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NOAA *Okeanos Explorer* Program

MAPPING DATA REPORT

CRUISE EX0904

Water Column Exploration Field Trial I
Gorda Ridge and Blanco Fracture Zone

June 1 - 12, 2009
San Francisco, CA to Newport, OR

Report Contributors:
Catalina Martinez

NOAA Office of Ocean Exploration and Research
1315 East-West Hwy, SSMC3, #10210
Silver Spring, MD 20910

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

3. Cruise Objectives

This cruise is a watercolumn exploration field trial cruise, designed to test and refine operations for conducting watercolumn exploration using NOAA Ship *Okeanos Explorer* (EX) systems and sensors.

Purpose/ Objectives of the cruise
The goals of this field trial cruise are more operational than exploratory. Like other field trials, this cruise has primary and secondary goals and objectives.

Primary Goal:
Test and evaluate EX, systems and sensors for water column exploration capabilities.

1. Exercise the Conductivity Temperature and Depth (CTD) rosette in vertical station casts and tow-yos to establish and refine SOPs, deploy and recover equipment, use and evaluate laboratory and computer processes.

2. Use the EM-302 Multibeam mapping system to test and evaluate system efficacy, SOPs, and processing capability for collecting water column data.

3. Evaluate onboard capabilities for processing and storing watercolumn samples collected during CTD operations and evaluate sample pipeline.

4. Learn how to recognize normal features and anomalies in the water column.

5. Continue testing and calibrating the shipboard USBL ROV Tracking System to prepare for future ROV operations.

Secondary Goal:
Continue preparations, training, testing and evaluating of other EX systems and sensors.

1. Continue training, SOP development and assessment of Telepresence system and Remote Exploration capabilities

2. Test data management pipeline components and system

Operating Area
The principal operating area is the axial valley and west flank of the Gorda Ridge, a spreading center off the coast of Oregon and California. During transit we will acquired data along the East end of the Mendocino Ridge. Further mapping and CTD operations were conducted along the Blanco Fracture Zone.

4. Summary of Major Findings

In all, over 3100 square nautical miles were mapped with the EM 302 multibeam sonar. CTDs conducted over plumes revealed they are not hydrothermal in nature but more likely gaseous, due to the lack of a presence of particulate matter.

5. Onboard Personnel

Name	Role	Affiliation
CDR Joseph Pica	Commanding Officer	NOAA Corps
Ms. Catalina Martinez	Expedition Coordinator	NOAA OER
LT Nicola VerPlanck	Field Operations Officer	NOAA Corps
Mr. Richard Patana	Commanding Officer	NOAA OMAO
Ms. Elaine Stuart	Senior Survey Technician	NOAA OMAO

Ms. Colleen Peters	Senior Survey Technician	NOAA OMAO
LTJG Megan Nadeau	Hydrographer	NOAA Corps
Mr. Richard Conway	Chief Electronics Technician	NOAA OMAO
Mr. Eric Thompson	Electronics Technician	NOAA OMAO
Mr. P. Scott Hill	Data Management	NCDDC
Mr. McKinley Freeman	Data Management	NCDDC
Ms. Sharon Walker	Oceanographer	PMEL
Mr. Ron Greene	Research Assistant	PMEL
Mr. Dave Lovalvo	ROV Manager	Eastern Oceanics
Mr. Dave Wright	ROV Pilot	Eastern Oceanics
Mr. George He	USBL Technician	LinkQuest

6. Cruise Statistics

Dates .....JD152 to JD162
Weather delays.....0 days
Total non-mapping days (USBL test & transits) .....4 days
Total mapping days.....6.5 days
Line kilometers of survey .....2382 km
Total area mapped.....3186 nm^2
Beginning draft .....4.33 m (bow) 4.30 m (stern)
Ending draft……4.12 m (bow) 4.33 m (stern)
Average ship speed for survey..... 10 kts
Total Gorda & Blanco area mapped .....501.78 nm^2

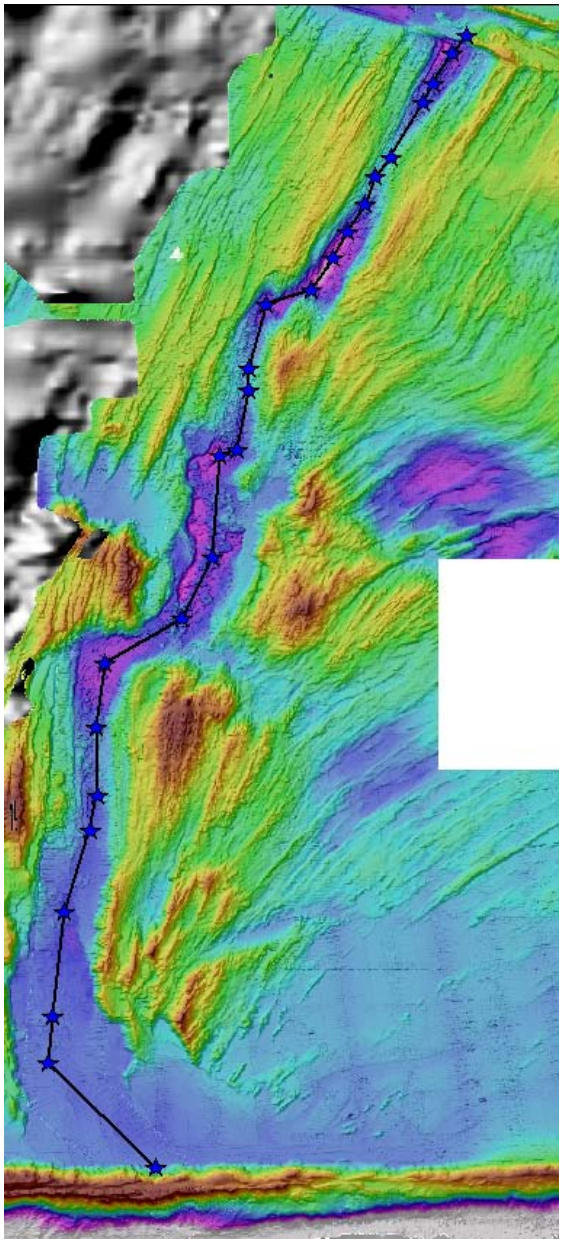

Figure 1. Location of Gorda Ridge and CTD stations.

Figure 2. NOAA Ship *Okeanos Explorer* (R337) used to map the Gorda Ridge.

7. 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 beams is determined by both phase and amplitude. However, 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. 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 unit (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 prior to the EX-0903 cruise (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).

Table 1. Initial system sensor offsets.

	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 2. Offset corrections determined by Patch Test.

Offset	Value
roll	0
pitch	0
yaw	0
latency	0

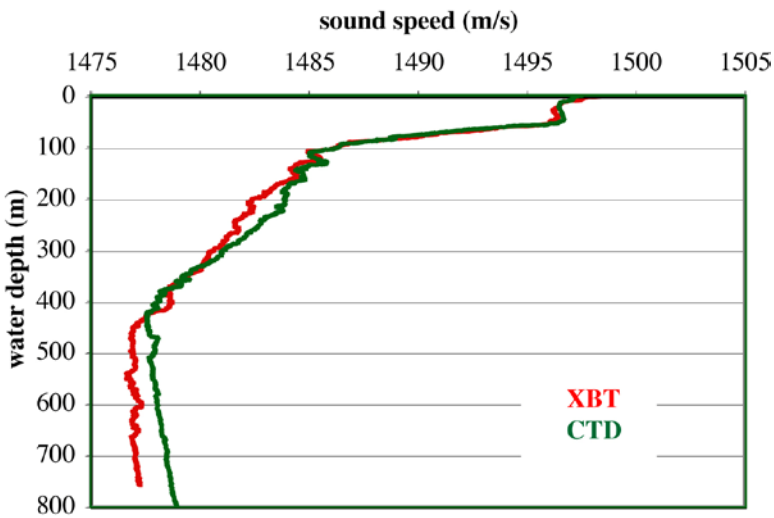

Figure 3. Comparison of sound speed calculated from XBT and CTD casts taken during cruise EX0903.

8. 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.

9. MBES Data Processing

June 1, 2009

Morning dock-side operations included live broadcasts to the University of Rhode Island's Inner Space Center during tours of the new Ocean Science and Exploration Center, as well as tests associated with the LinkQuest USBL system. The NCDDC data management team worked with the ETs and Survey Techs to locate the CIMS server on board and began troubleshooting issues associated with security and access that seem to plague us at every turn.

The ship left Pier 27 in San Francisco at 1300 and began transiting to reach deeper water to begin over-the-side USBL tests. The ship reached a depth of 700m-800m by approximately 1730 and an XBT was cast for the USBL test. Additional deep water USBL tests will be conducted between 0800 and 1200 tomorrow before the ship transits back to the San Francisco area to switch out a few members of the science party.

June 2, 2009

Morning operations involved deep water tests associated with the LinkQuest USBL system. The camera platform transponder was tested last night using the CTD winch and the ROV transponder was tested this morning in the same manner. Both transponders were found to be in working order, and the USBL system is working fine now that it has been wired correctly. The NCDDC data management team continued their efforts in developing a workaround on the ship's network and in sharing information with their map specialist at NCDDC for product generation.

Issues remain associated with the inability to use the 10-megabit pipe to send and receive data when not conducting remote science with the telepresence system. Information was sent to John McDonough, Craig Russell, and Webb Pinner, in the hope they could find a way to work through the security issues on shore and gain permission for us to alter the system in a manner more consistent with operations, so as not to continue to hamper our ability to operate efficiently and effectively from sea. For the short-term, these security barriers impact our ability to provide mapping products on this cruise, as we are short handed and planned to work with Mashkoor at UNH via the data pipe. For the long term, this is a barrier to our ability to operate remotely in general.

The ship began transiting back to the San Francisco area at 1200 for the small boat transfer that occurred at 1700 at the Golden Gate Yacht Club. Lovalvo, Wright, and He transferred off and Walker and Greene transferred on. Once the small boat was secured on deck, the ship began to transit out to the first operating area, the Escanaba Trough/Gorda Ridge. This transit is expected to take approximately 24 hrs.

June 3, 2009

An XBT was conducted at 0030, sound velocity (SV) was applied to multibeam data collected by the EM302. Sea state was very calm < 3 foot swells.

The ship continued transiting overnight to the possible plume site found during the EX0903 cruise located at the East end of the Mendocino Ridge to fill in gaps in the multibeam data acquired at that time, and to cast an opportunistic CTD to hopefully gain a more thorough understanding of the plume.

The first science meeting of the cruise was held at 0830 where Walker and Greene explained their objectives and described the target areas geologically, providing context for their CTD cast and mapping targets. They also described the sensors they brought to add to the CTD, and explained the significance of the parameters they will measure in terms of their association with vent plumes.

The possible plume was located at approximately 1515; LTJG Nadeau was able to capture some great screen grabs (see *Figure 4* below). The ship was positioned over the plume to cast a CTD by approximately 1600. An issue was identified in the way the

sensor data was coming in, so the CTD was brought back to the surface to switch out a sensor cable. The CTD was deployed a second time over the plume. It was determined that there was no particulate matter in the plume, indicating that this was not a hydrothermal vent site, but perhaps some sort of gas plume, possibly methane or carbon dioxide.

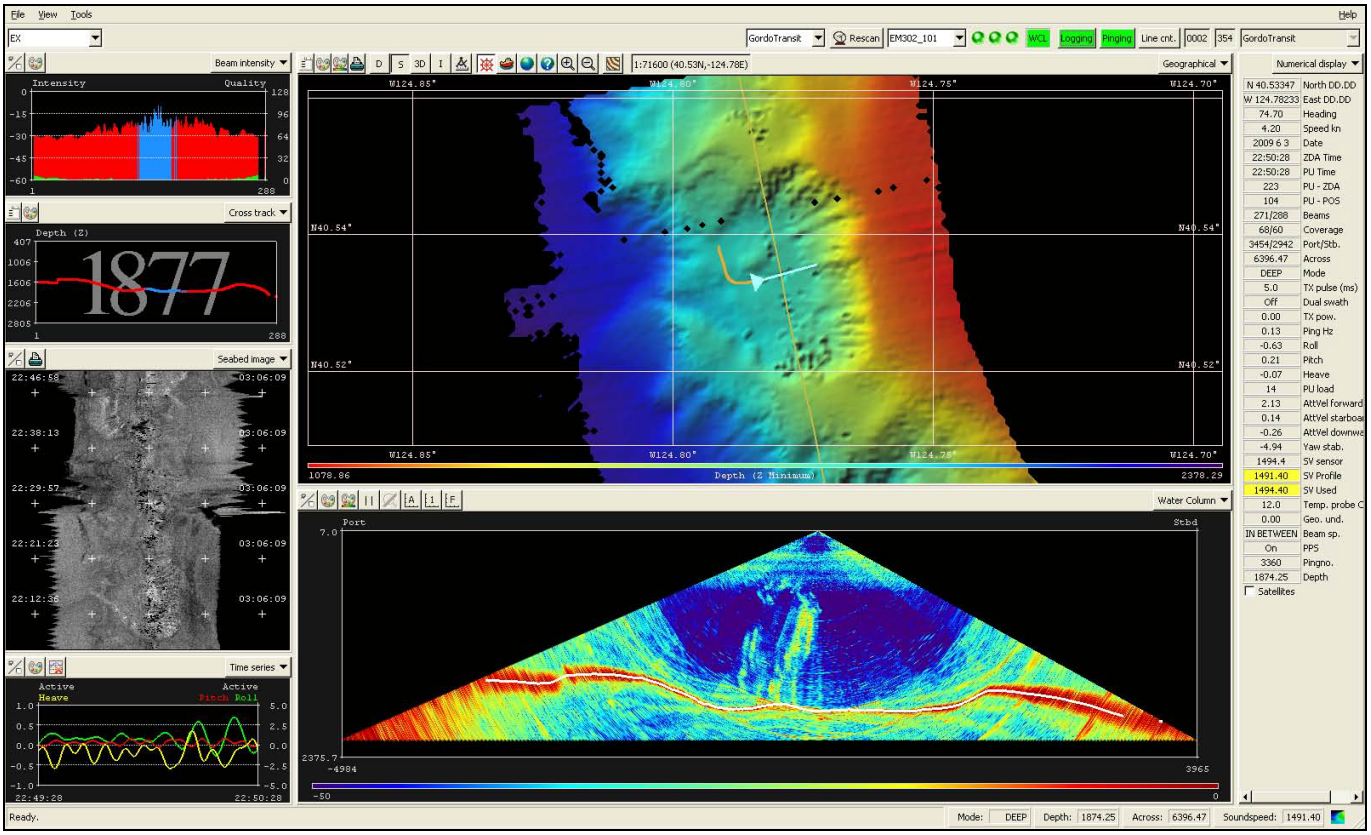

Figure 4. Screen grab taken today at approximately 1515 PDT of possible gas plume site initially detected during the EX0903 cruise located at the East end of the Mendocino Ridge.

The ship then continued transiting to the Escanaba Trough/Gorda Ridge area to begin mapping and CTD operations associated with the Vents program objectives.

June 4, 2009

The ship continued transiting overnight to the Escanaba Trough area and began acquiring multibeam data at 0600 as the ship reached the entrance to Escanaba Trough (see *Figure 5* below). An XBT cast was conducted at 0600 and SV was applied to multibeam data collected by the EM302. Seas continued to be calm < 3 foot swells.

The science team brought maps for their sample areas, but did not have good quality maps for their first two CTD cast sites at the entrance, so we mapped this region prior to the first cast to ground-truth the cast site locations. Two CTD's were cast along the Escanaba Trough region with multibeam data acquired between CTD cast sites. Multibeam data was not acquired while conducting CTD's.

There is an apparent short in one of the sensor cables, brought on board by the science team, that then shorted out the CTD during the second cast. The CTD was brought back on board to remove this cable and was successfully cast a second time in the same location. Walker will work with the ship's ETs to try to resolve the problem with this particular sensor cable, as it also resulted in problems yesterday.

After the first full day of mapping operations and CTD casts, it was clear the workload on the few people conducting these operations was tremendous. More survey technicians are needed, and LTJG Nadeau played a key role in assisting with acquiring/processing multibeam data to offset this workload.

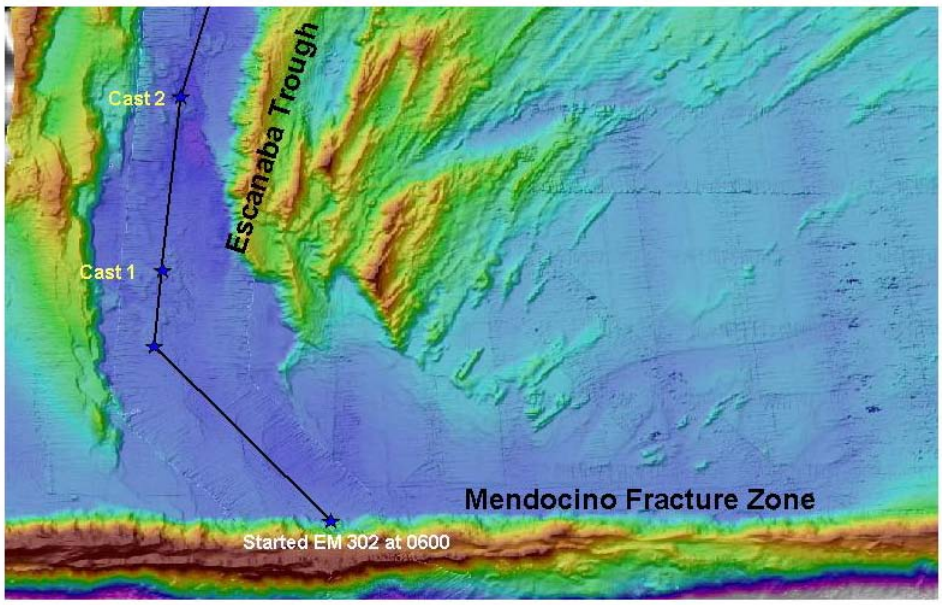

Figure 5. Screen grab taken from Walker's data in GeoTiff of the Escanaba Trough region where work was conducted today. Waypoints that mark the two CTD cast locations are labeled 'Cast 1' and 'Cast 2,' and the waypoint marking the start of the multibeam survey

June 5, 2009

An XBT cast was conducted at 0030 and SV was applied to multibeam data collected by the EM302. Seas continued to be calm < 3 foot swells.

Mapping of the Escanaba Trough continued overnight until 0800. The first CTD was cast at 0840 to a depth of about 3100 meters. The second CTD was cast at 1230 to a depth of about 3000 meters. As the CTD cast stations were closer together today, and as the 'doctored' sensor cable seemed to be holding up, we were able to fit a third CTD cast in at 1600 to a depth of 3300 meters. Seawater samples were collected in copper tubes from the Niskin bottles after each cast for later analysis of Helium and trace metals. (See *Figure 6* below)

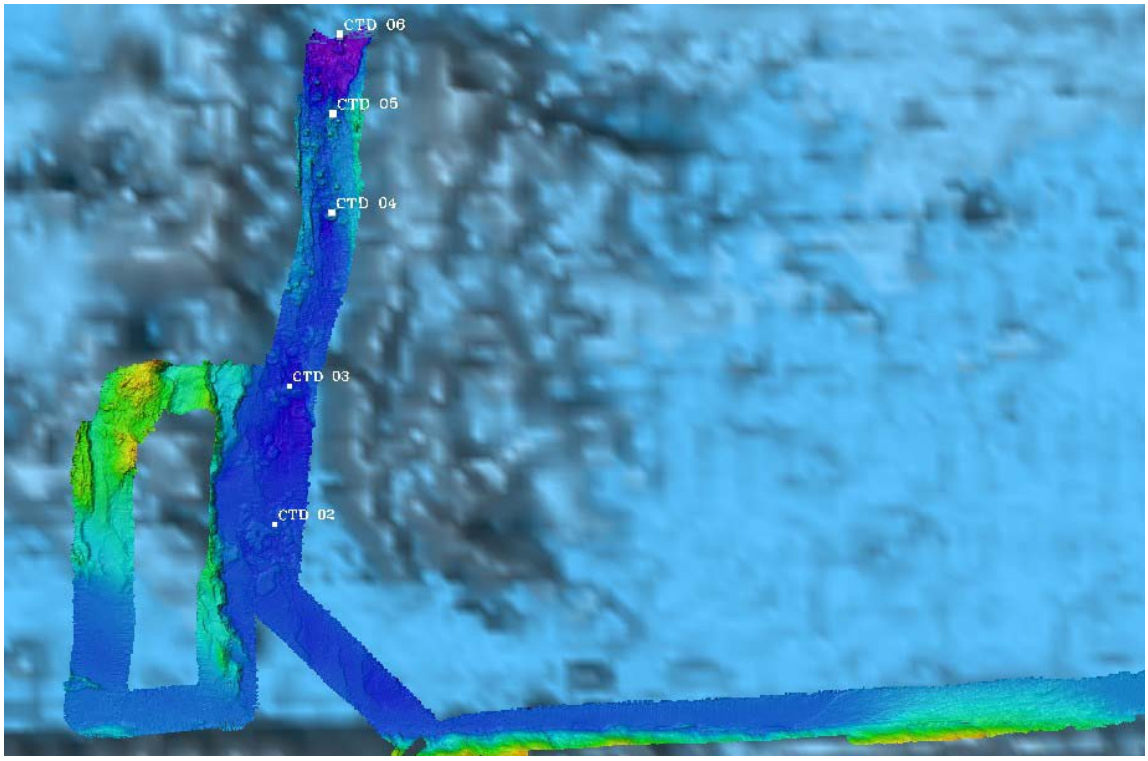

Figure 6. Screen grab taken in Fledermaus of multibeam data acquired with the shipboard EM 302 (with ETOPO2 data as background) of the Escanaba Trough region where work was conducted the past two days. Waypoints that mark the CTD cast locations are labeled as s

The sensor cable the ETs worked on with Walker appeared to be working well today, so hopefully it will hold out for the remainder of the cruise. The CTD stations are getting closer and closer together. They were about an hour's steam apart today and will be only about 20 minutes to half an hour apart starting tomorrow. Walker and Greene may decide to try a tow tomorrow if the ETs are able to fix the load cell in the CTD winch.

June 6, 2009

An XBT cast was not conducted this morning as the SV sensor was precisely accurate with the SV profile.

Mapping of the Escanaba Trough into Central Gorda Ridge continued overnight until 0800. The first CTD was cast at 0840 to a depth of about 3300 meters. The second CTD was cast at 1230 to a depth of about 3400 meters. Mapping was started again after the second CTD cast, at approximately 1530 and continued to the next cast site. The third CTD was cast at approximately 1730 to a depth of about 3600 meters. Seawater samples were collected in copper tubes from the Niskin bottles after each cast for later analysis of Helium and trace metals. Mapping started up again after the third cast at 2030 and continued throughout the night. (See *Figure 7* below for CTD cast locations.) Water column data has been collected throughout this survey for later processing by Mashkoor once he secures a Beta version of the Fledermaus software.

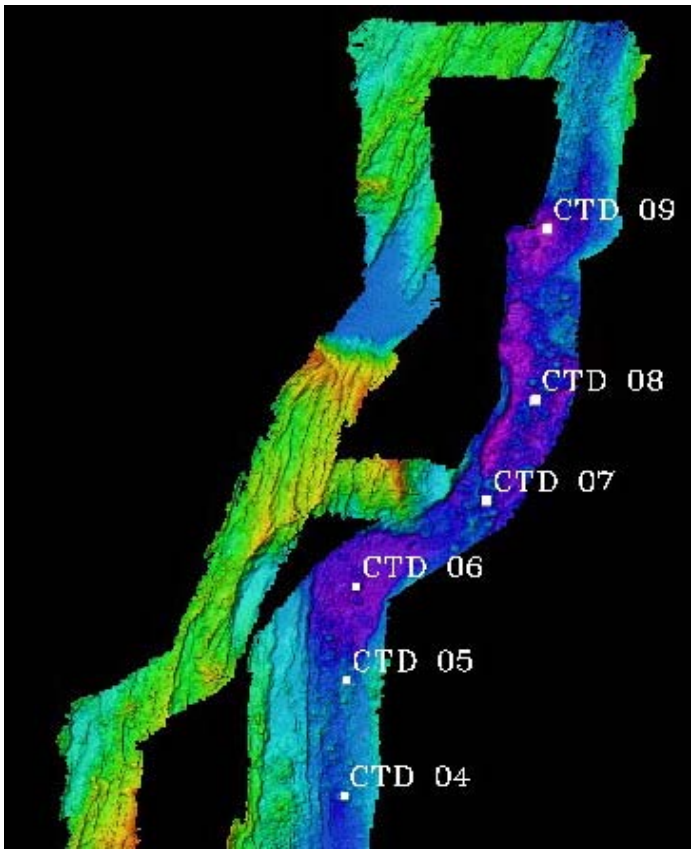

Figure 7. Screen grab taken in Fledermaus of multibeam data acquired during the past two days with the shipboard EM 302 of the Central Gorda Ridge region. Waypoints that mark the CTD cast locations are labeled as such, with CTD's 04-06 cast yesterday (June 5, 2

June 7, 2009

An XBT cast was conducted at 0030L and SV was applied to multibeam data collected by the EM302. Seas continued to be calm < 3 foot swells.

Mapping of the Escanaba Trough into Central Gorda Ridge continued overnight until 0820. The first CTD was cast at 0840 to a depth of about 3100 meters. The second CTD was cast at 1230 to a depth of nearly 3500 meters. Walker saw a potential temperature anomaly in the sensor data from this cast that could indicate hydrothermal activity. The third CTD was cast at approximately 1700 to a depth of about 3900 meters. Seawater samples were collected in copper tubes from the Niskin bottles after each cast for later analysis of Helium and trace metals. Multibeam data was acquired between CTD stations today, and will continue through the evening. (See *Figure 8* below for CTD site locations and multibeam data acquired).

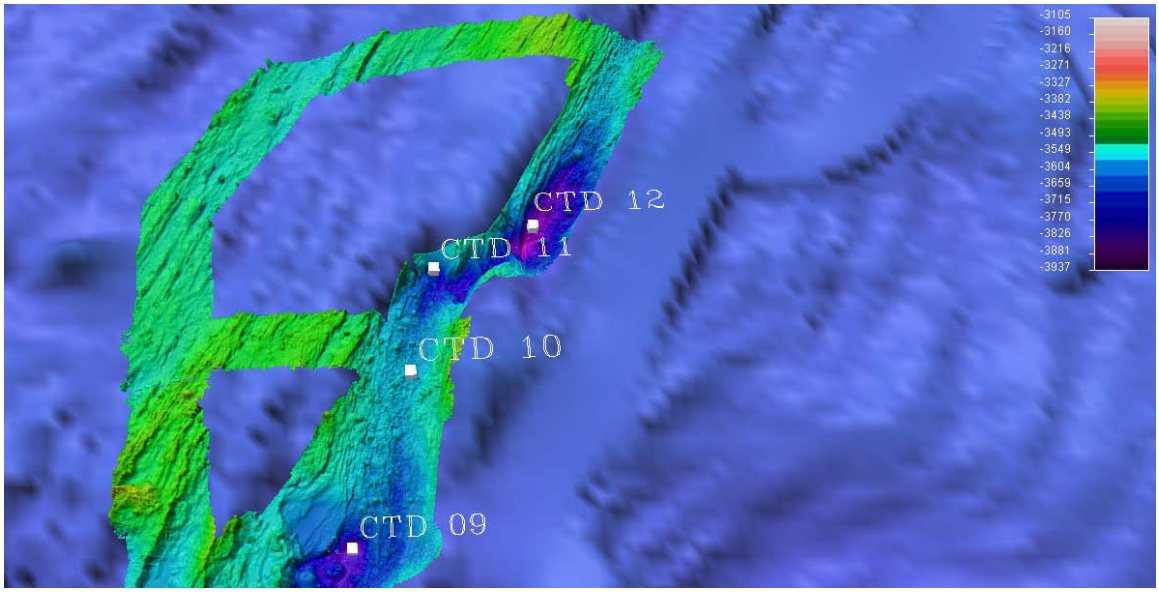

Figure 8. Screen grab taken in Fledermaus of multibeam data acquired the past two days with the shipboard EM 302 of the Central Gorda Ridge region. Waypoints that mark the CTD cast locations are labeled as such, with CTD 09 cast yesterday, June 6, 2009 and CTD'

Operations Officer VerPlanck drew the night's mapping operations on white boards in the control room and on the bridge to provide clear guidance on how to operate through the night (See *Figure 9*). To cut down on the amount of work necessary to draw this diagram on two white boards, a digital image was taken of the first white board from the bridge and this image was posted in the control room for the evening. This will be the daily standard.

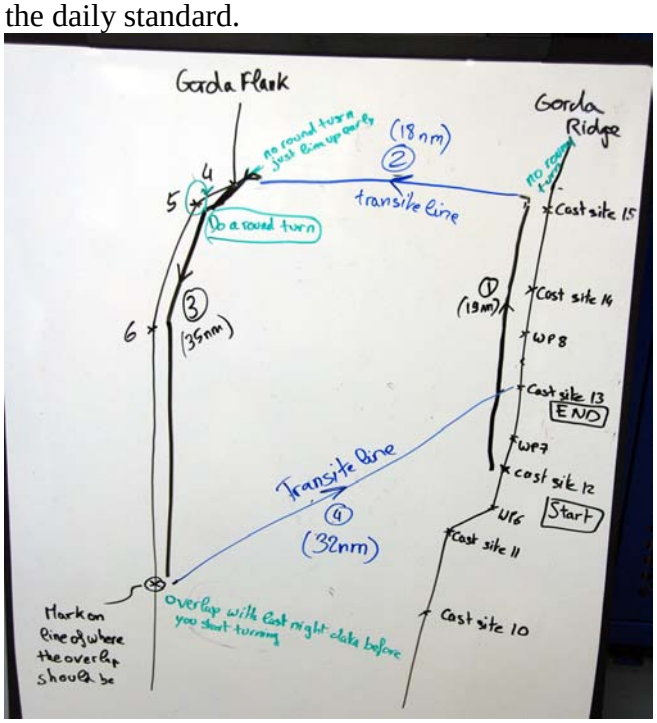

Figure 9. Night orders drawn on the bridge whiteboard by Operations Officer VerPlanck describing overnight mapping operations.

June 8, 2009

An XBT cast was conducted at 0030 and SV was applied to multibeam data collected by the EM302. Seas continued to be calm < 3 foot swells.

Mapping of Central and part of Northern Gorda Ridge continued overnight until 0730. Two CTD's were cast today. The first was cast at 0830 to a depth of about 3300 meters just North of the Central Gorda Ridge boundary. The second vertical cast of the day was conducted at 1630 to a depth of 2600 meters and positioned at the Sea Cliff hydrothermal field in Central Gorda. A plume signature was detected when the CTD descended to a depth of about 2250 meters, and continued nearly to the seafloor, demonstrating that this site remains active after nearly 25 years! *Figure 10* shows the dramatic signature from the Light Scattering Sensor (LSS) and Oxidation-Reduction Potential (ORP) sensors as the CTD descended. All on board were extremely excited by the results of this cast.

Evidence of hydrothermal venting was seen in this area during the first water column survey of the Gorda Ridge in 1985, and high-temperature vents were located at this site with the Navy's Sea Cliff submersible in 1988. We conducted our first tow-yo in the vicinity of the second CTD cast and successfully descended three times before the ship lost the ability to stay on the track line and the CTD was brought back on deck. The EM302 acquired multibeam data during the tow-yo as a test to combine water column capabilities and provide additional information associated with the CTD sensor data. Everyone was in agreement that the tow-yo provided invaluable experience to all involved. Another tow-yo will be conducted tomorrow.

Seawater samples were collected in copper tubes from the Niskin bottles after each cast for later analysis of Helium and trace metals. Multibeam data was acquired between CTD and tow stations today, and will continue through the evening.

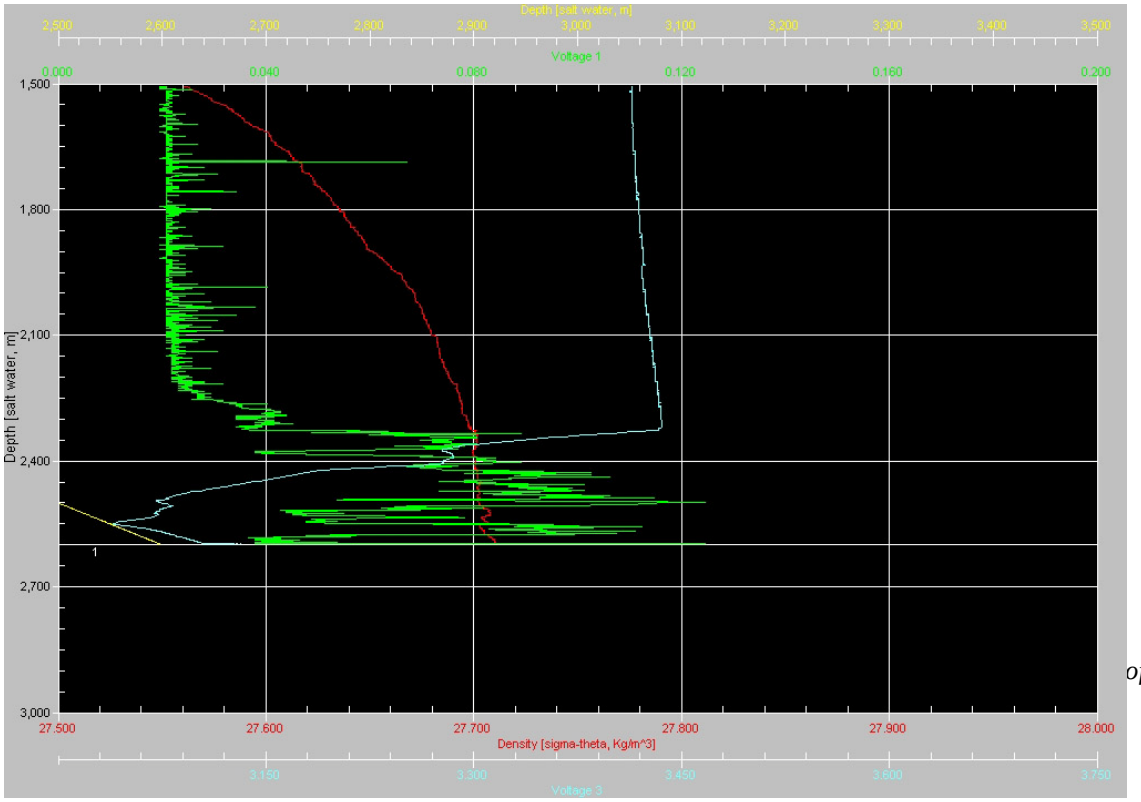

Figure 10. The second vertical cast of the day was positioned at the Sea Cliff hydrothermal field. The image shows the profile with depth of data from sensors on the CTD: the green line is the Light Scattering Sensor (LSS) which detects suspended particles; the blue line is the Oxidation-Reduction Potential (ORP) sensor which detects the presence of reduced chemical species (hydrothermal plumes are highly enriched in reduced chemical species, especially near the source); the red line is potential density. The particle anomaly began as the CTD descended past 2250 m, and increased dramatically along with the onset of the ORP anomaly at 2350 m. The plume was present nearly all the way to the seafloor (2610 m), and density inversions below 2500 m suggest we were sampling within the buoyant plume. All indications are that we were very close to the source, and that this site is still quite active after 25 years!

June 9, 2009

An XBT cast was conducted at 0200 and SV was applied to multibeam data collected by the EM302. Seas continued to be calm < 3 foot swells.

Mapping of Northern Gorda Ridge area was completed overnight and ended at 0700. The first CTD was cast at 0730 to a depth of about 3100 meters. The second and last tow of the cruise started at 1130 in about 2700 meters of water over the region the plume was detected during the second vertical cast yesterday. A second vertical cast was conducted at 1745 to a depth of about 3300 meters. Operations went very well today.

We completed the mapping efforts for Central Gorda and did not need to acquire more data between CTD casts today. Data was acquired during the tow, and will be acquired overnight as we transit to the East Blanco Depression area where we will conduct CTD casts tomorrow, June 10, 2009 (See *Figure 10* below).

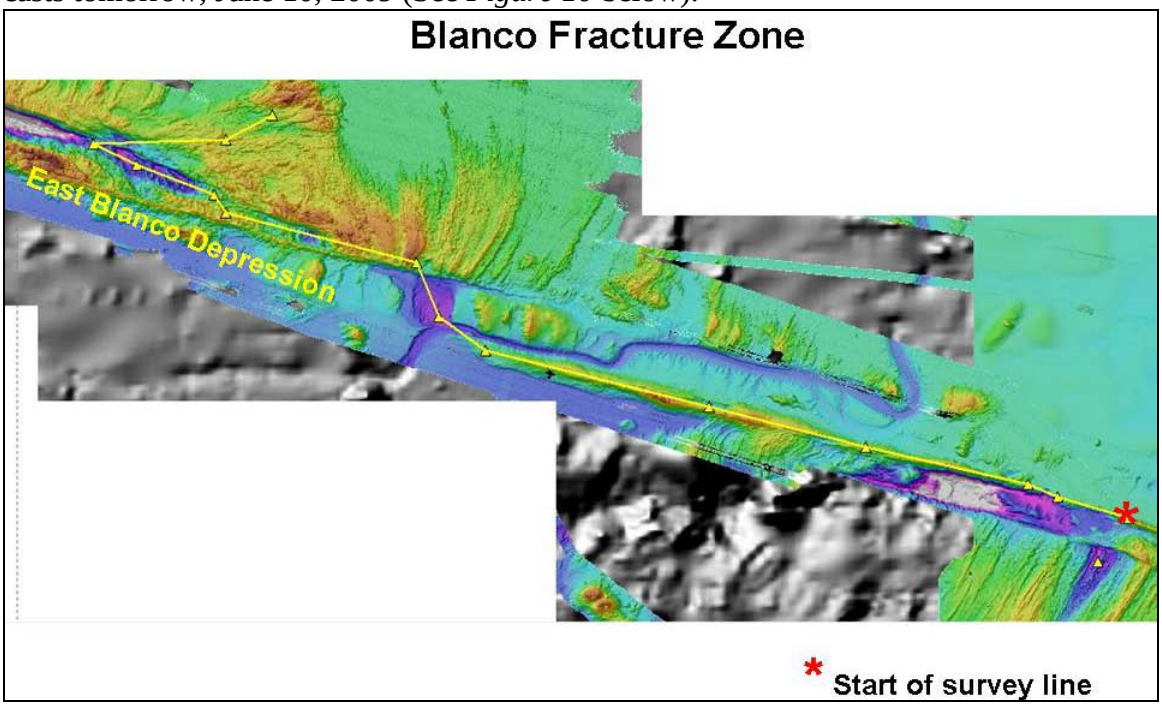

Figure 10. This image represents the 150 mile Blanco Fracture Zone survey line for this evening. Image courtesy of S. Walker.

June 10, 2009

An XBT cast was conducted at 0030 and SV was applied to multibeam data collected by the EM302. Seas continued to be calm < 3 foot swells.

Mapping of the 150 mile Blanco Fracture Zone survey line continued until 1330. Greene selected two CTD cast locations in the East Blanco Depression area for today. The first CTD was cast at 1330 to a depth of about 3200 meters. The second vertical cast was conducted at 1830 to a depth of about 3000 meters. Operations went very well today. (See *Figure 11* below)

Multibeam data was acquired between the two CTD cast locations in the East Blanco Depression region. The ship acquired multibeam data throughout the evening, filling in regions along the Blanco Fracture Zone. The last CTD is projected to be cast tomorrow morning in a sample site Greene calls Cascadia before the ship begins the transit to Newport, OR around 1200.

It was noticed that the ship had a two degree starboard list starting on June 9th. Engineering emptied ballast to compensate on June 10th which affected the stern by raising it four inches.

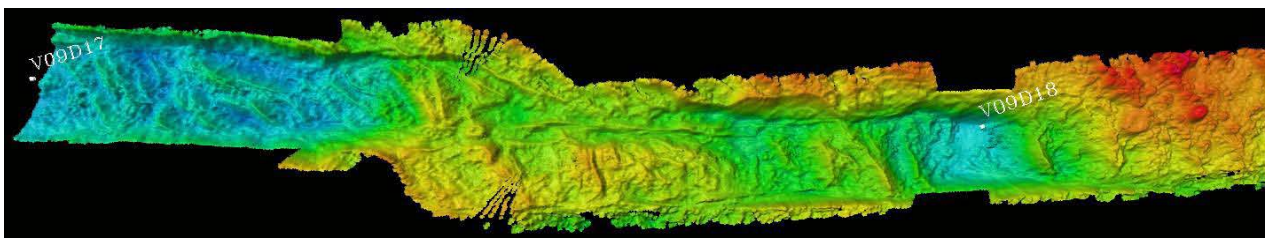

Figure 11. Framegrab from Fledermaus of multibeam acquired today of the two CTD cast sites in the East Blanco Depression area.

June 11, 2009

An XBT cast was conducted at 0030 and SV was applied to multibeam data collected by the EM302. Seas continued to be calm < 3 foot swells.

CTD cast was performed at 0730 in the Blanco Fracture Zone Greene calls Cascadia. Multibeam data was collected with the EM302 up to this site.

Once the CTD was completed at approximately 1200, the ship began its transit to Newport, OR.

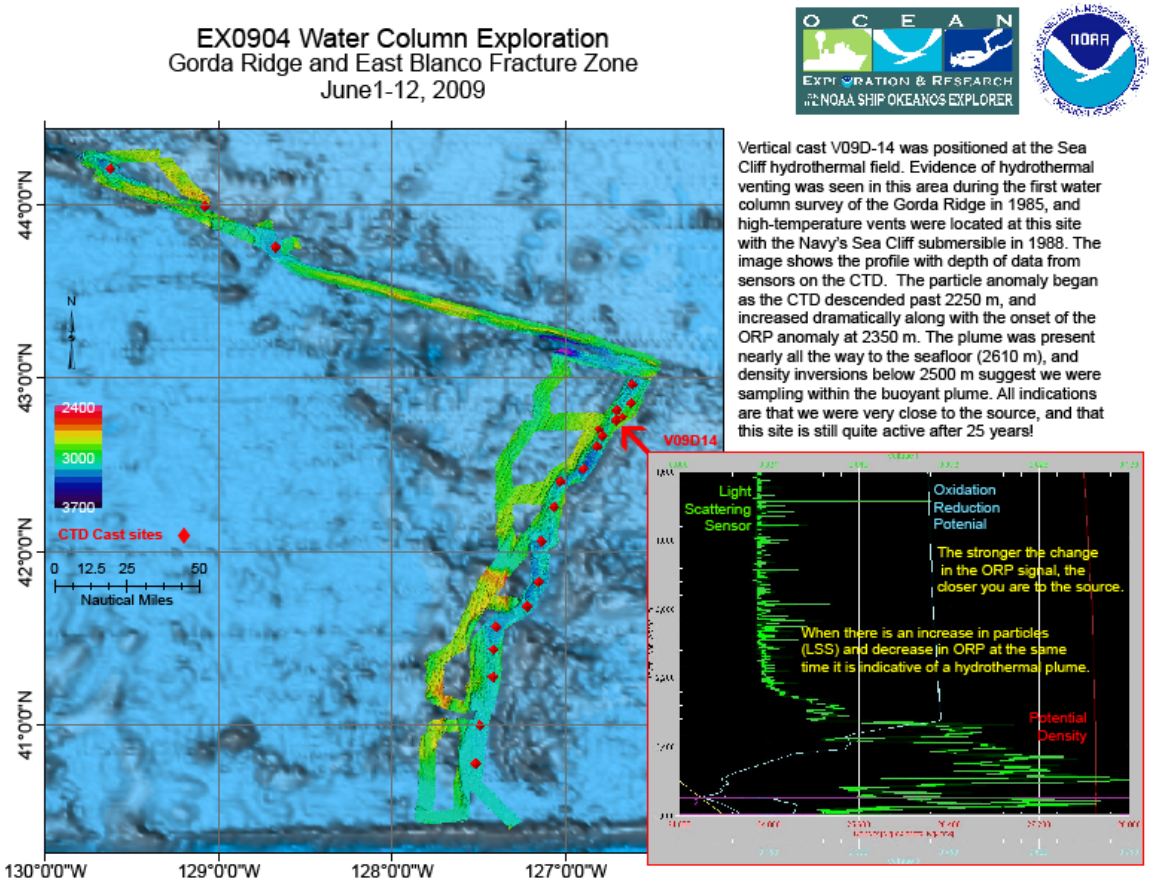

Figure 12.Final product of multibeam acquired throughout the cruise including all CTD cast sites positions of the Gorda and Blanco Depression areas.

June 12, 2009

Ship arriving in Newport, OR at approximately 1000.

10. Appendices

Appendix A: Locations of XBT casts

Probe Type	File name	Lat	Lon
Deep Blue	TD_00001.EDF	37 29.86523N	123 3.97461W
Deep Blue	TD_00002.EDF	40 1.62256N	124 31.09277W
Deep Blue	TD_00003.EDF	40 24.68066N	127 15.33789W
T-5	T5_00004.EDF	40	127

		31.40308N	35.87109W
T-5	T5_00005.EDF	42 16.00928N	127 21.19141W
T-5	T5_00006.EDF	42 42.7959N	127 14.12402W
T-5	T5_00007.EDF	42 53.30273N	127 8.32129W
T-5	T5_00008.EDF	43 18.04541N	127 15.41406W
T-5	T5_00009.EDF	43 36.07227N	128 26.53613W
T-5	T5_00010.EDF	44 16.62354N	129 32.04395W

Appendix B: 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 C: 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 3. 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 4. 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 5. 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 6. 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