CRUISE REPORT

NOAA Ship *Okeanos Explorer*

Water Column Exploration Field Trial I

Gorda Ridge and Blanco Fracture Zone

CRUISE EX0904

June 1, 2009 to June 12, 2009

San Francisco, CA to Newport, OR

Catalina Martinez, Expedition Coordinator

NOAA Office of Ocean Exploration and Research

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Introduction

This cruise is a water column exploration field trial cruise, designed to test and refine operations for conducting water column 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 CTD rosette in vertical station casts and tow-yos to establish and refine SOPs, deploy and recover equipment, utilize and evaluate laboratory and computer processes.
2. Utilize 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 water column 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. 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 acquire data along the East end of the Mendocino Ridge. Further mapping and CTD operations were conducted along the Blanco Fracture Zone.

Onboard Personnel

Ms. Catalina Martinez..... Expedition Coordinator
LT Nicola VerPlanck .....Field Operations Officer
Mr. Richard Patana .....Ship's Master
Ms. Elaine Stuart..... Senior Survey Technician
Ms. Colleen Peters ..... Senior Survey Technician
LTJG Megan Nadeau .....Hydrographer
Mr. Richard Conway..... Chief Electronics Technician
Mr. Eric Thompson..... Electronics Technician
Mr. P. Scott Hill.....NCDDC
Mr. McKinley Freeman .....NCDDC
Ms. Sharon Walker .....PMEL Oceanographer
Mr. Ron Greene .....PMEL Research Assistant
Mr. Dave Lovalvo..... Eastern Oceanics
Mr. Dave Wright..... Eastern Oceanics
Mr. George He .....LinkQuest

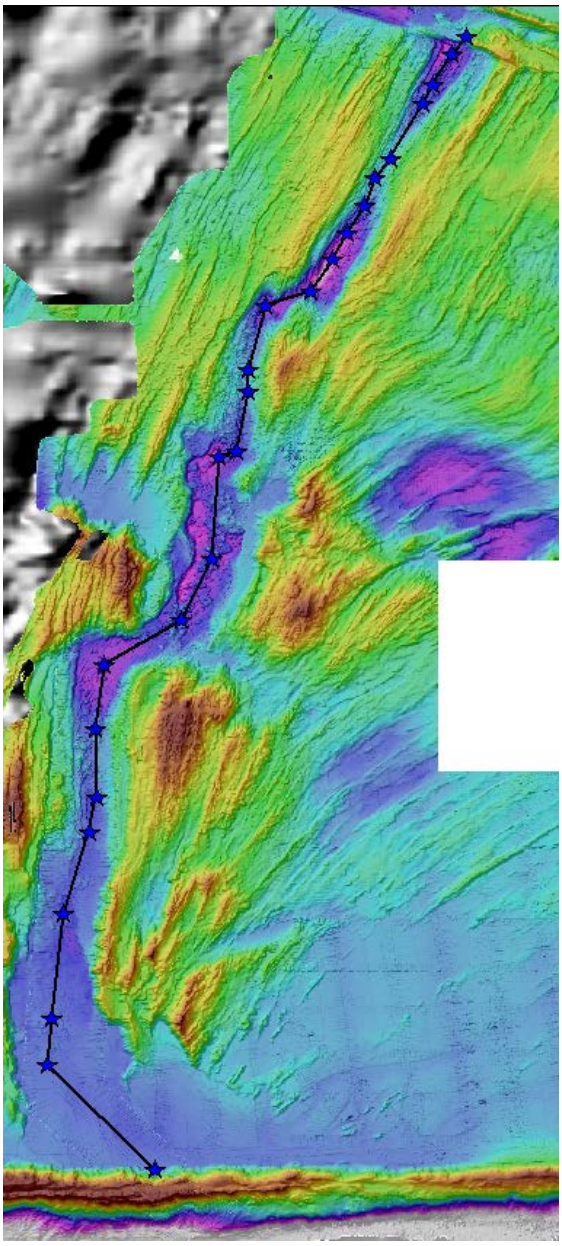

Figure 1. Location of Gorda Ridge and CTD stations.

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

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 equal spaced along each ping. Bottom detection on all beam 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. 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 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

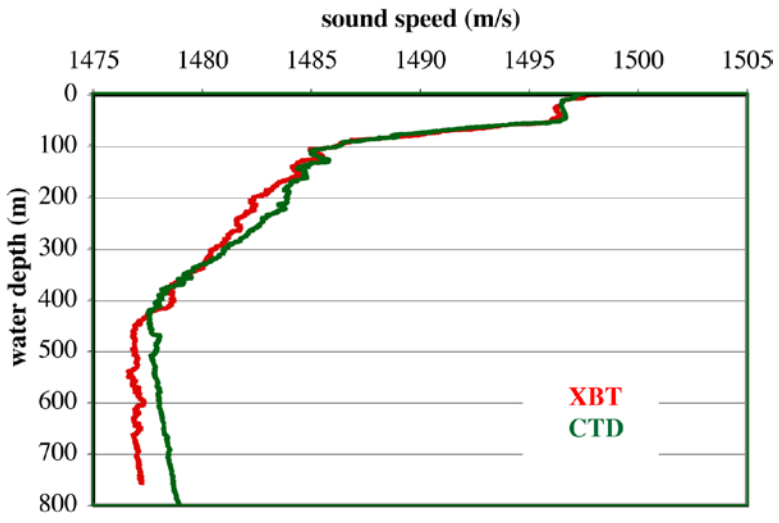

Figure 3. Comparison of sound speed calculated from an XBT and CTD cast at the patch test.

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 synchronizaton 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.

MBES Data Processing

Daily Log

JD 153 (Monday, June 1, 2009)

Morning dock-side operations included live broadcasts to the University of Rhode Island 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.

JD 154 (Tuesday, 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 of developing a workaround on the ship's network and sharing information with their map specialist at NCDDC for product generation.

Issues remain associated with the inability to utilize 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 that 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 huge barrier in our ability to operate remotely in general. As sharing information and data with personnel on shore is one of the OER Program's main objectives with the installation of the telepresence system on board, this situation should be resolved ASAP.

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.

JD 155 (Wednesday, 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.

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

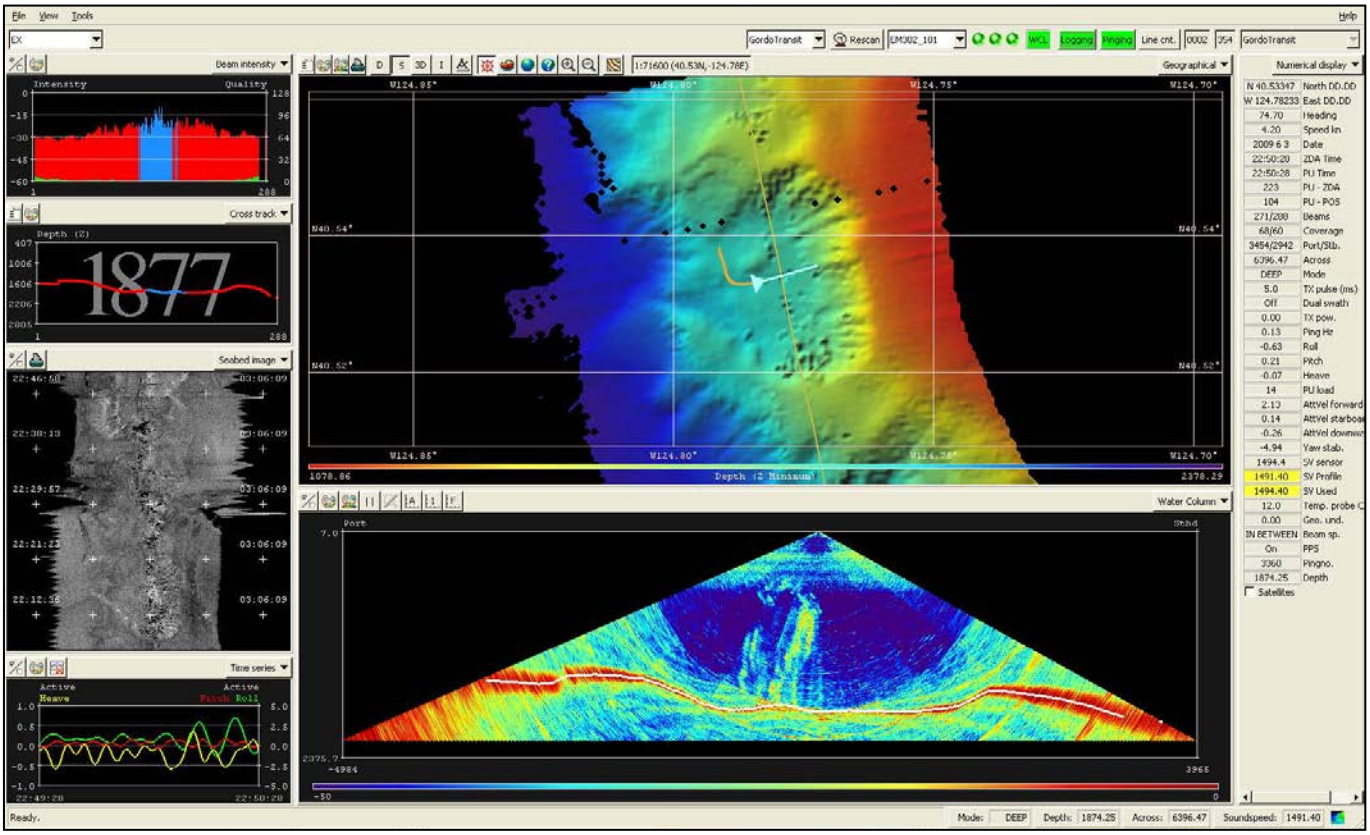

Figure 4. Screen grab taken today at approximately 1515 PDT of possible gas plume site initially detected during the EX0903 cruise located at the East end of the Mendocino Ridge.

JD 156 (Thursday, 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 that 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.

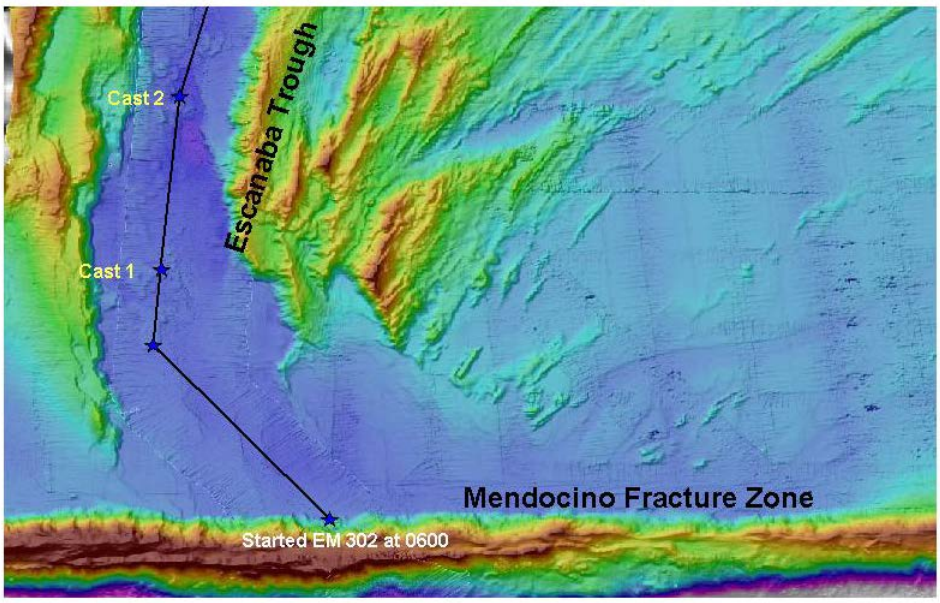

Figure 5. Screen grab taken from Walker's data in GeoTiff of the Escanaba Trough region where work was conducted today. Waypoints that mark the two CTD cast locations are labeled 'Cast 1' and 'Cast 2,' and the waypoint marking the start of the multibeam survey is also labeled accordingly.

JD 157 (Friday, 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)

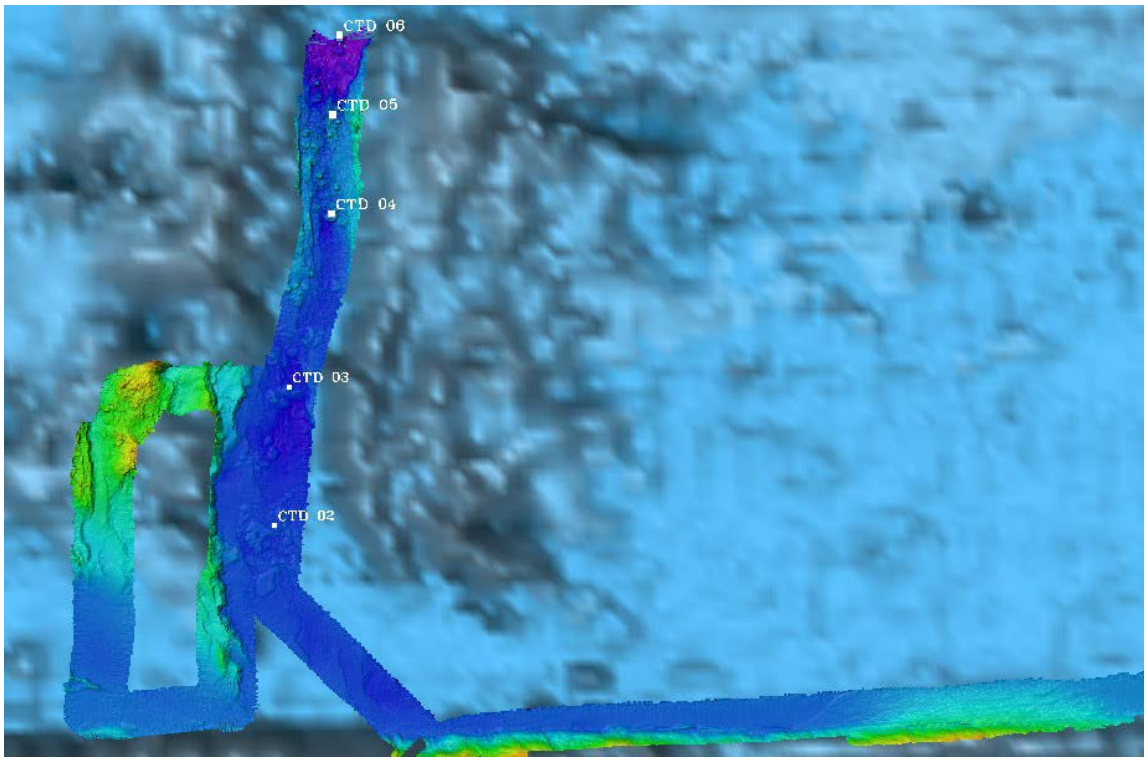

Figure 6. Screen grab taken in Fledermaus of multibeam data acquired with the shipboard EM 302 (with ETOPO2 data as background) of the Escanaba Trough region where work was conducted the past two days. Waypoints that mark the CTD cast locations are labeled as such. CTD's 02 and 03 were cast June 4, 2009 and CTD's 04-06 were cast June 5, 2009.

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.

JD 158 (Saturday, 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.

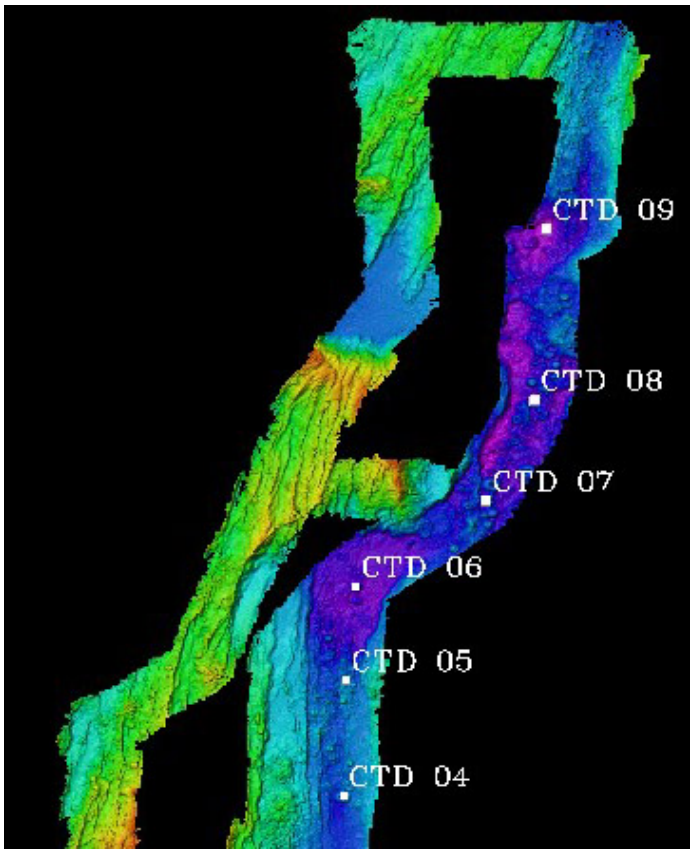

Figure 7. Screen grab taken in Fledermaus of multibeam data acquired during the past two days with the shipboard EM 302 of the Central Gorda Ridge region. Waypoints that mark the CTD cast locations are labeled as such, with CTD's 04-06 cast yesterday (June 5, 2009) and CTD's 07-09 cast today (June 6, 2009).

JD 159 (Sunday, June 7, 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 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).

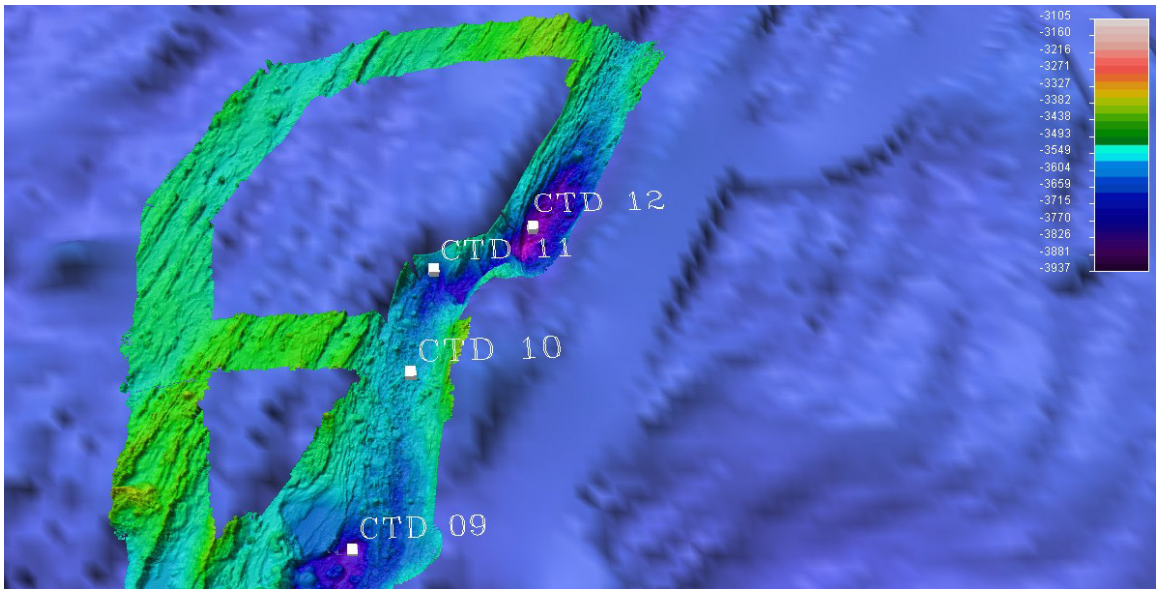

Figure 8. Screen grab taken in Fledermaus of multibeam data acquired the past two days with the shipboard EM 302 of the Central Gorda Ridge region. Waypoints that mark the CTD cast locations are labeled as such, with CTD 09 cast yesterday, June 6, 2009 and CTD's 10-12 cast today, June 7, 2009.

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.

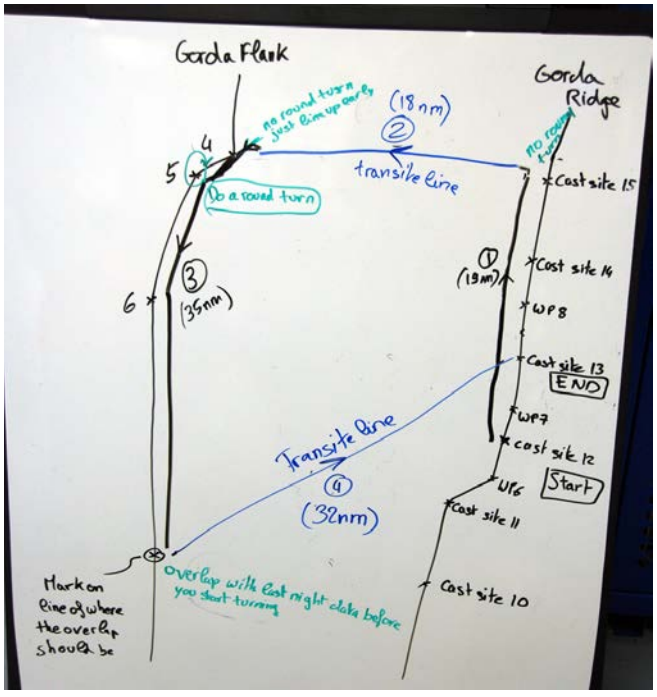

Figure 9. Night orders drawn on the bridge whiteboard by Operations Officer VerPlanck describing overnight mapping operations.

JD 160 (Monday, 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.

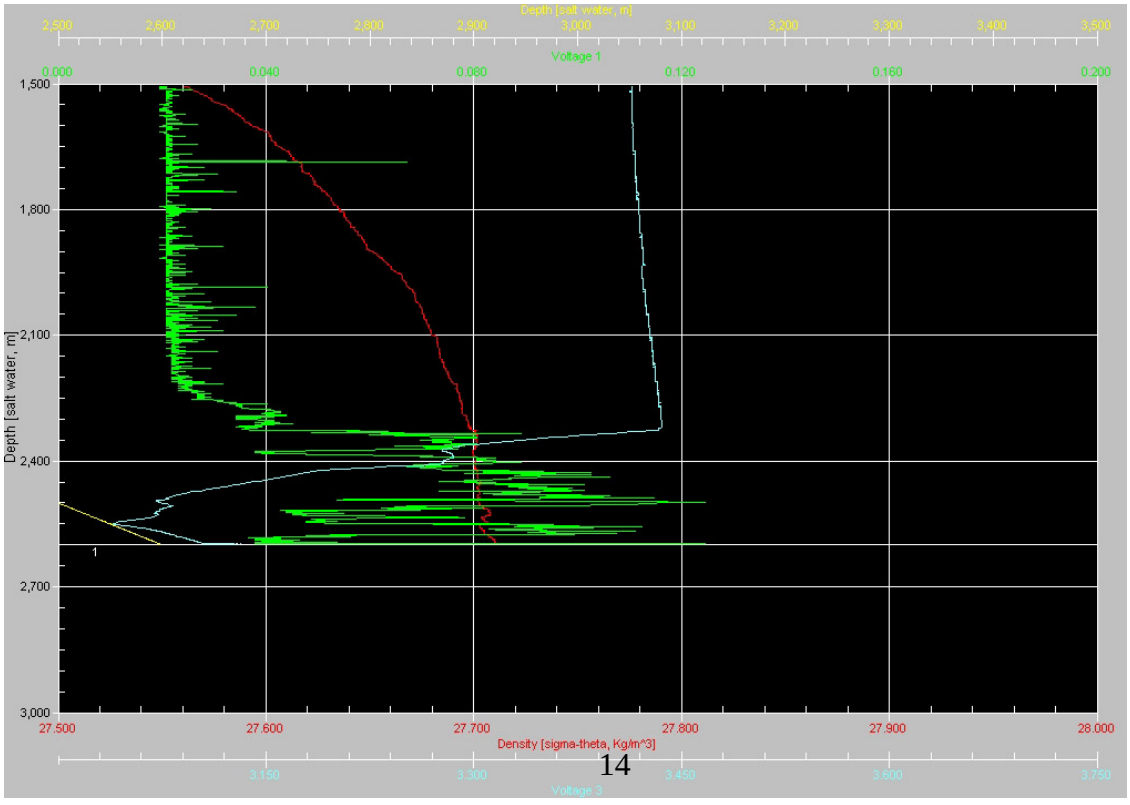

Figure 10. The second vertical cast of the day was positioned at the Sea Cliff hydrothermal field. The image shows the profile with depth of data from sensors on the CTD: the green line is the Light Scattering Sensor (LSS) which detects suspended particles; the blue line is the Oxidation-Reduction Potential (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!

JD 161 (Tuesday, 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 11* below).

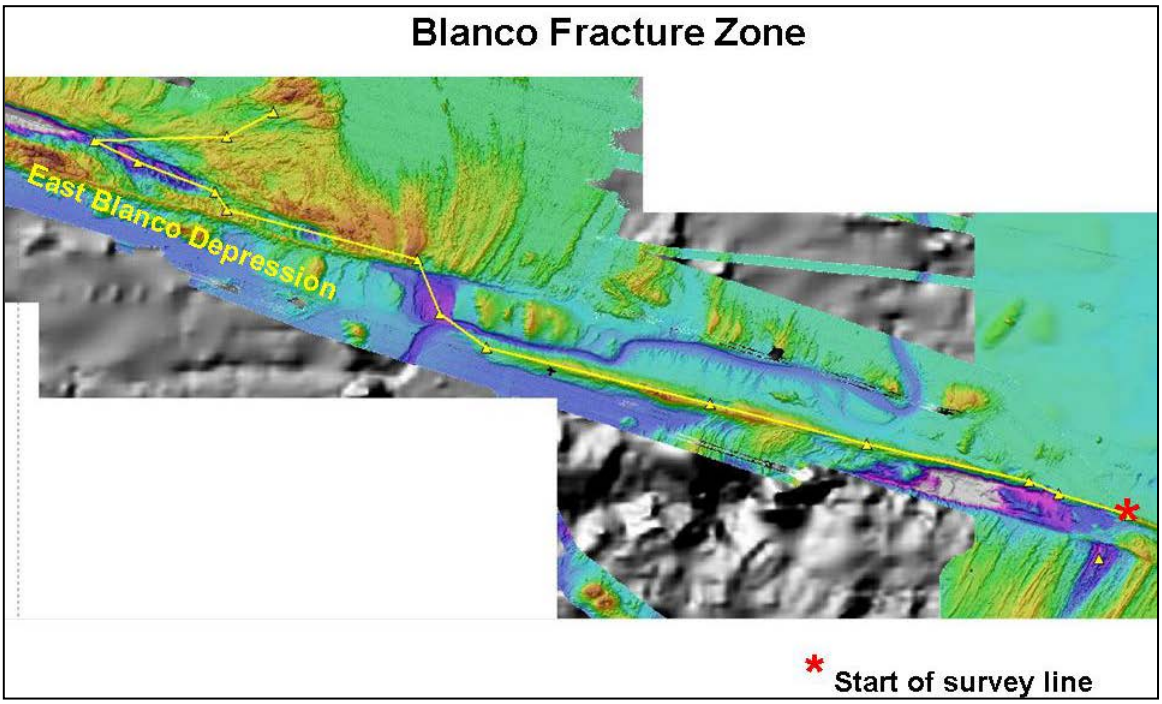

Figure 11. This image represents the 150 mile Blanco Fracture Zone survey line for this evening. Image courtesy of S. Walker.

JD 162 (Wednesday, 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 12* 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.

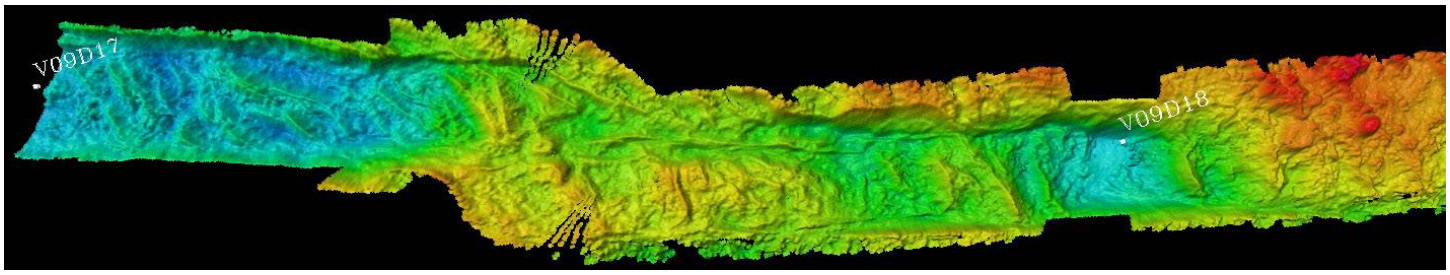

Figure 12. Framegrab from Fledermaus of multibeam acquired today of the two CTD cast sites in the East Blanco Depression area.

JD163 (Thursday, 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.

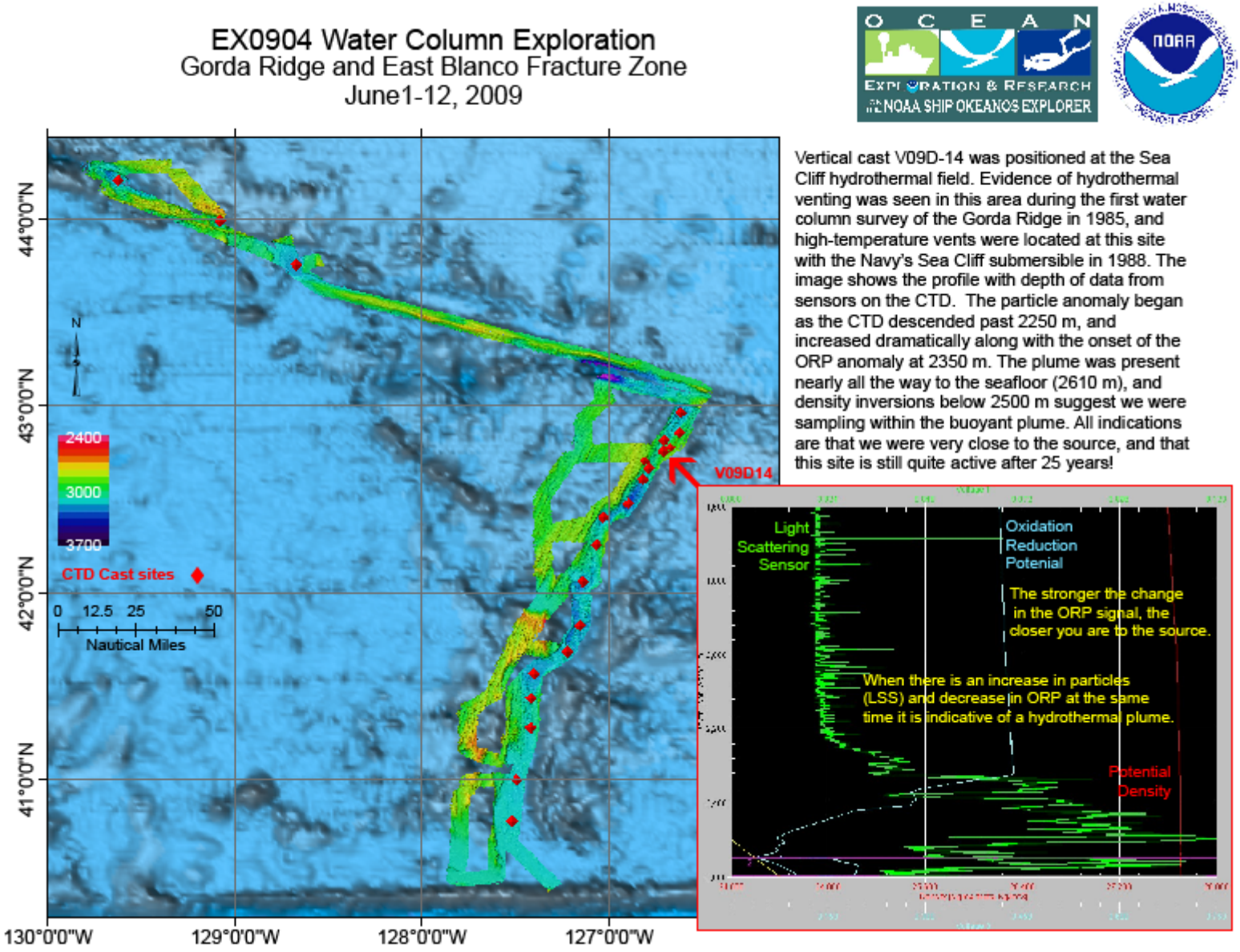

Figure 13. Final product of multibeam acquired throughout the cruise including all CTD cast sites positions of the Gorda and Blanco Depression areas.

JD 164 (Friday, June 12, 2009)

Ship arriving in Newport, OR at approximately 1000.

***Table 3*. Locations of CTD cast**

(See water column cruise report)

***Table 4*. Locations of XBT cast**

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 31.40308N	127 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

***Table 5*. 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 ..... 2381 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