using high resolution multibeam echosounder. The mapping included bathymetry, backscatter and water column data - also mapped using dual-frequency single beam sonar. The sub-surface was investigated over a total distance of 725 line km with the multichannel sub-bottom profiler and 1,547 line km with the parametric sub-bottom profiler. Sidescan sonograms were collected in three areas over specific features suspected of having seepage connection. Targeted investigations were also undertaken with physical and visual sampling (including underwater towed-video, vibrocore, grab and CTD) at a total of 58 stations.

Key preliminary observations from the survey are as follows:

- The seabed is characterised by a more complex network of geomorphic features than are evident on the national map of seabed features of Harris et al. (2003). Banks and terraces interspersed with a large network of valleys dominate the seabed. Valleys are populated mainly by bedforms and depressions, while ridges sit above banks and terraces.
- The survey area is dominated by coarse-grained, carbonate sediment, which is cemented in places. This interpretation is supported by the limited acoustic penetration (<5 m) of the parametric sub-bottom profiler. The limited cover of mobile sediments suggests a sediment-starved environment.
- Internal waves, observed in the single beam echograms, and highly turbid waters, observed in the towed-videos, suggest that strong tidal energy influence this region of the shelf.
- Bioturbated habitats and mixed patches of octocorals and sponges dominate the area. Infauna assemblages are dominated by crustaceans and polychaetes, and to a lesser extent echinoderms and molluscs.
- Seabed and water column features investigated did not show strong signs of active seepage; only two geochemical samples with higher oxygen demand might be indicative of seepage. However, many seabed features show potential relationships with deeper basin geology (e.g. faults).

Integration of this newly acquired data with existing seismic data will provide new insights into the geology of the Leveque Shelf. This work will contribute to the Australian Government's National CO_2 Infrastructure Plan (NCIP) by providing key seabed environmental and geological data to better inform the assessment of the CO_2 storage potential in this area of the Browse Basin. Datasets, imagery, and related research products from this survey will be made available to all stakeholders via the Geoscience Australia website.

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Appendix A Scientific and Technical Crew

Appendix Table A.1 Role and affiliation of personnel on leg 1 of survey GA0339/SOL5650, 2-15 May 2013

Name	Principal Role	Agency	Responsibility
Scott Nichol	Chief scientist, Sedimentologist	GA	Science leader, geological sample acquisition and processing
Andrew Carroll	Co-chief scientist, Marine ecologist	GA	Benthic ecology sample acquisition and processing, video characterisation
Kim Picard	Co-chief scientist, Multibeam and sub-bottom profiler operator and processor, and GIS data manager	GA	Multibeam and sub-bottom profiler operations, processing and data management, incl. GIS
Tony Nicholas	Sedimentologist (until 6 May, 2013)	GA	Geological sample acquisition and processing
Justy Siwabessy	Multibeam and single beam operator and processor (backscatter & water column data)	GA	Multibeam and single beam operations, processing and data management
Lynda Radke	Geochemist	GA	Geochemical sample acquisition and analysis
George Bernardel	Geophysicist and GIS support	GA	SBP, multibeam, and GIS support, geological sample acquisition.
Leonie Jones	Senior geophysicist, Seismic processor	GA	Multichannel sub-bottom data management & processing
Stephen Hodgkin	Multichannel sub-bottom and sidescan operator, and multibeam support	GA	Multichannel sub-bottom, sidescan sonar, and multibeam sonar support
Matthew Carey	Science technician	GA	Multibeam support, deploy and assist with sampling gear, lab processing of samples.
Marcus Stowar	Voyage leader, Marine biologist	AIMS	AIMS voyage leader, underwater towed-video operations

Appendix Table A.2 Role and affiliation of personnel on leg2 of survey GA0339/SOL5650, 15-30 May 2013

Name	Principal Role	Agency	Responsibility
Takehiko (Riko) Hashimoto	Chief scientist, Sedimentologist	GA	Science leader, geological sample acquisition and processing
Andrew Carroll	Co-chief scientist, Marine ecologist	GA	Benthic ecology sample acquisition and processing, video characterisation
Kim Picard	Co-chief scientist, Multibeam, Single beam and sub-bottom profiler operator and processor, and GIS data manager	GA	Multibeam and sub-bottom profiler operations, processing and data management, incl. GIS
Lynda Radke	Geochemist	GA	Geochemical sample acquisition and analysis
George Bernardel	Geophysicist and GIS support	GA	SBP, multibeam, and GIS support, geological sample acquisition.
Leonie Jones	Senior Geophysicist, Seismic processor	GA	Multichannel sub-bottom data management & processing
Olivia Wilson	Multibeam and single beam operator and processor (backscatter & water column data)	GA	Multibeam and single beam operations, processing and data management
Matthew Carey	Science technician	GA	Multibeam support, deploy and assist with sampling gear, lab processing of samples.
Stephen Hodgkin	Multichannel sub-bottom and sidescan operator, and multibeam support	GA	Multichannel sub-bottom, sidescan sonar, and multibeam sonar support
Craig Wintle	Science technician	GA	Vibrocore and sampling gear deployment
Marcus Stowar	Voyage leader, Marine biologist	AIMS	AIMS voyage leader, underwater towed-video operations

Appendix B Technical Report on Multibeam Sonar Operations

B.1 Introduction

B.1.1 System overview

Vessel – The survey was conducted on the Australian Institute of Marine Science Vessel RV *Solander*. The RV *Solander* is 35 m long and equipped with a moon pool through which the multibeam sonar head could be raised and lowered on a mounting system.

Multibeam unit - The multibeam sonar was a single head Konsberg EM 3002. The system has a nominal frequency of 300 kHz.

Motion referencing unit - Applanix PosMV 320 coupled with Auxiliary high precision C-Nav 2050R corrected GPS system.

Sound velocity Profiler – Sound velocities were measured using a Applied Microsystems SV Plus2 sound velocity profiler which was battery powered and deployed on rope or winch. Locations of the profiles are presented in below. CTD cast were collected throughout the survey and can be used for additional SVP if necessary

Time and position

All times are UTC

All positions are derived from the Global Navigational Satellite System and referenced to the World Geodetic System 1984 (WGS84)

B.2 Technical Notes

B.2.1 Multibeam System Components.

B.2.1.1 Transducer single sonar head with associated processing unit.

Head Serial No: 547 operated at 293 kHz.

Looking up angle set per head during operation was 65° or less depending on seabed terrain, depth and resolution required.

Beams per head: 160

Transmit specifications along track beamwidth: 1.5°.

Receive specifications beamwidth is inversely proportional with the cosine of the beam pointing angle with respect to the Sonar Head (i.e. beamwidth is 2.1° at ±45° beam pointing angle and 3.0° at ±60°).

Depth determination precision specified by manufacturer is 5 cm RMS.

Seafloor Information Software (SIS) system display, control and logging**: 3.8.3**

Processing Unit and sonar head software versions as follows:

2012.05.18 02:12

BSP67

BSP67 Master : 2.0.0 080912

BSP67 Slave : 2.0.0 080912

DMA PLD : 0.2 040317

FIFO FPGA : 1.0 040325

MASTER FPGA : 1.0 040329

RXI FPGA : 1.1 060102

EM3002 HCT: 3.0.3 090708

PU: 2.0.15 091126

Head: 548

DDS: 3.18 2005/11/24

FPGA: 1.4 081112

Installation

The sonar head was installed looking down, slightly forward of centre of the moon pool mounting flange. The system was setup in a moon pool on a trolley system and winched down the moon pool shaft and locked into position; the locked position being precise, extremely rigid and secure.

The Motion Referencing Unit (MRU) was mechanically fixed above the sonar head on the same moon pool shaft forward internal bulkhead. The GPS antennas were mounted slightly forward of the moon pool shaft on the rear of the rigid sun awning frame on the top external deck. The relationship between the sonar heads, MRU and GPS Antennae was accurately surveyed in 2008 whilst the vessel was on the hardstand. Modifications to the original survey being; the mounting plate was modified to incorporate a Simrad single beam sonar (ES70) head and an Innomar Sub-Bottom Profiler sonar head, along with adaptation neck and flanges to suit the new AIMS - ADCP mounting flange.

Changes to offsets were calculated from mechanical drawings of the newer components and in-situ measurements.

B.2.1.2 Motion Referencing System:

Applanix PosMV 320 coupled with Auxiliary high precision C-Nav 2050R corrected GPS system, consisting of:

- Inertial Measurement Unit (IMU)
  - Model: IMU2
- Processing unit; incorporating two GNSS receivers connected to two separate Applanix system GNSS antennas (BD950).
  - Model: MV V4
  - Serial: 2578
  - Firmware: POS MV320 V4 5.03
- Manufacturers Specifications:
  - Roll, Pitch accuracy: 0.02° (1 sigma with DGNSS)
  - Heave accuracy: 5 cm or 5 % (whichever is greater) for periods of 20s or less
  - Heading accuracy: 0.02° (1 sigma) with a 2 m antenna baseline.
  - Position accuracy: as per C-Nav 2050R
  - Velocity accuracy: 0.03 m s^{-1}
  - System time: UTC

Auxiliary GPS

C-Nav 2050R system with satellite GPS correction signal receiving antenna integrated into the GPS antenna assembly.

LBM serial No: 3076

Firmware version: 5.1.13

Manufacturers Specification: accuracy position (H) <10 cm (V) <15 cm

B.2.2 EM3002 system component offsets

The sonar head mounting brackets differed slightly compared to other surveys on the RV *Solander*. The mount was redesigned to fit a single beam Simrad ES70 sonar system and an Innomar sub-bottom profiler sonar head, thus the single EM3002 sonar head was 300 mm forward compared to the past.

Sonar Head installation parameters applied in the EM3002 Processing Unit

Locations in relation to the Reference Point (RP) which was the sonar head face centre.

The RP to the inertial measurement unit (IMU) offsets were applied in the motion referencing system.

X is positive in the forward direction,

Y is positive in the Starboard direction,

Z is positive in the downward direction.

Reference point (Ref)	X = 0.00	Y = 0.00	Z = 0.00
Port Sonar Head	X = 0.00	Y = 0.00	Z = 0.00
Starboard Sonar Head	X = 0.00	Y = 0.00	Z = 0.00

Angles in relation to the sonar head face and the IMU are measured up from the horizontal, rotation Port up is positive, Pitch bow up is positive, Heading rotation to starboard from forward is positive.

Angle offsets are applied in SIS for real-time acquisition post patch test.

Appendix Table B.1 Corrections applied in SIS during the survey

Line applied	Date	Yaw	Pitch	Roll
1-5	2/5/2013	0	0	0
1-327	2/5/2013–8/5/2013	359.3	0	-0.45
328-336	8/5/2013	0	0	0
337-449	8/5/2013–11/5/2013	359.77	-0.23	-0.43
450-455	11/5/2013	0	0	0
456-457	11/5/2013	359.77	-0.23	-0.43
458-512	11/5/2013–12/5/2013	359.5	0.1	-0.44
513-661	12/5/2013–16/5/2013	0.8	0.1	-0.44
662-669	16/5/2013	0	0	0
670-676	16/5/2013	0.8	0.1	-0.44
677-1466	16/5/2013–29/5/2013	0	0.1	-0.44

Waterline offset

Centre of EM3002 heads to water surface Z = - 2.80

Positioning and Motion Referencing

Installation parameters applied in the PosMV Processing Unit.

Locations were in relation to the Reference Point (Ref) which was the centre of the sonar head face.

X is positive in the forward direction,

Y is positive in the Starboard direction,

Z is positive in the downward direction.

X and Y values of component offsets were varied slightly in the first ten days of the survey for the purposes of resolving minor motion error in the data (see below)

At the end of survey it was still unknown if minor slippage was occurring in the moon pool lock down system or other components.

Applied from start of survey up until 09-05-2013 00:41hr UTC

Ref to **Inertial Measurement Unit** (IMU) X = 0.854 Y = 0.030 Z = -4.957

Ref to **Primary GNSS Antenna** (Port) X = 2.147 Y = -2.359 Z = -11.860

Ref to **Auxiliary GNSS Antenna** (C-Nav) X = 2.148 Y = -1.263 Z = -11.857

Applied from 09-05-2013 01:37hr until 11-05-2012 09:01hr UTC

Ref to **Inertial Measurement Unit** (IMU) X = 0.559 Y = -0.001 Z = -4.957

Ref to **Primary GNSS Antenna** (Port) X = 1.902 Y = -2.359 Z = -11.860

Ref to **Auxiliary GNSS Antenna** (C-Nav) X = 1.903 Y = -1.263 Z = -11.857

Applied from 11-05-2013 09:02hr until 12-05-2012 05:59hr UTC

Ref to **Inertial Measurement Unit** (IMU) X = 0.660 Y = -0.001 Z = -4.957

Ref to **Primary GNSS Antenna** (Port) X = 2.002 Y = -2.359 Z = -11.860

Ref to **Auxiliary GNSS Antenna** (C-Nav) X = 2.003 Y = -1.263 Z = -11.857

Applied from 12-05-2012 05:59hr UTC until end of survey

Ref to **Inertial Measurement Unit** (IMU) X = 0.660 Y = -0.030 Z = -4.957

Ref to **Primary GNSS Antenna** (Port) X = 2.002 Y = -2.359 Z = -11.860

Ref to **Auxiliary GNSS Antenna** (C-Nav) X = 2.003 Y = -1.263 Z = -11.857

Offset variation timings are those in relation to end times of Applanix True Heave (ATH) log files.

Pos MV320 system determined Base Line Vector for Port to Starboard GNSS

GPS Antennas X = -0.022 Y = 2.201 Z = -0.005

The Auxillary GNSS antenna is the CNav GNSS antenna and is located exactly midway between the Pos MV GNSS antennas.

Accuracy of antenna locations < 2 cm

B.2.3 Sound Velocity Profiler:

Applied Microsystems SV plus2 sound velocity profiler — battery powered and deployed on rope.

Manufacturer Specifications:

- Sound Velocity accuracy ± 0.05 m s^{-1}
- Temperature accuracy ± 0.05 °C
- Pressure Sensor accuracy ± 0.05FS (0-500 m)

Appendix Table B.2 Sound velocity profiles (SVP) collected during the survey

Cast	Latitude	Longitude	Date	Water depth (m)	Depth achieved (m)	SIS line applied	Comments
SM02	-15°50.97	121°33.66	3/05	90	90	Line 0031	
SM03	-15°43.99	121°24.49	5/05	97	96	Line 0134, 0396- 0400	For 396 to 400, error due to system reboot
SM04	-15°45.40	121°27.09	6/05	90	90	Line 0179	
SM05							
SM06	-16°01.50	121°13.94	10/05	86		Line 0393	
SM06a	-15°59.20	121°11.08	11/05	97		Line 0444	
SM07							
SM08							
SM09							
SM10	-15°51.73	121°42.28	16/05	69	69	Line 0662	
SM11	-15°46.91	121°51.00	18/05	78	78	Line 0746	Area 3; Faulty SVP conversion software, same profile as SM10
SM12	-15°54.18	121°23.26	20/05	96	96	Line 0871	Area 4 and 6; Faulty SVP conversion software, same profile as SM10
SM13	-15°54.72	121°16.99	20/05	100	99	Line 0882	Area 4

B.2.4 Tidal constituents and tidal zones used in Caris HIPS and SIPS:

During the survey, co-tidal solution was adopted for processing. The table below records the coordinates of the tidal constituents used to create tidal zones in Caris HIPS and SIPS. For more information about the tide zones, please contact the Geoscience Australia.

Appendix Table B.3 Coordinates of tidal constituents

#	Latitude	Longitude
1	15.96S	121.15E
2	15.93S	121.30E
3	15.93S	121.43E
4	15.73S	121.04E
5	15.82S	121.77E
6	15.73S	121.96E
7	15.23S	122.11E

#	Latitude	Longitude
8	15.12S	121.87E
9	15.78S	121.47E
10	17.82S	122.08E
11	17.41S	121.92E
12	16.85S	121.72E
13	16.39S	121.33E
14	16.22S	121.77E

B.3 Event log

Motion-like artefacts were observed throughout the survey. To find the source of the problem, the sonar head was lifted many times in the moon pool and thus, many patch tests were run. There were also changes to the lever arms values assigned in the POSMV due to re-calculations of position of the sonar head in relation to the CRP.

The survey can be divided in three main sections, mainly based on the artefact quality:

Phase 1 (2–9 May): During this period, the artefacts were minimal, but the weather was also very clement.

Phase 2 (10–15 May): This acquisition period was characterised by clement weather, but stronger artefacts (motion-like). During the 1st port stop, the head was lifted, cable checked, GAMS re-calibrated.

Phase 3 (15–28 May): Artefacts are similar to phase 1, i.e. smaller. However, with the weather deteriorating, motion-like artefacts were still considerable. During the crew change, the sonar head was checked and IMU tightened to the mount.

Area 3 was completed during this period. Note that a specific artefact to this area was detected. Part of survey lines are characterised by soundings/swaths that are off by about 50 cm compared to the adjacent lines. There appears to be no specific temporal pattern to the artefact.

Appendix Table B.4 Log of events

Action	Line applied	Comments
Patch test 1 (SIS, 0,0,0 calibration values)	1-5	Pre-survey.
Patch test 1 new applied offsets	1	Line count was reset after patch test and offsets entered in SIS
New lever arm values in POSMV	326	
GAMS calculation	328	
Patch test 2 (SIS, 0,0,0 calibration values)	0329-0336	Sonar head lifted up for check in moon pool. Back to port for Med-evac
Patch test 2 new applied offsets	337	
Patch test 3 (SIS calibration values not changed to 0,0,0)	450-455	Strong artefacts visible. Check on offset values
Patch test 3 new applied offsets	456	
New lever arm values in POSMV	464	
ATH logging STOP because GPS week	479	
New lever arm values and GAMS test	502	IMU: Y from 0.03 to -0.03
Patch test 4 (SIS calibration values not changed to 0,0,0)	503,507,509	Trying to find the cause to strong artefact present since PT 3. Line 507 of PT4 shows a 50 cm offset on 503 and 509
Heading offset changed in SIS	513	
Patch test 5 (Area 3)	662,664,669	After crew change. Sonar head lifted up for check. Tightening of the MRU unit
Heading calibration offset change	677	From 0.8 to 0
SIS changed from equiangle mode to equidistance	894-906	Equiangle mode was selected. Probably not many before

Appendix C Survey Details for Multichannel Sub-bottom Profiler Lines

Problems during acquisition

- For the first night of acquisition, only every second shot was recorded resulting in three fold data. This was because the acquisition system defaulted to recalibrating after every shot and was not ready to accept new data every two seconds. Advice from Geometrics solved this by recommending a much larger interval between recalibrations. This modification allowed every shot to be recorded, thus acquiring the desired six fold data.
- In some instances, the CSP-D generator would not run at 2000 joules (Hi 10), unless it had warmed up, presumably due to residual moisture from humidity in the wet lab. By the end of the survey, progressive failure required the generator to be operated only on a setting of 800 joules (Lo 10). This resulted in the unexpected benefit of compressing the characteristic sparker bubble pulse. When the generator tripped out, loss of data occurred, and in its malfunctioning phase, faulty delayed triggering also occurred.
- For the last seven lines acquired, channel 1 on the MicroEel failed, producing only noise.
- Sudden course corrections by the helmsman resulted in a yaw behaviour that changed the in line distance between the sparker and the streamer by the same amount for each channel. This phenomenon resulted in artefacts in the stack data, since the offsets used in normal moveout correction did not represent true source receiver offsets .The artefacts were somewhat reduced by correcting the offsets in processing for each shot, based on the change in travel time of the direct wave in water.

EBCDIC (text) header example

Example of an EBCDIC (text) header from one of the processed sparker sub-bottom profiler SEG-Y files. It contains metadata on acquisition parameters and the multichannel processing stream.

C1 FINAL SUB-BOTTOM PROFILER DATA PROCESSED BY GEOSCIENCE AUSTRALIA JUNE 2013
C2 DATA ACQUIRED BY GEOSCIENCE AUSTRALIA ON AIMS RESEARCH VESSEL SOLANDER
C3 SURVEY NO.: GA0340 SURVEY NAME: BROWSE BASIN MARINE
C4 LINE NO.: GA0340_019 GPS HEADING: 305 DEGREES
C5 RECORDING PARAMETERS
C6 SYSTEM: SEISMODULE DATE RECORDED: MAY 2013
C7 RECORDING GAIN: CHAN 1-24 0 dB
C8 RECORDING FILTERS: LOW-CUT 0 HZ, HIGH-CUT 0 HZ, NOTCH OUT
C9 SAMPLE RATE: 0.125 MS RECORD LENGTH: 0.5 s
C10 NO. CHANNELS: 24 DATA FORMAT: SEGY Revision 0 ON DISK
C11 SOURCE TYPE: SQUID 2000 SPARKER, CSP-D GENERATOR AT 2000 JOULES (Hi 10)
C12 SOURCE OFFSET: 6.5 M PERPENDICULAR SOURCE LAYBACK: 20 M
C13 SOURCE DEPTH: 0.5 M (APPROX) SP INTERVAL: 6.25 M
C14 CABLE MODEL: GEOMETRICS MICROEEL GROUP INTERVAL : 3.125 M
C15 CABLE LAYBACK: 45 M CABLE DEPTH: 2.5 M (APPROX)
C16 NEAR CHANNEL: 1 (APPROX 26 M) FAR CHANNEL: 24 (APPROX 97 M)
C17 CMP SPACING: 1.5625 METRES COVERAGE: 6 FOLD
C18 FINAL PROCESSING SEQUENCE : STACK 0.5 s, 0.25 ms
C19 1: Dummy line geom (CDP int 1.5625 m), corrected for missing SP as needed
C20 2: SEGY to 'disco' internal format
C21 3: Mute of leaked timing pulse and first arrivals
C22 4: Band pass filter 80/30 to 1500/72 (Hz/dB per octave)
C23 5: Whole trace amplitude balance
C24 6: Offset calculation, with lateral offset & yaw correction
C25 7: Dip based offset regularisation to integer values of offset
C26 8: Surface related multiple elimination (SRME)
C27 9: Common midpoint sort
C28 10: NMO correction (20% stretch mute), velocity function hung from WB
C29 11: Trim statics on window keyed to strongest reflectors
C30 12: AGC (25 ms gate)
C31 13: Common mid point stack
C32 14: Tailored water bottom mute (bytes 111-112)
C33 15: FX-decon and run mix
C34 16: Trace amplitude scaling (20 ms gate AGC, 50% whole trace weighting)
C35 17: Resample at 0.25 ms
C36 18: Application static for S & R depth and tide relative to MSL
C37 19: SEG-Y (Revision 1) output
C38 CDP coordinates in P190 file; navigation and tides derived from CNAV
C39 GADA, ENERGY DIVISION; COPYRIGHT COMMONWEALTH OF AUSTRALIA (GEOSCIENCE
C40 AUSTRALIA) 2013, CREATIVE COMMONS ATTRIBUTE 3.0 AUSTRALIA LICENCE

Summary of survey lines

Appendix Table C.1 Summary of line details for sparker sub-bottom profiler acquisition. First and last FFID indicate range of shots used in multichannel processing. First and last CDP indicate range of stacked traces in the final stack data.

Line Name	First FFID	Last FFID	First CDP	Last CDP	Length (km)
GA0340-001	1206	1773	88	4592	7.0
GA0340-002	2000	2216	88	1784	2.7
GA0340-003	3000	3764	88	6168	9.5
GA0340-004	4000	4879	88	7088	10.9
GA0340-005	5000	5256	88	2104	3.2
GA0340-006	6000	6727	88	5044	7.7
GA0340-007	7000	8855	88	7476	11.5
GA0340-008	9030	10740	153	7016	10.7
GA0340-009	11000	12198	88	4848	7.4
GA0340-010	13000	14067	88	4324	6.6
GA0340-011	15000	16083	88	4388	6.7
GA0340-012	17000	18147	88	4644	7.1
GA0340-013	19000	22605	88	14556	22.6
GA0340-014	23000	23440	89	1818	2.7
GA0340-015	24000	25044	89	4234	6.5
GA0340-016	26000	27152	89	4666	7.2
GA0340-017	28000	28285	89	1206	1.7
GA0340-018	29000	30111	89	4502	6.9
GA0340-019	31000	34268	89	13130	20.4
GA0340-020	35000	38588	89	14410	22.4
GA0340-021	39000	42330	89	13378	20.8
GA0340-022	43000	44427	89	5766	8.9
GA0340-023	45000	46571	89	6342	9.8
GA0340-024	47000	48573	89	6350	9.8
GA0340-025	49000	50518	89	6130	9.4
GA0340-026	51000	52588	89	6410	9.9
GA0340-027	54000	56599	89	10454	16.2
GA0340-028	57000	59676	89	10762	16.7
GA0340-029	60000	61617	89	6526	10.1
GA0340-030	62000	63716	89	6922	10.7
GA0340-031	64000	64965	89	3918	6.0
GA0340-032	65000	66654	89	6674	10.3

Line Name	First FFID	Last FFID	First CDP	Last CDP	Length (km)
GA0340-033	67000	68838	89	7410	11.4
GA0340-034	69000	70621	89	6542	10.1
GA0340-035	71000	72759	89	7094	10.9
GA0340-036	73000	76647	89	14646	22.7
GA0340-037	77000	80478	89	13970	21.7
GA0340-038	81000	84690	89	14818	23.0
GA0340-039	85000	88289	89	13214	20.5
GA0340-040	89000	90794	89	7234	11.2
GA0340-041	91000	92712	89	6906	10.7
GA0340-042	93000	94756	89	7082	10.9
GA0340-043	95000	96769	89	7134	11.0
GA0340-044	97000	98787	89	7206	11.1
GA0340-045	99000	100831	89	7382	11.4
GA0340-046	101000	102703	89	6870	10.6
GA0340-047	103000	104172	89	4746	7.3
GA0340-048	105000	107978	89	11970	18.6
GA0340-049	108000	111380	89	13578	21.1
GA0340-050	112000	115126	89	12546	19.5
GA0340-051	116000	117498	89	6050	9.3
GA0340-052	118000	118053	Aborted	Re-shot as 053	Not processed
GA0340-053	119000	122829	89	15374	23.9
GA0340-054	123000	124449	89	3084	4.7
GA0340-055	125000	125986	89	4002	6.1
GA0340-056	126000	126994	89	4034	6.2
GA0340-057	127000	128050	89	4258	6.5
GA0340-058	129000	130377	89	5566	8.6
GA0340-059	131038	132695	89	6686	10.3
GA0340-060	133000	134990	89	8018	12.4
GA0340-061	135000	137024	89	8154	12.6
GA0340-062	138000	139862	89	7506	11.6
GA0340-063	140000	141508	89	6090	9.4
GA0340-064	142000	143495	89	6038	9.3
GA0340-065	144000	145591	89	6422	9.9

Appendix D Survey Details for Parametric Sub-bottom Profiler Lines

Appendix Table D.1 List of survey lines for the parametric sub-bottom profiler acquisition. The Reference no. is used to identified the lines in Appendix Figure D.1 to Appendix Figure D.3. LF = low frequency channel (4 kHz).

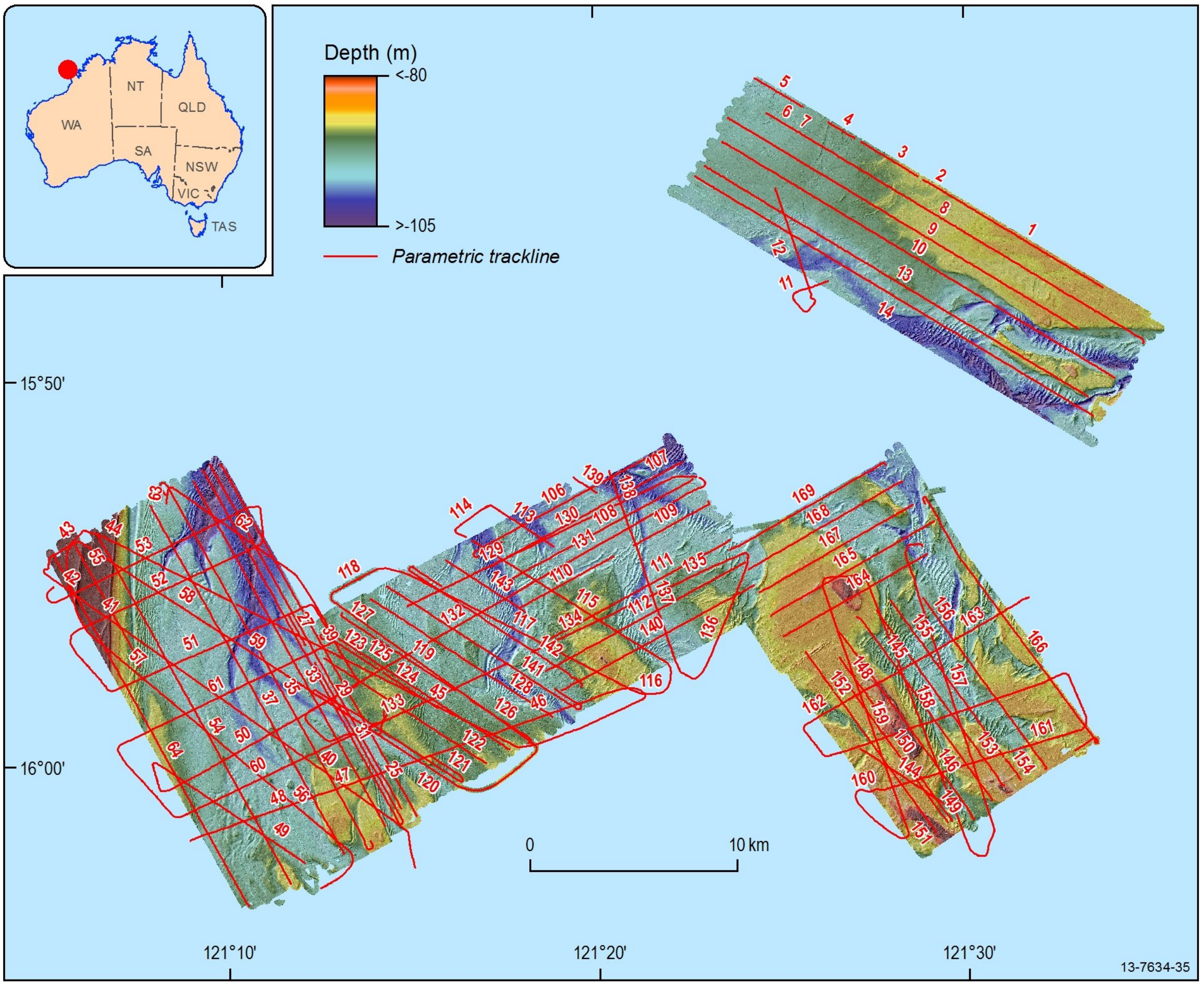
Line name	Reference no.	Area	Length (km)
GA0340_Area1_20130503_120307_LF	1	1	8.75
GA0340_Area1_20130503_123317_LF	2	1	1.24
GA0340_Area1_20130503_123908_LF	3	1	3.17
GA0340_Area1_20130503_125224_LF	4	1	1.46
GA0340_Area1_20130503_130312_LF	5	1	2.68
GA0340_Area1_20130503_191608_LF	6	1	1.39
GA0340_Area1_20130503_192357_LF	8	1	19.22
GA0340_Area1_20130504_022356_LF	9	1	19.68
GA0340_Area1_20130504_091425_LF	10	1	22.07
GA0340_Area1_20130504_190140_LF	11	1	1.90
GA0340_Area1_20130504_191408_LF	12	1	7.50
GA0340_Area1_20130505_131739_LF	13	1	21.57
GA0340_Area1_20130506_003938_LF	14	1	22.39
GA0340_Area2_20130507_055650_LF	25	2	18.93
GA0340_Area2_20130507_073705_LF	27	2	1.68
GA0340_Area2_20130507_074538_LF	29	2	9.24
GA0340_Area2_20130507_081832_LF	31	2	19.16
GA0340_Area2_20130507_115805_LF	33	2	18.94
GA0340_Area2_20130507_180856_LF	35	2	21.52
GA0340_Area2_20130508_010133_LF	37	2	19.16
GA0340_Area2_20130508_055819_LF	39	2	19.35
GA0340_Area2_20130509_161114_RAW_LF	40	2	18.56
GA0340_Area2_20130509_175209_RAW_LF	41	2	2.24
GA0340_Area2_20130509_180401_RAW_LF	42	2	2.69
GA0340_Area2_20130509_182303_RAW_LF	43	2	3.16
GA0340_Area2_20130509_190715_RAW_LF	44	2	7.20
GA0340_Area2_20130509_200042_RAW_LF	45	2	17.39
GA0340_Area2_20130509_215158_RAW_LF	46	2	18.94
GA0340_Area2_20130509_234309_RAW_LF	47	2	2.52

Line name	Reference no.	Area	Length (km)
GA0340_Area2_20130510_000000_RAW_LF	48	2	6.40
GA0340_Area2_20130510_163131_RAW_LF	49	2	9.54
GA0340_Area2_20130510_172750_RAW_LF	50	2	11.21
GA0340_Area2_20130510_185937_RAW_LF	51	2	17.39
GA0340_Area2_20130510_203908_RAW_LF	52	2	16.80
GA0340_Area2_20130510_223037_RAW_LF	53	2	8.54
GA0340_Area2_20130511_005437_RAW_LF	54	2	19.22
GA0340_Area2_20130511_040423_RAW_LF	55	2	6.82
GA0340_Area2_20130511_141435_RAW_LF	56	2	13.94
GA0340_Area2_20130511_153836_RAW_LF	57	2	6.37
GA0340_Area2_20130511_161416_RAW_LF	58	2	12.67
GA0340_Area2_20130511_173823_RAW_LF	59	2	8.13
GA0340_Area2_20130511_184129_RAW_LF	60	2	13.00
GA0340_Area2_20130511_195103_RAW_LF	61	2	12.54
GA0340_Area2_20130511_211507_RAW_LF	62	2	13.84
GA0340_Area2_20130511_223908_RAW_LF	63	2	1.24
GA0340_Area2_20130512_032539_RAW_LF	64	2	19.32
GA0340_Area3_20130512_154358_RAW_LF	65	3	5.60
GA0340_Area3_20130512_160447_RAW_LF	66	3	10.45
GA0340_Area3_20130512_164331_RAW_LF	67	3	2.88
GA0340_Area3_20130513_094633_RAW_LF	68	3	18.66
GA0340_Area3_20130513_154146_RAW_LF	69	3	1.74
GA0340_Area3_20130513_155207_RAW_LF	70	3	7.00
GA0340_Area3_20130513_163512_RAW_LF	71	3	3.79
GA0340_Area3_20130513_170150_RAW_LF	72	3	8.79
GA0340_Area3_20130513_180455_RAW_LF	73	3	12.74
GA0340_Area3_20130513_192901_RAW_LF	74	3	14.48
GA0340_Area3_20130513_205304_RAW_LF	75	3	9.68
GA0340_Area3_20130514_001642_RAW_LF	76	3	21.01
GA0340_Area3_20130516_225648_RAW_LF	77	3	16.42
GA0340_Area3_20130517_000000_RAW_LF	78	3	3.92
GA0340_Area3_20130517_081412_RAW_LF	79	3	2.28
GA0340_Area3_20130517_104815_RAW_LF	80	3	2.99
GA0340_Area3_20130517_110446_RAW_LF	81	3	1.18
GA0340_Area3_20130517_110933_RAW_LF	82	3	8.12
GA0340_Area3_20130517_114017_RAW_LF	83	3	5.29
GA0340_Area3_20130517_120006_RAW_LF	84	3	1.15

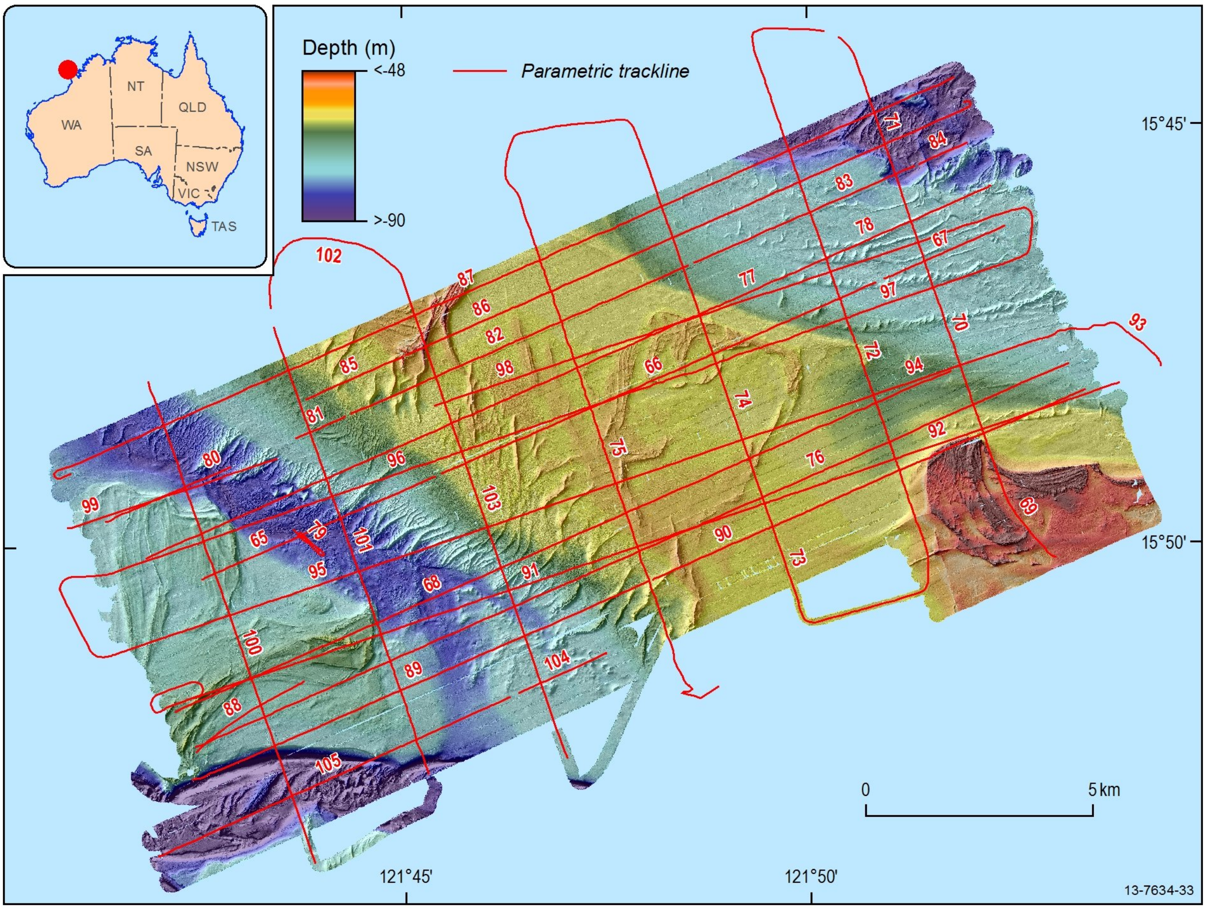
Line name	Reference no.	Area	Length (km)
GA0340_Area3_20130517_161819_RAW_LF	85	3	2.32
GA0340_Area3_20130517_162641_RAW_LF	86	3	13.84
GA0340_Area3_20130517_210711_RAW_LF	87	3	22.14
GA0340_Area3_20130518_101111_RAW_LF	88	3	2.83
GA0340_Area3_20130518_103113_RAW_LF	89	3	10.97
GA0340_Area3_20130518_111144_RAW_LF	90	3	10.39
GA0340_Area3_20130518_135434_RAW_LF	91	3	12.18
GA0340_Area3_20130518_151841_RAW_LF	92	3	12.40
GA0340_Area3_20130518_165053_RAW_LF	93	3	2.54
GA0340_Area3_20130518_171040_RAW_LF	94	3	12.44
GA0340_Area3_20130518_183448_RAW_LF	95	3	9.71
GA0340_Area3_20130518_194102_RAW_LF	96	3	12.75
GA0340_Area3_20130518_210514_RAW_LF	97	3	12.19
GA0340_Area3_20130518_222916_RAW_LF	98	3	14.68
GA0340_Area3_20130519_001352_RAW_LF	99	3	4.84
GA0340_Area3_20130519_012244_RAW_LF	100	3	11.23
GA0340_Area3_20130519_030637_RAW_LF	101	3	10.42
GA0340_Area3_20130519_042037_RAW_LF	102	3	4.22
GA0340_Area3_20130519_044746_RAW_LF	103	3	11.33
GA0340_Area3_20130519_142311_RAW_LF	104	3	2.11
GA0340_Area3_20130519_143145_RAW_LF	105	3	8.49
GA0340_Area4_20130520_063045_RAW_LF	106	4	12.01
GA0340_Area4_20130520_091823_RAW_LF	107	4	10.48
GA0340_Area4_20130520_120206_RAW_LF	108	4	10.77
GA0340_Area4_20130520_161537_RAW_LF	109	4	4.29
GA0340_Area4_20130520_163429_RAW_LF	110	4	5.20
GA0340_Area4_20130520_202456_RAW_LF	111	4	10.44
GA0340_Area4_20130521_103816_RAW_LF	112	4	10.96
GA0340_Area4_20130521_140137_RAW_LF	113	4	2.95
GA0340_Area4_20130521_142007_RAW_LF	114	4	3.41
GA0340_Area4_20130521_144356_RAW_LF	115	4	12.15
GA0340_Area4_20130521_160804_RAW_LF	116	4	1.62
GA0340_Area4_20130521_161558_RAW_LF	117	4	14.12
GA0340_Area4_20130521_173958_RAW_LF	118	4	3.51
GA0340_Area4_20130521_175746_RAW_LF	119	4	11.20
GA0340_Area4_20130521_190923_RAW_LF	120	4	12.43
GA0340_Area4_20130521_203326_RAW_LF	121	4	11.42

Line name	Reference no.	Area	Length (km)
GA0340_Area4_20130522_000312_RAW_LF	122	4	9.30
GA0340_Area4_20130522_023952_RAW_LF	123	4	3.53
GA0340_Area4_20130522_025524_RAW_LF	124	4	3.12
GA0340_Area4_20130522_032604_RAW_LF	125	4	10.37
GA0340_Area4_20130522_064241_RAW_LF	126	4	3.71
GA0340_Area4_20130522_070029_RAW_LF	127	4	6.67
GA0340_Area4_20130522_112844_RAW_LF	128	4	10.45
GA0340_Area4_20130522_132932_RAW_LF	129	4	7.96
GA0340_Area4_20130522_142314_RAW_LF	130	4	7.35
GA0340_Area4_20130522_151611_RAW_LF	131	4	12.64
GA0340_Area4_20130522_164013_RAW_LF	132	4	9.80
GA0340_Area4_20130522_174033_RAW_LF	133	4	11.44
GA0340_Area4_20130522_191443_RAW_LF	134	4	7.19
GA0340_Area4_20130522_200806_RAW_LF	135	4	4.77
GA0340_Area4_20130522_204602_RAW_LF	136	4	7.51
GA0340_Area4_20130522_212943_RAW_LF	137	4	7.55
GA0340_Area4_20130522_222305_RAW_LF	138	4	2.01
GA0340_Area4_20130522_230639_RAW_LF	139	4	1.31
GA0340_Area4_20130523_111729_RAW_LF	140	4	10.54
GA0340_Area4_20130523_192346_RAW_LF	141	4	12.76
GA0340_Area4_20130523_225706_RAW_LF	142	4	12.10
GA0340_Area4_20130524_020256_RAW_LF	143	4	4.54
GA0340_Area5_20130524_152558_RAW_LF	144	5	5.25
GA0340_Area5_20130524_163301_RAW_LF	145	5	11.00
GA0340_Area5_20130524_200529_RAW_LF	146	5	11.09
GA0340_Area5_20130524_222637_RAW_LF	147	5	0.00
GA0340_Area5_20130524_222638_RAW_LF	148	5	3.37
GA0340_Area5_20130524_231221_RAW_LF	149	5	3.40
GA0340_Area5_20130525_000440_RAW_LF	150	5	8.75
GA0340_Area5_20130525_022620_RAW_LF	151	5	8.36
GA0340_Area5_20130525_030100_RAW_LF	152	5	2.23
GA0340_Area5_20130525_072537_RAW_LF	153	5	10.43
GA0340_Area5_20130525_101652_RAW_LF	154	5	1.18
GA0340_Area5_20130525_102210_RAW_LF	155	5	9.24
GA0340_Area5_20130525_144241_RAW_LF	156	5	10.18
GA0340_Area5_20130527_141746_RAW_LF	157	5	15.04
GA0340_Area5_20130527_154841_RAW_LF	158	5	14.18

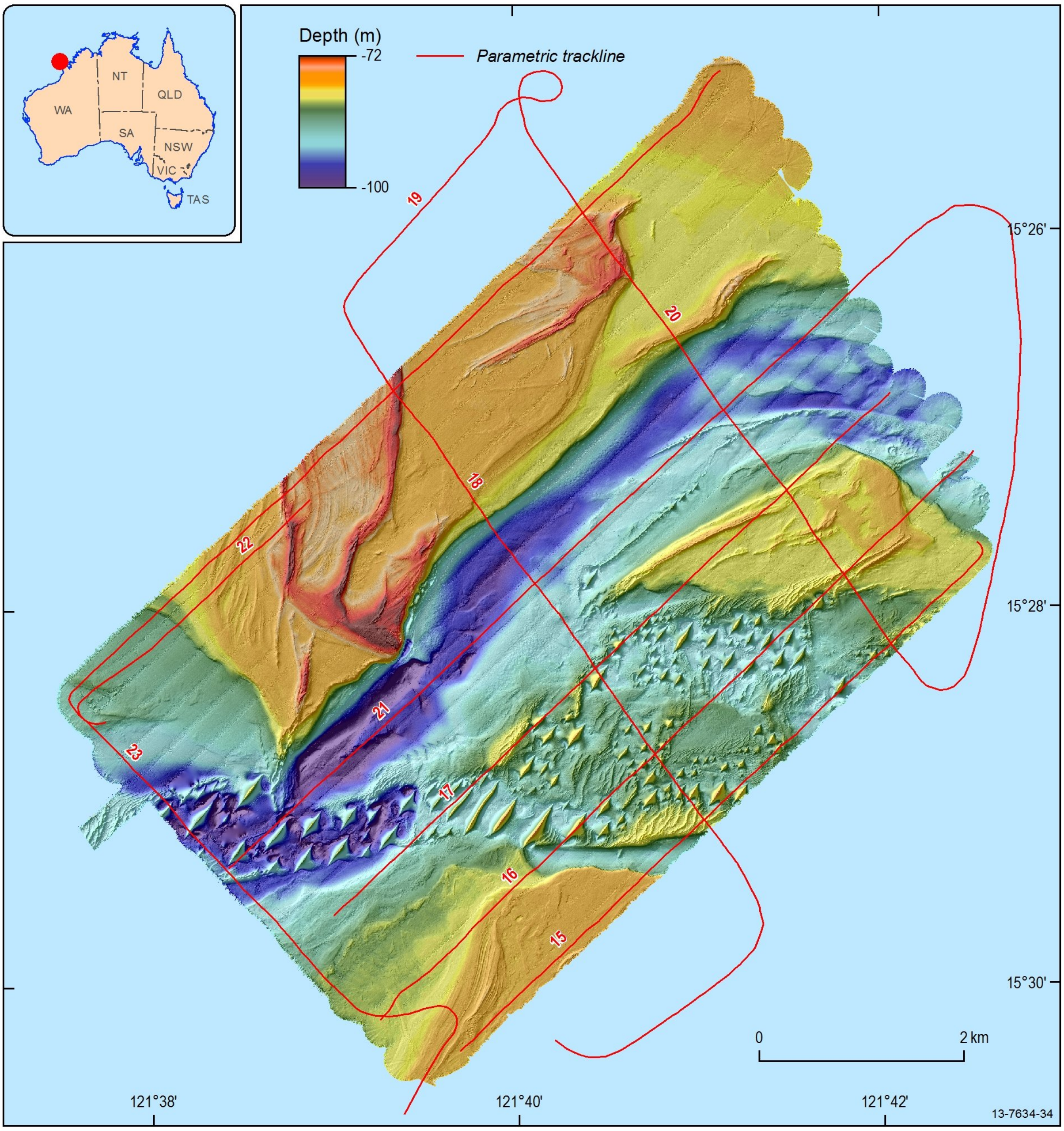
Line name	Reference no.	Area	Length (km)
GA0340_Area5_20130527_171918_RAW_LF	159	5	13.72
GA0340_Area5_20130527_184952_RAW_LF	160	5	13.36
GA0340_Area5_20130527_202028_RAW_LF	161	5	14.43
GA0340_Area5_20130527_215102_RAW_LF	162	5	15.12
GA0340_Area5_20130527_232137_RAW_LF	163	5	5.07
GA0340_Area5_20130528_120931_RAW_LF	164	5	7.94
GA0340_Area5_20130528_144558_RAW_LF	165	5	9.09
GA0340_Area5_20130528_204734_RAW_LF	166	5	16.32
GA0340_Area5_20130529_015531_RAW_LF	167	5	8.50
GA0340_Area5_20130529_045150_RAW_LF	168	5	8.54
GA0340_Area5_20130529_081202_RAW_LF	169	5	8.69
GA0340_Area10_20130525_212924_RAW_LF	15	10	7.19
GA0340_Area10_20130525_232549_RAW_LF	16	10	8.05
GA0340_Area10_20130526_015819_RAW_LF	17	10	7.46
GA0340_Area10_20130526_132858_RAW_LF	18	10	10.33
GA0340_Area10_20130526_144832_RAW_LF	19	10	3.76
GA0340_Area10_20130526_151224_RAW_LF	20	10	6.76
GA0340_Area10_20130526_155333_RAW_LF	21	10	15.11
GA0340_Area10_20130526_195846_RAW_LF	22	10	3.41
GA0340_Area10_20130526_203556_RAW_LF	23	10	15.16



Appendix Figure D.1 Location map showing the parametric sub-bottom profiler lines for Areas 1, 2, 4, and 5. The numbers correspond to the Reference no. found in Table D.1



Appendix Figure D.2 Location map showing the parametric sub-bottom profiler lines for Area 3. The numbers correspond to the Reference no. found in Table D.1



Appendix Figure D.3 Location map showing the parametric sub-bottom profiler lines for Area 10. The numbers correspond to the Reference no. found in Table D.1

Appendix E Survey Details for Geochemical Samples

Appendix Table E.1 List of sub-samples from the grabs designated for geochemical analysis. Grab numbers are shown in the columns. The letters/numbers C_XX correspond to the extensions that are applied to the survey/station/grab numbers in the corporate database to designate what analyses the sub-sample is intended for e.g. GA0340/08GR21C_D1 designates a sub-sample from GA Survey number 0340 (this survey) collected at Station 08 from Grab 021 for the purposes of elemental, carbonate and surface area analyses (C_D1).

Station	Chlorins, Porosity, Mineralogy (C_B1)	Chlorophyll abc (C_B2)	Porosity (C_B3)	SOD* (C_C1)	Bottle incubation (C_C2)	Core incubation (C_C3)	Elements, Carbonate, Specific Surface Area (C_D1)	Spare (C_E1)	Biomarkers (C_E2)	Specimen (C_S1)
01	003	&	&	003	@	003	003		003	
02	006	006	006	006	006		006		006	
03	009	009	009	009	009	009	009		x	
04	012	012	012	012	012		012		012	
06	015	015	015	015	015		015		x	
07	018	018	018	018	018		018		x	
08	021	021	021	021	021		021		021	
09	024	024	024	024	024	024	024	024	024	
10	027	027	027	027	027		027	027	027	
11	030	030	030	030	030		030	030	x	
12	033	033	033	033	033	033	033	033	033	
13	036	036	036	036	036	036	036	036	x	
14	014	014	014	014	014		014	014	x	
15	043	043	043	043	043	043	043	043	043	
16	046	046	046	046	046		046	046	x	

Station	Chlorins, Porosity, Mineralogy (C_B1)	Chlorophyll abc (C_B2)	Porosity (C_B3)	SOD* (C_C1)	Bottle incubation (C_C2)	Core incubation (C_C3)	Elements, Carbonate, Specific Surface Area (C_D1)	Spare (C_E1)	Biomarkers (C_E2)	Specimen (C_S1)
17	049	049	049	049	049		049	049	x	
18	053	053	053	053	053		053	053	x	
19	056	056	056	056	056		056	056	x	
20	059	059	059	059	059	059	059	059	059	
21	062	062	062	062	062		062	062	062	062
22	065	065	065	065	065		065	065	065	
23	068	068	068	068	068		068	068	x	068
24	071	071	071	071	071	071	071	071	x	071
25	074	074	074	074	074		074	074	x	
26	077	077	077	077	077	077	077	077	x	
27	080	080	080	080	080	080	080	080	x	
28	083	083	083	083	083		083	083	083	083
29	086	086	086	086	086		086	086	x	086
31	089	+	+	089	089	089	089	089	x	
32	092	092	092	092	092		092	092	x	
34	095	095	095	095	095	095	095	095	x	
35	+	+	+	+	+		096	+	+	
36	100	100	100	100	100		100	100	x	
37	103	+	+	103	103	103	103	103	x	
38	106	106	106	106	106		106	106	x	
39	109	109	109	109	109		109	109	x	
40	112	112	112	112	112	112	112	112	x	
41	115	115	115	115	115		115	115	x	

Station	Chlorins, Porosity, Mineralogy (C_B1)	Chlorophyll abc (C_B2)	Porosity (C_B3)	SOD* (C_C1)	Bottle incubation (C_C2)	Core incubation (C_C3)	Elements, Carbonate, Specific Surface Area (C_D1)	Spare (C_E1)	Biomarkers (C_E2)	Specimen (C_S1)
42	118	118	118	118	118		118	118	x	
43	121	121	121	121	121		121	121	x	
44	124	124	124	124	124		124	124	x	
45	127	127	127	127	127		127	127	x	
46	131	131	131	131	131		131	131	x	131
47	134	134	134	134	134		134	134	x	134
48	137	137	137	137	137		137	137	x	
49	140	140	140	140	140		140	140	x	140
50	+	143	143	+	143		143	143	x	
51	146	146	146	146	146		146	146	x	
52	+	+	+	+	+	+	149	+	+	149
53	152	152	152	152	152		152	152	x	
54	155	155	155	155	155		155	155	x	
55	158	158	158	158	158		158	158	x	
56	161	161	161	161	161		161	161	x	
57	164	164	164	164	164		164	164	x	
58	167	167	167		$167		167	167	x	

(&) equipment failure; (x) too sandy; (@) lost sample; ($) Initial sample (T=0) only; (+) poor recovery or inadequate surface; (^) time inadequate to complete incubation; (*) SOD refers to sediment oxygen demand.

Appendix F Survey Details for CTD Casts

Appendix Table F.1 CTD locations, water depths and weather conditions highlighted in the comments.

Station	CTD number	Area	Start longitude	Start latitude	End longitude	End latitude	Water depth (m)	Acquisition date	Comments
01	CTD01	1	121.552733	-15.815900	121.552400	-15.815617	93	5/5/2013	
05	CTD02	1	121.575283	-15.821167	121.574833	-15.820900	94	5/5/2013	full sun
06	CTD03	1	121.438233	-15.729300	121.438367	-15.729533	91	5/5/2013	full sun
08	CTD04	1	121.426883	-15.729567	121.426667	-15.729700	92	5/5/2013	full sun
09	CTD05	1	121.451533	-15.756667	121.451517	-15.756600	89	6/5/2013	full sun
10	CTD06	1	121.466017	-15.756200	121.466133	-15.756217	87	6/5/2013	full sun
11	CTD07	1	121.534483	-15.809717	121.534833	-15.809717	82	6/5/2013	sunset
12	CTD08	2	121.184883	-15.986167	121.184933	-15.986000	97	10/5/2013	partly cloudy
13	CTD09	2	121.233717	-15.999267	121.233400	-15.998867	97	10/5/2013	partly cloudy
15	CTD10	2	121.233333	-16.018000	121.232717	-16.017633	86	10/5/2013	partly cloudy; strong tidal flow; CTD trailing to aft
16	CTD11	2	121.122117	-15.931367	121.121483	-15.931217	88	11/5/2013	full sun
17	CTD12	2	121.165500	-15.953000	121.165133	-15.953133	93	11/5/2013	setting sun
18	CTD13	2	121.215117	-16.033533	121.214333	-16.033133	80	12/5/2013	full sun
19	CTD14	2	121.151517	-16.000033	121.150483	-15.999767	92	12/5/2013	setting sun
20	CTD15	3	121.709100	-15.847900	121.708867	-15.847817	71	14/5/2013	partly cloudy
21	CTD16	3	121.732500	-15.836433	121.731683	-15.836417	80	14/5/2013	overcast

Station	CTD number	Area	Start longitude	Start latitude	End longitude	End latitude	Water depth (m)	Acquisition date	Comments
22	CTD17	3	121.730667	-15.832683	121.730333	-15.832417	85	17/5/2013	partly cloudy
23	CTD18	3	121.738317	-15.841833	121.736967	-15.841500	80	17/5/2013	partly cloudy at dusk
24	CTD19	3	121.743417	-15.845583	121.743133	-15.845567	70	18/5/2013	partly cloudy
25	CTD20	3	121.736233	-15.853500	121.736200	-15.853583	67	18/5/2013	2nd attempt
26	CTD21	3	121.850000	-15.781800	121.849983	-15.781783	78	18/5/2013	sunny
27	CTD22	3	121.805617	-15.796000	121.805500	-15.795900	60	18/5/2013	sunny
28	CTD23	3	121.767083	-15.843883	121.766767	-15.843783	80	18/5/2013	setting sun
29	CTD24	3	121.821517	-15.817633	121.821417	-15.817933	58	19/5/2013	partly cloudy
31	CTD25	3	121.710633	-15.877500	121.710283	-15.877817	83	19/5/2013	nightfall
32	CTD26	3	121.876617	-15.819767	121.876400	-15.820100	48	20/5/2013	overcast and showers
33	CTD27	4	121.283217	-15.912050	121.284333	-15.912333	99	20/5/2013	
34	CTD28	4	121.348233	-15.895233	121.347983	-15.895033	97	21/5/2013	partly cloudy
35	CTD29	4	121.336133	-15.895700	121.335767	-15.895400	96	21/5/2013	partly cloudy
36	CTD30	4	121.295567	-15.921200	121.295500	-15.921333	95	21/5/2013	sunny
37	CTD31	4	121.290217	-15.904183	121.290400	-15.904300	94	21/5/2013	partly cloudy, setting sun
38	CTD32	4	121.310800	-15.943900	121.310417	-15.943483	90	23/5/2013	partly cloudy
39	CTD33	4	121.342417	-15.926267	121.341783	-15.925883	91	23/5/2013	partly cloudy
40	CTD34	4	121.339400	-15.896300	121.339017	-15.896233	94	23/5/2013	overcast
41	CTD35	4	121.276333	-15.978100	121.276117	-15.978217	91	23/5/2013	overcast
42	CTD36	4	121.309267	-15.949983	121.308233	-15.949817	91	24/5/2013	sunny
43	CTD37	4	121.262400	-15.952567	121.262000	-15.952567	91	24/5/2013	partly cloudy

Station	CTD number	Area	Start longitude	Start latitude	End longitude	End latitude	Water depth (m)	Acquisition date	Comments
44	CTD38	4	121.231417	-15.963300	121.231283	-15.963683	88	24/5/2013	dusk
45	CTD39	10	121.666500	-15.483117	121.651117	-15.499500	94	26/5/2013	sunny
46	CTD40	10	121.654917	-15.484733	121.653983	-15.484600	89	26/5/2013	sunny
47	CTD41	10	121.687017	-15.458367	121.686500	-15.458500	77	26/5/2013	nightfall
48	CTD42	5	121.431017	-15.951933	121.431183	-15.952217	83	27/5/2013	sunny
49	CTD43	5	121.483867	-15.982000	121.483917	-15.982000	96	27/5/2013	sunny
50	CTD44	5	121.469717	-15.979633	121.469717	-15.979617	89	27/5/2013	sunny
51	CTD45	5	121.448200	-15.985433	121.448200	-15.984033	89	27/5/2013	sunny
52	CTD46	5	121.485333	-16.027883	121.483117	-16.026800	76	27/5/2013	sunny
53	CTD47	5	121.519700	-16.008400	121.518850	-16.008567	79	27/5/2013	nightfall
54	CTD48	5	121.487317	-15.947467	121.488133	-15.948200	98	28/5/2013	sunny
55	CTD49	5	121.497167	-15.940283	121.497317	-15.940783	90	28/5/2013	sunny
56	CTD50	5	121.481800	-15.923500	121.481767	-15.923567	92	28/5/2013	sunny
57	CTD51	1	121.465683	-15.756867	121.465000	-15.756467	90	28/5/2013	sunny
58	CTD52	1	121.545800	-15.830317	121.544217	-15.829717	81	28/5/2013	sunny

Appendix G Survey Details for Surface Sediment Grab (GR) Samples

Appendix Table G.1 Smith McIntyre and Shipek grab sample (∞) locations, water depths and field descriptions. Note field descriptions are preliminary only, based on observations by shipboard sedimentologist and are subject to changes with further analytical testing. denotes no Munsell colour was described on station form.*

Station	Grab Number	Area	Longitude	Latitude	Water depth (m)	Munsell Colour	Sample description
01	GR01	1	121.5577	-15.8101	99	5Y 5/2	Muddy coarse sand, small shell pieces, few forams
01	GR02	1	121.5580	-15.8093	84.5	5Y 5/2	Muddy sand, rare shell fragments
02	GR04	1	121.5539	-15.8144	90	5Y 4/4	Mixed muddy coarse sand, some gravel, a possible coral clast
02	GR05	1	121.5543	-15.8145	90.4	5Y 4/3	Muddy gravelly sand, an organic clast present
03	GR07	1	121.5476	-15.8211	97.3	5Y 5/3	Medium coarse moderately well sorted sand, small shell pieces present
03	GR08	1	121.5478	-15.8210	97.3	5Y 6/4	Well-sorted, equigranular sand, rare shell pieces
04	GR10	1	121.5744	-15.8139	89.2	5Y 5/4	Gritty sand, several bioclasts
04	GR11	1	121.5755	-15.8150	89.9	5Y 5/3	Gritty poorly sorted sand, mollusc valves, bryozoa, echinoid spines (?) present
06	GR13	1	121.4320	-15.7315	91.2	2.5Y 5/6	Medium-coarse moderately well-sorted sand, forams and fine shell pieces present
06	GR14	1	121.4322	-15.7304	91.6	2.5Y 5/6	Gritty moderately sorted sand, small bivalve mollusc valves, forams, bryozoa pieces present
07	GR16	1	121.4379	-15.7296	90	2.5Y 6/4	Coarse shelly sand, moderately well-sorted, some fine fraction, bryozoa fragments present
07	GR17	1	121.4383	-15.7296	91.2	2.5Y 6/4	Moderately well-sorted coarse sand shell hash, composed predominantly of shell bryozoa and other carbonate pieces
08	GR19	1	121.4271	-15.7296	92.3	2.5Y 7/4	Coarse shelly sand, well sorted, some fine fraction
08	GR20	1	121.4273	-15.7296	91.9	2.5Y 6/4	Coarse shelly sand, large shell fragments, few small clasts

Station	Grab Number	Area	Longitude	Latitude	Water depth (m)	Munsell Colour	Sample description
09	GR22	1	121.4519	-15.7568	88.6	2.5Y 5/4	Medium-grained sand, poorly sorted, shell fragments
09	GR23	1	121.4526	-15.7570	88.6	2.5Y 5/4	Medium-grained sand, poorly sorted, shell fragments
10	GR25	1	121.4664	-15.7561	86.7	2.5Y 4/3	Medium-grained sand, minor shell fragments
10	GR26	1	121.4663	-15.7560	86.5	2.5Y 5/4	Shell sand
11	GR28	1	121.5340	-15.8097	82.3	2.5Y 5/4	Coarse gritty sand, few bivalve valves, shell pieces, bryozoan pieces, echinoid spines
11	GR29	1	121.5343	-15.8096	82.3	2.5Y 6/3	Coarse shelly sand, moderately sorted, shell pieces, echinoid spines
12	GR31	2	121.1844	-15.9867	97.9	2.5Y 5/3	Medium to coarse carbonate sand, poorly sorted
12	GR32	2	121.1847	-15.9867	97.2	2.5Y 5/4	Medium to coarse carbonate sand, poorly sorted
13	GR34	2	121.2347	-16.0001	98.1	2.5Y 5/3	Coarse shelly sand, minor mud
13	GR35	2	121.2342	-16.0000	97.4	2.5Y 5/3	Coarse shelly sand, minor mud
14	GR37	2	121.2373	-16.0011	94.2	2.5Y 5/3	Moderately sorted carbonate sand with minor mud
14	GR38	2	121.2369	-16.0009	93.9	2.5Y 5/3	Medium to coarse carbonate sand, moderately sorted
15	GR40	2	121.2346	-16.0194	95.3	2.5Y 5/4	Muddy coarse sand with shell fragments
15	GR41	2	121.2347	-16.0193	96.4	*	Muddy medium to coarse carbonate sand, shell fragments, poorly sorted
15	GR42	2	121.2335	-16.0193	85.8	*	Second drop, slightly off station, kept as extra sample from interfluve bank, slightly muddy sand
16	GR44∞	2	121.1232	-15.9307	89.3	2.5Y 5/4	Muddy to medium sand, moderate sorting
16	GR45∞	2	121.1230	-15.9306	88.4	2.5Y 5/4	Small sample, shelly sand with some large shell fragments
17	GR47∞	2	121.1654	-15.9522	93	2.5Y 5/4	Coarse shelly sand, shell fragment, gravel clast and cemented carbonate present
17	GR48	2	121.1653	-15.9523	93	2.5Y 5/4	Shelly sand
18	GR50	2	121.2143	-16.0335	80.4	2.5Y 5/4	Silty sand, hard seabed, <2 % recovery

Station	Grab Number	Area	Longitude	Latitude	Water depth (m)	Munsell Colour	Sample description
18	GR51	2	121.2162	-16.0336	85.3	2.5Y 5/4	Poorly sorted coarse carbonate, sand and gravel
18	GR52	2	121.2164	-16.0334	85.3	2.5Y 5/4	Poorly sorted sand, many shell fragments
19	GR54	2	121.1561	-16.0027	91	2.5Y 5/3	Moderately sorted muddy sand, minor shell fragments
19	GR55	2	121.1557	-16.0030	91	2.5Y 5/2	Sand, minor shell fragments
20	GR57	3	121.7087	-15.8481	70.5	2.5Y 5/4	Coarse carbonate sand, minor shell fragments
20	GR58	3	121.7093	-15.8480	71	2.5Y 4/4	Coarse sand, minor mud, shell fragments
21	GR60	3	121.7345	-15.8367	80	2.5Y 5/3	Sandy mud
21	GR61	3	121.7342	-15.8363	80	2.5Y 5/4	Muddy coarse sand, some shell fragments
22	GR63	3	121.7312	-15.8325	83.5	5Y 5/3	Muddy sand with some shell fragments
22	GR64	3	121.7312	-15.8327	83.5	5Y 5/3	Muddy sand with shell fragments
23	GR66	3	121.7384	-15.8424	78	5Y 5/3	Muddy sand, minor shell fragments
23	GR67	3	121.7376	-15.8423	79	5Y 5/3	Muddy sand, minor shell fragments
24	GR69	3	121.7433	-15.8456	70	5Y 5/3	Muddy sand with minor shell frags
24	GR70	3	121.7431	-15.8454	70	5Y 5/3	Muddy sand with minor shell fragments
25	GR72	3	121.7374	-15.8523	63	5Y 5/3	Muddy sand, fine carbonate particles present
25	GR73	3	121.7371	-15.8520	62	5Y 5/3	Muddy sand, fine carbonate particles present
26	GR75	3	121.8508	-15.7822	73	5Y 5/2	Medium grained shell hash sand, some mud content
26	GR76	3	121.8503	-15.7824	72	5Y 5/3	Medium grained shell hash sand, minor mud content
27	GR78	3	121.8066	-15.7967	56	5Y 5/3	Muddy coarse shell hash sand
27	GR79	3	121.8062	-15.7969	57	5Y 5/3	Muddy coarse shell hash sand
28	GR81	3	121.7663	-15.8444	78	5Y 5/3	Fine muddy sand, sticky consistency, shell fragments present

Station	Grab Number	Area	Longitude	Latitude	Water depth (m)	Munsell Colour	Sample description
28	GR82	3	121.7672	-15.8443	78	5Y 5/3	Fine muddy sand, sticky consistency, shell fragments present
29	GR84	3	121.8220	-15.8157	57	5Y 5/3	Fine-medium muddy shelly sand, common angular coarse shell frags; some coral rubble and blackened carbonate aggregates
29	GR85	3	121.8215	-15.8165	56	5Y 5/3	Muddy shelly sand, abundant angular coarse shell fragments
31	GR87	3	121.7112	-15.8778	85	5Y 5/3	Fine muddy sand with large coral fragments
31	GR88	3	121.7110	-15.8775	83	5Y 5/3	Fine muddy sand with cemented carbonates (shell/sand/coral coquina)
32	GR90	3	121.8775	-15.8202	46	5Y 6/2	Coarse shell/coral hash
32	GR91	3	121.8773	-15.8203	46	5Y 6/2	Medium sand with shell hash, minor mud and some biota
34	GR93	4	121.3478	-15.8953	96	5Y 5/3	Medium sand with scattered shell fragments, slightly muddy
34	GR94	4	121.3478	-15.8952	97	5Y 5/3	Medium sand with scattered shell fragments, slightly muddy
35	GR96	4	121.3370	-15.8958	95	5Y 5/3	Muddy medium sand with abundant fine-medium shell hash
35	GR97	4	121.3372	-15.8957	94	5Y 5/3	Muddy medium coarse sand with coarse shell fragments
36	GR98	4	121.2963	-15.9207	93	5Y 5/3	Muddy shelly sand with large fragments of cemented carbonate shelly sand
36	GR99	4	121.2965	-15.9372	93	5Y 5/3	Fragments of cemented carbonate sand common
37	GR101	4	121.2897	-15.9033	93	5Y 5/3	Mixed cemented carbonate sand, shells and coral rubble with matrix muddy sand
37	GR102	4	121.2897	-15.9033	93	5Y 5/3	Shelly, cemented carbonate sand
38	GR104	4	121.3112	-15.9440	90	5Y 5/3	Fine sand, occasional shell and cemented carbonate sand fragments
38	GR105	4	121.3113	-15.9440	89	5Y 5/3	Fine sand with minor shell and cemented carbonate fragments
39	GR107	4	121.3435	-15.9260	91	5Y 5/3	Fine muddy sand with shell fragments
39	GR108	4	121.3435	-15.9265	91	5Y 5/3	Fine muddy sand with shell fragments
40	GR110	4	121.3400	-15.8962	93	5Y 5/3	Muddy fine-medium sand with abundant shell fragments
40	GR111	4	121.3402	-15.8963	93	5Y 5/3	Fine muddy sand with abundant shell fragments

Station	Grab Number	Area	Longitude	Latitude	Water depth (m)	Munsell Colour	Sample description
41	GR113	4	121.2772	-15.9780	89	5Y 6/3	Medium shelly sand
41	GR114	4	121.2767	-15.9782	90	5Y 6/3	Medium shelly sand
42	GR116	4	121.3100	-15.9500	84	5Y 5/4	Coarse rubbly shell hash muddy sand with cemented carbonate sand aggregates
42	GR117	4	121.3100	-15.9503	89	5Y 5/4	Coarse rubbly shell hash muddy sand with cemented carbonate sand aggregates
43	GR119	4	121.2632	-15.9518	89	5Y 5/3	Muddy medium coarse shelly sand and isolated cemented carbonate sand fragments
43	GR120	4	121.2627	-15.9522	89	5Y 5/3	Muddy medium coarse shelly sand and isolated cemented carbonate sand fragments
44	GR122	4	121.2315	-15.9635	87	5Y 5/3	Muddy fine sand with scattered coarse shell fragments
44	GR123	4	121.2312	-15.9632	87	5Y 5/3	Muddy fine sand with scattered coarse shell fragments
45	GR125	10	121.6487	-15.4832	92	5Y 5/3	Medium-coarse shelly sand
45	GR126	10	121.6498	-15.4833	91	5Y 5/3	Medium-coarse shelly sand
46	GR128	10	121.6548	-15.4850	97	5Y 5/3	Coarse poorly sorted shell hash sand with coral and shell fragments
46	GR129	10	121.6553	-15.4845	95	5Y 5/3	Coarse poorly sorted shell hash sand with coral and shell fragments
46	GR130	10	121.6548	-15.4847	97	*	Coarse shell hash sand with coral/shell fragments. Poor recovery, <5 %, but a large fragment of carbonate recovered
47	GR132	10	121.6880	-15.4587	74	5Y 4/3	Fine-medium, slightly cohesive muddy sand
47	GR133	10	121.6878	-15.4585	75	5Y 4/3	Fine-medium, slightly cohesive sand and small fragments of cemented carbonate sand
48	GR135	5	121.4320	-15.9530	83	5Y 5/2	Coarse shell hash sand
48	GR136	5	121.4320	-15.9530	84	5Y 5/2	Coarse shell hash sand
49	GR138	5	121.4830	-15.9815	93	5Y 5/3	Medium-coarse moderately sorted sand with shell hash
49	GR139	5	121.4835	-15.9820	94	5Y 5/3	Medium-coarse moderately sorted sand with shell hash
50	GR141	5	121.4695	-15.9788	81	5Y 5/4	Fine muddy sand with occasional cemented carbonate fragments

Station	Grab Number	Area	Longitude	Latitude	Water depth (m)	Munsell Colour	Sample description
50	GR142	5	121.4697	-15.9793	81	5Y 5/4	Fine muddy sand with occasional cemented carbonate fragments
51	GR144	5	121.4465	-15.9847	86	5Y 5/4	Slightly muddy medium sand with shell fragments, relatively fine consistency.
51	GR145	5	121.4463	-15.9852	87	5Y 5/4	Slightly muddy medium sand with shell fragments, relatively fine consistency.
52	GR147	5	121.4832	-16.0282	73	5Y 5/4	Medium-coarse slightly muddy sand with shell hash, a large coral specimen recovered
52	GR148	5	121.4828	-16.0278	73	5Y 5/4	Medium-coarse slightly muddy sand with shell hash
53	GR150	5	121.5188	-16.0088	78	5Y 5/4	Medium-coarse shell hash sand with shell fragments
53	GR151	5	121.5180	-16.0088	78	5Y 5/4	Medium-coarse shell hash sand with shell fragments
54	GR153	5	121.4875	-15.9485	97	5Y 5/4	Fine to medium muddy sand and shell hash with coarser shell fragments and cemented carbonate sand
54	GR154	5	121.4877	-15.9488	97	5Y 5/4	Fine to medium muddy sand and shell hash with abundant carbonate sand and shell fragments
55	GR156	5	121.4992	-15.9408	89	5Y 5/4	Fine-medium muddy sand with shell hash and coarse fragments
55	GR157	5	121.4993	-15.9403	90	5Y 5/4	Fine-medium muddy sand with less shell hash than GR156. A very large sponge sample revered
56	GR159	5	121.4810	-15.9233	94	5Y 5/4	Medium-coarse shell hash sand with cemented carbonate sand fragments
56	GR160	5	121.4818	-15.9240	93	5Y 5/4	Medium-coarse shell hash with less shell hash, but more cemented carbonate fragments and muddier than GR159
57	GR162	1	121.4648	-15.7563	89	5Y 5/4	Medium-coarse shell hash sand with scattered cemented carbonate sand fragments
57	GR163	1	121.4652	-15.7568	89	5Y 5/4	Medium-coarse shell hash sand with scattered cemented carbonate sand fragments
58	GR165	1	121.5447	-15.8300	81	5Y 5/4	Fine muddy, slightly cohesive sand
58	GR166	1	121.5445	-15.8303	81	*	Fine muddy, slightly cohesive sand

Appendix H Survey Details for Vibrocores

Appendix Table H.1 Brief descriptions of cores recovered and their preliminary assessment from visual content observations. (STN= Station)

STN	Core/ section no. (no. of sections)	Survey area (associated geomorphic feature)	Longitude	Latitude	Length (m)	Water depth (m)	Brief description
22	VC01/1A (n = 1)	3 (Valley)	121.7310	-15.8337	0.30	81	Very poorly sorted, poorly stratified, shell hash and gravel, carbonate sediment, with bryozoans, sponge, echinoid, gastropod and coral fragments
22	VC02/1A (n = 1)	3 (Valley)	121.7315	-15.8327	0.26	82	Poorly to very poorly sorted shell hash and carbonate sandy to gravelly sediment with bivalves
28	VC03/1A (n = 1)	3 (Valley)	121.7671	-15.8445	0.59	79	Overall fining up, moderately sorted, carbonate gravel to sandy sediments, with in places shell hash. Occasional gastropods and bivalves.
29	VC04/1A (n = 1)	3 (Bank)	121.8250	-15.8188	0.49	58	Fining up poorly sorted carbonate sediments, occasional shells, cobbles at base.
30	VC05/1A (n = 1)	3 (Valley)	121.7447	-15.8465	0.45	80	Generally sandy carbonate sediments. Some gravel. Very poorly sorted.
57	VC08/1A (n = 1)	1	121.4647	-15.7563	0.7	90	Poorly sorted coarse-grained carbonate basal section (~ 0.70–0.30 m) overlain by fining-up carbonate sandy sediment. Some shell hash in the lower portion.
57	VC07/1A (n =1)	1	121.4648	-15.7563	1.22	90	Overall fining-up, from poorly sorted sands and gravels at the base (carbonate-rich sediment), to well sorted carbonate sand at the top. Occasional bivalve molluscs, occasional sub-angular carbonate gravel fragments.
57	VC06/3A, 2B, 1C (n = 3)	1	121.4650	-15.7550	2.52	89	Generally coarse-grained, poorly sorted carbonate-rich sandy to gravelly sediments with in places sub-angular gravel to cobble sized carbonate fragments. Carbonate sands largely composed of bryozoan, echinoid, bivalve and other biologically-derived carbonate.

Appendix I Survey Details for Underwater Towed-Video Transects

Appendix Table I.1 Broad-scale classification using the preliminary observations made during the recording of the underwater towed-videos collected during this survey.

STN	Camera no.	Area	Start longitude	Start latitude	End longitude	End latitude	Start depth (m)	End depth (m)	Transect duration	Transect length (m)	No. Stills (usable)	Seabed habitat classification	Seabed description
01	CAM01	1	121.5566	-15.8108	121.5510	-15.8180	85.6	97.0	0:29:39	1000	567 (159)	Mixed Patches	Mixed patches of sponges and octocorals interspersed with sediments
04	CAM02	1	121.5741	-15.8150	121.5761	-15.8272	92.4	99.7	0:29:19	1515	542 (240)	Bioturbated	Bioturbation, individual patches of sponges and octocorals interspersed with sediment
06	CAM03	1	121.4414	-15.7294	121.4321	-15.7322	91.9	92.2	0:25:50	1295	459 (221)	Bioturbated	Bioturbation, individual patches of sponges and octocorals interspersed with sediment
08	CAM04	1	121.4300	-15.7292	121.4218	-15.7327	92.5	92.9	0:25:42	1055	453 (291)	Bioturbated	Bioturbation, individual patches of sponges and octocorals interspersed with sediment
09	CAM05	1	121.4519	-15.7577	121.4616	-15.7653	90.9	90.6	0:41:42	1520	608 (392)	Mixed Patches	Mixed patches of sponges and octocorals interspersed with sediments
10	CAM06	1	121.4646	-15.7562	121.4726	-15.7610	89.2	88.2	0:26:37	1243	443 (300)	Bioturbated	Individual patches of sponges and octocoral interspersed with sediment
11	CAM07	1	121.5337	-15.8092	121.5343	-15.8180	83.4	100.2	0:22:41	1020	372 (265)	Mixed Patches	Mixed patches of sponges and octocorals interspersed with sediments
12	CAM08	2	121.1892	-15.9851	121.1802	-15.9894	94.9	98.4	0:32:30	1115	557 (380)	Bioturbated	Bioturbation, individual

STN	Camera no.	Area	Start longitude	Start latitude	End longitude	End latitude	Start depth (m)	End depth (m)	Transect duration	Transect length (m)	No. Stills (usable)	Seabed habitat classification	Seabed description
													patches of sponges and octocorals interspersed with sediment
13	CAM09	2	121.2319	-16.001	121.2401	-16.0051	95.0	92.0	0:39:54	1405	708 (426)	Bioturbated	Bioturbation, individual patches of sponges and octocorals interspersed with sediment
15	CAM10	2	121.2336	-16.0221	121.2349	-16.0144	86.8	92.8	0:33:43	900	630 (448)	Mixed Patches	Mixed patches of sponges and octocorals interspersed with sediments
16	CAM11	2	121.1253	-15.9318	121.11	-15.9288	91.3	78.8	0:30:23	1720	472 (358)	Mixed Patches	Mixed patches of sponges and octocorals interspersed with sediments
17	CAM12	2	121.1574	-15.9484	121.1587	-15.9489	94.9	94.9	0:02:16	145	167 (26)	Barren	Few epifauna, sandy and flat (<10 individuals over transect)
17	CAM12_1	2	121.1677	-15.9539	121.1578	-15.9497	99.7	94.9	0:33:52	1265	506 (384)	Bioturbated	Bioturbation, individual patches of sponges and octocorals interspersed with sediment
18	CAM13	2	121.2137	-16.0348	121.2177	-16.0354	90.9	89.9	0:33:27	515	585 (382)	Mixed gardens	Mixed gardens with dense epifaunal communities of sponges and octocorals, interspersed with some sediment
19	CAM14	2	121.1637	-15.9978	121.1484	-16.0005	91.2	92.5	0:26:50	1840	456 (316)	Bioturbated	Bioturbation, individual patches of sponges and octocorals interspersed with sediment
20	CAM15	3	121.7132	-15.8498	121.7041	-15.8465	71.1	73.1	0:28:33	1040	464 (371)	Bioturbated	Bioturbation, individual patches of sponges and octocorals interspersed with sediment

STN	Camera no.	Area	Start longitude	Start latitude	End longitude	End latitude	Start depth (m)	End depth (m)	Transect duration	Transect length (m)	No. Stills (usable)	Seabed habitat classification	Seabed description
21	CAM16	3	121.7373	-15.8427	121.7322	-15.8378	79.5	79.4	0:27:51	785	447 (306)	Bioturbated	Bioturbation, individual patches of sponges and octocorals interspersed with sediment
22	CAM17	3	121.7289	-15.8325	121.7392	-15.8359	84.0	82.3	0:28:24	1160	446 (334)	Bioturbated	Bioturbation, individual patches of sponges and octocorals interspersed with sediment
23	CAM18	3	121.7389	-15.8429	121.7326	-15.8379	79.8	79.4	0:18:56	880	68 (39)	Bioturbated	Bioturbation, individual patches of sponges and octocorals interspersed with sediment
24	CAM19	3	121.7545	-15.8451	121.738	-15.8463	83.6	73.8	0:35:48	1770	528 (425)	Mixed Patches	Mixed patches of sponges and octocorals interspersed with sediments
25	CAM20	3	121.7368	-15.8465	121.7356	-15.8623	73.4	70.4	0:47:04	1895	668 (501)	Mixed Patches	Mixed patches of sponges and octocorals interspersed with sediments
26	CAM21	3	121.8433	-15.7740	121.8505	-15.7831	75.1	73.9	0:33:41	1260	515 (372)	Bioturbated	Bioturbation, individual patches of sponges and octocorals interspersed with sediment
27	CAM22	3	121.8091	-15.7979	121.7989	-15.7950	58.4	58.5	0:24:29	1135	396 (292)	Bioturbated	Bioturbation, individual patches of sponges and octocorals interspersed with sediment
28	CAM23	3	121.7634	-15.8427	121.767	-15.8461	77.2	77.3	0:11:12	550	294 (133)	Mixed Patches	Mixed patches of sponges and octocorals interspersed with sediments
29	CAM24	3	121.8185	-15.8148	121.827	-15.8203	58.2	58.7	0:23:22	1110	373 (275)	Bioturbated	Bioturbation, individual patches of sponges and octocorals interspersed with sediment

STN	Camera no.	Area	Start longitude	Start latitude	End longitude	End latitude	Start depth (m)	End depth (m)	Transect duration	Transect length (m)	No. Stills (usable)	Seabed habitat classification	Seabed description
31	CAM25	3	121.7065	-15.8760	121.7167	-15.8798	70.3	91.8	0:30:00	1170	477 (356)	Mixed Gardens	Mixed gardens with dense epifaunal communities of sponges and octocorals, interspersed with some sediment
32	CAM26	3	121.8791	-15.8161	121.8749	-15.8270	59.4	50.0	0:30:13	1285	457 (363)	Mixed Patches	Mixed patches of sponges and octocorals interspersed with sediments
34	CAM27	4	121.3540	-15.8961	121.3393	-15.8925	99.2	96.0	0:34:04	1625	529 (286)	Mixed Patches	Mixed patches of sponges and octocorals interspersed with sediments
35	CAM28	4	121.3436	-15.8978	121.3337	-15.8940	95.1	96.8	0:20:56	1150	366 (215)	Mixed Patches	Mixed patches of sponges and octocorals interspersed with sediments
36	CAM29	4	121.2945	-15.9200	121.3033	-15.9276	97.7	93.2	0:31:14	1260	544 (418)	Bioturbated	Bioturbation, individual patches of sponges and octocorals interspersed with sediment
37	CAM30	4	121.2870	-15.9024	121.3015	-15.9064	99.7	97.0	0:43:08	1640	647 (486)	Mixed Patches	Mixed patches of sponges and octocorals interspersed with sediments
38	CAM31	4	121.3178	-15.9432	121.3087	-15.9435	90.9	92.1	0:21:04	980	450 (265)	Bioturbated	Bioturbation, individual patches of sponges and octocorals interspersed with sediment
39	CAM32	4	121.3520	-15.9255	121.3395	-15.9255	99.4	90.9	0:24:14	1340	458 (217)	Mixed Patches	Mixed patches of sponges and octocorals interspersed with sediments
40	CAM33	4	121.3421	-15.8965	121.3359	-15.8952	94.6	96.5	0:12:48	730	289 (108)	Bioturbated	Bioturbation, individual patches of sponges and octocorals interspersed with sediment

STN	Camera no.	Area	Start longitude	Start latitude	End longitude	End latitude	Start depth (m)	End depth (m)	Transect duration	Transect length (m)	No. Stills (usable)	Seabed habitat classification	Seabed description
41	CAM34	4	121.2781	-15.9768	121.2671	-15.9809	91.5	90.2	0:30:02	1310	486 (349)	Bioturbated	Bioturbation, individual patches of sponges and octocorals interspersed with sediment
42	CAM35	4	121.3128	-15.9490	121.306	-15.9512	88.4	95.9	0:14:30	760	284 (124)	Mixed Patches	Mixed patches of sponges and octocorals interspersed with sediments
43	CAM36	4	121.2637	-15.9532	121.2587	-15.9494	92.5	93.5	0:18:31	710	376 (202)	Bioturbated	Bioturbation, individual patches of sponges and octocorals interspersed with sediment
44	CAM37	4	121.2402	-15.9577	121.2294	-15.9654	90.7	89.7	0:30:07	1425	471 (318)	Bioturbated	Bioturbation, individual patches of sponges and octocorals interspersed with sediment
45	CAM38	10	121.6641	-15.4928	121.6468	-15.4827	78.2	98.6	0:30:33	2175	516 (296)	Mixed Patches	Mixed patches of sponges and octocorals interspersed with sediments
46	CAM39	10	121.6724	-15.4898	121.6522	-15.4849	77.0	96.3	0:29:08	2240	524 (221)	Mixed Patches	Mixed patches of sponges and octocorals interspersed with sediments
47	CAM40	10	121.6973	-15.4622	121.6821	-15.4564	80.1	87.6	0:30:31	1780	562 (328)	Mixed Patches	Mixed patches of sponges and octocorals interspersed with sediments
48	CAM41	5	121.4265	-15.9534	121.4379	-15.9542	85.1	83.5	0:27:46	1220	560 (339)	Bioturbated	Bioturbation, individual patches of sponges and octocorals interspersed with sediment
49	CAM42	5	121.4649	-15.9785	121.4859	-15.9822	81.4	92.4	0:55:14	2365	779 (601)	Mixed Gardens	Mixed gardens with dense epifaunal communities of sponges and octocorals, interspersed with some sediment

STN	Camera no.	Area	Start longitude	Start latitude	End longitude	End latitude	Start depth (m)	End depth (m)	Transect duration	Transect length (m)	No. Stills (usable)	Seabed habitat classification	Seabed description
51	CAM43	5	121.4557	-15.9867	121.4433	-15.9837	83.5	91.0	0:25:08	1385	434 (281)	Bioturbated	Bioturbation, individual patches of sponges and octocorals interspersed with sediment
52	CAM44	5	121.4904	-16.0270	121.4756	-16.0284	87.8	84.3	0:23:29	1590	456 (242)	Mixed Patches	Mixed patches of sponges and octocorals interspersed with sediments
53	CAM45	5	121.5299	-15.9990	121.5160	-16.0091	86.3	82.1	0:55:23	2070	793 (562)	Barren	Few epifauna, sandy and flat (>10 individuals over transect)
54	CAM46	5	121.4783	-15.9460	121.4945	-15.9511	94.9	86.9	0:36:29	1835	563 (398)	Mixed Patches	Mixed patches of sponges and octocorals interspersed with sediments
55	CAM47	5	121.4930	-15.9413	121.5016	-15.9413	99.0	94.9	0:19:09	920	364 (222)	Mixed Patches	Mixed patches of sponges and octocorals interspersed with sediments
56	CAM48	5	121.4729	-15.9235	121.4854	-15.9240	89.3	97.0	0:30:12	1335	471 (357)	Mixed Patches	Mixed patches of sponges and octocorals interspersed with sediments
58	CAM49	1	121.5500	-15.8314	121.5356	-15.8279	85.9	88.7	0:23:47	1595	511 (416)	Mixed Patches	Mixed patches of sponges and octocorals interspersed with sediments

Appendix J Survey Leader Daily Log

Leg 1: 2-15 May 2013, Scott Nichol – survey leader

Note: all times are in Western Australian Time

2/5/13 – Thursday

- In Port Broome (Roebuck Bay). Scott Nichol on board with Kim Picard and Justy Siwabessy to assist with installation of multibeam electronics.
- Remaining GA science crew arrived at wharf at 1400 hrs to assist with setup of labs.
- Kick-Off Meeting held at 1300 between SN, AIMS Cruise Leader (Marcus Stowar), the Vessel Master (Craig Bitter) and the Chief Engineer (Rob Williams) to discuss voyage plan and the plan for the following 48 hrs. This meeting also completed paperwork required for the Environment Plan, including the Pre-Mobilisation Environmental Audit and the Vessel Master Checklist for Environment Plan Compliance. In all matters the RV *Solander* was assessed as compliant with no issues arising. Minutes of the Kick-Off Meeting posted in the mess.
- A calibration patch test was completed successfully outside Roebuck Bay by 2230 hrs. This was followed by testing of other systems (chirper & single beam systems).
- An issue with the single beam echosounder caused a delay in our planned departure time. The system was not synchronising with the multibeam and chirper, preventing collection of co-located acoustic data. As this is a priority aspect of the survey and required Ian Atkinson to remain on board for technical assistance, the decision was made to move into Roebuck Bay to continue working on the issue. We also had Andrew Carroll still onshore because we cannot exceed 18 persons of board. A further constraint is that the Master must be at the helm while in the vicinity of Broome and he is also in need of rest.
- We decided to anchor overnight and transfer Ian onshore and bring Andrew onto the vessel at first light.

3/5/13 – Friday

- Departed Broome at 0700 hrs.
- Last night's issues with the single beam are confirmed as resolved, including a subsequent issue with the multibeam system that required a software reinstall on the SIS; this was completed by 0300 hrs Friday. Ian Atkinson, Kim Picard, Justy Siwabessy and Stephen Hodgkin all worked long hours to achieve a positive outcome.
- This morning the GA crew completed the RV *Solander* safety induction and vessel tour after breakfast. This was followed by a meeting of all personnel during which I provided a briefing of the outcomes of the Kick-Off Meeting held yesterday and of the Pre-Survey Environmental Audit and Vessel Masters Audit for Environmental Plan Compliance. This meeting also provided an overview of the survey objectives, the plan of activities for Leg 1 and of the setup of work stations in the ops room.
- An emergency muster drill was held at 0820 hrs, which included a briefing on abandon ship procedures. The muster was followed by an oil spill briefing on the back deck from the Chief

Engineer, during which the GA oil spill kit was unpacked and its use explained to all GA crew with specific reference to the winch power pack unit. This briefing also reviewed procedures for chemical spills in the lab and on the back deck.

- A fire drill was held at 1030 hrs during which the Master talked the GA crew through procedures to follow in the event of being the first on the scene to a fire. All went smoothly.
- Transit continued throughout the day in smooth seas.
- Upon arriving into the survey area we established communications with one of two fishing vessels working in the area. The skipper of the Carolina advised that they will be working in an area that intersects Area 1 for the next 3-4 days, laying up to 40 fish traps. We provided the co-ordinates of the Area 1 box and agreed to keep radio communications to assess our respective movements.
- Daily Meeting between Craig Bitter, Marcus Stowar and myself held at 1900 hrs to review and plan for the following day. No major issues.
- Weather fine and warm. Sea conditions calm with swell <0.5 m and light south-easterly breeze.
- Marine mammal sightings during daylight hours: Dolphins on two occasions. No whales.

4/5/13 – Saturday

- Swath mapping in Area 1 continued uninterrupted overnight and during the day with simultaneous logging of the water column (via single beam sounder) and chirper sub-bottom profiler. We have been making good time with mapping, achieving swath coverage greater than planned for. So we have been able to make up for some of the time lost from our late departure from Broome. All instruments are functioning well, with excellent quality data being acquired by the multibeam in calm sea conditions. However, we have experienced some interference between the chirper and multibeam, so in order to maximise multibeam data quality we have opted to operate the chirper every 5th swath line (i.e. ~1 km chirper line spacing).
- Thus far, mapping is showing the seabed is low relief with several low (3-4 m) narrow ridges likely formed in hard substrate, a well-defined 5 m scarp (eastern end of Area) that aligns with faults mapped in the pre-existing seismic data, small patches of pockmark-like depressions and localized fields of bedforms. However, we suspect the sediment cover is thin and patchy with exposed hard pavement in areas. Penetration by the chirper is poor, due to the suspected hard substrate. The trace from the single-beam sonar is clear, with several occasions of possible ‘flares’ above the seabed. The single-beam is also giving a clear periodic signal of water column turbulence at ~50 m water depth that is likely related to internal waves; a known oceanographic phenomenon on the NW shelf.
- Afternoon and early evening spent planning and preparing for sampling tomorrow and sparker operations overnight.
- Toolbox meeting for sparker held at 1900 hrs.
- Daily Meeting between Survey Leader, AIMS Rep., Vessel Master and GA FES Rep. held at 1930 hrs. No issues.
- No further communications with the Carolina, one of two fishing vessels working in the area.
- All on board are fit and well, and in good spirits.
- Wind 10-12 knots from SE. Swell <0.5 m from SE. Clear skies and very warm.
- Marine mammal sightings during daylight hours: No dolphins. No whales.

5/5/13 – Sunday

- Sub-bottom profiling continued overnight without interruption. Data quality is generally good with penetration to 200 ms below the seabed. We completed five of the six planned priority lines by 0730 hrs, then pulled in the gear to switch to daytime sampling operations. Sub-bottom profiling will be resumed tonight.
- Toolbox meetings held for towed-video, grab and CTD between 0830 and 0930 hrs. No issues.
- Sampling began at 0830 hrs with initial testing of the towed-video with gas sensors attached. No issues with the additional weight of the sensors, so these were used at each station. During the day we completed sampling operations at 8 stations, acquiring good quality towed-video and stills along 4 transects plus 21 sediment grabs divided across these transects. Grab sampling provided for sedimentology, infaunal duplicates and geochemical analysis across a range of targeted features, including: a major 5 m fault scarp that ties to the faults mapped in deeper seismic data, pockmark fields, and an active mega-ripple field located within a graben/channel feature. CTD casts and water samples were also collected from these same environments.
- The plan for tomorrow is to target additional pockmark fields that appear to be associated with sub-bottom structural features and to characterize a shoal feature that has the potential to support epibentos. From todays limited observations, however, epibenthic communities appear sparse in their distribution.
- During the day we provided the skipper of the Carolina with the co-ordinates for Areas 2 and 3 and the dates we expect to be in those areas to assist him plan fishing activities around our survey.
- Daily Meeting between Survey Leader, AIMS Rep., Vessel Master and GA FES Rep. held at 1930 hrs. No issues.
- All on board are fit and well, and in good spirits.
- Wind 5-10 knots from SE. Swell 0.5 m from SE. Clear skies and very warm. Forecast to remain the same for the next couple of days.
- Marine mammal sightings during daylight hours: No dolphins. No whales.

Appendix Table J.1 Sampling operations completed on Sunday, 5 May 2013.

Station	Latitude	Longitude	Depth (m)	Operations
01	- 15°48.606	121°33.462	99	Camera tow (CAM01) Grab – Smith McIntyre (GR01,GR02,GR03) CTD (CTD01)
02	-15°48.863	121°33.231	90	Grab – Smith McIntyre (GR04, GR05, GR06)
03	-15°49.266	121°32.857	97	Grab – Smith McIntyre (GR07, GR08, GR09)
04	-15°48.836	121°34.464	89	Camera tow (CAM02) Grab – Smith McIntyre (GR10, GR11, GR12)
05	-15°45.401	121°27.104	89	CTD (CTD02)
06	-15°43.888	121°25.917	91	Camera tow (CAM03) Grab – Smith McIntyre (GR13, GR14, GR15) CTD (CTD03)
07	-15°43.775	121°26.276	90	Grab – Smith McIntyre (GR16, GR17, GR18)
08	-15°43.775	121°25.628	92	Camera tow (CAM04) Grab – Smith McIntyre (GR19, GR20, GR21) CTD (CTD04)

6/5/13 – Monday

- Sub-bottom profiling continued overnight without interruption. We have completed all planned priority lines are progressively adding lines across key areas identified in multibeam data (e.g. across scarps, pockmark fields, potential flares). Sub-bottom profiling will be completed tonight. Data quality is generally good with penetration to 200 millisecs below the seabed. However, we are losing the high frequency signal component in the upper few metres of unconsolidated sediment resulting in a loss of some fine scale information.
- Sampling resumed at 1230 hrs today with three stations selected to target the coincidence of pockmark clusters, potential flares in the water column, low ridges, rugose seabed and associated benthic communities. These sites also tie to the deeper faults mapped in seismic data. Sampling included grabs for sedimentology, infaunal duplicates and geochemical analysis, plus towed-video and CTD casts. All operations were successful. Our observations of pockmark depressions from video are that they are associated with blocky carbonate concretions that form a broken hard substrate around the depression, and with schools of fish but very sparse epibenthos cover.
- This evening we are deploying the side scan sonar to map an area of pockmarks and rugose seabed associated with a deeper fault. The side scan should also provide better resolution of fields of megaripples that we have seen in towed-video adjacent to the pockmarks, but are not evident in the multibeam data.
- We had further communications with the Carolina in the morning, who moved into the northwestern sector of Area 1 to lay fish traps; however this did not impact directly on our sampling activities. The Carolina will be returning to Port tomorrow.
- Daily Meeting between Survey Leader, AIMS Rep., Vessel Master and GA FES Rep. held at 1930 hrs. No issues.

- All on board are fit and well, and in good spirits (Tony Nicholas struggling a bit today in the roll introduced by a slight swell; will keep an eye on him)
- Wind 10-12 knots from SE. Swell 1 m from SE. Clear skies and very warm.
- Marine mammal sightings during daylight hours: No dolphins. No whales.

Appendix Table J.2 Sampling operations completed on Monday, 6 May 2013.

Station	Latitude	Longitude	Depth (m)	Operations
09	- 15°45.410	121°27.112	89	Camera tow (CAM05) Grab – Smith McIntyre (GR22,GR23,GR24) CTD (CTD05)
10	-15°45.366	121°27.981	87	Camera tow (CAM06) Grab – Smith McIntyre (GR25, GR26, GR27) CTD (CTD06)
11	-15°48.583	121°32.038	82	Camera tow (CAM07) Grab – Smith McIntyre (GR28, GR29, GR30) CTD (CTD07)

7/5/13 – Tuesday

- Sub-bottom profiling was completed in Area 1 overnight and early this morning, without interruption. A total of 12 lines have now been acquired, plus transit lines with useful data. Leonie is continuing with the processing, and her overall assessment remains that we have “good data but not brilliant data”, due to the lack of the high resolution signal mentioned previously.
- Overnight we had a very successful deployment of the side scan sonar. We towed the side scan for 3 hrs across an area where fields of sandy megaripples were seen in the towed video, but were not evident in the multibeam data. As expected, the side scan imaged the megaripples in great detail, showing them to be distributed as discrete fields with abrupt boundaries and surrounded by flat seabed (and probably forming a sheet of active sand across large areas). This information has also clarified our interpretation of multibeam data in this area, which shows a narrow feature that we now think is the edge of the bedform field, not a low ridge (as initially thought). The side scan also imaged the pockmark fields very well; we also noted that there is no evidence in the side scan data for activity in the water column that might relate to active seeps.
- During the morning we completed the final two swath lines along the western edge of Area 1 to close-out that survey area.
- Transiting to Area 2 commenced at 1200 hrs, via the edge of Area 4. Staff kept busy with ongoing lab analyses, GIS processing and updating paperwork (station forms etc).
- Swath mapping of Area 2 commenced 1430 hrs.
- Daily Meeting between Survey Leader, AIMS Rep., Vessel Master and GA FES Rep. held at 1930 hrs hrs. Discussed deteriorating health of Tony Nicholas; seasickness brought on by the slight swell experienced the past 2 days. Agreed to monitor his condition closely over the next 12 hrs.
- All others on board are fit and well, and in good spirits.

- Wind 5-10 knots from SE. Swell <1 m from SE. Clear skies and very warm.
- Marine mammal sightings during daylight hours: No dolphins. No whales.

8/5/13 – Wednesday

- Swath mapping of Area 2 continued overnight and today without major interruption. This morning we had a minor issue with the presence of a large floating tree that would pose a collision hazard for us at night. The Solander crew launched the tender and attached a radar reflector to the tallest branch, allowing us to keep a watch for it at night. This operation took 45 minutes from our mapping time. Resumed mapping by 0845 hrs.
- Tony Nicholas' condition did not improve overnight. This morning he had developed a severe migraine and high blood pressure (level 1 hypertension), adding to the nausea and sensitivity to light and boat motion. We prescribed codeine in the mid-morning which by early afternoon had reduced the migraine pain and lowered his blood pressure. While Tony is stable now, we are concerned that his condition could deteriorate if sea conditions get rough over the next 6 days. On this basis, we decided it is in Tony's best interests to get him back on land.
- GA and AIMS were advised of our decision. Arrangements have been made for Tony to see a doctor in Broome tomorrow afternoon and for 2 nights accommodation with the option for more if needed.
- We continued to swath map until 1930 hrs before turning off Area 2 to commence our 13 hrs transit to Broome.
- Daily Meeting between Survey Leader, AIMS Rep., Vessel Master and GA FES Rep. held at 1930 hrs. No pressing issues beyond finalising arrangements for the onshore transfer of Tony Nicholas.
- All others on board are fit and well.
- Wind <5 knots from SE. Negligible swell; glassy in the afternoon. Scattered light cloud and hot.
- Marine mammal sightings during daylight hours: Dolphins on one occasion. No whales.

9/5/13 – Thursday

- Solander arrived into Broome at 0830 hrs this morning as planned. Tony Nicholas disembarked and was delivered to a motel by the shore based agent for Riverside Marine. Email confirmation from Riko Hashimoto that he had talked with Tony to confirm that he was checked into his accommodation and feeling improved already.
- While tied up at the Broome wharf we took the opportunity to do a visual check on the multibeam sonar heads, as they are in a new mounting. Minor wearing of one cable was found, requiring a modification to the cable tie arrangement. Otherwise all ok. Following the head inspection we completed a calibration patch test outside of Roebuck Bay and were underway on our return transit by 1130 hrs.
- Transit time spent planning of sampling sites for tomorrow, catching up with paper work and other domestic chores.
- Daily Meeting between Survey Leader, AIMS Rep., Vessel Master and GA FES Rep. held at 1920 hrs. Confirmed plans for sparker deployment overnight, to be followed by sampling tomorrow. No issues were raised.
- All on board remain fit and well, and in good spirits.
- Wind 5-10 knots from SE. Swell <0.5 m from SE. Scattered light cloud and hot.

- Marine mammal sightings during daylight hours: Dolphins on one occasion (outside Roebuck Bay). No whales.

10/5/13 – Friday

- Sparker profiling of Area 2 continued overnight without interruption. Data quality remains good with penetration to about 80 m with satisfactory resolution. Three priority lines were completed for this deployment, all correlating with pre-existing deep seismic lines.
- Sampling commenced at 0900 hrs and continued to 1600 hrs with the deployment of towed-video, Smith-Mac grab and CTD at four priority stations. Sites were identified from pre-existing seismic and multibeam data and included two pockmark fields, a deep hole associated with a fault, and a low ridge also potentially associated with a deep fault. Observations from the video and sediment grabs indicate that the seabed in Area 2 is characterised by muddy carbonate sands across generally flat seabed with very sparse epibenthic biota. Evidence for active sediment transport was observed from the presence of ripples and sand waves in channels to depths of 90 m. These areas are barren of any epibenthic communities.
- We deployed the side scan sonar across a pockmark field and potential seep site marked by a distinct hole in the southeast corner of the Area. Deployment was timed to coincide with a spring low tide (0.5 m), giving us the best opportunity to image any active seepage into the water column. The data shows a number of bright spots in the water column above the pockmarks but we need to process the data into a mosaic before making any interpretations.
- Swath mapping resumed after the side scan deployment.
- Daily Meeting between Survey Leader, AIMS Rep., Vessel Master and GA FES Rep. held at 1915 hrs. Confirmed plans for sparker deployment overnight, to be followed by swath in the morning and sampling tomorrow afternoon. No issues were raised.
- All on board remain fit and well, and in good spirits.
- Wind 10-15 knots from SE. Swell 1-2 m from SE. Scattered cloud, humid and very warm.
- Marine mammal sightings during daylight hours: No dolphins. No whales.

Appendix Table J.3 Sampling operations completed on Friday, 10 May 2013.

Station	Latitude	Longitude	Depth (m)	Operations
12	- 15°59.204	121°11.065	98	Camera tow (CAM08) Grab – Smith McIntyre (GR31,GR32,GR33) CTD (CTD08)
13	-16°00.008	121°14.080	98	Camera tow (CAM09) Grab – Smith McIntyre (GR34, GR35, GR36) CTD (CTD09)
14	-16°00.065	121°14.236	94	Grab – Smith McIntyre (GR37, GR38, GR39)
15	-16°01.163	121°14.073	95	Camera tow (CAM10) Grab – Smith McIntyre (GR40, GR41, GR42, GR43) CTD (CTD10)

11/5/13 – Saturday

- Sparker profiling of Area 2 continued overnight without interruption. Data quality remains good with penetration to about 80 m with satisfactory resolution. An additional four priority lines were completed during this deployment, all correlating with pre-existing deep seismic lines. This completes all priority lines for Area 2.
- Swath mapping resumed at 0730 hrs and continued to 1400 with one minor (15 min) interruption due to a freeze in the acquisition software, requiring a re-boot to the multibeam system. Otherwise the multibeam sonar system continues to deliver excellent data.
- Sampling commenced at 1400 hrs and continued to 1830 hrs with the deployment of towed-video, Smith-Mac & Shipek grabs and CTD at two stations. Smith-Mac grab failing to trigger, so swapped out for the Shipek grab. Sites were identified from pre-existing seismic and multibeam data and included two pockmark fields, and a low linear ridge potentially associated with a deep fault (site E in the Survey Sites Atlas). Video observations from the pockmark fields showed them to be characterised by mounds and hollows with blocks of cemented carbonate and very sparse epibenthic biota. As in Area 1, these areas of irregular seabed appear to provide habitat for fish, with small schools observed hovering over the mounds. It is likely that the water column ‘flares’ observed at these sites in single beam data are schools of fish.
- Sampling summary for Area 2 – we now have towed-video, sediment grabs and CTD (plus water samples) at priority sites C2, D1 and E (as listed in the BRG Survey Sites Atlas). More samples to come tomorrow, weather permitting.
- Daily Meeting between Survey Leader, AIMS Rep., Vessel Master and GA FES Rep. held at 1920 hrs. Confirmed plans for sparker deployment overnight, to be followed by swath for most of the day tomorrow. Aiming to be transiting to Area 3 by early Sunday evening. Plans for the port call on May 15 were discussed; all in place for loading and unloading with crane lifts to start at 0900.
- All on board remain fit and well, and in good spirits.
- Wind <5 knots from SE. Swell 1-2 m from SE. Clear skies and hot. Forecast for stronger winds late Sunday.
- Marine mammal sightings during daylight hours: No dolphins. No whales.

Appendix Table J.4 Sampling operations completed on Saturday, 11 May 2013.

Station	Latitude	Longitude	Depth (m)	Operations
16	- 15°55.844	121°07.393	89	Camera tow (CAM11) Grab – Smith McIntyre / Shipek (GR44,GR45,GR46) CTD (CTD11)
17	-15°57.132	121°09.924	93	Camera tow (CAM12) Grab – Shipek (GR47, GR48, GR49) CTD (CTD12)

12/5/13 – Sunday

- Sparker profiling of Area 2 continued overnight without interruption. An additional five lines were completed, providing east-west tie lies between the priority lines. These additional lines also provide representative cross-sections over the northwest oriented channels and banks. Sparker acquisition in Area 2 is now complete. Upon retrieval of the sparker source, a small spilt in the cable was found. This did not affect data quality but will require a repair before we deploy again. Steve Hodgkin will attend to this tonight.

- Swath mapping resumed at 0730 hrs and continued to 1430 hrs. Area 2 is now fully mapped.
- Sampling commenced at 1430 hrs and continued to 1800 with the deployment of towed-video, Smith-Mac grabs and CTD at two stations. Sites were identified from pre-existing seismic and multibeam data and included a 5 m high ridge potentially associated with a deep fault and a small pockmark field located on an area of flat seabed at site C1 in the Survey Sites Atlas.
- Video observations from the 5 m ridge revealed the richest assemblage of epibenthic biota seen thus far. Sponges, gorgonians and soft corals were all observed on a substrate of muddy gravelly sand. Grabs recovered a large amount of relict shell material within the gravelly sand, so our interpretation of the site is that it likely represents a drowned coastal landform associated with the palaeo-estuary mapped in multibeam further seaward of this site.
- Sampling summary for Area 2 – towed-video, sediment grabs and CTD (plus water samples) at priority sites C1, C2, D1 and E (as listed in the BRG Survey Sites Atlas).
- Daily Meeting between Survey Leader, AIMS Rep., Vessel Master and GA FES Rep. held at 1910 hrs. Plans for the next 24 hrs confirmed to include transiting to Area 3 and swath mapping for the next 40 hrs.
- All on board remain fit and well, and in good spirits.
- Wind <5 knots from SE, rising to 15 knots in the evening. Swell 1-2 m from SE. Clear skies and hot.
- Marine mammal sightings during daylight hours: No dolphins. No whales.

Appendix Table J.5 Sampling operations completed on Sunday, 12 May 2013

Station	Latitude	Longitude	Depth (m)	Operations
18	- 16°02.007	121°12.856	80	Camera tow (CAM13) Grab – Smith McIntyre (GR50,GR51,GR52,GR53) CTD (CTD13)
19	-16°00.163	121°09.365	91	Camera tow (CAM14 Grab – (GR54, GR55, GR56) CTD (CTD14)

13/5/13 – Monday

- Swath mapping of Area 3 continued overnight and all day in rough sea conditions. We are mapping in a northeast-southwest direction into an easterly 1-2 m short period swell. Solander is therefore rolling and pitching noticeably, making for trying conditions on board. Our mapping rate in Area 3 is expected to be slower than for Areas 1 and 2. This is a function of the sea conditions and shallower water depths (shoaling to 50 m), requiring a reduction in line spacing and swath width. Nonetheless, progress is being made and by 2000 hrs we had completed 25% of the Area.
- All persons on board have been directed to take extra care while moving around the vessel while sea conditions remain rough.

- Several GA crew are feeling the effects the irregular boat motions today and are taking the appropriate measures to manage their symptoms. Despite the conditions, all remain in a positive mood.
- Daily Meeting between Survey Leader, AIMS Rep., Vessel Master and GA FES Rep. held at 1900 hrs. Plans for the next 24 confirmed to include continued swath mapping and sparker deployment after midnight if the ease in sea conditions continues.
- Wind 20 knots from NE to E, easing to 12-15 knots in the afternoon. Swell 1-2 m from NE. Partly cloudy skies, warm and humid. Rain and strong winds forecast again for tomorrow
- Marine mammal sightings during daylight hours: No dolphins. No whales.

14/5/13 – Tuesday

- Sea conditions eased overnight, allowing deployment of the sparker for 6 hrs in Area 3. Three priority lines were completed, covering a total of 30 km along a north-south direction. Data quality is acceptable, but as in previous Areas signal penetration is limited to less than 100 m. The repair to the split in the sparker cable lasted the deployment but will need further maintenance before the sparker can be deployed again. Steve Hodgkin is confident that a proper fix can be achieved.
- Swath mapping in Area 3 resumed at 0600 hrs and continued uninterrupted until 1330 hrs. We then completed sampling at two stations, including site B1 and a side scan deployment across a field of pockmarks and sand waves; no water column activity was observed. This was the last opportunity to use the side scan as it is being swapped out for the vibracorer for Leg 2. Sampling also included towed video, sediment grabs and CTD casts. All operations were successful.
- Survey activities ceased at 1800, at which time we turned towards Broome to commence the 13 hr transit to port.
- Daily Meeting between Survey Leader, AIMS Rep., Vessel Master and GA FES Rep. held at 1900 hrs. Plans for the next 24 hrs confirmed to include continued swath mapping and sparker deployment after midnight if the ease in sea conditions continues.
- All on board are well and in good spirits.
- Wind 5-10 knots from SE, rising to 15 knots in the afternoon. Swell 1-2 m from SE. Partly cloudy skies, warm and humid. Showers and squalls in the late afternoon.
- Marine mammal sightings during daylight hours: No dolphins. No whales

Appendix Table J.6 Sampling operations completed on Tuesday, 14 May 2013.

Station	Latitude	Longitude	Depth (m)	Operations
20	- 15°50.887	121°42.524	71	Camera tow (CAM15) Grab – Smith McIntyre (GR57,GR58,GR59) CTD (CTD15)
21	-15°50.203	121°44.072	80	Camera tow (CAM16) Grab – (GR60, GR61, GR62) CTD (CTD16)

15/5/13 – Wednesday

- Solander arrived into Broome port at 0750 hrs as scheduled. The overnight transit was relatively comfortable despite the 25 knot south-easterly wind and associated swell.
- Loading and unloading of equipment and supplied proceeded as planned.
- R Hashimoto, C Wintle and O Wilson embarked at 0830 hrs, and S Nichol and J Siwabessy disembarked at 1310 hrs after completing handovers.
- Other GA scientific crew transferred to shore at 0930 hrs for various errands and rest, returning to vessel by 1635 hrs.
- Cranes were used to unload the sidescan sonar, and load the vibrocorer, fridge and supplies onto the vessel between 1300 and 1430 hrs.
- Wilson and Hashimoto received a safety induction from the skipper, and all three GA crew joining Leg 2 will receive a full vessel induction on Thursday morning.
- Weather conditions deteriorated during the day, making refuelling and transfer to shore of solid waste too dangerous. It was therefore decided to delay departure of Leg 2 until Thursday.
- Daily Meeting between Survey Leader, AIMS Rep. and Vessel Master held at 1930 hrs. Plans for the next 24 hours confirmed to include completion of refuelling and waste transfer, and commencement of transit to survey area by 1230 hrs, reaching the Area 3 very late Thursday or very early Friday.
- Wind 20-30 knots from SE. Swell 1-2 m from SE with much locally generated wind wave activity. Rain for most of the day.
- All on board are generally well and in good spirits. However, Leonie Jones indicated that she is progressively becoming fatigued through her night shifts, which is impacting on her ability to process sub-bottom profiler data in a timely manner. Discussions will be held during Thursday with GA and AIMS crew to achieve a solution to this potential OH&S issue. Also, Hashimoto experienced suspected mild food poisoning as a result of breakfast at a retail outlet in Broome earlier today. After bedrest during the afternoon, full recovery appears to have been achieved.
- Marine mammal sightings during daylight hours: No dolphins. No whales

Leg 2: 15-30 May 2013, Takehiko (Riko) Hashimoto – survey leader

16/5/13 – Thursday

- After being anchored in Roebuck Bay overnight, the vessel returned to Broome port for refuelling, arriving at 0740 hrs.
- Refuelling and solid waste unloading was completed and the vessel commenced transit to Area 3 of the survey area at 1040 hrs. By this stage, the weather conditions had improved significantly with sunny skies.
- The new GA crew joining Leg 2 (Wilson, Wintle, Hashimoto) received a full vessel induction from AIMS crew in the late morning. In the early afternoon, all crew participated in emergency muster, man-overboard and deck spill drills.
- Daily Meeting between Survey Leader, AIMS Rep. and Vessel Master held at 1900 hrs. Plans for the next 24 hours confirmed include the resumption of multibeam mapping of Area 3 and sampling.
- All on board are well and in good spirits. Discussions were held with GA and AIMS crew in regard to managing Leonie Jones' fatigue issue. It was decided that the Sparker should be deployed between 2000 and 2200 hrs to allow Leonie to monitor initial data acquisition, and then for Leonie to have bedrest thereafter until the morning.
- Wind 5-10 knots from SE. Swell 1-2 m from SE. Early light rain giving way to sunshine by late morning.
- Marine mammal sightings during daylight hours: No dolphins. No whales

17/5/13 – Friday

- Vessel arrived over Area 3 shortly before midnight on Thursday and multibeam calibration was successfully completed over a selected area of the Area between 0000 and 0100 hrs.
- Multibeam mapping commenced at 0100 hrs. It was decided to resume mapping in the northern part, rather than complete the southern part started during Leg 1, as features of interest (hard ridges, 'coffee bean' depressions) appeared to continue to the north. An issue with ambiguity over the sign convention used in SIS was resolved through communications with Anne Fleming at GA. An interference issue was also noted upon commencement of a Chirper line; it appears to have been managed for now through adjustments to the Chirper frequency and the swath width.
- Multibeam swath mapping was carried out until 1430 hrs, then two stations were sampled, resulting in the collection of six grabs, two video transects and two CTD measurements. One station (22) targeted a field of 'coffee bean' depressions, which may potentially represent erosional moats around exposed tops of dune ridges mantled by sediment. Vibrocoring (preceded by a 'toolbox' meeting) was attempted at this station but was unsuccessful due to tidal bottom currents (1.5 knots) and vessel drift. The Vessel Master will attempt a different technique in positioning the vessel from tomorrow's operations.
- Another station (23) targeted what appeared to be a small mud volcano. Grab sampling revealed that the surface sediments at both stations were muddy sands with shell fragments, although pieces of cemented carbonates (crust, tube) were also recovered from the mud volcano site.
- All on board are well and in good spirits. After agreement from GA and AIMS crew, it was decided to relocate Leonie Jones' workspace for the Sparker data processing to her cabin. This

appears to have resolved the issues raised by Leonie with space and noise levels at her previous work location.

- Daily Meeting between Survey Leader, AIMS Rep. and Vessel Master held at 1900 hrs. Plans for the next 24 hours confirmed include the continuation of multibeam mapping, sparker profiling and sampling within Area 3.
- Wind 5-10 knots from SE. Swell 1 m from SE. Partly cloudy, warm and humid.
- Marine mammal sightings during daylight hours: No dolphins. No whales.

Appendix Table J.7 Sampling operations completed on Friday, 18 May 2013.

Station	Latitude	Longitude	Depth (m)	Operations
22	- 15°49.95	121°43.87	83	Camera tow (CAM17) Grab – Smith McIntyre (GR63,GR64,GR65) CTD (CTD17)
23	-15°50.55	121°44.30	78	Camera tow (CAM18) Grab – (GR66, GR67, GR68) CTD (CTD18)

18/5/13 – Saturday

- Multibeam mapping of Area 3 continued until 0800 hrs.
- Between 0800 and 1800hrs, sampling was carried out at six sites within Area 3. This included vibrocoring at two sites, resulting in limited recovery (less than 1 m length) of sub-bottom sediments. The technique of driving the vessel into the tidal currents appears to have prevented the corer from toppling (as was the case yesterday), however, penetration was limited by a hard layer or large shell fragments. In total, 15 grabs, 5 video tows, 5 CTD measurements and 3 vibrocores were collected.
- Results of sampling indicate that the more elevated parts of Area 3 are mantled by muddy shelly sand, while the bottom sediments within valleys are slightly more muddy. In both settings, local bathymetric highs, such as sand ridges and possible mud volcanoes, were often areas of highest biodiversity.
- The Sparker sub-bottom profiler was deployed at 2200 hrs. At the time of deployment, it was discovered that a build-up of moisture within the electronics was preventing the running of the profiler at its optimal power output. The profiler was initially run at a lower power level, but normal operation resumed after the electronics dried out naturally.
- Daily Meeting between Survey Leader, AIMS Rep. and Vessel Master held at 1930 hrs. Plans for the next 24 hrs confirmed include the continuation of multibeam mapping, sparker profiling and sampling within Area 3.
- All on board are well and in good spirits.
- Wind 5-10 knots from NE. Swell 1 m from SE. Mostly sunny, very warm and humid.
- Marine mammal sightings during daylight hours: No dolphins. No whales.

Appendix Table J.8 Sampling operations completed on Saturday, 19 May 2013

Station	Latitude	Longitude	Depth (m)	Operations
22	- 15°50.02	121°43.86	81	Vibrocore (VC01, VC02)
24	- 15°50.74	121°45.00	70	Camera tow (CAM19) Grab – Smith McIntyre (GR69,GR70,GR71) CTD (CTD19)
25	-15°51.14	121°44.25	63	Camera tow (CAM20) Grab – (GR72, GR73, GR74) CTD (CTD20)
26	-15°46.93	121°51.05	73	Camera tow (CAM21) Grab – (GR75, GR76, GR77) CTD (CTD21)
27	-15°47.80	121°48.40	56	Camera tow (CAM22) Grab – (GR78, GR79, GR80) CTD (CTD22)
28	-15°50.66	121°45.98	78	Camera tow (CAM23) Grab – (GR81, GR82, GR83) CTD (CTD23), Vibrocore (VC03)

19/5/13 – Sunday

- Sparker sub-bottom profiling commenced the previous night continued until 1400hrs. Data quality is fair, with profiling of sediments to over 80 m depth in some valleys. However, in most places, penetration is poor due to hard material at or near the seabed.
- Sampling was completed at three locations between 1400 and 1830 hrs. In total, 6 grabs, 2 video tows, 2 CTD measurements and 2 vibrocores were collected. Results indicate that much of Area 3 is underlain by cemented bioclastic carbonate sands, often containing coral debris, mantled to a varying degree by unconsolidated muddy sand. Basement structure appears to control the present-day seabed morphology in some places, e.g. reef-like structures over basement/volcanic highs apparent on reflection seismic data.
- Multibeam mapping of the southern part of Area 3 commenced at 1830 hrs and will continue into early Monday morning.
- Daily Meeting between Survey Leader, AIMS Rep. and Vessel Master held at 2015 hrs. Plans for the next 24 hours confirmed include the completion of multibeam mapping in Area 3, and commencement of Area 4 mapping and sampling.
- All on board are well and in good spirits.
- Wind 10-15 knots from NE and N. Swell below 1 m from W. Partly cloudy with occasional light showers, very warm and humid.
- Marine mammal sightings during daylight hours: No dolphins. No whales.

Appendix Table J.9 Sampling operations completed on Sunday, 19 May 2013.

Station	Latitude	Longitude	Depth (m)	Operations
29	-15°48.94	121°49.32	57	Camera tow (CAM24) Grab – (GR84, GR85, GR86) CTD (CTD24), Vibrocore (VC04)
30	-15°50.79	121°44.68	80	Vibrocore (VC05)
31	-15°50.66	121°45.98	85	Camera tow (CAM25) Grab – (GR87, GR88, GR89) CTD (CTD25)

20/5/13 – Monday

- Multibeam mapping of the southern part of Area 3 commenced last night continued until 0800 hrs. It was decided to extend the mapping area in the southeastern corner of Area 3 to better image a carbonate bank at the edge of the Area.
- Sampling was then completed at one location over the carbonate bank between 0800 and 1000 hrs, resulting in the collection of 3 grabs, 1 video tow and 1 CTD measurement. The bank is mantled by coarse shell/coral hash and muddy sand.
- Further infill multibeam mapping followed sampling, completing the mapping of Area 3. Transit to Area 4 was commenced at 1130 hrs.
- Multibeam mapping of Area 4 commenced after 1330 hrs. Due to a forecast change in wind direction, it was decided to map Areas 4 and 6 together, but as two separate, roughly square, blocks. This will allow more flexibility in changing line orientation with the wind and wave direction.
- Daily Meeting between Survey Leader, AIMS Rep. and Vessel Master held at 1915 hrs. Plans for the next 24 hrs confirmed include the continuation of Area 4 mapping and sampling.
- All on board are generally well and in good spirits. Rougher conditions since last night have resulted in mild cases of seasickness, which are being managed through medication, bedrest and fresh air.
- Marine mammal sightings during daylight hours: No dolphins. No whales.

Appendix Table J.10 Sampling operations completed on Monday, 20 May 2013.

Station	Latitude	Longitude	Depth (m)	Operations
32	-15°49.21	121°52.65	46	Camera tow (CAM26) Grab – (GR90, GR91, GR92) CTD (CTD26)
33	-15°54.74	121°17.06	99	CTD (CTD27)

21/5/13 – Tuesday

- Multibeam mapping of the eastern half of Area 4 continued until 0930 hrs. A network problem resulted in temporary suspension of data acquisition during early morning; the problem was resolved with the assistance of Ian Atkinson at GA.
- Making use of the favourable weather and sea conditions, four sites were sampled during the day, resulting in the collection of 11 grab samples, 4 video tows and 4 CTD casts. Pockmark-like depressions on the seafloor were identified on multibeam data acquired within Area 4, coinciding with faults and volcanics imaged by reflection seismic. However, video footage and sampling have indicated that some of these features are palaeokarst formed on drowned carbonate reefs. Infill multibeam acquisition occurred over lunchtime, breaking sampling activities.
- Multibeam resumed between 1700 and 2000 hrs, after which Sparker profiling commenced.
- Daily Meeting between Survey Leader, AIMS Rep. and Vessel Master held at 1915 hrs. Plans for the next 24 hrs confirmed include the continuation of Area 4 mapping Sparker profiling, depending on wind and wave conditions.
- Cloud clearing during the day to a mostly fine day. Winds from NW/W in the morning turning fresh S/SE in the late morning. Calm seas during the morning, then swells of up to 1.5 m from SE/E from late morning onward. Mild and drier.
- All on board are generally well and in good spirits. Periods of higher wave conditions have resulted in mild cases of seasickness, which are being managed through medication, bedrest and fresh air.
- Marine mammal sightings during daylight hours: No dolphins. No whales.

Appendix Table J.11 Sampling operations completed on Tuesday, 21 May 2013.

Station	Latitude	Longitude	Depth (m)	Operations
34	-15°53.72	121°20.87	96	Camera tow (CAM27) Grab – (GR93, GR94, GR95) CTD (CTD28)
35	-15°53.75	121°20.22	95	Camera tow (CAM28) Grab – (GR96, GR97) CTD (CTD29)
36	-15°55.24	121°17.78	93	Camera tow (CAM29) Grab – (GR98, GR99, GR100) CTD (CTD30)
37	-15°54.20	121°17.38	93	Camera tow (CAM30) Grab – (GR101, GR102, GR103) CTD (CTD31)

22/5/13 – Wednesday

- Sparker profiling commenced Tuesday night at 2000 hrs was suspended at 0500 hrs on the Skipper’s advice due to increasing wave activity.

- Multibeam mapping of the western half of Area 4 commenced thereafter and has continued throughout the day. It was decided to align the multibeam lines with the wave direction, and to reduce the cruising speed when heading into the waves to preserve data quality.
- No sampling was carried out due to the windy and rough conditions.
- A weekly audit of spill risk control measures and solid waste disposal facilities was undertaken on board, in accordance with the EP requirements. No issues were identified.
- Daily Meeting between Survey Leader, AIMS Rep. and Vessel Master held at 1930 hrs. Plans for the next 24 hrs confirmed include the continuation of Area 4 mapping and Sparker profiling, depending on wind and wave conditions.
- Partly cloudy with SE winds 10-20 knots. Swells of 1.5-2 m from SE. Cool to mild.
- All on board are generally well and in good spirits. Increased wave activity has resulted in mild cases of seasickness, which are being managed through medication, bedrest and fresh air.
- Marine mammal sightings during daylight hours: No dolphins. No whales.

23/5/13 – Thursday

- Sparker profiling commenced Wednesday night at 2000 hrs was suspended at 0700 hrs due to an electrical fault in the equipment. Stephen Hodgkin is confident that the equipment can be repaired, although this is expected to take 24 hrs.
- Multibeam mapping was carried out during the hours of 0700-1000, 1300-1400 and from 1730 onward.
- Sampling was carried out at four sites during the day, resulting in the collection of 12 grab, 4 video transects and 4 CTD casts. One of the sites was a location along a video transect previously completed on 21 May, which recorded an anomalous spike in the CO_2 sensor reading over a pockmark field. However, todays sampling did not reveal a CO_2 anomaly or obvious seafloor evidence for seepage.
- Daily Meeting between Survey Leader, AIMS Rep. and Vessel Master held at 1930 hrs. Plans for the next 24 hours confirmed include the continuation of Area 4 mapping and Sparker profiling, depending on wind and wave conditions.
- Mostly cloudy with SE winds 10-20 knots. Swells of 1-2 m from SE. Cool to mild.
- All on board are generally well and in good spirits. Continuing wave activity has resulted in mild cases of seasickness, which are being managed through medication, bedrest and fresh air.
- Marine mammal sightings during daylight hours: No dolphins. No whales.

Appendix Table J.12 Sampling operations completed on Thursday, 23 May 2013.

Station	Latitude	Longitude	Depth (m)	Operations
38	-15°56.64	121°18.67	90	Camera tow (CAM31) Grab – (GR104, GR105, GR106) CTD (CTD32)
39	-15°55.56	121°20.61	91	Camera tow (CAM32) Grab – (GR107, GR108, GR109) CTD (CTD33)
40	-15°53.77	121°20.40	93	Camera tow (CAM33) Grab – (GR110, GR111, GR112) CTD (CTD34)
41	-15°58.68	121°16.63	89	Camera tow (CAM34) Grab – (GR113, GR114, GR115) CTD (CTD35)

24/5/13 – Friday

- Multibeam mapping commenced Thursday night continued until 1300 hrs, when the mapping of Area 4 was completed.
- Despite forecasts of deteriorating conditions, wind and wave conditions remained stable, allowing sampling at three sites during the afternoon that resulted in the collection of 9 grab, 3 video transects and 3 CTD casts. The sites were selected on the basis of pockmark-like features apparent on the multibeam data and/or apparent connectivity with fluid migration features or faults at depth apparent on reflection seismic data. The results of sampling indicated that some pockmark-like features are areas of irregular topography in cemented carbonate sand.
- The Sparker sub-bottom profiler was deployed at 1930 hrs, after repairs to the equipment by Stephen Hodgkin. However, at the time of writing, profiling had not commenced due to further electrical issues. If successful, tonight's profiling will complete the last remaining profile over Area 4 and take the vessel into Area 5.
- Daily Meeting between Survey Leader, AIMS Rep. and Vessel Master held at 2000 hrs. Plans for the next 24 hrs confirmed include the completion of Sparker profiling over Area 4, commencement of Area 5 mapping, and possible sampling in the afternoon, depending on wind and wave conditions.
- Mostly sunny with E winds 10-20 knots, easing in the afternoon. Swells of 1-2 m from SE, decreasing in the afternoon. Mild to warm.
- All on board are generally well and in good spirits. Wave activity resulted in mild cases of seasickness during the morning, which were managed through medication, bedrest and fresh air.
- Marine mammal sightings during daylight hours: No dolphins. No whales.

Appendix Table J.13 Sampling operations completed on Friday, 24 May 2013.

Station	Latitude	Longitude	Depth (m)	Operations
42	-15°57.00	121°18.60	84	Camera tow (CAM35) Grab – (GR116, GR117, GR118) CTD (CTD36)
43	-15°57.11	121°15.79	89	Camera tow (CAM36) Grab – (GR119, GR120, GR121) CTD (CTD37)
44	-15°57.81	121°13.89	87	Camera tow (CAM37) Grab – (GR122, GR123, GR124) CTD (CTD38)

25/5/13 – Saturday

- The Sparker profiling commenced last night continued into very early Saturday morning. Profiling was carried out using a smaller Squid due to ongoing issues with the larger (the normally deployed) Squid.
- The remaining time during Saturday was spent multibeam mapping Area 5. Mapping was temporarily interrupted during the morning to investigate a drifting object.
- Sampling planned for the afternoon was postponed due to rough conditions.
- Daily Meeting between Survey Leader, AIMS Rep. and Vessel Master held at 1945 hrs. Plans for the next 24 hrs confirmed include the completion of multibeam mapping of Area 5, commencement of mapping, sampling and Sparker profiling of Area 10 (new Area proposed by the Basin Resources Group to replace Areas 7 and 8).
- Partly cloudy and warm with NE winds 10-20 knots, becoming cooler and sunny with fresh SE/NE wind to 30 knots from mid-morning. Swells of 1-2 m from E, increasing to 2.5 m from mid-morning.
- All on board are generally well and in good spirits. Rough conditions have resulted in several cases of seasickness, which are being managed through medication, bedrest and fresh air.
- Marine mammal sightings during daylight hours: No dolphins. No whales.

26/5/13 – Sunday

- Multibeam mapping of Area 5 was completed very early morning and the vessel transited to Area 10 to commence multibeam mapping at approximately 0500 hrs.
- Wind and wave conditions improved significantly in the early hours of the morning, allowing sampling of Area 10 from 1300 to 1800 hrs. 10 grab samples, 3 video transects and 3 CTD casts were collected at 3 sites. Observations indicated that areas of likely fluid migration from underlying ?Miocene volcanics (identified from reflection seismic data) coincided with the locations of carbonate banks at the seafloor. A field of large symmetrical dunes, with local relief of up to 15 m high, was also observed. The dunes are located within channels between carbonate banks, oriented perpendicular to the tidal current directions. Video footages revealed that the dunes are composed of gravelly carbonate sand, that was observed to be suspended by strong tidal currents, causing turbulence and a change in the water colour at the sea surface.

- An outage of the multibeam acquisition system occurred during the afternoon. After extensive investigation, Matt Carey identified the issue as a network switch failure, which was promptly rectified.
- Daily Meeting between Survey Leader, AIMS Rep. and Vessel Master held at 1915 hrs. Plans for the next 24 hrs confirmed include the completion of multibeam mapping and Sparker profiling of Area 10 overnight, transit back to Area 5 for sampling during Monday, and Sparker profiling at night.
- Sunny and mild to warm with E/NE winds to 15 knots. Swells of up to 1.5 m from E, decreasing during the afternoon.
- All on board are generally well and in good spirits. Rough conditions over the previous days have resulted in cases of mild, general fatigue among both GA and AIMS crew. The improving wind and wave conditions will undoubtedly help in recuperation.
- Marine mammal sightings during daylight hours: No dolphins. No whales.

Appendix Table J.14 Sampling operations completed on Sunday, 26 May 2013.

Station	Latitude	Longitude	Depth (m)	Operations
45	-15°28.99	121°38.92	92	Camera tow (CAM38) Grab – (GR125, GR126, GR127) CTD (CTD39)
46	-15°29.10	121°39.29	97	Camera tow (CAM39) Grab – (GR128, GR129, GR130, GR131) CTD (CTD40)
47	-15°27.52	121°41.28	74	Camera tow (CAM40) Grab – (GR132, GR133, GR134) CTD (CTD41)

27/5/13 – Monday

- Sparker profiling of Area 10 commenced last night continued into the earliest hours of today. Profiling was successfully completed using the normal (the larger) Squid but running at a lower power setting. The ongoing issue with the Sparker acquisition system has been traced to the power source, rather than the Squid. The lower power setting appeared to result in good imaging, with a better spread of frequencies than at a higher power setting.
- Multibeam mapping of Area 10 was completed after Sparker profiling. The vessel then transited back to Area 5 and sampling was commenced there after 0800 hrs. 18 grab samples, 5 video transects and 6 CTD casts were collected at 6 sites. Strong tidal currents caused issues with positioning during sampling and visibility during video tows, and some pockmark-like features and scarps, identified on multibeam bathymetry data and associated with possible fluid migration at depth, could not be confirmed through imaging or sampling.
- Infill multibeam mapping of Area 5 took place over lunch and dinner hours to improve data quality and coverage.
- Sparker profiling of Area 5 was commenced at 2000 hrs and will continue into early Tuesday morning.

- Daily Meeting between Survey Leader, AIMS Rep. and Vessel Master held at 1915 hrs. Plans for the next 24 hours confirmed include the completion of Sparker profiling of Area 5 overnight, and the completion of all sampling in Area 5 and nearby Areas during tomorrow.
- Sunny and mild to warm with E/NE winds to 15 knots during the morning, becoming light in the afternoon. Swells of up to 1 m from E, decreasing during the afternoon.
- All on board are well and in good spirits. Cases of seasickness and fatigue caused by rough conditions in the previous days appear to have been resolved through much improved conditions.
- Marine mammal sightings during daylight hours: No dolphins. No whales.

Appendix Table J.15 Sampling operations completed on Monday, 27 May 2013.

Station	Latitude	Longitude	Depth (m)	Operations
48	-15°57.18	121°25.92	83	Camera tow (CAM41) Grab – (GR135, GR136, GR137) CTD (CTD42)
49	-15°58.89	121°28.98	93	Camera tow (CAM42) Grab – (GR138, GR139, GR140) CTD (CTD43)
50	-15°58.73	121°28.17	81	Grab – (GR141, GR142, GR143) CTD (CTD44)
51	-15°59.08	121°26.79	86	Camera tow (CAM43) Grab – (GR144, GR145, GR146) CTD (CTD45)
52	-16°01.69	121°28.99	73	Camera tow (CAM44) Grab – (GR147, GR148, GR149) CTD (CTD46)
53	-16°00.53	121°31.13	78	Camera tow (CAM45) Grab – (GR150, GR151, GR152) CTD (CTD47)

28/5/13 – Tuesday

- Sparker profiling of Area 5 commenced on Monday night was successfully completed in the morning.
- Most of the morning was spent completing sampling at three sites within Area 5, targeting pockmark-like features observed in the multibeam data. One of the sites provided a clear video imaging of these features, which appear to comprise a series of crater or gully-like depressions rimmed by sand dunes and shell/cemented carbonate rubble mounds.
- In the afternoon, the vessel transited to Area 1 to sample two sites. One site targeted suspected pockmarks identified during a video tow completed during Leg 1. Three attempts at vibrocoring resulted in a maximum core recovery of 2.5 m. The surface sediments within the pockmarked area are fine carbonate sands, underlain by cemented coarse shell-hash sand.
- Infill multibeam mapping of Area 5 took place over breakfast and during the evening to improve data quality and coverage.

- Daily Meeting between Survey Leader, AIMS Rep., Vessel Master and GA Field Services Reps.held at 1915 hrs. Plans for the next 24 hours confirmed include packing, data backups and cleaning up in preparation for demobilisation early Thursday morning.
- Sunny and mild to warm with E/NE winds to 15 knots during the morning, becoming light in the afternoon. Swells of up to 1 m from E, decreasing during the afternoon.
- All on board are well and in good spirits.
- Marine mammal sightings during daylight hours: No dolphins. No whales.

Appendix Table J.16 Sampling operations completed on Tuesday, 28 May 2013.

Station	Latitude	Longitude	Depth (m)	Operations
54	-15°56.91	121°29.25	97	Camera tow (CAM46) Grab – (GR153, GR154, GR155) CTD (CTD48)
55	-15°56.45	121°29.95	89	Camera tow (CAM47) Grab – (GR156, GR157, GR158) CTD (CTD49)
56	-15°55.40	121°28.86	94	Camera tow (CAM48) Grab – (GR159, GR160, GR161) CTD (CTD50)
57	-15°45.38	121°27.89	89	Grab – (GR162, GR163, GR164) CTD (CTD51) Vibrocore (VC06, VC07, VC08)
58	-15°49.80	121°32.68	81	Camera tow (CAM49) Grab – (GR165, GR166, GR167) CTD (CTD52)

29/5/13 – Wednesday

- Infill multibeam mapping of Area 5 commenced yesterday continued throughout most of today, while all crew commenced preparations for demobilisation on Thursday.
- A briefing for all GA staff was held by the Survey Leader at 0830 hrs to confirm the schedule leading up to the arrival at Broome port, scheduled at 0600 hrs on Thursday, and the subsequent transfer to shore.
- A weekly audit of spill risk control measures and solid waste disposal facilities on board was undertaken by the Survey Leader at 0845 hrs, in accordance with the EP requirements. No issues were identified.
- The vessel commenced transit to Broome port at 1830 hrs, upon completion of Area 5 infill mapping and the scientific programme for the marine survey.
- Daily Meeting between Survey Leader, AIMS Rep., Vessel Master and GA Field Services Rep.held at 1915 hrs. Plans for the next 24 hrs confirmed include transit to Broome port, ETA at 0700hrs Thursday, disembarkation of most GA scientific crew around 0930 hrs, and completion of demobilisation by mid-afternoon.
- Sunny and warm with E/NE winds to 10 knots. Swells of less than 0.5 m from E/SE.
- All on board are well and in good spirits.

30/5/13 – Thursday

- After an overnight transit, the vessel arrived at Broome port shortly before 0700 hrs.
- Upon docking, demobilisation commenced. The GA scientific crew disembarked incrementally between 1030 and 1200 hrs. The GA Field Services crew continued demobilisation into the late afternoon. Freighting arrangements for equipment will be finalised during Friday.
- The survey was completed successfully, with all proposed high-priority survey Areas mapped, and a large number of sites sampled for potential fluid migration and environmental characterisation.
- Apart from two minor OH&S incidents and the precautionary transfer of one GA crew back to land during Leg 1, no major incidents were recorded during the survey.
- Sunny and warm with light E/NE winds. Swells of less than 0.5 m from E/SE.
- All crew have arrived ashore in good health and spirits. Most GA crew plan to return to Canberra during Friday and over the weekend.