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NOAA *Okeanos Explorer* Program

MAPPING DATA REPORT

CRUISE EX0903
U.S. Law of the Sea Cruise to Map the Eastern
Mendocino Ridge, Eastern Pacific Ocean

May 5, to May 26, 2009
San Francisco, CA to San Francisco, CA

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1. Introduction

The *Okeanos Explorer* Program

Commissioned in August 2008, the NOAA Ship *Okeanos Explorer* is the nation's only federal vessel dedicated to ocean exploration. With 95% of the world's oceans left unexplored, the ship's combination of scientific and technological tools uniquely positions it to systematically explore new areas of our largely unknown ocean. These exploration cruises are explicitly designed to generate hypotheses and lead to further investigations by the wider scientific community.

Using a high-resolution multibeam sonar with water column capabilities, a deep water remotely operated vehicle, and telepresence technology, *Okeanos Explorer* provides NOAA the ability to foster scientific discoveries by identifying new targets in real time, diving on those targets shortly after initial detection, and then sending this information back to shore for immediate near-real-time collaboration with scientists and experts at Exploration Command Centers around the world. The subsequent transparent and rapid dissemination of information-rich products to the scientific community ensures that discoveries are immediately available to experts in relevant disciplines for research and analysis

Through the *Okeanos Explorer* Program, NOAA's Office of Ocean Exploration and Research (OER) provides the nation with unparalleled capacity to discover and investigate new oceanic regions and phenomena, conduct the basic research required to document discoveries, and seamlessly disseminate data and information-rich products to a multitude of users. The program strives to develop technological solutions and innovative applications to critical problems in undersea exploration and to provide resources for developing, testing, and transitioning solutions to meet these needs.

Okeanos Explorer Management – a unique partnership within NOAA

The *Okeanos Explorer* Program combines the capabilities of the NOAA Ship *Okeanos Explorer* with shore-based high speed networks and infrastructure for systematic telepresence-enabled exploration of the world ocean. The ship is operated, managed and maintained by NOAA's Office of Marine and Aviation Operations, which includes commissioned officers of the NOAA Corps and civilian wage mariners. OER owns and is responsible for operating and managing the cutting-edge ocean exploration systems on the vessel (ROV, mapping and telepresence) and ashore including Exploration Command Centers and terrestrial high speed networks. The ship and shore-based infrastructure combine to be the only federal program dedicated to systematic telepresence-enabled exploration of the planet's largely unknown ocean.

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2. Report Purpose

The purpose of this report is to briefly describe the mapping data collection and processing methods, and to report the results of the cruise. For a detailed description of the *Okeanos Explorer* mapping capabilities, see appendix F and the ship's readiness report, which can be obtained by contacting the ship's operations officer (ops.explorer@noaa.gov).

3. Cruise Objectives

Cruise EX0903 had two separate objectives. The primary cruise objective was to test, troubleshoot, refine, and evaluate *Okeanos Explorer* mapping systems, sensors, protocols, and processes as they related to the systematic exploration mission of the ship. Specific goals pertaining to this objective were:

- Completion of a deep water patch test for the EM 302 sonar
- Resolution of multibeam and sub-bottom sonar cross-talk interference
- Refinement of data products pipeline and documentation
- Investigation of bubble sweep down effects on mapping instrument performance
- Evaluation of EM 302 backscatter data
- Identify and map targets for future ROV performance acceptance testing

The secondary cruise objective was to continue preparation, personnel training, and evaluation of non-mapping *Okeanos Explorer* systems and sensors. Specific goals pertaining to this objective were:

- Continued development and testing of the integrated telepresence system
- Continued ROV operations readiness preparations.

Both objectives were completed within the context of mapping the eastern extent of the Mendocino Ridge (Fig. 1) for the U.S. Extended Continental Shelf (ECS) Project bathymetry program.

4. Mapping Personnel

Name	Role	Affiliation
CDR Joseph Pica	Commanding Officer	NOAA Corps
Mr. Mashkoor Malik	Cruise Coordinator	NOAA OER
Dr. James V. Gardner	Chief Scientist	UNH-CCOM/JHC
Lt. Nikola VerPlanck	Field Operations Officer	NOAA Corps
Ms. Elaine Stuart	Senior Survey Technician	NOAA OMAO
Ms. Colleen Peters	Senior Survey Technician	NOAA OMAO
Mr. Jim Kintzele	Chief Electronics Technician	NOAA OMAO
Mr. Eric Thompson	Electronics Technician	NOAA OMAO
Mr. Jared Harris	Engineer	Kongsberg Maritime AS
Mr. Christopher Paul	Multibeam watchstander	OER Intern
Ms. Hillary Hall (departed in Eureka, CA)	Multibeam watchstander	OER Intern
Mrs. Kelly Carignan	Multibeam watchstander	OER Intern

5. Cruise Statistics

Dates	JD125 to JD245
Weather delays	0 days
Total non-mapping days (transits)	5 days
Total mapping days	8.5 days
Line kilometers of survey	6028 km
Total area mapped	14,136 km^2 (5458 mi^2)
Beginning draft	4.81 m (bow) 4.49 m (stern)
Ending draft	m
Average ship speed for survey	8.9 kts
Total Mendocino Ridge area mapped	km^2

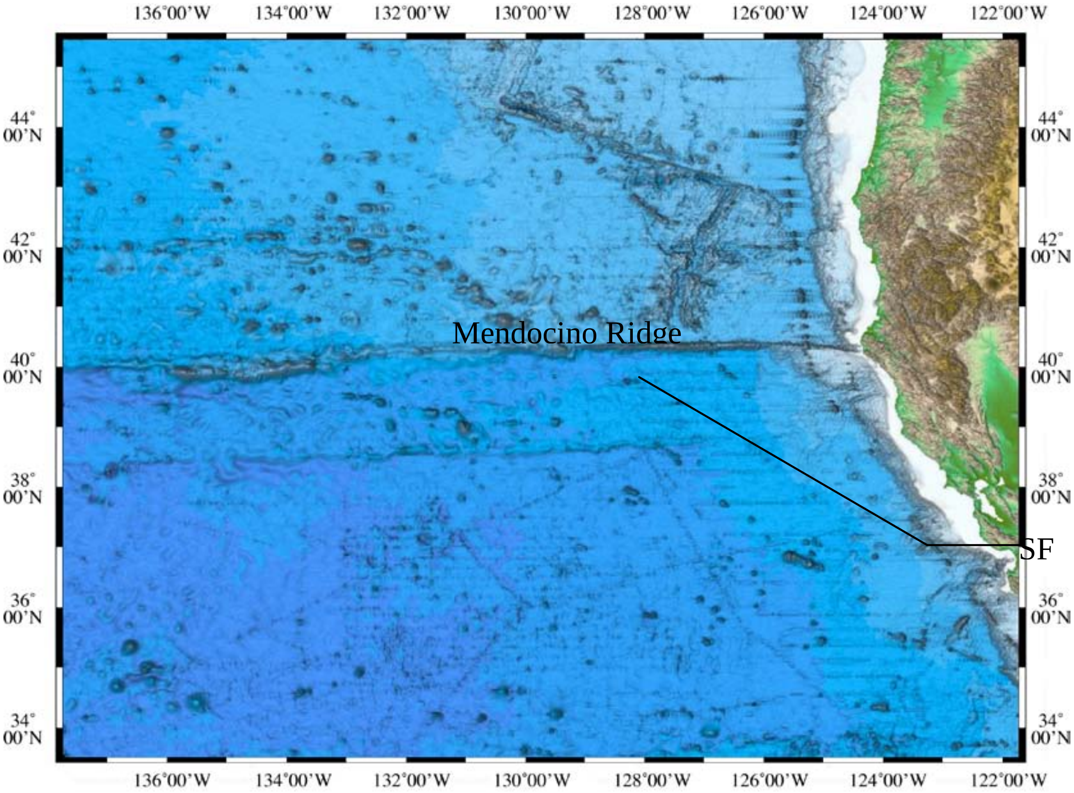


Figure 1. Location of eastern Mendocino Ridge and transit track (black line) from San Francisco, CA to the patch test area.

Figure 2. NOAA Ship Okeanos Explorer (R337) used to map the eastern Mendocino Ridge.

6. The Multibeam Echosounder System and Associated Systems

A hull-mounted Kongsberg Simrad EM302 MBES system was used to map bathymetry and acoustic backscatter. The EM302 30-kHz MBES system transmits a 0.5˚ wide swath and forms up to 432-1˚ receive apertures over a maximum swath of 150˚. A thermosalinograph with an intake somewhat distant from the transducers was used to measure the salinity and water temperature at the sonar array and from those data a sound speed was calculated. The High Density Equidistant beamforming mode was used for the EM302 to produce seafloor footprints of each receive beam that are equally spaced along each ping. Bottom detection on all beam is determined by both phase and amplitude. For beams at near-normal incidence the depth values are determined by center-of-gravity amplitude detection but for most of the beams the depth is determined by interferometric phase detection. Individual soundings along track are spaced approximately every 20 m, regardless of survey speed. The manufacturer states that, at the 7-ms pulse length (deep mode), the system is capable of depth accuracies of 0.3 to 0.5% of water depth. A pulse length of 7 ms was used in depths shallower than 3000 m but the pulse length was increased to 20 ms in deeper depth to increase the signal-to-noise ratio.

The motion reference units (MRU) was an Applanix POS/MV 320 version 4 for instantaneous heave, pitch and roll and heading. The EM302 system can incorporate transmit beam steering up to ±10˚ from vertical, and yaw and roll compensation up to ±10˚. The Applanix POS/MV was interfaced with a C&C Technologies C-Nav differential-aided GPS (DGPS) receiver that provides real-time correctors to the DGPS position fixes, providing an accuracy of <±0.5 m. All horizontal positions were georeferenced to the WGS84 ellipsoid and vertical referencing was to instantaneous sea level.

The Simrad EM302 is capable of simultaneously collecting full time-series acoustic backscatter along with the bathymetry. This represents a time series of backscatter values across each beam footprint on the seafloor. If the received amplitudes are properly calibrated to the outgoing signal strength, receiver gains, spherical spreading, and attenuation, then the calibrated backscatter should provide clues as to the composition of the surficial seafloor.

All systems are referenced to a stable reference mark located close to the POS/MV sensors. The position of each system was surveyed relative to the reference mark providing a table of initial offsets (Table 1). A patch test was run immediately prior to the mapping to determine any static offset corrections (Tables 1 and 2).

Water-column sound-speed profiles were calculated from casts of Sippican model Deep Blue (760 m maximum depth and extrapolated to deeper depths) expendable bathythermographs (XBTs) to measure temperature as a function of depth routinely every 6 hours and between scheduled casts as required. A Sea Bird Electronics model SBE-9plus CTD was used to calibrate the XBTs during the patch test. The two temperature sensors (serial no. 5001 and 5017) and the two conductivity sensors (serial no. 3451 and 3449) were last calibrated by Sea Bird Electronics on May 29, 2008. Derived sound-speed profiles derived from the two systems (CTD vs XBT) were compared between the systems to calibrate the XBT (Fig. 3).

	Location Offsets			**Angular Offsets**		
Sensor	**Forward**	**Stbd**	**Down**	**Roll**	**Pitch**	**Heading**
POS 1	0.00	0.00	0.00			
POS 2	0.00	0.00	0.00			
POS 3	0.00	0.00	0.00			

Tx tdr	6.147	1.822	6.796	0.00	0.00	359.98
Rx tdr	0.00	0.00	0.00	0.00	0.00	0.03
Attitude 1	0.00	0.00	0.00	0.00	-0.70	0.00
Attitude 2	0.00	0.00	0.00	0.00	0.00	0.00

Draft 4.81 m bow, 4.49 m stern
Stand-alone heading 0.00

Table 1. Initial system sensor offsets.

Offset	Value
roll	0
pitch	0
yaw	0
latency	0

Table 2. Offset corrections determined by Patch Test.

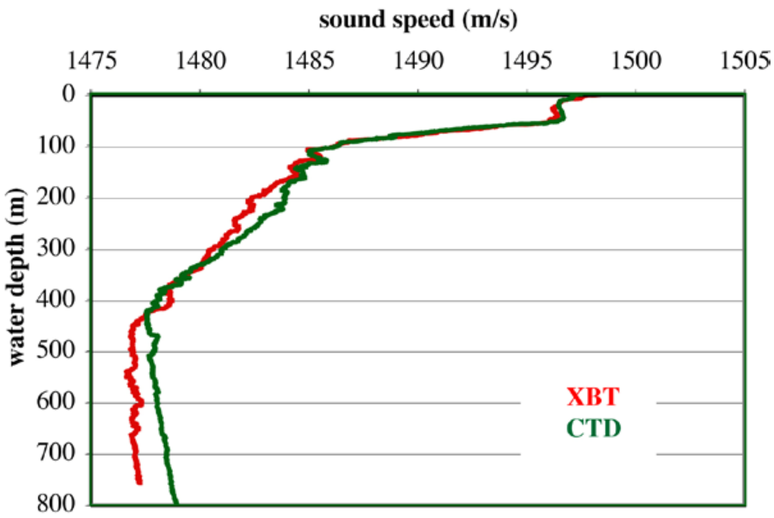


Figure 3. Comparison of sound speed calculated from an XBT and CTD cast at the patch test.

7. Ancillary Systems

Although a Knudsen 3260 3.5-kHz high-resolution subbottom profiler is installed on the ship, it has not been synchronized with the EM302 MBES. The lack of synchronization results in severe interference on the MBES data. In addition, the 3260 can record the subbottom data only in a proprietary Knudsen KEB format or a Knudsen version of SEG-Y. Although SEG-Y is the standard format for seismic data, the KEB format is non-standard. Tests both before and during the initial transit from San Francisco shows that the latest version of the Knudsen PostSurvey software and Chesapeake Technologies SonarWizMap4 can read the Knudsen SEG-Y files. But, because of the severe interference, the subbottom profiler was not used during the mapping.

8. MBES Data Processing

The raw Simrad multibeam bathymetry and acoustic backscatter data were processed aboard ship using the University of New Brunswick's SwathEd software suite, version 20080916. Each Simrad raw.all file was collected by the onboard Kongsberg Simrad SIS data-acquisition system. Once a line was completed, the raw.all file was copied to a server that could be accessed by the UNH computer via a shipboard network. Each raw.all file was renamed from the system-generated file name to *Mendocino line_n_raw.all* (see Table 3) so that later each file could be easily identified to the area. The line numbers commenced with Mendocino_line_transit1 and then Mendocino_line_1 when the actual mapping began. Each raw.all file is composed of individual data packets of beam bathymetry (range and angle), beam average and full time-series acoustic backscatter, navigation, parameters, sound-speed profiles, orientation and sound speed at the transducer. The first step in the processing separates each of these data packets into the individual files.

The second step in the processing plots the navigation file so that any bad fixes can be flagged. Once this step is completed, the validated navigation is merged with the bathymetry and acoustic backscatter files.

The third step involves editing (flagging) individual soundings that appear to be fliers, bad points, multipaths, etc. The entire file of soundings is viewed and edited in a sequence of steps through the file. Once the bathymetry file has been edited, the valid individual soundings are gridded into subarea DTM maps and the co-registered valid acoustic backscatter full beam time series is assembled into a file and gridded into subarea mosaics.

The entire region to be mapped was subdivided into 70 subarea bathymetry maps and (Fig. 4, upper panel). Each subarea map was designed to maximize the spatial resolution allowed by the mapped water depths within the area. The region was also subdivided into larger Mendocino East and Mendocino West regional maps and mosaics with 40 m/pixel spatial resolution (Figs. 4, lower panel).

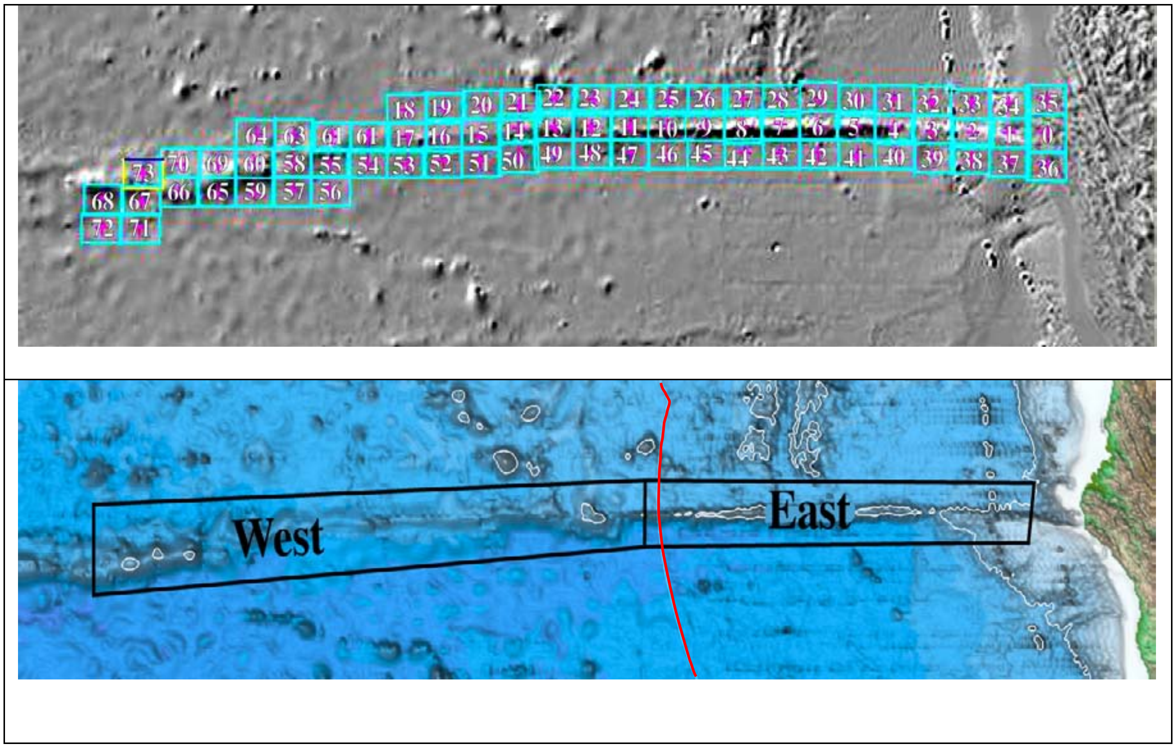


Figure 4. (upper panel) Seventy one sub area maps. (lower panel) Subdivision of regional area and U.S. EEZ boundary (red).

9. The Area: Eastern Mendocino Ridge

The area to be mapped during the Mendocino Ridge cruise was defined by the westward extension of the ridge beyond the U.S. EEZ (Fig. 4 lower panel, black polygons). In order to satisfy the requirements of UNCLOS Article 76, the region between the ~1000 and 5000-m isobaths was mapped to provide the necessary bathymetry for the development of a potential U.S. extended continental shelf claim beyond the U.S. EEZ.

The exhaustive study of the U.S. data holdings pertinent to the formulation of U.S. potential claims of an extended continental shelf under the United Nations Convention of the Law of the Sea (UNCLOS) (Mayer, et al., 2002) did not identify this area as one of the regions where new bathymetric surveys are needed. However, the ECS Task Force considered the Mendocino Ridge might be a potential extension for the U.S. The Mayer et al. (2002) report recommended that multibeam echosounder (MBES) data are needed to rigorously define (1) the foot of the slope (FoS), a parameter of the two UNCLOS-stipulated formula lines, and (2) the 2500-m isobath, a parameter of one of the UNCLOS-stipulated cutoff lines. Both of these parameters, the first a precise geodetic isobath and second a geomorphic zone, are used to define an extended continental shelf claim. The Center for Coastal and Ocean Mapping/Joint Hydrographic Center (CCOM/JHC) of the University of New Hampshire was directed by the U.S. Congress, through funding to the U.S. National Oceanic and Atmospheric Administration (NOAA), to conduct the new surveys and archive the resultant data.

The section of Mendocino Ridge, properly called the Gorda Escarpment, was previously mapped between 125˚W and 128˚W using the GLORIA long-range side-scan sonar (EEZ-SCAN, 1986; Masson et al, 1988) and then with a SeaBeam 2100 multibeam (Dziak et al., 2001). However, none of these data were considered accurate enough or extensive enough for a UNCLOS submission.

The general region is located in the eastern North Pacific Ocean west of Cape Mendocino, CA (Fig. 1). Physiographically, the Mendocino Ridge is a narrow, linear ridge standing more than 1 km above the basin floor with a summit generally more than 1000 m deep. Several published studies divide Mendocino Ridge into the seismically active Gorda Escarpment that extends east from Gorda Ridge and the seismically inactive Mendocino Ridge that extends west from Gorda Ridge (Fig. 5), although the feature is clearly one continuous ridge. Geologically, the ridge represents the plate boundary between the Pacific, North American and Gorda Plates (Atwater, 1979; 1989).

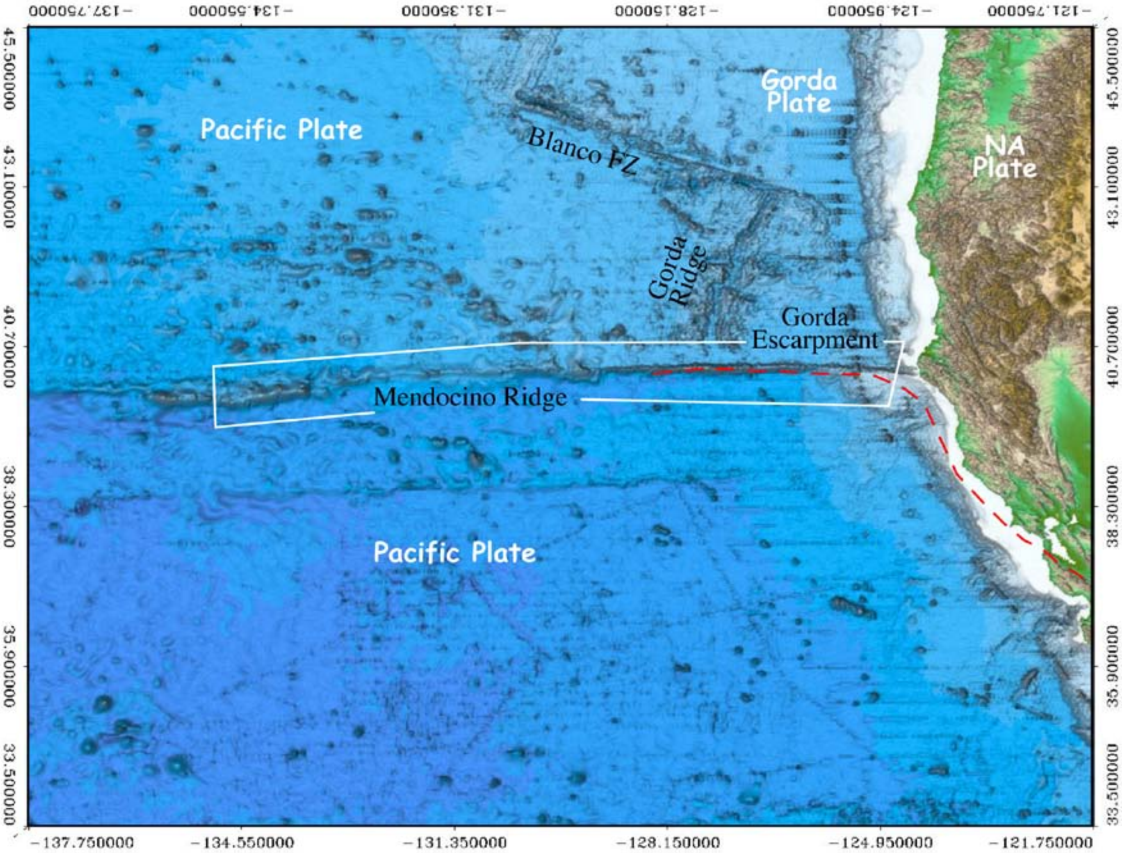


Figure 5. Overview map of physiographic features in Mendocino Ridge area.

Rocks dredged from the ridge range in composition from tholeiitic and alkaline basalts (Engel and Engel, 1963; Krause et al., 1964; Fisk et al., 1993; Kela et al., 2007). Fisk et al. (1993) report rounded basalt pebbles and cobbles dated at ~11 Ma and suggest the rounding is the result of erosion in a beach environment. Consequently, they propose the Mendocino Ridge has subsided ~1000 m in the past 11 Ma. This interpretation is in opposition to that of Silver (1971) and Gulick et al. (2001) who used seismic data to suggest north-south compression and underthrusting at the Gorda Escarpment by the Gorda Plate. The Silver (1971) and Gulick et al. (2001) interpretations require uplift (transpression) of the Gorda Escarpment.

Deep Sea Drilling Project Leg 5 drilled two sites (Sites 33 and 34) just south of the mapped area. Site 33 is located at the far distal reaches of the Delgada Fan and has a mixed lithology of pelagic and hemipelagic sediment. Site 34 is located well within the turbidite province of Delgada Fan (McManus et al., 1970). Interestingly, both sites collected volcanic ash in the Pleistocene sections.

It cannot be over emphasized that this cruise represents a cruise-of-opportunity for the U.S. UNCLOS Bathymetry Project to systematically collect high-quality multibeam bathymetry of the Mendocino Ridge for the U.S. UNCLOS efforts. The primary objective of the cruise was to trouble-shoot the new Kongsberg Maritime EM302 multibeam echosounder. However, the NOAA Office of Ocean Exploration and Research offered the UNH U.S. UNCLOS mapping project as much as two weeks of *Okeanos Explorer* time to map the ridge at no cost to the U.S. UNCLOS project *if the testing proved successful*. But, because testing was the first priority, it was understood that if the MBES system did not perform up to specifications, then little or no UNCLOS mapping could be accomplished. In the end, the testing was successful and almost all of the required area of the eastern Mendocino Ridge was mapped.

10. Daily Cruise Log

JD 125 (Tuesday, May 5, 2009)

The morning and early afternoon were spent on a noise test at the dock. The plan was to power down the ship and have only the UPS running the scientific lab's computers. When the Chief Engineer shut down power to the ship, the UPS tripped into a bypass mode and all power was cut. The UPS failed. The ETs found that one of the fuses on the UPS had been only hand tightened and may have arced. The UPS was repaired and the test began. The test included running the Kongsberg BIST noise tests and recording the noise from the hull hydrophone as each of the mechanical and electrical systems were brought on line. Although the hull hydrophone data may have been corrupted because the hydrophone was not powered on, the Kongsberg BIST noise tests were all successfully run. The data from the Kongsberg BIST noise tests show that noise fluctuates, apparently randomly, from ~40 dB to more than 90 dB, although the fluctuation is not correlated with any of the ships mechanical or electrical systems.

The second test was to scope the power feeds into the Kongsberg EM302 TRU box to investigate whether the box was receiving clean power or power spikes. The scope test showed very clean power to the TRU box with no spikes.

It was concluded that no more tests were necessary, so the ship was prepared for departure. The ship departed San Francisco at 1515 L (JD 125 2215 Z) and headed west away from the weather and for deep water to begin the transit to the Mendocino Ridge patch test site.

JD 126 (Wednesday, May 6, 2009)

The EM302 MBES was run unattended through the night as we transited down the continental slope. The system was in in-between mode, ±60˚ swath width, forced deep mode and no spike filter. The EM302 did not do well keeping bottom detection on the steep slope, losing bottom most of the way down. Once in the basin at ~3800 m, the system had difficulty keeping bottom lock in automatic mode, but did fairly well when forced to deep mode. The acquired swath was consistently ~90° although the swath width was forced at 120°. There was quite a lot of ship motion with heaving at ±2.5 m, pitching of ±5° and rolling at ±10°. The bow had been ballasted down to ~ -1.5° and the ship was not plowing through the seas, so bubble sweep did not appear to be a problem. Ship speed was 9.4 kts and the ping period was 4.8 s/ping. Only 23 starboard beams were recorded; all the other 193 starboard beams were rejected by the EM302 acquisition system (Fig. 6). In addition, there was no apparent correlation between ship motion and loss of bottom detection.

All systems were shut down at 1130L (1830Z) so that the ETs could balance the load on the science-services UPS. The systems were brought back on line at 1700L. after the repair to the UPS. Two ground faults were discovered during the repairs, so a Kongsberg BIST test was run once the MBES was brought back up. A series of consecutive BIST tests after the UPS repair showed noise levels below 60 dB on all tests. The seas calmed throughout the afternoon and evening.

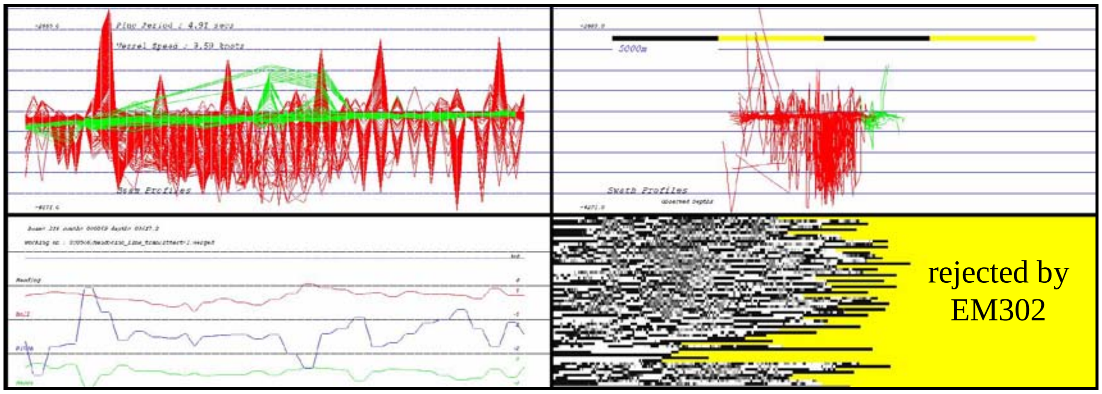


Figure 6. Beams (upper left panel) and swaths (upper right panel) from 60 pings in 3500 m water depths. Data are from transittest-1_raw.all file.

JD 127 (Thursday, May 7, 2009)

The EM302 was run throughout the night in Extra Deep mode. The seas were only ±3 ft and the wind was only ~10 kts; almost perfect conditions. The processed data from the previous night shows a lot of heave (Fig. 7) and what appears to be sector-boundary artifacts in the data (Fig. 7). Consequently, transit test line 46 was run collecting EM302 data in Extra Deep mode, FM, dual swath, in-between mode. In addition, the heave was recorded from the POS/MV so that it could be post-processed in CARIS. This test is to determine whether the POS/MV v.4 TrueHeave is performing properly.

heave artifacts

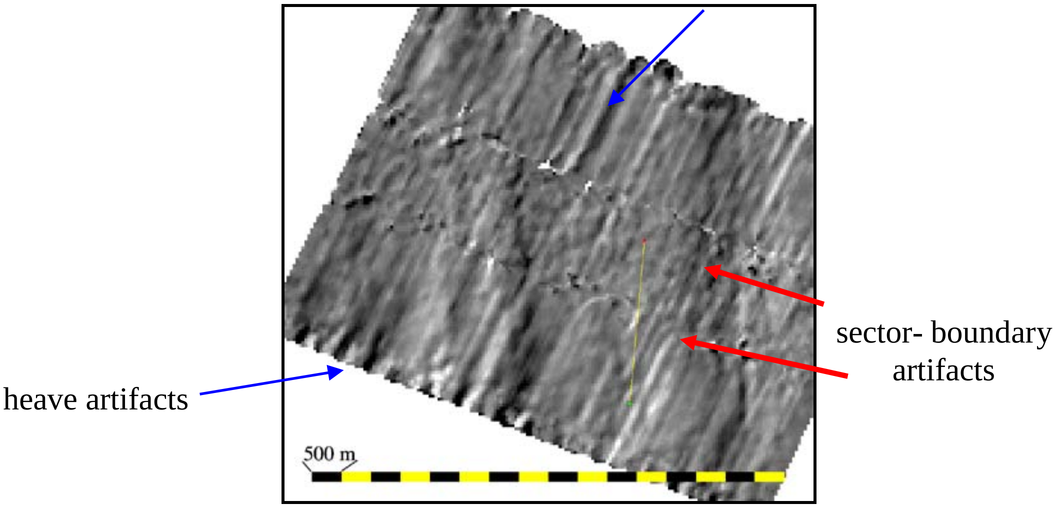


Figure 7. Transit test line 43 showing heave. Water depth 4400 m.

Transit test line 47 recorded changed from transit test line 46; it is in in-between mode and ping mode is Automatic. The system chose Deep mode when placed in Automatic. All other settings are same as transit test line 46. Figure 8 shows the results.

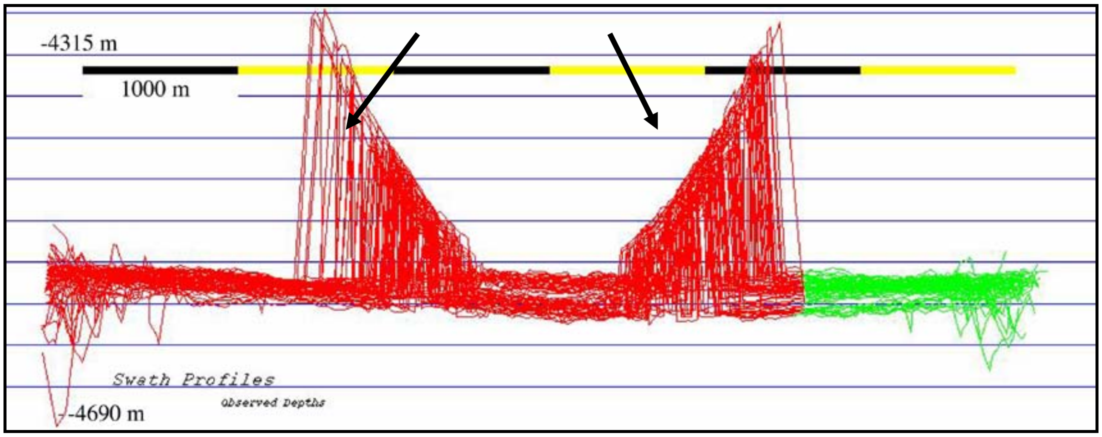


Figure 8. Unedited swath profiles from transit test line 43 showing pronounced side-lobe artifacts (arrows) at the three sector boundaries.

Transit line 46 was run in Extra Deep mode and transit line 47 was in Deep mode for comparison (Fig. 9). Transit line 48 in equiangle mode, FM, dual ping, Auto ping mode.

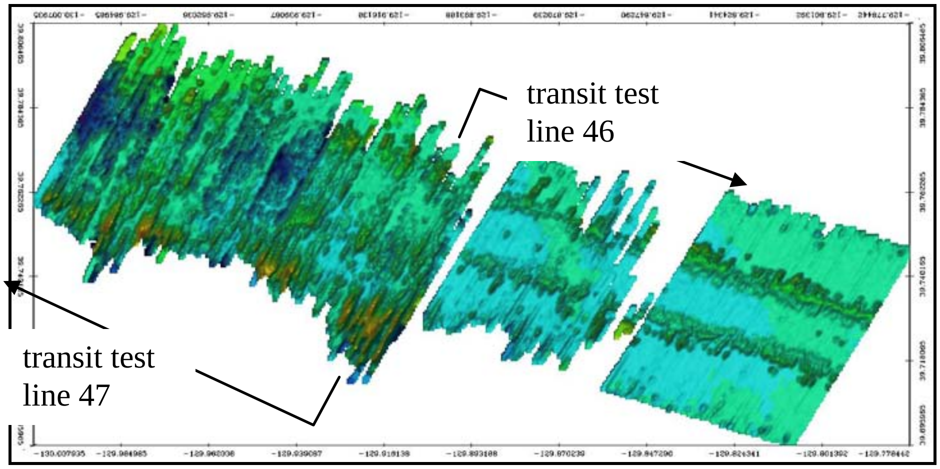


Figure 9. Comparison of Extra Deep mode (line 46) and Automatic (i.e., Deep) mode (line 47).

Transit test line 49 set up in equiangle beam spacing, FM and Dynamic modes. The system chose Very Deep mode in 4400 m water depths.

We reached the patch-test site at 1200L and by 1246L (1946Z) the CTD was in the water for the initial calibration run for sound speed. The cast took 5 hours and was completed at 1700L. The comparison confirmed that data from the Sippican Deep Blue XBT can be used to calculate an accurate sound speed for the upper 800 m of the water column (Fig. 10).

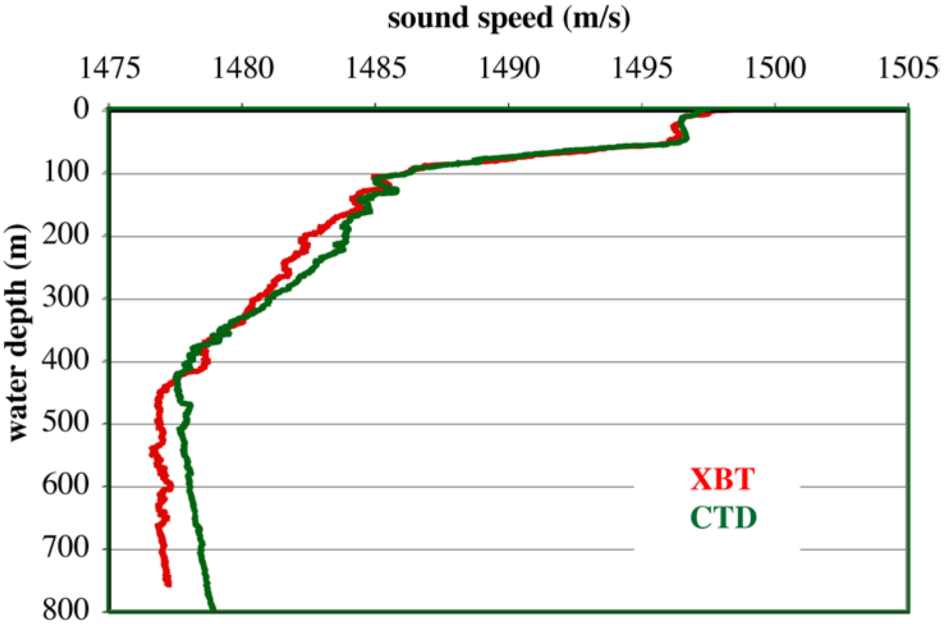


Figure 10. Comparison of sound speed calculated from a Deep Blue XBT and a Sea Bird CTD.

After the CTD was completed, we mapped due north over Mendocino Ridge. Once out of the sediment and onto the hard basalt of the ridge, the artifacts disappeared and bottom detection improved considerably. It became readily apparent that the problems we've been having with bottom detection occurred when collecting data in low-impedance sediments.

We changed our intended plan and laid out a long mapping line along the summit of Mendocino Ridge, starting roughly at the mid-point of our proposed mapping UNCLOS polygon.

The weather stayed beautiful all day and the swell was <4 ft.

The end of the transit line to the beginning of the first long E-W line is line 9. Line 9 was started late in the evening.

JD 128 (Friday, May 8, 2009)

The day was spent mapping Line 11 heading east along the crest of Mendocino Ridge. The data is high quality with no bottom-detection problems. The weather was sunny with 25 kt winds but only a 4-ft swell. By afternoon the seas had built to ~6 ft and were building as we sailed east towards the California Current. The data continued to be pretty high quality because we were mapping over the basaltic crest of Mendocino Ridge with its high acoustic impedance.

By 1430L the seas were enough to cause some bubble sweep and cavitations on the thermosalinograph. However, these effects were not enough to seriously degrade the data quality.

The first cross check was run using the Line 11 crossing of the dipline. The results were very good (Fig. 11), especially considering all the rough topography of Mendocino Ridge. The cross-check test involved 146,922 soundings and the mean water-depth difference is 1.9 m ($2\sigma = \pm 41.3$ m) in a mean water depth of 3214 m (0.06% of water depth).

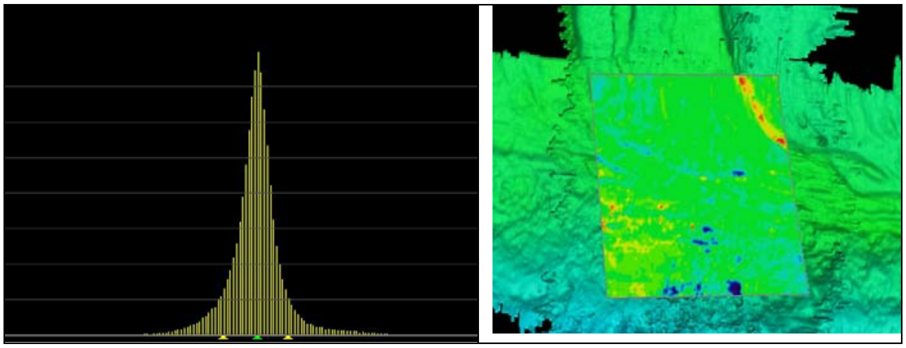
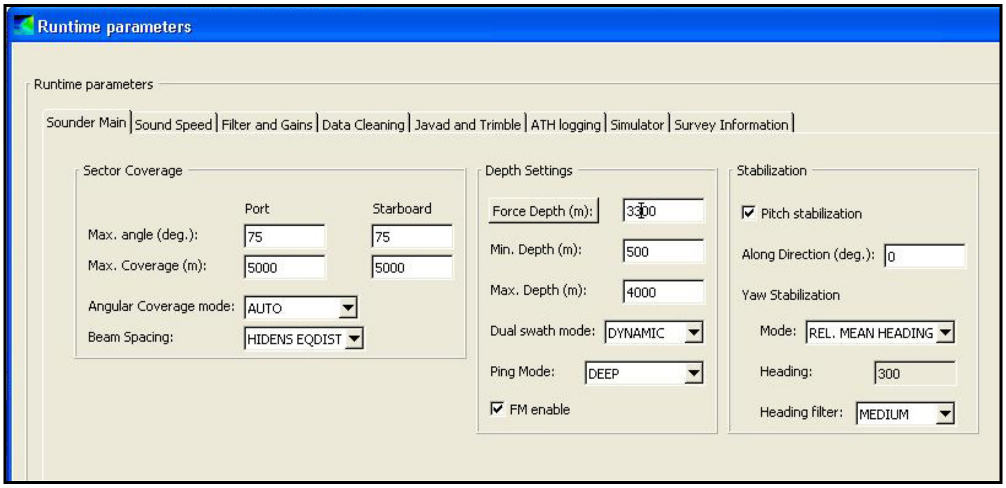


Figure 11. Cross-check errors using Line 11 vs dipline. The interior rectangle is the area of comparison.

By 1800 L, the seas and wind had continued to build and the Captain suggested we terminate Line12, transit to the north 5 km, and then begin Line 17 mapping west where the weather was reported to be much better. Throughout the afternoon and evening we experienced rolls >10° and heaves of ±2 m.

JD 129 (Saturday, May 9, 2009)

Woke up to relatively calm seas (swells of 3 ft) and not too much ship motion. Data quality is high. The last several minutes of Line 19 and all of Line 20 were corrupted because the Angular Coverage mode was in the runtime parameters was set in Manual coverage at ±75°, whereas it should have been set in Auto. After a few day of fiddling with the settings, the best settings for mapping are shown in Figure 12.


Runtime parameters

Runtime parameters

Sounder Main | Sound Speed | Filter and Gains | Data Cleaning | Javad and Trimble | ATH logging | Simulator | Survey Information

Sector Coverage

	Port	Starboard
Max. angle (deg.):	75	75
Max. Coverage (m):	5000	5000

Angular Coverage mode: AUTO

Beam Spacing: HIDENS EQDIST

Depth Settings

Force Depth (m): 3300

Min. Depth (m): 500

Max. Depth (m): 4000

Dual swath mode: DYNAMIC

Ping Mode: DEEP

☑ FM enable

Stabilization

☑ Pitch stabilization

Along Direction (deg.): 0

Yaw Stabilization

Mode: REL. MEAN HEADING

Heading: 300

Heading filter: MEDIUM

Figure 12. The runtime-parameter settings that produced the best data.

Line 22 is the first segment of an east-running line on the north side of Mendocino Ridge. The seas continued to be mild but the data began to suffer because of water depth (~3200 m) and pelagic sediments (low reflection coefficient) (Fig. 13)

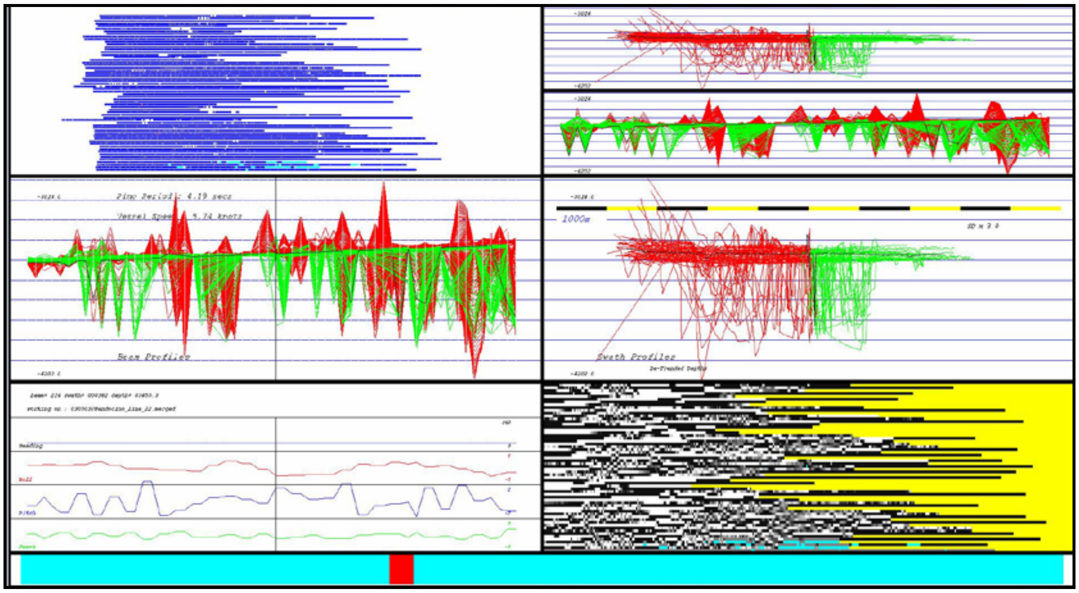


Figure 13. Screen grab of processing Line 22 collected in 3200 m water depth in pelagic sediments. Settings were Very Deep, Dual Swath, FM, high-density equiangular, Auto Angular Coverage, Max power.

JD 130 (Sunday, May 10, 2009)

The weather was nice with a 2- to 3-ft swell and a light wind; almost perfect conditions for mapping. By evening, it was downright calm. We continued on an eastward course. Lines 23 and 24 have severe refraction. We crossed to the east of Escanaba Trough of Gorda Ridge and the sediments became much more reflective (turbidites from the Eel & Columbia Rivers). The higher reflectivity allowed very strong bottom detection.

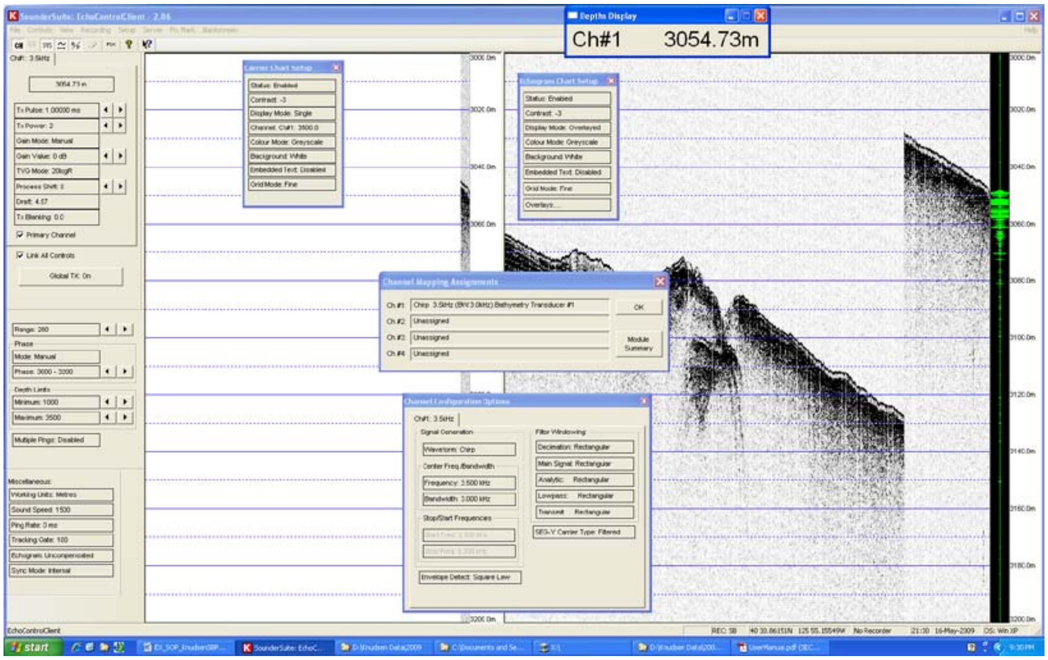
Line 27 ended the long east line at the survey polygon eastern boundary at 1800 L (0100 Z). We slowed to a crawl and powered off all electronics while the ET once again fixed ground faults in the UPS.

JD 131 (Monday, May 11, 2009)

Line 29 was run to the west until we had to break line at 0300 L to transit to Eureka to pick up a Kongsberg Simrad engineer. During the transit, the ETs continued to have problems with ground faults in the UPS. All scientific power was taken off the UPS during the night.

Around 1030 L, the ETs were working on the disk drives and immediately the EM302 was not able to record any pings. It could transmit, but not receive.

We finally got the Knudsen 3260 CHIRP subbottom profiler to work on the transit into Eureka. The settings that worked in shallow water on shown on Figure 14.



Ch#1: 3.5kHz
3054.73 m
Tx Pulse: 1.00000 ms
Tx Power: 2
Gain Mode: Manual
Gain Value: 0 dB
TVG Mode: 20logR
Process Shift: 0
Draft: 4.57
Tx Blanking: 0.0
☑ Primary Channel
☑ Link All Controls
Global TX: On
Range: 200
Phase
Mode: Manual
Phase: 3000 - 3200
Depth Limits
Minimum: 1000
Maximum: 3500
Multiple Pings: Disabled
Miscellaneous
Working Units: Metres
Sound Speed: 1500
Ping Rate: 0 ms
Tracking Gate: 100
Echogram: Uncompensated
Sync Mode: Internal

Carrier Chart Setup
Status: Enabled
Contrast: -3
Display Mode: Single
Channel: Ch#1: 3500.0
Colour Mode: Greyscale
Background: White
Embedded Text: Disabled
Grid Mode: Fine

Echogram Chart Setup
Status: Enabled
Contrast: -3
Display Mode: Overlayed
Colour Mode: Greyscale
Background: White
Embedded Text: Disabled
Grid Mode: Fine
Overlays...

Channel Mapping Assignments
Ch #1 Chirp 3.5kHz (BW 3.0kHz) Bathymetry Transducer #1
Ch #2 Unassigned
Ch #3 Unassigned
Ch #4 Unassigned
OK
Module Summary

Channel Configuration Options
Ch#1: 3.5kHz
Signal Generation
Waveform: Chirp
Center Freq./Bandwidth
Frequency: 3.500 kHz
Bandwidth: 3.000 kHz
Stop/Start Frequencies
Envelope Detect: Square Law
Filter Windowing
Decimation: Rectangular
Main Signal: Rectangular
Analytic: Rectangular
Lowpass: Rectangular
Transmit: Rectangular
SEG-Y Carrier Type: Filtered

Figure 14. Set-up parameters for Knusden 3260 CHIRP subbottom profiler.

We arrived at Eureka Harbor at 1230 L, picked up the Kongsberg engineer and departed Eureka at 1345 L.

The Kongsberg engineer (Jared Harris) got the EM320 running at 1835 L by swapping around the #1 and #4 transmit boards, even though the BIST tests showed all the boards passed. We decided to allow him a night's sleep, so we transited to the eastern boundary of the survey polygon and mapped to the west along the crest of Mendocino Ridge throughout the night. Lines 30, 31, 32 and 33 were testing and the transit back to the eastern boundary of the survey polygon.

Line 34 is the beginning of the W line that was run over night.\

JD 132 (Tuesday, May 12, 2009)

The Kongsberg engineer spent the morning installing a new patch to the version 3.6.1 SIS software and the data quality improved considerably. The late morning and all afternoon was spent collecting data south of the Mendocino Ridge in pelagic sediment (low impedance) in 4500 m water depths. The data quality was excellent, at 7 kts and even at 10 kts. The settings were as before except the Along Direction was set at 5°, pushing the receive beams 5° forward of nadir.

The weather conditions continued to be ideal for mapping. We mapped Mendocino Ridge filling in holidays throughout the afternoon and evening.

JD 133 (Wednesday, May 13, 2009)

Weather continued to be calm with swell <2 ft. Perfect mapping conditions. The MBES worked through the night unattended and collected high-quality data. However, the swath width continued to be less than anticipated, typically the swath was only 3.5 x water depth in 1750 m of water (± ~64° swath), 2.9 x water depth in 2300 m and 2 x water depth in 3400 m.

At 0915 L the MBES stopped pinging during Line 48. It stopped pinging a few hours earlier, but then, after about a dozen cycles, it started pinging again. This time it did not start up again. The temperature at the TRU was checked, but looked fine. The KM engineer started working on the case.

It appears that one or more of the receive boards is damaged, most likely because of the power supplied to the TRU is not coming from the UPS, but has bypassed the UPS. The ground faults of several days ago apparently affected one of the receive boards and it finally failed. All the transmit boards pass the BIST test, but each one fails in one slot or the other. The Seattle office of Kongsberg does not have a receive board on hand, so the replacement board must come from Norway. If the engineer can’t get the system working, the fallback plan is to have the KM engineer remove two of the receive boards and reconfigure the EM302 to 1° transmit beam and 2° receive apertures so we can eventually resume collecting data.

By dinnertime, the engineer had isolated the problem to a communication problem between the disk drive and the main EM302 unit. Evidently, if there is a choke-up communicating with the disk, the EM302 stops beam forming. Wires were restrung, switches checked out and the transmit-receive boards were all checked. The system was still in the 0.5°x 1° mode and it was fired up at 1945 L and it ran. We next ran two N-S lines, one over the other, on the shelf in ~300 m water depths. The system seemed to be fine. So, we ran off the shelf and ran a line west along the south of Mendocino Ridge to see how it works in deep water and pelagic sediments.

JD 134 (Thursday, May 14, 2009)

Another fine day for mapping; calm seas and wind. Testing in water depths of ~300 m looked promising so we traveled to deeper water and line 49 was run at 9 kts heading west along the southern Mendocino Ridge.

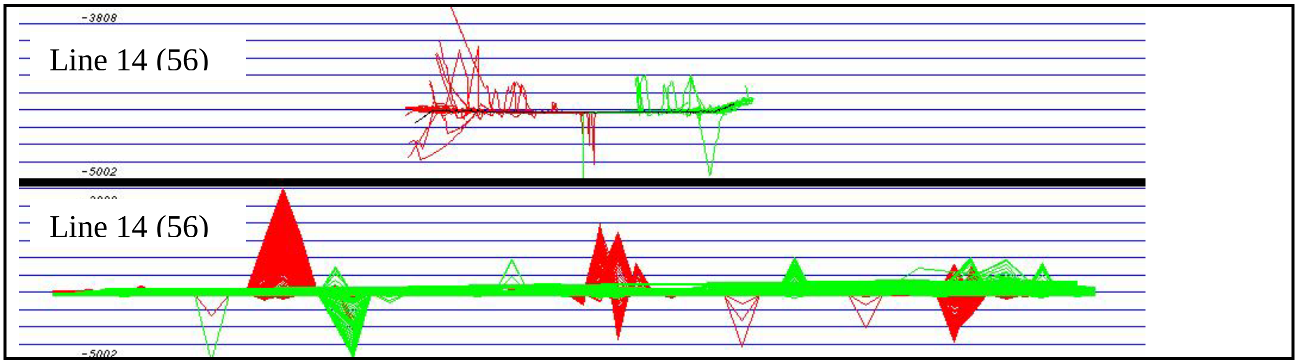
The seas got lumpy in the afternoon and evening but the data quality did not suffer. We mapped west out to ~4500 water depths and reran line 42 with the latest patches and settings to determine if these were an improvement over the original patch installed by the KM engineer. Projecting the beams 5˚ forward greatly reduces the specular nadir return.

JD 135 (Friday, May 15, 2009)

The racetrack lines were run throughout the night and morning. The main comparison was between ship lines 14 (my line 56) and 1ine 18 (my line 60) (Fig. 15). The settings for the two lines are shown in the table below:

Line	Software version	settings		
14	1.4.6	Auto coverage	Auto mode	Pitch 2˚
18	1.4.5	Auto coverage	Auto mode	Pitch 2˚

<u>Gains & Filters</u>
Spike filter: Strong
Range Gate: Normal
Penetration: Medium
Slope and Sector Tracking
Normal Incidence Sector
Angle from Nadir: 12˚



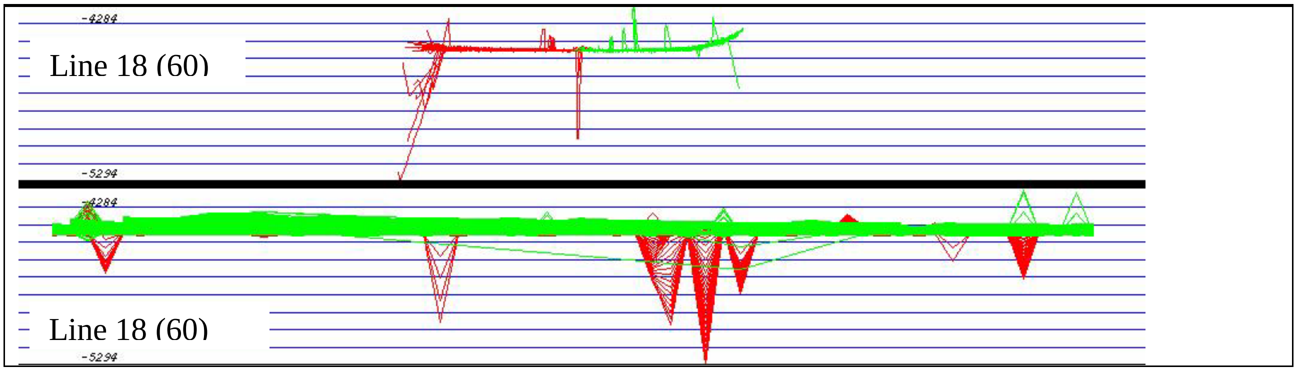


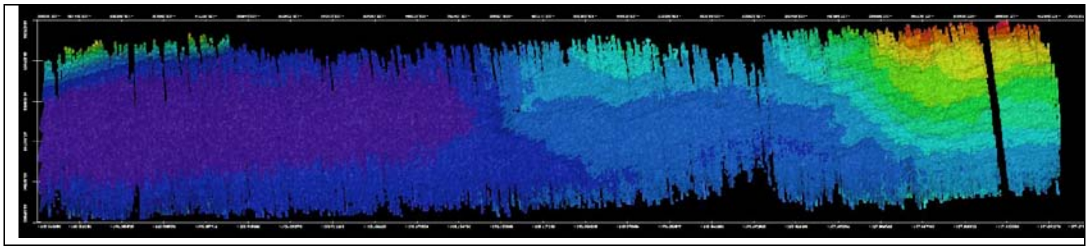
Figure 15. Comparison of beams and pings for ship line 14 (line 56) (upper two panels and ship line 18 (line 60) (bottom two panels).

The patch test was completed at 2100 L and we transited to the north of Mendocino Ridge to begin mapping to the east on a return to Eureka, CA to drop off the Kongsberg engineer and the video technicians.

A comparison of the DTMs created from the two racetrack lines clearly shows software version 1.4.5 does not reject valid data in the outer beams compared to software version 1.4.6 (Fig. 16). A cross-check analysis of the DTM from ship line 18(60) vs the data from ship line 14(56) gave a mean depth difference of -1.3 m ($\sigma = \pm 48.7$ m) in 4517 m water depth, or a mean depth precision of 0.03% of water depth. A difference surface shows the differences are randomly distributed over the analyzed area with no correlation with nadir, outer beams or along-track patterns.

More work was done on the UPS in the morning after completing the racetrack testing. Once the UPS work was completed and the MBES was put back onto the UPS, we proceeded to run a patch test.

The pitch and roll part of the patch test was run on N-S lines (lines 63 and 64) that crossed from the deep (~4450 m) southern basin to the shallower (~3000 m) northern basin. A roll test was run in the racetrack area (lines 58 and 60) in the deep the southern basin and showed no offset. Timing was run on lines 64 and 65 and showed no offset. Data from adjacent lines of the meandering channel along the proximal northern basin show that there is no yaw offset.



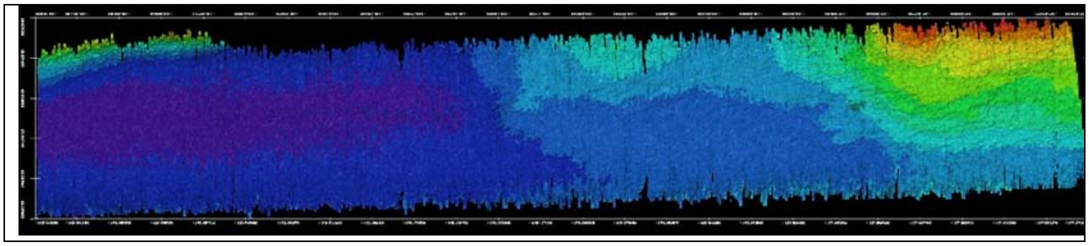


Figure 16. DTMs for ship line 14 (56) (upper panel) and ship line 18 (60) (lower panel.

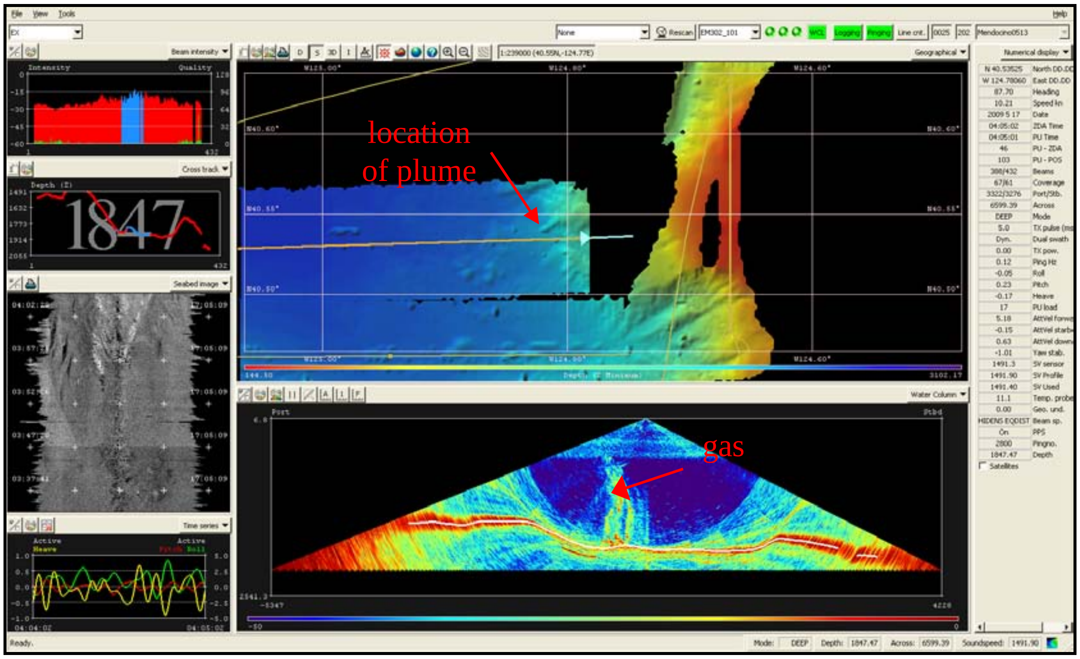
JD 136 (Saturday, May 16, 2009)

The night watch began mapping on a line running east on the north side of Mendocino Ridge. After several hours of mapping, they realized the new swath did not overlap the previous data. So, they broke the line, moved it south, and resumed mapping. Mapping continued throughout the morning in lumpy seas and clear skies.

Experimentation shows that the dual swath mode in ~3000 m water depths does not have enough time to charge the transmit capacitors so full power is not achieved. It is best to force the system out of dual swath mode in depths deeper than ~3000 m (depending on bottom strength).

We stopped logging the EM302 at 1030L to experiment with the Knudsen triggering problem. After an unsuccessful test to have the EM302 delay and trigger the Knudsen 3260, we transited back to the break-off point and resumed mapping east along the northern part of Mendocino Ridge at 1600L.

The east-running line 71 was completed at 2125L. On the transit to Eureka, we crossed over Eel Fan and onto the slope. The water column display (Fig. 17) began to show what appears to be gas in the water column at ~1845 m water depth, slightly advected to the north, presumably by currents. The apparent gas plume emanated from a large margin failure with very high acoustic backscatter (Fig. 18).

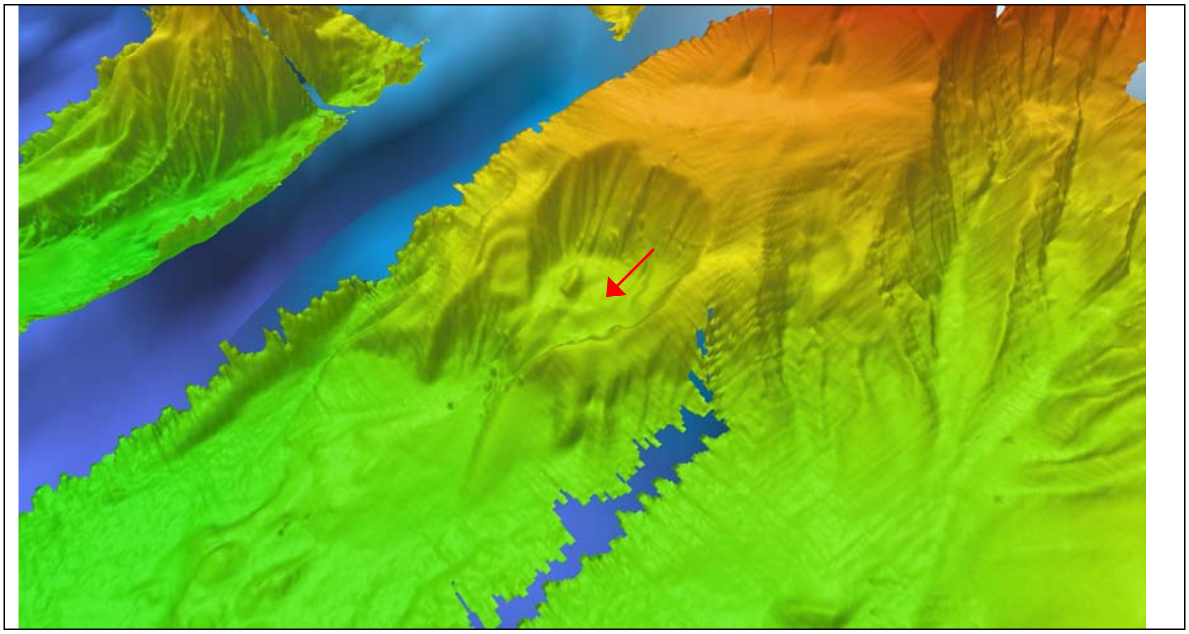


N 40.53525	North DD.DD
W 124.78060	East DD.DD
87.70	Heading
10.21	Speed kn
2009 5 17	Date
04:05:02	ZDA Time
04:05:01	PU Time
46	PU - ZDA
103	PU - POS
388/432	Beams
67/61	Coverage
3322/3276	Port/Stb.
6599.39	Across
DEEP	Mode
5.0	TX pulse (m
Dyn.	Dual swath
0.00	TX pow.
0.12	Ping Hz
-0.05	Roll
0.23	Pitch
-0.17	Heave
17	PU load
5.18	AttVel forw
-0.15	AttVel starb
0.63	AttVel down
-1.01	Yaw stab.
1491.3	SV sensor
1491.90	SV Profile
1491.40	SV Used
11.1	Temp. probe
0.00	Geo. und.
HIDENS EQDIST	Beam sp.
On	PPS
2800	Pingno.
1847.47	Depth

☐ Satellites

Mode: DEEP Depth: 1847.47 Across: 6599.39 Soundspeed: 1491.90

Figure 17. Apparent gas in the water column (red arrow) shown in the water-column display (lower panel).



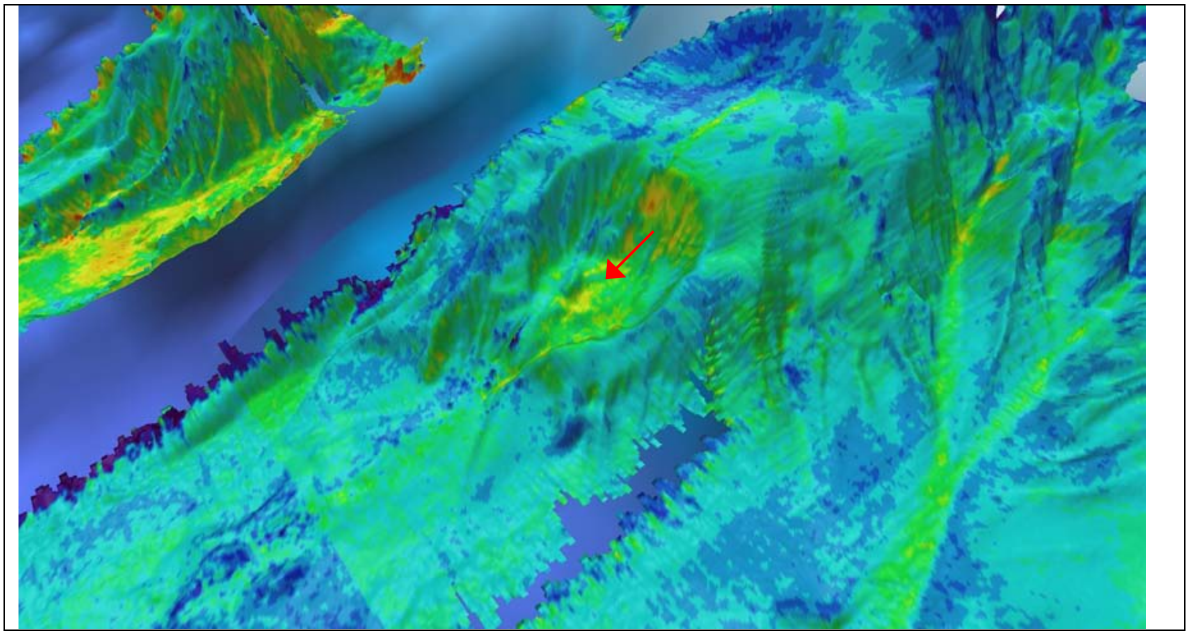


Figure 18. (upper panel) DTM showing area of apparent gas in water column (red arrow). (lower panel) Acoustic backscatter of same area, showing high backscatter.

JD 137 (Sunday, May 17, 2009)

A short mapping line was running west and then was terminated for the transit to Eureka to disembark the Kongsberg engineer, video engineers and one watchstander (Hillary Hall). Ms. Hall said she was advised by the ship nurse to depart in Eureka because she was having a reaction to some medications she was taking.

The disembarkation was completed by 0915L and we transited to the SE corner of the Mendocino Ridge survey to begin mapping to the west. Line 82 began the west-running line at the SE corner of the bottom of the East survey. The seas were pretty lumpy all afternoon and evening but the data quality in 2000 m water depths did not suffer much. That said, we still had to take the EM302 out of Auto mode and force it to Very Deep mode to keep bottom detection.

JD 138 (Monday, May 18, 2009)

The wind and sea calmed down during the night and the morning was relatively quiet. The MBES ran all night in Manual/Very Deep mode in 4000 to 4500 m depths without any intervention. Swath widths in these depths is ~1.6 x WD.

A switch of power to the repaired UPS required shutting down the MBES for about an hour starting at 0900L. The line was terminated, the one-hour switch to UPS was completed, and we doubled back to continue the line. The line was resumed (line 87) at 1100L.

JD 139 (Tuesday, May 19, 2009)

Calm morning; perfect for mapping. The afternoon got cloudy and breezy and a little lumpy. We continued mapping in the eastern half of Mendocino Ridge, filling in holidays and preparing for the long line to the western half. The long line west (line 96) was started at 1600 L. This is the southern-most, and last, line of the East section of Mendocino Ridge.

JD 140 (Wednesday, May 20, 2009)

Swells up to ~5 ft and choppy seas all night and all day. Lots of bubble sweep during the night. Had to terminate the line and spent an hour to replace another fuse in the UPS. Spent the morning mapping the southern extent of the large volcanic field. The EM320 was put in manual Extra Deep at 4600 m and kept there, giving a swath of 1.4 x water depth.

The East block of Mendocino Ridge was completed at 1900 L and we began a long line along the ridge crest in the West block.

A crossline check of Line 2 vs Line 105 shows a mean error of 6 m (σ =±41 m) or 0.13% of water depth in 4600 m water depths (Fig. 19)

JD 141 (Thursday, May 21, 2009)

The day was calm, bright and perfect weather for mapping. The system spent the night and day in Auto Very Deep Mode in ~4300 m depths and needed no intervention. The entire day was spent on the first long line in the Mendocino West block.

At ~1145L the POS/MV crashed; that ended Line 109. It took about 5 minutes to get the POS/MV back online.

We stopped mapping at the western end of the Western block and ran Line 111 to the SW to search for water deeper than 5000 m to see what depth the EM302 finally could not get bottom detection.

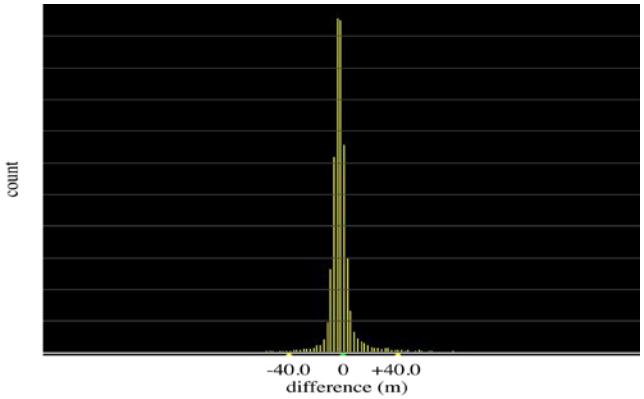


Figure 19. Crossline check between Lines 2 and 105.

The results of the deep-water extinction test is shown in Table 5. Once the test was completed, we transited back to the western border of the Western block and mapped a line eastward to the north of the previous mapped lines. We resumed the mapping at 2100L.

Table 5.

nadir depth (m)	swath width (x WD)	mode
5150	1.3	Extra deep
5150	1.6	Very deep
5313	1.6	Very deep

Table 3. Results of deep-water extinction test.

JD 142 (Friday, May 22, 2009)

Breezy, clear and cool with a ~5-ft swell causing some pitch and heave. Data quality still high but pitching is creating some bubble sweep even though the swells are not large. Slowed to ~8 kts but that didn't make much difference. Switched to Manual Very Deep mode and that stopped the dropped pings because of heave and pitch. We continued to map in the western block of Mendocino Ridge. The seas got rougher during the afternoon, which caused a lot of bubble sweep and bottom-detection loss.

JD 143 (Saturday, May 23, 2009)

The night and morning were foggy, a little lumpy causing some pitching but it died down by 1100 L. Data quality is high in Auto (Very Deep) mode with a 3˚ forward pitch.

JD 144 (Sunday, May 24, 2009)

A beautiful and calm day that is perfect for mapping. The data quality is excellent and the system has been in Auto mode all day. Line 119 was terminated so that we could map back to the east and complete mapping the section of the ridge before we had to transit back to San Francisco.

JD 145 (Monday, May 25, 2009)

The day was a bit lumpy but the data quality was excellent. Line 122 ended the mapping of eastern Mendocino Ridge at 0930 L. We began the transit to San Francisco.

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12. Appendices

Appendix A. Conversion table of NOAA raw.all file names to UNH file names by Julian Day

JD	Data Folder	NOAA file name .all	UNH file name raw.all	Notes
126	**090506**	**0000_20090506_001600**	**Mendocono_line_SFtest-1**	testing
	090506	0001_20090506_030243	Mendocino_line_transittest2	in basin @ 3700 m
	090506	0002_20090506_033243	Mendocino_line_transittest4	
	090506	0003_20090506_040243	Mendocino_line_transittest5	
	090506	0004_20090506_040345	Mendocino_line_transittest6	
	090506	0005_20090506_050257	Mendocino_line_transittest7	
	090506	0006_20090506_125808	Mendocino_line_transittest8	
	090506	0007_20090506_132816	Mendocino_line_transittest9	
	090506	0008_20090506_135807	Mendocino_line_transittest10	
	090506	0009_20090506_142811	Mendocino_line_transittest11	
	090506	0011_20090506_150014	Mendocino_line_transittest12	
	090506	0012_20090506_153037	Mendocino_line_transittest13	
	090506	0013_20090506_160035	Mendocino_line_transittest14	
	090506	0014_20090506_163044	Mendocino_line_transittest15	
	090506	0015_20090506_170035	Mendocino_line_transittest16	
	090506	0016_20090506_173042	Mendocino_line_transittest17	
	090506	0017_20090506_180042	Mendocino_line_transittest3	testing @4200 m
127	**090507**	**0018_20090507_000012**	**Mendocino_line_transittest18**	
127	090507	0019_20090507_003006	Mendocino_line_transittest19	
127	090507	0020_20090507_010011	Mendocino_line_transittest20	
127	090507	0021_20090507_024245	Mendocino_line_transittest21	
127	090507	0022_20090507_031238	Mendocino_line_transittest22	
127	090507	0023_20090507_034243	Mendocino_line_transittest23	
127	090507	0024_20090507_041241	Mendocino_line_transittest24	
127	090507	0026_20090507_051244	Mendocino_line_transittest26	
127	090507	0027_20090507_054245	Mendocino_line_transittest27	
127	090507	0028_20090507_065431	Mendocino_line_transittest28	
127	090507	0029_20090507_072429	Mendocino_line_transittest29	
127	090507	0030_20090507_07543	Mendocino_line_transittest30	
127	090507	0031_20090507_082435	Mendocino_line_transittest31	
127	090507	0032_20090507_085431	Mendocino_line_transittest32	
127	090507	0033_20090507_092433	Mendocino_line_transittest33	
127	090507	0034_20090507_095428	Mendocino_line_transittest34	
127	090507	0035_20090507_102433	Mendocino_line_transittest35	
127	090507	0036_20090507_105429	Mendocino_line_transittest36	
127	090507	0037_20090507_112428	Mendocino_line_transittest37	
127	090507	0038_20090507_115436	Mendocino_line_transittest38	
127	090507	0039_20090507_122436	Mendocino_line_transittest39	
127	090507	0040_20090507_125436	Mendocino_line_transittest40	
127	090507	0041_20090507_132438	Mendocino_line_transittest41	
127	090507	0042_20090507_135429	Mendocino_line_transittest42	
127	090507	0043_20090507_142430	Mendocino_line_transittest43	
127	090507	0044_20090507_145430	Mendocino_line_transittest44	
127	090507	0045_20090507_152458	Mendocino_line_transittest45	
127	090507	0046_20090507_154751	Mendocino_line_transittest46	
127	090507	0047_20090507_161844	Mendocino_line_transittest47	
127	090507	0048_20090507_170603	Mendocino_line_transittest48	

JD	Data Folder	NOAA file name .all	UNH file name raw.all	Notes
127	090507	0049_20090507_173611	Mendocino_line_transittest49	
127	090507	0050_20090507_180605	Mendocino_line_transittest50	
127	090507	0001_20090507_235441	Mendocino_line_1	Start of dipline
128	**090508**	**0002_20090508_003116**	**Mendocino_line_2**	**dipline**
128	090508	0003_20090508_012230	Mendocino_line_3	too small to process
128	090508	0004_20090508_012414	Mendocino_line_4	too small to process
128	090508	0005_20090508_012928	Mendocino_line_5	too small to process
128	090508	0006_20090508_013106	Mendocino_line_6	Dipline on basalt
128	090508	0007_20090508_033213	Mendocino_line_7	turn
128	090508	0008_20090508_034359	Mendocino_line_8	transit to start W-E
128	090508	0009_20090508_051019	Mendocino_line_9	continued
128	090508	00010_20090508_053655	Mendocino_line_10	turn
128	090508	00011_20090508_054833	Mendocino_line_11	**first long W-E line**
128	090508	00012_20090508_192137	Mendocino_line_12	cont. east
129	**090509**	**0013_20090509_000325**	**Mendocino_line_13**	**turn**
129	090509	0014_20090509_010705	Mendocino_line_14	turn
129	090509	0015_20090509_011147	Mendocino_line_15	turn
129	090509	0016_20090509_012944	Mendocino_line_16	turn
129	090509	0017_20090509_013559	Mendocino_line_17	**first long E-W line**
129	090509	0018_20090509_060208	Mendocino_line_18	continue west
129	090509	0019_20090509_120047	Mendocino_line_19	continue west
129	090509	0020_20090509_180008	Mendocino_line_20	eol W line-**bad data**
129	090509	0021_20090509_201225	Mendocino_line_21	transit to next line
129	090509	0022_20090509_204106	Mendocino_line_22	sol E line
130	**090510**	**0023_20090510_000013**	**Mendocino_line_23**	**continue E refract**
130	090510	0024_20090510_055945	Mendocino_line_24	continue E refract
130	090510	0025_20090510_120039	Mendocino_line_25	continue E
130	090510	0026_20090510_190520	Mendocino_line_26	continue E
131	**090511**	**0027_20090511_000008**	**Mendocino_line_27**	**end of E line**
131	090511	0028_20090511_020059	Mendocino_line_28	start of W line
131	090511	0029_20090511_055916	Mendocino_line_29	end of W line
131	090511	0030_20090511_085731	Mendocino_line_30	transit to Eureka
131	090511	0031_20090511_090915	Mendocino_line_31	transit to Eureka
131	090511	0032_20090511_170641	Mendocino_line_32	transit back to survey
132	**090512**	**0033_20090512_011826**	**Mendocino_line_33**	**start of W line**
132	090512	0034_20090512_042941	Mendocino_line_34	cont. W
132	090512	0035_20090512_061609	Mendocino_line_35	cont. W
132	090512	0036_20090512_120514	Mendocino_line_36	cont. W
132	090512	0037_20090512_141846	Mendocino_line_37	cont. W
132	090512	0038_20090512_154639	Mendocino_line_38	cont. W
132	090512	0039_20090512_162859	Mendocino_line_39	rerun earlier part
132	090512	0040_20090512_162859	Mendocino_line_40	testing in pelagics
132	090512	0041_20090512_162859	Mendocino_line_41	testing in pelagics
132	090512	0042_20090512_203032	Mendocino_line_42	racetrack test

JD	Data Folder	NOAA file name .all	UNH file name raw.all	Notes
133	**090513**	**0043_20090513_002209**	**Mendocino_line_43**	**Mapping in E**
133	090513	0044_20090513_002209	Mendocino_line_44	turn
133	090513	0045_20090513_002209	Mendocino_line_45	turn
133	090513	0046_20090513_002209	Mendocino_line_46	Mapping in E
			No line 47	
133	090513	0048_20090513_123503	Mendocino_line_48	Mapping in E
134	**090514**	**0010_20090514_112351**	**Mendocino_line_49**	**Mapping W**
134	090514	0003_20090514_025216	Mendocino_line_50	N-S slope line
134	090514	0009_20090514_091151	Mendocino_line_51	N-S slope line
134	090514	0011_20090514_180447	Mendocino_line_52	Mapping W
135	**090515**	**0012_20090515_000015**	**Mendocino_line_53**	**Mapping W**
135	090515	0013_20090515_023546	Mendocino_line_54	racetrack test
135	090515	0013_20090515_030157	Mendocino_line_55	racetrack test
135	090515	0014_20090515_031323	Mendocino_line_56	racetrack test
135	090515	0015_20090515_063334	Mendocino_line_57	turn
135	090515	0016_20090515_064617	Mendocino_line_58	racetrack test
135	090515	0017_20090515_092307	Mendocino_line_59	racetrack test
135	090515	0018_20090515_101056	Mendocino_line_60	racetrack test
135	090515	0019_20090515_130644	Mendocino_line_61	racetrack test
135	090515	0021_20090515_165556	Mendocino_line_62	transit to patch test
135	090515	0000_20090515_191444	Mendocino_line_63	N-S pitch patch test
135	090515	0002_20090515_214344	Mendocino_line_64	S-N pitch patch fast
136	**090516**	**0002_20090516_003212**	**Mendocino_line_65**	**S-N pitch patch slow**
136	090516	0006_20090516_031834	Mendocino_line_66	turn
136	090516	0007_20090516_053927	Mendocino_line_67	mapping to E
136	090516	0008_20090516_074820	Mendocino_line_68	mapping to E
136	090516	0009_20090516_093928	Mendocino_line_69	mapping to E
136	090516	0024_20090516_221307	Mendocino_line_70	mapping to E
137	**090517**	**0025_20090517_000658**	**Mendocino_line_71**	**end mapping to E**
137	090517	0026_20090517_041836	Mendocino_line_72	transit south
137	090517	0027_20090517_053615	Mendocino_line_73	testing
137	090517	0028_20090517_064402	Mendocino_line_74	testing
137	090517	0029_20090517_064431	Mendocino_line_75	includes a turn
137	090517	0030_20090517_072637	Mendocino_line_76	to Eureka
137	090517	0031_20090517_084659	Mendocino_line_77	includes a turn
137	090517	0032_20090517_085545	Mendocino_line_78	to Eureka
137	090517	0033_20090517_104320	Mendocino_line_79	to Eureka
137	090517	0034_20090517_105327	Mendocino_line_80	testing
137	090517	0035_20090517_110103	Mendocino_line_81	shelf to SE corner
137	090517	0036_20090517_184519	Mendocino_line_82	transit to SE corner
137	090517	0037_20090517_202019	Mendocino_line_83	Begin line to west
138	**090518**	**0038_20090518_000046**	**Mendocino_line_84**	**continuing west**
138	090518	0039_20090518_040031	Mendocino_line_85	continuing west
138	090518	0040_20090518_131111	Mendocino_line_86	continuing west
138	090518	0041_20090518_185823	Mendocino_line_87	continuing west

JD	Data Folder	NOAA file name .all	UNH file name raw.all	Notes
139	**090519**	**0042_20090519_000000**	**Mendocino_line_88**	**end west**
139	090519	0043_20090519_033348	Mendocino_line_89	turn
139	090519	0044_20090519_034645	Mendocino_line_90	east
139	090519	0045_20090519_060015	Mendocino_line_91	east
139	090519	0046_20090519_083912	Mendocino_line_92	east
139	090519	0047_20090519_091202	Mendocino_line_93	east
139	090519	0048_20090519_095208	Mendocino_line_94	east
139	090519	0049_20090519_170303	Mendocino_line_95	east
139	090519	0051_20090519_185115	Mendocino_line_96	east
139	090519	0052_20090519_220151	Mendocino_line_97	south transit
139	090519	0054_20090519_225319	Mendocino_line_98	west
140	**090520**	**0055_20090520_000204**	**Mendocino_line_99**	**west**
140	090520	0056_20090520_060012	Mendocino_line_100	east
140	090520	0059_20090520_125021	Mendocino_line_101	east
140	090520	0060_20090520_162827	Mendocino_line_102	east
140	090520	0061_20090520_181432	Mendocino_line_103	west
140	090520	0063_20090520_230147	Mendocino_line_104	west
141	**090521**	**0064_20090521_000743**	**Mendocino_line_105**	**last line in East**
141	090521	0065_20090521_014531	Mendocino_line_106	first line in West
141	090521	0066_20090521_060405	Mendocino_line_107	mapping west
141	090521	0067_20090521_121020	Mendocino_line_108	mapping west
141	090521	0068_20090521_180003	Mendocino_line_109	mapping west
141	090521	0070_20090521_185321	Mendocino_line_110	mapping west
141	090521	0071_20090521_211534	Mendocino_line_111	extinction line
142	**090522**	**0072_20090522_000005**	Mendocino_line_111a	**extinction line**
142	090522	0072_20090522_000005	Mendocino_line_111b	
142	090522	0075_20090522_060032	Mendocino_line_112	mapping east
142	090522	0076_20090522_083257	Mendocino_line_113	mapping east
142	090522	0077_20090522_120029	Mendocino_line_114	mapping east
142	090522	0078_20090522_180125	Mendocino_line_115	mapping east
143	**090523**	**0079_20090523_000030**	**Mendocino_line_116**	**mapping east**
143	090523	0081_20090523_064917	Mendocino_line_117	mapping west
143	090523	0082_20090523_120513	Mendocino_line_118	mapping west
143	090523	0083_20090523_182047	Mendocino_line_119	mapping west
143	090523	0084_20090523_182047	Mendocino_line_119	mapping west
143	090523	0085_20090523_234624	Mendocino_line_120	mapping east
144	**090524**	**0086_20090524_060206**	**Mendocino_line_121**	**mapping east**
144	090524	0087_20090524_060206	Mendocino_line_122	mapping east
		END OF CRUISE	**END OF CRUISE**	

Appendix B. Location of XBT cast

XBT number	Latitude N	Longitude W
1	38.503792	-125.468180
2	40.027510	-130.291178
3	40.341730	-130.258886
4	40.348570	-129.052897
5	40.355334	-127.879020
6	40.406570	-126.784537
7	40.400750	-127.811637
8	40.393470	-129.047265
9	40.385986	-130.307487
10	40.434261	-129.673877
11	40.441100	-128.508520
12	40.448377	-127.236198
13	40.455611	-125.990788
14	40.371712	-124.791423
15	40.368780	-125.375140
16	40.365560	-126.003890
17	40.548645	-125.344824
18	40.416305	-124.788119
19	40.404690	-124.479790
20	40.392850	-126.522499
21	40.223718	-128.347917
22	40.339413	-127.148145
23	40.303646	-126.074740
24	40.309713	-124.799854
25	40.308529	-125.110221
26	40.304578	-126.299105
27	40.300553	-127.511361
28	40.267582	-128.325049
29	40.416895	-128.057927
30	40.416895	-128.001888
31	40.526445	-127.717953
32	40.513505	-126.630176
33	40.513505	-125.531169
34	45.799800	-125.763330
35	40.529802	-125.023226
36	40.334066	-125.011589
37	40.348071	-124.722884
38	40.260083	-125.700326
39	40.252271	-126.876725
40	40.248324	-128.121973

XBT number	Latitude N	Longitude W
41	40.247331	-128.721794
42	40.256608	-129.950033
43	40.290629	-129.826205
44	40.295520	-128.764160
45	40.344531	-127.819385
46	40.201461	-127.760400
47	40.201461	-127.760400
48	40.208570	-128.909994
49	40.177616	-129.859131
50	40.128422	-129.419108
52	40.219360	-130.401042
53	40.150134	-131.634684
54	40.070418	-132.907536
56	39.991150	-134.172233
59	39.711829	-135.432080
60	39.931714	-134.867529
61	40.084078	-133.672656
64	40.220060	-131.327588
65	40.333057	-130.507357
66	40.262162	-131.752979
67	40.190780	-133.005713
68	40.187976	-133.665706
69	40.237581	-132.878304
70	40.314962	-131.648926

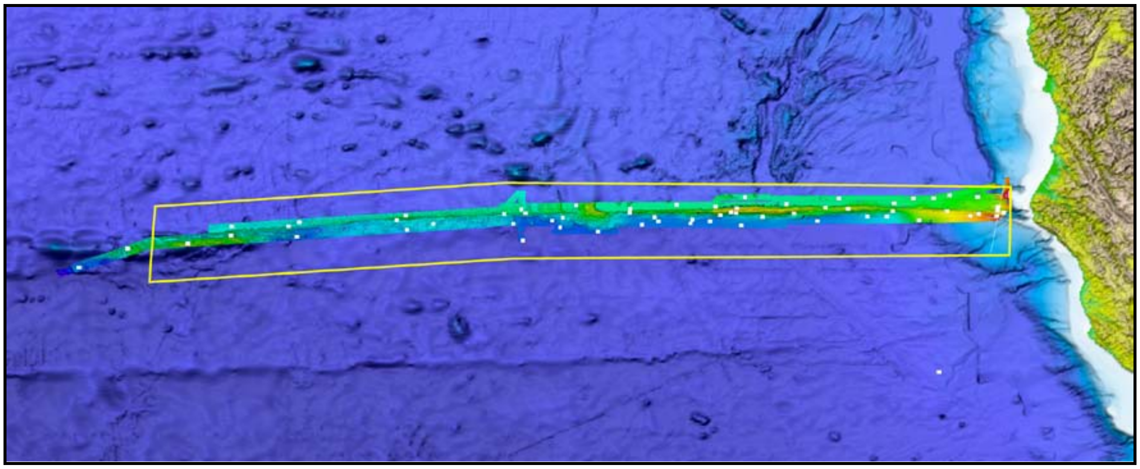


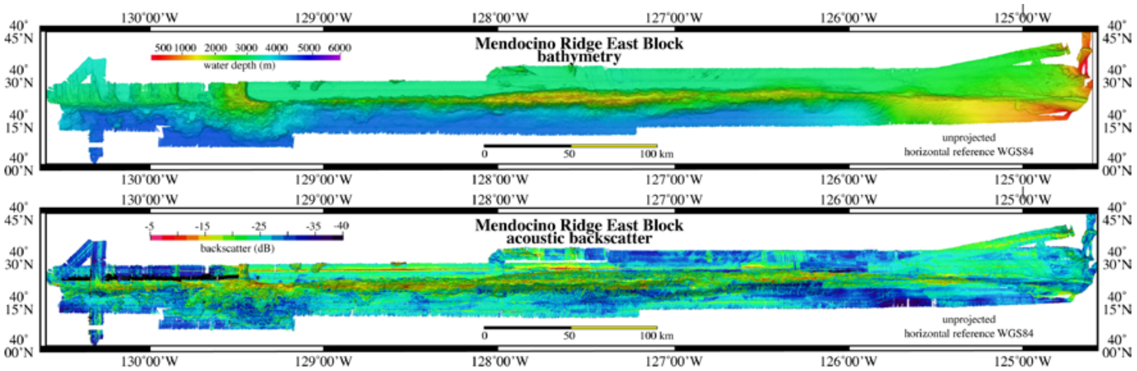
Figure 20. Map of locations of XBT (white dots). Backdrop is the newly acquired bathymetry.

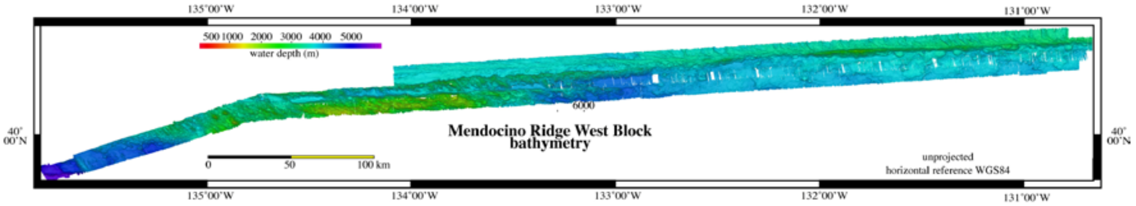
Appendix C. Cruise Calendar

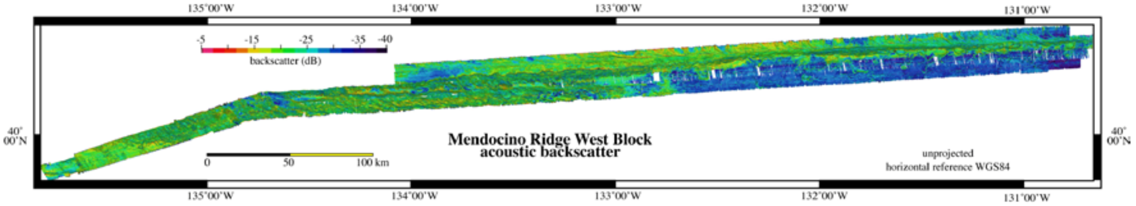
May 2009

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
JD123 3	JD124 4	JD125 5 depart San Francisco, Ca 1515L	JD126 6 transit to Mendocino	JD127 7 transit & CTD/XBT test start mapping Line 11	JD128 8 mapping in east half	JD129 9 mapping in east half
JD130 10 mapping in east half transit to Eureka, CA	JD131 11 pick up KM engineer testing & mapping	JD132 12 mapping in East & testing	JD133 13 EM302 died testing all day	JD134 14 mapping in East testing	JD135 15 mapping in East testing	JD136 16 mapping in East & testing
JD137 17 transit to Eureka, CA drop-off	JD138 18 mappingin East	JD288 19 mappingin East	JD139 20 finished mapping in East moved to West	JD140 21 mapping in West	JD141 22 mapping in West	JD142 23 mapping in West
JD143 24 ended mapping in West headed to SF	JD144 25 transit to SF	JD145 26 arrive San Francisco, Ca 1000L	JD146 27	JD147 28	JD148 29	JD149 30
JD150 31						

Appendix D. Color shaded-relief bathymetry and acoustic backscatter maps of eastern section of Mendocino Ridge.







Appendix E. List of Acronyms and Abbreviations

BIST – Built In System Test CO – Commanding Officer

CTD – conductivity temperature and depth equipment

CW – continuous wave

dB – decibels

DGPS –Differential Global Positioning System

DTM – digital terrain model

ECS – Extended Continental Shelf

ET – Electronics Technician

EX – NOAA Ship *Okeanos Explorer*

FM – frequency modulation

FOO – Field Operations Officer

Km – kilometers

KM – Kongsberg Maritime AS

Kt(s) – knots

Ma – megaannum

MBES – multibeam echosounder

NOAA – National Oceanic and Atmospheric Administration

OER – Office of Ocean Exploration and Research

OMAO – Office of Marine and Aviation Operations

SST – Senior Survey Technician

TRU – transmit and receive unit

UNCLOS – United Nations Convention on the Law of the Sea

UNH-CCOM/JHC – University of New Hampshire Center for Coastal and Ocean Mapping / Joint Hydrographic Center

UPS – uninterruptable power supply

US EEZ – United States Exclusive Economic Zone

WD – water depth

XBT – eXpendable BathyThermograph

Appendix F. EM302 Description and Operational Specs

EM 302 : Ideal for Ocean Exploration

There are several features of the Okeanos Explorer's 30 kHz multibeam that make it an excellent tool for ocean exploration. The following is a brief description of these features.

Depth Range

The system is designed to map the seafloor in water depths of 10 to 7000 meters. This leaves only the deepest parts of the deeper ocean trenches out of the EM 302's reach. Moreover, operational experience on the *Okeanos Explorer* has shown consistent EM 302 bottom detection at depth ranges in excess of 8000m.

High Density Data

In multibeam data, the denser the data, the finer resolution maps you can produce. The system can operate in dual swath, or multiping mode, which results in increased along track data density. This is achieved by detecting two swaths per ping cycle, resulting in up to 864 beams per ping.

The Okeanos Explorer mapping team typically operates the multibeam in high density equidistant ping mode, which results in up to 864 soundings on the seafloor per ping.

Full Suite of Data Types Collected

The system collects seafloor backscatter data, which provides information about the character of the seafloor in terms of bottom type.

The system also collects water column backscatter data, which has the ability to detect gaseous plumes in the water column. The full value of this feature is still being realized.

FM chirp mode is utilized in water depths greater than 1000 meters, and allows for the detection of the bottom further out from nadir than with previous 30 kHz systems.

Multibeam Primer

The area of the seafloor covered, or ensonified, by a single beam within a pulse of sound, or ping, is called the beam footprint. This beam footprint is defined in terms of the across track and along track values. Both of these values are dependent on water depth and the beam width at which the sound pulse is transmitted and received. The across track beam width value is also dependent on the receive angle, or "listening" angle, of the system, and the angle from nadir which it is received from. The receive angle for the receive transducer on the Okeanos Explorer EM302 is 1°, which is the smallest possible angle currently available for the EM302 system. The further out from nadir a sounding occurs, the larger the footprint will be. For example, as seen in Table 1 below, in 2000 meters of water, a beam footprint will have a radius of 18 meters at nadir but 25 meters by the time it hits the seafloor at an angle 140 degrees out from nadir.

Calculated acrosstrack acoustic beam footprint for EM 302 (high density ping mode, 432 soundings/profile)				
Water depth (m)	**Angle from nadir**			
50	1 deg RX center	90 deg	120 deg	140 deg
100	1	0.5	1	1
200	2	1	2	3
400	4	2	3	5
1000	7	4	6	10
2000	18	9	16	25
4000	35	19	32	-
6000	70	37	-	-
7000	105	56	-	-

Table 4. Calculated across track EM 302 beam footprint. Reference: Kongsberg Product description, Kongsberg document 302675 Rev B,ate 14/06/06, p. 17.

Calculated acrosstrack sounding density for EM 302 (high density ping mode, 432 soundings/profile)			
Water depth (m)	**Swath Width**		
50	90 deg	120 deg	140 deg
100	0.2	0.4	0.9
200	0.5	0.8	1.7
400	0.9	1.6	3.5
1000	1.9	3.2	6.9
2000	4.6	8.1	17.4
4000	9.3	16.2	-

Table 5. Calculated across track EM 302 sounding density. Reference: Kongsberg Product description, Kongsberg document 302675 Rev B, Date 14/06/06, p. 17.

Acrosstrack sounding density describes the spacing between individual soundings on the seafloor in the acrosstrack direction. The maximum swath of the EM 302 is 150 degrees. At this swath, the sounding density will be the least dense, since the beams will be spread out over a larger horizontal distance over the seafloor. As the swath angle (width) is decreased, the sounding density will increase, as the same number of beams are now spread out over a smaller horizontal distance over the seafloor.

Calculated ping rate and alongtrack resolution for EM 302					
140 deg swath, one profile per ping					
			Alongtrack distance between profiles (m)		
Water depth (m)	**Swath Width (m)**	**Ping Rate (pings/second)**	**@4 kts**	**@8 kts**	**@12 kts**

50	275	3.2	0.7	1.2	1.9
100	550	1.8	1.1	2.2	3.3
200	1100	1	2.1	4.2	6.3
400	2200	0.5	4.1	8.2	12.2
1000	5500	0.2	10	20	30
2000	8000	0.1	15.2	30.5	45.7
4000	8000	0.06	19.2	38.5	57.7
6000	8000	0.04	24.5	49	73.4

Table 6. Calculated ping rate and along track EM 302 sounding density, one profile per ping. Reference: Kongsberg Product description, Kongsberg document 302675 Rev B, Date 14/06/06, p. 15.

Calculated ping rate and alongtrack resolution for EM 302					
140 deg swath, two profiles per ping					
Water depth (m)	**Swath Width (m)**	**Ping Rate**	**Alongtrack distance between profiles (m)**		
			@4 kts	**@8 kts**	**@12 kts**
50	275	3.2	0.3	0.6	0.9
100	550	1.8	0.6	1.1	1.7
200	1100	1	1.1	2.1	3.2
400	2200	0.5	2	4.1	6.1
1000	5500	0.2	5	10	15
2000	8000	0.1	7.6	15.2	22.8

Table 7. Calculated ping rate and along track EM 302 sounding density, two profiles per ping. Reference: Kongsberg Product description, Kongsberg document 302675 Rev B, Date 14/06/06, p. 15.

Reference: Kongsberg Product Description: EM 302 multibeam echosounder