NOAA *Okeanos Explorer* Program

MAPPING DATA REPORT

CRUISE EX0905
Mapping Field Trials II
Mendocino Volcano Field I and II

June 17 - 27, 2009
Newport, OR to Astoria, OR

Report Contributors:
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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. 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 D and the ship's readiness report, which can be obtained by contacting the ships operations officer (ops.explorer@noaa.gov).

3. Cruise objectives

Cruise EX0905 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 small boat break-in and orientation.
- Assessment and evaluation of Cruise Information Management System (CIMS) performance.
- Develop protocols for mapping shore support.
- Refinement of data precuts pipeline, documentation, and sensor integration.
- Establishment of protocols for handling discoveries, anomalies, and interesting finds.
- Mapping he extent of the volcanic fields discovered on cruise EX0903

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:

- Training of the mapping team
- Resolve pending telepresence issues

Both objectives were completed within the context of mapping complex geological areas in the vicinity of Mendocino Ridge, Gorda Ridge and nearby volcanic fields, which are of national and regional interest.

4. Participating personnel

Name	Role	Affiliation
CDR Joseph Pica	Commanding Officer	NOAA Corps
Mashkoor Malik	Cruise Coordinator/Mapping Team Lead	NOAA OER
LT Nicola VerPlanck	Field Operations Officer	NOAA Corps
Elaine Stuart	Senior Survey Technician	NOAA OMAO
Colleen Peters	Senior Survey Technician	NOAA OMAO
Michelle Heller	Mapping watch stander	NOAA OER Intern
Sylvia Rodriguez-Abudo	Mapping watch stander	NOAA OER Intern
David Armstrong	Mapping watch stander	NOAA OER / UNH Intern
Joel DeMello	Mapping watch stander	NOAA OER / UNH Intern

5. Mapping sonar setup

NOAA *Okeanos Explorer* (EX) is equipped with a 30 kHz Kongsberg EM 302 multibeam sonar and a 3.5 kHz Knudsen sub-bottom profiler (SBP 3260). Due to ongoing interference problems only the EM 302 was used to collect data during this cruise.

EM 302 is also capable of recording bottom and water column backscatter. The water column backscatter data were only recorded during the times when an interesting feature was observed in the water column. For most of the cruise, the EM 302 only recorded bottom bathymetric and backscatter. The ship used a POS MV ver. 4 to record and correct the multibeam data for any motion. C-NAV GPS system provided DGPS correctors with position accuracy expected to be better than 2.0 m.

All the corrections (motion, sound speed profile, sound speed at sonar head, draft, sensor offsets) are applied during real time data acquisition in SIS ver. 1.04. XBT casts (Deep blue Max depth 760 m) were taken every 8 hours (0000, 0800 and 1600 local time). XBT cast data were converted to SIS complaint format using NOAA Velocwin ver. 8.92 Plus.

Onboard processing of bathymetric data was done in CARIS HIPS ver. 6.1 and cleaned with 'Swath Editor' and 'Subset Editor'.

The latest patch test for the EM 302 was performed in May 2009 which showed only a pitch bias of 0.7 degrees. These patch test values were used during data acquisition throughout this cruise.

6. Cruise Calendar

June 2009						
Mon	**Tue**	**Wed**	**Thu**	**Fri**	**Sat**	**Sun**
15	16 Mission party boarded	17 Departure Newport, OR	18 Mapping Gorda Ridge	19 Mapping Gorda Ridge	20 Mapping volcanic Field II	21 Small boat operations Mapping volcanic Field II
22 Small boat operations Transit to volcanic field I	23 DP Training Transit to volcanic field I	24 Mapping volcanic Field I	25 Mapping volcanic Field I Transit to Astoria, OR	26 Transit to Astoria, OR	27 Arrival Astoria, OR	28

7. Daily cruise log

(ALL TIMES LOCAL Pacific Daylight Time)

June 17, 2009

Set sail at 1400 PDT from Newport, OR to northern edge of Gorda Ridge earlier mapping with ETA 18 June 0800 PDT. Mapping ops will commence tomorrow morning to supplement the data collected during EX0904.

Mission party boarded the ship on 16 June 0330 PDT. June 16 and 17 was spent to orient the visiting student interns with ship operations. Senior Survey Technicians Stuart and Peters also ran training sessions on using mission control room and operating Multibeam acquisition system. PS Malik did a training session on general mapping principles and mapping objectives of this cruise.

Over night transit to the Gorda Ridge.

June 18, 2009 – Continued mapping filling in data holidays left during the EX0904 cruise. Observed some interesting features in the EM 302. Not having sufficient scientific information available onboard, the images were sent to Dr. Jim Gardner (UNH)
for further scientific investigation.

Email Replies from Dr. Gardner:
"The main structure you transited over is called Heceta Bank. It is indeed a big fold caused by the Juan de Fuca plate under thrusting the North American plate. MBARI mapped it with an EM300, but their resolution only allows girding at 30 m/pixel; consequently, their data don't show all that beautiful fold structure. MBARI and Chris Goldfinger at Oregon State Univ. have both published on Heceta Bank and a USGS guy named Park Snavely published on seismic data from the bank. As for the strange pattern on the SW part of your line; their data do show a lot of surface texture in that area. I'm guessing the texture is reflecting outcrops, again caused by compression between the two plates. So, that transit line is beautiful, but I don't think it qualifies

as a "discovery". I put an sd file I made from the MBARI EM300 data on the ccom anonymous server in a folder called "For_Mashkoor". Perhaps you can download it. It's 51.6 mb."

Due to slow speed internet connection the ship was not able to download the file.

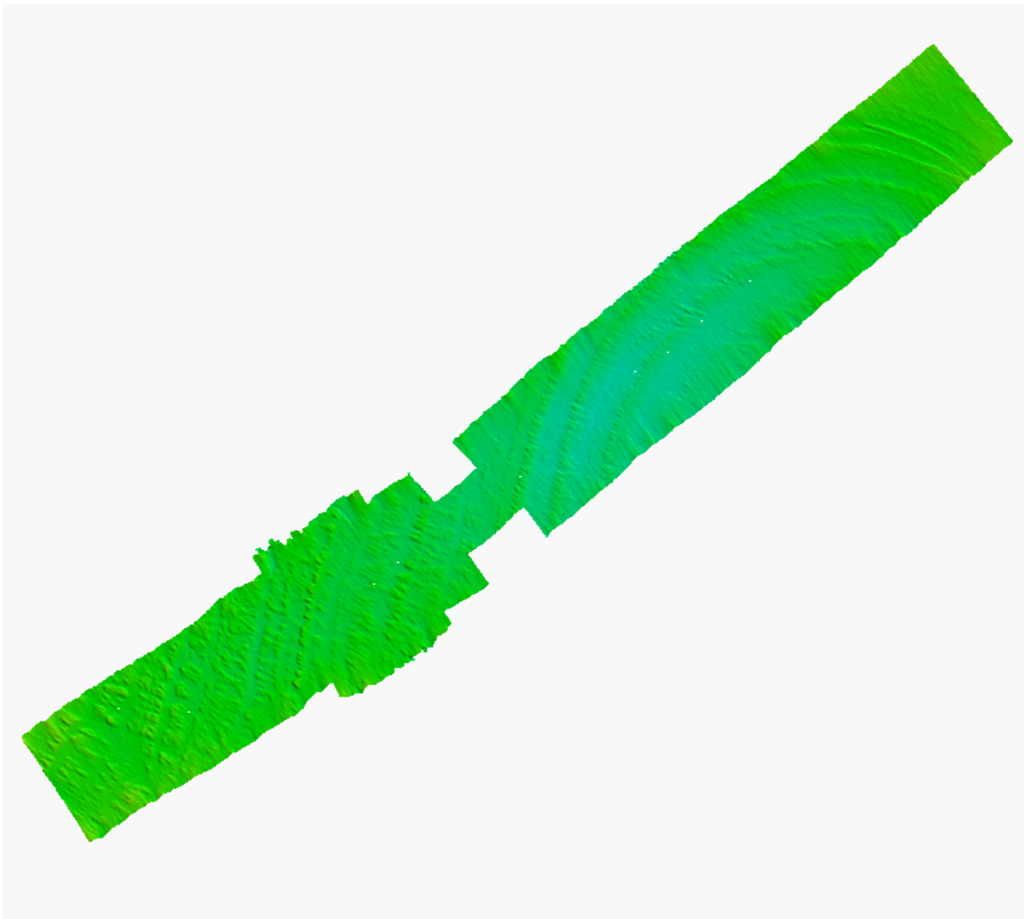

Figure 1. Interesting circular features observed during transit from Newport, OR to Gorda Ridge.

June 19, 2009 – Completed the mapping in the Gorda Ridge and now transiting to Volcanic field # 2. During transit to the Volcanic field, an attempt will be made to overlap the existing data.

XBT cast #5 at 1600. At 1950 changed along direction from 3 to 0 to help sonar keep bottom track. Had to force depth routinely before the shift change. XBT cast #6 conducted at 2345.

June 20, 2009 - mapping in transit to Mendocino ridge volcano site #1. Had to force depth few times to help sonar find ocean floor. UPS malfunctioned during night and now operating in by-pass mode. Over night mapping in the southern section of volcanic field to find the extent of volcanism.

XBT cast #7 at 0800. XBT cast #8 at 1600. At 1855, all lights in POS turned red but bounced back after a few seconds. First bulb in SIS also went red. Corrected itself.

June 21, 2009 - 1400 stopped mapping to start small boat operations drill. The small rescue boat is a new addition to EX inventory and its engine needs to be broken in to make it fully operational.

2100 XBT cast #11 (XBT_062109_ 11_thinned.asvp). Small boat ops until 5pm. At 1850 Pos/MV dropout ~ around similar time as yesterday. All lights turned red but went back to normal after a few minutes.

June 22, 2009 – Overnight transited to the northern side of volcanic field II and now heading towards east. Small boat ops started 0900 PDT and will continue until afternoon.
Once finished with boat operations started transit to volcanic field I.

1743 XBT cast #14 (XBT_062209_14_thinned.asvp). XBT cast #15 conducted at 2100 (XBT_062209_15_thinned.asvp) because of the large difference (~4 deg.) between the last probe and the temperature probe.

June 23, 2009 - 0000 XBT cast #16 (XBT_062309_16_thinned.asvp). It was repeated because of a jump in temperature around 200m. The file was overwritten.
At 0620 the ballast tanks were emptied, changes in depth may have impact on data.
0800 XBT cast #17 (XBT_062309_17_thinned.asvp).

1100 – 1600 Bridge DP training was carried out for bridge watch keepers. Collected ~ 1 hour of data at a single location (Line#0035_20090623_204327_EX) which can be useful for calculating standard deviations on the data.

1856 XBT cast #18 (XBT_062309_18_thinned.asvp). At 2006, experienced "red triangle of death" which corrected itself within a few seconds.

June 24, 2009 – 0000 XBT cast #19 (XBT _062409_19_thinned.asvp). Everything normal.

0900 – 1115 CTD cast over new volcano/ seamount.

1600 XBT #20 (XBT_062409_20_thinned.asvp). Rough seas causing system to regularly lose the bottom (seas 6-10 ft). PV-POS dropouts during turn at 2050. UPS alarm went off at 2145.

June 25, 2009 – Due to very rough sea conditions the ship was unable to maintain speeds higher than 7 kts.

0200 – Ship decided to break off the survey to start heading for Astoria, OR. Did not finish the extent of volcanic field I fully.

8. Appendices

Appendix A. Table of XBT/ CTD casts

Date	Time	XBT/CTD Filename	Lat	Long	Remarks

	(Local Time)				
061809	0800	TD_0001	43.0 N	126.67 W	
061809	1600	TD_0002	42.0 N	127.17 W	
061909	0000	TD_0003	40.9 N	127.8 W	
061909	0800	TD_0004	40.39 N	128.75 W	
061909	1600	TD_0005	40.2 N	130.35 W	
062009	0000	TD_0006	40.1 N	131.804 W	
062009	0800	TD_0007	39.993 N	133.46 W	
062009	1600	TD_0008	39.89 N	134.28 W	
062109	0000	TD_0009	39.92 N	132.77 W	
062109	0800	TD_0010	39.81 N	134.38 W	
062109	2100	TD_0011	40.1 N	134.64 W	
062209	0000	TD_0012	40.14 N	133.98 W	
062209	0800	TD_0013	40.25 N	133.68 W	
062209	1743	TD_0014	40.33 N	132.46 W	
062209	2100	TD_0015	40.38 N	131.56 W	
062309	0000	TD_0016	40.42 N	130.94 W	
062309	0800	TD_0017	40.45N	129.66W	
062309	1856	TD_0018	40.98 N	129.69 W	
062409	0000	TD_0019	41.43 N	129.63W	
062409	0900	CTD_062409_01_.asvp	40.62 N	129.649 W	
062409	1600	TD_0020	41.1 N	129.55 W	
062509	0000	TD_0021	41.1 N	129.48 W	

Appendix B. Table of data files collected during the cruise

S.No.	Date	File Name	Location	Remarks
1	061809	0001_20090618_012534_ShipName	Transit	
2		0004_20090618_020102_ShipName	Transit	Interesting features < 100 m depth
3		0003_20090618_015219_ShipName	Transit	
4		0005_20090618_080102_ShipName	Transit	
5		0006_20090618_140111_ShipName	Transit	
6		0000_20090618_151922_EX	Gorda Ridge	
7		0001_20090618_211919_EX	Gorda Ridge	
8	061909	0002_20090619_031924_EX	Gorda Ridge	
9		0003_20090619_091922_EX	Gorda Ridge	
10		0000_20090619_104840_EX	Mendocino	
11		0001_20090619_140050_EX	Mendocino	
12		0002_20090619_200044_EX	Mendocino	
13	062009	0003_20090620_020047_EX	Mendocino	
14		0004_20090620_080049_EX	Mendocino	
15		0005_20090620_140049_EX	Mendocino	
16		0006_20090620_200052_EX	Mendocino	

17		0007_20090620_205132_EX	Mendocino	Turn
18		0008_20090620_205506_EX	Mendocino	
19		0009_20090620_212151_EX	Mendocino	Turn
20		0010_0090620_212308_EX	Mendocino	
21	062109	0011_20090621_030329.EX	Mendocino	
22		0012_20090621_062817.EX	Mendocino	
23		0013_20090621_065416_EX	Mendocino	
24		0014_20090621_125423_EX	Mendocino	
25		0015_20090621_162918_EX	Mendocino	Turn
26		0016_20090621_162918_EX	Mendocino	
27		0017_20090621_200225_EX	Mendocino	
28		0018_20090621_214334_EX	Mendocino	
29	062209	0019_20090622_002107_EX	Mendocino	
30		0020_20090622_040501_EX	Mendocino	Turn
31		0021_20090622_071550_EX	Mendocino	
32		0022_20090622_103748_EX	Mendocino	
33		0023_20090622_155838_EX	Mendocino	Small Boat, Wide turns
34		0024_20090622_170741_EX	Mendocino	
35		0025_20090622_180126_EX	Mendocino	Small Boat, Wide turns
36		0026_20090622_185229_EX	Mendocino	
37		0027_20090622_191737_EX	Mendocino	Small Boat, Wide turns
38	062309	0028_20090622_194139_EX	Mendocino	
39		0029_20090623_014145_EX	Mendocino	Transit to volcano field 1
40		0030_20090623_074142_EX	Mendocino	
41		0031_20090623_091112_EX	Mendocino	
42		0032_30090623_135501_EX	Mendocino	Multiple turns
43		0033_20090623_145744_EX		Detected a seamount
44		0034_20090623_170715_EX		DP Training
45		0035_20090623_204327_EX	Mendocino	
46		0036_20090623_232407_EX	Mendocino	
47		0037_20090623_235519_EX	Mendocino	
48		0038_20090624_031053_EX	Mendocino	Turn
49		0039_20090624_052316_EX	Mendocino	Turn
50		0040_20090624_055139_EX	Mendocino	
51		0041_20090624_115139_EX	Mendocino	
52		0042_20090624_125159_EX	Mendocino	Turn
53		0043_20090624_132859_EX	Mendocino v1	
54		0044_20090624_150011_EX	Mendocino v1	Turning back to go to do a CTD cast at the seamount
55		0045_20090624_183456_EX	Mendocino	CTD cast + turns
56		0046_20090624_190302_EX	Mendocino	W-E Cross of seamount
57		0047_20090624_195623_EX	Mendocino	Transit to original survey line of the day
58	062409	0048_20090624_204540_EX	Mendocino	
59		0049_20090625_024539_EX	Mendocino	
60		0050_20090625_032609_EX	Mendocino	Turn
61	062509	0051_20090625_034923_EX	Mendocino	
62		0052_20090625_090147_EX	Mendocino	
63		0007_20090625_091127_EX	Transit	Transit to Astoria, OR

64		0008_20090625_151121	Transit	Transit to Astoria, OR
65		0009_20090625_211121_EX	Transit	Transit to Astoria, OR
66	062609	0010_20090626_031123_EX	Transit	Water column data collected as well
67		0011_20090626_091124_EX	Transit	Water column data collected as well
68		0012_20090626_151121_EX	Transit	Water column data collected as well

Appendix C. List of acronyms

BIST – Built In System Test

CO – Commanding Officer

CIMS – Cruise Information Management System

CTD – conductivity temperature and depth

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

kHz - kilohertz

Km – kilometers

KM – Kongsberg Maritime AS

Kt(s) – knots

Ma – megaannum

MBES – multibeam echosounder

NCDDC – National Coastal Data Development Center

NGDC – National Geophysical Data Center

NOAA – National Oceanic and Atmospheric Administration

NODC – National Oceanographic Data Center

OER – Office of Ocean Exploration and Research

OMAO – Office of Marine and Aviation Operations

ROV – Remotely Operated Vehicle

SST – Senior Survey Technician

SV – sound velocity

TRU – transmit and receive unit

TSG - thermosalinograph

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

USBL – ultra-short base line

WD – water depth

XBT – expendable bathythermograph

Appendix D: 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 1. Calculated across track EM 302 beam footprint. Reference: Kongsberg Product description, Kongsberg document 302675 Rev B, Date 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 2. 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 3. 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					
			Alongtrack distance between profiles (m)		
Water depth (m)	**Swath Width (m)**	**Ping Rate**	**@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 4. 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

Appendix E. Field Products describing data results

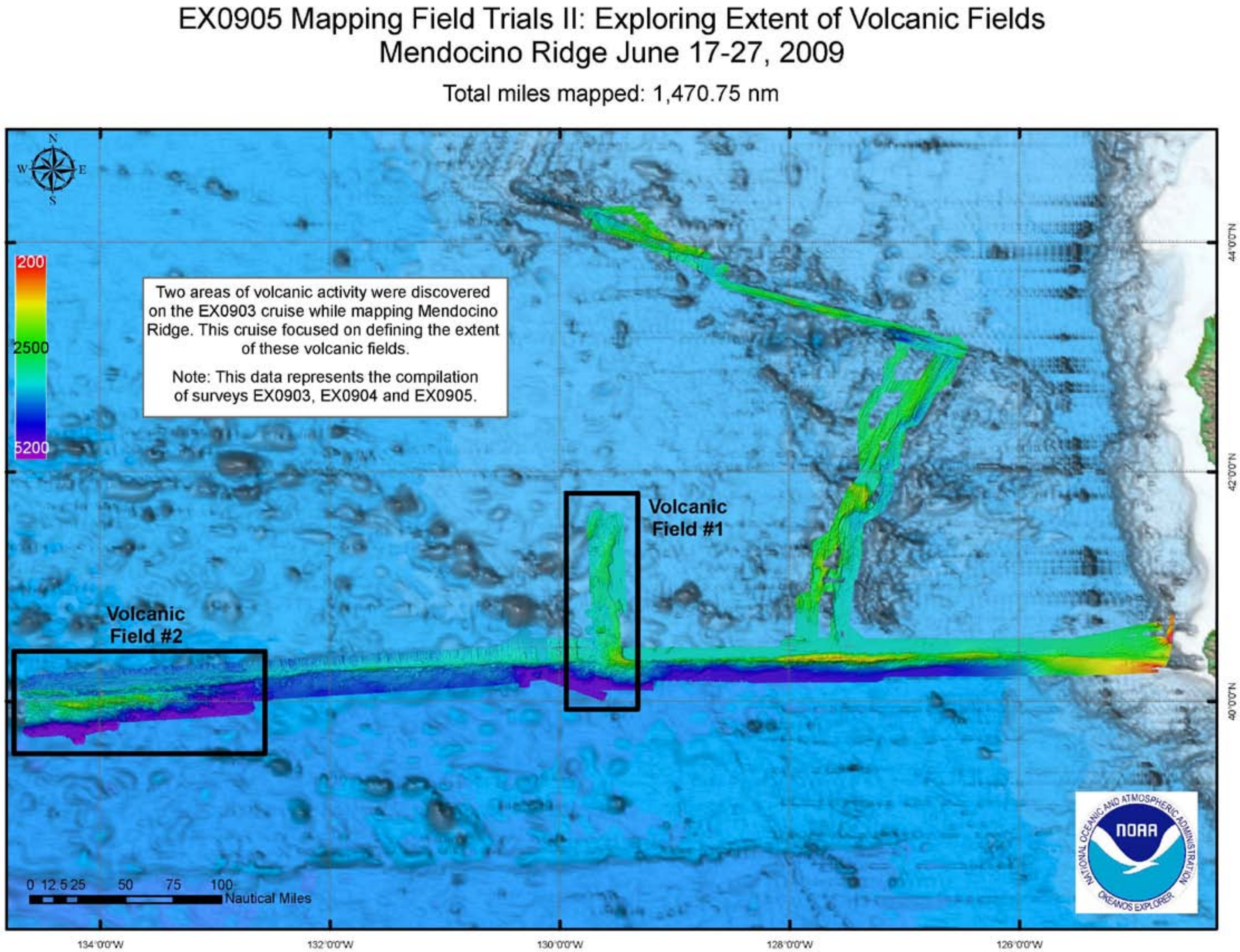

Figure 2. Over view of exploration area, 50m grid, produced with Fledermaus and ArcMap. Background image compiled by Sandwell and Smith with the screen image generated in Fledermaus.

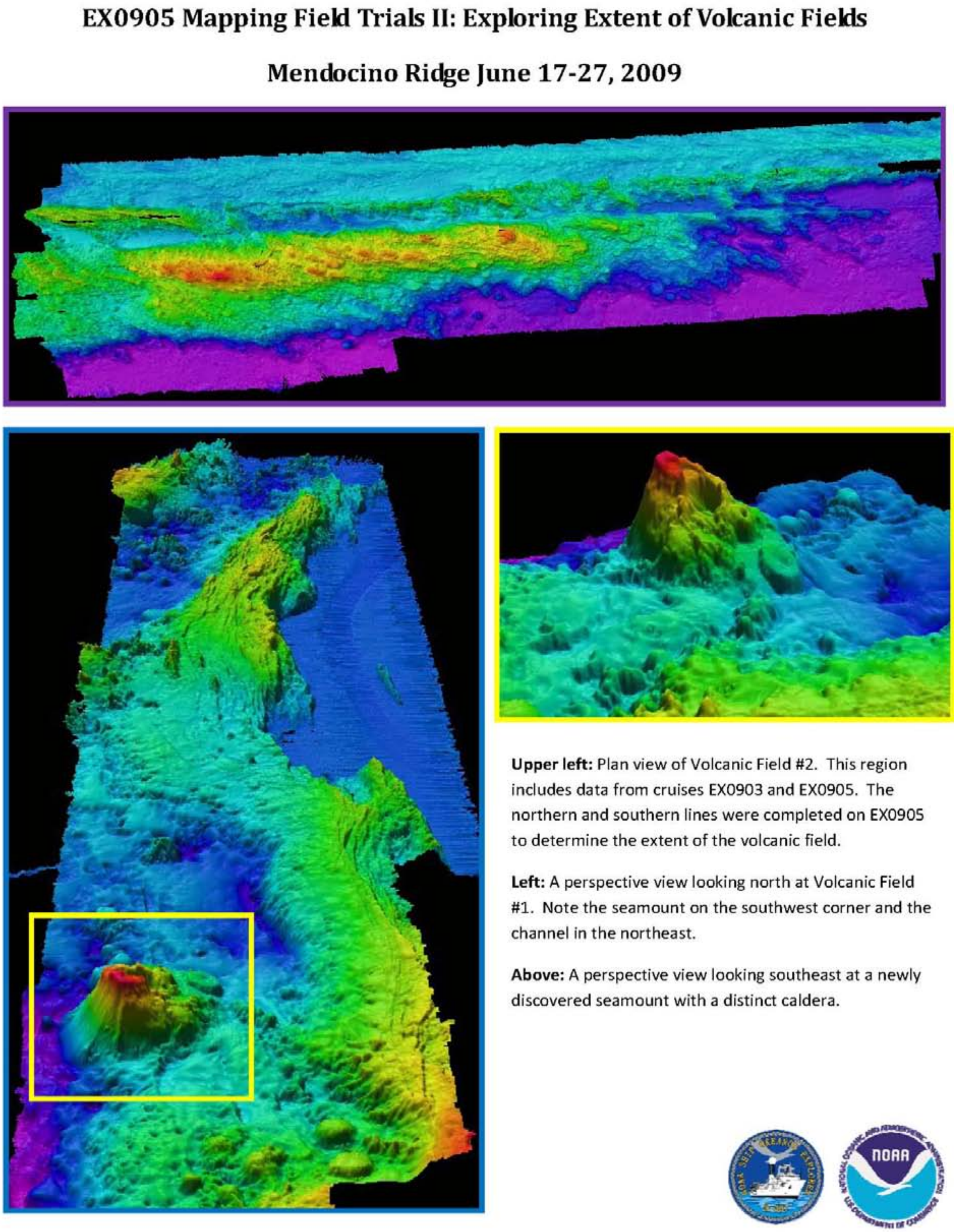

Figure 3. Detailed views of interesting features observed. EM302 data shown in Fledermaus, with 50m grid cell size.

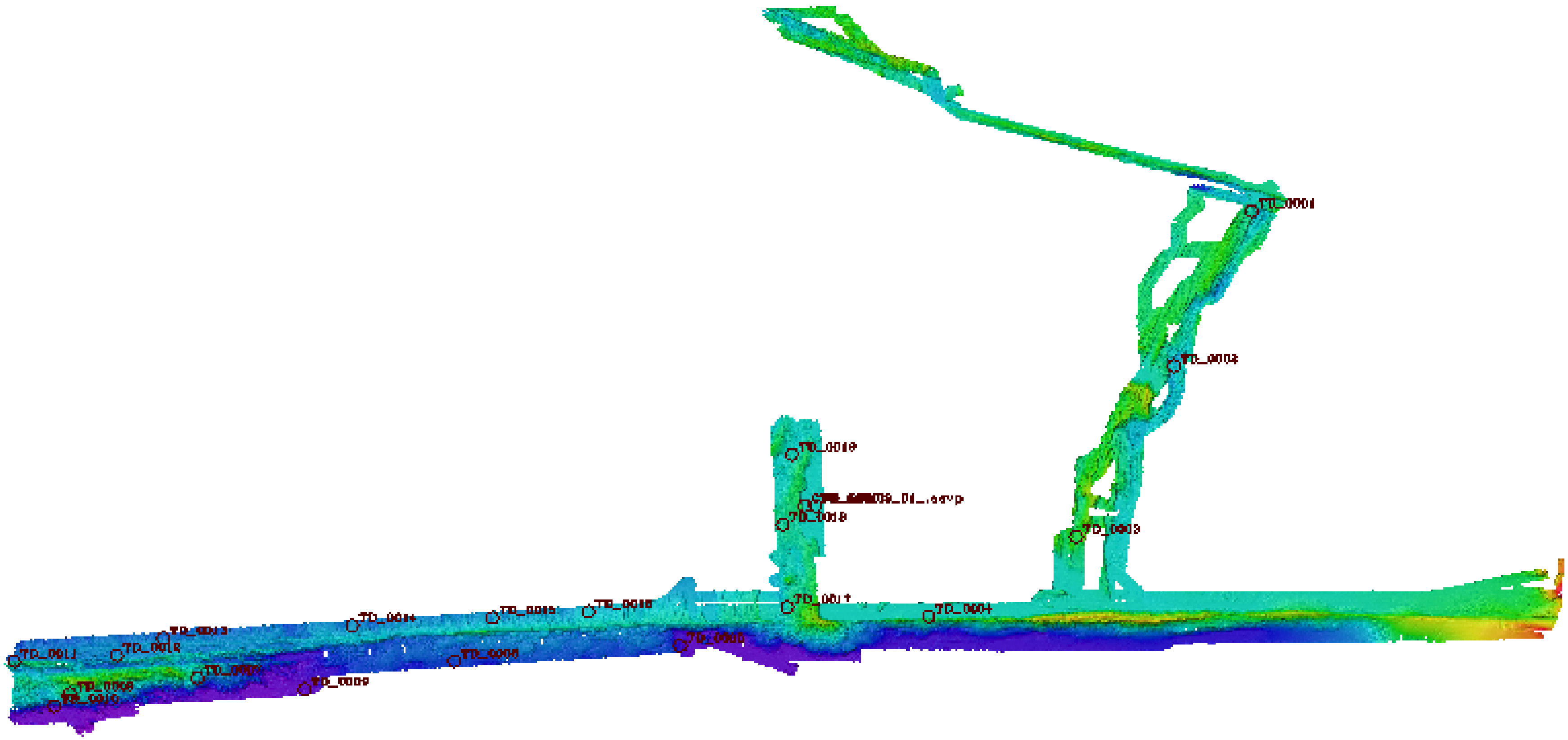

Figure 4. Bathymetric map (50m grid, generated in Fledermaus) overlaid with XBT casts.