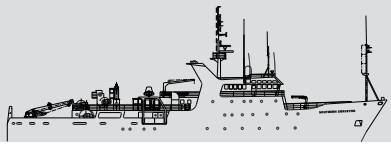


MARINE
NATIONAL FACILITY

2013 program

RV *Southern Surveyor*

CSIRO

voyage summary SS2013_v02

SS2013_v02

Voyage: Carbonate sedimentation at the southern margin of reef growth in the Tasman Sea.

Voyage period
Start: 08/02/2013
End: 25/02/2013
Port of departure: Brisbane, Australia
Port of return: Sydney, Australia

Responsible laboratory
University of Wollongong
School of Earth and Environmental Sciences,
University of Wollongong, Australia

Chief Scientist
Colin Woodroffe
University of Wollongong

Principal Investigators
Brendan Brooke and Scott Nichol
Geoscience Australia

Scientific Objectives

This research aims to determine the extent and composition of carbonate environments on and around volcanic edifices in the northern Tasman Sea. We plan to undertake the following investigations, listed in order of priority:

1. Examine the bathymetry and sedimentary environments across the shelf around Balls Pyramid, the remnant of a volcanic island just south of Lord Howe Island, from which such data are presently lacking; this will provide a basis for a more complete mapping of benthic habitats in the Lord Howe Marine Park.

2. Establish, using underwater towed video, whether a relict reef exists on the Balls Pyramid platform; this will confirm preliminary evidence that there may be a feature similar to the fossil reef on the shelf around Lord Howe, and would make it the southernmost known reef in the Pacific. Extend towed video to map major habitats of the Lord Howe Island Marine Park.

3. Extract rock cores from the Lord Howe relict reef (and that on the Balls platform, if found) providing material for component, age and geochemical determinations that will yield further insights into sea-level and climate (including palaeotemperature) history.

4. Collect vibrocores from the inner shelf on the Lord Howe shelf (and on the Balls platform if suitable areas are identified), in the lee of the relict reef, to determine the stratigraphy, source and depositional history of sequences of sediment revealed on Topas sub-bottom profiles and which appear to contain generations of 'lagoonal' sediment perhaps indicating that earlier reef features predated, and may underlie, the relict reef.

5. Undertake preliminary bathymetry transects and Topas sub-bottom profiles across the margin of Middleton and Elizabeth Reefs on the transit to Lord Howe Island as a pilot study to better plan further data collection around these reefs in 2014.

6. Determine whether terraces identified on the shelf edge contain evidence of earlier episodes of reef development or are cut into basalt; this will provide evidence of sea level, clarifying the nature of the shoreline when the sea was at these heights (60-70m water depth), and would extend known distribution of pre-Holocene reef if shown to be biogenic features.

7. Examine slump features around both volcanic edifices to clarify their extent, and the nature and composition of sediment that covers them; this will clarify the post-eruptive history of the volcanic islands, and show the degree to which carbonate sediment from the shelf or hemipelagic sediment veneers their margins.

8. Resolve the morphology of the toe of the volcanoes, and collect mulitbeam sonar data on one or more of the small seamounts that have been detected adjacent to the Lord Howe volcano; this will clarify the nature of sediments and sedimentary deposits at the toe, and provide insights into the origin and benthic habitats of previously unknown seamounts.

9. Deploy sea-surface drifters to track ocean currents along the eastern margin of Australia. Drifters are expendable (not recovered) and can be deployed while underway.

Voyage Objectives

This research aims to extend our understanding of shallow benthic habitats in the Tasman Sea, specifically mapping the bathymetry and substrate of environments around Lord Howe Island and Balls Pyramid. Reconnaissance surveys will be undertaken at Middleton and Elizabeth Reefs, en route to Lord Howe Island, in preparation for future voyages on the *RV Investigator* to these reefs.

The overall voyage objectives are:

- to undertake substrate sampling across shelves around Lord Howe and Balls Pyramid
- to undertake benthic habitat mapping using underwater video in the LHI marine park
- to map the extent of, and sample, the fossil reef around the Balls Pyramid platform
- to undertake further mapping and sampling of the fossil reef around Lord Howe Island
- to determine reef morphology in detail using swath mapping
- to explore stratigraphy by sub-bottom profiling and shallow core recovery
- to sample adjacent sedimentary environments by grab sampling or Vibrocoring
- to recover dredge samples from shelf-margin sites
- deploy five ocean drifters during transits (x2) and in the vicinity of Lord Howe and Balls Pyramid (x3)

The overall voyage objectives are:

1. SWATH bathymetry and backscatter (30 kHz),
2. Shallow (<100 m) sub-bottom profiles Topas 18
3. Underwater video footage,
4. Seabed sediment samples, rock dredge, rotary cores and vibrocores.
5. Water conductivity, temperature, depth, surface current speed and direction

Results

Results in relation to Scientific Objectives

Our research aimed to determine the extent and composition of carbonate environments on and around volcanic edifices in the northern Tasman Sea.

We achieved this by undertaking mapping and sampling on each of the seamount just to the north of Middleton Reef, Elizabeth Reef, the shelf around Lord Howe Island, and around Balls Pyramid, the southernmost volcanic outcrop in this seamount chain.

The nine objectives were met as follows:

Bathymetry and sedimentary environments across the shelf around Balls Pyramid

The entire platform on which Balls Pyramid (~280 km^2) sits was mapped using the EM300 multibeam sonar system, and a series of grab samples, vibrocores, and rotary drill cores were collected, as well as extensive underwater video. In combination these provide an outstanding set of data which will enable mapping of the benthic habitats of this section of the Lord Howe Marine Park.

Establish whether a relict reef exists on the Balls Pyramid platform

EM300 multibeam sonar data clearly delineated a low-profile reef structure on the Balls Pyramid platform. Rotary cores from several sites on this structure confirm that many of the shallowest features, in around 30 m water depth, are reef limestone and that a coral reef once flourished on this platform, similar to the fossil reef on the shelf around Lord Howe Island. This represents the southernmost reef in the Pacific, and is a significant discovery, indicating that there were similar reef habitats to those found around Lord Howe Island.

Extract rock cores from the Lord Howe and Balls relict reefs

Rotary cores of coral reef sediment were successfully retrieved from both the shelf around Balls Pyramid, and that around Lord Howe Island, and samples will be described and analysed in order to determine their age and the environments in which they were formed.

Collect vibrocores from the shelves around Lord Howe Island and Balls Pyramid

The vibrocorer was successfully deployed to recover cores of several metres length that will enable further investigation of the depositional history of sequences of unconsolidated sediment, as revealed more broadly on Topas sub-bottom profiles, and are likely to comprise 'lagoonal' sediment associated with the relict reef.

Preliminary bathymetry and sub-bottom data for Middleton and Elizabeth Reefs

A transect was undertaken onto and off both reef platforms along which EM300 and Topaz sub-bottom data were collected on the transit voyage – useful data was collected to better plan further data collection around these reefs on future voyages.

Characterise shelf-edge terraces

Several terraces were identified on the shelf edge around Balls Pyramid, particularly in 60-70 m water depth. The multibeam sonar data collected will enable a fuller description of these terraces. Underwater video footage was recorded traversing onto and off the shelf, and this will allow us to describe these features and habitats in greater detail. A vibrocore on the terrace indicates that they have an extensive carbonate sand cover. It remains unclear whether these terraces are eroded into basalt, or contain constructional reef, and this will be a focus of future study.

Examine slump features and composition of sediment that covers them

A multibeam sonar and Topas transect was collected across the slump feature on the western flank of the Lord Howe shelf. Grab samples indicate that the upper section is covered with carbonate sand derived from the shelf, and that lower sections have a higher mud content with a volcanoclastic gravel component.

Resolve the morphology of the volcanoes

Mulitbeam sonar data was collected across the toe of the slump feature to the west of Lord Howe Island, which when collated with existing bathymetry data will enable a fuller description of the geomorphology of the slopes of these volcanoes. The seamount to the north of Middleton Reef was also examined and swath data collected during our transit will extend the level of detail available for this seamount. It rises to around 300m water depth, and grab samples indicate there are carbonate sediments on top of it, with a rocky outcrop in the middle of the platform. Samples collected by rock dredge indicate that this was a basalt outcrop with some biogenic carbonate – both volcanic and carbonate rocks were recovered.

Deploy sea-surface drifters to track ocean currents

Five ocean drifters were deployed, three in the vicinity of Lord Howe Island and Balls Pyramid and two during transits.

Results in terms of Voyage Objectives

This voyage has extended our understanding of shallow benthic habitats in the Tasman Sea. The geomorphology of Balls Pyramid has been mapped with the EM300 to a high level of detail over the entire platform, and we have comprehensively identified major benthic habitats using towed underwater video and still photography. Further data was also collected around Lord Howe Island, and this and the new Balls Pyramid data will contribute directly to the background knowledge against which the Marine Park's management objectives are set. Valuable reconnaissance survey work was undertaken at Middleton and Elizabeth Reefs, and on the seamount to the north of these reefs, en route to Lord Howe Island, in preparation for future voyages on the *RV Investigator.*

The overall voyage objectives were met as follows:

- substrate sampling across shelves around Lord Howe and Balls Pyramid

The substrate throughout much of the marine park is now known in much greater detail as a result of extensive multibeam sonar mapping, several towed video transects, with thousands of still photographs of the seabed, and from grab samples and vibrocores

- benthic habitat mapping using underwater video

The extensive video and still footage provides unprecedented coverage and detail of the benthic habitats and will provide the ground-truth data for modelling habitats and communities across the shelf.

- mapping the extent of fossil reef around the Balls Pyramid platform

The multibeam sonar data provides an excellent characterisation of the seabed morphology and 3D view of the surface of the shelf around Balls Pyramid. The extent of the fossil coral reef can be determined from this, with confirmation of its composition at selected rock drill sites.

- further mapping and sampling of the fossil reef around Lord Howe Island

Further multibeam data closer to Lord Howe Island fills data gaps and extends the mapping of habitats around the island, and two rock cores recovered further samples from the fossil reef

- detailed reef morphology using swath mapping

Multibeam sonar mapping over Balls Pyramid, and further mapping over the Lord Howe platform provide sufficient detail to now map the entire extent of reef habitats in this section of the Lord Howe Commonwealth Marine Reserve.

- stratigraphy by sub-bottom profiling and shallow core recovery

Topas sub-bottom profiler data has been collected across all of Balls platform, and additional data has been collected around Lord Howe Island

- sample sedimentary environments by grab sampling or vibrocoring

Particularly good recovery of vibrocores (up to 6m) from 'lagoonal' basins on Balls platform should provide excellent insights into the sedimentary history of areas of sand accumulation, and several cores on the Lord Howe shelf should extend understanding of the pattern of sand accumulation, ground-truthing Topas data collected on this, and an earlier, voyage.

- recover dredge samples from shelf-margin sites

Grab samples were collected from a slump feature on the west side of Lord Howe Island, and a dredge successfully sampled both volcanic and carbonate rocks on the top of an un-named seamount north of Middleton Reef

- deploy five ocean drifters during transits (x2) and in the vicinity of Lord Howe and Balls Pyramid (x3)

These drifters were deployed

Data collected included:

- 630km^2 of multibeam sonar bathymetry and backscatter (30 kHz) data within the Lord Howe Island Commonwealth Marine Reserve
- 2500 km of shallow (<100 m) Topas sub-bottom profiler data
- Underwater video footage, 18 deployments, 10 hours 41 minutes of video and 6793 stills
- 14 seabed grab samples, 1 rock dredge, 10 rotary cores and 15 vibrocores (see Tables)
- Underway conductivity, temperature, surface current speed and direction.

Voyage Narrative

Transit to Middleton Reef

RV *Southern Surveyor* left Brisbane on the morning of Friday 8 February 2013 and sailed to Middleton Reef. Weather was favourable, with 2-3m E swell, winds ESE at <20knots; mostly sunny. An Ocean drifter was deployed on Friday, and the cable was respooled on the GA winch.

A seamount was examined on Sunday 10 February. Multibeam sonar data and grab and dredge samples were collected at this unnamed seamount 30km north of Middleton Reef. The topography of the upper surface of the seamount, in around 300m of water depth, was mapped in detail using the EM300 multibeam sonar system, augmenting swath data acquired by the NORFANZ voyage in 2003. Grab sampling indicates that carbonate sediments veneer the platform, and a rock dredge was deployed to sample a knoll in the centre of the platform and both basaltic and carbonate rocks were recovered.

Middleton and Elizabeth Reefs

At Middleton Reef the underwater video camera system was deployed and video footage, as well as a sequence of stills, was acquired over the relatively flat area in ~40m of water to the north of Middleton Reef. This provided an opportunity to test the underwater video-stills system on the shallow shelf on the northwestern margin of the reef. Adjustments were made to the video camera and lights to improve image quality; and resolve problems with intermittent USBL signals. Swath and Topas transects were undertaken between the seamount and Middleton Reef, and between Middleton and Elizabeth Reefs. These will assist planning a more detailed investigation of Middleton and Elizabeth Reefs and other seamounts in the Lord Howe Island seamount chain on the *RV Investigator*. A notable break of slope was observed on the southern margin of Middleton Reef at around 300 m water depth, broadly coincident with the depth of the seamount to the north. Sea conditions were favourable with 2-3m swells and ESE winds.

Balls Pyramid

RV *Southern Surveyor* arrived in the Lord Howe Island Marine Park on the morning of Monday 11 February. Weather conditions were good on arrival, 2-3 m swell and ESE winds at 10 knots. The multibeam sonar computer hard drive failed at ~10 am, and the computer was replaced and a range of other related software issues solved during the day. The vibrocorer was used to collect two cores of carbonate sand, in 40-50 m water depth in the centre of the platform, each of about 3.5 m length, and two towed video camera transects were acquired.

A week was spent mapping Balls Pyramid. During this time the weather was particularly favourable, with light winds from the east or southeast and a particularly extensive set of observations and samples were taken. The EM300 multibeam system was used in a sequence of traverses of the shelf around Balls Pyramid and high-resolution topography and backscatter were acquired across the platform which varies from 30 to 50 m water depth. The details of the topography, which comprises complex former coral reefs developed over the eroded volcanic edifice, emerged during the week. Balls Pyramid forms a spectacular monolith in the centre of the platform, flanked by Observatory Rock

and Wheatsheaf Islet. A further volcanic outcrop, South East Rock is clearly marked on the chart; however, our swath mapping revealed no feature at the location where a shoal rising to 8.8m appears on the chart, but a smaller feature exists to the west of it.

On Tuesday 12 February, the submersible rock drill was used. We deployed it at two sites in the morning. At the first site the drill barrel became jammed (2.5m penetration) and was lost and resulted in minor damage to the drill rig. At the second site we drilled 1.5m into the seabed and successfully recovered 75cm of core material (coral reef framework). Drilling was suspended in the afternoon due to the rising swell, and towed video transects were undertaken with swath acquisition overnight.

On Wednesday 13 February, towed video acquisition was continued, but moderate winds and short period swell (2-3 m SE swell, 20 knot SE winds) made deployments of the towed video off the after deck difficult. The deployment procedure was reviewed during the afternoon to improve safety and avoid damage to the camera system. A range of minor issues with the camera system were resolved during the day. Some excellent footage of a range of carbonate seabed habitats was acquired, including encrusted hardground, sand banks and sheets, red/green marcroalgae and coral/algae.

On Thursday 14 February, conditions were suitable (2 m SE swell, 10-20 knot SE winds) for the deployment of the underwater drill. We drilled throughout the day and collected five cores. Three of the cores (1.2 – 2 m) contained coral framestone and appear to confirm that a large coral reef existed around Balls Pyramid, similar to what was discovered around Lord Howe Island during our 2008 MNF voyage. Reef limestone occurred in most of the 8 cores taken. Coral was prominent in several of these cores, but the extent to which they were lithified and subject to diagenetic processes seemed to vary between cores and will be further analysed in the laboratory.

On Friday 15 February a further 9 vibrocores were retrieved, the most successful recovering 5.63 m of carbonate sands. On Saturday 16 February seven video transects were collected across the southern, central and northern areas of the shelf over a range of benthic habitat types including low mixed coral-sponge-algae reef, sand and gravel beds, sand and brown macroalgae beds and carbonate hardground. Camera tows were typically 500m long with position of the camera recorded by a USBL system. Still photographs of high quality were acquired at 5 second intervals during the tows. The survey of Balls Pyramid was completed on Sunday 17 February with 2 further rock drill cores, 8 grab samples, and swath acquisition until midday on Monday 18 February.

Lord Howe Island and shelf

On 18 February, RV *Southern Surveyor* moved to Lord Howe Island, where Brendan Brooke left the vessel transferring to the Marine Park's inflatable and Tanya Whiteway joined the ship-board party. Brendan took the opportunity to liaise with Ian Kerr the LHIMP Manager, and to present a public talk on results of the survey to inform the Lord Howe Island community that day. Two rock cores were acquired from the western margin of the shelf around Lord Howe Island, with core recovery of 1.2 and 1.3 m in patch reef and relict reef ridge, respectively (the latter including *in situ* fossil coral). Two camera tows were acquired in the same area while sea conditions remained favourable (3 m SE swell, 15-20 knot E wind).

On Tuesday 19 February, vibrocores were collected at four stations to the north and east of Lord Howe Island. Core recovery ranged from 0.1m to 3.3m in sandy sediments. However, the weather began to deteriorate (3 m SE swell, 20-25 knot E wind) and the vibrocorer was damaged on recovery. Swath mapping along the eastern side of Lord Howe Island was undertaken overnight extending mapping of the shelf undertaken on our MNF cruise in 2008. The weather deteriorated further on Wednesday 20 February, and deployment of most equipment was not possible. A series of grab samples was taken over a slump feature off the western margin of Lord Howe, and overnight details of the toe of this feature were mapped by multibeam sonar. Deteriorating sea and weather conditions curtailed sampling activities on Thursday 21 February with the wind gusting toward 40 knots, and only swath mapping was possible as the vessel could not be held into the wind for sampling. Adverse weather and rough seas (3-4 m SE swell, sustained 30-35 kn SE wind [gusts to 50 knots in squalls], raining all day [100 mm in 24 hrs]) meant that swath mapping was only possible on the sheltered western side of Lord Howe Island, and conditions did not allow the completion of mapping that had been planned on the most northwestern margin of the Balls Pyramid platform. The return transit to Sydney was commenced on the morning of Saturday 23 February.

Summary

Weather conditions were atypically favourable during the week spent studying Balls Pyramid (although deteriorating during the latter part of the voyage), and a remarkably detailed map of the upper surface of the platform around the Pyramid was acquired. Both rock drill and vibrocorer performed well and we have been able to demonstrate that coral reefs were much more extensive in the past. Underwater video and still photography acquired will enable detailed mapping of benthic habitats across this platform, revealing the diversity of coral communities that are found on some of the higher parts of the fossil reefs (but which no longer appear to be reef-forming). Only limited sampling was possible around Lord Howe Island once the weather deteriorated, however, we will be able to provide further insights into the nature of benthic habitats that will be of use to park managers. Preliminary investigations around the margins of Balls and Lord Howe platforms, and of Elizabeth and Middleton Reefs, and the seamount just north of these reefs, will guide a more detailed study of the deep-water margins of these platforms and the seamounts and reefs to the north as part of future research surveys on the *RV Investigator*.

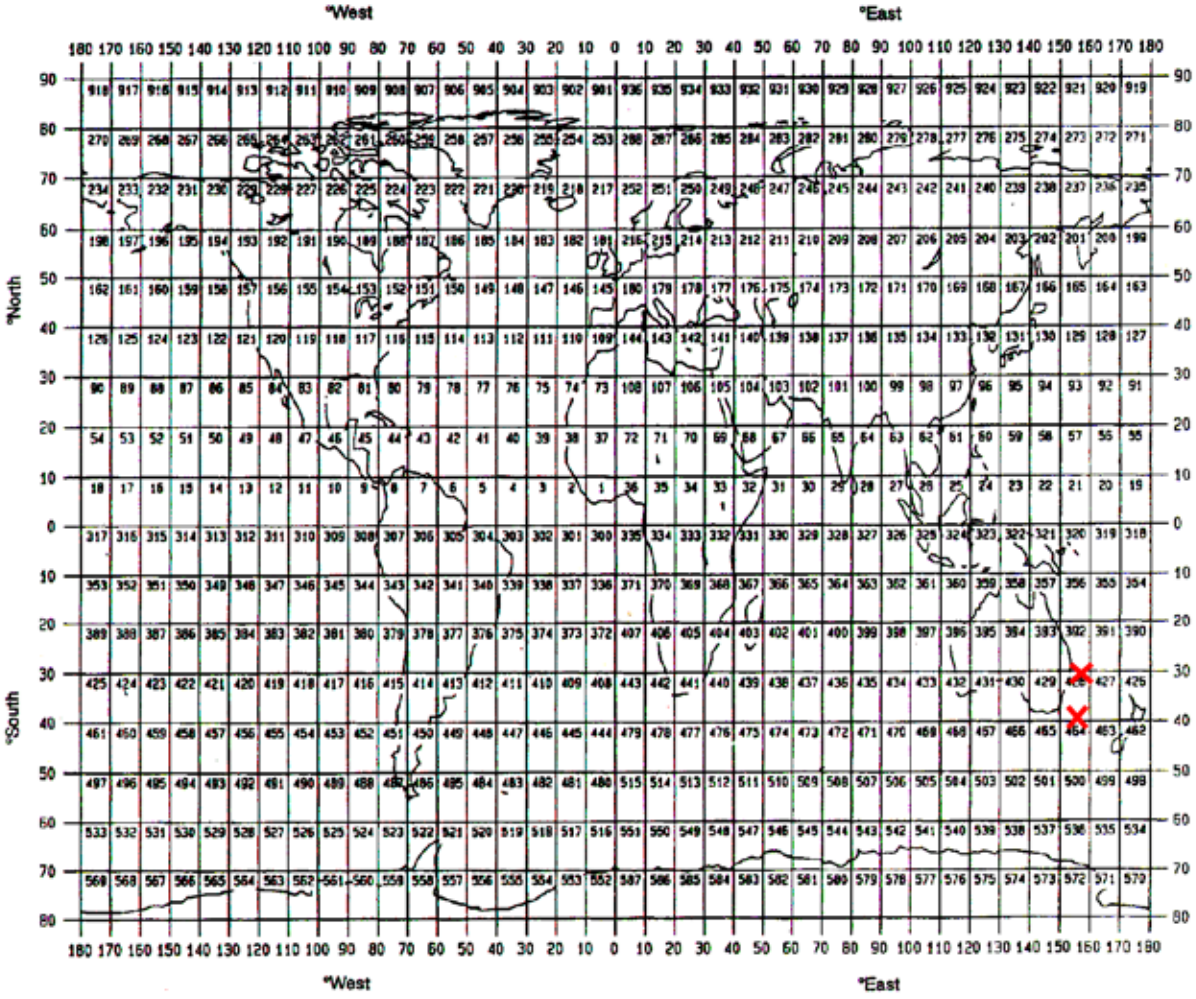
Principal Investigators:

A. *Professor Colin Woodroffe,* University of Wollongong

B. *Dr Brendan Brooke,* Geoscience Australia

C. *Dr Scott Nichol,* Geoscience Australia

GEOGRAPHIC COVERAGE - INSERT 'X' IN EACH SQUARE IN WHICH DATA WERE COLLECTED



MOORINGS, BOTTOM MOUNTED GEAR AND DRIFTING SYSTEMS									
Item No.	PI	Approximate position						Data Type	DESCRIPTION
		Latitude			Logitude				
		deg	min	N/S	deg	min	E/W		
1	C	26	59.8	S	153	44.5	E	D06	Ocean drifter 101921
2	C	31	15.6	S	159	08.8	E	D06	Ocean drifter 101924
3	C	31	51.5	S	159	12.2	E	D06	Ocean drifter 101919
4	C	31	33.3	S	159	01.9	E	D06	Ocean drifter 101925
5	C	33	20.9	S	153	1.6	E	D06	Ocean drifter 101920

SUMMARY OF MEASUREMENTS AND SAMPLES TAKEN					
Item No.	PI	No.	Units	Data Type	DESCRIPTION
1	C	14	grabs	G02	Grab samples for sediment analysis – see Tables 2, 3 and 4
2	B	10	cores	G03	Rock cores from fossil reef – see Tables 5 and 6
3	C/A	18	tow	G08	Underwater video camera tow and still photography– see Table 7
4	**B**	**15**	**cores**	**G04**	Vibrocores for sediment stratigraphy – see Tables 8 and 9
4	**B**	**630**	**km2**	**G74**	Swath mapping of Balls Pyramid and Lord Howe Island shelves
5	**B**	**2500**	**km**	**G90**	Acoustic Topas sub-bottom profiling
6	**B**	**1**	**dredge**	**G01**	Rock samples from dredge

Table 1

LIST OF STATIONS				
Station No.	**Lat**	**Long**	**Depth (m)**	**Operation**
01GR01	29°12.5466' S	158°59.9505'E	326	Smith-Mac Grab
02GR02	29°12.7658' S	159°00.2880'E	308	Smith-Mac Grab
03DR01	29°12.747' S	159°00.147'E	314 start	Rock Dredge
04CAM01	29°26.078' S	159°04.661'E	37	Towed video
05VC01	31°46.5391' S	159°15.5947'E	46	Vibrocorer
06VC02	31°46.6185' S	159°17.1824'E	54	Vibrocorer
07CAM02	31°46.531' S	159°16.353'E	56	Towed video
08CAM03	31°46.898' S	159°15.665'E	49	Towed video
09RC01	31°46.533' S	159°16.169'E	37	Rock core
10CAM04	31°46.767' S	159°13.381'E	41	Towed video
11CAM05	31°47.0589′ S	159°19.443'E	60	Towed video
12CAM06	31°51.918' S	159°16.975'E	66	Towed video
13CAM07	31°49.192' S	159°14.330'E	45	Towed video
14CAM08	31°47.358' S	159°13.864'E	42	Towed video
15CAM09	31°46.641' S	159°13.303'E	46	Towed video
16CAM10	31°44.487' S	159°12.303'E	49	Towed video
17CAM11	31°42.668' S	159°11.722'E	78	Towed video
18RC02	31°46.782' S	159°13.485'E	38	Rock core
19RC03	31°47.758' S	159°13.998'E	38	Rock core
20RC04	31°47.406' S	159°13.826'E	43	Rock core
21RC05	31°47.0797' S	159°19.0873'E	42	Rock core
22RC06	31°44.370' S	159°14.633'E	36	Rock core
23VC03	31°46.835' S	159°15.477'E	44	Vibrocorer
24VC04	31°47.6644' S	159°16.5784'E	44	Vibrocorer
25VC05	31°43.792' S	159°18.9954'E	86	Vibrocorer
26VC06	31°43.9656' S	159°18.274'E	55	Vibrocorer
27VC07	31°45.123' S	159°18.329'E,	49	Vibrocorer
28VC08	31°45.7704' S	159°17.098'E	49	Vibrocorer
29VC09	31°43.520' S	159°15.375'E	50	Vibrocorer

LIST OF STATIONS (continued)				
Station No.	**Lat**	**Long**	**Depth (m)**	**Operation**
30VC10	31°43.657' S	159°15.962'E	47	Vibrocorer
31VC11	31°44.391' S	159°14.283'E	40	Vibrocorer
32CAM12	31°48.838' S	159°15.535'E	35	Towed video
33CAM13	31°49.476' S	159°18.893'E	50	Towed video
34CAM14	31°47.350' S	159°17.387'E	49	Towed video
35CAM15	31°45.240' S	159°18.406'E	46	Towed video
36CAM16	31°45.204' S	159°19.206'E	53	Towed video
37RC07	31°49.475' S	159°16.581'E	40	Rock core
38GR03	31°50.674' S	159°15.952'E	50	Smith-Mac Grab
38GR04	31°50.767' S	159°15.699'E	49	Smith-Mac Grab
39GR05	31°51.926' S	159°16.920'E	60	Smith-Mac Grab
39GR06	31°51.946' S	159°16.956'E	60	Smith-Mac Grab
40GR07	31°52.041' S	159°16.963'E	73	Smith-Mac Grab
40GR08	31°52.035' S	159°17.021'E	73	Smith-Mac Grab
41GR09	31°49.639' S	159°18.301'E	52	Smith-Mac Grab
41GR10	31°49.520 S	159°18.340'E	52	Smith-Mac Grab
42RC08	31°49.8788' S	159°19.421'E	72	Rock core
43RC09	31°33.104' S	159°01.950'E	26	Rock core
44RC10	31°33.570' S	159°00.296'E	34	Rock core
45CAM17	31°33.263' S	159°01.617'E	38	Towed video
46CAM18	31°33.863' S	159°00.306'E	46	Towed video
47VC12	31°28.513' S	159°01.755'E	60	Vibrocorer
48VC13	31°29.194' S	159°03.099'E	50	Vibrocorer
49VC14	31°36.014' S	159°08.408′E	53	Vibrocorer
50VC15	31°35.014' S	159°08.819'E	50	Vibrocorer
51GR11	31°33.2381' S	158°58.052'E	832	Smith-Mac Grab
52GR12	31°34.233' S	158°51.105'E	2321	Smith-Mac Grab
53GR13	31°35.0306' S	158°53.165'E	2072	Smith-Mac Grab
54GR14	31°34.915' S	158°53.9978'E	1938	Smith-Mac Grab

Table 2

Smith-Macintyre grab sample sites on un-named seamount (G02; PI = C)				
Station No.	**Lat**	**Long**	**Depth (m)**	**Material**
01GR01	29°12.5466' S	158°59.9505'E	326	Empty
02GR02	29°12.7658' S	159°00.2880'E	308	Coarse carbonate sand

Table 3

Smith-Macintyre grab sample sites on shelf around Balls Pyramid (G02; PI = C)				
Station No.	**Lat**	**Long**	**Depth (m)**	**Material**
38GR03	31°50.674' S	159°15.952'E	50	Carbonate sand and gravel
38GR04	31°50.767' S	159°15.699'E	49	Gravelly carbonate sand
39GR05	31°51.926' S	159°16.920'E	60	Coarse carbonate sand
39GR06	31°51.946' S	159°16.956'E	60	Coarse carbonate sand + gravel
40GR07	31°52.041' S	159°16.963'E	73	Cobble – hard ground
40GR08	31°52.035' S	159°17.021'E	73	Carbonate sand and gravel
41GR09	31°49.639' S	159°18.301'E	52	Carbonate sand and trace gravel
41GR10	31°49.520 S	159°18.340'E	52	Coarse carbonate sand + gravel

Table 4

Smith-Macintyre grab sample sites on margin of Lord Howe shelf (G02; PI = C)				
Station No.	**Lat**	**Long**	**Depth (m)**	**Material**
51GR11	31°33.2381' S	158°58.052'E	832	Coarse carbonate sand
52GR12	31°34.233' S	158°51.105'E	2321	Empty
53GR13	31°35.0306' S	158°53.165'E	2072	Muddy carbonate sand
54GR14	31°34.915' S	158°53.9978'E	1938	Silt

Table 5

Rock core sites on shelf around Balls Pyramid (G03, P=B)					
Core No.	**Lat**	**Long**	**Water depth (m)**	**Penetration (m)**	**Recovery (m)**
09RC01	31°46.553' S	159°16.169'E	37	1.50	0.74
18RC02	31°46.782' S	159°13.485'E	38	1.84	1.26
19RC03	31°47.758' S	159°13.998'E	38	2.31	1.96
20RC04	31°47.406' S	159°13.826'E	43	0.93	0.50
21RC05	31°47.0797' S	159°19.0873'E	42	1.99	1.99
22RC06	31°44.370' S	159°14.633'E	36	2.40	0.35
37RC07	31°49.475' S	159°16.581'E	40	2.90	0.70
42RC08	31°49.8788' S	159°19.421'E	72	2.98	0.59

Table 6

Rock core sites on shelf around Lord Howe Island (G03, P=B)					
Core No.	**Lat**	**Long**	**Water depth (m)**	**Penetration (m)**	**Recovery (m)**
43RC09	31°33.104' S	159°01.950'E	26	2.37	1.26
44RC10	31°33.570' S	159°00.296'E	34	1.45	1.19

Table 7

Camera tow (G08, P=C/A)				
Tow No.	**Lat**	**Long**	**Depth (m)**	**Ends**
04CAM01	29°26.078' S	159°04.661'E	37	start
04CAM01	29°26.236' S	159°04.360'E	36	finish
07CAM02	31°46.531' S	159°16.353'E	56	start
07CAM02	31°46.413' S	159°17.039'E	56	finish
08CAM03	31°46.898' S	159°15.665'E	49	start
08CAM03	31°46.897′S	159°16.344′E	38	finish
10CAM04	31°46.767' S	159°13.381'E	41	start
10CAM04	31°46.506′S	159°13.880′E	41	finish
11CAM05	31°47.0589′ S	159°19.443'E	60	start
11CAM05	31°47.057'S	159°18.661'E	52	finish
12CAM06	31°51.918' S	159°16.975'E	66	start
12CAM06	31°52.249' S	159°17.292'E	124	Finish
13CAM07	31°49.192' S	159°14.330'E	45	start
13CAM07	31°49.487' S	159°14.716'E	45	finish
14CAM08	31°47.358' S	159°13.864'E	42	start
14CAM08	31°47.773′S	159°14.027′E	39	finish
15CAM09	31°46.641' S	159°13.303'E	46	start
15CAM09	31°47.035' S	159°13.828'E	41	finish
16CAM10	31°44.487' S	159°12.303'E	49	start
16CAM10	31°44.690' S	159°12.757'E	45	finish
17CAM11	31°42.668' S	159°11.722'E	78	start
17CAM11	31°43.045' S	159°11.904'E	59	finish
32CAM12	31°48.838' S	159°15.535'E	35	start
32CAM12	31°49.399' S	159°15.068'E	41	finish
33CAM13	31°49.476' S,	159°18.893'E	50	start
33CAM13	31°49.905' S	159°19.451'E	76	finish
34CAM14	31°47.350' S	159°17.387'E	49	start
34CAM14	31°47.749' S	159°17.623'E	41	finish
35CAM15	31°45.240' S	159°18.406'E	46	start
35CAM15	31°45.453' S	159°18.886'E	51	finish
36CAM16	31°45.204' S	159°19.206'E	53	start
36CAM16	31°45.403' S	159°19.776'E	83	finish
45CAM17	31°33.263' S	159°01.617'E	38	start
45CAM17	31°33.097' S	159°02.011'E	33	finish
46CAM18	31°33.863' S	159°00.306'E	46	start
46CAM18	31°33.569' S	159°01.004′E	33	finish

Table 8

Rock core sites on shelf around Balls Pyramid (G03, P=B)					
Core No.	**Lat**	**Long**	**Water depth (m)**	**Recovery (m)**	**Material**
05VC01	31°46.5391' S	159°15.5947'E	46	3.47	Carbonate sand
06VC02	31°46.6185' S	159°17.1824'E	54	3.41	Coarse carbonate sand/gravel
23VC03	31°46.835' S	159°15.477'E	44	2.19	Gravel
24VC04	31°47.6644' S	159°16.5784'E	44	3.77	Coarse carbonate sand
25VC05	31°43.792' S	159°18.9954'E	86	3.35	Carbonate sand
26VC06	31°43.9656' S	159°18.274'E	55	3.28	Carbonate sand
27VC07	31°45.123' S	159°18.329'E,	49	5.63	Coarse carbonate sand
28VC08	31°45.7704' S	159°17.098'E	49	3.51	Carbonate sand
29VC09	31°43.520' S	159°15.375'E	50	2.62	Carbonate sand
30VC10	31°43.657' S	159°15.962'E	47	2.25	Carbonate sand and gravel
31VC11	31°44.391' S	159°14.283'E	40	0.74	Basaltic sand

Table 9

Rock core sites on shelf around Balls Pyramid (G03, P=B)					
Core No.	**Lat**	**Long**	**Water depth (m)**	**Recovery (m)**	**Material**
47VC12	31°28.513' S	159°01.755'E	60	3.28	Carbonate sand
48VC13	31°29.194' S	159°03.099'E	50	0.10	Carbonate sand
49VC14	31°36.014' S	159°08.408′E	53	3.23	Carbonate sand
50VC15	31°35.014' S	159°08.819'E	50	3.00	Carbonate sand

Curation Report

Item No.	DESCRIPTION
1	Multibeam sonar data – Geoscience Australia, University of Wollongong
2	Acoustic Topas sub-bottom profiling – Geoscience Australia
3	Video footage and still photographs of seabed – Geoscience Australia, University of Wollongong
4	Rock dredge samples – Geoscience Australia
5	Rock core samples – Geoscience Australia
6	Vibrocore samples – Geoscience Australia
7	Grabs amples – Geoscience Australia
8	Ocean drifter data – NOAA – see http://www.aoml.noaa.gov/phod/dac/gdp_drifter.php

Voyage track chart

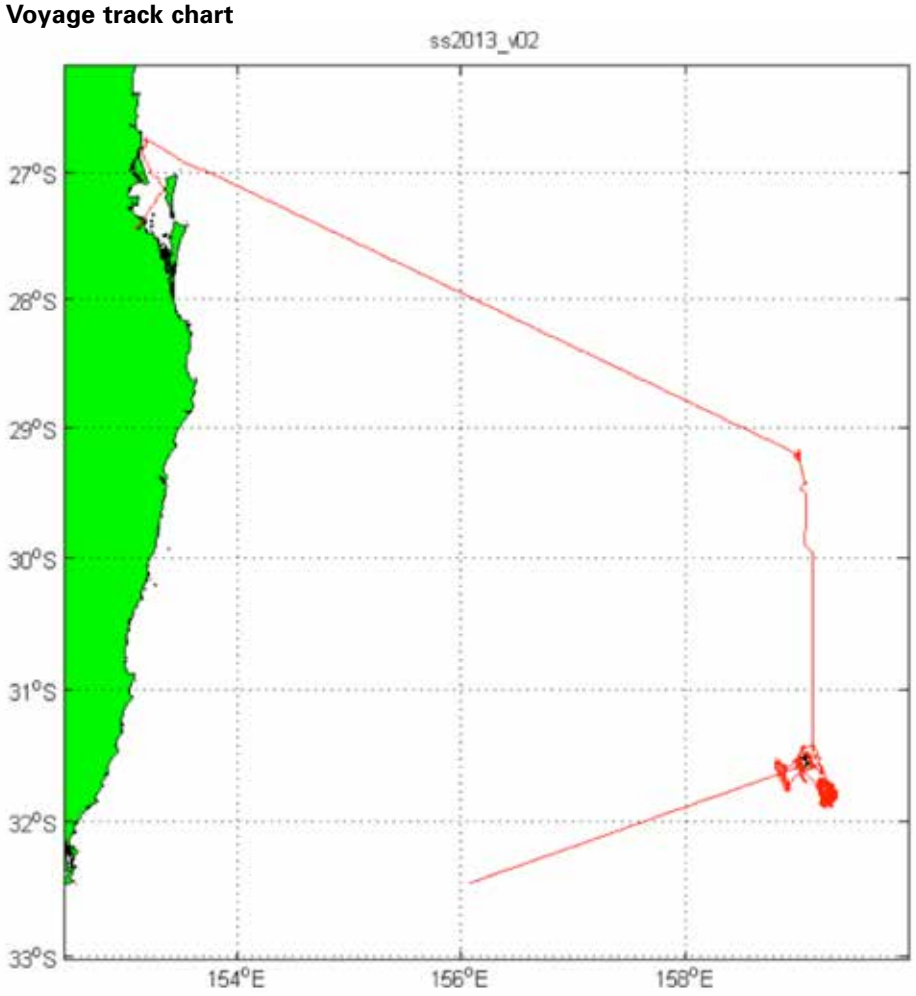


Figure 1. Ship track

General ocean area(s): South Pacific Ocean, Tasman Sea

Specific areas: Elizabeth and Middleton Reefs, Lord Howe Island, Balls Pyramid

Personnel list

Scientific Participants

Name	Affiliation	Role
Prof Colin Woodroffe	SEES, UOW	Chief Scientist
Dr Brendan Brooke	GA [8/2 – 18/2]	Deputy Chief Scientist
Mr Chris Gallen	DPI	Tow video operations
Dr Scott Nichol	GA	Geologist
Michelle Linklater	SEES, UOW	PhD student, benthic mapping
Kim Picard	GA	GIS/acoustics and Topas
Craig Wintle	GA	Mechanical Technician
Mark Sharah	GA	Mechanical Technician
Matthew Carey	GA	Electronics technician (tow video)
Stephen Hodgkin	GA	Electronics technician (tow video)
Tanya Whiteway	GA [18/2 – 25/2]	Spatial data
Bruce Barker	CMAR	MNF Voyage Manager
Brett Muir	CMAR	MNF Electronics Support / Deputy Voyage Manager
Tara Martin	CMAR	MNF Swath support 1
Rick Smith	CMAR	MNF Swath support 2
Hugh Barker	CMAR	MNF Computing Support

Marine Crew

Name	Role
Michael Watson	Master
John Boyes	Chief Mate
Simon Smeaton	2nd Mate
Fred Rostron	Chief Engineer
Stephan Dunmall	1st Engineer
Graeme Perkins	2nd Engineer
Tony Hearne	Chief IR
Matt Streat	IR
Jonathon Lumb	IR
Lewis Coombe	IR
Nathan Arahanga	IR
Michael O'Connor	Chief Steward
Bruce Maher	Chief Cook
Oliver Herlihy	2nd Cook

Acknowledgements

We acknowledge the Marine National Facility and CSIRO for time on the RV *Southern Surveyor*. We particularly thank the Master and crew of the vessel for making this a successful voyage. We appreciate the considerable assistance of Bruce Barker as MNF Voyage Manager, and the professionalism of the CSIRO/MNF personnel. We thank the Lord Howe Island Marine Park Authority for permission to undertake research in the marine park, and Ian Kerr, park manager, for help in planning the voyage and for facilitating the personnel change. We thank Dave Holdway and Ray De Graff of the Field and Engineering Services Group at Geoscience Australia for project and logistical support.

We acknowledge funding support from Geoscience Australia, the University of Wollongong, the NSW Department of Primary Industries, and the Lord Howe Island Marine Park Authority. This voyage is a contribution to the National Environmental Research Program (NERP) through the Marine Biodiversity Hub.

Colin D. Woodroffe (UOW)
Chief Scientist

Figures

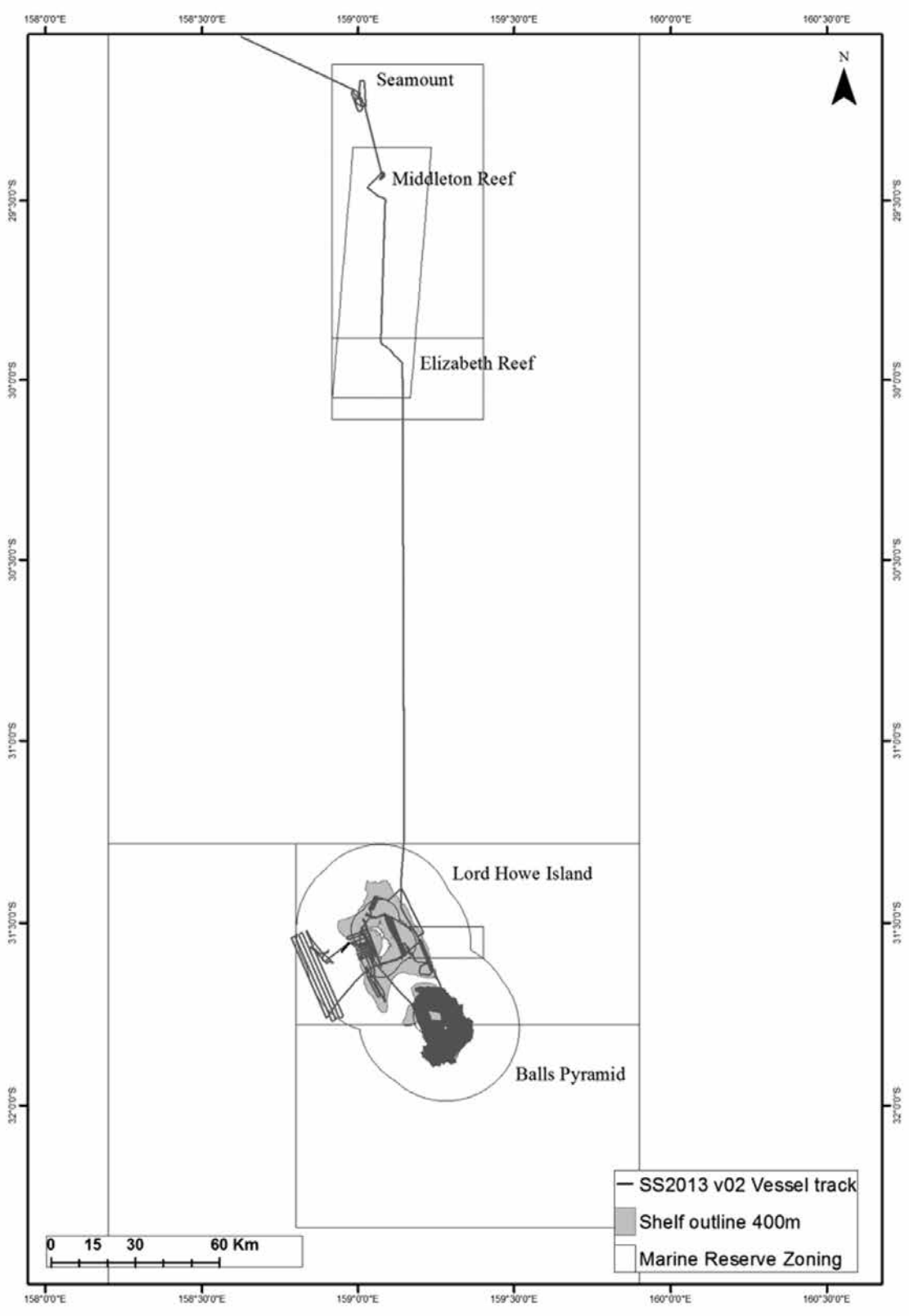


Figure 2. Ship operations in Temperate East Marine Region.

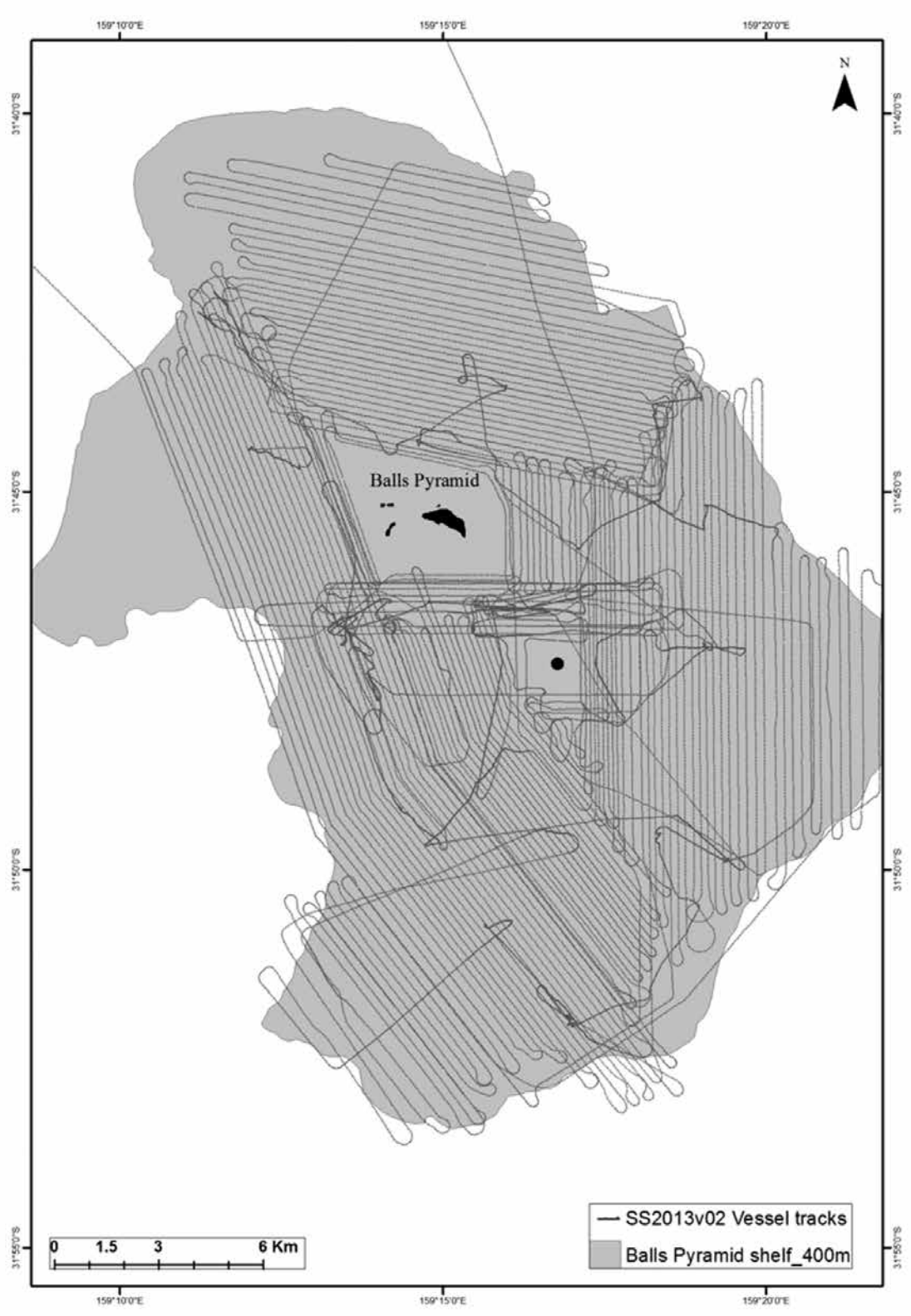


Figure 3. Ship track and swath acquisition lines on the shelf around Balls Pyramid.

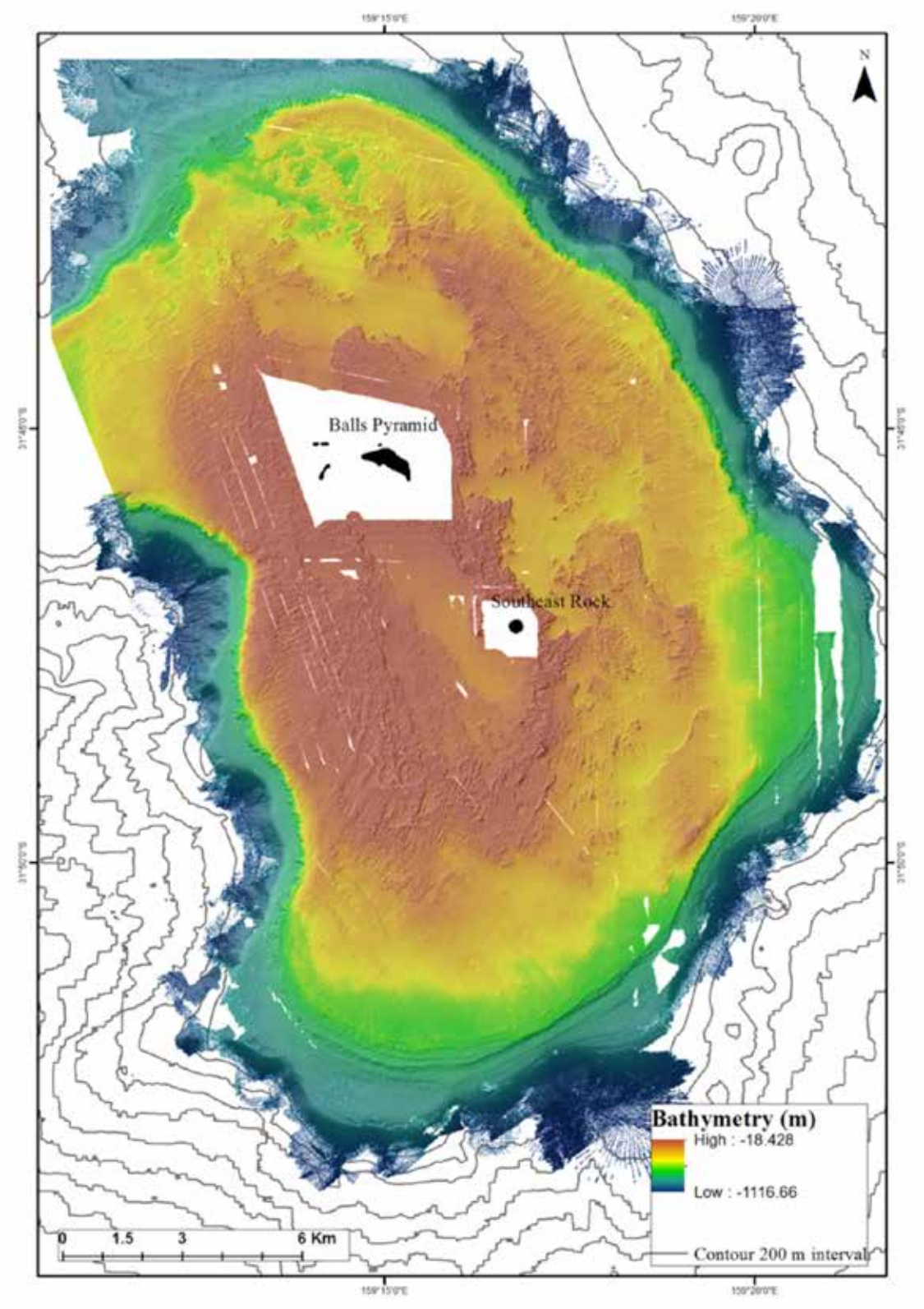


Figure 4. Bathymetry over shelf around Balls Pyramid.

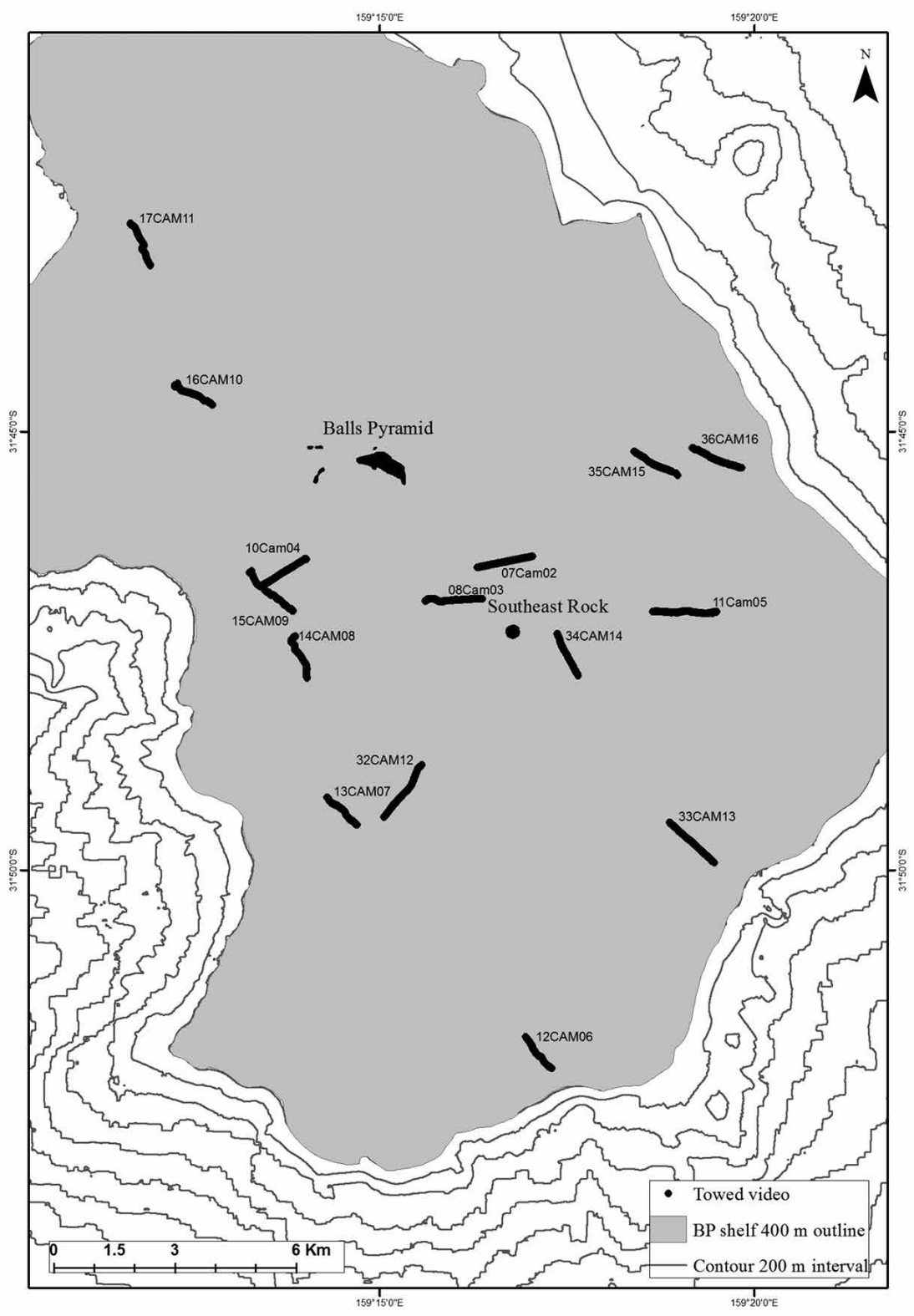


Figure 5. Location of towed video transects on the shelf around Balls Pyramid.

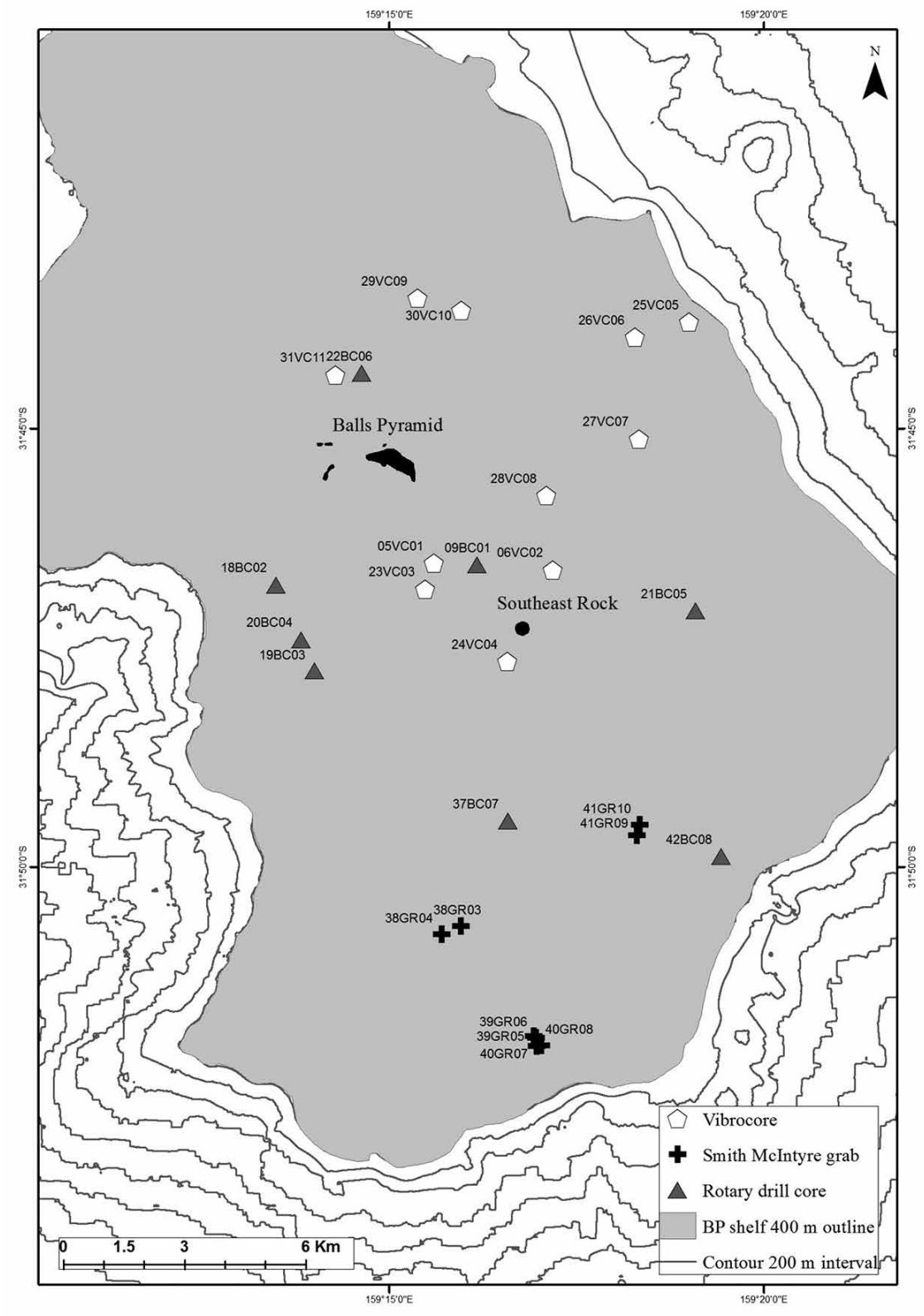


Figure 6. Core and grab sample locations on the shelf around Balls Pyramid.

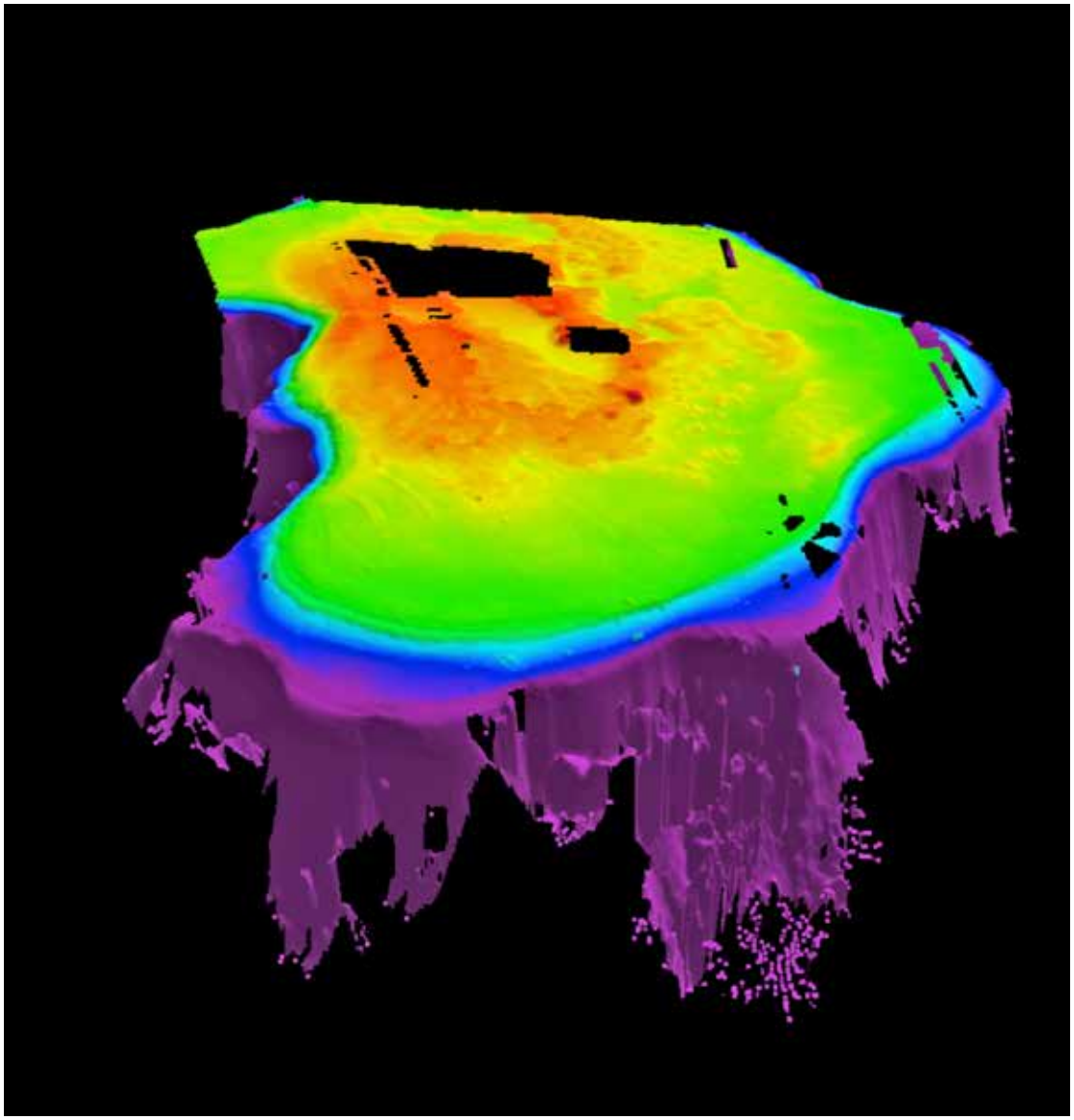


Figure 7. 3D visualisation of topography over shelf around Balls Pyramid.

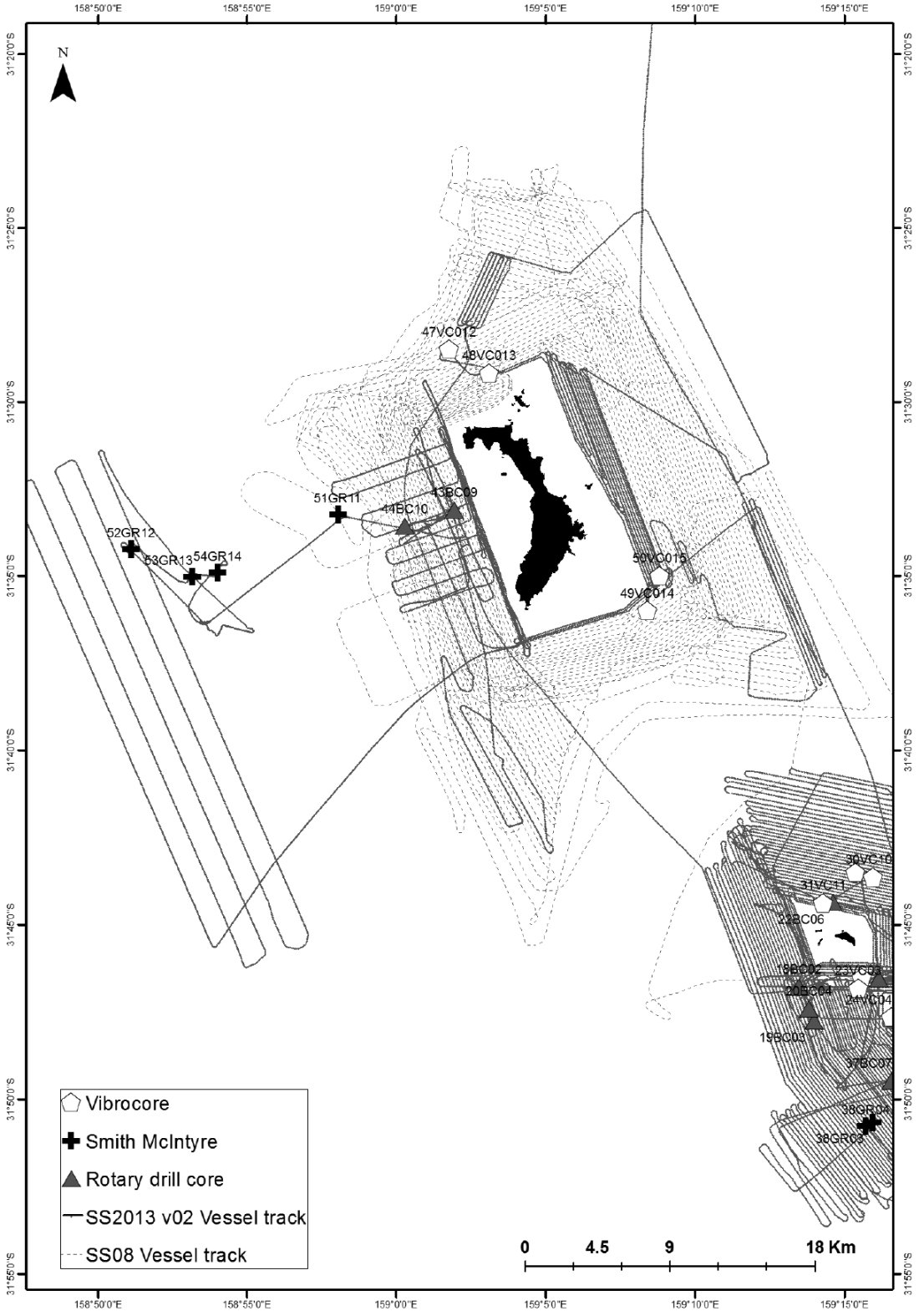


Figure 8. Location of surveys around Lord Howe Island.

CSR/ROSCOP PARAMETER CODES

METEOROLOGY

M01 Upper air observations
M02 Incident radiation
M05 Occasional standard measurements
M06 Routine standard measurements
M71 Atmospheric chemistry
M90 Other meteorological measurements

PHYSICAL OCEANOGRAPHY

H71 Surface measurements underway (T,S)
H13 Bathythermograph
H09 Water bottle stations
H10 CTD stations
H11 Subsurface measurements underway (T,S)
H72 Thermistor chain
H16 Transparency (eg transmissometer)
H17 Optics (eg underwater light levels)
H73 Geochemical tracers (eg freons)
D01 Current meters
D71 Current profiler (eg ADCP)
D03 Currents measured from ship drift
D04 GEK
D05 Surface drifters/drifting buoys
D06 Neutrally buoyant floats
D09 Sea level (incl. Bottom pressure & inverted echosounder)
D72 Instrumented wave measurements
D90 Other physical oceanographic measurements

CHEMICAL OCEANOGRAPHY

H21 Oxygen
H74 Carbon dioxide
H33 Other dissolved gases
H22 Phosphate
H23 Total – P
H24 Nitrate
H25 Nitrite
H75 Total – N
H76 Ammonia
H26 Silicate
H27 Alkalinity
H28 PH
H30 Trace elements
H31 Radioactivity
H32 Isotopes
H90 Other chemical oceanographic measurements

MARINE CONTAMINANTS/POLLUTION

P01 Suspended matter
P02 Trace metals
P03 Petroleum residues
P04 Chlorinated hydrocarbons
P05 Other dissolved substances
P12 Bottom deposits
P13 Contaminants in organisms
P90 Other contaminant measurements
B01 Primary productivity
B02 Phytoplankton pigments (eg chlorophyll, fluorescence)
B71 Particulate organic matter (inc POC, PON)
B06 Dissolved organic matter (inc DOC)
B72 Biochemical measurements (eg lipids, amino acids)
B73 Sediment traps
B08 Phytoplankton
B09 Zooplankton
B03 Seston
B10 Neuston
B11 Nekton
B13 Eggs & larvae
B07 Pelagic bacteria/micro-organisms
B16 Benthic bacteria/micro-organisms
B17 Phytobenthos
B18 Zoobenthos
B25 Birds
B26 Mammals & reptiles
B14 Pelagic fish
B19 Demersal fish
B20 Molluscs
B21 Crustaceans
B28 Acoustic reflection on marine organisms
B37 Taggings
B64 Gear research
B65 Exploratory fishing
B90 Other biological/fisheries measurements

MARINE GEOLOGY/GEOPHYSICS

G01 Dredge
G02 Grab
G03 Core – rock
G04 Core – soft bottom
G08 Bottom photography
G71 In-situ seafloor measurement/sampling
G72 Geophysical measurements made at depth
G73 Single-beam echosounding
G74 Multi-beam echosounding
G24 Long/short range side scan sonar
G75 Single channel seismic reflection
G76 Multichannel seismic reflection
G26 Seismic refraction
G27 Gravity measurements
G28 Magnetic measurements
G90 Other geological/geophysical measurements