Australia's Marine National Facility

VOYAGE SUMMARY ss2011_v06

The Perth Abyssal Plain: Understanding Eastern Gondwana Break-up

Voyage period:
20/10/2011 to 09/11/2011

Port of departure:
Fremantle, Australia

Port of return:
Fremantle, Australia

Responsible laboratory:
Earthbyte Group
School of Geosciences,
Madsen Building F09,
University of Sydney,
Sydney 2006, Australia

Chief Scientist(s)
Simon Williams
Earthbyte Group

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Scientific Objectives

The objectives of this voyage are to investigate:

Objective 1:

The crustal nature of the Gulden Draak Ridge, Batavia Knoll, and Dirck Hartog ridge – continental and/or volcanic – in order to further constrain plate tectonic models of the early separation between India and Australia and also to understand the interaction between the seafloor-spreading system and volcanism related to the Kerguelen hotspot. Sampling of these features should help constrain composition of basement rocks and lead to greater understanding of the interaction between spreading and mantle plume processes. If, overall, any of the zones represent extended continental crust, it is possible that continental rocks could be recovered. If only igneous rocks are recovered, then their geochemical composition may be indicative of the dominant formation processes – seafloor spreading vs mantle plume. This objective relates primarily to Nathan Daczko and Jacqueline Halpin.

Objective 2:

The age and formation history of the 'de Gonneville Triangle'. This piece of oceanic crust is located at what was the triple junction of rifting between Australia-India-Antarctica. How and when the de Gonneville Triangle and the Naturaliste Fracture zone formed have important implications for plate tectonic models attempting to reconstruct the pre-rift fit and the break-up and spreading history of the India-Australia-Antarctica triple-plate system. Understanding the de Gonneville Triangle is especially important because prior to Australia-Antarctic break-up it was immediately adjacent to the Enderby Basin, and the two basins should reveal the same magnetic anomaly patterns but current interpretations reveal considerable discrepancies. This objective relates primarily to Joanne Whittaker, Dietmar Müller and Simon Williams.

Objective 3:

The age distribution of oceanic crust across both the east and west Perth Abyssal Plain. Acquiring ridge-perpendicular magnetic anomaly profiles are crucial in order to constrain the early spreading history between India and Australia and the pre-breakup fit between India-Antarctica and Australia. Of particular importance is the oceanic crust located southwest of the Dirck Hartog Ridge. Sampling in the Perth Abyssal Plain region will help to resolve uncertainties regarding the early spreading history and the full-fit of the India-Australia-Antarctica triple plate system. This objective relates primarily to Joanne Whittaker, Dietmar Müller and Simon Williams.

Voyage Objectives

Objective 1:

The use of a magnetometer is planned in order to acquire magnetic anomaly data that will reveal the magnetic patterns of the Perth Abyssal Plain and constrain the timing of formation of this ocean floor. The acquisition of ~3000 km of magnetic anomaly data is planned (Figure 1). One magnetic profile is planned across the east Perth Abyssal Plain, to complement magnetic anomaly data already existing in this basin. Four magnetic anomaly profiles are planned crossing the poorly sampled west Perth Abyssal Plain, with one magnetic profile also crossing the de Gonneville Triangle. All these tracks are planned to trend roughly NW-SE in order to be perpendicular to the spreading fabric of these basins. Tracks have been planned to avoid the influence of intra-basin, small-scale volcanism as much as possible.

Objective 2:

We plan to undertake 6 dredges to sample the Batavia Knoll, Gulden Draak Ridge, southern flank of the Naturaliste Fracture Zone, and three locations along the Dirck Hartog Ridge (Figure 1) Ideally, we would also like to dredge the de Gonneville Triangle, but the seafloor of this feature is in water depths greater than ~4000 m, so will not be included in this voyage unless an extra ~1000m of cable can be sourced. We have planned for the acquisition of approximately 3.5 days of multibeam (swath) and single beam sonar profiles to assist with the selection of sampling sites. We plan to swath-map potential dredge locations in order to identify dredge targets. Dredging by previous *Southern Surveyor* voyages in the region used swath-mapping to identify dredge targets and was very successful. The Perth Abyssal Plain has water depths ranging from about 1000-2500 m for the tops of the ridges/plateaus to 5500 m in the middle of the abyssal plain. However, the maximum possible dredge depth using the standard *Southern Surveyor* dredging equipment is ~3500 m. Therefore, we have planned to take dredge samples from ridges where water depths are less than 3500 m. The Simrad EM 300 works best in water depths less than 3000 m, so for some of the deeper dredges we may have to rely on the 12 kHz echosounder and 3.5 kHz sub-bottom profiler to identify good outcrop locations.

Results

Scientific Objective 1:

Successful. Continental rocks (gneiss, granite, sandstone) were dredged from both the Batavia Knoll and the Gulden Draak Ridge (Figure 1: dredge sites 1, 2, and 3) suggesting that these plateaus are continental in nature and rifted off a departing India. A small amount of weathered basalt was recovered from the Gulden Draak Ridge (Figure 1: dredge site 4), suggesting that this more southern plateau was affected by volcanism, however due to the highly altered nature of the samples it is unlikely that further analysis will be able to ascertain whether these rocks have Kerguelen plume affinities or otherwise. Three successful dredges were undertaken along the Dirck Hartog Ridge recovering peridotite (Figure 1: dredge 5) and basalts (Figure 1: dredge sites 6 and 7). The samples collected suggest that the Dirck Hartog Ridge is not a continental feature and future analysis will investigate the provenance of the seamounts composing the Dirck Hartog Ridge and whether they are related to the magmatic processes of the Kerguelen Plume.

Scientific Objective 2:

Unsuccessful. Magnetic and dredge data to be collected at the de Gonneville Triangle was the last data we aimed to collect during the voyage (see Figure 2). Both magnetic and dredge data collected during the early part of the voyage was highly successful and showed somewhat unexpected results. Following these initial results, the decision was made to focus the remaining time on collecting further data related to Scientific Objectives 1 and 3 at the expense of Objective 2.

Scientific Objective 3:

Successful. During the voyage six magnetic profiles were collected across the Perth Abyssal Plain, (1) two basin-wide magnetic profiles (Figure 1: profiles 1, 2a and 2b), (2) two profiles across the previously poorly mapped southwest Perth Abyssal Plain (profiles 3 and 4), and (3) two profiles sampling the western Perth Abyssal Plain and crossing the trough into the Wharton Basin (Figure 1, profiles S1 and S2). Onboard analysis of profile 1 unexpectedly revealed possible Cenozoic magnetic anomaly reversals at the far western extent of the Perth Abyssal Plain. Due to this unexpected finding, the decision was made to collect further magnetic anomaly profiles (S1 and S2) in order to test competing hypotheses regarding the formation and emplacement of the two plateaus, Batavia Knoll and Gulden Draak Ridge, and the prominent trough located north of the Batavia Knoll.

Voyage Objective 1:

Successful. We collected continuous, good quality magnetic anomaly profiles in all the planned areas (Figure 1 and 2) with the exception of the planned profile across the de Gonneville Triangle. Additional profiles were acquired to examine the links between the western Perth Abyssal Plain and the Wharton Basin. The magnetometers generally worked well – the first magnetometer we used developed a leak on the third day, but this unit was replaced by a backup device which functioned correctly for the remainder of the voyage. Overall we were able to recover continuous, good quality data for all attempted profiles.

Voyage Objective 2:

Successful. We planned to undertake 6 dredges (Figure 2) and we exceeded our expectations by successfully dredging 7 locations (2 on the Batavia Knoll, 2 on the Gulden Draak Ridge and 3 on the Dirck Hartog Ridge, see Figure 1). Rock samples were recovered at each site included granite, gneiss, sandstone, peridotite and basalt. We did not undertake the planned dredge at the edge of the de Gonneville Triangle for the reasons stated above.

Voyage Narrative

Depart Fremantle, 20/10/2011

Magnetic Profile 1, 20/10/2011 to 24/10/2011

Swathing data collection begins soon after departure. Magnetometer deployed around 1900 once deeper water is reached, some initial teething problems, one related to an incorrect setting in the magnetometer software (SeaLink). The purpose of this long, straight profile is for magnetic anomaly interpretation. During this time the data collected are magnetometer data and swath bathymetry.

The main issue during this profile occurred during the late afternoon on 23/10/2011 when the data from the magnetometer became spiky, although the data still appeared to be usable. Around 17:30 a leak warning was observed from the magnetometer recording software. The ship slowed down, the leaking magnetometer taken out of the water, and the reserve magnetometer put into the water. The ship turned around, retracing the path to 5 km beyond the point at which the leaking magnetometer was switched off, then the ship turned again to continue on the original course with overlap between the last data collected from the original and replacement magnetometers. The replacement magnetometer functioned fine. The CSIRO technical staff opened up the unit and found around 50ml of water along with a loose screw inside. The unit was left to dry and reassembled the next day. Other issues arose from the software used to record the data from the magnetometer, which was temperamental throughout the voyage. The software appended incorrect coordinates and times to the data in the output files.

The quality of swath bathymetry data during the first profile was generally poor, since the water depths were typically ~5000 m, beyond the normal capability of the system.

Swath Mapping, 24/10/2011

End of first magnetic profile, then ship turns south towards Batavia Knoll. From this time until the dredging the ship's path was dictated by the swath mapping, magnetometer data was also collected. The transit to the Knoll follows a gentle zig-zag path to cross a large bathymetric trough 4 times. Upon reaching the Knoll, a systematic swath mapping survey is carried out with the aim of identifying possible dredge sites. The survey comprises parallel NE-SW lines 3-4 km apart to generate a 20km wide band from NW to SE across the knoll. The lower slopes of the NW side show interesting structures, however above depths of ~2800 m the bathymetry levels off and several parallel swaths indicate the top of the knoll is a vast featureless expanse (ie not ideal for dredging). Two additional lines are added going across the knoll in a NW-SE direction, to see what the other sides looks like before returning to the NW side in time for dredging early the following morning.

Dredges 1-2, 26/10/2011

Dredging on the northwest margin of the Batavia Knoll. The dredge at site 1 yielded granites, gneisses and some fault rocks. Site 2 yielded a large boulder of fossiliferous sandstone and other smaller sandstone samples.

Magnetic Profiles S1, S2 and 2a, 26/10/20 to 31/10/2011

Acquisition of supplementary magnetic profiles (ie not part of original voyage plan) into the Wharton Basin. These profiles were added to the voyage plan on the basis of the data collected on the first profile and the dredge sites – the aim was to test the symmetry of magnetic anomalies across the bathymetric trough to the north of Batavia Knoll. Following these profiles, the ship transited back across Batavia Knoll to begin the second planned magnetic profile, leading SE towards the Dirck Hartog Ridge.

31/10/2011

Following completion of the magnetic profile down to Dirck Hartog Ridge, the original plan involved dredging at three sites on Dirck Hartog Ridge. The discovery of continental rocks at Batavia Knoll meant that the (likely analogous) Gulden Draak Knoll was even more of a priority. Hence the decision to delay the Dirck Hartog Ridge dredges until the return journey, and proceed directly to the highest priority site. A transit along the Dirck Hartog Ridge was still necessary, during which the highest/steepest parts of the ridge (based on gravity data) were swath mapped to identify potential dredge sites for the return journey. Two sites were identified near to planned dredge sites #3 and #4.

Magnetic Profile 3, 31/10/2011 to 2/11/2011

Magnetic Profile and swath data acquired on NW-SE line between Dirck Hartog Ridge and Gulden Draak Knoll

Dredge 3, 2/11/2011

Crossing the Gulden Draak Knoll from east to west, the bathymetry eastern side is smooth (ie no potential dredge sites) so ship continues straight to western side. Dredge sites are identified on the western margin in the afternoon. The dredge recovers a large haul of rocks which include sandstone and siltstone but also rounded cobbles of granite and gneiss and a few angular fresh pieces of metapelitic and granitic gneiss which were likely in situ. Rare altered fault rocks and ?basalts were also collected. Proceed overnight to second swathing/dredging area on the north slope of the Knoll.

Dredge 4, 3/11/2011

Systematic swath map from early hours of morning, identify dredge site by 6am, dredging carried out that morning. The dredge brings in a small haul of strongly weathered basalts and rare Mn-oxide cemented talus.

Magnetic Profile 4, 3/11/2011 to 5/11/2011

Acquisition of magnetic profile 4 on a NW-SE line from Gulden Draak Knoll to Dirck Hartog Ridge.

Dredges at sites 5 and 6, 5/11/2011

Arrive at 6am at dredge site on Dirck Hartog Ridge, identified from earlier transit across the ridge. This dredge was the unusually tricky for the crew due to the following wind (all other dredges were conducted into the wind), hence the ship required more manoeuvring to ensure the dredge sinks properly. The dredge at site 5 brings in a large load of serpentinised peridotite and minor sandstones, altered fault rock and cemented talus. Transit to second dredge site undertaken at high speed to allow second dredge further north along the ridge to be carried out later afternoon. Second dredge of day returns moderate haul of variably altered amygdaloidal basalt and cemented talus. To save time, the magnetometer was not deployed between dredge sites 5 and 6.

Dredge Site 7, 6/11/2011

Transit northwards overnight to dredge site at northern end of Dirck Hartog Ridge. Swath map until 9am then carry out dredge on northeast facing slope, recovering a smallish haul of amygdaloidal basalt. Further swath mapping until 3pm departure to next waypoint then start of final magnetic profile back towards Fremantle.

Magnetic Profile 2b, 6/11/2011 to 8/11/2011

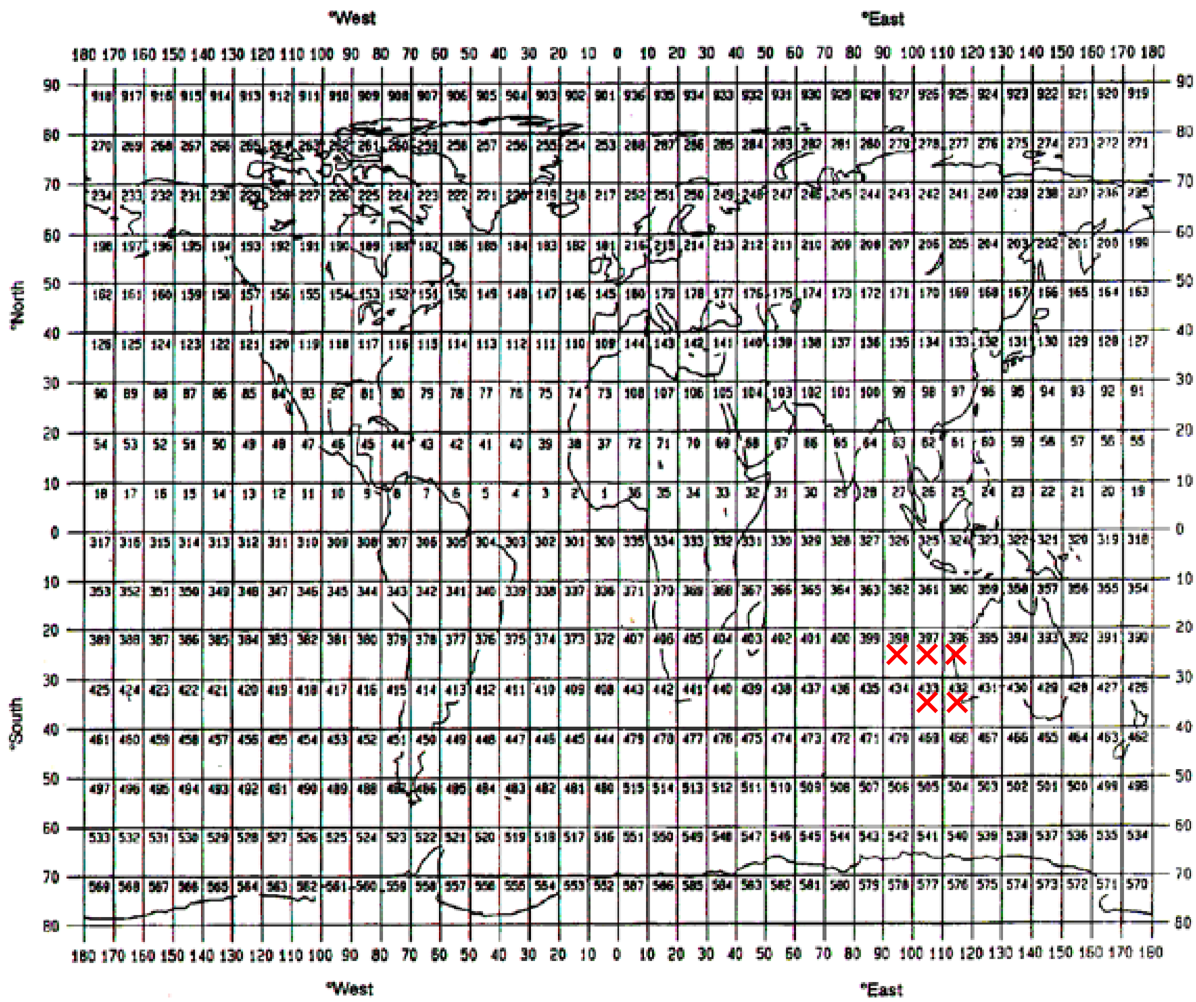
Acquisition of magnetic profile 2b (the track is a continuation of profile 2a acquired earlier in the voyage). Magnetic data are collected along this profile until 1600 on 8/11 (after reaching an area where existing magnetic data coverage is already good). At this point, the magnetometer is removed from water and the original magnetometer (ie the one that leaked) put back in the water for 15 minutes to check it is functioning correctly. Then remove this magnetometer, end of instrument towing.

Arrive Fremantle, 9/11/2011

Summary

Overall, the voyage was highly successful. The collection of continental rocks from both the Batavia Knoll and the Gulden Draak Ridge will enable us, for the first time, to confirm that these large underwater plateaus are microcontinents left behind as seafloor spreading moved India progressively away from Australia. The magnetic anomaly data collected was of a good quality and will enable us to better understand the tectonic processes acting on the separating Indian and Australian continents, and the mechanism/s that led to the formation of the Batavia Knoll, Batavia Trough and Gulden Draak Ridge. Dredge samples collected from the Dirck Hartog Ridge indicate that this feature is not continental in nature and the good quality of the samples obtained will enable further research to ascertain whether there is any link between this feature and the Kerguelen Hotspot.

A red "x" indicates where data was collected.



SUMMARY OF MEASUREMENTS AND SAMPLES TAKEN

ITEM NO.	PI	NO	UNITS	DATA TYPE	DESCRIPTION
1	A	7880	Line km	G74	Multibeam bathymetry acquired using ship-installed system. Continuous recording for the entire voyage. Data recorded for identification of dredge sites and study of seafloor geomorphology.
2	A	7400	Line km	G28	Total magnetic intensity of the Earth's magnetic field recorded in nanoTesla using towed magnetometer. Continuous recording for the entire voyage, with the following exceptions (a) dredge sites, (b) track between dredge sites 5 to 6, and (c) beginning and end of voyage near Fremantle. Data recorded for analysis of magnetic polarity reversals within ocean crust, interpretation of the age distribution of oceanic crust within the study area.
					Dredge Samples: Rock samples from dredges. Dredge samples recovered at 7 sites, for the purpose of conducting detailed lab-based analysis. This will include studies of whole-rock composition, mineralogy, age-dating, pressure-temperature paths (for metamorphic rock samples), depositional environments (for sedimentary rock samples).
3	C	40	kg	G01	Rock samples from dredge #1, NW scarp of Batavia Knoll. Fresh granites, granite gneisses, schists, intermediate (?)paragneisses
4	C/E	40	kg	G01	Rock samples from dredge #2, NW scarp of Batavia Knoll. Fossiliferous sandstones
5	C/E	40	kg	G01	Rock samples from dredge #3, W scarp of Gulden Draak. grt-sill-bt gneiss, granite gneiss, granite and granite gneiss cobbles, turbidites, sandstones, minor altered basalt
6	C	10	kg	G01	Rock samples from dredge #4, N scarp of Gulden Draak. Strongly altered basalts and talus
7	C	100	kg	G01	Rock samples from dredge #5, W scarp of Southern Dirck Hartog Ridge. Serpentinied peridotites, red sandstones, Mn-oxide cemented talus
8	C	30	kg	G01	Rock samples from dredge #6, Central Dirck Hartog Ridge. Amygdaloidal basalts, Mn-oxide cemented talus
9	C	30	kg	G01	Rock samples from dredge #7, NE scarp of Northern Dirck Hartog Ridge. Amygdaloidal basalts, Mn-oxide cemented talus

CURATION REPORT

ITEM NO.	DESCRIPTION
1	The digital swath data will be stored at the School of Geosciences, The University of Sydney. It will also be added to the database at Geoscience Australia, Canberra
2	The digital magnetic anomaly data will be stored at the School of Geosciences, The University of Sydney. It will also be added to the database at Geoscience Australia, and added to the international NGDC repository.
3	Rock samples will split between Macquarie University and Sydney University, with Macquarie University storing all rocks except for sandstones recovered from the Batavia Knoll and Gulden Draak Ridge, which will be stored at the University of Sydney.

Figure 1: Ship track undertaken during the ss2011_v06 voyage.

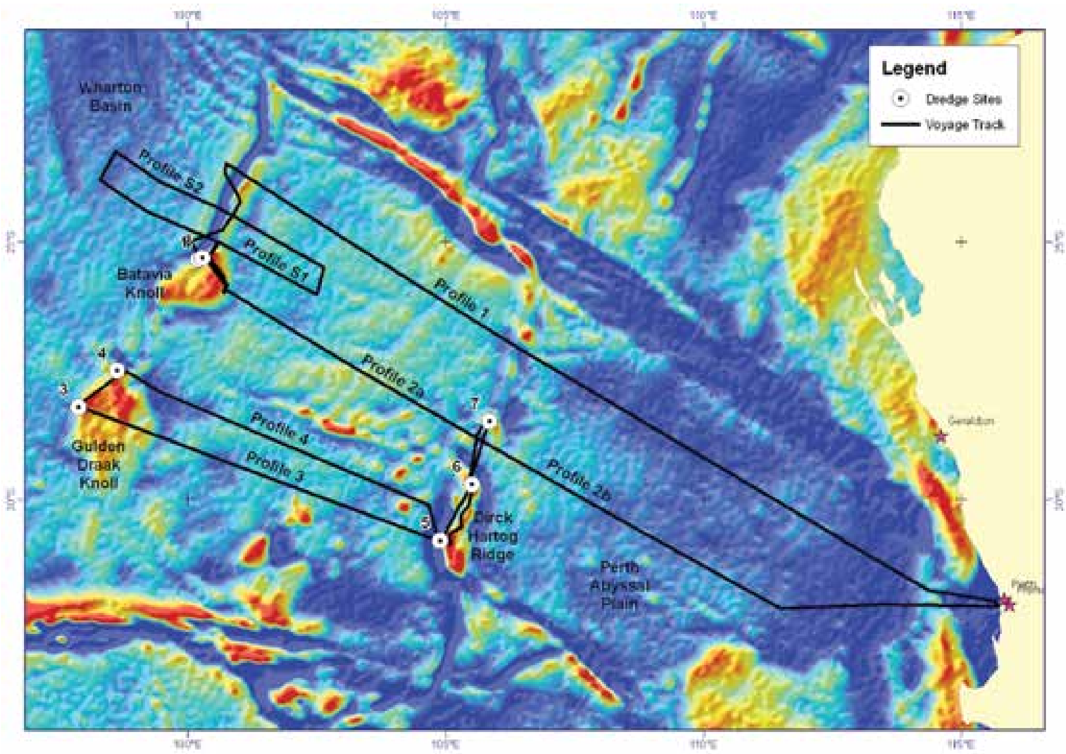
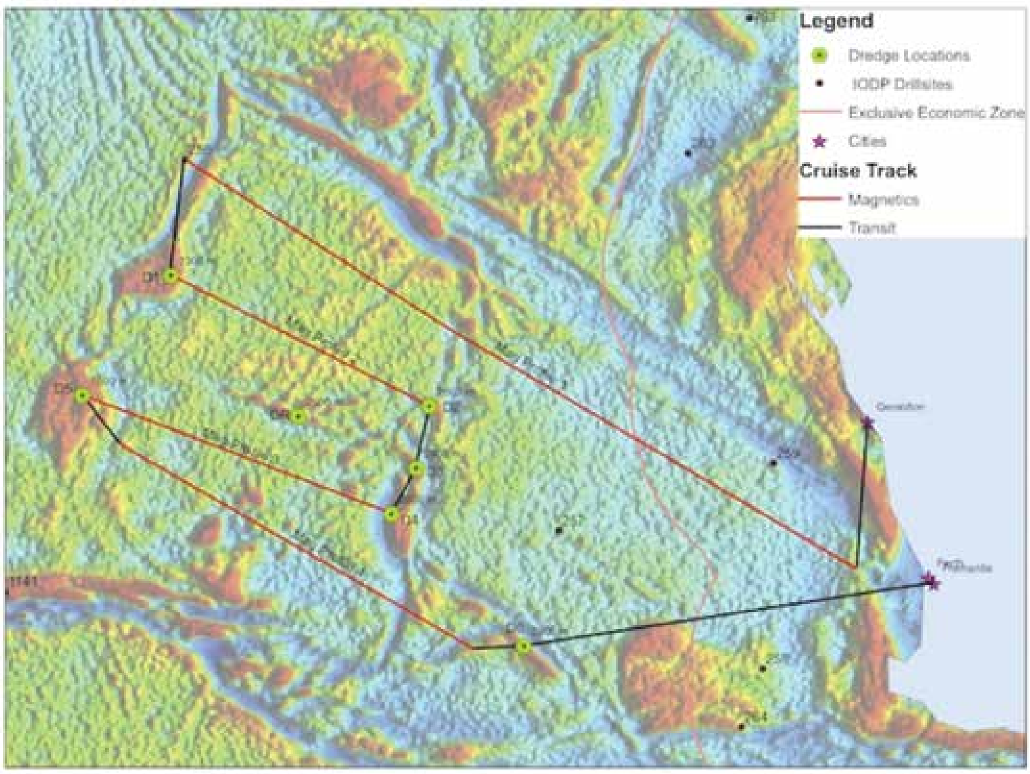


Figure 2: Planned ship track for the ss2011_v06 voyage prior to departure.



Personnel list

Scientific Participants

Dr Simon Williams	University of Sydney	Chief Scientist (tectonics/magnetics scientist)
Dr Jacqueline Halpin	University of Tasmania	Geochemical/geochronology scientist
Dr Nathan Daczko	Macquarie University	Geochemical/geochronology scientist
Dr Roi Granot	Ben-Gurion University, Israel	Magnetics/tectonics scientist
Jack Healy	University of Sydney	Magnetics student
Madeline Kobler	Macquarie University	Geochemical/geochronology student
Robyn Gardner	Macquarie University	Geochemical/geochronology student
Adrien Bronner	Institut de Physique du Globe Strasbourg	Continental margin tectonics student
Aedon Talsma	University of Sydney	Tectonics student
Nathan Butterworth	University of Sydney	Tectonics student
Zohar Ehrlich	Ben-Gurion University, Israel	Magnetics/tectonics student
Don McKenzie	CSIRO/MNF	MNF Voyage Manager
Hugh Barker	CSIRO/MNF	MNF Computing Support
Drew Mills	CSIRO/MNF	MNF Electronics Support
Tara Martin	CSIRO/MNF	MNF Swath Support

Marine Crew

Name	Role
Mike Watson	Master
John Boyes	1st Mate
Tom Watson	2nd Mate
Nick Fleming	Chief Engineer
Mike Yorke-Barber	1st Engineer
Philip Christopher	2nd Engineer
John Howard	CIR
Kel Lewis	IR
Jonathon Lumb	IR
Nathan Arahanga	IR
Peter Taylor	IR
Stuart Mills	Chief Cook
Aaron Buckleton	2nd Cook
Michael O’Connor	Chief steward

Acknowledgements

We would like to acknowledge the support of Statoil, who provided the funds to cover ancillary costs associated with the voyage, such as flights and shipping.

Dr Simon Williams
Chief Scientist

CSR/ROSCOP PARAMETER CODES

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