Cruise TN365 of the Thomas G. Thompson
Report
Marion Rise, Southwest Indian Ridge

February 21st to March 28th, 2019

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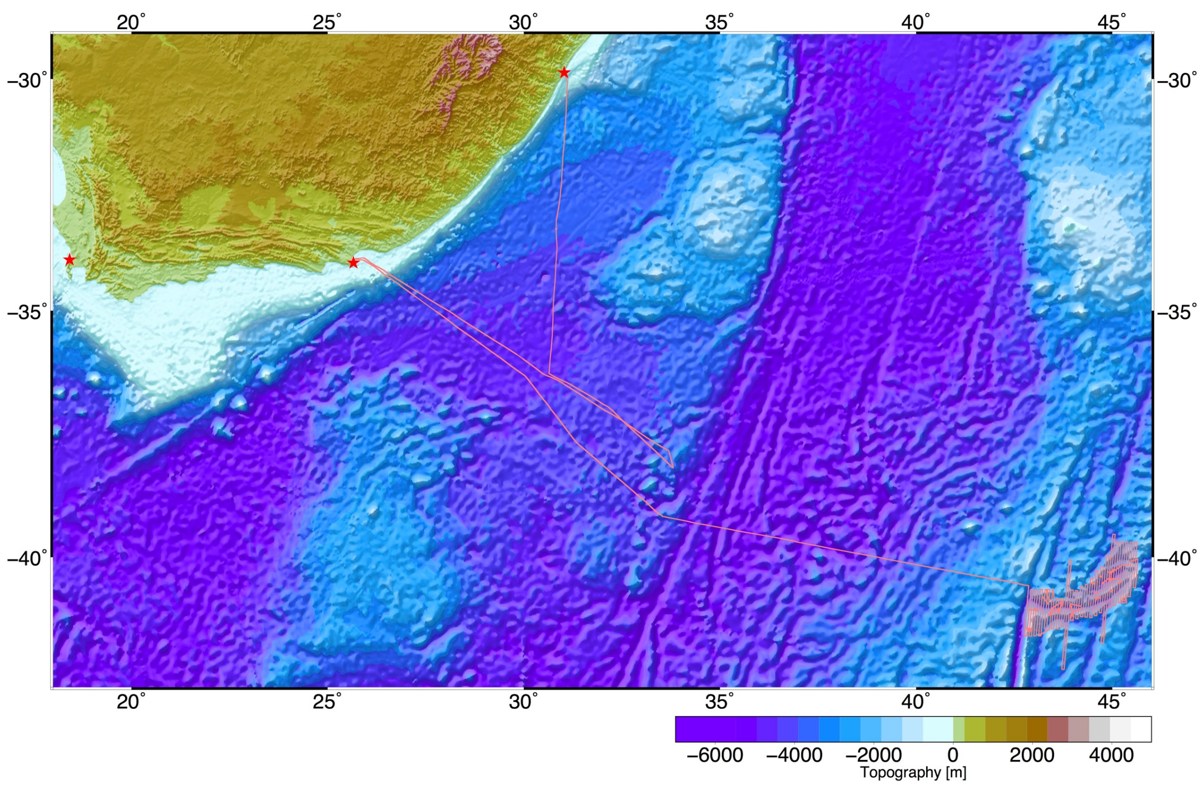

Track RV Thomas G. Washington Cruise TN365

Index

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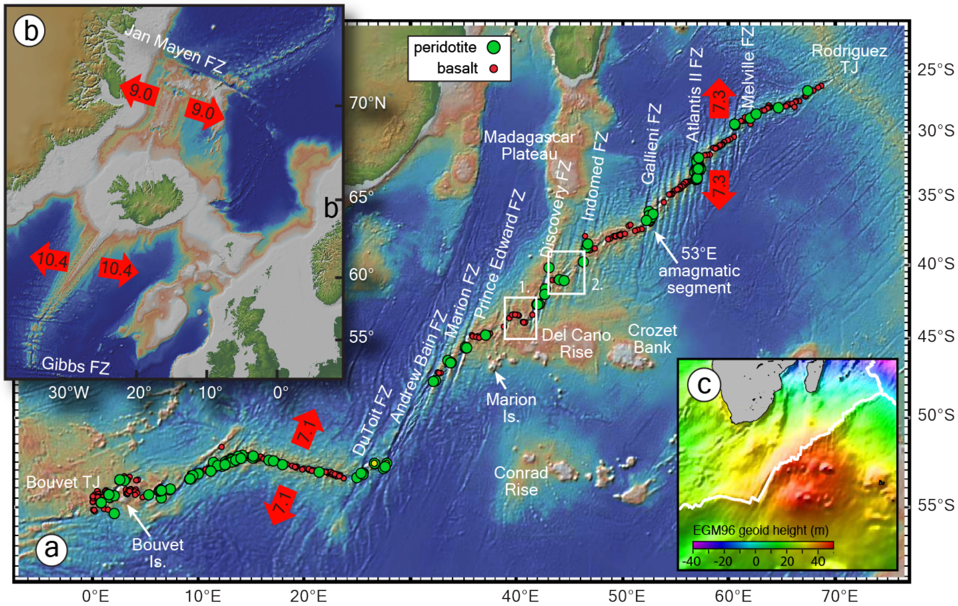

Figure 1. a. SW Indian Ridge with basalt (red) and peridotite (green) sample locations modified from Zhou & Dick (Zhou & Dick, 2013. b. Icelandic Rise plotted at the same scale for reference. C. Southern Oceans

Introduction

Cruise TN365 of the RV Thomas G. Thompson is Leg 1, of a 2 Leg international program to study a section of the Southwest Indian Ridge that extends ~2,000 km from the Andrew Bain to the Gallieni FZ that crosses over the Marion Platform. It represents the crest of the Marion Rise, which extends along the ridge from 25°E to 60°E rising from its deepest points at ~25° and 60°E (_______-M and ____P_-m respectively) to 1000-m depth at ~36°E (Fig. 1). The main program objective is to test the hypothesis that the rise is isostatically supported by ancient residues of a prior mantle-melting event, as opposed to representing thick crust and hot mantle associated with a near-ridge mantle plume as believed for Iceland. Scattered dredge hauls of anomalously-depleted granular abyssal peridotites from the region were previously interpreted as demonstrating that the ridge generated crust is often thin or discontinuous across the platform; consisting of alternating large exposed mantle domains, thin crust, and locally robust magmatic centers. If correct, then the rise would be supported by light buoyant mantle, not by a hot fertile mantle plume or dynamic upwelling.

This then is postulated to be the result of lateral mantle heterogeneity produced by recycling different Gondwana mantle provinces; reflecting the pre-breakup lateral transition from Archaean Craton to the west, and the Proterozoic East African Orogenic Belt (EAOB) to the east. The region is unique as it is the nexus that connects the Indian Ocean and South Atlantic isotopic provinces, marks the end point of the Marion hotspot track, and contains the extension of the key geophysical boundary separating the Archean craton and the Neoproterozoic East African Orogenic Belt (EAOB). The Marion

Platform then, would be underlain by highly depleted arc-mantle wedge material and the remains of subducted ocean crust and sediment delaminated or sheared off from the underlying mantle of the EAOB with the breakup of Gondwana and the formation of the Southwest Indian Ridge.

Proposed Scientific Program

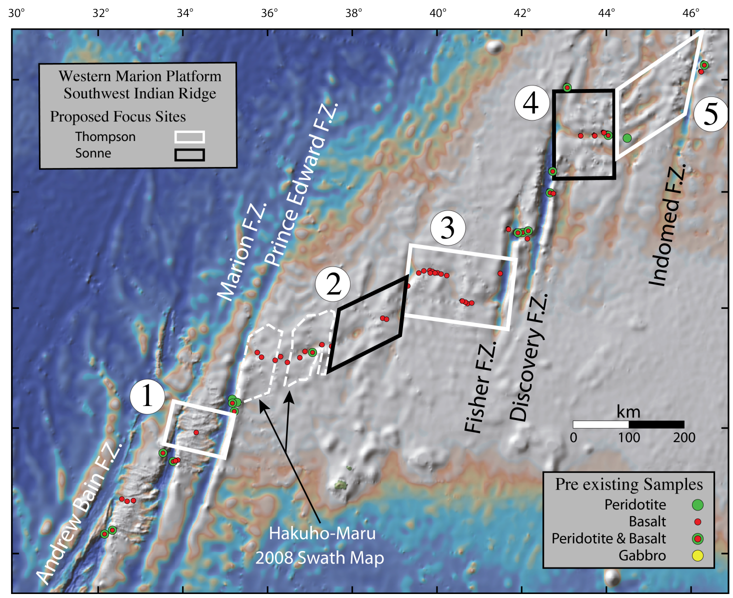

Figure 2. Funded work plan for the two ship Marion Rise Program. Black boxes are the US focus sites for swath mapping and sampling with additional near-bottom mapping by the Sentry ROV. White boxes are the German focus sites for swath mapping and sampling. The US cruise was designed to precede the German cruise so that it could identify key tectonic and hydrothermal targets for the German ROV.

The proposed scientific program included two separate expeditions, one US and one German. Both the US and German cruise proposal were funded, including the current cruise on the RV Thomas G. Washington, and the RV Sonne for March 2020. Additional support was provided by Tongji University with funding for 3 days additional ship time and for the ROV Sentry. The follow-on Sonne cruise will include a German ROV. The region to be studied was divided into 5 work areas shown in Figure 2. Area 1 is an optional site that would only be dredged on a stopover during transit, time permitting. Areas 2 and 4 were to be mapped by the German ship RV Sonne, while areas 3 and 5 would be mapped by the Thompson. The sites were staggered as the US cruise would search for possible hydrothermal sites in advance of the Sonne, which would be equipped with an ROV. The US ship would also deploy MAPRs for this purpose, as well as conducting Sentry ROV surveys. The latter would also provide locations for ROV dives designed to make detailed sampling traverses on core complexes and other tectonic features.

One additional feature of this dual ship operation was that both ships would make parallel R/T transits over the Discovery and Fisher Transforms, mapping this unusual double transform system at no cost to the program, which with the recent, but not yet released Hakuho-Maru section, would complete swath mapping of the ridge over the Marion Rise.

Funded US Operational Program

The US operational program funded (Table 1) included 33 days at sea. With additional funding provided by the Tongji, 3 days were added to the cruise to accommodate addition of the ROV Sentry. Thus, without reducing the funded program, we could simultaneously collect microbathymetry and dredge. In all, 14 days were allocated for dredging in the l plan, which at a conservative estimate of 4 dredges per day, would allow 48 dredge hauls to be accomplished. The addition of three extra days would compensate for the requisite time for Sentry deployments and recoveries during which we would be unable to dredge – roughly 5 hours per dive (one hour minutes for over the side operations two hours R/T to deploy Sentry to the bottom, plus up to several hours when time remaining before recovery was too short for a dredge). It was expected that this extra time was actually generous, and would allow some extra dredging time.

Table 1. Funded Operational Plan for the RV Thomas G. Thompson

Duration	33 Days		
Ports	Durban-Durban		
Transit	km	nm	Days (@ 10 kts)
Durban - 37.5°E,44.6°S	1633	881.7	3.7
Transit C Complexes	168	90.7	0.4
Transit to Orthogonal seg	301	162.5	0.7
Transit to Oblique Seg	88	47.5	0.2
Transit Oblique Seg	250	135.0	0.6
Transit to Durban SA	1700	917.9	3.8
	Transit		9.3
Station			
39°-42°E	28 dredges		7.0
43°-46´E	28 dredges		7.0
Survey	km	nm	
Box 1 Survey (2,000 m)	182	98	
50 k2/hr	132	71	
		7004	5.8
Box 2 Survey (3000 m)	121	65	
75 km2/hr	189	102	
		6668	3.7
		Total at Sea	32.9
		Actual	**36**

US Program Carried Out

The actual program conducted was abbreviated by the necessity of returning a sick scientist to South Africa two days into the cruise for medical treatment, which used 4 day's round-trip to return to the ship's position was when the emergency evacuation was declared. This left the cruise critically short of time for both Sentry and dredging operations, requiring a serious modification of the cruise plan if were to accomplish our main objectives. However, an additional problem arose when the Captain of the Thompson made it clear that he was uncomfortable with dredging in rough weather. This took the Chief Scientist by surprise as dredging in rough weather in the Southern Ocean has been routine in the past. Whereas this was routinely done in seas with high winds over 20 kt, and wave heights up to 20 feet, it was clear that this was not going to occur on the Thompson. This was further complicated by an inexperienced dredging technician whose dredging technique was limited to one inefficient technique: first laying out several hundred meters of cable at 10 m/mm while the ship steamed an equivalent distance, and then hauling in the wire at 10-m/m. Compared to simply towing the dredge with the ship, this increased bottom time required on-bottom for dredging by an hour for each dredge. Further, operations were restricted to dynamic positioning of the ship along the dredge track. As the ship's bow thruster is weak, the ship could not hold position on a given heading, restricting the heading and thus the targets we were able to dredge even in light conditions. Dredging without using dynamic positioning was not allowed to be an option, even though this was done successful in all oceans for many years, and drift dredging, a standard means of dredging in rough weather in the Southern Oceans was also not accepted as an option despite the many years this was done with great success.

Realizing this, the Chief Scientists had to radically change the cruise plan. The original plan called for the US to dredge and map areas 3 and 5 (Fig. 2), and the Germans areas 2 and 4. Thus, each cruise, if only one was funded, would map and sample the mantle both to the east and the west of the Discovery FZ. The Discovery FZ is a key discontinuity on the Marion Rise, separating the region presumably affected by flow of enriched hot mantle from the Marion Plume to that unaffected by that flow due to the large offset of the transform. Showing that large mantle exposures exist on either side of the Discovery Transform, and that the mantle is similar in composition, is the key test as to whether or not the Marion Rise, or at least part of it, is supported by the Marion Plume.

It was decided that our only option was to concentrate on the northern research areas, which were just far enough north that we could expect much better weather. This leaves the US cruise objectives, as funded by the NSF, critically dependent on obtaining the resources necessary to carry out a similar survey in the southern region in March 2020 on the Sonne in Areas 2 and 3. As the Sonne is 384 feet long, and several times the size of the Thompson, the expectation is that we will have no problem operating there in rough weather. This is a gamble, as the US participation, Sentry, a necessary magnetometer, and a gravimeter for the Sonne cruise is dependent on support from the NSF, for which there is no commitment at present.

The bathymetric, gravity and magnetics survey in Areas 4 and 5 were highly successful as discussed later in this report. However, the dredging program was very disappointing due to the limitations on dredging imposed by the Thompson, as discussed in the dredging section of this report. The sampling was insufficient to adequately characterize the diverse and often new feature seen in the oblique spreading center, and inadequate to test the extent of mantle heterogeneity. It was sufficient, however, in combination with the excellent magnetics and gravity, to demonstrate that at leas 50% of the seafloor in the oblique spreading region has no crust. It also found incontrovertible evidence of explosive volcanism at the ridge segment adjacent to the southern ridge-transform-intersection of the Indomed Transform.

Table 2. Operations conducted, RV Thomas G. Thompson Cruise TN365

Duration	36 Days		
Ports	Durban-Cape Town		
Transit	km	nm	
Durban from Durban	1633	881.7	7.25
Transit to Cape Town SA	1700	917.9	5.04
Station			
Transit & Setup	33 dredges		5.46
Deck to Deck			6.66
Sentry Deployment			
Survey	km	nm	
Geophysical Survey Areas 4 and 5 42°45'E to 45°40'E 41°32'S to 39°29'S	4,497	2,428	14.1
		Total at Sea	32.9
		Actual	**36**

Note that the days do not add up due to some double counting of time, which will be worked out post-cruise.

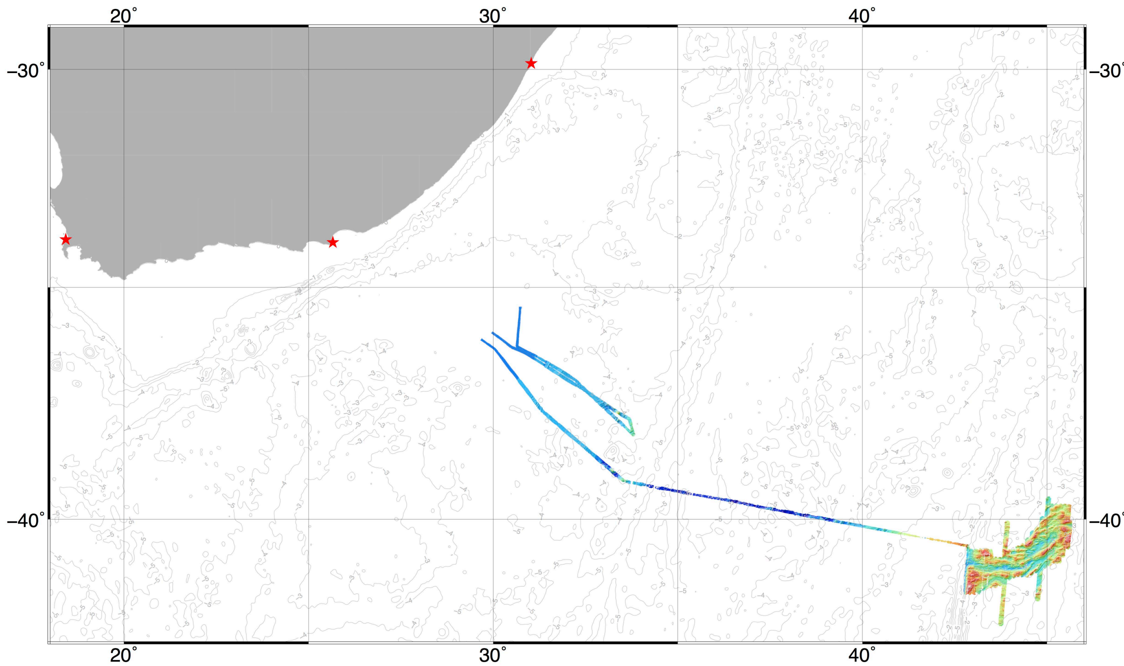

Figure 1. Bathymetric survey, RV Thomas G. Thompson Cruise TN365

EM302 Multibeam Bathymetry

Multibeam Data Acquisition Information: The multibeam data on the R/V Thompson was collected using a Kongsberg Simrad EM302 multibeam bathymetry echo-sounder. The sonar operates at a frequency of 30 kHz, with an angular coverage of up to 150 degrees and 432 soundings per swath (864 soundings in dual swath mode when shallower than 3000 m). Pings were collected every 6-10 seconds. Survey tracks were spaced at 5 km which, given the swath widths acquired, was found to adequately maximize coverage while minimizing data gaps between lines.

The software used to acquire EM302 data was the Kongsberg Seafloor Information System (version 4.3.2). For acquisition, the following runtime parameters were used. Dual swath mode was set to dynamic. The max angle was set to 70° for both port and starboard, and the max coverage was set to 5000 m for both port and starboard. The angular coverage mode was set to “auto”. The beamspacing HD was set to “eqdst”. Pitch stabilization was on, with the along direction set to 0° and auto tilt turned off. The yaw stabilization mode was set to “rel mean heading”, with the heading filter set to medium. “Min swath distance” was set to 0 m, while “external trigger” and “3D scanning” were both turned off.

The main parameters manipulated by the Watchstanders during data collection were the “Max Depth” and “Ping Mode” in the Runtime Parameters window. During periods of particularly rough seas, the multibeam system had difficulty correctly finding the water bottom, which required constant attention by the Watchstanders to maintain an adequate "maximum depth" parameter and use the "force depth" to help the system find the correct seafloor depth. The "Ping Mode" in the EM302 application window was adjusted by the Watchstanders according to water depth, which impacted the swath coverage and the data quality. The majority of the survey was conducted using the "Deep" and "Very Deep" Ping Modes. "Deep" mode was used for water depths below approximately 3,300 m, and "Very Deep" mode was used for water depths in excess of 3,300 m.

The acquisition software had difficulty displaying large amounts of data, manifested as gaps of data that were not rendered in the display window. As such, multiple surveys were created throughout the duration of the cruise to reduce the amount of data displayed at one time.

In addition to multibeam bathymetry, the EM302 system collected acoustic backscatter data, measuring the intensity of seafloor reflectivity.

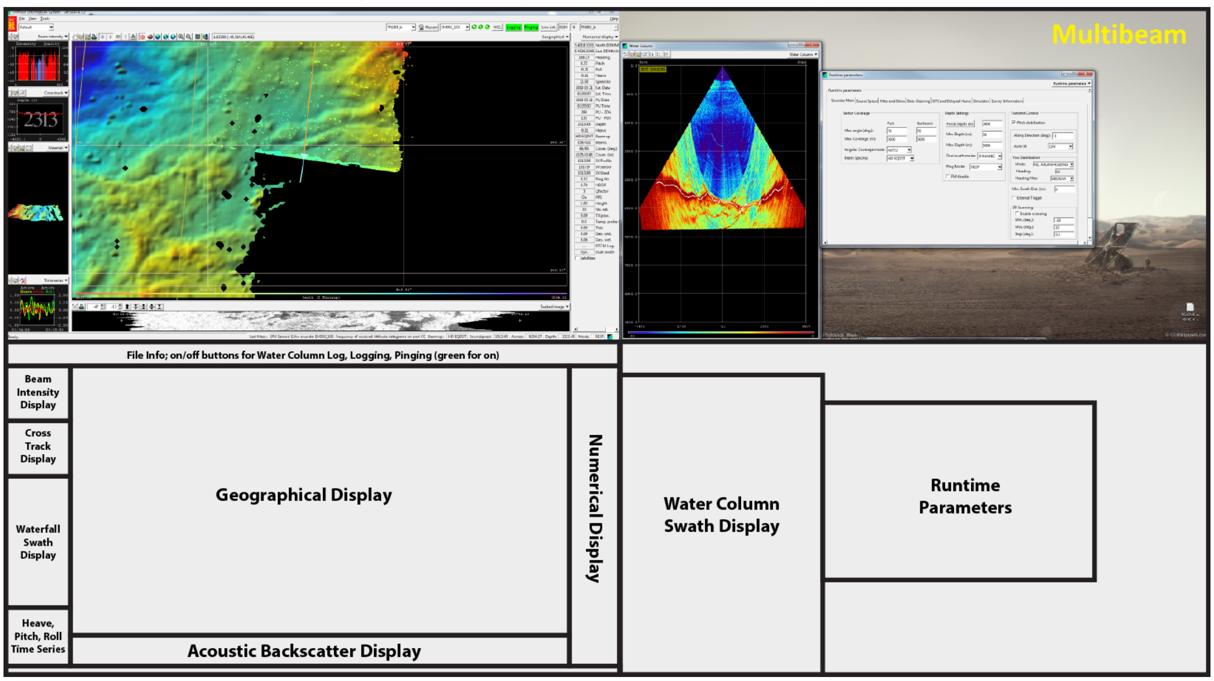

Figure 2. Diagram showing Kongsberg Seafloor Information System acquisition software display windows used during TN365.

<u>Multibeam Data Processing Workflow Summary:</u> Watchstanders processed the shipborne multibeam bathymetry data shortly after it was acquired. Data processing was done on a Macbook Pro laptop computer (MacOS Sierra 10.12.6) running a virtual box (Ubuntu 16.04) with MB-System installed. Each multibeam file (approximately 0.5 hours of data collection) was processed individually.

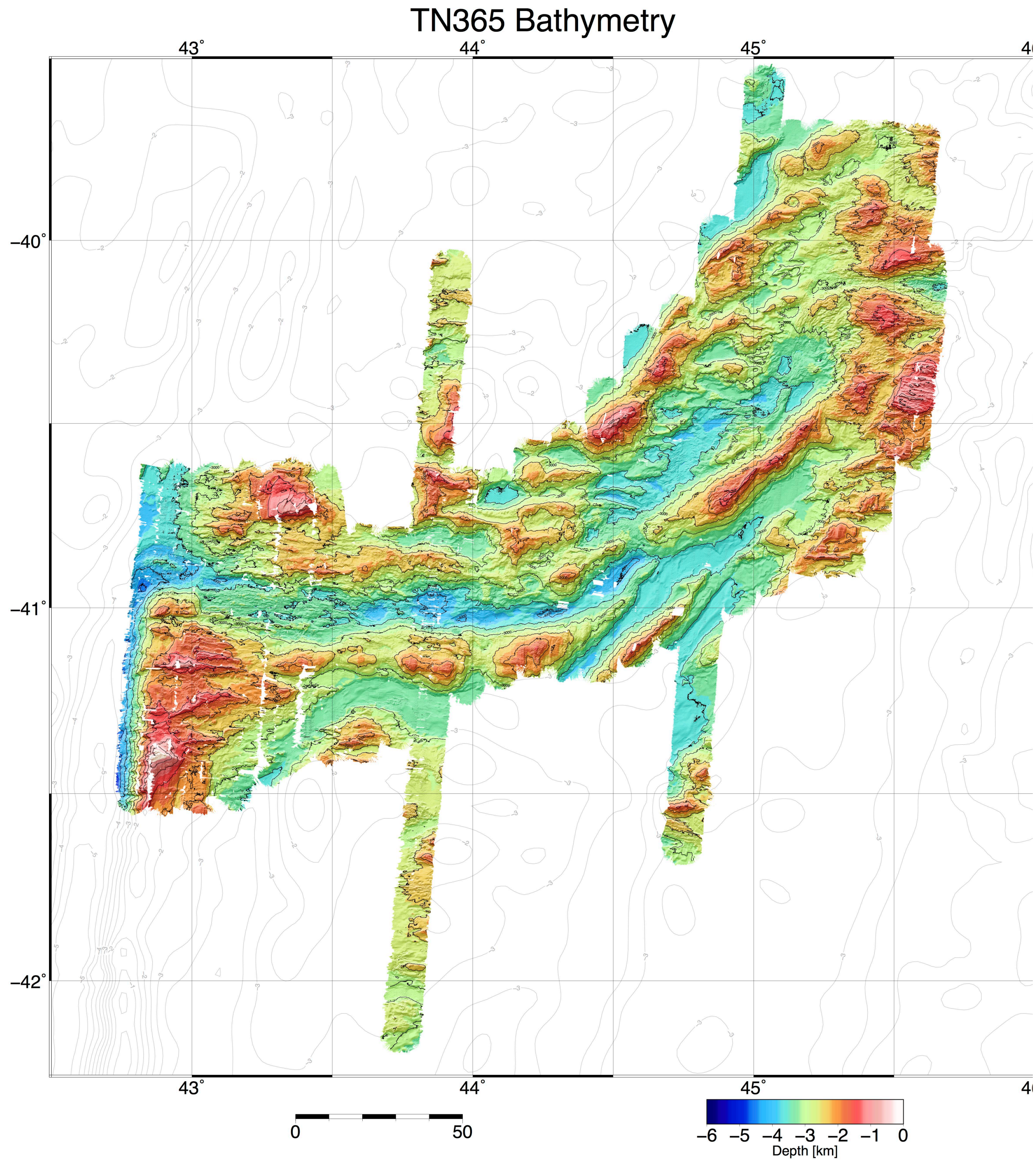

Figure 3. RV Thomas G. Thompson Cruise TN365 bathymetry

During the pre-editing step, raw data (*.all files) were converted to MB format (*.mb59 files) for processing using MB-System using a prepared script. During the editing step, manual ping editing was done (mbedit) to remove erroneous data points (pings). During the post-editing step, bathymetry data grids (25 m resolution) were created and plotted for each individual file using a prepared script. The coincidently recorded acoustic backscatter was also gridded and plotted, which displayed the intensity of seafloor reflections. These grids were loaded into the QGIS project (version 2.18.23) for quality check and dredge planning.

The individual data files were combined and gridded at 50 m during the survey. Due to limitations in data size, multiple sub-grids were created across the survey region, each containing a few hundred individual multibeam files. These sub-grids were merged together upon completion of the survey into a single grid.

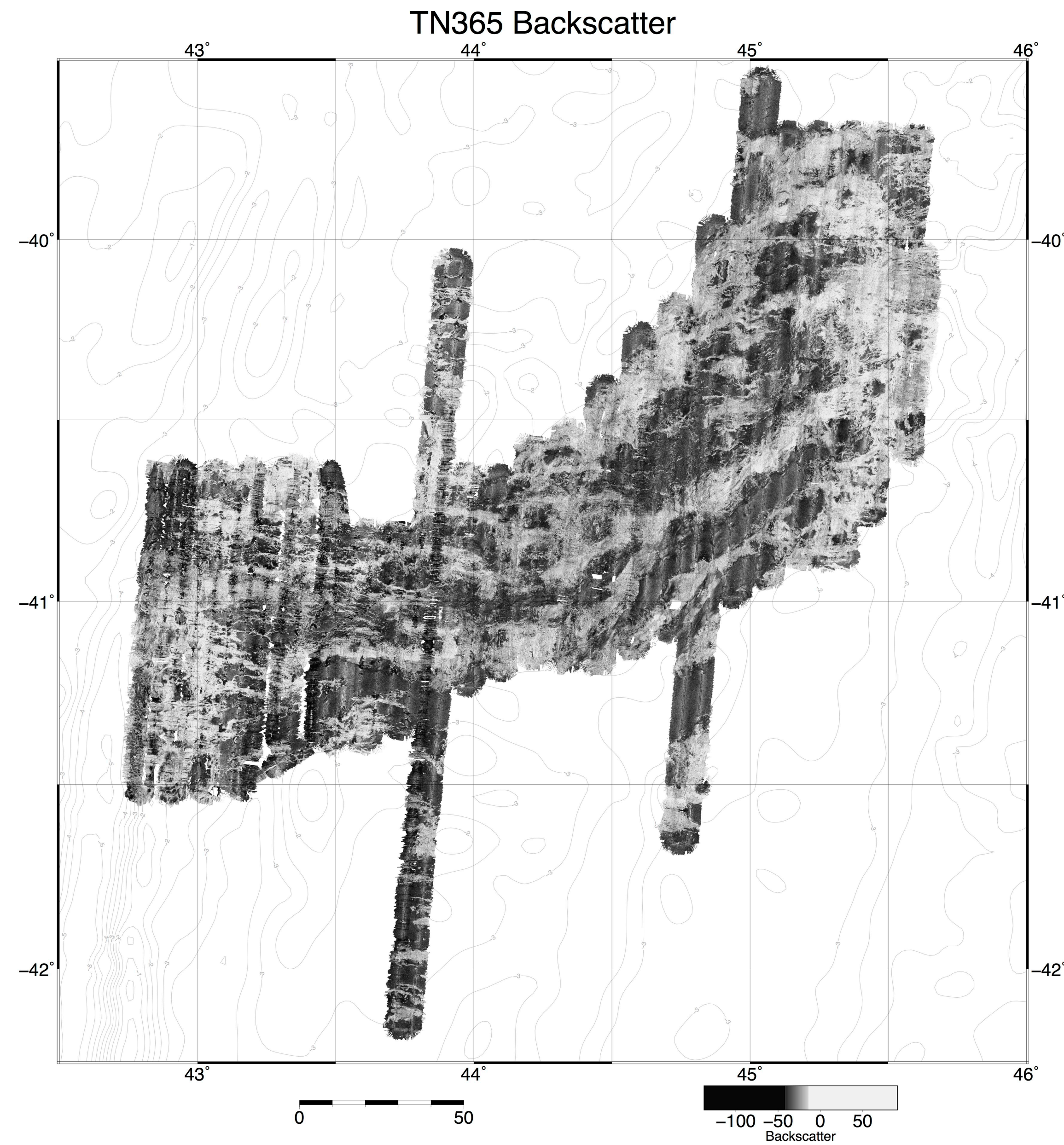

Figure 4. Back scatter image made using Seabeam intensity. Bright colors indicate a hard surface, while dark colors indicate sediment.

Sea surface magnetometer

A Marine Magnetics Seaspy-2 marine magnetometer (www.marinemagnetics.com) was used collect sea surface magnetic measurements during the cruise. The Seaspy-2 magnetometer is an Overhauser nuclear precession type of sensor that collects absolute total field data at a fast rate (typically for this cruise 1 sec rep rate) with a reported accuracy of 0.1 nT. The magnetometer was deployed from a small winch on the port side of the fantail. Both the winch and magnetometer (Fig. 1) were supplied by the WHOI-MISO facility. The winch was too slow for deploying the magnetometer system, so for the majority of the cruise the magnetometer was deployed and recovered by hand and figure-eighted on deck. The towed magnetometer cable is 300 m in length. We kept about 8 m on deck with the remainder deployed over the rail was 292 m. The total length behind the GPS referenced tie point of the ship (0,0) was 337 meters. A coaxial conductor deck cable (100 m) ran on the port side of the ship through the Hydrolab into the Computer lab. Data from the magnetometer were logged by a laptop computer running BOB software (freely available from Marine Magnetics). A GPS feed was provided by the ship's marine techs which was used as the UTC time reference for the measurements. The magnetometer was used during transits and the main survey at the typical transit speeds of the ship between 11.5 and 12 kts. Neither the integrity of the cable and sensor bottle or data quality suffered from this tow speed. The magnetometer performed well. The first laptop we used appeared to have some problems with the serial to usb connection and crashed and lost connection a few times. A second replacement laptop performed flawlessly. Sea surface magnetic profile times are listed in Table 1. A map of tracks and the anomalies are shown in Figs. 2 and 3

Figure 1. MISO Seaspy-2 surface towed magnetometer and winch.

Table 1 Surface towed magnetometer operations

Start Time UTC (Julian Day / time)	End Time UTC (Julian Day / time)	Line number	Length (km)	Comments
53 / 16:30	55 / 08:40	T1	861.2	Transit from Durban and back to Port Elizabeth
57 / 01:00	59 / 17:23	T2	1248.4	Transit from Port Elizabeth
59 / 17:24:44.50	59 / 23:00:01.50	1	106.96	Start of GPX survey
59 / 23:13:43.00	59 / 04:01:03.50	2	99.32	
60 / 04:15:05.50	60 / 09:17:26.50	3	98.05	
60 / 09:33:25.50	60 / 00:39:55.50	4	99.26	
61 / 00:55:33.50	61 / 05:43:48.50	5	98.05	
61 / 05:59:01.50	61 / 03:07:14.50	6	99.09	
62 / 03:19:54.50	62 / 09:07:18.50	7	99.57	
62 / 09:22:45.50	62 / 14:13:20.50	8	99.39	
62 / 14:28:00.50	62 / 19:11:14.50	9	83.33	
62 / 19:27:45.50	62 / 23:17:21.50	10	83.27	
64 / 04:01:44.50	64 / 08:17:08.50	11	84.39	
64 / 08:20:11.50	64 / 13:48:56.50	12	83.08	
64 / 14:07:44.50	64 / 17:36:54.50	13	64.34	
64 / 17:53:02.50	64 / 20:54:25.50	14	63.42	
64 / 21:11:10.50	64 / 00:21:34.50	15	64.19	
65 / 00:36:09.50	65 / 08:46:23.50	16	58.95	
67 / 09:02:48.50	67 / 16:04:06.50	17	144.30	
67 / 16:17:50.50	67 / 06:02:01.50	18	233.37	
68 / 06:26:48.50	68 / 14:05:30.50	19	168.96	
68 / 14:18:35.50	68 / 17:28:23.50	20	64.23	
68 / 17:49:54.50	68 / 20:50:17.50	21	63.54	
68 / 21:03:41.50	68 / 23:59:59.50	22	60.07	
69 / 00:15:21.50	69 / 03:31:01.50	23	69.02	
69 / 03:46:19.50	69 / 20:06:41.50	24	64.11	
70 / 20:21:34.50	70 / 23:40:55.50	25	69.29	
71 / 00:00:00.50	71 / 03:14:09.50	26	67.77	
71 / 03:29:40.50	71 / 07:28:19.50	27	84.41	
71 / 07:42:52.50	71 / 12:00:54.50	28	84.26	
71 / 12:15:14.50	71 / 22:23:25.50	29	101.53	
71 / 22:37:50.50	71 / 03:24:21.50	30	96.75	
72 / 03:38:07.50	72 / 15:42:09.50	31	106.39	
72 / 15:57:57.50	72 / 22:22:31.50	32	98.89	
73 / 22:38:42.50	73 / 04:48:21.50	33	124.61	
74 / 05:02:59.50	74 / 13:26:35.50	34	188.24	
74 / 13:42:36.50	74 / 10:43:41.50	35	234.99	

75 / 10:57:22.50	75 / 18:13:59.50	36	159.50	
75 / 18:28:49.50	75 / 17:45:47.50	37	143.53	
76 / 17:59:47.50	76 / 00:20:23.50	38	137.80	
77 / 00:04:08.50	77 / 07:05:25.50	39	132.93	
77 / 07:19:47.50	77 / 16:50:21.50	40	131.49	
78 / 17:05:24.50	78 / 05:48:02.50	41	131.89	
79 / 06:03:29.50	79 / 11:43:44.50	42	126.71	
79 / 12:00:14.50	79 / 00:40:24.50	43	127.36	
80 / 00:54:59.50	80 / 06:11:38.50	44	117.75	
80 / 06:25:01.50	80 / 12:13:11.50	45	118.74	
80 / 12:26:37.50	80 / 16:49:58.50	46	98.27	
80 / 17:05:38.50	80 / 20:11:25.50	47	62.18	End of GPX survey
82 / 10:45	85 / 8:57	T3	1640 (to EEZ)	Transit to Cape Town (estimate)
TOTAL			8747.2	

Processing steps:

The raw magnetic data were first parsed with a perl script (read_seaspy.plx) into an ascii time-stamped file and then loaded into MATLAB for further processing. The time-stamped magnetic data were merged with the ship's CNAV3050 navigation data on a daily basis. The data were filtered for any spikes in the field or navigation and saved as binary MAT files. For each daily file, a correction was applied for the layback position of the fish behind the ship. The regional magnetic field was removed from the observed data using the IGRF2015 coefficients predicted for 2019, to give the magnetic anomaly. The data were then output to ascii time, lon, lat, value files which could then be input into the QGIS mapping system. We used GMT to grid these along track anomaly data into a map. The observed anomaly map was further reduced-to-the-pole to account for the phase shift of the anomalies at this latitude. The approximate phase shift is calculated to be approximately -20.6 degrees. These maps were also loaded in to the GIS for planning and further analysis (see Figures XXX and YYY).

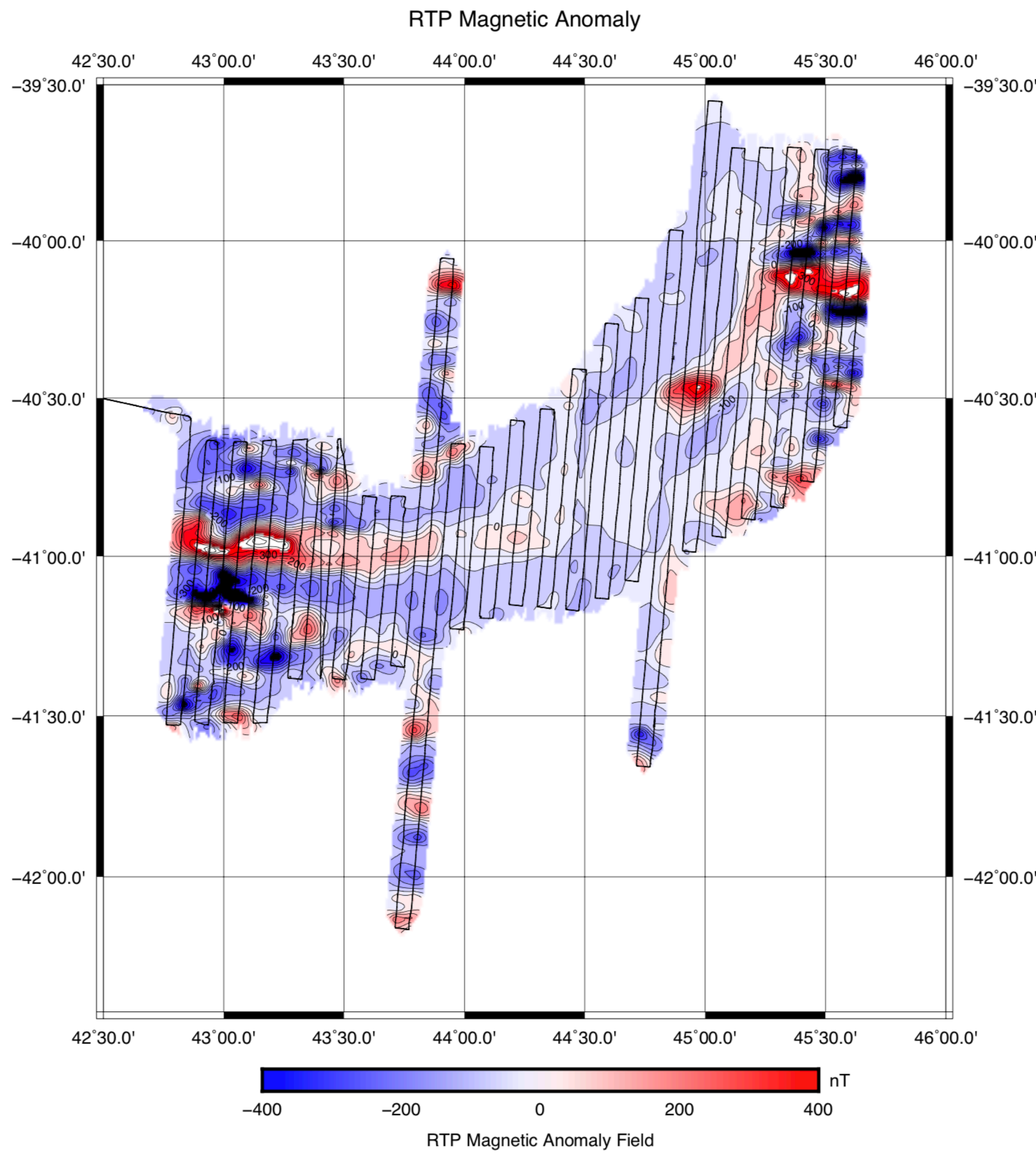

Figure 2. Gridded magnetics collected by RV Thomas G. Thompsons on Cruise TN365

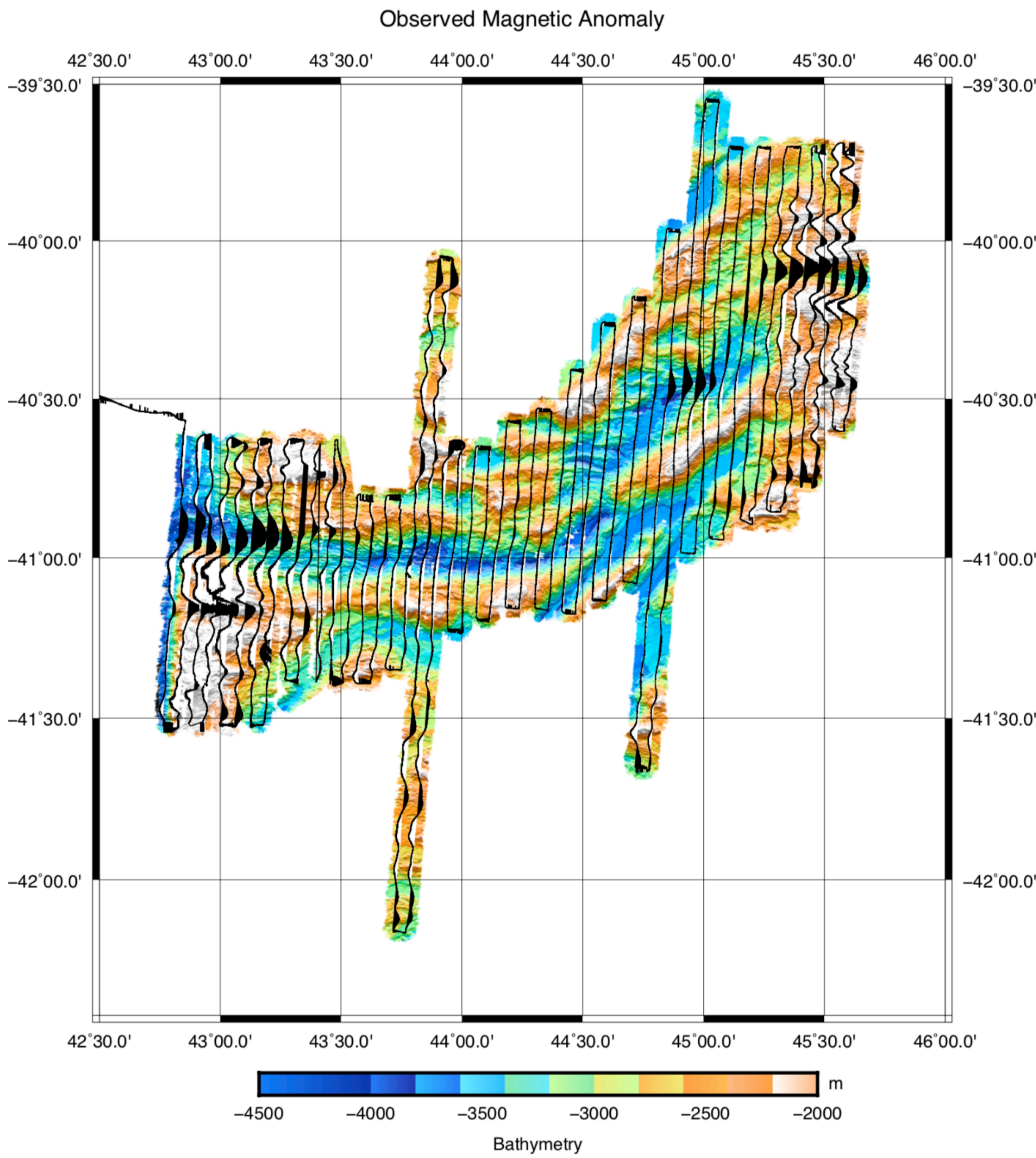

Figure 3. Magnetic anomalies along track with 5-km line spacing superimposed on the bathymetric survey.

Sentry Group Report

1 Summary

This document summarizes operations with the Sentry autonomous underwater vehicle (AUV) during the TN-365 Dick cruise. Included in this report is the vehicle conguration; basic vehicle and sensor perfor- mance; and post-dive reports (with summary statistics and narratives). This report does not attempt to describe the scientic results or conclusions. A detailed description of the data les resulting from this cruise is provided in a separate document. Individual dive summaries for Sentry dives 527-531 follow | each of these is a free-standing document summarizing the dive.

2 Cruise Log

This section provides a brief chronological summary of Sentry activities during the cruise. Additional infor-mation on specific dives is available in the dive reports.
21 FEB 2019 Departed Durban South Africa.
22 FEB 2019 In Transit.
23 FEB 2019 Vessel turned around and started heading towards Port Elizabeth to drop o sick science
party member.
24 FEB 2019 In Transit.
25 FEB 2019 Transfered ill science party member at Port Elizabeth. Began transit to work site.
26 FEB 2019 In transit.
27 FEB 2019 In transit.
28 FEB 2019 Arrived on station site4. Severe weather once on station, started vessel multibeam survey.
01 MAR 2019 Vessel multibeam survey, dredge.
02 MAR 2019 Sentry527 deployed and recovered. 7 hour dive, called up early due to impending weather.
03 MAR 2019 Sunday No Sentry Dive due to weather.
04 MAR 2019 Monday No Sentry Dive due to weather.
05 MAR 2019 Ships Multibeam survey.
06 MAR 2019 Depoyed Sentry528 at 05:00 local. Dredged during dive. Waveglider deployed for the Sentry
dive.
07 MAR 2019 Recovery of Sentry528, 06:00 local.
08 MAR 2019 Ship Multibeam surveying.
09 MAR 2019 Ship Multibeam surveying.
10 MAR 2019 Deployment of Sentry529 10:00 local. Three dredges completed during dive.
2
11 MAR 2019 Recovery of Sentry529, 10:00 local. Dredging followed Sentry dive, nal dredge of the day
had a large wuzzle and took extra time for the dredge to come on board.
12 MAR 2019 Ship multibeam surveying.
13 MAR 2019 Ship multibeam surveying and dredging.

14 MAR 2019 Deployment and recovery of Sentry530, deploying at 04:00 local, and recovery at 21:30 to
avoid impending weather.
15 MAR 2019 Ships multibeam with dredging.
16 MAR 2019 Ships multibeam with dredging.
17 MAR 2019 Ships multibeam with dredging.
18 MAR 2019 Deployment of Sentry351 at 13:00. Excellent weather.
19 MAR 2019 Recovery of Sentry531. Waveglider recovery following Sentry.
20 MAR 2019 Weather still holding, ship multibeam surveying.
21 MAR 2019 Ships Multibeam survey and dredging
22 MAR 2019 Dredging Ops
23 MAR 2019 Depart Station
24 - 27 MAR 2019 In transit
28 MAR 2019 Arrive Cape Town South Africa

3 Vehicle Conguration

4 Navigation

All dives were navigated using real time Doppler Velocity Log (DVL) velocity inertial measurement unit (IMU) attitude measurements. External aiding during descent was performed with Ultra-Short Baseline (USBL) throughout the cruise. Dive specic notes on navigation are included in the dive reports. All nal navigation consists of a track where the DVL/IMU track was fused with the USBL xes in post-processing. 4.1 Coordinate origins

The vehicle's control system uses simple equidistant coordinates. This system uses an origin, dened in terms of latitude and longitude with the World Geodetic System 1984 (WGS84) datum, and a xed scaling between meters displacement from the origin. We use the identical routines that have been used by the National Deep Submergence Facility (NDSF) assets Alvin and Jason for decades. Likewise we always used the same origin for Sentry and Alvin at each site. These simple coordinates have several advantages for realtime control of a vehicle. Unlike Universal Transverse Mercator (UTM) grid coordinates, the x and y axes intersect at right angles and align with true east and north respectively at the origin. These coordinates distort quickly as one moves away from the origin, but we solve that problem by putting the origin close to the operating area. We almost always report our results in latitude/longitude, so most users need not be aware of these details. 4.2 USBL Calibration and Performance Notes

A CASIUS calibration of the USBL system was not conducted during this cruise.

5 Items of Note

This section summarized details which are worthy of note or mention for future reference but which do notconstitute problems:

N.1: Waveglider was on board for cruise and operated for roughly two weeks in the water. No major issues with the WG, everthing worked really well.

N.2: server van was located main deck, portside forward. Spares van was forward.

N.3: The 480vAC power from the ship was dirty and causing problems with our equipment. Report attached to this document.

N.4: The Sentry AC unit died, which made cooling the container very dicult. Suggest buying an AC unit or more Fans.

N.5: Charge current was limited to 3 amps due to running the chargers o of extension cords from the lab power.

N.6: We were not able to display navG on the bridge due to network restrictions, only the sonardyne display.

N.7: USBL pole requires 30min for launch and recovery.

4

6 Ship Specific Information

This section summarizes ship specific information factual, good, and bad and is meant primarily to facilitate more effective use of the same vessel in the future.

S.1: Sentry Nav station and personnel were stationed in "Hydrolab".

S.2: Hydrolab is extremely noisy, with an AC unit that is constantly running and makes conversations dificult. Would choose to be in diferent lab next time.

S.3: USBL pole takes over 30 minutes to deploy and recover.

S.4: 480VAC power to the van was very noisy and required lab power for most of the equipment inside the container.

S.5: Sentry launched and recovered starboard side.

S.6: Ships small boat was used for the single recovery of the waveglider.

7 Technical Issues

Sentry Multibeam bathymetry (M Cheadle)

Five Sentry dives were performed during cruise TN365, each aimed at addressing specific geological questions. Dive 527 was across an actively decapitating oceanic core complex. Dives 528 and 531 were over the volcanic axes of normal spreading segments, and dives 529 and 530 were over detachment faults bounding peridotite massifs. For each of the following descriptions, three visualizations of the data are presented: i) a “flat” map with no vertical exaggeration; ii) the Sentry map displayed within the context of the regional multibeam bathymetric map with a 1:1 vertical exaggeration and iii) a labelled, perspective, view of the Sentry map with 1:1 vertical exaggeration. Additional close up maps are presented for dive 530.

Sentry dive 527

Sentry dive 527 was a partial dive which aborted early. It traversed the rifting “toe” of the Mponjwana oceanic core complex (Figure 1a; 1b). The dive began in the north and traversed the partially mass wasted surface of the detachment fault. One landslide headwall (10-20 m high) is visible, and a second shallow, landslide scallop is visible just above the southern faulted margin of the core complex (Figure 1c). Corrugations with a wavelength of 30-40m and an amplitude of 1 to 2 m are visible on the detachment fault surface in the Sentry data and these are not visible in the multibeam data (figure 1c). The Sentry map crosses the rift that is forming as the toe of the core complex is decapitated as it migrates over the ridge axis (Figure 1b). The northern wall of the rift exhibits a rotated fault block which shows ~130m of throw, and the (peridotite?) detachment fault surface to the north is collapsing into the valley formed by the rotating fault block. The main rift valley is 300 m deep. A row of, not recent, pillow basal mounds is found in the bottom of this rift valley, perhaps indicating the beginning of a new volcanic axis. The presence of sediments within this valley suggests the rifting/decapitation is not currently active. The southern wall of the rift exhibits landslide deposits from mass wasting of the southern dome of the oceanic core complex.

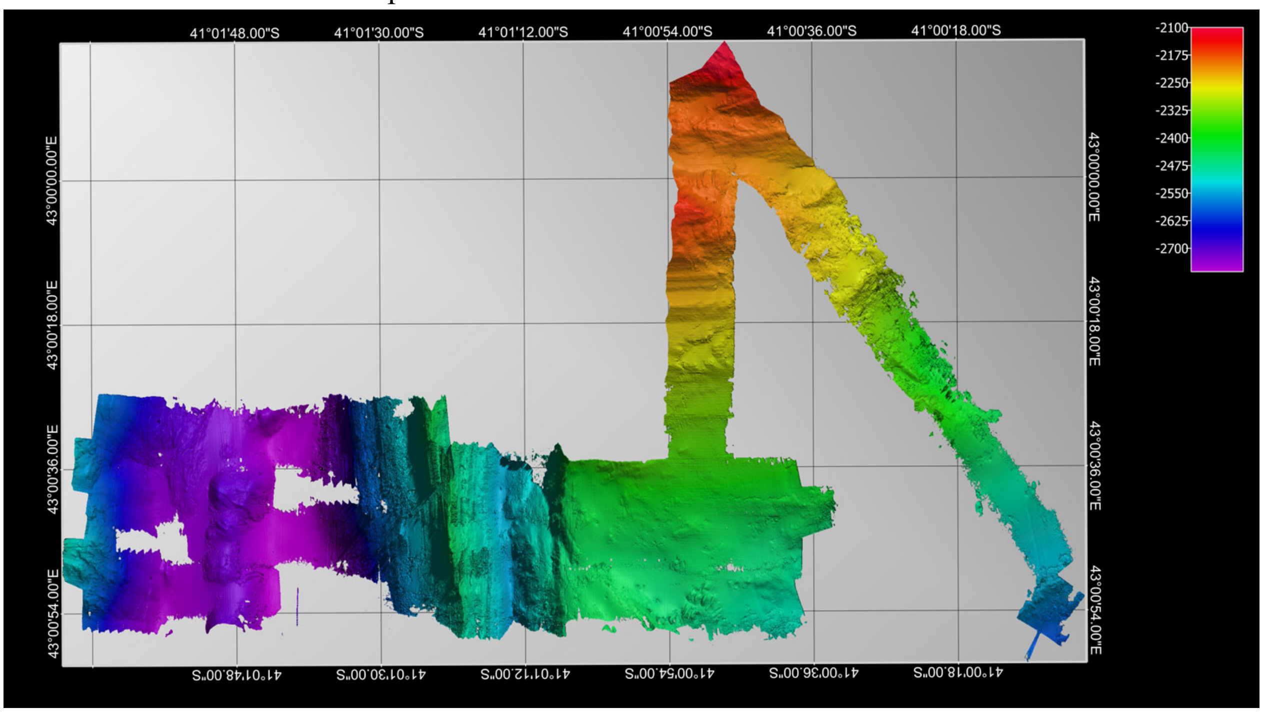

Figure 1 a “Flat” map of Sentry dive 527 with zero vertical exaggeration.

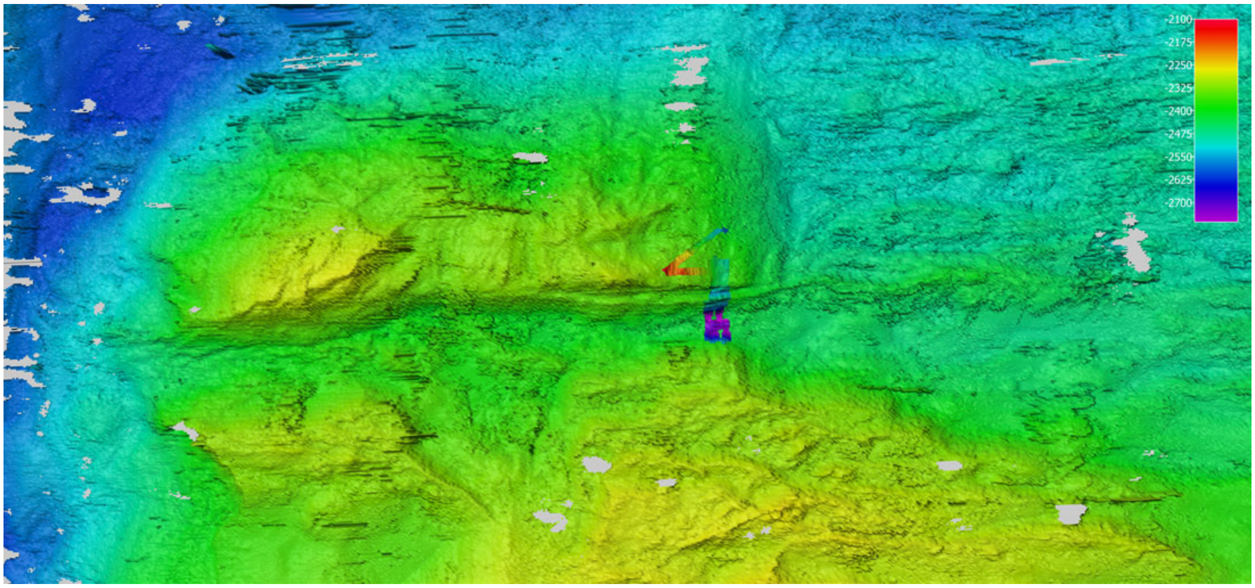

Figure 1b Sentry dive 527 within the context of the TN 365 multi beam map. Image shows the rifting/decapitation of the toe of the oceanic core complex. 1:1 vertical exaggeration.

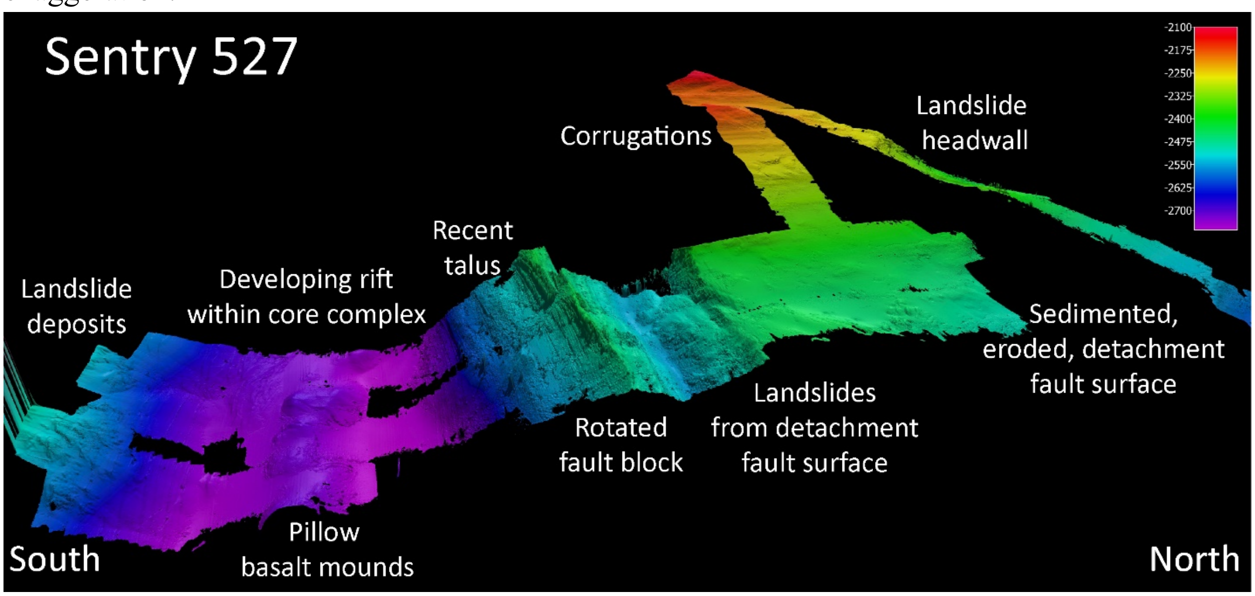

Figure 1c Perspective view of Sentry dive 527. 1:1 vertical exaggeration.

Sentry dive 528

Sentry dive 528 traversed the sedimented volcanic axis of the normal ridge segment (Figure 2a, 2b). Recently faulted, partially sedimented, pillow basalt mounds are present in the north of the sentry map and the original, unfaulted, pillow mounds were on the order of ~ 100m in diameter (Figure 2c). Sediments with pock marks cover a faulted axial volcanic terrain and increase in thickness to the south. The faults exhibit throws of up to 200m and exhibit WSW to EW trends. Sediment channels are visible in the bottom of the valleys and suggest a, possibly sediment laden, current flowing down slope to the east.

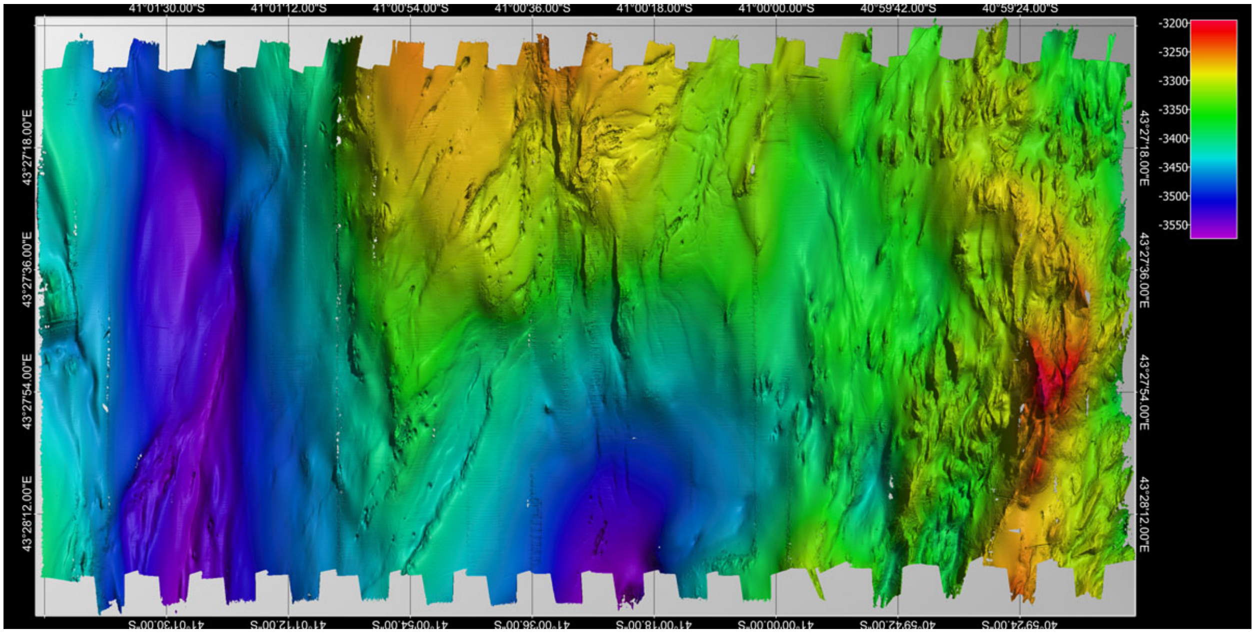

Figure 2a "Flat" map of Sentry dive 528 with zero vertical exaggeration.

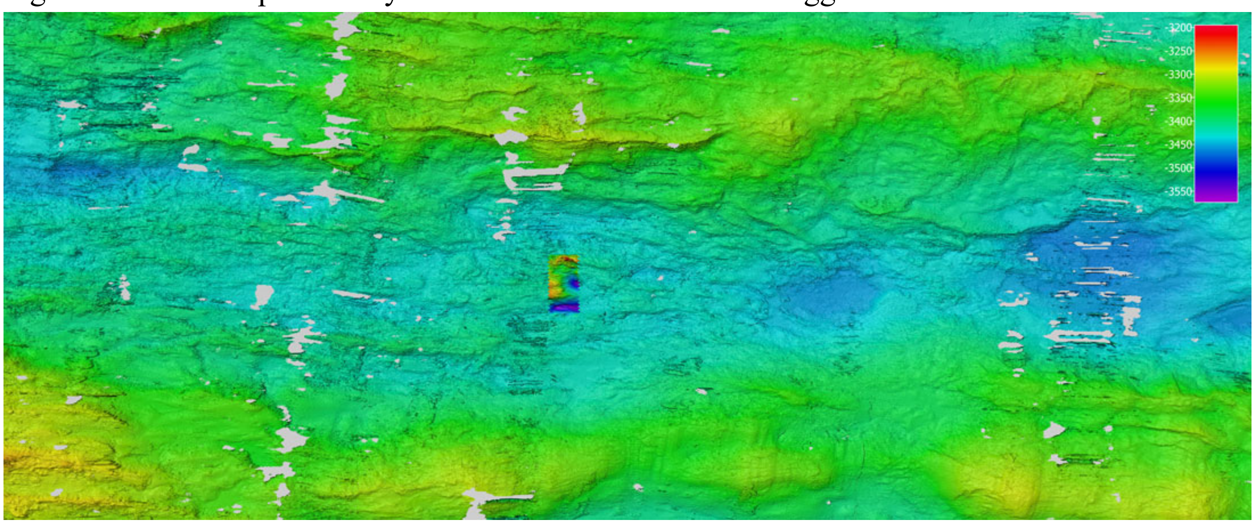

Figure 2b Sentry dive 528 within the context of the TN 365 multi beam map. Image shows the axial valley of the western normal ridge segment. 1:1 vertical exaggeration.

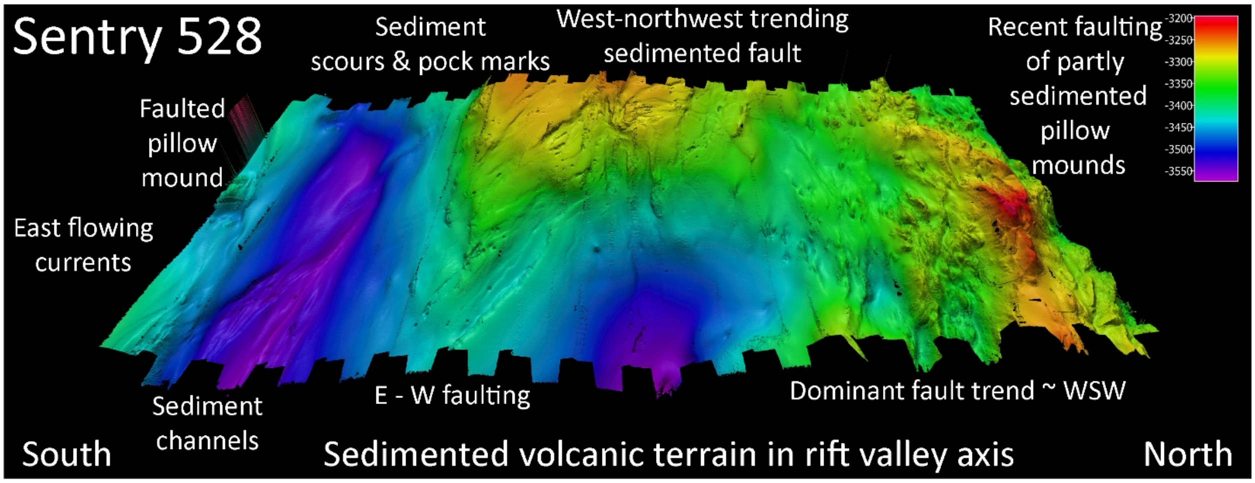

Figure 2c Perspective view of Sentry dive 528. 1:1 vertical exaggeration.

Sentry dive 529

Sentry dive 529 traversed a mass wasted, emerging, detachment fault on the southern side of the amagmatic part of the normal ridge segment (Figure 3a; 3b). The mapped area forms part of a domal ridge of peridotite that runs the length of the southern margin of the amagmatic normal ridge segment (Figure 3c). Elsewhere the ridge shows distinct corrugations, but here, the detachment fault surface shows mass wasting, although terraces within the mass wasting area may reflect original structural or mylonitic layering within the detachment fault. The surface has a mean dip of ~20° to the north. The northern end of the map extends into the axial valley. Here the axial valley is sedimented, but ~ 100m diameter pillow basalt mounds are visible due to scouring of the sediment by a westerly flowing current. The lower part of the hillslope is heavily sedimented with some scouring around up to 20m diameter boulders, and with pock marking. About half way up the slope, talus begins to dominate over sediment, which is derived from two arcuate headwall scarps about 40m and 80m high respectively. A 100m fault scarp at the top of the slope may be the continuation of a possible volcanic ridge visible further to the west in the multibeam data. 10m wavelength sediment dunes are visible in the southwestern corner of the map. Possible outcrop near the base of the headwall scarp in the south west of the map may expose shingle structure within the eroded detachment fault.

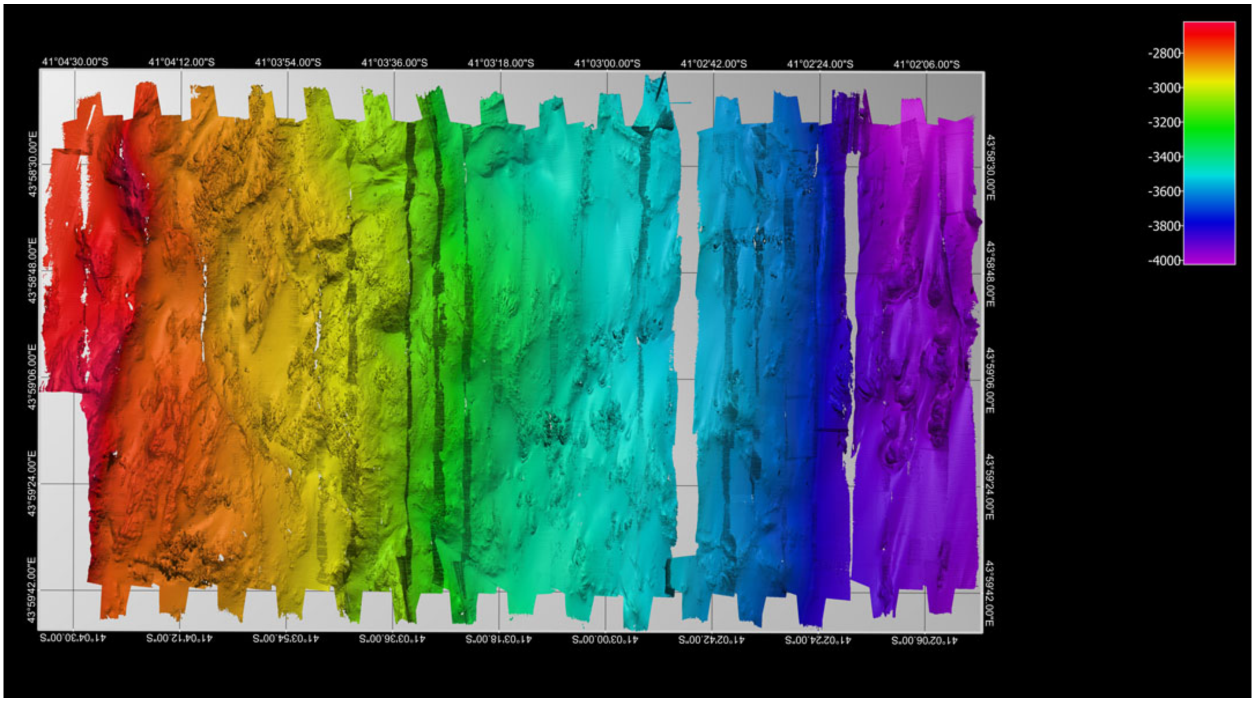

Figure 3a "Flat" map of Sentry dive 529 with zero vertical exaggeration.

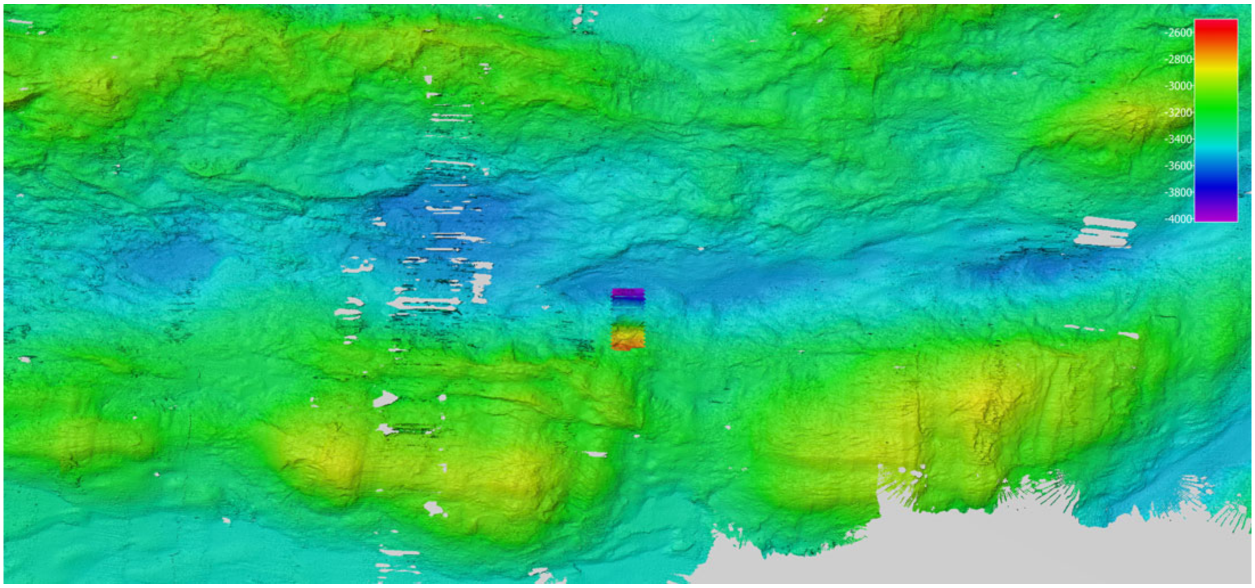

Figure 3b Sentry dive 529 within the context of the TN 365 multi beam map. Image shows the axial valley of the eastern end of the normal ridge segment. The Sentry dive mapped part of the northern margin of the peridotite domal ridge that forms the southern margin of the axial valley in this area. 1:1 vertical exaggeration.

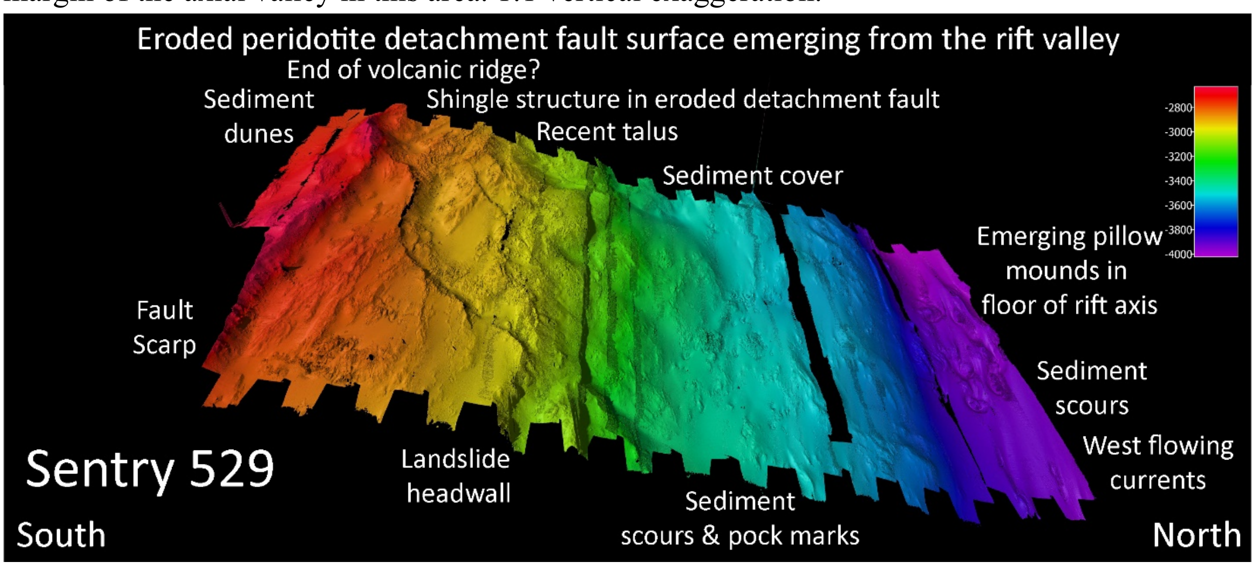

Figure 3c Perspective view of Sentry dive 529. 1:1 vertical exaggeration.

Sentry dive 530

Sentry dive 530 was designed to cross the transfer zone within the oblique spreading segment where the magmatic axis jumps to the North (Figure 4a; 4b). It traversed an eroded peridotite detachment fault surface (Figure 4a; 4c). The map shows part of a surface that dips to the north at ~ 8°. The surface is highly eroded by 5-10 m deep, 20 m wide, sediment filled, gullies. These create ~ 10 m high walls which reveal the shingled, anastomosing layering of the mylonites within the detachment fault (Figure 4d; 4e). The detachment fault itself dips north at 17-20°. A conspicuous set of SW-NE trending faults cut less common, NW-SE trending faults.

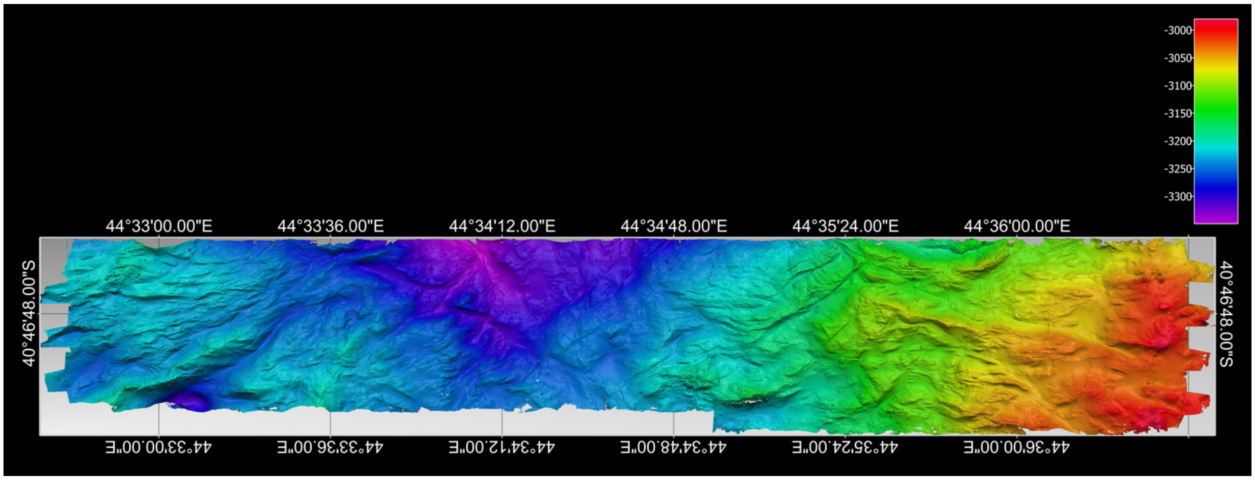

Figure 4a "Flat" map of Sentry dive 530 with zero vertical exaggeration.

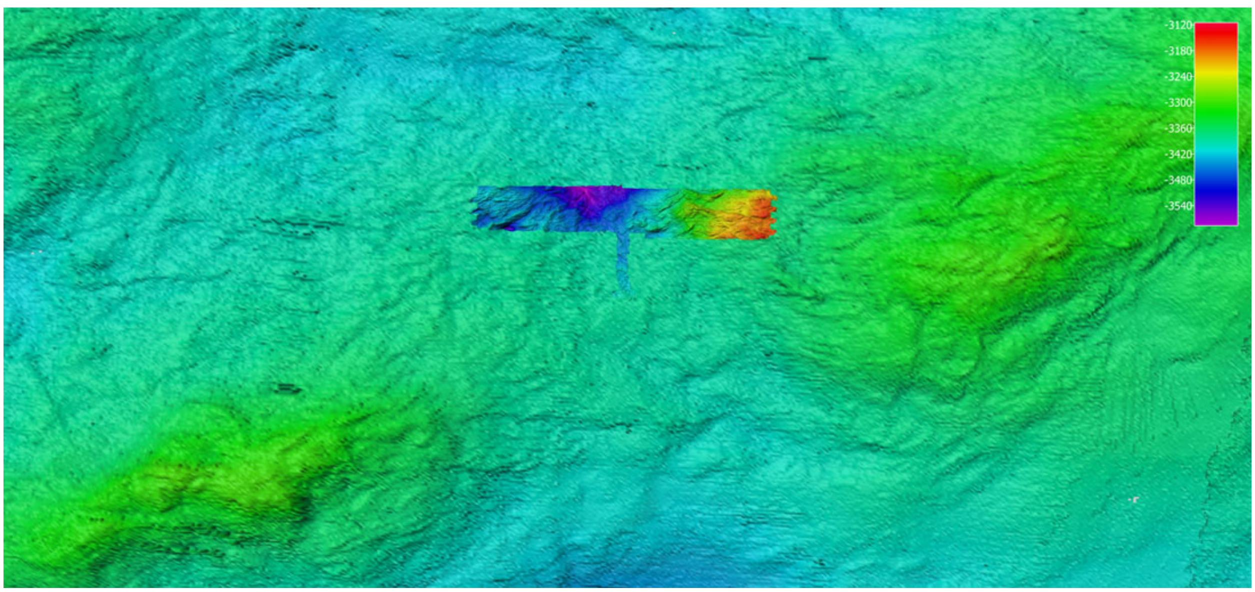

Figure 4b Sentry dive 530 within the context of the TN 365 multi beam map. Image shows the eastern, oblique part of the peridotite domal ridge that forms the southern margin of the axial valley in this area. The ridge axis jumps from south to north of the Sentry mapped area at this location. 1:1 vertical exaggeration.

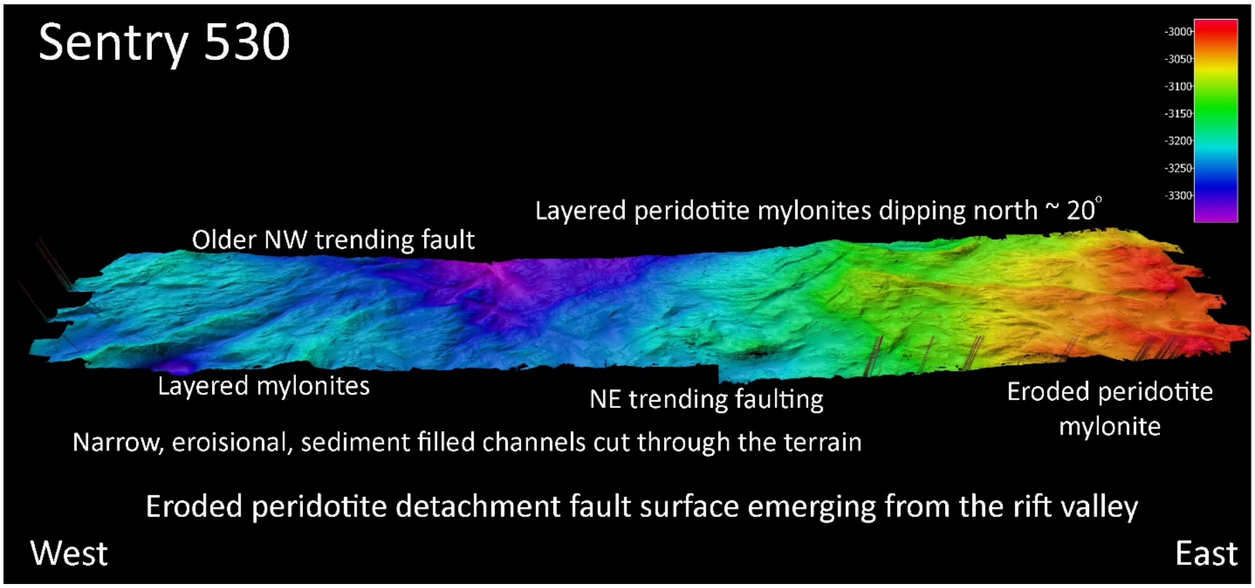

Figure 4c Perspective view of Sentry dive 530. 1:1 vertical exaggeration.

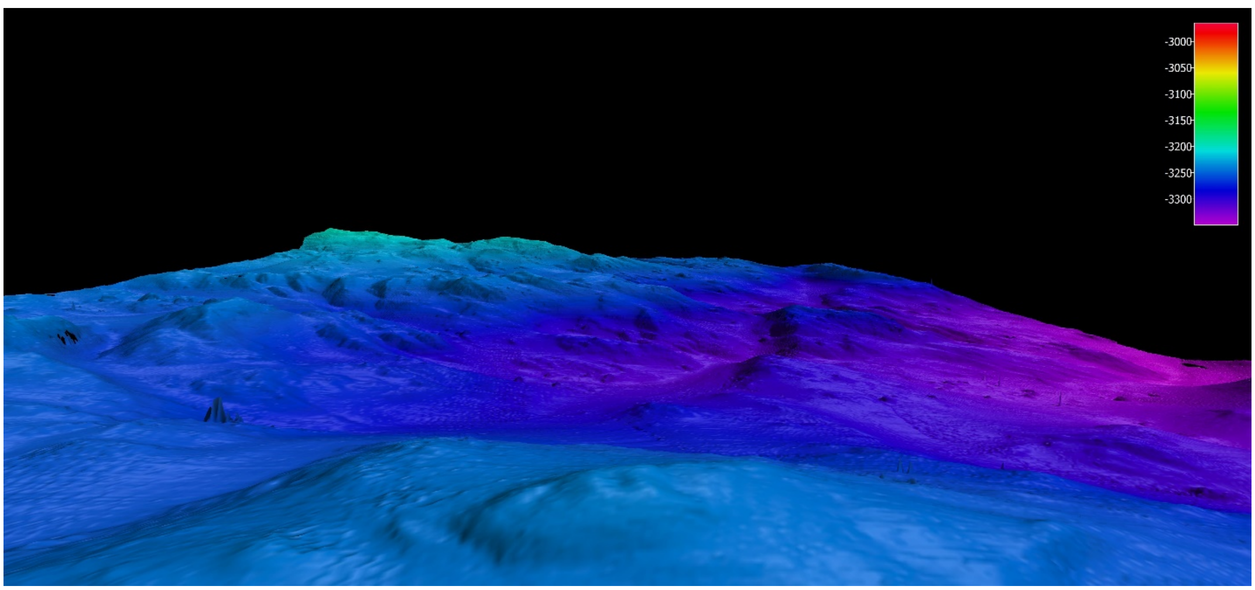

Fig 4d low angle view looking west of the shallowly dipping (~ 20º to the North [right in this picture]) layering within the peridotite mylonites.

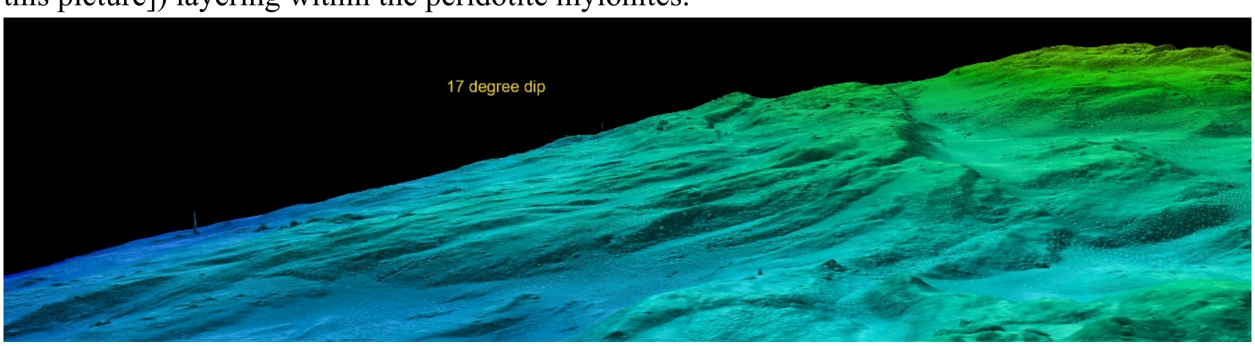

Figure 4e Low angle view looking east of the shallowly dipping (~ 20° to the north [left in this picture]), anastomosing, layering within the peridotite mylonites.

Sentry dive 531

Sentry dive 531 was designed to investigate the active neo volcanic axis within the oblique spreading ridge segment (Figure 5a; 5b). The southern part of the map consists of relatively recent, 200m diameter, 80 m tall, pillow basalt mounds which show evidence of incipient E-W faulting (Figure 5c). The terrain broadly ages to the north with a large volcanic construct (volcano?) near the left centre of the map showing clear mass wasting and with the pillow basalt mounds becoming more sediment covered towards the north. Figure 5b shows the extent of the major faults that cut the terrain and shows that they form the northern wall of the axial valley and the older pillow basalt mounds are being sedimented and uplifted out of the axial valley. These faults have throws of 60m and 140m within the area of the Sentry map. The Sentry map extends to the very southernmost end of the active pillow basalt mound field with a major E-W fault lying immediately south of the end of the map.

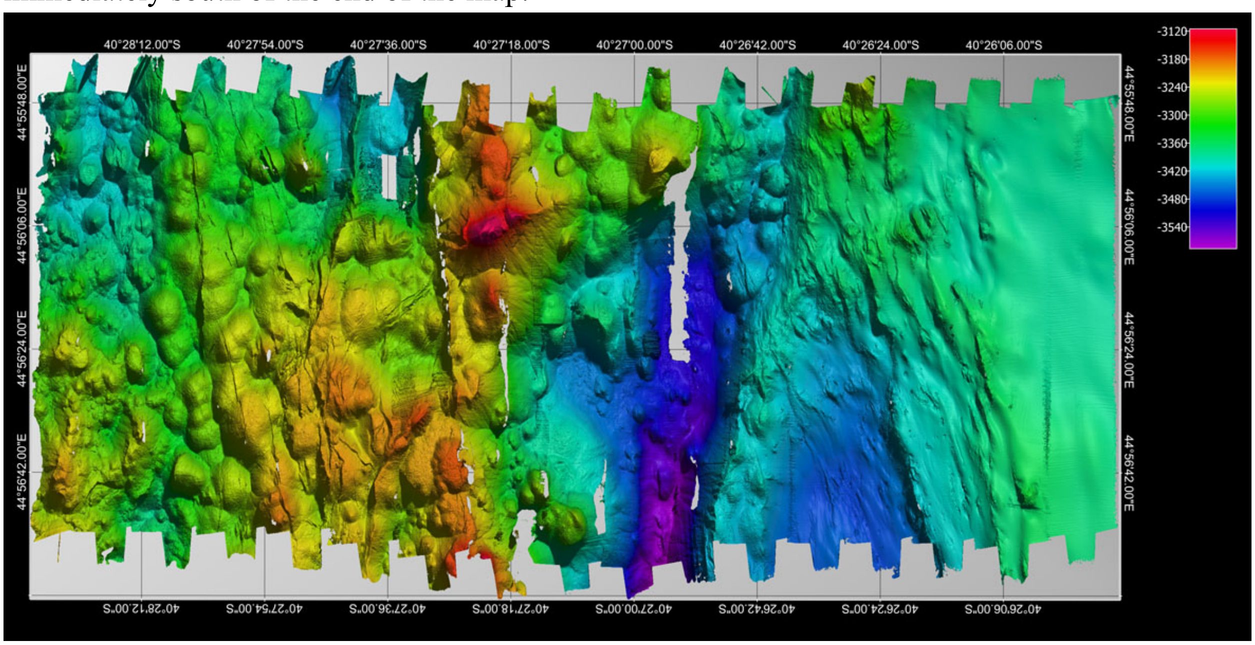

Figure 5a "Flat" map of Sentry dive 531 with zero vertical exaggeration.

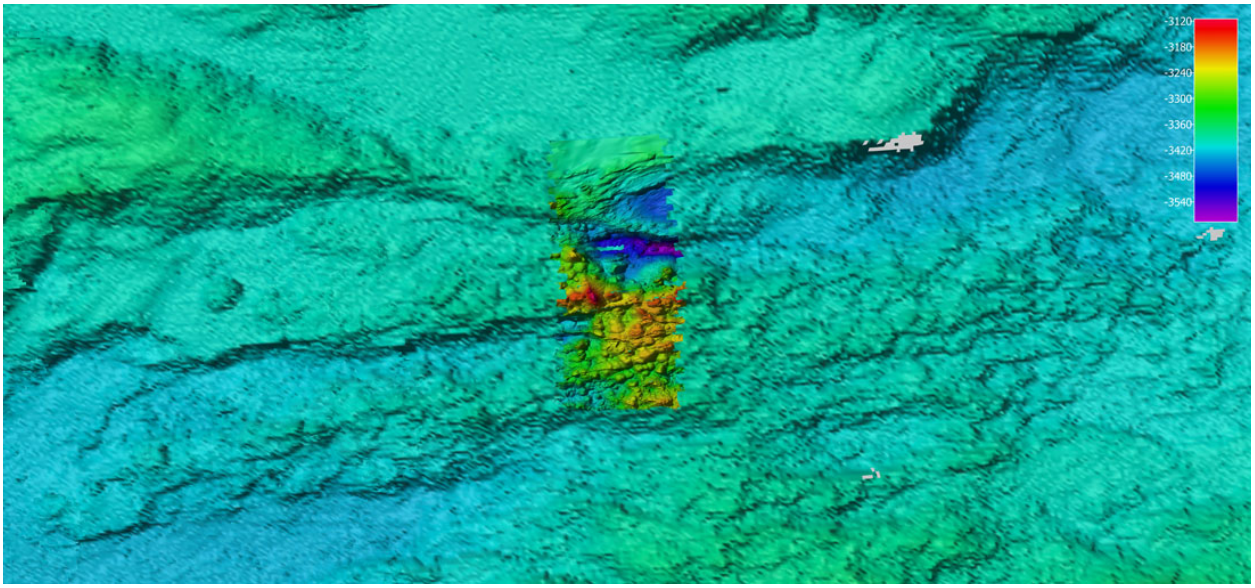

Figure 5b Sentry dive 531 within the context of the TN 365 multi beam map. Image shows the likely active ~ E-W neo volcanic segment within the oblique spreading centre. 1:1 vertical exaggeration.

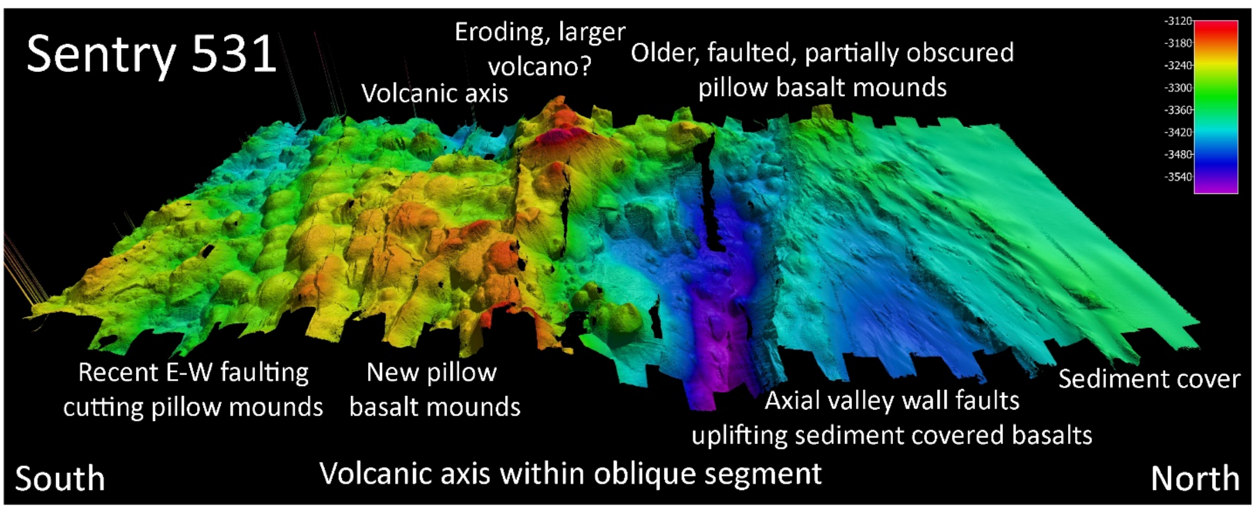

Figure 5c Perspective view of Sentry dive 531. 1:1 vertical exaggeration.

Dredging Results

Methods: Dredges were conducted by bringing the ship on station using the ships dynamic position system, then paying out wire to a depth of 300 to 350 meters and attaching a pinger to the wire. During 9 rift valley dredges, a MAPR was attached to the dredge wire above the MAPR (see MAPR section of this report). The technician then lowered the dredge to seafloor depth, generally at 40 to 50 m/m, and then moved the ship at 0.3 to 0.5 kts while paying out wire to match the ship's movement for 300 to 350 m, or until the pinger depth above seafloor was 50 m. The wire would then be retrieved at 10 m/m until the dredge was nearly off the seafloor, as determined from the acoustic bounce of the pinger. The process would then be repeated, two or three times. The scientists did not view this as an efficient method of dredging, but could not persuade the captain to modify it. For hauls were made with the University of Washington dredges, which have a chain bridle. However, the results were disappointing, and standard large WHOI dredges were used for the remainder of the dredging program.

Results: Overall, the results were disappointing (see Dredge Location Table included in this Report) as only 33 dredges were made during the allotted time span 12.2 days, and 8 of the dredges were empty, while four others recovered less than 2 kg of rock. The usual calculation for dredging is 4 dredges per day, including transit and set up time. The bridge and technician waited until the ship was perfectly positioned each time, which took additional time due to the weak bow thruster. Moreover, as discussed earlier, the mode of dredging used could only be accomplished with a narrow scope into the wind. This limited our dredging targets, which were thus not always optimal, accounting for the low recovery. In all, 618 rocks weighing 1376 kg, including one large plagioclase phenocryst rich basalt weighing ~200 kg. Deck to Deck time for the dredges totaled 6.66 days, while the transit and set up time was 5.46 days, amounting to 12.2 days devoted to dredging.

Sample Curation (Ellen Roosen)

During the TN 365 cruise to the Marion Rise, Southwest Indian Ridge, we successfully completed 25 dredges. The samples were divided among three repositories in three different countries: Woods Hole Oceanographic Institution, MA USA; the University of Hannover, Hannover, Germany and Tongji University in Shanghai, China as well as personal samples taken by the science party. Personal samples were taken first. The rest of the rock sample was then split into three parts with the US taking half. Then Germany and China would split the rest. In cases where there wasn't enough rock sample to split three ways, the US would take half when possible and then Germany and China would decide who would take which rock from that dredge depending on the future science to be done on the rocks. When small pieces of glass were present, but not enough to split among the repositories, the scientists who were interested in the glass were encouraged to work together to utilize the sample to the maximum. This encouraged collaboration among the scientists. Some of the rocks were too small to cut on the rock saws brought on the cruise, so one of the repositories took the rock with the understanding that once the rocks arrived after the cruise, the rock would be cut into appropriate pieces and sent to the other two repositories. There were times when there wasn't enough rock to split at all, but there was a personal interest in the rock to do analysis. In this case, the rock was given to the scientist interested in doing the analysis with the understanding that the unused portion would be returned to the Woods Hole Repository.

There were many stages in the curation of the rocks starting with the photographing of the dredge once it was placed on deck. The dredge bag was emptied onto a tarp and photographed when possible. If there was any biology, the scientist interested in the microbes on the rocks or any other biology brought up in the dredge was collected first and cataloged along with a photo. The rocks were either placed in a bucket with the dredge # on it or brought directly to the rock saws and cut. Once cut, the rocks were taken to the lab and placed on the table. When the whole dredge was cut and sorted, a photo of the complete dredge was again taken with the dredge # on an id card. The rocks were then labeled with white paint and black sharpie, weighed and described. Each individual rock was then photographed. The scientist/student interested in a dredge would fill out a sample request which was reviewed and then approved depending on the research and amount needed. Sometimes there wasn't enough for everyone and a decision was made as to who got a sample or sometimes the amount was adjusted. The rocks were then cut into the appropriate sample size, distributed amongst the appropriate person/repository and then bagged. A sample sheet was then filled out by each person receiving a rock sample. Each repository also filled out a sample sheet. All of the above activities were maintained by a running check list on the white board in the main lab.

The rock distribution is as follows: US taking 601 rocks with personal sampling totaling 231 for a grand total of 832 rocks, Germany taking 514 rocks with personal sampling totaling 21 for a grand total of 535 rocks, and China taking 482 rocks with personal sampling totaling 193 for a grand total of 675 rocks.

Once the rocks arrive at WHOI, an IGSN number will be given to each rock.

Sample Requests

The US Portion of the samples from this cruise are archived at Woods Hole Oceanographic Institution Seafloor Sample Laboratory. WHOI curatorial policy follows that of the US National Science Foundation, and can be found at https://www2.whoi.edu/site/seafloorsampleslab/. Sample requests must be made in advance directed through

WHOI Sample Distribution Policy (March 2018)

The sample distribution policies outlined below are intended to encourage effexctive utilization of the nationwide sea floor sample collections funded by NSF. The Woods Hole Oceanographic Institution (WHOI) Seafloor Samples Laboratory is prepared to furnish samples and data to interested researchers and students within the global scientific community who express a legitimate interest and need. As stated below the collector is entitled to a two-year moratorium on sampling. However, it is the US Chief Scientist's intent to limit this two one year, and interested parties with legitimate requests should contact him at hdick@whoi.edu. Generally speaking, rock sampling takes considerable time and requires personal selection of samples. The rock images included in this report can be used as a basis for a request. Those wishing samples, however, should plan on traveling to Woods Hole to personally select, mark, cut and label them.

Statement of Proposed Research: All requests for samples should be accompanied by a concise statement describing the study for which samples are needed, including methods or procedures to be used, the specific scientific problem to be addressed by the study, and the names of collaborating investigators. Additionally, requests should be accompanied by a description of the laboratory facilities available to the requestor and the source of financial support that will fund the related work. All of this information should be provided via the "Sample Request Form". If these details differ significantly for associated investigators, the nature of their proposed research, facilities, and funding should also accompany the sample request.

Sample Request Review and Proprietary Rights of the Collector**:** The PI will retain authority to approve sample requests until two years from when samples are logged into the repository database. This restriction is enforced in order that those investigators directly involved with the collection of samples will have adequate time to complete their initial work on the material. With permission of the PI, certain samples may be released for study prior to the end of that period. The curator or lab director may impose special conditions on the distribution of samples in order to ensure effective utilization of the material. Such special conditions would include the storage of samples in either refrigerated or frozen space. Following the period of proprietary access, sample requests will be approved by the curator's office. All sample requests, during and following the period of proprietary access, must be submitted to the WHOI Seafloor Samples Lab using the online "Sample Request Form". The curatorial staff will review and approve all sample requests.

Responsibilities of Person Receiving Samples:

1. The original alphanumeric samples label should be used to identify individual samples referred to in published papers. Any departure from this scheme should be clearly equated with the original labeling system in the published papers or

data summaries. This labeling system will be explained in the information supplied with the samples.

2. Published papers should acknowledge the source of samples and the appropriate grant of funding agency which supported the cruise recovering the samples. This information will be supplied at the time the samples are acquired. These papers should also acknowledge the financial support responsible for maintaining the WHOI Seafloor Samples Laboratory This information will be provided at the time of sampling.
3. Copies of all published papers, reports or data summaries utilizing samples from the collection should be sent to the appropriate WHOI staff scientist, and the WHOI Seafloor Samples Laboratory. One electronic copy of all published reports, papers, or data where samples have been used should be sent to the WHOI Seafloor Samples Laboratory at seafloorsampleslab@whoi.edu for inclusion in the repository database. This helps track the effectiveness of NSF's investment in national sample archiving facilities as well as justify future sample requests by an investigator.
4. The researcher should return all unused samples or portions of samples to the curator at the completion of the work.
5. Recipients of samples should not co-opt the services of other investigators or undertake research projects which differ substantially from work originally proposed, without obtaining the approval of the curatorial staff.

Rock Description (Danieli Brunelli

Igneous Rocks

<u>Ultramafic rocks:</u> Ultramafic rocks consist of primary mantle-derived rocks such as peridotites and dunites, as well as deformed ultramafic mylonites and ultra-mylonites clearly derived from a peridotitic protolith. Twelve of twenty-four dredges contain peridotites, while ultra-mylonites were recovered in five dredge hauls (D13, D14, D15, D19, D23). Three of these dredges (D15, D19, and D23) contain both porphyroclastic and mylonitic peridotites. Ultramafic rocks represent ca. 56% of the total recovery (ca. 661 kg). Among the mantle-derived rocks, the two most abundant occurrences are harzburgite (40.3%) and ultramafic mylonite (36.2%) followed by lherzolite (19.7%), dunite (3.8%) and one sample of olivine websterite (see Fig. 1A)

Fig. 1 Proportions of ultramafic rocks (left), and sample picture of olivine websterite (right).

Peridotites, websterite and dunites:

<u>Modal distribution:</u> The peridotites (n=186) are extremely serpentinized and weathered. For about twenty samples there was no means to define relative modal abundances. In some samples, however, spinel or Cpx was still recognizable.

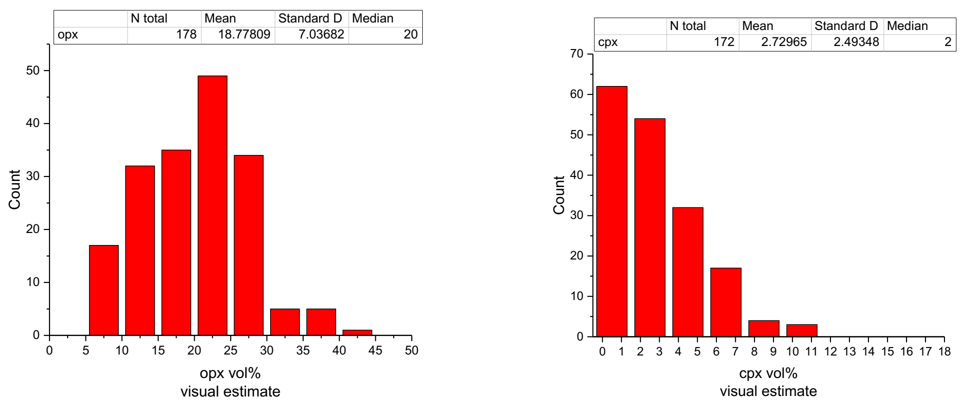

Fig. 2 Frequency distribution of orthopyroxene (left) and clinopyroxene (right) volume abundances for the entire dataset. Bin size is 5% and 2% respectively.

Based on a visual estimation of mineral abundances it appears that the majority of the recovered peridotites are spinel-field equilibrated harzburgites (142 out of 186 samples). Overall the mean Cpx content is 2.7 vol%, ranging from zero (no Cpx detected with hand lens observation) to 10 vol%. Orthopyroxene and olivine modal abundances average 75.7 and 18.8, respectively, with ranges of 50—93 and 5—40 vol% respectively. One single olivine websterite has been observed (TN365-D18-46, see Fig. 1B). It is represented by an aggregate of cm sized Opx and Cpx in equal amounts (ca 30%) forming an irregular vein in a relatively small sample.

Only 5 out of 186 peridotites show plagioclase (Dredges 9 and 17) as minute interstitial grains clearly derived by melt percolation at shallow depth.
Dunites are reported in 4 sites (Dredges 9,11,18,19) frequently in contact with pyroxene-poor peridotites (Dredge 18), and often show a sharp contact with the host rock. All dunites contain spinel finely disseminated in the olivine matrix, locally forming large holly-leaf grains (up to 7 mm - TN365-D19-25). Sparse plagioclase grains or irregular veinlets are present in 5 out of 19 samples in dredge D18 and D19.

Peridotite textures: The definition of the textures in the hand sample is based on pyroxene morphology. Olivine does not allow a visual evaluation because of pervasive alteration and lack of recognizable textural characters. Textures range from protogranular (n=4 samples) to porphyroclastic (n=178), protointergranular (n=15) and protomylonitic (n=6).

Large Opx with subhedral habit showing no recrystallization and very weak or absent cleavage bending have been defined as protogranular with crystal plastic deformation index 0-0.5 (scale from 0 to 5). Porphyroclastic rocks are defined when pyroxenes show clear cleavage bending, irregular shape and locally minor evidence of recrystallization; for these rocks crystal plastic deformation index ranges 1-2.5. Protomylonitic peridotites have a crystal plastic deformation index 3-4. A detailed description of the textures is reported in the following paragraphs.

The textural evolution of these peridotites shows two apparent trends. The main trend consists of a continuous progressive crystal plastic deformation from protogranular to ultramylonitic terms. The second occurrence shows the evolution of the intermediate porphyroclastic trend to protointergranular textures where orthopyroxene becomes progressively more irregular in shape, developing deeply embayed and tiny elongated interstitial intergranular structures.

Protogranular peridotites are characterized by large subhedral pyroxenes. The crystal plastic deformation undergone by these rocks is nearly absent or very low. Weak bending of the mineral cleavage is occasionally observed in bastitized orthopyroxene and clinopyroxene grains. Spinel has holly leaf interstitial shape. They have the most abundant pyroxene content and the largest grains size (up to 30 mm).

Porphyroclastic textures represent a more evolved term from a structural point of view and are characterized by diffuse grain size reduction of the olivine matrix, pyroxene stretching and local formation of new grains in pressure shadows and visible bending of the pyroxene cleavage system in particular for clinopyroxene. This latter characteristic has been systematically observed in the recovered peridotites. Clinopyroxenes are often associated or included in large orthopyroxene grains. Spinel has holly leaf shape but frequently forms interdigitated micro-aggregates with small Opx grains. Its distribution is highly heterogeneous locally showing clear mineral trails crosscutting the sample.

Poikilitic spinel grains are common. Sp-px-ol symplectites are frequent in these rocks and in some samples form graphic aggregates large up to 7 mm in dredge D18.

Protomylonitic peridotites are relatively rare. They represent a more evolved textural evolution at increasing (ductile) deformation rate. Their reduced occurrence with respect to the abundance of both undeformed (protogranular to porphyroclastic) and mylonitic textures suggests shear focusing to be extremely efficient after nucleation of the shear bands in the peridotitic units forming discrete bodies with restricted or negligible transitional regions. These rocks present the textural characters of the mylonitic textures, with rounded pyroxene porphyroclasts mantled by neoblast selvages elongated along sigma-type wings. The neoblasts aggregates extend laterally giving rise to micro banding of the matrix at the mm scale. Spinel is often rounded but is never found as new grain selvages, while tiny interstitial spinel are dispersed in the matrix.

Protointergranular peridotites. The progressive ductile evolution from protogranular to porphyroclastic terms is locally overprinted by a near-solidus event resulting in the formation of extremely irregular (ortho-) pyroxene textures. This texture is here defined as protointergranular characterized by orthopyroxene grains showing deep narrow embayments and extended branchy elongations with tiny interstitial terminations among the olivine grains of the groundmass (see Fig. 4). Clinopyroxene and spinel are sometimes associated to orthopyroxene grains but are more frequently dispersed in the olivine matrix forming trails crosscutting the whole texture. Poikilitic textures are frequent, mostly consisting of orthopyroxene oikocrysts hosting olivine or spinel chadacrysts. Sometimes spinel hosts orthopyroxene chadacrysts or forms tiny intergrowths with it. Notably, these rocks are richer in pyroxenes with respect to the porphyroclastic rocks.

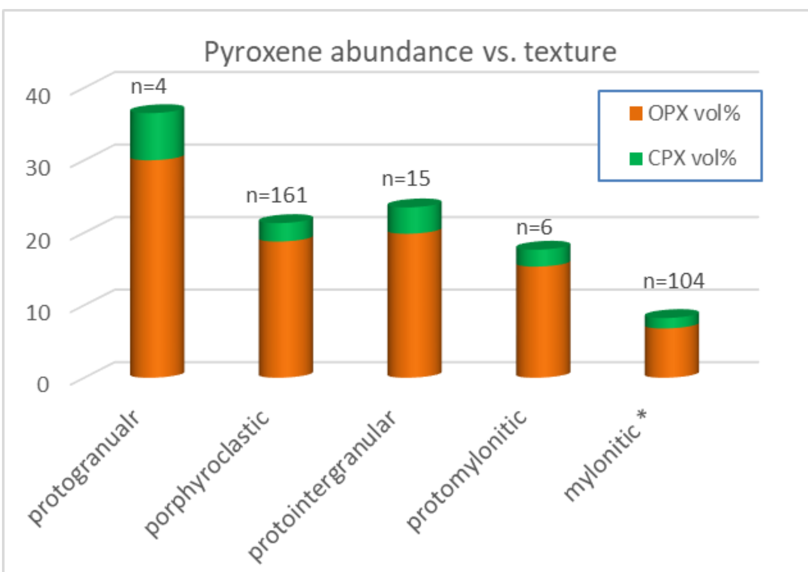

Fig. 3 Relative abundance of pyroxene (Opx & Cpx vol%) for the different lithologies in the described rock suite. (*) Mylonitic pyroxene abundance refers to the relict porphyroclasts in mylonitic and ultramylonitic rocks.

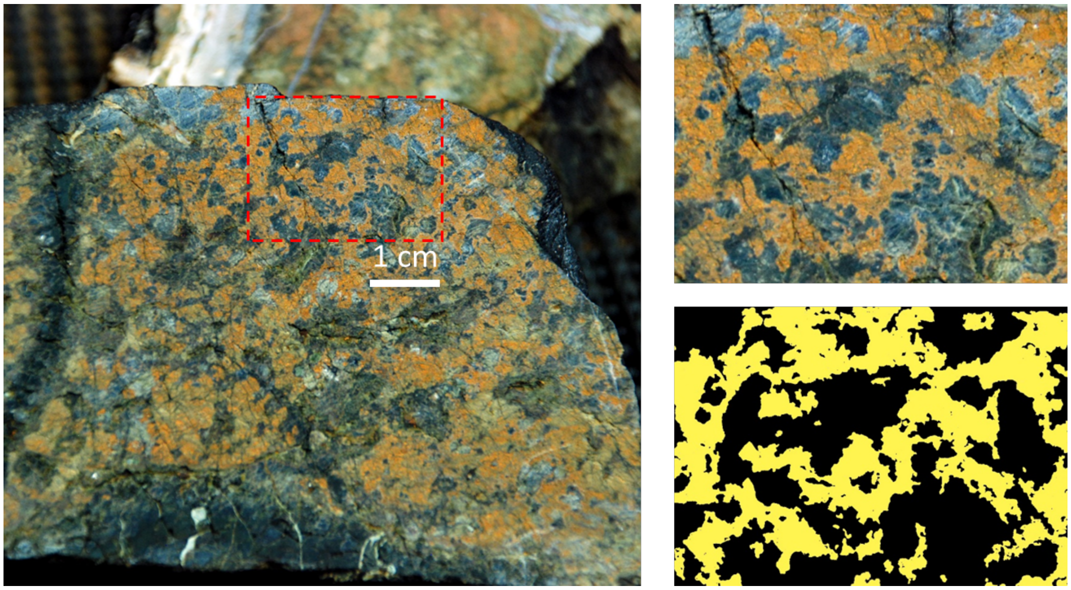

Fig. 4 Sample TN-D28-9: an example of protointergranular texture as defined in the text. An enhanced contrast detail and a two-color mapping show the sub-poikilitic branchy texture of the pyroxenes with tiny terminations and deep narrow embayments.

The contemporaneous presence of deep embayments and tiny extended branches, the development of poikilitic textures, the heterogeneous distribution of mineral phases at the sample scale and the mineral trail are all suggestive of a near-solidus process with a continuous dissolution/precipitation of Opx-Cpx and spinel in the presence of melt in the spinel facies. These structures cannot survive a pervasive crystal plastic deformation and therefore bear witness melt-rock interactions before rapid quenching of the rock in the spinel facies and brittle exhumation onto the seafloor.

Ultramafic mylonites represent ca. 40% of recovered ultramafic rocks and 20% of the total recovery. These rocks are extremely deformed; mylonites (n=27) plot in the upper end of the mylonitic scale (matrix >82%) and grade to ultramylonites (n=72), the latter representing the major textural occurrence of this rock type. Their crystal plastic deformation index range 4-5.

Ultramylonites appear as massive rocks with a matrix grainsize <0.1 mm. They frequently show a rather fresh core. Porphyroclasts are mainly pyroxenes, with minor olivine recognizable by serpentine replacement. Overall the average Opx porphyroclasts represent 8.5 and 3.2 % of the rock volume in mylonitic and ultramylonitic rocks respectively, whereas Cpx averages 0.9 and 0.6. The grain size of the relict porphyroclasts is 2.3 and 1.9 for Opx and 1 and 0.7 for Cpx respectively in mylonitic and ultramylonitic rocks (see plot below).

The composition of the mylonite matrix cannot be defined based on the lens observation only. A fine (0.1-2 mm) olivine- and pyroxene-rich layering is often present.

However, several samples present a pervasively homogenized matrix suggesting an extreme grain size reduction.

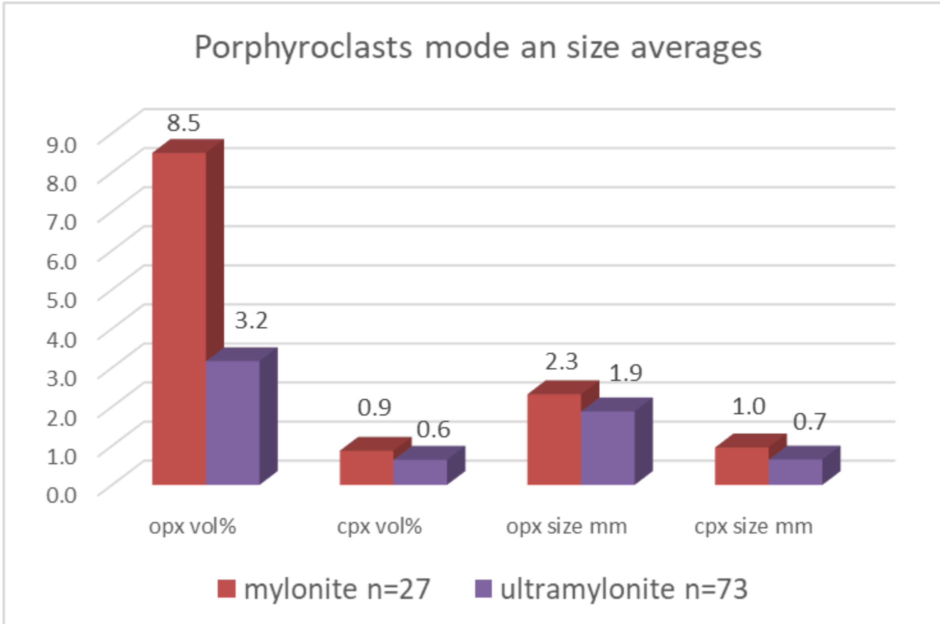

Figure 5 Average modal content and grain size of relict porphyroclasts in mylonitic and ultramylonitic rocks.

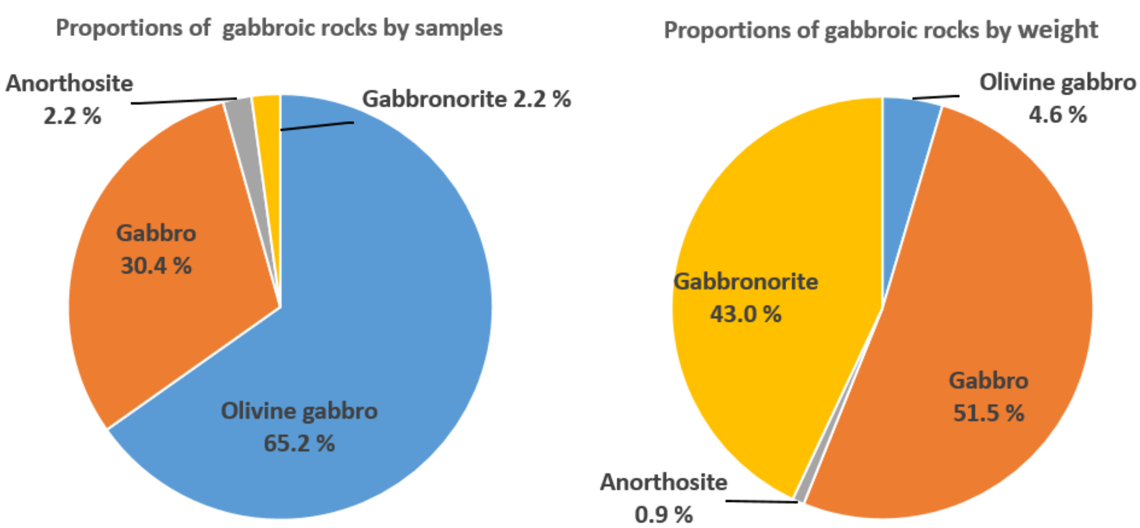

Figure 6. Proportions of the different gabbroic rocks sampled during Expedition TN365, by numbers of samples (left) and by weight (right).

Gabbroic Rocks

Gabbroic rocks were recovered only in a few dredges: dredge #1, #4, #9, #18, #19, and #21. Only one dredge, #1, contained exclusively gabbro. In dredge #21, gabbros are the most common rock type (21 samples, compared to 15 diabases and basalts), but all these samples from dredge #21 corresponds to very small, cm-sized pieces. The proportions of the different gabbroic rocks are shown in Fig. 6.

Olvine gabbros are medium grained rocks with an average grain size of 1-2 mm showing a granular texture. For a reliable mode estimation, the rock pieces are too small. Average modal olivine content is 15 %; some of the pieces seem to contain both clinopyroxene and orthopyroxene. One sample, D21-5, shows an intrusive contact between two olivine gabbros with different textures. The host olivine gabbro is fine-grained with granular texture, while the intruding gabbro is medium grained showing up to 5 mm long elongated olivine grains. These are parallel aligned perpendicular to the contact, forming a typical comb structure. This clearly indicates an intrusive contact, where the crystallizing olivines used a former surface for unidirectional growth (Fig. 7). The contact is sutured, implying that the host gabbro was not completely frozen during the intrusion.

Gabbros show typical granular textures with average grain sizes varying between 5 and 20 mm. Sample D21-2 shows a typical poikilitic texture with up to 3 cm-sized clinopyroxenes enclosing 1-2 mm-sized plagioclases The modal contents of plagioclase and clinopyroxene within the gabbros are highly variable with values between < 20-60 vol% and 40- >80 vol%, respectively.

Fig. 7. Intrusive contact between a medium and a fine-grained olivine gabbro. The medium grained olivine gabbro (upper part) shows a typical comb structure indicating an intrusion of this rock into the fine-grained olivine gabbro.

Gabbronorite/anorthosite: Sample D21-1 is the only gabbronorite collected during cruise TN365. This rock shows a poikilitic texture, with up to 3 cm-sized poikilitic orthopyroxene, enclosing ~ 2 mm-sized plagioclase, but also a few grains of olivine and clinopyroxene. The matrix between the oikocrysts is granular with grain sizes of 2-3 mm consisting of plagioclase, clinopyroxene and olivine. The modal amounts of plagioclase, clinopyroxene, and orthopyroxene are 60, 10, 30 vol%. A few grains of olivine are visible. At the outermost rim of this sample a mm-thick vein of anorthosite is visible, probably corresponding to a thin intrusion. The contact is sutured, implying that this corresponds more to an intrusion in a mush state than a late intrusion of felsic material into an already frozen host rock. The texture of the anorthositic rock is fine-grained granular. No other minerals have been observed in this rock.

Gabbroic rocks associated with the mantle: While most of the gabbros correspond to typical cumulate gabbros well-known form the plutonic sections of the oceanic crust, two gabbroic samples are probably related to the mantle-sequence. Gabbro D9-32 corresponds to a melt-impregnated peridotite, with a coarse grained, protogranular texture, and modal amounts of plagioclase, olivine, and orthopyroxene of 30, 10, 60 vol%, respectively. D18-53 was the only gabbroic sample in Dredge 18, which otherwise contained only peridotites. This rock, formally described as gabbro, corresponds probably to a former gabbroic intrusion within the mantle rocks, which was during the serpentinization process converted into rodingite-like paragenesis.

Basalts, diabase, dolerite

The goal of the sampling program is to characterize the basalts and determine how they differ from the associated peridotites as well as from ridge segments to the west and east. The dredging program resulted in twelve dredges that contained mainly basalts. The samples are in general fresh to slightly altered and approximately 180 samples are fresh enough for complete petrographic descriptions, major, trace element analyses and determination of radiogenic isotope composition (Sr, Nd, Hf and Pb). This, although some of the samples are small in size, but many of those are glassy or aphyric.

Dredge 4, 5 and 6 on the western end of the survey area are north of the expected neo-volcanic zone while dredge 7, 9 and 10 were in the rift zone of the eastern end of the survey area, west of 43°30'E. Dredge 27, 30 and 31 on the eastern side of the survey area, east of 45°E were in the rift zone and also yielded abundant basalt. Only several of the samples in Dredge 6 had more than 0.1mm of manganese crust; the remainder of the basalt samples, even those away from the rift zone had only manganese veneers but no large accumulations. Extrusive samples are dominantly basalts that show pillow-type structures. In addition, there a number of microcrystalline basalts that could also be interpreted as diabase. A few samples in Dredge 27 are potentially more evolved andesites based on their large crystal cargo in a glassy matrix. The

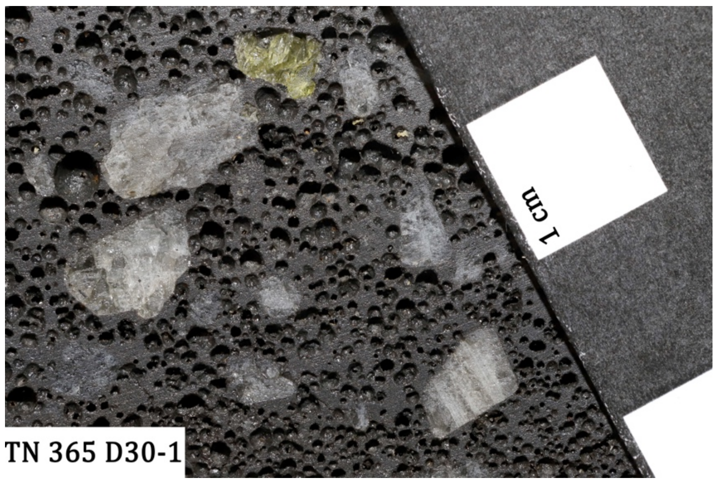

Fig. 8. Sample D30-1 showing a highly vesicular basalt with phenocrysts of plagioclase and one grain of green olivine at the upper border of the image.

basalts have two phenocryst phases, plagioclase and olivine, with plagioclase more frequently occurring.

Of the described samples 4% has more than 10% plagioclase crystals with some having in excess of 50% plagioclase, 8% of the samples have between 5-15% plagioclase and 60% is devoid of plagioclase phenocrysts. 2% of the samples have 5 or more% modal olivine, 12% have between 1 and 5% olivine phenocrysts, while 9% of the samples has less than 1% olivine crystals. Vesicularity varied and 21% of the samples have >10% vesicles with a maximum of 70%, 12% of the samples have between 5 and 10% vesicles and 48% have between 1 and 5% vesicles. The basalts on the western end tend to be more crystal rich and especially basalts from Dredge 31 have a high abundance of plagioclase crystals which show twinning, zonation and contain melt inclusions. Basalts from Dredge 30 at approximately 2200 meter depth are unusual in that they are highly vesicular with 70-80%

vesicles and have both plagioclase and olivine phenocrysts (see Fig. 8 where large white crystals are plagioclase and green crystal is olivine).

Comparing the west-side versus the east-side dredges the crystallinity and vesicularity of the western side samples is less with plagioclase crystal size generally at less 2 mm and olivine less than 1 mm, vesicles are on average less than one millimeter. Dredge 27, 30 and 31 contains flows with large plagioclase crystals (up to several centimeters) as well as large and abundant vesicles.

METAMORPHIC PETROLOGY

The sample collection mainly comprises basalt, diabase, dolerite, gabbro (very rare) as well as various textural and mineralogical varieties of peridotites. In general, all peridotites show a high degree of alteration, both of superimposed weathering (often up to 90-100%) but also of metamorphic overprinting.

For all rock types metamorphic conditions range from the zeolite-prehnite-pumpellyite to the low-grade greenschist-facies. Without back-up by thin sections assignment of metamorphic grade is difficult and fraught with a high degree of uncertainty. To tentatively describe the conditions of metamorphic overprinting in hand specimen we used the following criteria:

- *Zeolite-, prehnite-pumpellyite facies (basalts, diabase, dolerite)* - clear Identification of clay minerals and/or zeolite-like vesicle fillings and/or prehnite and/or albite.
- *Greenschist-facies (basalts, diabase, dolerite)* - unambiguous identification of serpentine-minerals, chlorite and/or epidote, ± albite.
- *Greenschist-facies (peridotite)* - identification of serpentine-group minerals. Hydration processes affecting ultramafic rocks generally take place over a considerable temperature range. More recent studies indicated that the widely quoted textbook temperatures of 100-300 °C often are exceeded. However, unambiguous temperature constraints can only be determined by a more detailed petrological study. In the studied samples talc is rare and tremolitic amphiboles have not been identified at all, suggesting temperatures <400 °C.

Ultramafic rocks

All rocks show a high degree of hydration and pervasive metamorphic overprinting (Fig. 9) of up to lower greenschist facies conditions (presumably <400 °C, as talc is rare and amphiboles have not been recognized at all). Primary minerals (olivine, orthopyroxene, clinopyroxene, Cr-spinel) have largely been altered to serpentine-group minerals, oxides (mostly magnetite) and ± talc; among the primary phases relictic Cr-spinels and clinopyroxenes show the highest degree of preservation. Completely serpentinized rocks have the visible mineral assemblage serpentine–magnetite. Partially altered peridotites mainly consist of the mineral assemblage serpentine–magnetite, ± (in decreasing order of abundance) relicts of Cr-spinel, clinopyroxene, orthopyroxene. Unaltered or partially preserved olivine has not been recognized. Among the serpentine-group minerals lizardite and chrysotile are the main varieties that can be expected in low-grade serpentinites, but clear identification is only possible with transmission electron microscopy or Raman spectroscopy. Talc was only rarely unambiguously documented. Most of the originally pyroxene-bearing rocks are characterized by pseudomorphic textures indicating static serpentinization. Besides the formation of serpentine-group minerals, low temperature alteration is also evidenced by the presence of clay minerals, various Fe-oxyhydroxides causing yellowish or reddish staining.

Veins within ultramafic rocks: Most ultramafic rocks contain a common network of veinlets composed of serpentine-group minerals and/or oxides. Mostly straight Carbonate veinlets/veins (most likely aragonite) also occur, playing a subordinate role. Almost all the peridotite samples contain one to three vein types that are irregular, network, branched, cross fractures or straight (Fig. 10). The veins vary from 0.1 to 10 mm in thickness, 0.1 to 85 % in volume, and white, whitish, light green, greenish, dark red, blackish, black in color. Visible vein minerals include clay, serpentine, oxide, calcite, epidote and talc.

Fig. 9 D22-1: peridotite, ca. 80% altered, clay minerals, serpentine, oxides; D22-6: peridotite, ca .95% altered with whitish, irregular serpentine vein.

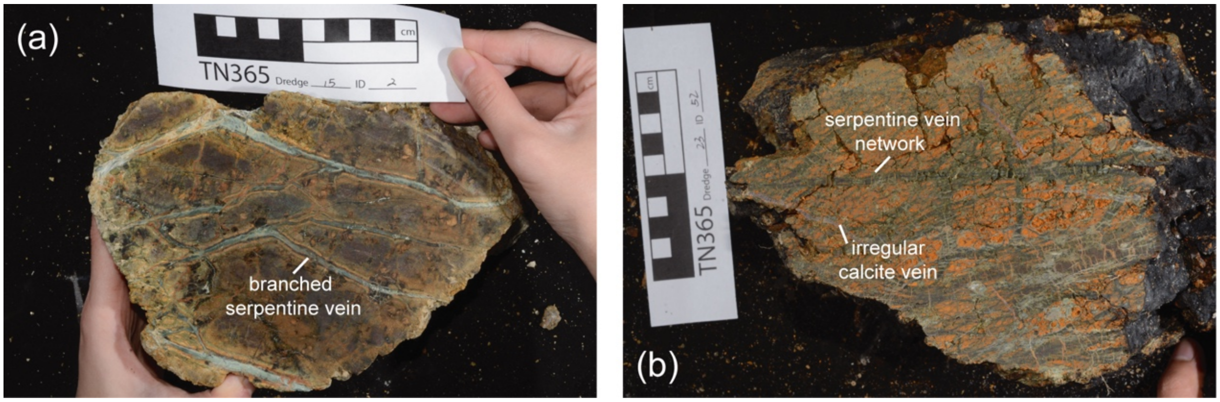

Fig. 10 Veins in peridotite. (a) Branched greenish serpentine veins; (b) Greenish serpentine vein network and irregular whitish calcite vein.

Gabbro

All gabbroic rocks irrespectively of their rock type are altered in the greenschist facies, with an average alteration degree of ~ 50 %. About 20% of the gabbroic rocks show in addition a metamorphic overprint in the zeolite-, prehnite-pumpellyite facies.

Olivine is typically altered to serpentine, often in combination with Fe oxides sometimes forming typical aggregates of orange-reddish "iddingsite". Clinopyroxene is mostly overgrown by chlorite, very probable in combination with actinolite, which was not clearly identified. The alteration of orthopyroxene in sample D21-1 is quite striking, consisting of serpentine, chlorite and oxide with a shiny appearance probably due to disseminated tiny oxides, probably similar to bastite. plagioclase was altered to albite, sometimes in combination with prehnite. In gabbro D21-2 plagioclase shows a special alteration texture with rims overgrown by a mixture of chlorite and oxide, with an apparent zoning with increased alteration intensity to the rims of the grains. About two third of all gabbroic samples shows effects of seafloor weathering expressed by the presence of clay minerals.

Veins within gabbros: Most of the (olivine) gabbros have no veins. Four out of 45 gabbro samples have irregular or network veins, which can be categorized into four types. They are: 1) irregular white prehnite veins of ≤1 mm thick and 0.5-1% in volume; 2) irregular black actinolite veins of 1 mm thick and ~0.5% in volume; 3) greenish serpentine veins network with 0.1 mm thick and 0.5% in volume; 4) irregular whitish calcite veins of 1 mm thick and 0.1% in volume.

Basalts

Rocks of this group often are relatively fresh and include samples with glass rinds and unaltered olivine. The visible alteration assemblage mainly comprises clay minerals, zeolite, chlorite (often as vesicle filling), oxides and albite (partially replacing the original plagioclase) (Fig. 11). Prehnite is relatively rare. The alteration features document at least zeolite-prehnite conditions, but in many cases overprinting at lower greenschist facies temperatures is very likely.

Veins within basalts. The vein types of basalts are dominated by straight and irregular shapes, with the presence of branched type in only one sample (Fig. 12). The veins range from 0.1 to 5 mm in thickness, and 0.1 to 1.5 % in volume. Their colors vary from colorless, whitish, light grey, greenish, dark green, brownish to blackish. Visible vein minerals consist of clay, chlorite, epidote, plagioclase, oxide, calcite and quartz.

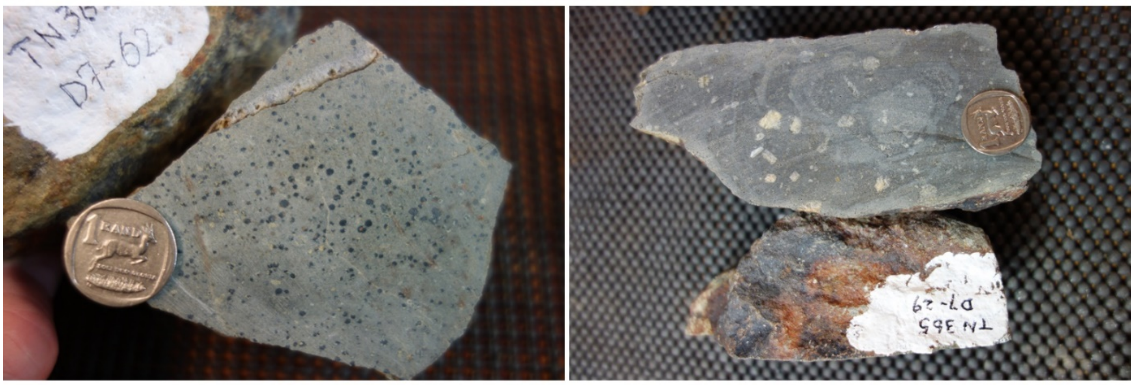

Fig. 11 D7-62: greenschist-facies basalt, vesicles filled with chlorite; D7-29: greenschist-facies basalt; plagioclase partially altered to albit

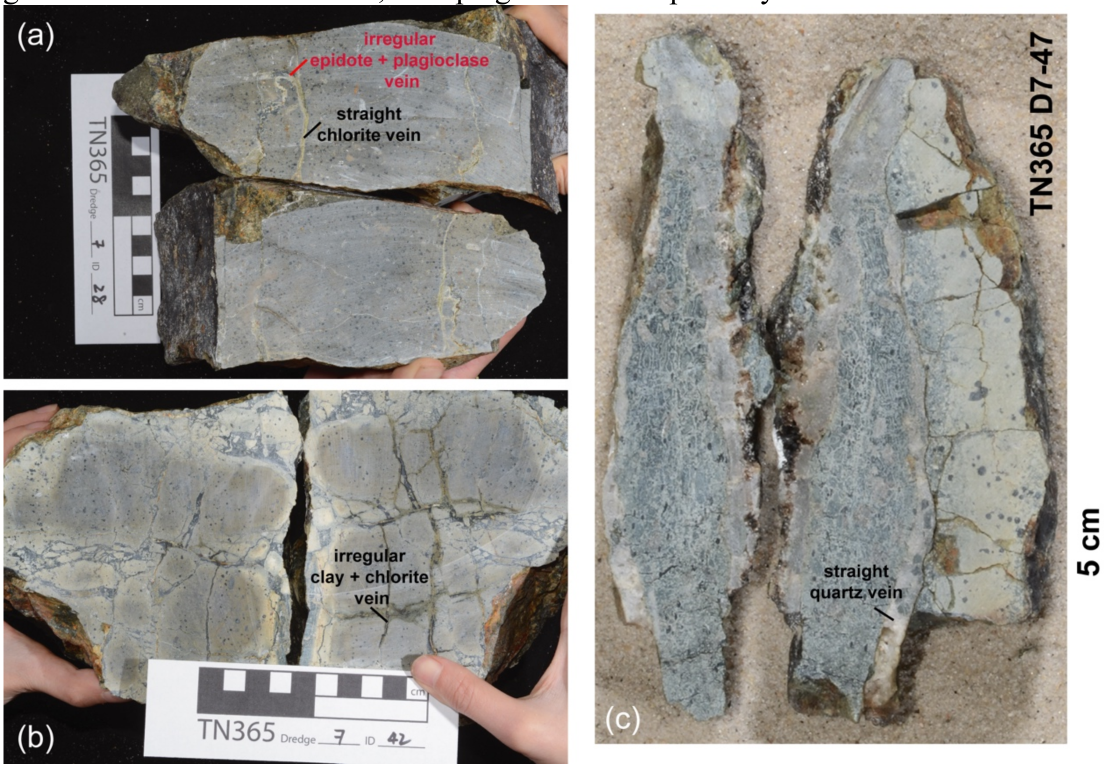

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Fig. 12 Veins in basalt. (a) Straight greenish chlorite vein and irregular whitish-dark green epidote + plagioclase vein; (b) Irregular light gray and blackish vein composed of clay and chlorite; (c) Straight colorless quartz vein.

Diabase and dolerite

Rocks of this group only constitute a small proportion of the rock collection. The visible alteration assemblage mainly comprises clay minerals, chlorite, epidote, oxides and albite. The degree of alteration ranges from ca. 20-90 %, but mostly is >50% (Fig. 13). The alteration features indicate greenschist-facies overprinting.

Veins within diabases and dolerites. Six out of 23 diabase samples have veins that are straight, irregular or branched (Fig. 14). They vary from white, light grey, light green, dark green and yellowish in color and are 0.1 to 3 mm in thickness and 0.1 to 2% in volume. Visible vein minerals include clay, chlorite, quartz, epidote, oxide and plagioclase. Three samples out of 11 dolerites have one or two types of veins that are irregular in shape, 0.5 to 1 mm thick and 0.1% in volume. They have whitish, greenish and dark green colors with visible vein minerals mostly composed of clay and chlorite (Fig. 15).

Fig. 13 D7-1: dolerite, vesicles filled with clay minerals indicative of very low-grade overprinting; yellowish colour in the outer parts due to greenschist-facies growth of epidote; D7-2; dolerite showing the same features as D7-1.

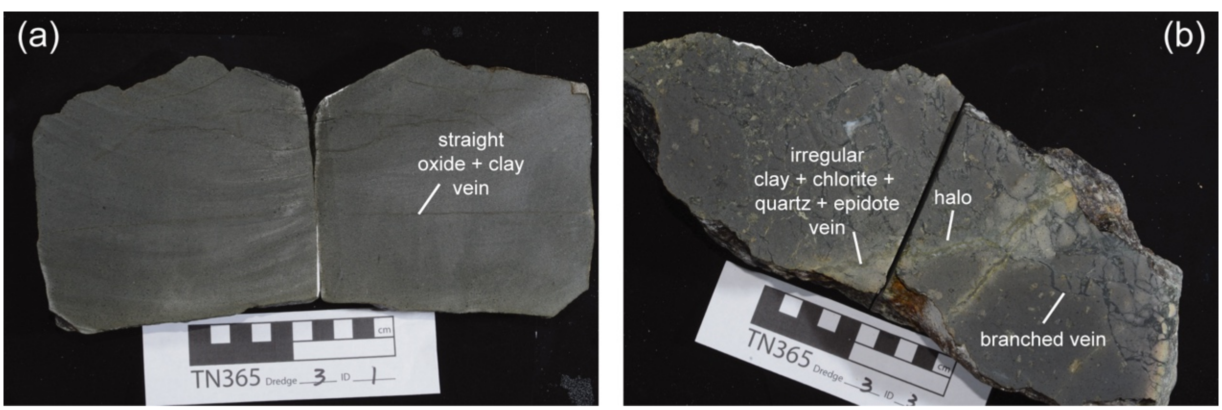


Fig. 14 Veins in diabase. (a) Straight light gray and dark green oxide + clay veins; (b) Dark-green veins show branched shape, where the yellowish vein with irregular shape and halos consisting of clay, chlorite, quartz and epidote.

Fig. 15 Veins in dolerite. Irregular greenish and whitish clay + chlorite vein.

STRUCTURAL NOTES

Recovered rocks present distinct deformation characteristics according to their lithology.

Mantle-derived peridotites record a high-T ductile deformation mainly occurring in the spinel stability field. A handful of protogranular lherzolites, which represent the lowest degree of crystal plastic deformation likely record the primary structure and texture prior to incorporation into the lithosphere. In these rocks orthopyroxenes have a large, subhedral habit with no visible cleavage bending; their crystal plastic deformation index is very low ranging 0-0.5 (scale from 0 to 5). A steady increase of the crystal plastic deformation is observed in the porphyroclastic (1-2.5) and protomylonitic peridotites (3-4). Pyroxenes in porphyroclastic rocks show clear cleavage bending, irregular shape and locally minor evidence of recrystallization. They are locally accompanied by a magmatic lineation represented by clinopyroxene and spinel mineral trails. Plagioclase, when present, does not show a clear magmatic lineation even though their form takes on an interstitial percolative texture.

Protointergranular peridotites present the same crystal plastic deformation index of the porphyroclastic group but in general possess more significant heterogeneity of the pyroxene distribution and crystal size. These rocks frequently show orthopyroxene mineral lineations even though they are heterogeneously distributed at the sample scale locally suggesting a shear-driven melt percolation event (sample TN365-D28-2).

Gabbroic rocks present overall weak or absent crystal plastic deformation and no clear magmatic lineations. The orthopyroxenite recovered in dredge D9 presents a pegmatoid texture with weak sub-lineations of the large Opx grains.

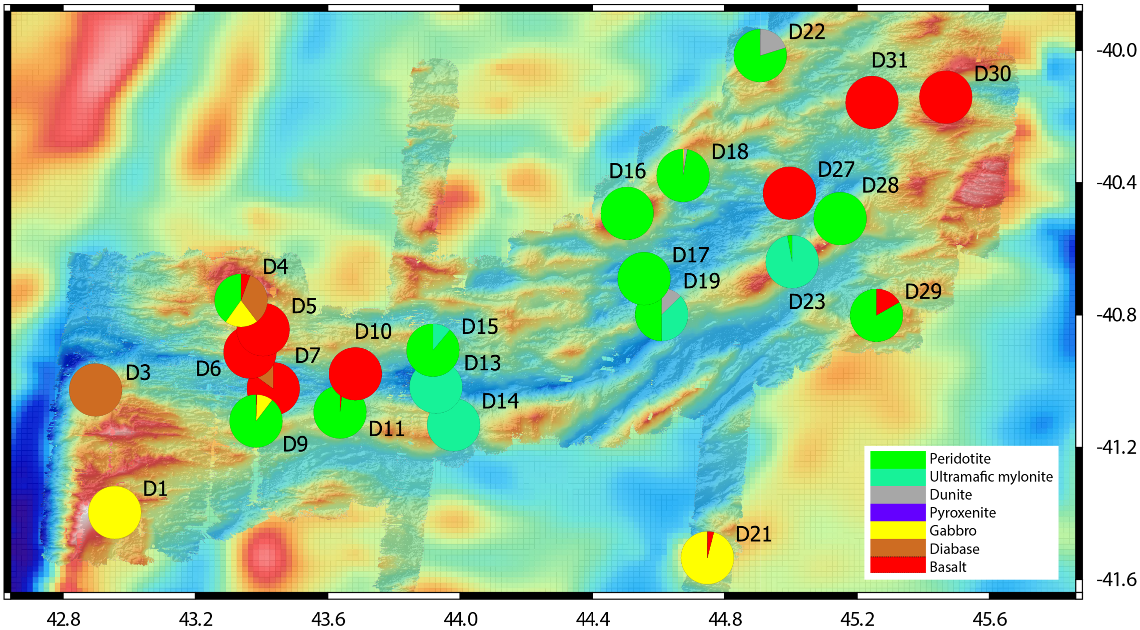


Figure 15. Location and contents of successful dredges made during Cruise TN365.

The low-T deformation pattern of the peridotites is characterized by polygenic sets of anastomosed mm-thick fracture systems. These systems are continuously filled by serpentine followed by carbonates frequently interspersed by quartz and clays. Tiny sedimentary fillings appear close to the outer surfaces grading to hydrothermal carbonates inward. Serpentine crystallization is often polygenic showing multiple events in a single sample. The serpentine to carbonate crystallization is more frequently antitaxial than syntaxial, resulting in serpentine-cored veins with carbonate rinds.

A set of tiny submillimetric thick, 2-3 cm long, discontinuous serpentine veins is present in almost all samples possibly resulting by compensation of volume expansion during serpentinization.

Extrusive rocks are almost entirely represented by pillow sectors with the exception of the porphyric lavas in dredge D31 and the scoriaceous materials recovered in dredge D30, possibly of an explosive origin. Porphyric D31 lavas have no evident flow textures and fracture system.

Pillow basalts present the radial thermal joint fracturing and brittle cracking filled by hydrothermal mineralization reaching up to the greenschist thermal conditions.

The PMEL MAPR

The PMEL MAPR (Miniature Autonomous Plume Recorder) was used on this cruise. The MAPR was provided by Sharon Walker of NOAA/PMEL. It is a durable, self-contained instrument that records data of temperature, pressure, optical backscatter (LBSS, or "nephelometer") and oxidation-reduction potential (ORP) sensors located at one end of the instrument. Data is recorded internally, and cannot be accessed or viewed during deployment. The MAPR was either clamped onto the trawl wire 375 m above the dredge or attached to the Sentry. The main purpose of having the MAPR is to "sniffy" out hydrothermal vents by recording the chemistry in the water. Once aboard, the data was downloaded and plotted up using the macro GetBinaryData and put into an excel spreadsheet and then plotted by using Matlab. During this cruise, the MAPR was used in the spreading center of the Rift Valley looking for possible hydrothermal vents. We had 8 successful MAPR casts with the dredge operations (Dredges 7, 9, 12, 13, 15, 20, 25, and 30) and two successful Sentry dive operations (Dive # 530 and 531). There were a number of casts where we were not able to use the MAPR due to several issues as well as a lost Sentry dive. The main issue was that the MAPR would switch the start date to 01/02/2003 so it wouldn't start when it was programmed. This is what happened on the Sentry 529 dive. Once this was noticed, the MAPR was then started while still connected to the computer in the lab and allowed to collect ambient data to make sure the MAPR was actually running. The MAPR communications was also unreliable at times-not recognizing entered commands.

Gravity

Marine gravity was obtained with a GNS Science-supplied gravimeter from New Zealand (courtesy of: Dr. Fabio Caratori-Tontini). The instrument is a Lacoste and Romberg S-80 marine gravimeter upgraded to a ZLS Ultrasys control system (Fig. XX). This instrument is essentially a marine version of the zero-length spring (ZLS) gravity meter that is used on land but with a gimbaling system and fibre-optic gyros and accelerometers. The instrument was installed in the computer lab of the ship. Data were recorded on a small dedicated laptop at a 1 Hz data rate with hourly files. Time is provided by the laptop clock, which was synchronized to the GPS signal taken from the ship. The raw data file in fixed format contains id, year, julian day, timestamp (hh,mm,ss), filtered gravity, spring tension, cross coupling, raw beam gravity, etc (see output format detail below).

TN365 2019 6012131710784.4110768.01 5.61 -1213.1 155. 7. -15. 0. 9. 224. 204. -570. 544. FFFFFF 8.

Translated as : 2019, 60, 12:13:17, 10784.41, 10768.01, 5.61, -1213.1, 155.0, etc

A gravity tie was done in Fremantle following installation of the meter and prior to the transit over to South Africa. Another gravity tie was done in Durban on the pier adjacent to the ship which was not far from the absolute gravity tie nearby in the Port of Durban management offices. An A-B-A tie was done in Cape Town at the ship (A station, Duncan dock) and at the known gravity tie location (B) located near the graving dock.

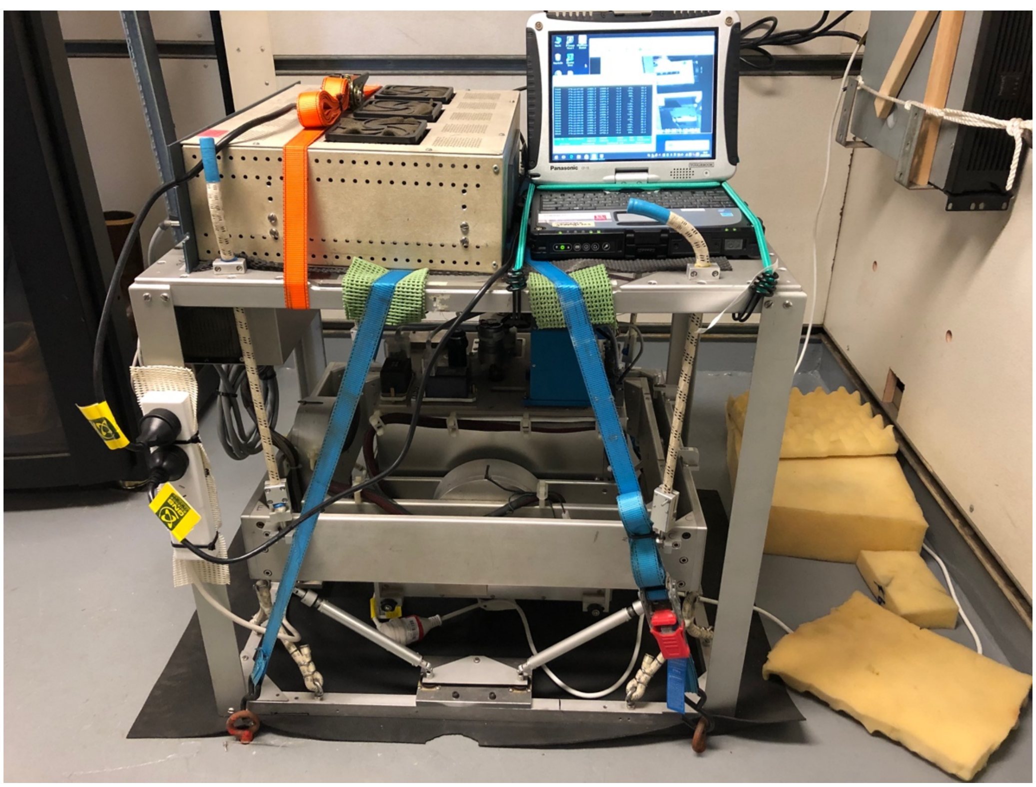


Figure XX Lacoste and Romberg S-80 Marine gravimeter with ZLS Ultrasys operating system.

Parsing of raw data is carried out by creating a bash script (Appendix A1) to read raw gravity data from the gravimeter as well as coordinates, GPS Antenna height, Speed Over Ground (SOG), and Course Over Ground (SOG) of the vessel from the navigation system. We use POSMV-5 navigation system so both gravity and bathymetry data are defined by the same positioning system.

From the raw gravity data, we extract time (dec hours), Spring Tension/ST (CU), Cross Coupling/CC (CU), and average Beam/B (mV). From navigation system we extract longitude (dec degrees), latitude (dec degrees), GPS height (m), COG (dec degrees), and SOG (knots).

The data is interpolated to have the same time stamp (Appendix A2) and segmented into survey lines (Appendix A3) before proceeding to the next step.

1. Free-Air Anomaly

Gravity values is obtained by fundamental gravity equation:

$$g = k_f \cdot (ST + k_b \cdot \dot{B} + CC)$$

where

- ST is the spring tension value;
- B is the beam derivative;
- CC are the cross-coupling corrections;
- k_f = 0.9899 (S-80 gravimeter scale factor);
- k_b = 30 mGal.mV^{-1} (S-80 gravimeter beam derivative factor at 1 Hz).

From relative gravity data, Free-Air Anomaly (FAA) is obtained through a series of corrections namely lever arms, absolute gravity, vertical acceleration, Eotvos, latitude, and free-air correction. The lever arms correction is carried out to calculate the position of the gravimeter relative to the height of the GPS antenna:

$$H = H_0 + \delta H$$

where

- H_0 is the GPS elevation;
- δH = -12.17 m (vertical distance between POSMV-5 GPS antenna and gravimeter)

Absolute gravity correction is given by:

$$\delta g_{abs} = g_{abs}^0 - k_f \cdot ST_0$$

where

- g_{abs}^0 = 979348.66 mGal (absolute gravity at the Port of Durban)
- ST_0 = 9672.49 (spring tension value read by gravimeter at the Port of Durban)

Vertical acceleration correction is given by:

$$\delta g_{AU} = \ddot{H} = \dot{V}_U$$

where

- $\dot{V}_U$ is the second derivative of H

Eotvos correction, which is accelerations due to the ship travelling to the east or west, will reduce or increase the gravity significantly. The correction is given by:

$$\delta g_{eot} = 7.508 \cdot S \cdot \cos(\varphi) \cdot \sin(H) + 0.004154 \cdot S^2$$

where

- S is the ship SOG (knots)
- φ is the latitude
- H is the ship COG (dec degrees)

Latitude correction to remove the attraction of the reference ellipsoid is given by:

$$\delta g_{lat} = 978032.67715 \cdot \frac{1 + 0.00193185138639 \cdot \sin(\varphi)}{\sqrt{1 - e^2 \cdot \sin^2(\varphi)}}$$

Free-air correction to remove the elevation of the gravimeter above the geoid is given by:

$$\delta g_{fa} = 0.3086 \cdot H$$

Hence, the FAA is described as:

$$\delta g_{fa} = g + \delta g_{abs} + \delta g_{AU} + \delta g_{eot} + \delta g_{lat} + \delta g_{fa}$$

Finally, the remaining gravity variation is smoothed first pass using a gaussian filter with 3600 s window (1-hour average). A second pass filter is carried out using another gaussian filter with 600 s window (10-minute average). Both passes result in a certain phase shift, then it is important to compare the observed FAA with satellite FAA before proceeding to the next steps. This whole process can be employed using the Matlab script in Appendix A4.

FAA grid can then be produced using GMT (Appendix A5). The script creates gridded FAA data using surface and near-neighbor interpolation methods. Surface interpolation is the most ideal method as it uses adjustable tension on continuous curvature spline, but it will extrapolate areas with no data in it. Hence, a mask using near-neighbor interpolation method is created to flat these extrapolated data as near-neighbor computes grid with by interpolating the the 8 nearest values of each data point. The masked surface FAA is then padded with satellite data to enable continuous computation on the next steps.

2. Bouguer and Mantle Bouguer Anomaly

Bouguer and Mantle Bouguer Anomaly (MBA) is computed using the gravfft function of GMT, which computes gravitational attraction of 3D surfaces. Bouguer anomaly is computed by removing the seawater-crust interaction using the average density contrast ($\rho_{seawater}$ = 1.03 g/cc; ρ_{crust} = 2.8 g/cc), with similarly gridded bathymetry from the multibeam survey. MBA is then computed by downward-continuing the Bouguer anomaly to a certain depth (here we use 5 km thick crust) and remove the crust-lithosphere interaction using the average density contrast ($\rho_{lithosphere}$ = 3.33 g/cc). These processes are employed using the GMT script in Appendix A6.

3. Final Processed Data

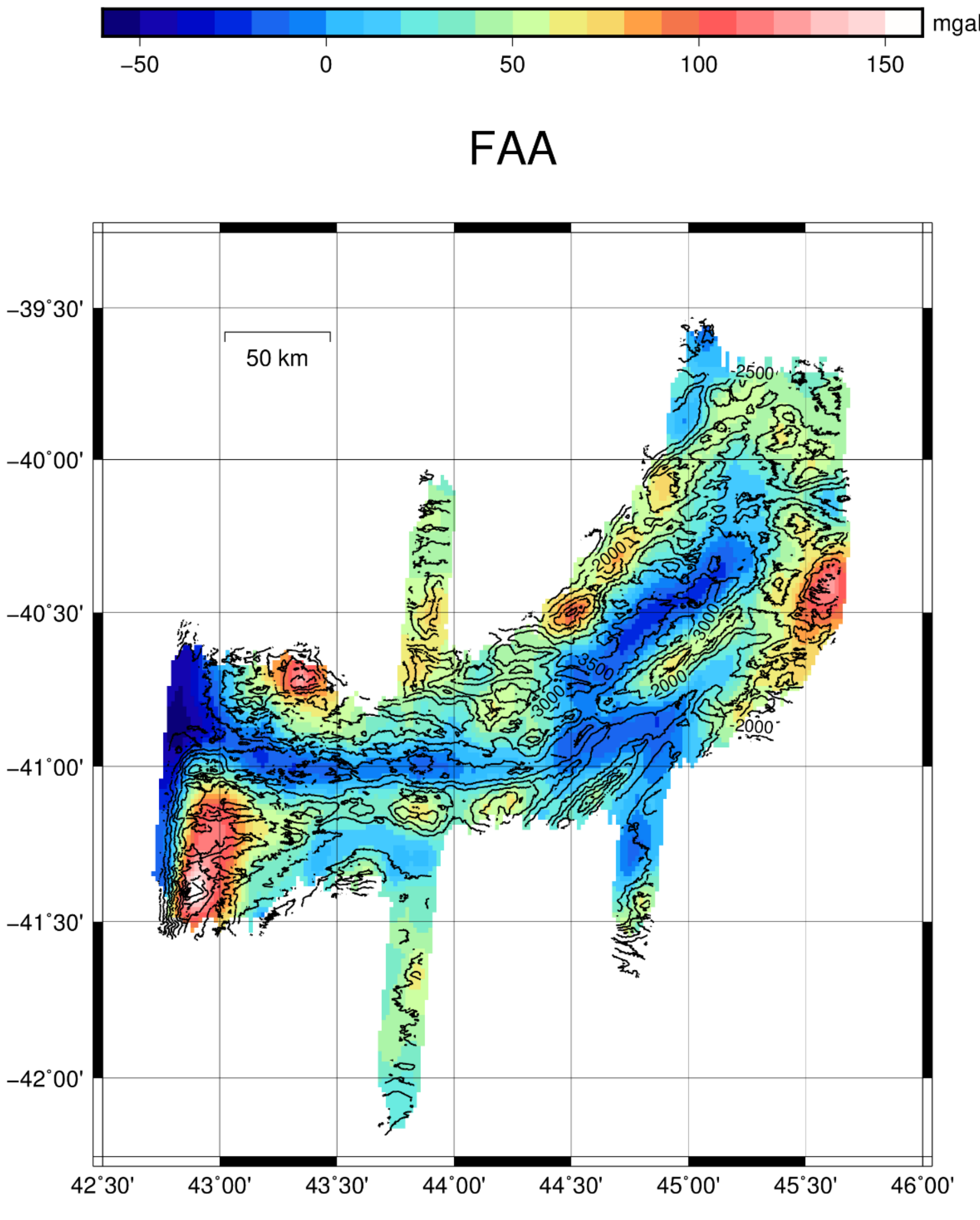
Final processed data is recorded in:

- XYG FAA file with columns that include longitude, latitude, FAA
- XY file to plot track lines that include longitude and latitude
- Gridded FAA, Bouguer Anomaly, and MBA files

Additional technical details, methodS used in processing the data and computing the anomalies and scripts can be found in the Geophysics File appended to this report.

Gridded Gravity Maps

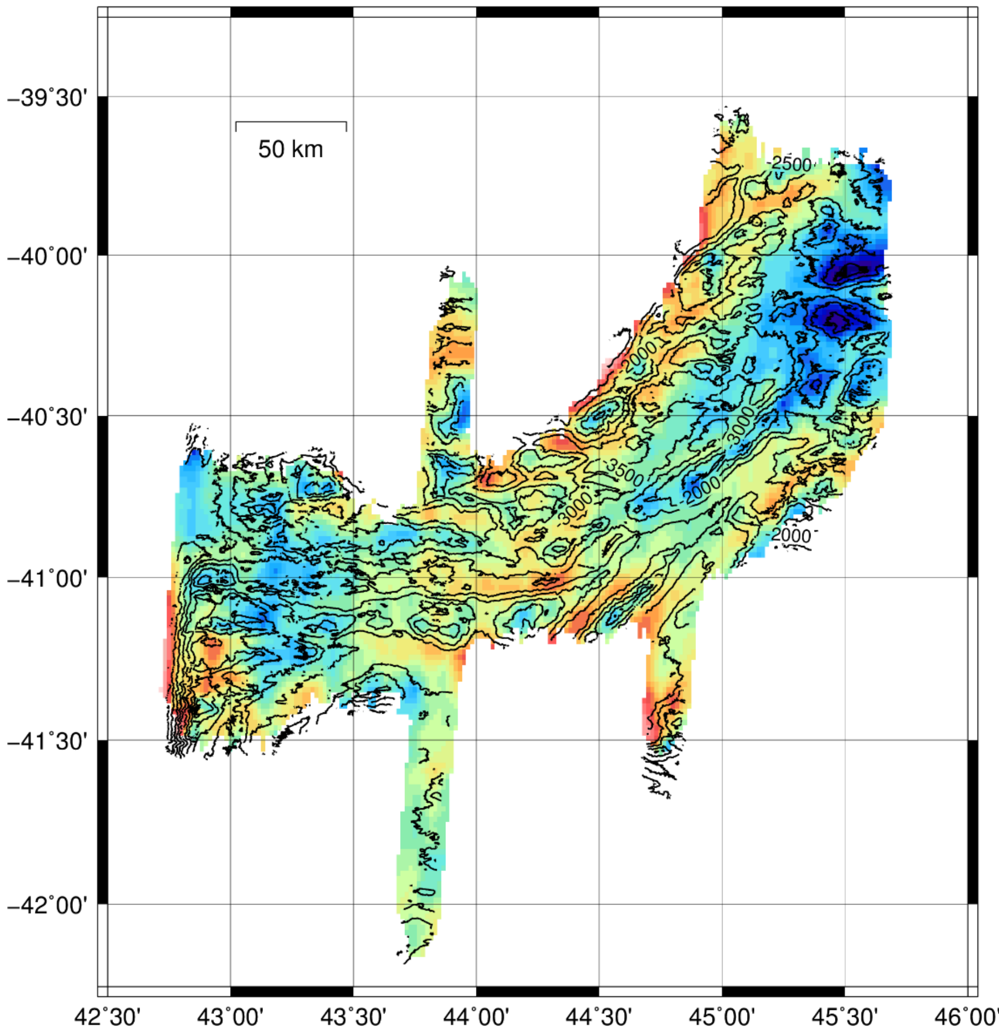
Free-Air Anomaly
Overlaid by 500 m contours



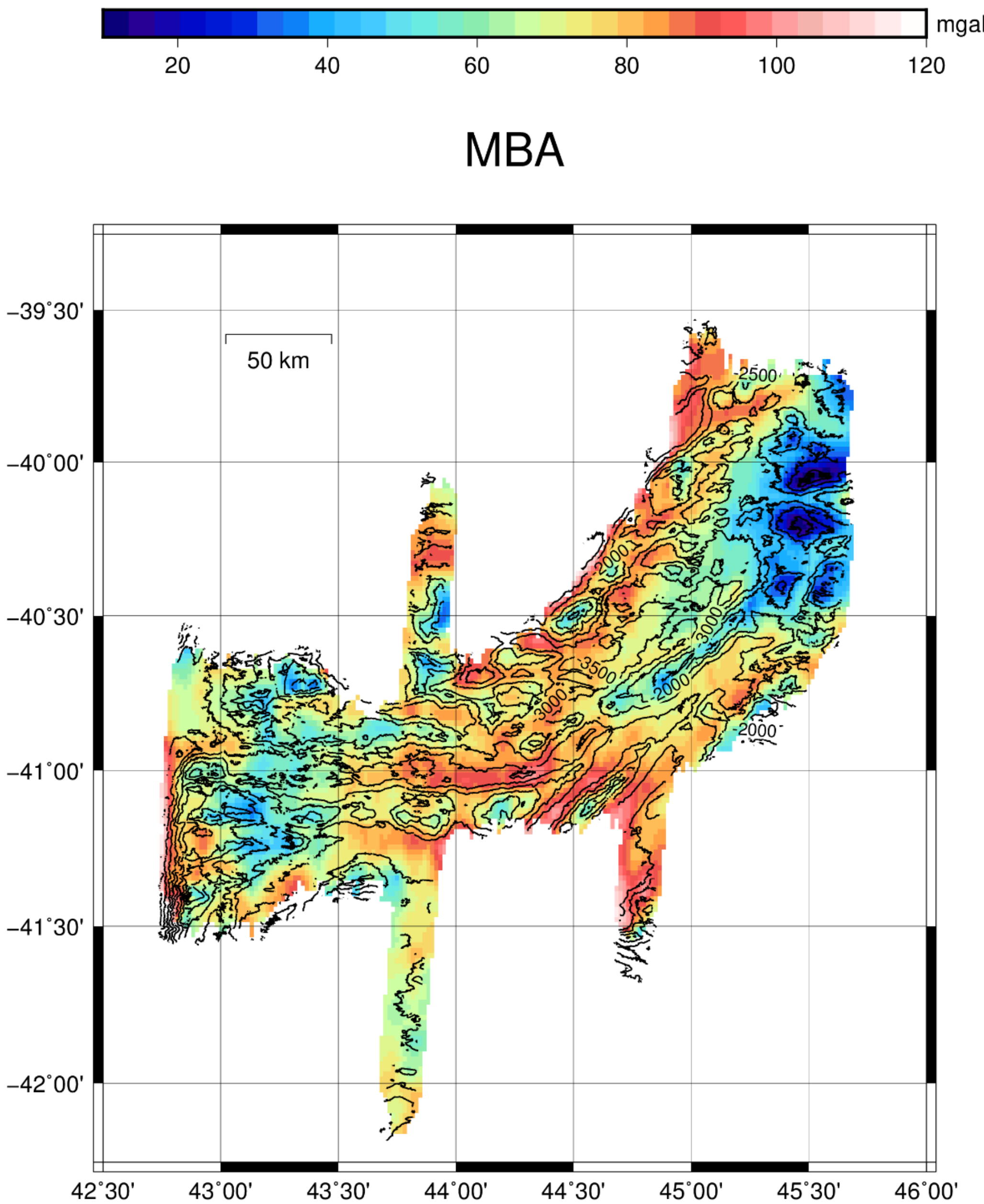
<u>Bouguer Anomaly</u>

Overlaid by 500 m contours

Bouguer Anomaly



Mantle Bouguer Anomaly
Overlaid by 500 m contours



Education and Outreach

Outreach activities associated with the TN365 (Marion Rise) cruise were extensive before and throughout the cruise, and included the following –

1) Ship-to-shore webcasts with classrooms (K-12 and post-secondary) in China, Germany, Indonesia, Wales, and the U.S. including California, Florida, Minnesota, Mississippi, New York, South Dakota, Texas and Wyoming.
2) Daily updates of the Marion Rise web site (www.marionrise.org), including blog posts, daily science update, pictures of the day, birds and videos.
3) Social media outreach (Twitter)
4) Sacred Heart School in Kingston, MA students building and tracking the mini-boat/drifter 'Sacred Heart Star of the Sea' (launched from Thomas G. Thompson on March 22, 2019).

Ship-to-shore webcasts

Thirty-one ship-to-shore webcasts were given to K-12 schools and post-secondary institutions across the United States, Indonesia, Germany, the UK and China. These virtual classroom connections reached nearly 1100 students and members of the public (Table 1), allowing them to engage directly with the shipboard science party as operations and discoveries were being made.

The outreach team (2 people are required- one to hold the iPad & "video" and the other to talk) used an iPad (preloaded with slides), tripod and case, *Zoom* with wireless routers around the ship, and enhanced HighSeasNet bandwidth. Stephen and Sonia (marine techs) ensured adequate bandwidth by monitoring internet use during broadcasts. Test *Zoom* sessions between the classroom and ship were carried out before each webcast to check connections. Due to the noise on deck, some participants remarked about difficulty in hearing during tours. For future webcasts of this type, an external microphone with built-in speaker is recommended for use on deck.

Following each webcast, the responsible individual at each school or institution was sent an email asking for feedback and assessment of the program to help revise the project real time. Responses are included in Appendix A. Overall, the two outreach personnel felt the program was a great success and enjoyed working with the wide variety of participants.

Table 1. Ship-to-Shore Outreach Participation

Date	Location	Grade Level	# Participants
Feb. 25	Laramie WY	5th - 8th	23
Feb. 26	UK (Wales)	college	23
Feb. 26	Laramie WY	1st - 2nd	18
Feb. 27	New York	5th	54
Feb. 27	Laramie, WY	3rd 4th	61
Feb. 28	Converse Co., WY	4 through 8	6
Mar. 1	Green River, WY	6th 7th	40
Mar. 1	South Dakota	6th 7th	11
Mar. 4	Green River, WY	6th 7th	40
Mar. 5	Florida	college	12
Mar. 5	Laramie WY	8th	16
Mar. 6	Duluth, MN	6th	18
Mar. 7	Laramie, WY	college	11
Mar. 7	Laramie, WY	8th grade	13
Mar. 8	Laramie, WY	3-5th	43
Mar. 12	Green River, WY	6th 7th	25
Mar. 12	Laramie, WY	1st 2nd	42
Mar. 13	Jakarta, Indonesia	8th	160
Mar. 13	Virtual Wyoming	elem/ms	14
Mar. 14	Florida	college	12
Mar. 15	Laramie, WY	5th	35
Mar. 18	Powell, WY	HS senior	20
Mar. 19	Las Angeles, CA	Kindergarten	138
Mar. 20	Shanghai, China	college	10
Mar. 20	Hanover, Germany	college	18
Mar. 21	Mississippi	college	15
Mar. 21	Texas	5th 6th	16
Mar. 22	Jakarta, Indonesia	5th	61

Mar. 25	Hanover, Germany	elementary	20
Mar. 26	Florida	college	12
Mar. 27	Jakarta, Indonesia	10th	106
			1093

Table 1. Date, location, number of participants, and ages represented for TN365 outreach webcasts (Feb 25-Mar 1827, 2019).
The ship to shore broadcast to the Wyoming Virtual Academy was one of the highlights of the series. During this broadcast, we "*Zoomed*" to 14 students each in a different rural location.

Marion Rise Web site- www.marionrise.org (as of March 22nd, 2019)

A website was created at www.marionrise.org (Fig WW) prior to the cruise and continues. As of March 22nd, 77 pages were published. The website received 2,596 visits from over 1,851 unique users (Figures XXa). They viewed an average of 5 pages per visit, producing 13,167 individual page views. Five short online videos will be published immediately after the expedition ends; the web site and monitoring will continue for at least 10.5 months post-cruise.

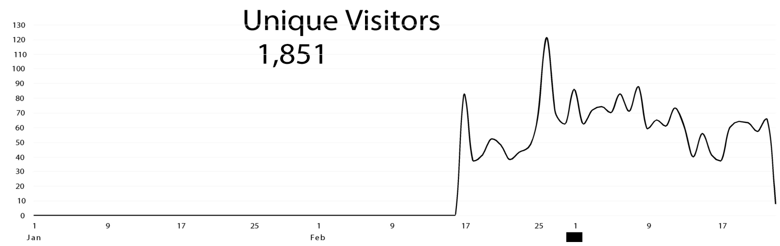
Of the visits, 55% were via desktop devices and 36% by mobile devices. Visits tended to be direct via the url., with 10% coming via social media (Fig XXa). The website was most avidly visited from the US (57%), Germany (19%), UK (7%), Indonesia (4%) & South Africa (4%) (Fig XXb) – mostly due to the nationality of the scientists on board. In total, the site had visits from 35 different counties.

The most popular pages were "Home" (2774) the daily blog (2480 page views) and the daily Science Update (2004 page views) (Fig. XXc).

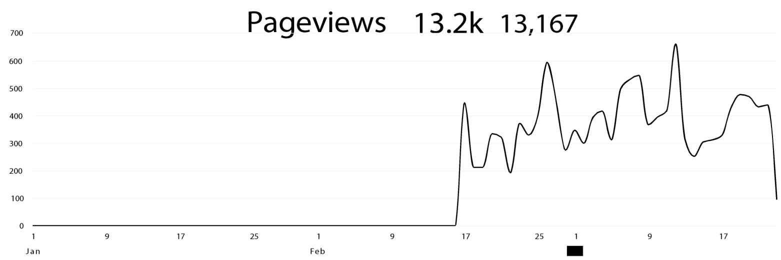
Fig WW. Screen grab of the top of the home page of www.marionrise.org

Traffic
Feb 15 – Sat, Mar 23, 2019

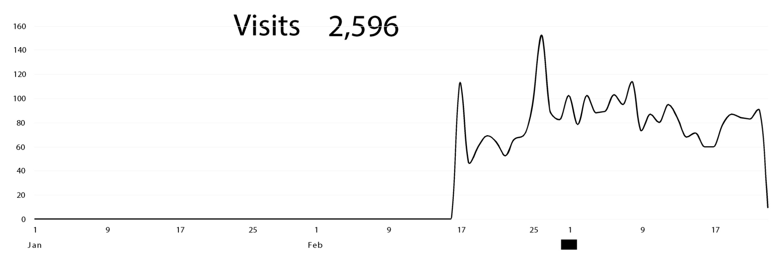
Unique Visitors



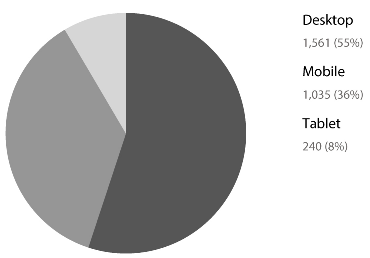
Pageviews



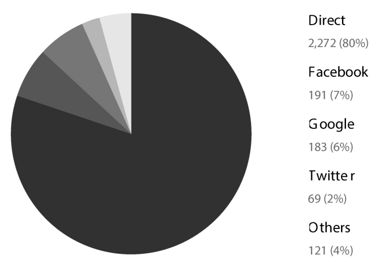
Visits



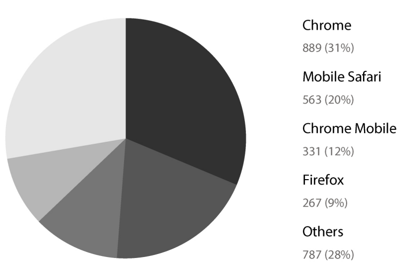
Visits by Device Type



Visits by Source



Visits by Browser



Visits by Operating System

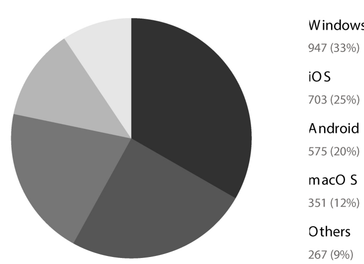
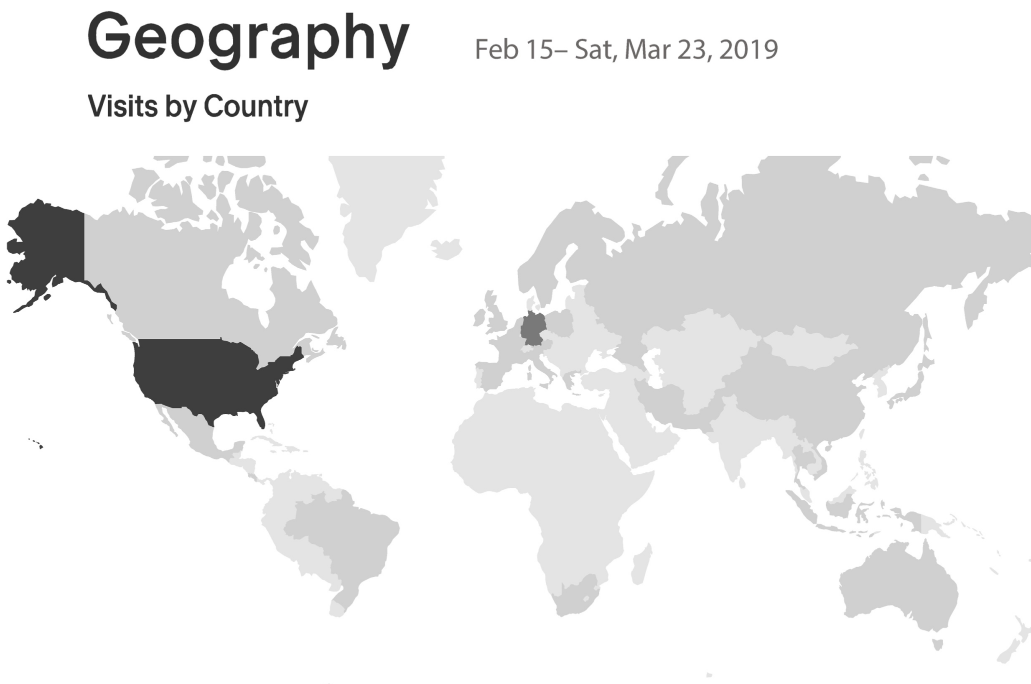
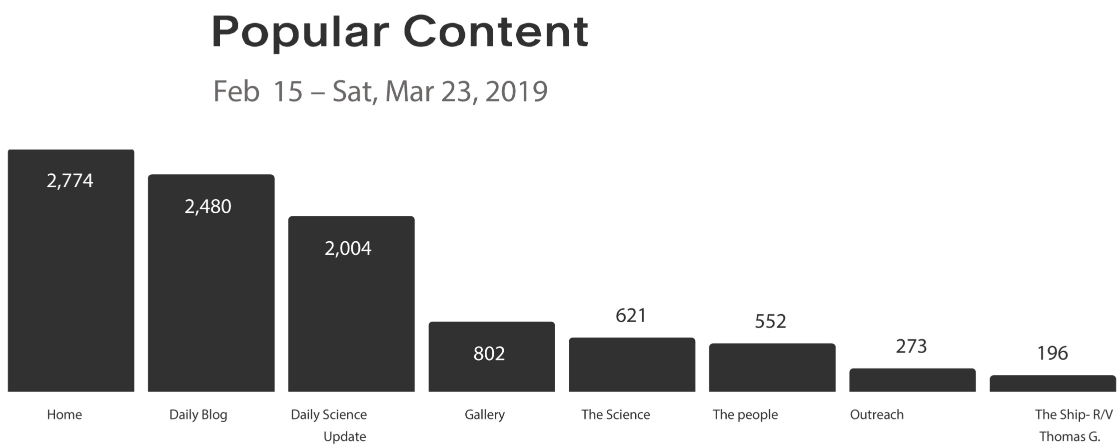


Figure XXa. Analytics for daily visits to the marionrise.org web site



Location	Visits	Location	Visits	Location	Visits
United States	1615	Belgium	18	Vietnam	2
Germany	548	Canada	11	Austria	2
United Kingdom	187	Sweden	8	Australia	2
Indonesia	102	Norway	6	Greece	1
South Africa	102	Finland	5	Costa Rica	1
Italy	68	Iran	4	Aruba	1
Netherlands	33	Ireland	4	Poland	1
France	32	Thailand	3	Argentina	1
Japan	22	Chile	3	Cape Verde	1
China	20	Singapore	2	Pakistan	1
Brazil	18	Mexico	2	Russia	1

Figure XXb. Geography analytics for the Marionrise.org web site



Page Name	Page Views	Page Name	Page Views	Page Name	Page Views
Home	2774	Sally Swims w/Sentry	107	Contact	66
Daily Blog	2480	Slackjaw Sally Stands '	99	People are arriving	64
Daily Science Update	2004	The Scientists	95	Staying Current	63
Gallery	802	Crushing It!	88	Who Dunit(e)?	63
The Science	621	Culinary Crew	88	Oiler Onboard	60
The People	552	Jackpot-peridotite	85	Our first geology!	59
Sentry	285	Marion Island	83	The Equinox	57
Outreach	273	Buckets of Basalt	77	Another day of survey	55
The Ship	196	Under Pressure	72	I want to break free!	52
Slackjaw Sally Arrives	161	Another Day in Paradis	70	Interview Dr. Dick	51
Boat Building Begins!	130	Scratch that idea	67	We're collecting data!	51
Sentry Makes a Splash	120	The word of the day	67	Dredging the oblique	48
Exciting Times	111	Another Day, another c	66	Sacred Heart Star of t	47

Figure XXc. Most popular content analytics for the Marionrise.org web site

Social media outreach

A social media presence was maintained on *Twitter*, highlighting activities associated with the cruise and published 28 tweets up to March 23rd. This presence was run by Sarah Newnes. It was retweeted by the British Geological Survey, the National Science Foundation (Geo.) and Woods Hole Oceanographic Institution.

Mini-boat/drifter *'Sacred Heart Star of the Sea'*

As part of the educational outreach program, alumni of Sacred Heart School provided a mini-boat/drifter kit from 'Educational Passages' for students to build, paint, name, and equip with instructions and contact information for if/when the boat comes ashore. Students at the school wrote letters to potential finders and included them in sealed bags in the hold. The hold also contained a rock sample with written explanation of the cruise mission and a postcard from the captain.

Goals of this outreach included –
1) Provide an engineering enrichment activity
2) Develop a team-building experience constructing the boat
3) Allow students the opportunity to learn more about ocean currents and winds in general, and more specifically, collect new data from the Southern Indian Ocean for NOAA, and the marine community

The boat was completed in January 2019 and shipped from Woods Hole to be loaded on the *R/V Thomas G. Thompson.* The *'Sacred Heart Star of the Sea'* was launched at the end of operations at Marion Rise on March 22, 2019 (to avoid possible collision during nighttime operations) (Fig, XY). Stay tuned to see where she travels!

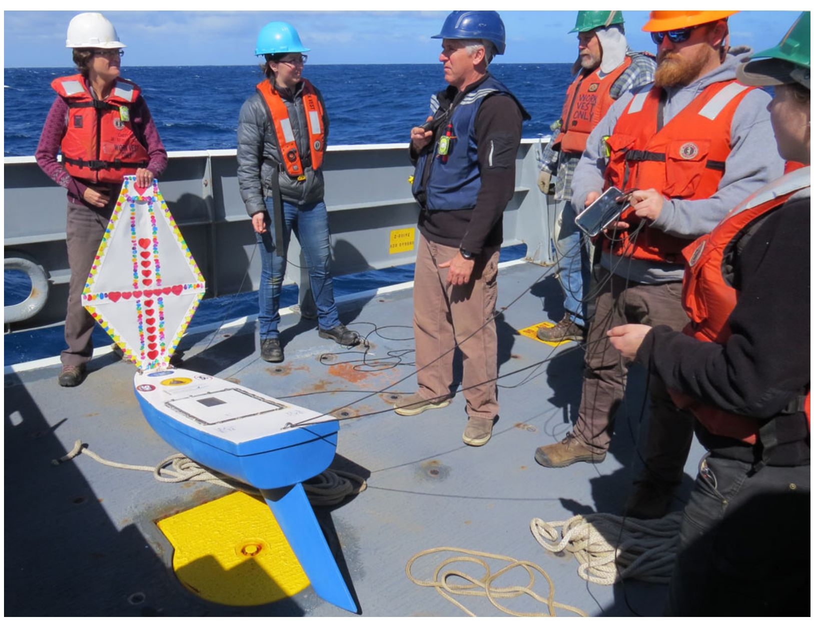


Figure XY mini-boat on deck about to be launched.

See for updated mini-boat locations

1. http://educationalpassages.org/boats/starofthesea/

Theresa Williams
Mike Cheadle

Appendix A – TN365 webcast review comments

Nathalia, Cardiff University U.K.:
"Thanks a lot for the broadcasting today. There were 23 students/staff in class and I have asked them for any comments or feedback, and they said the talk was very interesting and insightful. The video transmission was working fine with good resolution.

It was, however, sometimes difficult to hear what Sarah was saying, maybe because she was far from the microphone. This is something that also happened from our side, when the students (and I) were asking Mike questions. So, I think that is the only thing we can improve for the next broadcastings.

On the personal side, I would like to thank Mike for explaining how the whole process of getting on board works."

Anne, New York:
"Wow!!!! The kids were energized by their contact with you. I will send more specific feedback tomorrow when I get a bit more time to have them reflect on the experience."

Jessica, rural Wyoming:
"We very much enjoyed the chat! We liked seeing the ship and being able to ask questions. Having the slides during the chat and using them along with your explanations was very nice- we liked that!

One thing that could be improved was that it was hard to hear the person who was in front of the camera during the tour, but when the other spoke (behind the camera) it was much easier to hear.

Could you send us the link to the other website you referenced that was made for a previous research expedition you had been on? We would like to follow both the Marion Rise website and look at the other site you also spoke briefly about."

Teresa, Laramie WY (2 broadcasts):

“The first broadcast for the Mars is Ours, Transporter XLS, was to 20 students and 3 adults. It went well and the students mentioned touring the ship in their final presentation.

The second broadcast was to 8th graders. There were 13 students and 3 adults. The sub was really impressed with the presentation. The students were engaged.”

Dogan, Laramie WY:
“We heard you very well. A few people you interviewed were hard to hear. The microphone should be closer to them. Our students were engaged. Except for the occasional wandering of attention that some had. The map and showing us what you found was exciting to the students. It would have been enlightening to see scientists examine the rocks and teach the students how to identify what they are or where they came from.”

Karen, Wyoming (3 broadcasts, 88 students, 9 adults):
“Feedback from students: They felt it was very easy to understand and kid friendly, they loved the tour and the one group really liked seeing the Indian Ocean. They liked being able to meet scientists from around the world. The slideshow helped them better understand the content.

Comments for future broadcasts from the students: Can you take pictures of the captain's cabin? Talk longer to the scientists, try to do all broadcasts during the daylight hours so they can see outside (I explained the time difference, but maybe next time I could request my students to an assembly so it would be all 88 kids at once, or a science wide assembly). They wanted to know more about the rock samples, see the crane in action, and more of the technology on the ship.”

Wendy, Powell, WY:
“That was awesome! Some of my students are going into the service and really thought it was cool! Thanks for taking the time to stream into my class. I could see and hear you great.”

Rachel, Las Angeles, CA:
“Because our kids are so young, their attention spans are short so they did get wiggly during the tour since it was so comprehensive and did have some high-level vocab. We did a whole unit on maps and globes so they were so excited to see a huge paper map - something they don't see often with the prevalence of digital maps!

One thing that was helpful was to mute our microphone and have teachers restate what you were saying in kid-friendly ways - so as you showed the cabins, having teachers go "raise your hand if you have a bunk bed" or when you showed the brownies (they were very impressed) saying "do we have brownies for dinner? - nooooo".

They loved to ask questions but, as I expected, most of their questions were animal-related since that's what they know about the ocean. It was super cool to see some rock samples since I don't know if their little minds yet know that the whole world, even under the ocean, is made from rock. It was also very cool to meet researchers from all over the world to show that all kinds of people work together.

I do wish someone had asked how to become a scientist! Our school is pretty focused on going to college and that would have been an awesome learning point to show that if you work hard and do go to college, you can have cool jobs like yours!

They had a blast and haven't stopped talking about it all day. Again, thank you so much for this opportunity!"

Elizabeth, South Dakota:
"There were 10 students and 1 adult. They enjoyed it just thought if the internet connection had been better, they would have gotten more out of it. We don't have great internet out here. I think we would have heard more details about the ship and research too, is what they had mentioned."

Mona, Hannover Germany:
"We were 18.5 people in the room (0.5 because Insa is pregnant). All Earth science students. The broadcast was great. Some would have liked to focus more on living on the ship and others were very excited about the insight into the work and first results. So, I'd say it was pretty good the way it was."

Anne, New York:
"The students loved the exchange with the two of you on Wednesday. They maintained focus throughout most of the exchange while sitting in a tight space with friends - that says something in itself. However, they were fascinated by life on the ship, something most of them have never contemplated. In addition, they enjoyed having their eyes opened to exploration of the ocean floor and the projects the scientists are pursuing.

They jotted notes on post-its to a few questions I posed based on your queries. I only asked one class of 24 students to respond and several jotted down similar answers. I only included each answer once (basically).

What did you most enjoy learning?
1. how the rocks were collected
2. about the cool technology they use to help them study the ocean floor and analyze rocks onboard the ship

3. foam heads shrink when they go to the bottom of the ocean due to water pressure
4. wifi does not work so well across the world
5. how rocks are studied and how many people it takes to study them
6. the ship has sound wave sensors at the bottom of it
7. the food on the ship is awesome
8. how magnets can be used to see how old rocks are
9. studying rocks can tell how old rocks are
10. an unmanned submersible is used to map the ocean floor
11. learned about the boat and what you do
12. there are different ways to measure the ocean floor
13. you communicate with kids around the world

What went well?

1. we were well-behaved and didn't talk much - HA!
2. you have everything organized so that you know where everything will go. Also, if something were to go wrong you would know.
3. everything was explained clearly, not like most scientist explanations. They made sure the kids understood.
4. liked seeing the instruments used to collect and study rocks
5. cool slides
6. I liked that you spent so much time answering our questions - no matter what they were. You made us feel that all of our questions were good ones.
7. we were able to hear the scientists through the microphone
8. showing us all of the rooms - they're so neat
9. we were able to be taught by people half way across the world
10. we were able to ask questions and we got answers
11. they answered OUR questions
12. explaining everything
13. how you went around the boat showing us different areas. That helped me know how you run things on the boat.
14. the camera worked well

*There were many responses about the appreciation they had for you answering their questions in an understandable fashion.

How can the interaction be improved?

1. the tools were shown too quickly. I wanted to spend more time seeing them.
2. a demonstration of what they do and what they told us about would have been helpful
3. explain more rather than moving so quickly through the boat

4. they could have had rocks so they could have shown us what and how they analyze the rocks on the boat
5. it would have been helpful if it wasn't nighttime so we could see the ocean
6. the pictures you showed were great. More pictures would have been helpful.
7. It might have been better if you had a plan of what you were going to do and present beforehand.
8. could have been more focused on your work and not the boat
9. more pictures - we would remember them longer
10. find a better way of taking someone back if they are seasick
11. prepared things for us to do
12. sometimes their talking was difficult to understand
13. more pictures
14. improve the connection of the video
15. the wifi was glitchy
16. not have the camera so wobbly"

TN365 Daily Cruise Narratives

February 21st to March 28th, 2019 (Julian Day 53-87)

Julian Day 52 | February 21st, 2019

Daily Summary:

TN365 set sail from Durban, South Africa on February 21st, 2019 at 11h21 UTC, with the pilot off at 11h42. The ship cruised at 12 knots south towards waypoint 1. Watchstander shifts began upon departure, taking event logs every 20 minutes. No geophysical systems recorded data. Seas were rough and skies were cloudy.

Evening Science Meeting Summary:

No evening science meeting.

Julian Day 53 | February 22nd, 2019

Daily Summary:

TN365 proceeded towards waypoint 1 at 12 knots. The multibeam system was activated at 16h04 UTC and started recording data at 16h19. The magnetometer was deployed at 16:30. The southeast turn at waypoint 1 occurred at 20h54. Watchstanders were trained in the multibeam data processing workflow and began data processing operations.

Evening Science Meeting Summary:

Henry Dick lectured on "Remelting Gondwanan Mantle: A History of the Southwest Indian Ridge".

Julian Day 54 | February 23rd, 2019

Daily Summary:

TN365 reached waypoint 2 at 3h50 UTC. At 12h51 the ship turned back towards Durban for a possible medical evacuation, before changing heading to sail for Port Elizabeth at 14:52. The magnetometer logging computer crashed at 17h31, and resumed collecting data at 17h39. At 21h13, the magnetometer lost communications and was restarted. Ship speed was ~12 knots throughout the day. Seas were smooth and skies were partly cloudy.

Evening Science Meeting Summary:

The Sentry Team gave a talk about the capabilities and technical specifications of the Autonomous Underwater Vehicle Sentry. They covered the internal structure of the vehicle, including the position of the side-scan sonar, magnetometers, and positioning system, and the deployment and recovery operations.

Julian Day 55 | February 24th, 2019

Daily Summary:

TN365 headed towards Port Elizabeth for a medical evacuation. The EEZ was reached at 08h40 UTC where the multibeam was switched off and the magnetometer was recovered. Ship speed throughout the day was approximately 12 knots and COG was 302°. Seas were smooth and the weather was partly sunny.

Evening Science Meeting Summary:

Maurice Tivey gave a talk on the geophysics operations of the cruise and the specifications of the instruments onboard. Topics covered included multibeam, magnetics and gravity.

Julian Day 56 | February 25th, 2019

Daily Summary:

TN365 headed to Port Elizabeth. The speed of TN365 was fluctuated for gear test at 03h00 UTC. Personal was transferred to a rescue boat to head to shore at 05h11, after then the ship turned around towards SA-4 (36°22.18´S, 30°02.94´E) at 05h22. Seas were smooth and the weather was sunny.

Evening Science Meeting Summary:

Vincent Salters gave a talk on isotopic constrains on the source of the Rahat volcanic field.

Julian Day 57 | February 26th, 2019

Daily Summary:

TN365 continued to head towards the survey area by way of waypoints SA-4 and SA-3. Geophysical data acquisition logging resumed upon leaving the EEZ, with the multibeam at 01h13 UTC and the magnetometer at 01h18. SA-4 (36°22.18´S, 30°02.94´E) was reached at 03h00. At 04h41, the magnetometer logging computer crashed, with logging resuming at 04h48.

At 07h00, the ship speed was slowed from 12 knots to 8 knots by decision of the captain to delay our arrival to the survey to hopefully avoid poor weather conditions anticipated in that area on Thursday. Weather was variable throughout the day between cloudy and rainstorms with some lightning, but seas were relatively calm given the weather.

Evening Science Meeting Summary:

Fuwu Ji gave a talk on the geochemistry of hydrothermal fluids from Longqi Field at the Southwest Indian Ridge.

Julian Day 58 | February 27th, 2019

Daily Summary:

TN365 began the day heading towards the southwest survey area. The magnetometer logging computer lost connection with the towfish, occurring at 03h03 UTC, 06h32, and 17h44, which was fixed by checking the cable connection on the back deck. The magnetometer logging computer crashed multiple times and was restarted, occurring at 06h02, 06h47, 17h27, and 23h51. A brief period where the multibeam system missed returns in the center of the swath occurred at 10h00.

In the mid-morning, the decision was made to alter the cruise survey plan. The southwest survey area was changed to a survey directly west of the northeast survey area, which was originally to be completed by the German survey on the R/V Sonne next year. Approximately north south track lines were plotted across this area, directly merging into the former northeast survey track plan. The ships course was changed to this newly created survey region at 06h29, and the ships speed was increased to 12 knots. During the afternoon and evening, the ships speed fluctuated up to 15 knots due to favorable wind and swell directions. Weather varied between sunny and rainy during the day, and the seas were relatively calm.

Evening Science Meeting Summary:

Henry Dick talked about the dredging and rock description workflow.

Julian Day 59 | February 28th, 2019

Daily Summary:

TN365 began the day continuing on towards the survey area. In anticipation of starting the survey, an xbt was launched at 17h01 UTC to collect a sound speed profile for the multibeam system and the subbottom profiler was turned on at 17h13.

The start of the survey (40° 33.66’ S, 42° 51.9’ E) was reached at 17h20, turning due south to survey the first line. Line 1 was completed at 22h57 (41° 31.3866’ S, 42° 45.6399’ E), and line 2 began at 23h12 (41° 31.7431’ S, 42° 48.9184). The ship speed was 11 to 13 knots throughout the day.

The magnetometer logging computer crashed multiple times and was restarted, occurring at 05h43, 12h33, 20h22, and 23h09. The magnetometer logging computer briefly lost connection with the towfish at 14h33 and 17h27.

Weather was stormy with high seas. Winds briefly peaked at over 100 knots as the ship passed through the storm.

Evening Science Meeting Summary:

Jurgen's talk was postponed to the following day. The meeting was short with general announcements and a follow-up on how pleased the South African government was with the geophysical data collected during transit.

Julian Day 60 | March 1st, 2019

Daily Summary:

TN365 continued with the geophysical mapping survey. Line 2 ended at 04h00 UTC (40°38.3080'S, 42° 55.6379'E) and line 3 started at 04h15 (40°38.5589'S, 42° 58.6508'E). Line 3 ended at 09h18 (41° 31.4010' S, 42 52.7438' E). At 10h17, the ship broke from the survey track to circle back and prepare for dredging operations. The ship was slowed to 4 knots and the magnetometer was recovered at 10h39 while the ship made a counterclockwise loop to fill in gaps in the multibeam coverage. At 12h20, the slowed to a stop and held station, and the multibeam pinging was stopped. The marine techs were working on fixing the winch room camera, so a second counterclockwise loop was done to further fill multibeam gaps, starting at 12h56 and ending at 14h17.

The first dredge of the cruise occurred in the late afternoon at. Dredge 1 went into the water at 15h48, was on the bottom (~1400 m) at 16h30, came off the bottom at 18h54, and was on deck at 19h28. The dredge recovered <1 kg gabbro. Following dredging, the geophysical mapping survey resumed, with multibeam logging at 20h25 and magnetometer logging at 20h30.

The magnetometer logging computer crashed multiple times and was restarted, occurring at 09h19, and the magnetometer logging computer briefly lost connection with the towfish at 00h04.

Weather was sunny with high winds that weakened through the day. The seas had some significant long-wavelength swells.

Evening Science Meeting Summary:

Juergen Koepke gave a talk about the formation and cooling of the lower crust in the Oman Ophiolite.

Julian Day 61 | March 2nd, 2019

Daily Summary:

TN365 continued with the geophysical mapping survey. Line 4 ended at 00h40 UTC (40° 38.3992’ S, 43° 02.5487’ E) and line 5 started at 00h52 (40° 38.1858’ S, 43° 05.4582’ E). Line 5 ended at 05h44 (41° 31.2725’ S, 42° 59.9296’ E) and line 6 started at 05h59 (40° 38.1858’ S, 43° 05.4582’ E). The multibeam acquisition system crashed at 06h19 and was restored at 06h22.

At 08h34, the ship turned west off of line 6 (41° 02.0030’ S, 43° 07.0256’E) to reposition to a site for AUV Sentry deployment, with the magnetometer turned off and recovered immediately out after completing the turn. At 09h24, the ship held station to await Sentry deployment, and the multibeam and subbottom profilers were turned off at 09h27. At 10h20 an XBT was completed to acquire a sounds speed profile for the Sentry Team. AUV Sentry was deployed at 10h54.

The ship repositioned to at 12h40 to prepare for dredge operations. Dredge 2 was put in the water at 13h16 and was on bottom at 14h30, upon which dredging proceeded from south to north. The dredge was brought off the bottom at 15h42 and was on deck at 16h37. This dredge was empty.

Sentry was recovered at 17h52, with the USBL pole retracted at 18h10 and the multibeam turned on at 18h12. Dredge 3 began deployed at 19h23, was on bottom at 20h23, was brought off bottom at 22h41, and was on deck at 23h29. Three diabase samples were recovered. Following dredging, the ship sailed east to resume geophysical mapping on line 6.

Weather was sunny with light wind and calm seas.

Evening Science Meeting Summary:

At the science meeting, Henry reminded everyone on the importance of life vest and hard hats when scientists operate on the aft-deck. He also gave a brief introduction on the detachment faults, and showed the dredge plan for later in the night.

Julian Day 62 | March 3rd, 2019

Daily Summary:

At the start of the day, TN365 proceeded to resume line 6. At 00h15 UTC, the magnetometer was deployed, and the multibeam began logging at 00h17. At 00h59, the ship turned back onto line 6. Line 6 was completed at 03h52 (40° 38.0942’ S, 43° 09.78756’ E) and line 7 was started at 03h21 (40° 38.0018’ S, 43° 13.1852’ E). Line 7 ended at 09h07 (41° 31.3966’ S, 43° 07.3651’ E) and line 8 was started at 09h23 (41° 31.1815’ S, 43° 01.0114’ E). At 09h48, the multibeam logging system crashed, and resumed logging at 09h53. Line 8 was completed at 14h20 (41° 37.7674’ S, 43° 19.1013’ E) and line 9 began at 14h26 (40° 37.9352’ S, 43° 21.0876’ E). The magnetometer was recovered at 15h19 for a possible dredge operation, and was re-deployed at 16h30 when the dredge was called off. Line 9 was finished at 19h21 (41° 22.8386’ S, 43° 15.9649’ E) and line 10 started at 19h28 (41° 23.0707’ S, 43° 19.6857’ E). At 23h42, the ship turned off line 10 to head west towards dredge site D4

Weather was sunny with high winds and rough seas.

Evening Science Meeting Summary:

At the science meeting, Henry overviewed the plan to begin dredging at 4am the next morning and continue throughout the day as weather allows, and Huaiyang Zhou gave a talk about his past ROV cruise to the South China Sea.

Julian Day 63 | March 4th, 2019

Daily Summary:

At 00h30 UTC, the magnetometer was recovered in preparation for dredging. At 01h00, dredge site D4 was reached, and at 01h33, the multibeam logging was stopped. At 02h21, Dredge 4 was in the water, and was back on deck at 09h10. Dredge 4 recovered talc-serpentine schist, diabase, and gabbro. At 10h03, dredge site D5 was reached. Dredge 5 was put in the water at 10h25 and back on deck at 14h43. Dredge 5 recovered pillow basalt. Multibeam logging was resumed from 15h01 to 15h33 while the ship repositioned to dredge site D6. Dredge 6 was put in the water at and back on deck at 20h49. Dredge 6 recovered basalt. At 21h33 UTC, multibeam logging resumed and the magnetometer was deployed. Magnetometer data logging began at 21h41. At 22h00, the multibeam system crashed and was restarted. At 22h46, the ship turned to repeat running line 7 due to poor data quality on the first pass.

There was a light wind and medium swells.

Evening Science Meeting Summary:

At the science meeting, Mike Cheadle gave a talk on the tectonics of ocean core complex formation and overviewed the tectonics shown in the data collected thus far.

Julian Day 64 | March 5th, 2019

Daily Summary:

TN365 began the day re-running line 7 to replace the poor data collected on the first pass. Line 7 was completed at 02h40 UTC (41° 31.1612’ S, 43° 07.3345’ E) and the ship turned northeast towards the start of line 11. Line 11 began at 04h01 (41° 23.2579’ S, 43° 24.2901’ E), heading northward. The magnetometer logging computer lost connection with the towfish at 05h19, and regained connection at 05h20.

Line 11 was completed at 08h15 (40° 37.9756’ S, 43° 28.4615’ E). The magnetometer had a power overload error at 09h17, and the ship speed was slowed to 6 knots at 09h30 UTC to check the deck cable. Line 12 was started at 09h33 (40° 48.7115’ S, 43° 31.0788’ E). The magnetometer error was attributed to a break in the deck cable, and the Sentry engineers worked to fix the cable. The magnetometer came back online at 11h22, and the ship sped back up to full speed at 11h30.

Line 12 was completed at 13h51 (41° 23.0976’ S, 43° 27.2253’ E) and line 13 started at 14h05 (41° 23.3340’ S, 43° 30.4230’ E). Line 13 was completed at 17h37 and line 14 started at

17h52. Line 14 was completed at 20h54 (41° 22.9515' S, 43° 34.1246' E) and line 15 started at 14h05 (41° 23.2002' S, 43° 37.7544' E).

Weather was windy with rough seas early, which changed to sunny with calm seas later in the day.

Evening Science Meeting Summary:

At the science meeting, the recently processed magnetic anomaly data was shown and dredge targets for the next day were discussed.

Julian Day 65 | March 6th, 2019

Daily Summary:

TN365 began the day on line 15. Line 15 was completed at 00h20 UTC (40° 48.6533' S, 43° 41.7054' E) and line 16 started at 00h34 (40° 48.5687' S, 43° 45.0836' E).

At 00h48, the ship turned off line 16 (40° 50.9275' S, 43° 44.8989' E) to head to the Sentry launch site. The ship was slowed at 01h58 and the magnetometer was recovered at 02h13. The Sentry launch site was reached at 02h42. The multibeam and subbottom profiler were turned off for Sentry operations at, and the USBL pole was lowered at 02h51. Sentry was launched at 03h35 (40° 59.6306' S, 43° 27.8571' E). The ship began repositioning to deploy the wave glider at 05h56, and was in position (41° 01.1450' S, 43° 27.8088' E) at 06h23, with the wave glider in the water at 06h36.

The ship began moving towards dredge site 7 at 06h50, with multibeam logging from 06h55 to 07h06, when the dredge site was reached (41° 01.5018' S, 43° 26.1576' E). Dredge 7 was in the water at 07h25 (41° 01.4877' S, 43° 26.1640' E) and was back on deck at 13h52 (41° 00.8027' S, 43° 26.1654' E). Dredge 7 contained hydrothermally altered basalt, brecciated basalt, and dolerite.

The ship began moving towards dredge site 8 with multibeam logging at 14h19, and the site was reached at 14h38 (41° 00.8131' S, 43° 24.2419' E). Dredge 8 was in the water at 16h06 (40° 59.9976' S, 43° 13.0217' E) and was back on deck at 21h44 (40° 59.4539' S, 43° 31.0197' E). Dredge 8 had no rocks.

The ship left the dredge site at 22h05 to reposition to 40° 59.2572' S, 43° 28.3960' E to communicate with Sentry and prepare for retrieval the following morning.

The weather was sunny and the seas were calm. As Maurice proclaimed, "it is officially nice outside".

Evening Science Meeting Summary:

At the science meeting, the description groups discussed the rocks acquired in the dredge.

Julian Day 66 | March 7th, 2019

Daily Summary:

TN365 began the day with recovering Sentry at 03h35 UTC (40° 59.4413’ S, 43° 27.7893’ E). The USBL pole was pulled up shortly after, at 04h40, and the ship proceeded to dredge site 9 with the multibeam on at 04h15. Dredge site 9 was reached at 05h15 (41° 07.2953’ S, 43° 23.0201’ E) and the multibeam logging was stopped. Dredge 9 was in the water at 05h48 (41° 07.2967’ S, 43° 23.0191’ S). At 08h56, the trawler popped the sheave, causing a stoppage in dredging until the problem was fixed at 09h26 UTC. Dredge 9 was on deck at 11h40 (41° 07.7841’ S, 43° 23/0216’ E) and contained mostly peridotite and one piece of basalt. At 11h40, the multibeam logging resumed and the ship began transit to dredge site 10.

Dredge site 10 was reached and multibeam logging was stopped at 13h26, with dredge 10 in the water at 13h36 (40° 58.7220’ S, 43 41.0394’ E). At 14h39 the winch level winding got stuck, and was fixed at 15h28. Dredge 10 was back on deck at 21h06 (40° 58.2150’ S, 43° 41.1597’ E). Dredge 10 contained basalt and glass. At 21h57, the multibeam logging resumed and the ship began transit to dredge site 11.

Dredge site 11 was reached and multibeam logging was stopped at 22h55 (41° 04.6340’ S, 43° 37.9681’ E); however, due to a prevailing current from the north, the site was adjusted to facilitate a more favorable dredging orientation. The new site was reached at 23h26 (41° 05.6416’ S, 43° 38.3123’ E). Dredge 11 was in the water at 23h29 (41° 05.6413’ S, 43° 38.3125’ E). Dredging continued into the following morning.

The weather was partly cloudy and the seas were calm.

Evening Science Meeting Summary:

At the science meeting, Gabby gave a presentation on the gravity data collected thus far. The sample sheets were also discussed in detail for the members of the science party that are interested in taking samples. There was also another Watchstander meeting following the Science Meeting to go over the dredge log sheets again.

Julian Day 67 | March 8th, 2019

Daily Summary:

TN365 began the day with dredge 11 in progress. Dredge 11 was back on deck at 04h21 UTC (41° 05.3755’ S, 43° 37.9838’ E). Dredge 11 contained chips of peridotite. Following dredge 11, the ship proceeded towards line 16 to continue geophysical mapping. The multibeam and subbottom profiler were turned on at 04h31, and the magnetometer began logging at 05h01. The ship started line 16 at 06h14 (40 50.9060’ S, 43 45.1340’ E). Line 16 was completed at 08h46 (41° 20.5724’ S, 43° 41.6188’ E) and Line 17 began at 09h02 (41° 20.9126’ S, 43° 45.2081’ E). Line 17 was completed at 16h03 (40° 03.3063’ S, 43° 54.1380’ E) and Line 18 began at 16h17 (40° 03.4544’ S, 43° 57.5607’ E). The magnetometer software crashed at 20h11, and was back online at 20h13. At 20h32, the ship reduced speed to 8-9 knots due to rough seas.

The weather was partly cloudy and the seas were calm during the day, with the weather and sea state deteriorating into the night.

Evening Science Meeting Summary:

At the science meeting, the structural, igneous, and metamorphic aspects of the latest dredges were discussed.

Julian Day 68 | March 9th, 2019

Daily Summary:

TN365 began the day with geophysical mapping of Line 18. The magnetometer software could not find the towfish from 04h46 to 04h48 UTC. Line 18 was completed at 06h06 (42° 09.6049’ S, 43° 42.7370’ E) and Line 19 began at 06h24 (42° 09.7191’ S, 43° 46.3829’ E). Line 19 was completed at 14h04 (40° 38.6217’ S, 43° 56.7442’ E) and Line 20 began at 14h19 (40° 38.8406’ S, 44° 00.3341’ E). Line 20 was completed at 17h32 (41° 13.8196’ S, 43° 56.8396’ E) and Line 21 began at 17h47 (41° 13.9343’ S, 43° 59.7858’ E). Line 21 was completed at 20h49 (40° 39.1404’ S, 44° 03.9029’ E) and Line 22 began at 21h05 (40° 39.4169’ S, 44° 07.5061’ E). Line 22 was completed at 23h57 (41° 11.2725’ S, 44° 03.7843’ E). The day ended during the turn towards Line 23.

The weather was overcast and the seas were rough, with conditions improving as the day went on.

Evening Science Meeting Summary:

At the science meeting, Shi Cheng gave a talk on plagioclase ultra-ferric basalts from the Southwest Indian Ridge.

Julian Day 69 | March 10th, 2019

Daily Summary:

TN365 began the day turning onto Line 23 at 00h13 UTC (41° 11.4436’ S, 44° 07.5317’ E). Line 23 was completed at 03h29 (40° 34.1608’ S, 44° 11.5266’ E) and Line 24 began at 03h47 (40° 34.9081’ S, 44° 15.1630’ E). The ship turned west off of line 24 at 06h02 (41° 00.0467’ S, 44° 11.7662’ E) to head to the Sentry deployment site. The magnetometer was recovered at 06h33. The Sentry deployment site was reached at 07h17, and the multibeam and subbottom profiler were turned off at 07h20. Sentry was deployed at 08h05 (41° 04.8177’ S, 43° 58.9989’ E). The ship began transiting to Dredge Site 12 at 09h50.

Dredge 12 was in the water at 12h04 (41° 00.9038’ S, 43° 58.4370’ E). Dredge 12 was back on deck at 17h20 (41° 00.5223’ S, 43° 58.3750’ E). Dredge 12 was empty. At 17h25, the ship began transit to Dredge Site 13. The ship slowed at 18h02 since Sentry got off track, with Sentry back on track and the transiting resuming at 18h34. Dredge 13 was in the water at 19h59 (41° 10.8330’ S, 43° 55.6748’ E), with dredge activity continuing into the next morning.

The weather was sunny seas were very calm.

Evening Science Meeting Summary:

At the science meeting, Dominik Mock gave a talk on layered gabbro in the Oman Ophiolite.

Julian Day 70 | March 11th, 2019

Daily Summary:

TN365 began the day midway through Dredge 13. Dredge 13 was back on deck at 00h52 UTC, and contained mylonetic peridotite. The ship began moving to Dredge site 14 at 01h01, arriving at 01h51.

Dredge 14 was in the water at 02h01. A brief technical issue caused the winch to stop at 03h33. Dredge 14 was back on deck at 06h39, and contained peridotite. The ship then began transiting to the Sentry recovery site at 06h40, arriving at 07h15.

Sentry was on deck at 08h21 (41° 04.8235' S, 43° 59.3873' E). At 08h48, the multibeam system was turned on as the ship moved towards Dredge Site 15, arriving at 10h00.

Dredge 15 was in the water at 10h16. While pulling up the wire, it was found to be heavily twisted (14h28, with 112 m still out), which delayed recovery. Dredge 15 was back on deck at 17h28 (40° 54.1281' S, 43° 55.1756' E) and contained serpentinized peridotite and basalt.

At 17h50, the ship began moving towards line 24 to resume the survey. The multibeam system was turned on at 18h05, and the magnetometer began logging at 18h08. Line 24 was resumed at 19h08 (40° 57.6223' S, 44° 12.5121' E). Line 24 was completed at 20h06 (41° 09.0468' S, 44° 11.1333' E), and Line 25 began at 20h22 (41° 09.1552' S, 44° 14.6802' E).

Line 25 was completed at 23h40 (40° 32.1616' S, 44° 18.9244' E), and Line 26 began at 23h56 (40° 32.3684' S, 44° 22.5940' E).

The weather was sunny and seas were calm.

Evening Science Meeting Summary:

At the science meeting, Dominik Woelki gave a talk on the tectonic setting and formation of the Troodos Ophiolite, and Henry Dick went over the Sentry dive bathymetry.

Julian Day 71 | March 12th, 2019

Daily Summary:

TN365 began the day on Line 26. Line 26 was completed at 03h15 (41° 09.5882' S, 44° 18.1670' E), and Line 27 began at 03h30 UTC (41° 09.7963' S, 44° 21.7605' E). Line 27 ended at 07h28 (40° 24.4587' S, 44° 26.9951' E), and Line 28 began at 07h43 (40° 24.7404' S, 44° 30.5918' E). The multibeam software crashed at 10h39 and was restarted at 10h44. Line 28 ended at 12h01 (41° 09.7937' S, 44° 25.2777' E), and Line 29 began at 12h16 (41° 10.1340' S, 44° 28.7040' E).

At 15h34 (40° 30.9532' S, 44° 33.3870' E), the ship turned off Line 29 to head west to Dredge Site 16. The magnetometer was recovered at 15h38.

Dredge 16 was in the water at 16h20 (40° 29.6183’ S, 44° 30.3930’ E). Dredge 17 was back on deck at 19h46 (40° 19.8783’ S, 44° 30.0527’ E), and contained peridotite, carbonate, and coral. At 20h31, the magnetometer was deployed as the ship moved to continue Line 29.

Line 29 was resumed at 21h01 (40° 31.1647’ S, 44° 33.3870’ E). Line 29 was completed at 22h22 (40° 15.8536’ S, 44° 35.0714’ E), and Line 30 began at 22h38 (40° 16.1680’ S, 44° 38.5602’ E).

The weather was partly cloudy and seas were calm.

Evening Science Meeting Summary:

At the science meeting, the dredge contents were discussed.

Julian Day 72 | March 13th, 2019

Daily Summary:

TN365 began the day on Line 30. Line 30 was completed at 03h24 UTC (41° 07.9803’ S, 44° 32.5980’ E), and Line 31 began at 03h38 (41° 07.9280’ S, 44° 36.1390’ E). At 05h57 (40° 41.6106’ S, 44° 38.5472’ E), the ship turned west off of line 31 towards Dredge Site 17 and the magnetometer was recovered. The multibeam system logging was turned off at 06h31. After multiple adjustments to the dredge site, the ship was on station at 07h07.

Dredge 17 was in the water at 07h24 (40° 41.4888’ S, 44° 33.4170’ E). Dredge 17 was back on deck at 12h15 (40° 41.2578’ S, 44° 33.7180’ E), and contained peridotite. The ship was underway to resume Line 31 and the multibeam logging was turned on at 12h26, and the magnetometer was deployed and started logging at 12h44.

The ship resumed Line 31 at 12h54 (40° 42.4063’ S, 44° 38.9753’ E). Line 31 ended at 15h43 (40° 10.7200’ S, 44° 42.7900’ E), and Line 32 began at 15h58 (40° 11.1457’ S, 44° 46.1178’ E). The gravimeter logging crashed at 16h00 and was resumed at 16h07. At 17h00, the ship broke from line 32 (40° 23.2690’ S, 44° 44.9706’ E) to head for Dredge Site 18, with the magnetometer recovered at 17h18 UTC.

Dredge 18 was in the water at 17h58 (40° 22.7454’ S, 44° 40.5279’ E). Dredge 18 was back on deck at 22h26 (40° 22.2834’ S, 44° 40.5325’ E), and contained peridotite and a piece of metagabbro. The ship was underway to resume Line 32 and the multibeam logging was turned on at 22h24, and the magnetometer was deployed and started logging at 23h10. The ship turned back onto Line 32 at 23h21 (40° 22.5301’ S, 44° 44.1943’ E)

The weather was cloudy and seas were relatively calm.

Evening Science Meeting Summary:

At the science meeting, Daniele Brunelli talked about the Romanche Fracture Zone and his upcoming cruise there, and Henry Dick discussed the following days dredge and Sentry plan.

Julian Day 73 | March 14th, 2019

Daily Summary:

TN365 began the day on Line 32. At 01h30 UTC (40° 47.7817' S, 44° 40.7121' E), the ship turned off line 32 towards the Sentry site, with the magnetometer recovered at 01h36 and the multibeam and subbottom profiler turned off at 02h20. Sentry was in the water at 02h59 (40° 47.9500' S, 44° 34.6001' E).

At 06h05, the ship proceeded to Dredge Site 19, arriving at 06h32. Dredge 19 was in the water at 06h46 (40° 47.9797' S, 44° 36.5913' E). Dredge 19 was back on deck at 11h33 (40° 47.7300' S, 44° 36.8197' E), and contained peridotite.

At 11h48, the ship proceeded to Dredge Site 20, arriving at 12h52. Dredge 20 was in the water at 12h58 (40° 51.1975' S, 44° 34.0828' E). Dredge 20 was back on deck at 17h51 (40° 51.6440' S, 44° 34.1256' E), and was empty.

At 17h57, the ship left Dredge Site 20 to recover Sentry. Sentry was back on board at 19h51 (40° 47.2921' S, 44° 34.7511' E). The USBL pole was recovered at 20h17. The ship then was underway to rejoin line 32, with the multibeam system turned on at 20h28, and the magnetometer logging at 20h36.

The ship resumed Line 32 at 20h58 (40° 47.4852' S, 44° 42.0140' E). Line 32 was completed at 22h24 (41° 04.6251' S, 44° 40.0798' E), and Line 33 began at 15h58 (41° 04.7199' S, 44° 43.4970' E). At 23h04, the multibeam logging software crashed, and was back up and running at 23h06.

The weather was overcast and seas were relatively calm.

Evening Science Meeting Summary:

At the science meeting, Sarah Newnes presented a talk about her current work in the industry as a geophysicist. Henry also went over the future dredge plan.

Julian Day 74 | March 15th, 2019

Daily Summary:

TN365 began the day on Line 33. Line 33 was completed at 042h47 UTC (39° 57.9609' S, 44° 51.18918' E), and Line 34 began at 05h03 (39° 58.2654' S, 44° 54.6845' E). Line 34 was completed at 13h27 (41° 39.3279' S, 44° 42.8594' E), and Line 35 began at 13h40 (41° 39.6729' S, 44° 46.1964' E).

At 14h30 (41° 30.1615' S, 44° 47.4698' E), the ship left line 35 to head to Dredge Site 21 and the magnetometer was recovered. The dredge site was reached at 15h20. Dredge 21 was in the water at 15h40 (41° 32.1124' S, 44° 44.8935' E). Dredge 21 was back on deck at 19h013 (41° 32.0576' S, 44° 44.48587' E), and contained peridotite. The ship moved to resume line 35 at 19h20, with the magnetometer deployed at 19h37. The ship resumed Line 35 at 19h40 (41° 31.6910' S, 44° 47.45180' E).

The weather was overcast and seas were relatively calm.

Evening Science Meeting Summary:

At the science meeting, John Greene (with help from Maurice Tivey, and Gabriella Alodia) gave an update of the geophysical data collected so far, including the multibeam bathymetry, acoustic backscatter, processed magnetics, magnetic anomaly and spreading rates picks, and mantle Bouguer gravity anomaly. The survey and dredge plan for the remainder of the cruise was also presented. Mike Cheadle also presented a 3D overview of the recent Sentry bathymetry data.

Julian Day 75 | March 16th, 2019

Daily Summary:

TN365 began the day on Line 35. At 03h45 UTC (40° 00.8703' S, 44° 57.8240' E), the ship turned off line 35 towards Dredge Site 22, with the magnetometer recovered at 03h51, and arrived at Dredge Site 22 at 04h18 with the multibeam and subbottom profiler turned off at 04h21. Dredge 22 was in the water at 04h22 (40° 00.9903' S, 44° 54.4958' E). Dredge 22 was back on deck at 07h46 (40° 01.2584' S, 44° 54.5918' E), and contained peridotites and one piece of carbonated/cemented breccia.

The ship resumed Line 35 at 07h57 (40° 01.2657' S, 44° 54.5916' E). Line 35 was completed at 10h43 (39° 33.0046' S, 45° 00.8442' E), and Line 36 began at 10h56 (39° 33.1297' S, 45° 04.1073' E).

Line 36 was completed at 18h15 (40° 59.1514' S, 44° 54.4956' E), and Line 37 began at 18h29 (40° 59.1446' S, 44° 57.8429' E).

At 20h45 (40° 35.7073' S, 45° 00.4407' E), the ship turned off line 37 towards Dredge Site 23, with the magnetometer recovered and the multibeam and subbottom profiler turned off at 21h10, arriving at Dredge Site 23 at 21h16. Dredge 23 was in the water at 21h21 (40° 38.4064' S, 45° 00.2928' E). Dredge 23 was still on bottom by the end of the day.

The weather was overcast and seas were relatively calm.

Evening Science Meeting Summary:

At the science meeting, Michael Broeker presented a talk about his current work in geochronology and metamorphic rocks, specifically at Greece and Iran. Henry also went over the near-future dredge plan.

Julian Day 76 | March 17th, 2019

Daily Summary:

TN365 began the day with Dredge 23. At 02h05 UTC (40° 37.8946' S, 44° 59.9230' E), Dredge 23 was off bottom and on deck at 02h39 (40° 37.8963' S, 44° 59.9132' E), with the magnetometer deployed at. At, the ship was back to the track line 37. The magnetometer was recovered at 05h59 after the ship turned off line 36 to Dredge Site 24 at 05h44 (40° 14.2228' S, 45° 02.8710' E). The multibeam and subbottom profiler turned off at 06h36.

Dredge Site 24 was reached at 06h30. Dredge 24 was in the water at 06h55 (40° 16.9831' S, 44° 59.4117' E). Unfortunately, the winch wrapped on itself at 08h03 and could not be deployed further, so the dredge had to be recovered. The dredge was back on deck at 09h39 (40° 16.9625' S, 44° 59.4314' E) and the ship moved to a spot to try to deploy and cut the wire. The multibeam system was turned on at 09h44 while in transit. The ship deployed 2474 m of wire at 10h25 (40° 17.8011' S, 44° 53.0171'E) to try and cut the wire near the wrap point. This was unsuccessful as the tension could not be brought off the wire to cut it, and the wire recovery began at 12h50. The wire was recovered at 13h40 UTC. The ship proceeded to resume Line 37, with the magnetometer logging beginning at 14h06, and the multibeam logging at 14h26. The ship turned back on to Line 37 at 14h49 (40° 15.2536' S, 45° 02.9006' E). Line 37 was ended at 17h47 (39°40.0388' S, 45° 06.66' E), where Line 38 was started at 18h00 (39° 42.2568'S 45° 10.0745'E). While underway, the ~2500 m of wire was transferred onto another winch so it could be cut at the wrapped point and reterminated.

The weather was sunny and seas were calm.

Evening Science Meeting Summary:

At the science meeting, Qiang Ma talked about the deformation mechanisms of Fe-Ti oxides and their impact on the rheology of lower oceanic crust. Henry summarized what happened during the day.

Julian Day 77 | March 18th, 2019

Daily Summary:

TN365 began the day on Line 38. At 00h11 UTC (40° 56.1107' S, 45° 01.6873' E) the ship completed Line 38. At 00h34 TC (40° 56.4399' S, 45° 05.2533' E) the ship started Line 39.

At 07h04 (39° 42.0418' S, 45° 13.6407' E) the ship completed line 39, and the ship started Line 40 at 07h20 (39° 42.3266' S, 45° 17.0484' E).

At 11h02 (40° 25.2697' S, 45° 11.6484' E) the ship broke off Line 40 to move towards the Sentry dive location. At 11h11 (40° 25. 2624' S, 45° 09.3537' E) the multibeam logging was turned off. At 11h49 (40° 25.2452' S, 45° 00.4772' E) the magnetometer was recovered. At 12h23 (40° 25.2465' S, 44° 55.6396' E), the ship was on station for the Sentry dive. At 12h51 (40° 25.2270' S, 44° 55.6372' E) Sentry was in the water.

At 14h38 (40° 25.1616' S, 44° 55.6054' E) the ship moved toward Dredge Site 25. At 16h31 (40° 28.9870' S, 44°54.8791' E), Dredge Site 25 was reached. At 16h35 (40° 28.9952' S, 44° 54.8859' E), the dredge was in the water. At 21h56 (40° 28.6622' S, 44° 54.8818' E) the dredge was back on deck, and was empty. The decision was made to dredge in the same location, with Dredge 26 in the water at 22h12. Dredge 26 was on bottom at the end of the day

The weather was sunny and seas were calm.

Evening Science Meeting Summary:

At the science meeting, Ben Urann gave a presentation on tectonics of the 16° N area of the Mid-Atlantic Ridge and the peridotite chemistry. Henry Dick also updated the group on his most recent thinkings of the area.

Julian Day 78 | March 19th, 2019

Daily Summary:

TN365 began the day conducting Dredge 26 (40º28.6656'S, 49.548838'E), which returned to the deck 02h42 UTC. At 02h51 the ship moved to Dredge Site 27 (40º25.9678'S, 44º59.8157'E), where Dredge 27 entered the water at 03h45. Dredge 27 arrived on deck at 09h11, and contained basalt.

At 09h20, the ship began to steam to the Sentry recovery site (40º26.2571'S, 44º56.7495'E), arriving at 09h43. Sentry began to ascend from the seafloor at 11h07, and was on deck at 11h53. The USBL pole was pulled up at 12h04, and the ship proceeded to the Waveglider pickup site (40º25.1464'S, 44º57.4903'E); the Waveglider was on deck at 12h57.

At 13h26, the ship headed to rejoin survey line 40; the magnetometer was deployed at 13:31 (40º25.1631'S, 44º58.2023'E). Multibeam logging began at 14h20 (40º25.2005'S, 45º09.2404'E). The multibeam crashed at 14h31 (40º25.1821'S, 45º11.2004'E), and was back online at 14h36 (40º26.1319'S, 45.12.0209'E). The ship ended Line 40 at 16h50 (40º52.9430'S, 45º09.0835'E) and began Line 41 at 17h05 (40º52.8320'S, 45º12.6155'E). The multibeam crashed at 18h11 (40º40.5505'S, 45º13.8181'E) and was back online less than one minute later. The magnetometer went down at 18h35 (40º35.8564'S, 45º14.4403'E) and recovered within one minute.

At 19h18 and position 40º27.9257'S 45º15.3388'E, the ship broke from Line 41 toward Dredge Station 28 (40º30.6091'S, 45º08.9967'E). The magnetometer was turned off and pulled in ahead of Dredge 28 at 19h53 (40º30.0775'S, 45º09.4884'E). The ship arrived at Dredge Station 28 at 20h10 (40º30.6091'S, 45º08.9967'E) and held station. Multibeam was turned off at 20h12. Dredge 28 was deployed overboard at 20h18 (40º30.6066'S, 45º08.8864'E).

The weather was sunny and seas were calm with light winds ten knots or less.

Evening Science Meeting Summary:

At the science meeting, Chun-Zhou Liu gave a presentation on SWIR peridotite chemistry. Henry Dick discussed regional tectonics and his preliminary interpretations of the day's bathymetry.

Julian Day 79 | March 20th, 2019

Daily Summary:

TN365 began the day retrieving Dredge 28 (40º30.7886'S, 45º09.5330'E) at 00h52 UTC, which returned peridotite. At 01h07, the ship began steaming to rejoin Line 41 and magnetometer was deployed (40º30.7567'S, 45º09.6304'E). Multibeam logging began at 01h23 (40º31.7682'S, 45º12.1981'E).

The ship resumed Line 41 at 01h38 (40º28.3079'S, 45º15.3440'E). The ship reached the end of Line 41 at 06h00 (39º42.0092'S, 45º23.3049'E). The ship began Line 42 at 06h20 (39º45.3072'S, 45º23.7250'E). The ship completed Line 42 at 11h46 (40º50.7105'S, 45º16.3475'E). Line 43 began at 12h00 (40º50.8358'S, 45º19.6578'E).

The ship turned and the magnetometer stopped logging at 12h27 (40º45.7581'S, 45º20.3689'E). The magnetometer was on deck at 12h45 (40º45.8495'S, 45º22.5921'E). The ship turned toward Dredge Site 29 at 12h47 (40º45.9599'S, 45º22.7609'E). The multibeam was turned off 13h16 (40º47.9487'S, 45º15.9518'E). The ship arrived at Dredge Site 29 at 13h23 (40º48.1168'S, 45º15.5997'E). The dredge was in water 13h31 (40º48.1158'S, 45º15.6088'E). Dredge 29 was on deck at 17h09 (40º47.9404'S, 45º15.7643'E), and contained serpentinite and diabase.

The ship began turning at 17h20 (40º47.9423'S, 45º15.5672'E). The magnetometer was deployed at 17h26 (40º48.2079'S 45º15.5672'E). The magnetometer was deployed and multibeam logging began at 17h30 (40º48.5316'S, 45º15.5384'E). The magnetometer started logging and ship began speeding up at 17h33 (40º49.0535'S, 45º15.4426'E). The ship turned to add small segment and rejoin Line 43 at 18h01 (40º53.2495'S, 45º16.3067'E). The ship turned north back toward track line 43 at 18h20 (40º53.0791'S, 45º21.5333'E). The ship turned back to 005º and resumed line 43 at 19h05 (40º44.9750'S, 45º20.3805'E).

The weather was sunny and seas were calm.

Evening Science Meeting Summary:

At the science meeting, Fiona Clark gave a presentation on mantle xenoliths from the Kaapval Craton and their genesis.

Julian Day 80 | March 21th, 2019

Daily Summary:

TN365 began the day on Line 43. At 00h39 UTC, the ship completed Line 43 (39º42.4382'S, 45º27.4659'E) and began turning. At 00h55, the ship began Line 44 (39ª42.6915'S, 45º30.9906'E). At 06h11, the ship completed Line 44 (40º45.7879'S, 45º23.7960'E) and began turning, at which time the 3.5 kHz was turned off. The ship commenced Line 45 at 06h25 (40º45.9097'S, 45º27.2232'E), at which time the 3.5 kHz was turned back on.

At 12h11, the ship completed Line 45 (39º42.4104'S, 45º34.4373'E) and began turning, at which time the 3.5 kHz was turned off. The ship commenced Line 46 at 12h26 (39º42.3951'S, 45º37.7897'E), at which time the 3.5 kHz was turned back on.

At 16h50, the ship completed Line 46 (40º35.3902'S, 45º32.0488'E) and began turning, at which time the 3.5 kHz was turned off. The ship commenced Line 47 at 17h205 (40º35.7524'S, 45º35.3809'E), at which time the 3.5 kHz was turned back on.

The end of Line 47, and end of survey, occurred at 20h07 at 40º02.8526'S, 45º39.2041'E. The ship turned toward Dredge 30 Survey Site at 20h20 (40º02.6327'S, 45º37.0134'E). The magnetometer software was turned off (12h43, 40º03.7865'S, 45º32.1285'E). The magnetometer was pulled in at 21h10 at 40º04.4182'S, 45º30.5799'E. Dredge 30 went over at 22h25 (40º08.5960'S, 45º28.1777'E).

The weather was mostly cloudy and seas were generally six feet or less.

Evening Science Meeting Summary:

At the science meeting, Justin Fuji gave a presentation on AUV Sentry. His presentation outlined what data is available from each dive, how to access the data, and general Sentry operational abilities.

Julian Day 81 | March 22th, 2019

Daily Summary:

TN365 began the day on dredge site 30 with the dredge on bottom. At 00h52 UTC, the multibeam crashed (40°8.8384'S, 45°27.9511'E). Dredge 30 was on deck at 02h27 (40°8.8391'S, 45°27.9507'E), and contained highly vesicle basalt.

At 02h38 the ship headed for dredge station 31 (40°8.7955'S, 45°27.8756'E). At 03h40 it arrived at dredge station 31 (40°9.4996'S, 45°14.8003'E). At 03h53, dredge 31 was over (40°9.5249'S, 45°14.7689'E). At 08h29, dredge 31 was on deck (40°9.7350'S, 45°14.5618'E), and contained porphyritic basalt.

At 08h45, the small boat from Sacred Hearts school was freed to the high seas (40°9.7658'S, 45°14.5124'E).

At 08h51, the ship was heading for dredge station 32 (40°9.8335'S, 45°14.4100'E). At 10h43, the ship arrived at dredge site 32 (40°19.6785'S, 44°55.8918'E). At 10h55, dredge 32 was over (40°19.6755'S, 44°55.8926'E). At 14h53, dredge 32 was on deck (40°19.8165'S, 44°55.7291'E), and the dredge was empty.

At 15h00, the ship was turning, heading towards dredge site 33 (40°19.8189'S, 44°55.7074'E). At 15h40, the ship was on station at dredge site 33 (40°13.2476'S, 44°56.4848'E). At 15h52 dredge 33 was over (40°13.1420'S, 44°56.3996'E). At 19h5, dredge 33 was on deck (40°13.2078'S, 44°55.9488'E), and was empty. At 19h57, the ship turned and headed towards dredge site 34 (40°13.2086'S, 44°55.9456'E). At 21h08, the ship was again turning towards dredge site 34, and made correction to station coordinates (40°23.0597'S, 44°56.4243'E). At 21h13, the ship slowed for unknown reasons at the time, which were later found to be a problem with the Z-drive (40°23.43'S, 44°56.31'E). At 22h00, the ship was only operating on one Z-drive (40°25.6240'S, 44°53.3551'E). Troubleshooting on the Z-drive issue continued into the next day.

The weather was mostly cloudy and seas were generally heavy, with significant wave heights building from the southwest and approaching 7 meters toward the afternoon. Winds remained under 20 knots.

Evening Science Meeting Summary:

At the science meeting, Haizhou Li gave a presentation on the microbiology of the deep ocean and his research at identifying their genetic markers.

Julian Day 82 | March 23th, 2019

Daily Summary:

TN365 began the day with only one Z-drive operating, going towards dredge station 34. At 05h11 UTC, dredge 34 was abandoned and the ship began the transit back to Cape Town, with the Z-drive problem still unresolved (40°48.0120'S, 44°22.2221'E). At 05h40, both Z-drives were running again (40°47.2418'S, 44°20.3362'E), and the ship speed was incrementally increased to ensure that the problem Z-drive would continue operating. At 08h08, multibeam logging started (40°43.9453'S, 44°3.9149'E). At 10h20, the ship slowed down for magnetometer deployment (40°38.5595'S, 43°37.9548'E). At 10h21, the magnetometer was in the water (40°38.4800'S, 43°37.7520'E). At 10h49, the magnetometer started logging, and the ship began speeding up (40°37.2970'S, 43°34.0523'E). At 19h33, the magnetometer was offline for maximum of 12 min; brought back online at 19h33 (40°13.4778'S, 41°35.1207'E).

The weather was mostly cloudy and seas were generally heavy, with significant wave heights building from the southwest and approaching 7 meters toward the afternoon. Winds remained under 20 knots.

Evening Science Meeting Summary:

At the science meeting, Pingping Liu gave a presentation on the Mg isotopy in earth's oceanic mantle and Mg cycle.

Julian Day 83-87 | March 24th-28th, 2019

Summary:

TN365 transited towards Cape Town on March 24th to 28th for and early arrival on March 28th, 2019. In transit, multibeam data and magnetic data were acquired until reaching the South African EEZ. The cruise report was also compiled. Equipment and samples were packed up in anticipation of arrival in Cape Town.

Evening Science Meeting Summary:

During transit, the evening science meetings continued, with Chris Doorn, Yiqiong Chen, and Theresa Williams giving talks.

Cruise Log TN-365   Maurice Tivey
Note: Local time (South Africa): 2 hrs ahead GMT
February 2019

GMT	Local Time	Comments
11:21 Feb 21 jd=52	13:21 Feb 21 jd=52	Depart Durban 29 deg 52.2591'S 31 deg 1.9881'E
11:42	13:42	Pilot disembarked
12:00	14:00	Ship begins transit to the first waypoint Breezy and overcast winds 20+ kts – seas rough and bumpy Transiting at ~ 12 kts WP 1 36 degrees 18.18' S 30 degrees 38.58' E WP 2 36 degrees 59.22' S 32 degrees 8.82'E WP 3 42 degrees 29.22' S 39 degrees 43.80'E Note Wp1 to WP 2 is to accommodate South African researchers for their ECS application.
12:00 Feb 22 jd=53	14:00 jd=53	Sunny to partly cloudy – winds dropped to 14 kts Continue transit to first waypoint
16:04	18:04	Turned on EM302 multibeam system
16:19	18:19	EM302 datalogging initiated
16:30	18:30	MISO Seaspy-2 Magnetometer deployed ~300 m aft of ship. Some issues with magnetometer with noisy data. Sample rate 1 Hz and auto-tuning was not working to lock onto a signal. Tried manual tuning but communication seemed flaky. Getting a high gradient signal alert.
GMT	Local Time	Comments
		Unplugged all connectors and reconnected. That seemed to improve the signal on the maggie. Set tuning to auto tuning and it locked on to 28800 nT.

		Other issue is GPS to Maggie giving erroneous longitude. Seems to be some bad characters in the GPS signal making the parsing flip out. Just use the GPS timebase for the Maggie.
20:00	22:00	Magnetometer seems to be working smoothly now.
20:54 jd=53	22:54	At WP1 made turn to WP2 on a course of 117 degrees
03:50 Feb 23 Jd=54	05:50	At WP2 make turn to WP3
09:30 Jd=54	11:30	High overcast, partly sunny, winds 5kts, light seas Continue along track to WP3 and start of survey at ~12 kts
12:51 jd=54	14:51	Ship turns onto NW course to return to Durban for a medical emergency We will maintain survey mode until we reach the 200 nm limit.
15:00 jd=54	17:00	Captain decides to return to Port Elizabeth – slightly closer to us and has requisite medical facilities and ship's agent offices.
08:00 Feb 24 jd=55	10:00	Overcast skies, light winds ~ 5-7 kts, light seas. Continue to transit NE
08:40 jd=55	10:40	Turn off magnetometer and recover on deck Turn off logging of multibeam mapping system. We are entering into the South African 200 nm EEZ. We continue to transit towards Port Elizabeth for medical evac.
00:00 Feb 25 jd=56	02:00	In transit to Port Elizabeth for medical evac. 12 kts
04:00 jd=56	06:00	Change course for Algoa Bay, Port Elizabeth
GMT	Local Time	Comments
05:11	07:11	Transfer medical evacuee to rescue boat for transfer to shore in Port Elizabeth
05:22 jd=56	07:22	Port Elizabeth. Ship turns to exit Algoa Bay and resume transit back south to survey site.
09:00 jd=56	11:00	Sunny, a few clouds, light seas, 10 kt breeze. In transit to waypoint SA-4 (south African survey line for ECS)

		SA-4 36 degrees 22.18' S 30 degrees 2.94' E SA-3 37 degrees 43.45' S 31 degrees 21.07' E Waiting to cross into international waters to turn on survey systems and deploy maggie.
00:00 Feb 26 Jd-57	02:00	Continue in transit to SA-4
01:00 Jd=57	03:00	Exit the South African EEZ. Deploy magnetometer – slow ship to 4kts Turn on EM302 multibeam
07:00	09:00	Ship slowed to 8 kts to delay our arrival at the survey site. Bad weather is forecast for Thursday 2/28 so this puts us arriving on Friday 3/1.
10:18	12:18	Overcast, breezy with 25 kts winds, whitecaps but only moderate wind wave <10ft.
13:32	15:32	At WP SA-3 continue transit south to S-1 at 8 kts WP S-1 (start of survey)
03:06	05:06	Maggy error – could not find towfish. Checked and reset connections and restarted system.
05:56	07:56	Maggy computer crashed – restarted system
GMT	Local Time	Comments
06:28 Feb27 jd=58	08:28	39 deg 11.9840' S 33 deg 33.5486'E Change course to 085 degrees to revised starting waypoint S-1 S-1 40 deg 33.612 S 42 deg 52.956 E It has been decided to just do the northeastern ridge survey site (survey site 2) instead of heading to the south west site because of lost time (med evac) and EEZ concerns. Will do entire ridge segment between Indomed and Discovery FZs.
06:32	08:32	Maggy lost connection Re-established connection by resetting system
09:20	11:20	Increase speed to 12+ kts. With following sea we are reaching 14.5 kts (15 to 16) in places.

		Transiting today with following sea
21:00	23:00	Appear to have slowed down somewhat – only making 11.5 to 12 kts now. Winds are down from 25 kts to 14 kts.
17:01	19:01	Run an XBT to 1000 m for sound speed profile
17:22	19:22	Arrive at S-1 waypoint and head to beginning of survey
17:27	19:27	SOL 1 start multibeam and geophysics survey
22:57 Jd=59	00:57	EOL 1 head over to line 2
23:12 Jd=59	01:12	SOL 2
04:00 Mar 1 Jd=60	06:00	EOL 2 head over to line 3
04:15	06:15	SOL 3
09:18 Jd=60	11:18	End of line 3 move to SOL 4
<u>GMT</u>	<u>Local Time</u>	<u>Comments</u>
10:00	12:00	We would like break the survey line at 41 deg 23.525' S 42 deg 57.15' E Turn west to 41 deg 22.71 S 42 deg 48.852'E and slow to 4 kts while we recover the magnetometer.
10:58	12:58	Maggie recovered on deck
11:08 Mar 1 Jd=60	13:08	Continue multibeam survey to fill in some gaps over the top of this hill at 8 kts 41 deg 26.119' S 42 deg 51.931' E 41 deg 23.598' S 42 deg 52.440' E Back to trackline 41 deg 23.838' S 42 deg 57.172' E
12:20 Mar 1 Jd=60	14:20	Slowing ship to hold station to get ready for a dredge. However the winch room camera is not working so need some time to fix it – so will fill in with some more multibeam tracks.
12:42	14:42	Start a "Fill-in" survey on summit of hill while we wait for winch room camera to be fixed.

		41 deg 23.492' S 42 deg 52.142' E 41 deg 24.722' S 42 deg 51.404' E 41 deg 26.329' S 42 deg 54.479' E 41 deg 24.575' S 42 deg 54.877' E
14:17	16:17	Finished "fill-in' survey
14:32	16:32	Ship hove to ready to dredge – winch room camera has been fixed. Will set up to dredge fossil inside corner high on Discovery transform fault
15:48 Mar 1 Jd=60	17:48	Start Dredge – 1 41 deg 23.8928' S 42 deg 57.4405' E (1400 m depth) 41 deg 24.8110' S 42 deg 56.2300' E (~800 m depth) Dredge in water
19:28	21:28	Finished Dredge-1 Dredge on deck. A handful of small rocks – gabbro.
GMT	Local Time	Comments
		Return to survey line 4
20:30 Mar 1 Jd=60	22:30	Redeploy magnetometer Start multibeam
00:40 Mar 2 Jd=61	02:40	EOL 4
00:52	02:52	SOL 5
05:43	07:43	EOL 5
05:59 Jd-61	07:59	SOL 6
08:35 Jd=61	10:35	Ship is turning to Sentry launch site
08:59	10:59	Recover magnetometer Turn off multibeam and 3.5 khz chirp
10:20	12:20	XBT completed
10.54 Mar 2 Jd=61	12:54	Sentry dive 527 USBL pole id down

10:21??		Move over to dredge location
13:16 Mar 2 Jd=61	15:16	Start Dredge-2 41 deg 1.7'S 42 deg 59.948'E 2655 m
14:30	16:30	Dredge on bottom
16:37	18:37	Dredge-2 on deck empty
17:52 Mar 2 Jd=61	19:52	Sentry Dive-527 back on deck
18:10	20:10	USBL pole retracted Move over to start dredge 3
19:23	21:23	Start Dredge-3 41 deg 1.6806 42 deg 53.9727 'E 2440 m
GMT	Local Time	Comments
22:38	00:38 Mar 3	Bringing Dredge-3 back.
23:29 Mar 2 Jd=61	01:29	Dredge-3 back on deck Dredge recovered 3 cobble-sized diabase dike rocks – greenschist facies alteration
00:15 Mar 3 Jd=62	02:15	Deploy magnetometer, turn on multibeam. Head over to rejoin and restart line 6 where we left off before the sentry and dredge operations
00:53 Mar 3 Jd=62	02:53	Turning back onto line 6
03:06 Mar 3 Jd=62	05:06 Mar 3	EOL 6
03:21 Jd=62	05:21	SOL 7
07:20 Mar 3 Jd=62	09:20	Surveying in rough weather speed down to 9.4 kts Multibeam is bad on this south bound tracks
09:07	11:07	EOL 7

Mar 3		
09:23	11:23	SOL 8 Weather bad, seas 20+ ft winds 25-30 kts making multibeam poor quality
14:20	16:20	EOL 8 40 deg 37.767'S 43 deg 19.101' E
14:26	16:26	SOL 9 40 deg 37.935'S 43 deg 20.901' E
19:12	21:12	EOL 9
19:28	21:28	SOL 10
		Weather moderating somewhat as we transit north. Multibeam is better on north bound tracks
23:17	01:17	EOL 10 Turn west and head to a waypoint to turn south to dredge site for a fill-in of multibeam
23:42	01:42	Turn ship south towards dredge 4 target
GMT	Local Time	Comments
00:30 Mar 4 Jd=63	02:30	Recover magnetometer Seas have abated substantially, winds down to 3 kts
01:00	03:00	At Dredge 4 location – will wait until 02:00 to begin prep for dredge
02:21	04:21	Start Dredge-4 40 45.385'S 43 20.316'E depth…
09:10 Mar 4 Jd=63	11:10	Dredge-4 on deck Small handful of pebble-sized rocks recovered Multiple lithologies
09:30 Mar 4 Jd=63	11:30	Move south to dredge-5 location Weather sunny with high clouds, seas light, winds 20 kts Seems to be building towards next storm tonight
10:03	12:03	At Dredge-5 position
10:25	12:25	Start Dredge-5 40 deg 50.740' S 43 deg 24.332' E 2414 m depth
11:22 Mar 4 Jd=63	13:22	Dredge 5 on bottom
14:43	16:43	Dredge 5 on deck.

		Move over to next dredge site
15:52	17:52	Dredge 6 in the water 40 deg 54.796’S 43 deg 21.999’E
20:41	22:41	Dredge 6 on deck
21:33	23:33	Go back to geophysics surveying. Turn on multibeam and deploy magnetometer
22:46	00:46	Ship turning onto repeat line 7
GMT	Local Time	Comments
02:40 Mar 5 Jd=64	04:40	End of repeat line 7 – head over to start of line 11
04:01	06:01	SOL 11
05:19	07:19	Lost maggie towfish connection
05:20	07:20	Maggie Connection came back
08:15	10:15	EOL 11
09:27	11:27	Maggie deck cable broken – no maggie data logging Slow ship to 6 kts while we attempt a repair
09:33	11:33	SOL 12
11:30	13:30	Maggie repaired and back recording. Bring ship up to full speed
13:51	15:51	EOL 12
14:05	16:05	SOL 13
17:37	19:37	EOL 13
17:54 Mar 5 Jd=64	19:54	SOL 14
20:54	22:54	EOL 14
21:05	23;05	SOL 15
00:20 Mar 6 Jd=65	02:20	EOL 15
00:34	02:34	SOL 16
00:48	02:48	Break off survey – transit over to Sentry launch site but keep surveying
02:13	04:13	Recover Maggie on deck

		Weather has calmed down substantially. No wind wave and only long swell. Winds ~ 3 kts. Sunny
02:51	04:51	Deploy USBL pole
03:35 Mar 6 Jd=65	05:35	Sentry launch position 40 deg 59.627'S 43 deg 27.831'E
GMT	Local Time	Comments
06:36	08:36	Launch waveglider 41 deg 0.903'S 43 deg 27.0134'E
06:50	08:56	Head over to start dredge 7 using WHOI dredge
07:25	09:25	Start dredge 7 Has pinger, MAPR and USBL 41 deg 1.598'S 43 deg 26.158'E
13:52	15:52	Dredge 7 recovered on deck
		Head over to do dredge 8
16:06 Mar 6 Jd=65	18:06	Start Dredge 8 40 deg 59.997' S 43 deg 31.0212'E 3700 m
21:44	23:44	Dredge 8 on deck
22:30	00:30	Head over to babysit Sentry
03:31 Mar 7 Jd=66	05:31	Sentry recovered on deck End of Sentry Dive 528
04:40	06:40	Retrieve USBL pole
04:15	06:15	Drive over to dredge 9 site
05:14	07:14	Arrived at dredge station
05:48	07:48	Start Dredge 9 41 deg 07.2967'S 43 23.0191'E 2364 m
08:56	10:56	Winch problem with level wind
11:40	13:40	Dredge 9 back on deck
		Transit over dredge 10 site
13:36	15:36	Start Dredge 10 40 deg 58.7220'S 43 deg 41.0410'E 3721 m

		Winch problem with level wind
15:28	17:28	Winch problem fixed back going down with wire
21:06	23:06	Dredge 10 on deck
21:57	23:57	Move to dredge station 11
<u>GMT</u>	<u>Local Time</u>	<u>Comments</u>
23:29 Mar 7 Jd=66	01:29	Start Dredge 11 41 deg 05.6413'S 43 deg 38.3125'E
04:21 Mar 8 Jd=67	06:21	Dredge 11 back on deck
04:31	06:31	Start back on transit over to survey line Turn multibeam back on
04:55	06:55	Deploy maggy
06:12	08:12	Start turn onto line 16 to resume the survey
06:14	08:14	SOL 16
08:46	10:46	EOL 16
09:02	11:02	SOL 17
16:03	18:03	EOL 17
16:17	18:17	SOL 18 (long line)
20:11	22:11	Maggy program crashed - restarted
04:46 Mar 9 Jd=68	06	Lost maggy connection – back on after brief reset
06:06		EOL 18
06:24		SOL 19 (long line)
14:04		EOL 19
14:19		SOL 20
17:32		EOL 20
17:47		SOL 21
20:49		EOL 21
21:05		SOL 22
23:57		EOL 22
00:13 Mar 10 Jd=69		SOL 23 41 deg 4.8048'S 43 deg 58.9977'E

03:29		EOL 23
03:47		SOL 24
06:02		Break off survey to go over to Sentry dive site
06:48		Recover maggy on deck
GMT	Local Time	Comments
07:17 Mar 10 Jd=69		Arrive at Sentry site Mulitbeam turned off 41 deg 4.8048'S 43 deg 58.9977'E
08:05 Mar 10 Jd=69		Sentry Dive 529 In water
09:50		Transit over to Dredge 12 site
13:36		Start Dredge 12 41 00.9039'S 43 58.4370'E 3906 m
17:20		Dredge 12 on deck
		Sentry found to have gone off track. Slow ship to get good fixes as we transit to next dredge target
19:59 Mar 10 Jd=69		Start Dredge 13 41 10.2904'S 43 55.8539'E 3626 m
00:52 Mar 11 Jd=70	02:52	Dredge 13 on deck
01:01	03:01	Moving to dredge site 14
02:01	04:01	Start Dredge 14 41 08.0035'S 43 58.8856'E 1865 m depth
06:39	08:39	Dredge 14 on deck
06:40	08:40	Moving over to Sentry recovery position
08:21 Mar 11 Jd=70	10:21	Sentry on deck End of Dive 529
		Moving to next dredge site
10:16	12:16	Start Dredge 15 40 54.4647' S 43 55.1714'E 2670 m
11:20 Mar 11 Jd=70	13:20	Dredge 15 on bottom

14:28		Coming up the wire had a wuzzle at ~100 m or so. Had to stop and fix the wuzzle. ~ 3 hrs+
GMT	Local Time	Comments
17:28 Mar 11 Jd=70		Dredge 15 finally on deck
17:59		Transit over to resume line 24 Deploy magnetometer
18:05		Turn on multibeam Heading to line 24
19:08		Resume line 24
20:06		EOL 24
20:22	22:22	SOL 25
23:40	01:40	EOL 25
23:56 Mar 11 Jd=70	01:56	SOL 26
03:15 Mar 12 Jd=71	05:15	EOL 26
03:30	05:30	SOL 27
07:28	09:28	EOL 27
07:43	09:43	SOL 28
10:39 Mar 12 Jd=71	12:39	Multibeam crashed
10:44		Multibeam back on logging
12:01		EOL 28
12:16		SOL 29
15:34		Break off line 29 to go over to dredge site
16:20		Start Dredge 16 40 deg 29.6187'S 43 deg 30.3893
19:46		Dredge on deck
20:00		Move ship to the west fill in a gap in the multibeam coverage on massif. The turn to head east to rejoin the survey line.
		Deploy magnetometer
GMT	Local	Comments

	Time	
21:01 Mar 12 Jd=71		Ship turns to resume Line 29
22:22		EOL 29
22:38 Mar 12 Jd=71		SOL 30
03:24 Mar 13 Jd=72	05:24	EOL 30
03:38	05:38	SOL 31
05:55	07:55	Break off line 31 to go to dredge target in spreading axis
06:12 Mar 13 Jd=72	08:12	Recover magnetometer on deck Stop logging multibeam
		Moving over to dredge target. Target keeps changing, so keep moving the ship
07:24 Mar 13 Jd=72	09:24	Start Dredge 17 40 deg 41.4888'S 44 deg 33.4170'E depth 3455 m
12:15	14:15	Dredge 17 on deck Peridotite recovered.
12:44	14:44	Start moving ship to resume survey track Deploy magnetometer
12:54	12:54	Resume survey line 31
15:43	17:43	EOL 31
15:58	17:58	SOL 32
17:00		Breaking off survey line 32 to go to a dredge target
17:18		Recover magnetometer
17:58		Start Dredge-18 40 deg 22.7454'S 44 deg 40.5279'E
22:26		Dredge 18 back on deck, peridotite rocks
22:44		Get ship moving to return to survey line 32
23:11		Deploy magnetometer. Turn on multibeam logging
GMT	Local Time	Comments
23:21		Resume survey line 32

Mar 13 Jd=72		
01:31 Mar 14 Jd=73		Ship breaking off survey line 32 to go to launch sentry and then a dredge target
01:40		Recover magnetometer
		Head to Sentry launch site
02:59 Mar 14 Jd=73		Launch Sentry Dive 530 40 deg 47.9696'S 44 deg 34.6001'E
		Listen to Sentry get to the bottom and start driving
06:05		Start to head over to dredge 19 site
06:46 Mar 14 Jd=73	08:46	Start Dredge 19 40 deg 47.9819'S 44 deg 36.5913'E
11:33	13:33	Dredge 19 on deck
12:52	14:52	Start Dredge 20 40 deg 51.9768 44 deg 34.1074'E
17:51	19:51	Dredge 20 on deck – nothing in dredge
17:57	19:57	Head over to Sentry recovery site
19:51 Mar 14 Jd=73	21:51	Sentry recovered on board End of Sentry Dive 530
20:00		Getting Sentry stowed and pulling up USBL pole
20:11		USBL pole secure. Begin transit back to survey line
20:33		Deploy magnetometer, Multibeam back logging
20:58		Resuming course on Line 32
22:24		EOL 32
22:39		SOL 33
23:04		Multibeam crashed
23:06 Mar 14 Jd=73		Multibeam back on logging
GMT	Local Time	Comments
04:47 Mar 15 Jd=74		EOL 33

05:03		SOL 34 long line south of axis for Chron-5
13:27 Mar 15 Jd=74		EOL 34 Weather is mild but overcast and foggy. Winds are < 10 kts seas are <10 ft.
13:40		SOL 35
14:30		Break off from line 35 and turn and recover the magnetometer
		Magnetometer on deck
		Move over to Dredge 21 site
15:40 Mar 15 Jd=74		Start Dredge 21 41 deg 32.1095'S 44 deg 44.8971'E depth 1715 m At southernmost edifice on second long line.
19:01 Mar 15 Jd=74		Dredge 21 on deck
19:20 Mar 15 Jd=74		Transit back to survey line 35
19:37		Deploy magnetometer
20:00 Mar 15 Jd=74		Resume survey line 35
03:51 Mar 16 Jd=75		Turn off survey line to dredge site
04:12		Recover magnetometer
04:18		Arrived at Dredge site
04:22		Start Dredge 22 40 deg 00.9903'S 44 deg 54.4958'E depth 1962 m
07:46		Dredge 22 on deck
GMT	Local Time	Comments
07:57 Mar 16 Jd=75		Move ship to rejoin survey line 35
08:16		Deploy magnetometer
08:21		Resume line 35
10:43		EOL 35

10:56		SOL 36
18:15		EOL 36
18:29		SOL 37
20:40		Slow down and break off survey to go over to dredge site
20:45		Recover the magnetometer on deck Head over to dredge site
21:06		Turn to head to dredge site
21:21 Mar 16 Jd=75		Start Dredge 23
02:39 Mar 17 Jd=76		Dredge 23 back on deck – fresher looking peridotite
03:06		Return to survey line Deploy magnetometer
03:31		Rejoin survey line 37
05:44 Mar 17 Jd=76	07:44	Break off survey line to go to dredge.
05:49		Recover magnetometer on deck. Head over to dredge site.
06:55		Start Dredge 24 40 deg 16.9829'S 44 deg 59.4117' E depth 2431 m
08:03		Winch has a problem with wire on drum. Wire bent wrapped on itself on drum and broke a few strands. We'll need to cut off this section of wire.
09:39	11:39	Recover pinger and dredge back on deck.
GMT	Local Time	Comments
09:40 Mar 17 Jd=76	11:40	End of aborted Dredge 24
10:25	12:25	Will spool out 2400 m of wire with dead weight on it and try cutting off. Move ship over to a deep hole location for wire dump.
10:40		Ship at deep hole site. Spool out of the wire.

13:00 Mar 17 Jd=76	15:00	Tried cutting off 2400 m of wire but the load snapped when trying to release tension by using yale grip. So will recover the wire back on the drum and then spool off on deck somehow.
14:00	16:00	Ship underway to rejoin survey line
14:15	16:15	Deploy magnetometer
14:49	16:49	Rejoin survey line 37
17:47	19:47	EOL 37 During the survey – the ship decided to winch the damaged trawl wire off onto another winch spool on the O2 deck. 2500 m of wire successfully unspooled onto the backup drum. Reterminating the new bitter end of the trawl wire. Will do pull tests in the morning.
18:00 Mar 17 Jd=76	20:00	SOL 38
00:11 Mar 18 Jd=77	02:11	EOL 38
00:34	02:34	SOL 39
07:04	09:04	EOL 39
07:20	09:20	SOL 40
GMT	Local Time	Comments
11:02 Mar 18 Jd=77	13:02	Break off survey line and head over to Sentry dive target. Trawl wire is ready for dredging again.
12:51 Mar 18 Jd=77	14:51	Launch Sentry Sentry Dive 531 40 deg 25.227-0’ S 44 deg 55.6372’ E
		Monitor Sentry descent and bottom navigation
14:38	16:38	Move over to Dredge target site
16:35	18:35	Dredge 25 – on small neovolcanic zone

		40 deg 28.9952'S 44 deg 54.8859'E depth 3634 m
21:56	23:56	Dredge 25 on deck no rocks
22:12 Mar 18 Jd=77	00:12	Start Dredge 26 - repeat dredge further up the neovolvanic ridge 40 deg 28.6656' S 44 deg 54.8839' E
02:42 Mar 19 Jd=78	04:42	Dredge 26 on deck - no rocks
03:45	05:45	Start Dredge 27 40 deg 25.9681 ' S 44 deg 59.8197'E
09:11	11:11	Dredge 27 on deck - basalt
09:20	11:20	Move ship back to Sentry dive area to monitor Sentry's position and ascent.
11:53		Recover Sentry on deck End Sentry Dive 531
12:00	14:00	Bring up USBL pole
12:19	14:19	Move over to recover the waveglider. Calm weather.
12:57	14:57	Ship put small boat in the water to help in recovery of the waveglider. Seas are calm and recovery goes smoothly. Waveglider safely on board.
13:26	15:26	Move the ship to rejoin the survey line.
13:31	15:31	Deploy the magnetometer. Having problems with the multibeam.
GMT	Local Time	Comments
14:30 Mar 19 Jd=78	16:30	Rejoin survey line 40 heading south. Multibeam still off, but finally get it going 14:35
16:50	18:50	EOL 40
17:05	19:05	SOL 41
18:11	20:11	Multibeam crashed
18:13	20:13	Back on line with multibeam
19:18	21:18	Break off survey line to dredge.
19:42	21:42	Recover the magnetometer
		Move over to dredge site 28
20:18 Mar 19 Jd=78	22:18	Start Dredge 28 40 deg 30.6065'S 45 deg 08.8864'E depth 2129

00:52 Mar 20 Jd=79	02:52	Dredge 28 on deck
01:07	03:07	Move off to deploy magnetometer and rejoin survey line heading north.
01:38	03:38	Rejoin survey line 41 heading north
05:55xxx		EOL 41
06:10xx		SOL 42
11:46 Mar 20 Jd=79	13:46	EOL 42
12:00	14:00	SOL 43
12:27	14:27	Break survey line to go to next dredge site 28
12:45	14:45	Recover the magnetometer
		Move over to Dredge site
13:31 Mar 20 Jd=79	15:31	Start Dredge 29 40 deg 48.1168 ‘ S 45 deg 15.6088’E 2066 m depth
17:09	19:09	Dredge on deck
18:01		Ship moves off to rejoin survey line. Will loop around the southern end of the core complex to complete the mapping of it on all sides.
GMT	Local Time	Comments
17:33 Mar 20 Jd=79	19:33	Deploy the magnetometer
19:05	21:05	Rejoin survey line 43 heading north
00:39 Mar 21 Jd=80	02:39	EOL 43
00:55	02:55	SOL 44
06:11	08:11	EOL 44
06:25	08:25	SOL 45
12:11	14:11	EOL 45
12:26	14:26	SOL 46
16:50	18:50	EOL 46
17:05	19:05	SOL 47
20:07	22:07	EOL 47 – End of geophysical survey of spreading segment.

		Turn towards the next dredge target (D30). Winds picking up. 25kts going higher. Squall coming in
20:43 Mar 21 Jd=80	22:43	Slow the ship to 6 kts and recover the magnetometer on the winch drum. About 30 minutes to recover. Squall came on during mag recovery – 35kts+.
		Continue transiting over to dredge target. Have to shift to south wall of spreading center due to wind shift to south.
		Move ship south to dredge target on south wall.
22:21	00:21	Arrive at dredge target. Ship setting up position. ~ 25kts winds from the south.
22:25 Mar 21 Jd=80	00:25	Start Dredge 30 - axial rift valley south wall 40 deg 08.5960'S 45 deg 28.1777'E depth 2200 m
GMT	Local Time	Comments
02:27 Mar 22 Jd=81	04:27	Dredge on deck
02:38	04:38	Move ship to next dredge target
03:40	05:40	Arrive at dredge site
03:53	05:53	Start Dredge 31 40 Deg 9.4996'S 44 deg 14.7689'E depth 2742 m
08:29	10:29	Dredge on deck -
08:45	10:45	Launch small boat for outreach. Website for tracking is:
08:51	10:51	Move ship to next dredge target. Heavy swell from the southwest 6-8 meters. Breezy but winds 10-15 kts.
10:43	12:43	Arrive at dredge site
10:55	12:55	Start Dredge 32 40 deg 19.6755'S 44 deg 55.8926'E depth 2939 m
14:53	16:53	Dredge on deck

15:00	17:00	Move ship to next dredge site. Moving in the trough. Swell seems to be abating.
15:40 Mar 22 Jd=81	17:40	Arrive at dredge site.
17:01 Mar 22 Jd=81	19:01	Start Dredge 33 40 deg 13.1663'S 44 deg 56.3981'E depth 2182 m
19:50		Dredge on deck - empty
19:59	21:59	Start ship heading to next dredge site DR34 – 18 nmiles
21:13		Ship lost power to its port Z-driver propulsion. Cooling problem. Speed cut from 12 kts down to 4-5 kts. Engineers are trying to get the drive back online.
23:48 Mar 22 Jd=81	01:48	Still transiting at 4.5 kts due to ship's propulsion issues. Will skip dredge target 34 and keep heading to target DR35.
GMT	Local Time	Comments
05:11 Mar 23 Jd=82		Still have engine problems speed 3.8 kts. Decide to head to Cape Town
07:20		Appears that the engines have been fixed. Speed is gradually coming up.
08:08		Start multibeaming
10:21		Deploy magnetometer using the winch
10:49		Mag logging on
		Heavy swell 8 m. and winds ~20kts
11:40	13:40	In transit to Cape Town, SA Swell has diminished and winds ~20kts
17:00 Mar 24 Jd=83		In transit to Cape Town, SA Swell and winds have built up to make an uncomfortable ride. Multibeam has lots of bad pings due to ship motion. We are passing through a frontal system.
10:15 Mar 25 Jd=84		In transit to Cape Town, SA We have passed through the frontal system and the weather conditions are slowly improving. Multibeam is getting better returns.
08:57 Mar 26 Jd=85	10:57	In transit to Cape Town, SA We have reached the South African EEZ. We stop multibeam logging and recover the magnetometer on board.

		END of geophysical mapping program.
Mar 27 Jd=86		In transit to Cape Town, SA.
06:30 Mar 28	08:30 Mar 28	Cape Town harbor Pilot
07:30 Mar 28	9:30 Mar 28	At Duncan dock, Cape Town END OF CRUISE

Appendix- EM302 Multibeam Bathymetry

Processing Scripts

1preeditMB.sh- Converts raw .all files to .mb59 files and auxiliary files (also inserts meta data).

```
#!/bin/csh

###### --
# Written by Jared Kluesner, UCSC
# modified by MT for TN272 cruise
# Modified by JAG 2018 for Marion Rise R/V Thompson

# Put this script in the folder where unprocessed .all files exist
# Type "./1preeditMB.sh" in terminal to create the .mb59 format files from .all files and generate all the aux. files.
# Followed by "mbedit" (ping editing) and “3posteditMB.sh" (processing, gridding, and plotting)

# !!!Edit metadata information in part 5 below to match ship and cruise!!!

###### --


#---------------------------------------------------------------------------
#  1. Grab the *.all files from the cruise data and compile an input list
#---------------------------------------------------------------------------

if(-e file_list) rm -rf file_list
ls *.all >> file_list
set tmp_file = `cat file_list`

#---------------------------------------------------------------------------
#  2. Convert from *.all to *.59 file
#---------------------------------------------------------------------------

foreach i ($tmp_file)

   set INFILE = $i:t
   set OUTFILE = {$INFILE:r}.mb59

   echo Processing ....  $OUTFILE

#------------ -P1 = no ping averaging, -S2 = no data used if ship speed < ~ 1 kts
```

```
  mbcopy -P1 -F58/59 -S2 -I$i -O$OUTFILE

end



#------------------------------------------------------------------------------
#  3. Create the datalist file and MB 59 format
#------------------------------------------------------------------------------

if(-e file_list) rm -rf file_list
ls *.mb59 >> file_list
set tmp_file = `cat file_list`

if(-e datalist.raw) rm -rf datalist.raw

foreach i ($tmp_file)

  set INFILE = $i:t
  echo "$INFILE 59" >> datalist.raw
  echo Processing ....  $INFILE

end



#------------------------------------------------------------------------------
#  4. Generate the ancillary files "inf", "fbt", and "fnv"
#------------------------------------------------------------------------------


if(-e file_list) rm -rf file_list
ls *.mb59 >> file_list
set tmp_file = `cat file_list`

foreach i ($tmp_file)

  echo Processing ....  $i
  mbdatalist -F59 -N -I$i
```

```
end

rm file_list



#-------------------------------------------------------------------------------
#  5. Add meta data to the "par" file
#  See metadata notes below
#-------------------------------------------------------------------------------

if(-e file_list) rm -rf file_list
ls *.mb59 >> file_list
set tmp_file = `cat file_list`

foreach i ($tmp_file)

  echo Processing ....  $i
  mbset -I $i \
    -PMETAVESSEL:"R/V Thompson" \
    -PMETAINSTITUTION:"UW" \
    -PMETAPLATFORM:"Research Ship" \
    -PMETASONAR:"Kongsberg - EM302" \
    -PMETASONARVERSION:"EM302" \
    -PMETACRUISEID:"SWIR Marion Rise 2019" \
    -PMETACRUISENAME:"Thompson - Marion Rise" \
    -PMETAPI:"Henry Dick" \
    -PMETAPIINSTITUTION:"WHOI" \
    -PMETACLIENT:"WHOI" \

end

#-------------------------------------------------------------------------------

rm file_list
#rm *.all
#-----
# All done!
```

echo Finished!

#---
Metadata notes for -P option (see mbset man page for additional)
METAVESSEL string-sets mbinfo metadata string for vessel
METAINSTITUTION string-sets mbinfo metadata string for vessel operator institution or company
METAPLATFORM string-sets mbinfo metadata string for sonar platform (ship or vehicle)
METASONAR string-sets mbinfo metadata string for sonar model name
METASONARVERSION string-sets mbinfo metadata string for sonar version (usually software version)
METACRUISEID string-sets mbinfo metadata string for institutional cruise id
METACRUISENAME string-sets mbinfo metadata string for descriptive cruise name
METAPI string-sets mbinfo metadata string for principal investigator
METAPIINSTITUTION string-sets mbinfo metadata string for principal investigator
METACLIENT string-sets mbinfo metadata string for data owner (usually PI institution)

3posteditMB.sh- Applies MBedit processing to data, grids bathymetry and backscatter data (grid resolution can be altered in file), and plots data.

```
#!/bin/csh

###### --
# post-editing process
# written by MT for TN272 cruise/EM302 system; updated for Marion Rise (gridmaker.sh and test_mapper.sh)
# Edited by JAG 2018 for Marion Rise R/V Thompson

# Preceeded by "1preeditMB.sh" (preprocessing and metadata) and "mbedit" (ping editing)

# Type "./3posteditMB.sh" in terminal to apply processing, grid bathymetry and sidescan, and plot bathymetry and sidescan

# !!!Uncomment open command for correct operating system (Linux vs OSx) in Step 3!!!

###### --

# set grid spacing
set grddxdy=50/50 # dx/dy/units [if no units, assumes meters]

#-----------------------------------------------------------------------------
```

```
#  1. Apply processing to data
#-----------------------------------------------------------------------------
ls -1 | grep mb59$ > tmplist
mbdatalist -F-1 -I tmplist > datalist

# Apply processing to data
echo Applying Processing to Data Files...
mbprocess -Idatalist -F-1 -V
# --
rm tmplist
ls -1 | grep p.mb59$ > tmplist
mbdatalist -F-1 -I tmplist > datalistp

#-----------------------------------------------------------------------------
#  2. Grid multibeam and sidescan data
#-----------------------------------------------------------------------------
# Grid Multibeam data (-A2: bathymetry data positive upward)
echo Gridding MultiBeam Data- file: procMBgrid.grd...
mbgrid -F-1 -Idatalistp -E$grddxdy -U1 -A2 -G111 -N -C2/1 -OprocMBgrid -v
# --

# Grid Sidescan data (-A4 for sidescan data)
echo Gridding Sidescan Data- file: procSSgrid.grd...
mbgrid -F-1 -Idatalistp -E$grddxdy -U1 -A4 -G111 -N -C2/1 -OprocSSgrid -v


#-----------------------------------------------------------------------------
#  3. Create plots of multibeam and sidescan data
#-----------------------------------------------------------------------------
## Plot Multibeam data (color shaded relief bathymetry) and Sidescan data (Grayscale fill of
sidescan data)
echo Plotting MultiBeam and Sidescan Data...
# Define data files to be plotted:
set DATA_FILEMB = procMBgrid.grd
set DATA_FILESS = procSSgrid.grd
set PS_FILEMB = procMBgrid.grd.ps
set PS_FILESS = procSSgrid.grd.ps
set MAP_PROJECTION = M
set MAP_SCALE = 7.5i
set MAP_REGION = $DATA_FILEMB
```

```
#
# Delete any existing gmt.conf file
if (-e gmt.conf) then
echo Deleting gmt.conf...
/bin/rm gmt.conf
endif
#
# Set temporary GMT defaults
echo Setting temporary GMT defaults...
gmt gmtset PROJ_LENGTH_UNIT inch
gmt gmtset PS_MEDIA archA
gmt gmtset FONT_ANNOT_PRIMARY 12,Helvetica,black
gmt gmtset FONT_ANNOT_SECONDARY 10,Helvetica,black
gmt gmtset FONT_LABEL 12,Helvetica,black
gmt gmtset FONT_TITLE 14,Helvetica,black
gmt gmtset PS_PAGE_ORIENTATION LANDSCAPE
gmt gmtset COLOR_BACKGROUND black
gmt gmtset COLOR_FOREGROUND white
gmt gmtset COLOR_NAN white
#
# Make color palette
gmt grd2cpt procMBgrid.grd -Csealand -Z > MB.cpt
gmt grd2cpt procSSgrid.grd -Cgray -Z > SS.cpt
#
# Make color image
echo Running gmt module grdimage...
#
gmt grdimage $DATA_FILEMB -J$MAP_PROJECTION$MAP_SCALE \
-R$MAP_REGION -CMB.cpt \
-P -K -Xc -Yc -V >! $PS_FILEMB
#
gmt grdimage $DATA_FILESS -J$MAP_PROJECTION$MAP_SCALE \
-R$MAP_REGION -CSS.cpt \
-P -K -Xc -Yc -V >! $PS_FILESS
#-----
# Make contour plot
echo Running gmt module grdcontour...
gmt grdcontour $DATA_FILEMB -J$MAP_PROJECTION$MAP_SCALE \
-R$MAP_REGION \
-C100 -Wc1p\
```

```
-P -K -O -Xc -Yc -V >> $PS_FILEMB
#-----
# Make color scale
echo Running gmt module psscale...
gmt psscale -CMB.cpt \
-Ba200 \
-D3.0538/-0.5000/6.1076/0.1500h \
-B+l"Topography (m)" \
-P -K -O -V >> $PS_FILEMB
#
gmt psscale -CSS.cpt \
-Ba10 \
-D3.0538/-0.5000/6.1076/0.1500h \
-B+l"Reflectivity" \
-P -K -O -V >> $PS_FILESS
#-----
# Make basemap
echo Running gmt module psbasemap...
gmt psbasemap -J$MAP_PROJECTION$MAP_SCALE \
-R$MAP_REGION \
-B3m -B+t"MultiBeam Bathymetry Grid" \
-P -O -Xc -Yc -V >> $PS_FILEMB
#
echo Running gmt module psbasemap...
gmt psbasemap -J$MAP_PROJECTION$MAP_SCALE \
-R$MAP_REGION \
-B3m -B+t"SideScan Sonar Grid" \
-P -O -Xc -Yc -V >> $PS_FILESS
#-----
# Delete surplus files
/bin/rm -f gmt.conf
#
echo Opening Images...
## Open command: Uncomment for correct OS!!!!
# For Linux (written for Ubuntu)
xdg-open $PS_FILESS
xdg-open $PS_FILEMB

#-----
# All done!
```

```
echo Finito!
# --------------------------------------------------------------
```