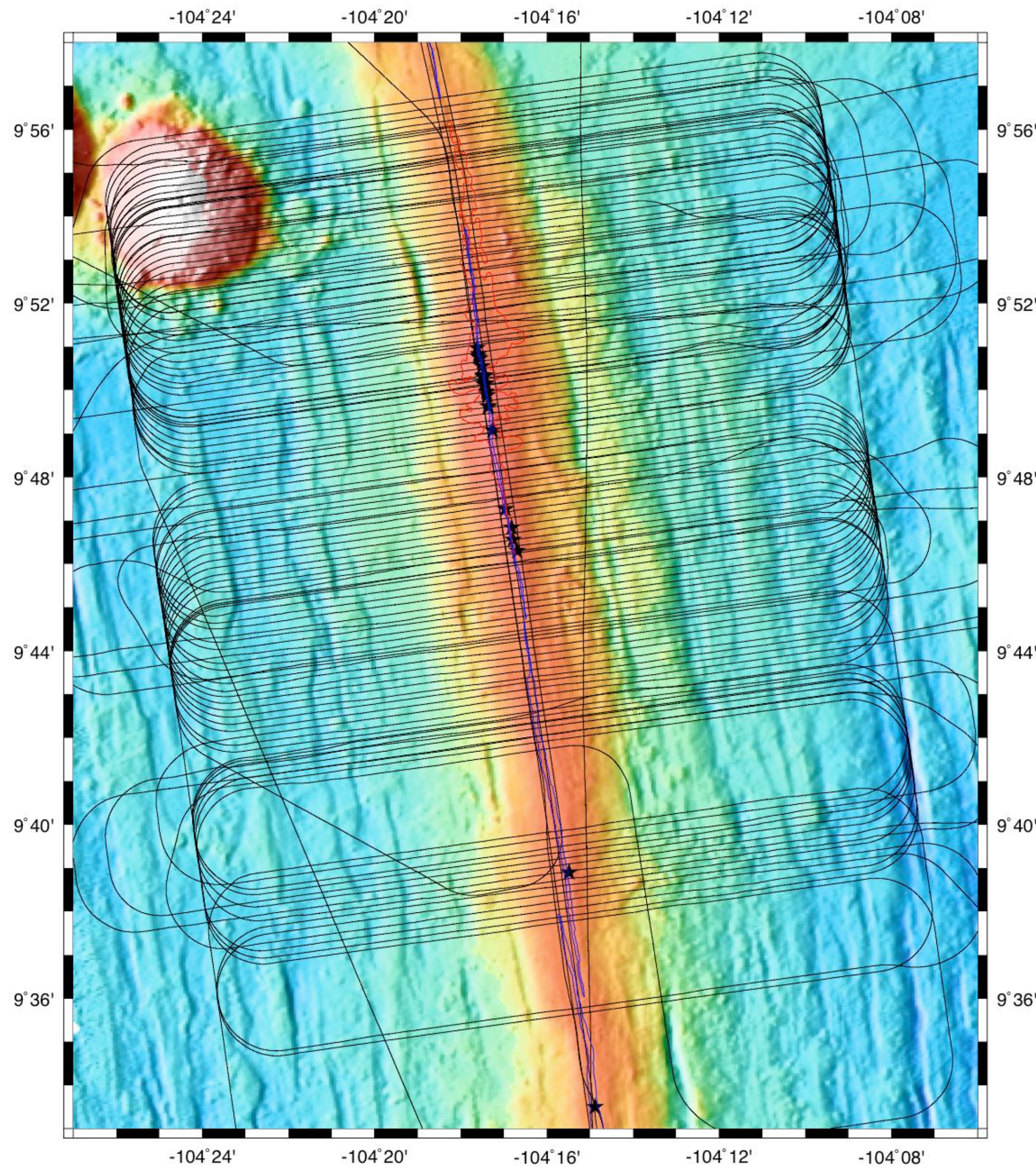
MGL0812 Cruise Report

A 3D MCS investigation of the magmatic-hydrothermal system at the East Pacific Rise 9° 50’N.



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1. **Scientific Motivation and Project Objectives**

About a quarter of a century ago it was demonstrated that magma bodies beneath the fast spreading mid-ocean ridge of the East Pacific Rise (EPR) could be imaged by multichannel seismic reflection (MCS) profiling. This remarkable discovery initiated a period of intensive research that has seen many MCS profiles acquired along, across and adjacent to the EPR ridge axis between 16° N and 20°S. With the single exception of the 1997 ARAD survey, these experiments have aimed for broad coverage of the EPR with 2D seismic profiles, often motivated by the objective of examining the axial magma chamber (AMC) and internal crustal structure in places where the ridge's morphology, geochemistry, or other features exhibited a range of tectonomagmatic characteristics. As a result, the total seismic reflection coverage of the EPR ridge axis is extensive while sparse.

During the same quarter century many areas of the EPR have been examined in detail both directly from submersible dives and sampling programs, as well as indirectly using high-resolution acoustic mapping techniques. Several areas are now extremely well characterized from the perspective of surface phenomena including faulting, volcanism, hydrothermal and biological activity. What has emerged are two unique perspectives on fast spreading ridge processes: one based on analysis of detailed observations from relatively small focus areas at the seafloor; the other comprising a well-developed understanding of the broad-scale spatial characteristics of the magmatic system and internal crustal structure of fast spreading ridges. What has not yet emerged is an understanding of how the magmatic system, which is known at large spatial scales (1.0-100.0 km), is coupled to volcanic/hydrothermal/biological systems, which are known at comparatively small spatial scales (0.001-1.0 km). Nor do we have more than an intuitive appreciation for the relationships between the temporal variations in subsurface magma systems and highly transient phenomena observed at the seafloor like faulting, volcanism and hydrothermal venting.

The research community selected the EPR at 9°50'N as one of the RIDGE 2000 Integrated Study Sites (ISS) in which to focus a decade of research and discovery at a fast-spreading ridge segment with the overarching goal of "*understanding the mid-ocean ridge as a complex geobiological system with interconnected parts related through diverse controls and feedbacks*". The EPR at 9°50'N, one of the fastest spreading centers on Earth, is a highly dynamic magmatic, hydrothermal, and biological system that presents an ideal opportunity to observe and measure changes in and linkages between surface and sub-surface mid-ocean ridge processes on decadal time-scales. Two volcanic eruptions have now been observed at the site, in 1991 and most recently 2005-2006. Hydrothermal activity is prolific at the EPR 9°50'N area including both focused high temperature vents and areas of diffuse flow. A substantial collection of time-series measurements now exist that describe the evolution of the vents and associated biological communities since the 1991 eruption and now through the 2005/2006 eruption.

The primary goal of expedition MGL0812 were to use the newly available multi-streamer capability of the R/V Langseth to create an accurate 3D seismic reflection image of the magmatic-hydrothermal system within the East Pacific Rise 9°50'N site by imaging the structure of the axial magma chamber (AMC) lid and shallow oceanic crust at a resolution, geometric accuracy, and scale comparable to seafloor observations of hydrothermal, biological, and volcanic activity. 3D migration techniques will allow us to construct geometrically accurate high-resolution images of the magma system and its distribution in the subsurface, while 3D amplitude variation with offset (AVO) analysis will allow us to determine the seismic properties (e.g., velocity, density, Poisson's ratio) that are proxies for the porosity and fluid content of the magma body. The 6 km offset of the hydrophone streamers will permit a detailed 3D characterization of the thickness and velocity of seismic Layer 2A and the upper part of Layer 2B. By providing 3D images and physical property mapping at a resolution comparable to the scale of variation of surface phenomenon, we can address several of major questions at the EPR site that focus on the relationships and interactions between sub-surface and surface processes. The 3D volume will also allows us to address the structure of the lower crust, the Moho transition zone, and uppermost mantle with unprecedented detail. Furthermore, our 3D seismic study will establish a baseline image of the magma body and upper crust against which changes in geometry and physical properties can be detected in the future using 4D time-lapse seismic imaging.

2. Survey Plan

Our planned survey included a primary 3D box of 142 lines spanning the ridge axis from 9°57' to 9°34'N and 3 axis parallel lines designed for dedicated AVO studies of magma lens properties. The 3D box was positioned to provide full coverage of the region that erupted in 2005-06 and previously in 1991, extending from the northern end of the 2005/06 lava flows at 9°57'N to the presumed southern limit of diking at 9°39'N. The southern end of the planned survey at 9°34' was designed to capture the 9°36'-38' third-order discontinuity and a portion of the adjoining segment. A number of previous studies of crustal and mantle structure are located in this region from which a wide range of complementary data are available.

The three axis-parallel lines included one primary line extending the full length of the ridge axis from Siqueiros to Clipperton Fracture Zones, approximately centered along the axial summit trough and two shorter parallel lines from 10°05 to 9°20'N. These shorter lines were spaced 300 m from the main axis line to provide a ~ 900 m wide swath of 24 CDP lines spanning the entire width of the AMC in this region (500-700 m based on the 1985 Conrad study) in order to facilitate AVO studies across the melt lens. The primary axis line was designed to provide coverage of the unsurveyed segment south of the 9°03'N OSC (the southern limit of the 1985 Conrad survey was ~8°50'N) and to transect the 3D MCS ARAD study at the OSC in order to facilitate comparison and assess possible change in magma lens structure and seismic properties.

Within the 3D box, planned sail lines were spaced 300 m apart, at an orientation of 082°. With streamer separation of 150 m and two gun string sources fired alternately on distance at 37.5 m intervals, this configuration provides eight 37.5 m spaced CMP lines with each pass and a 37.5 m by 6.25 m static bin cell size. Sail lines were 24 km long to provide full fold coverage for the central 16 km about the ridge axis with 4 km on each end of the line for run-in and run-out and to ensure accurate streamer positioning. Our initial survey was planned assuming one half cable length for run-out (3 km) but was revised at the beginning of the cruise on discussion with the Senior Science Officer Robert Steinhaus and Chief Navigation Specialist David Martinson. They advised that 4 km pull through after the last full-fold shot point was needed to ensure that the streamers to the mid-section acoustics would be through the turn and straight enough in order to be able to accurately position the streamers to the desired specifications of <3 m for receiver locations.

Line numbering was determined following industry convention with the southernmost planned sail line numbered 1000, incrementing by 8 (for the 8 CDP lines with each pass), to the northernmost sail line 2316. For all lines, the shot point range for the full fold box was planned to be 1000 to 1432. Shotpoints are numbered from west to east, hence shot point numbers decrease along line for sail lines shot from east to west.

The survey was split into 3 racetracks designed to cover the desired survey region with the seam pass of each racetrack located away from primary survey targets. The racetracks were also designed to shoot the highest priority vent region from 9°51' to 9°46' spanning two racetracks but in a consistent direction (east to west). The nominal minimum turning radius was 5000 m. However, during operations slightly larger turning radius was needed to maintain tension on the streamer cables at acceptable levels.

3. Survey Summary

Acquisition on MGL0812 had two distinct and very different phases. In the first the vessel departed Manzanillo on June 29th and returned on the evening of July 10th having experienced failures in the two seismic compressors after less than 60 km of acquisition. Deployment of the towed equipment had been relatively straightforward, beginning around 0800 on July 1st and was completed around 2:30 pm on the 3rd. Acquisition began and ended on July 4th. Attempts to diagnose the compressor problems and restore them involved major efforts on the part of the ship's engineering department assisted by airgun personnel. Only after all possible avenues for at sea repairs were exhausted was the decision taken to return to port. Repairs were made in port with the assistance of Al Walsh from Lamont OMO and representatives from Caterpillar Diesel. The vessel left Manzanillo midday on the 13th to continue the cruise.

The second phase of the cruise was a distinct contrast to the first. Acquisition began on July 16th after a deployment that took around 36 hours. While a series of problems during the second phase were encountered, none were particularly unexpected given the complexity of the operation with four streamers and two source arrays. Most maintenance was achieved through extended line changes in which the vessel continued a racetrack line beyond the end of the required grid line. This is a very efficient way to achieve maintenance, most of which was anticipated and routine. Extended line changes were most often needed for source array preventative maintenance. These extended lines changes totaled 44 hours[1] (Airguns: 14 hours 39 minutes, Streamer: 16 hours 45 minutes, Compressors: 11 hours 10 minutes, Recording system: 27 minutes, Workboat: 20 minutes, Whale sighting: 22 minutes, Ship steering: 21 minutes)

Loss of acquisition due to marine mammal sightings was minimal as expected for the area, but a significant amount of time was lost due to sighting of turtles that were fairly common. The PAM system experienced numerous problems and was eventually substituted with use of a hull mounted hydrophone. PAMs are not designed for the harsh environment involved in towing within the seismic array equipment and the numerous deployments and retrievals that are involved with marine seismic work. A more robust system will need to be developed if passive monitoring continues to be considered necessary.

The final pattern of lines is shown in figure 3.1. They comprise a suite of along axis lines, a large 3D grid, a smaller 3D grid and a number transit and cross axis lines that complement the main grid.

Along axis lines extend throughout the entire ridge segment from the Clipperton to Siqueiros Fracture Zones. Between the Clipperton Fracture zone and 9° 41’ N we acquired three parallel lines along the axis. Between this latitude and 9° 20’N we obtained two parallel lines and one axial south of that latitude.

3D coverage was achieved in two areas. The larger comprises a set of 94 (one partial) equally spaced lines forming the 3D grid between 9° 57’ N and 9° 42’ N. Note that the area of three-line along axis coverage extends through this area. This grid is made up of lines from all of racetracks #1 and #2 and the northern lines of racetrack#3. This area is complete with re-shoots and infill. This area covers the two principal hydrothermal vent areas in a continuous fashion. Assuming that the imaged depth is 10 km this represents a correctly imaged volume of 4512 km^3, although the acquired volume is considerably larger considering the ends of lines that are acquired with partial fold. Many of the 2D profiles show features of interest within the regions where data of less than full-fold was obtained and could be of value in interpreting the data in the volume.

[1] This is not the total time involved in maintenance because normal turns are used for maintenance. This represents the time the turns were extended beyond the normal turn time.

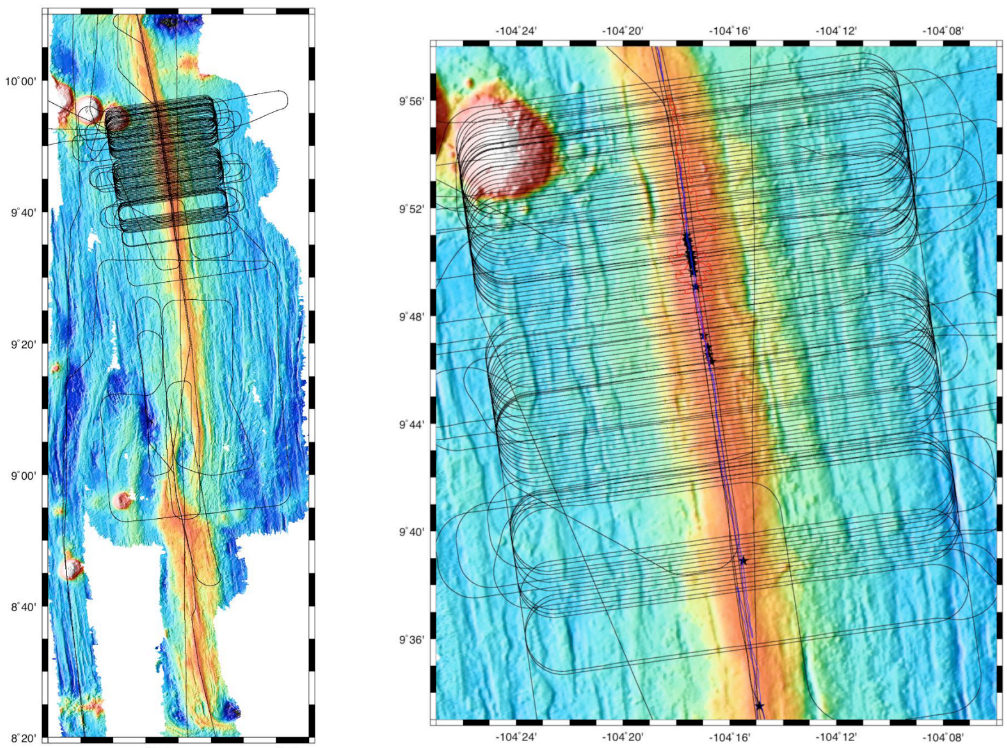

Figure 3.1 (left) Track map for full survey region superimposed on new multibeam bathymetry data collected during survey. (right) Close up for 3D survey box.

The second 3D area is comprised of 14 southern lines acquired in the incomplete racetrack#3. This area is separated from the larger grid by a gap of 11 lines or 3.3 km that is the area of racetrack #3 that was not acquired. The 14-line group constitutes an imaged volume of 672 km^3 using the assumed depth of imaging of 10 km. This grid of lines encompasses Conrad line 29 from the 1985 cruise as well as vent B and extends just to the northern end of the third order discontinuity centered at 9° 37' N.

South of this region we acquired a pair of lines that crossed the ridge at about 9° 35'N and a single line just south of 9°30'N. The latter crosses the ridge at the site of vent K and is the same location as a cross axis line acquired by Conrad in 1985. This line also extended farther east than the 3D grid lines to examine the area where the OBS undershoot experiment had identified a mantle anomaly located significantly off axis. The pair of lines is located at the southern end of a third order discontinuity at 9°37' N, the northern end of which is included in the area of racetrack#3's southern group of lines.

In addition we acquired three lines opportunistically during transits and a north-south line east of the ridge crest extending south from the southern end of the main 3D grid, through the smaller 3D grid and crossing the pair of lines at 9° 35'N. Although acquired off axis this line is designated AXIS5. The purpose was to map the extent of an event recognized in the mid-crust to the east of the axis as described in the Initial Results section of this report.

Acquisition ended at 0157 August 16th part way through the shooting of an infill line within racetrack#1 heading west. Lack of fuel and/or problems with the ability to accurately assess fuel on board forced us to cease survey operations 2 days short of the total 10 day extension granted by NSF. The towed equipment was retrieved over the next 12 hours and the vessel transited to Manzanillo in the morning of the 19th.

In all, the cruise accomplished the acquisition of 3,781.95 km of sail line data. There are 111 (one partial) across axis lines that required 10 repeated lines and, given our time constraints, a minimum of 14 infill lines. That is, completion of 111 cross axis lines that can be used in the 3D processing required a total of 135 lines of acquisition. This means that 18% of the total cross axis acquisition was used for reshoots and infilling. This is somewhat less than the 25% multiplier on planned lines for a 3D grid that is often used in the seismic industry. Given the modest feathering observed during our survey (see section 5 below), 25% is probably an appropriate figure to use in planning academic surveys as well.

Each of the lines acquired represents eight CMP profiles and hence the CMP line acquisition is 30,255.60 km. This comprises 99,888 shots and 186,998,336 source-receive pairs and with a sampling rate of 2 milliseconds a total of **957,890,520,320** data samples, which at 4 bytes per sample adds up to some 3.7 TB of data including headers.

Despite the difficult set back at the beginning of the cruise and several during, we accomplished close to 80% of the planned work, collected a volume of data that will be analyzed for many years and have made very important discoveries that can be reported immediately at the forthcoming 2008 Fall AGU meeting.

Overcoming the challenges presented by this cruise relied completely on the skill and professionalism of the leadership and members of the science technical support party and of the vessel's captain, officers and crew. The PI's are deeply appreciative and grateful for their dedicated efforts. The PIs are also deeply grateful to the managers at NSF who provided a 10-day extension to the cruise to ensure that it was a success. Had this extension not been granted we would have barely achieved 50% of the intended coverage and would not have met the scientific objectives of the program.

4. Daily Narrative

Transit and deployment (1200 June 29th – 0100 July 4th)

Research Vessel Marcus G. Langseth departed Manzanillo, Mexico around noon[2] on 29th July, 2008 to begin transiting to the East Pacific Rise work area. Multi-beam recording was begun after leaving Mexican EEZ. Deployment of the towed equipment began

[2] Local times are used throughout; minus 5 hours behind GMT.

around 0800 July 1st starting with Streamer #1, starboard side, followed by the starboard paravane (baravane or door) taking streamer to initial park position, then port side outer streamer #4 and port side baravane to park position. The outer streamers are kept in the park position during deployment of the inner streamers #2 and #3. Deployment of starboard streamer #2, then port streamer #3 followed and then connected to associated baravanes for final spread configuration and baravanes fully deployed. After streamer deployment the four gun strings, two on each were deployed. With all seismic equipment in the water the magnetometer was deployed from the port side as well as the PAM (Passive Acoustic Monitor) used for marine mammal surveillance.

Only routine maintenance was needed during deployment of the towed equipment. This included changing several streamer sections, GPS transmitter on one tailbuoy and minor adjustments to birds. Most of this work was anticipated from the assessment at the end of the previous cruise and involved no unusual procedures or delays.

All the towed equipment was ready for acquisition around 2:30 pm July 3rd so the deployment was accomplished in less than three days. The vessel was well south of the intended start point at around 8° 15' N at the end of the first along-axis line south of the overlapping spreading center (OSC) at $9^0$3'N.
First shot to the full receiving array was recorded on July 4th at around 0100.

Data collection (0100 July 4th – 0900 July 4th)
Data were collected along the ridge axis to the south of the OSC then on to the western limb of the OSC. These are lines AXIS1 and AXIS2. Acquisition ended just before 0900 on the same day, July **4th**, due to the development of problems with both seismic compressors. The vessel was maneuvered to the east then south to move south and re-occupy the position at which the compressors failed.

Compressor failures, return to Manzanillo (July 4th – July 10th)
Failures occurred in both seismic compressors soon after the start of operations on the first planned line of the cruise. The failures are distinct on the two compressors. On the starboard side unit the failure was in the engine that drives the compressor (rather than the compressor itself). The unit experienced automatic shutdown with indications of low lubrication pressure. The unit was unable to run for more than about 3 hours before the automatic shutdown occurred. This unit had been rebuilt in San Diego just ahead of this cruise and had not been experiencing this issue during previous operations. The port compressor had a failure in the final stage of the intercooler unit of the compressor itself involving serious water leakage.

In principal it might have been possible to make one working engine/compressor combination out of the two systems available (given that each had distinct and different problems) but repeated attempts to make repairs over the holiday weekend were unsuccessful. Personnel from the airgun department augmented engine department staff in a round the clock effort to return the compressors to operation but without success. The difficulty of making repairs at sea was enhanced by the fact that the problems occurred on a holiday weekend so communications with Caterpillar in the US were not very helpful.

During the time spent seeking a solution to the compressor problems the vessel made a bathymetric survey of the OSC and adjacent region to extend multi-beam coverage that is sparse in the area.

Following a conference call[3] with Lamont OMO at 2:30 pm on Monday 7th it was concluded that all plausible efforts had been made to repair the compressors at sea and we would need to engage expertise from Caterpillar to be successful. At around 3pm we began retrieval of the towed equipment to start transit to Manzanillo.

All the equipment was secured by 0400 on the 8th. The retrieval was relatively straightforward, although sea conditions required that we pick up the gear traveling away from the direction of Manzanillo and hence extending the transit time. The only problems with the equipment discovered during retrieval were one tailbuoy #4 that had lost an entire set of floatation on one side and was towing flat in the water, a near vessel acoustic unit on streamer #4 that had come free of its collars and slipped down the streamer to the position of the second acoustic unit, and a depth control bird on streamer #2 had asymmetrically distorted wings.

Transit to Manzanillo was uneventful and the vessel arrived in port around 8pm on the 10th. Al Walsh from Lamont OMO and Caterpillar representative were available to meet the vessel on arrival.

Compressor repairs; Manzanillo (July 11th – 13th)

Al Walsh and two representatives from Caterpillar together with members of the ship's engineering department effect repairs to the compressors that permit the cruise to recommence. Separating the components of the shutdown system and tapping lubrication pressure at a different site on the engine overcame the automatic shutdown problem. The engine overhaul in San Diego included a standard upgrade that enlarged the diameter of some oil lift ways that deliver lubrication from the pump to other parts of the engine. This implicitly leads to a small reduction in oil pressure at locations in the engine most distant from the pump, especially when the engine is hot. This would seem to account for the three hour run period in that this would be about the time required for the engine to reach a temperature that reduces the oil pressure enough to trip the shutdown. Taking the oil pressure at a different point overcomes that issue without danger to the engine performance. In port this engine was run successfully for more than 6 hours, well into its high temperature range, giving confidence that it would perform well during regular operations.

To solve the compressor issue on the port engine a crossover high-pressure link is made between the fifth stages of the two compressors that connects them into one. This allows

[3] Ljungrenn and Walsh at OMO Lamont: Mutter, Carbotte, Canales, Nedimovic, Steinhaus, Johnson, Captain, and Chief Pica.

the compressor unit for the now functional starboard compressor to be driven from either the starboard or port engines. High-pressure tubing was obtained for this purpose and the needed work commenced in port and completed at sea on the return transit to the work area.

Repairs were sufficiently complete that the cruise could be restarted and the vessel left Manzanillo, clearing the harbor breakwater at noon on the 13th. The repairs for both compressors were work around solutions with permanent repairs planned to be made in coming maintenance periods [4].

Transit and deployment (noon July 13th – 6:30 pm July16th)

Transit from Manzanillo to the work area was made difficult because Tropical Storm Elida that reached hurricane status for a period of time passed through the region between port and the work area. The departure was delayed to ensure that we passed behind the storm track but nevertheless the seas were rough and transit speeds were initially restricted to around 7 knots. Seas progressively calmed during transit as the vessel moved south of the storm track and deployment began in relatively calm weather around 1030 on the 15th well north of the work area.

Deployment proceeded very smoothly in reducing seas. Only significant issue was a non-responding bird at location 6 on streamer #2 that required retrieval to that location after the streamer was almost fully deployed. On deployment all tailbuoys were functioning as well as the streamer acoustics and all streamer sections were in good condition.

Acquisition began at around 6:30pm 16th July.

Data collection (July 16th – August 16th)

Along axis lines (July 16th - July 18th)

Acquisition began on the western of the along-axis lines (AXIS3) beginning in approximately the middle of the planned 3D survey area and working to the south. Soon after starting work a problem was recognized with the compressor repair in which the high-pressure hose used as part of the connection between the two compressor end stages overheated. The manufacturer's recommendation is for a maximum operating temperature of 250°F and temperatures in excess of 280°F were measured. Contact with the manufacturer did not make clear whether the high temperature would reduce the design life of the hose (from 7 to 4 years) or create a dangerous situation with the potential for a catastrophic failure and a cage was built around the hose to ensure no hazard in the event that the hose failed at high pressure.

Shooting continued along the western along-axis line (AXIS3) then diverted west to pick up the original line on the western limb of the OSC that had been discontinued on July

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[4] A note in advance of the remainder of this narrative: the compressor repairs although temporary solutions, enabled operation for the duration of our survey and there were no significant subsequent failure issues.

4th. On completion of this line the vessel made a slow turn north to work up the eastern limb of the OSC (AXIS2). At around 4 pm on the 17th a crack was recognized in the high-pressure line in the compressor crossover line and work broke off to make a repair. The vessel made a loop to the east acquiring multi-beam data in previously un-surveyed areas while compressor maintenance was carried out. The repair was made and work recommenced in the evening of the same day.

Also, on the same day, July 17th, we received word that NSF had granted a 10-day extension to compensate for the time lost due to compressor failures and associated repairs. Given this good news the plan then became to attempt to acquire as much of the planned 3D grid as possible and make contingency for modifying the plan based on experience with acquisition of the first part of the 3D grid.

On the 18th the vessel worked north through the 3D area along the ridge axis (AXIS2R1). At the northern end of this line the vessel made a turn to the west and steamer #4, the outermost streamer on the port side immediately surfaced. The turn was aborted and proper streamer towing was restored by manipulating birds in sequence to avoid overlapping adjacent streamer #3 (these streamers did, in fact, overlap but while towing at different depths). This streamer had been experiencing difficulty with keeping trim along the last part of the along-axis line and appeared to be disturbed by vane wash from the port paravane. The problem arose from a long period swell that is derived from distant storms such at Elida that were passing to the north of the area and generated significant swell. A decision was taken to tow all streamers at 10 meters for the remainder of the cruise. Thus along axis lines prior to the start of 3D work (AXIS1-AXIS2R1) are acquired at 7.5 meter tow depth, and all 3D lines are acquired with 10 meter tow depth. Gun towing depth was not changed and so remained at 7.5 meters.

To re-establish streamer trim the vessel was required to steam north and well away from the 3D survey grid. Moving back south toward the start of the 3D work a short line was acquired (Transit1) late in the day that crossed one of the Lamont seamounts to test systems and make use of the available time.

3D Survey Operations

3D Survey Racetrack #1 (0100 July 19th - 2030 July 31st)

First shot was acquired on the first line (EPR3D-2132P) of the 3D survey grid at 0100 on the **19th** July. This line is at the center of the first of the three racetracks that comprise the planned area for 3D coverage. This line crosses the ridge just north of 9° 53’ N, north of the area of concentrated high temperature vents.

On **July19th** we completed the following lines:
EPR3D-2132P 01:04 - 02:59
EPR3D-1940P 04:30 - 09:10
EPR3D-2124P 10:41 - 12:19
EPR3D-1932P 14:48 - 18:17
EPR3D-2316P 22:05 - 01:22 (July 20th)

As the last of these lines were being shot it became apparent that there had been an error in setting up the lines for the first racetrack and that the second and fourth of these lines had been shot to the south of the first and third, meaning that the northern half of the first racetrack had not been entered into the navigation correctly. Having recognized the error, at the end of EPR3D-1932P the vessel turned north to begin collecting the first line at the northernmost end of the first racetrack (EPR3D-2316P). The additional transit time proved somewhat fortuitous as it allowed for a period for airgun work on the extended traverse north. The two lines shot in error are part of the intended grid but were shot out of sequence. They were incorporated back into the shooting without any problem as part of racetrack #2. The northernmost line (EPR3D-2316P) was commenced on this day.

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On the **20th** acquisition continues routinely in racetrack #1. There were no significant problems with data collection. At the end of line EPR3D-2100 the line change was extended for routine airgun maintenance.

On **July 20th** the following lines were acquired:
EPR3D-2116P 01:44 - 04:40
EPR3D-2308P 06:10 - 09:31
EPR3D-2108P 10:58 - 13:43
EPR3D-2300P 15:09 - 18:26
EPR3D-2100P 20:58 - 22:32

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Acquisition on July **21st** was routine with the exception of a "turtle gap" on line EPR3D-2284 that necessitated a power down and ramp up with loss of a total of 174 shots that require infill. Additionally there was a short line change extension between this line and EPR3D-2084 due to a brief ship's autopilot malfunction.

On **July 21st** the following lines were acquired:
EPR3D-2292P 01:59 - 04:56
EPR3D-2092P 06:31 - 09:39
EPR3D-2284P 11:02 - 13:47
EPR3D-2084P 15:38 - 18:51
EPR3D-2276P 20:18 - 23:14

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Fairly routine acquisition continued on the **22nd** of July with continued progress on racetrack #1. One line extension was made for gun maintenance. Section 34 on Streamer #1 became very noisy and cannot be incorporated into the data for processing. Though very distinct in form the noise is very high amplitude and persists through filtering and so these traces are not usable from this time. Most likely the section has been damaged and water entered electrical connections.

Additionally this day (**22nd**) the Passive Acoustic Monitor (PAM) that is used to listen for vocalizations of marine mammals progressively failed. There were two systems aboard ship – a SEAMAP streamer and a Right Waves streamer. The SEAMAP system, the primary system on the vessel failed and was replaced with the Right Waves streamer but the replacement itself proved problematic and only one hydrophone was operative. This raised the possibility of complete failure of the PAM acoustic monitoring with potentially very serious negative impacts on the acquisition program.

On **July 22nd** the following lines were acquired:
EPR3D-2276P 02:06 - 04:59
EPR3D-2268P 06:39 - 09:50
EPR3D-2068P 11:10 - 13:55
EPR3D-2260P 15:24 - 17:34
EPR3D-2060P 20:08 - 22:55

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On the **23rd** acquisition was proceeding normally until a compressor cooling systems failure occurred. This problem was distinct from those that arose on July 4th and caused the vessel to go to port, although for a time they seemed related. This problem involved leakage in the seawater plate cooler for the engine of the starboard compressor, and required draining the cooling system and repair of the leak. The failure occurred near completion of the EPR3D-2244. The line was aborted at 09:45 and was re-shot when repairs were made. The vessel progressed east during repairs and the first line to be shot after work recommenced (EPR3D-2044) was begun east of the 3D grid creating a somewhat longer line at this location.

On **July 23rd** the following lines were acquired:
EPR3D-2252P 00:16 - 03:20
EPR3D-2052P 04:48 - 07:43
EPR3D-2244P 09:07 - 09:45 (aborted)
EPR3D-2044P 19:04 - 22:47

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Acquisition on the **24th** was routine except for the need on three occasions to power-down for turtle sightings. These sightings may not indicate an increased presence of turtles as the weather had been consistently clearer in the last several days and this may have permitted more regular observations of marine life.

In association with the diminished ability to recognize vocalizations because of the reduce performance of the PAM this raised concerns about the potential for shutdown of operations or for numerous interruptions that would lead to the need for substantial infilling costing considerably in survey time. This concern lead to a conference phone call to Lamont OMO that included MMO personnel Joseph Beland and Giovanni Caltavuturo to discuss possible options for procedures in the event that the PAM were to fail completely and request clarification of procedures to be followed for turtle sightings. There was some urgency to this as the weekend was approaching (26th, 27th) and we would have been without guidance in the event of a failure on the weekend. One reading of the IHA would suggest that we would be unable to acquire data if the PAM were to become inoperative.

In an attempt to provide a backup to the PAM, hydrophones from the first section of one of the seismic streamers were connected to the PAM system. The hope was that these phones might have sufficient sensitivity and range to provide a plausible alternate to the

PAM itself. In fact, this proved not to be suitable as the high frequency sensitivity of the streamer phones are much too low to be an alternate.

On **July 24th** the following lines were acquired:
EPR3D-2244R 00:09 - 03:03 (R designates re-shoot)
EPR3D-2036P 04:38 - 07:45
EPR3D-2236P 09:12 - 12:15
EPR3D-2028P 14:04 - 16:35
EPR3D-2228P 18:07 - 21:17

•

Word was received from Paul Ljunggren at Lamont OMO that pending advice to the contrary we should proceed with the operational plan that failure of the PAM would not terminate operations and that we would continue with visual observations as the means of monitoring marine mammals and turtles.

This day, July **25th** we also extended a line across the Lamont seamount closest to the ridge to image the internal structure. We had recognized a distinct diffracted feature in the summit region that had characteristics very similar to the response of the AMC on the ridge and hence very suggestive of the presence of a magma body in the seamount and this justified an extension of several hours to make a longer pass over the seamount so that an image could be properly reconstructed through migration (the planned line lengths do not include a migration aperture sufficient to properly migrate features in the seamount). This extension was rewarded by the observation of a feature that suggests a magma lens in the shallow sub-surface of the seamount.

On **July 25th** the following lines were acquired:
EPR3D-2020P 23:08 - 01:19
EPR3D-2228I 02:49 - 06:12 (Infill)
EPR3D-2012P 07:49 - 11:05
EPR3D-2220P 12:31 - 16:11
EPR3D-2228P 18:02 - 20:53
EPR3D-2212P 22:31 - 01:16 (26th)

•

Acquisition on this day July **26th** included an unusual error in that line EPR3D-2204 was acquired with only the port side gun string firing at double the normal firing rate. The error was surprisingly difficult to detect as most of the displays and indications in the main lab did not show evident indications of unusual functioning; the error was detected in the lab when the real time brute stack produced errors due to inconsistencies in the shot header information. The source of the error was not immediately apparent. The line was recorded and can be incorporated in the imaging but was re-shot.

On **July 26th** the following lines were acquired:
EPR3D-1996P 02:45 - 05:45
EPR3D-2204P 07:08 - 09:43 (Rejected)
EPR3D-2220P 11:23 - 14:19

EPR3D-2204R 15:46 - 18:21 (Repeat)
EPR3D-1988I 19:46 - 22:35

•

This day July **27th** mostly involved routine acquisition. One line change was extended to take care of gun repairs on the starboard array. As this extended line change was being made there were two different turtle sightings that lead to source power down and ramp up. Data lost for the turtles was outside the full-fold range of data collection and will not require reshooting.

On **July 27th** the following lines were acquired:
EPR3D-2196P 00:03 - 03:00
EPR3D-1980P 04:27 - 07:14
EPR3D-2188P 08:39 - 11:33
EPR3D-1972P 15:19 - 17:42
EPR3D-2180P 19:07 - 21:59

•

The **28th** began with an encounter with a fishing vessel of unknown nationality. The vessel came close behind the Langseth and passed between the ship and the tailbuoy, closer to the tailbuoy. The vessel did not respond to radio communications in English, Chinese or Spanish nor did it move when flares were fired in its direction. It appeared to be picking up a long-line and moved away, we believe, only when observing the four tailbuoys approaching. The fishing vessel moved across the towed arrays without apparent harm to the arrays at that time[5].

One line change was extended to do preventative maintenance on the compressors including changing fuel filters.

As the afternoon progressed the acoustics at the head of streamer #4 became intermittent and then failed completely and the decision was made to pick up the equipment and carry out repairs. This is a time consuming operation as it involves brining streamer #3 in until it could be tied across away from streamer #4 to give room for work. The paravane on the port side also needed to be brought on board to allow streamer #4 to be retrieved.

The first of the acoustics was fouled with fishing line but otherwise seemed in good condition and the second acoustic appeared undamaged. The steamer was brought in until bird #3 and that bird replaced as it had been malfunctioning. Replacing the acoustic transponders did not reestablish the acoustic positioning and the first active streamer section was then swapped out, which reestablished positioning for the head of streamer #4. Acquisition began again in the late morning on the 29th (next day).

[5] Note that on retrieval of the towed equipment fishing gear was found on the streamers.

On **July 28th** the following lines were acquired:
EPR3D-1964P 23:25 - 02:01
EPR3D-2172P 03:26 - 06:25
EPR3D-1956P 08:28 - 11:24
EPR3D-2164P 18:11 - 20:54

•

Restarted acquisition on the **29th** at around 0830 and as we prepared for work a whale was sighted leading to mandatory power down. The first line was acquired beginning at around 0930. PAM failed overnight and data acquisition continued. Acquisition was otherwise uneventful.
On **July 29th** the following lines were acquired:
Line EPR3D-2156P 09:29 - 12:42
Line EPR3D-2172P 14:09 - 16:35
Line EPR3D-2148P 17:54 - 20:50
Line EPR3D-1996I 22:12 - 00:53 (30th)

•

On the **30th** an alternate to the towed PAM was created using the wideband hydrophone installed in the hull of the vessel in the sonar pod. The intended purpose of this phone is for monitoring cavitations around the multibeam echo sounder but the hydrophone is sufficiently broadband that it is suitable as an alternate to the towed PAM in frequency range. The MMO personnel are able to use this hydrophone even though the emissions from the nearby 3.5 kHz and the multibeam are strong. The 3.5 kHz was turned off since it isn't used for science on this leg.

The most significant issue this day was the fairly catastrophic failure of airgun hose bundle #1 for the starboard side aft gun string at around 6:30 pm. This type of failure cannot be repaired on board through re-termination so the bundle was replaced by another available on board that had been swapped out in Manzanillo because of failures in the electronics that caused positioning to be unknown for that gun string. Continued shooting infill with the array on the port side and starboard having only one string until the repair was completed at around 0300. Upon deployment it was found that the positioning capability of the bundle had returned and hence data acquired after the bundle repair has all gun strings properly located.

On **July 30th** the following lines were acquired:
EPR3D-2140P 01:58 - 04:45
EPR3D-1940I 06:08 - 09:01
EPR3D-2284P 11:02 - 13:39
EPR3D-2116I 14:50 - 17:32
EPR3D-2252IandJ 18:37 - 21:52 (one string source after 18:49)

•

Work on replacement to the hose bundle was completed in the early morning and acquisition continued on the first racetrack.

Significant discussion this day, **31st**, involved efforts to secure a vessel to achieve a Medivac of a party member who has a condition deemed to require removal from the vessel. Lamont OMO had explored numerous possibilities since the problem developed a few days ago and all proved unviable leaving the possibility that the Langseth would need to transit to Acapulco causing a loss of acquisition that would make achieving the scientific objectives of the cruise very questionable. Late in the day it was learnt that a tug boat would be chartered from the port of Manzanillo and could come to the work area by Sunday. This news came as a great relief given the time penalty incurred earlier in the cruise.
3D Racetrack #1 complete with primaries, re-shoots and infill at 22:30!!!!

On **July 31st** the following lines were acquired:
EPR3D-2092I 23:02 - 01:42
EPR3D-2140I 06:06 - 09:36
EPR3D-1988J 10:58 - 13:22
EPR3D-2236R 14:56 - 18:06
EPR3D-2076I 00:46 - 03:28

•

Along axis data acquisition (August 1st)
After completion of acquisition on Racetrack #1 and given the uncertainties that surrounded acquisition thus far it was decided that we should complete work on the three axis lines before attempting racetrack#2. Recall that we completed a section of AXIS 3 going south immediately after return from Manzanillo. That line commenced within the planned 3D survey grid and shot south to the OSC before looping back north through the 3D grid area. Before commencing the 3D grid of ridge-perpendicular lines.

Transit 2 was acquired between the end of racetrack #1 and the start of the new axis sequence. After overlapping the start of the existing AXIS 3 data were acquired north through the 3D grid to the end of the northern extent of the ridge segment on AXIS3P2. The vessel then turned back south on an along axis line parallel to the other two and ran through the 3D grid area completing the line at around 9:30 pm. This was followed by a transit with no acquisition to the first line of Racetrack #2, EPR3D1780P.
The tug boat departed from Manzanillo at around 0200 this day.

On **August 1st** the following lines were acquired:
EPR3D-Transit2 23:29 - 05:15
EPR3D-Axis3P2 05:21 - 12:21
EPR3D-Axis4P 14:39 - 21:22
•

Racetrack #2 (August 2nd 00:44 – August 9th)
Racetrack #2 comprises 36 tracks (Racetrack #1 is 49 plus repeats and infill) and planned to provide the maximum coverage for a given time as it has the shortest possible turns between racetrack lines – approximately 65 minutes – as these have no straight sections,

the vessel being in a continuous turn. This has the disadvantage of increasing streamer tensions that had already increased due to presumed barnacle incrustation.
One whale sighting today lead to an extended line change

On **August 2nd** the following lines were acquired:
EPR3D-1780P 00:44 - 03:35
EPR3D-1924P 04:51 - 07:33
EPR3D-1772P 08:40 - 11:49
EPR3D-1916P 13:26 - 15:48
EPR3D-1764P 16:59 - 20:29
EPR3D-1908P 21:44 - 00:06

•

In the morning of August **3rd** we rendezvoused with the tug from Manzanillo and transferred two people – the Chief Mate and Science Officer Anthony Johnson to that vessel. This was accomplished on an extended line change to the west using the Langseth's rescue boat. The weather was fair and the transfer was accomplished very efficiently. The next line was shot from the extended location and hence is longer than others in Racetrack #2.

Late in the day an air hose leak caused source string #4 to be removed from the source array and EPR3D 1892P was shot with single source and repeated during infill.

On **August 3rd** the following lines were acquired:
EPR3D-1756P 01:16 - 04:22
EPR3D-1900P 05:30 - 07:59
EPR3D-1748P 09:51 - 14:17
EPR3D-1892P 15:27 - 18:38 (Single Source)
EPR3D-1740P 19:58 - 23:08

•

Routine acquisition was accomplished this day August 4th with good progress through Racetrack#2. One extended line change for preventative maintenance on the gun array.

On **August 4th** the following lines were acquired:
EPR3D-1884P 00:15 - 02:35
EPR3D-1732P 04:04 - 07:17
EPR3D-1876P 08:28 - 11:07
EPR3D-1724P 13:15 - 17:17
EPR3D-1868P 18:29 - 21:11
EPR3D-1716P 22:30 – 01:47

•

Acquisition this day, August **5th**, was generally good with the significant exception of a recording failure due to a lockup of the SEISRES system on line EPR3D - 1860P. This line was rejected due to the large amount of recording loss and was repeated. The line was extended to perform a system reset. The next line experienced similar problems but not as severe with several areas having a few missed shots. The next line was also extended on the line change to trouble-shot the system. After the next line on which a few shots were also missed, the system returned to normal performance. Some part of the problem may have been due to filling of disk storage space.

Acquisition includes infill lines in the northern half of the racetrack so the total length of racetrack will be several lines longer than 36 lines that were originally planned.

On **August 5th** the following lines were acquired:
EPR3D-1868I 03:02 - 05:48
EPR3D-1708P 07:05 - 10:15
EPR3D-1860P 11:30 - 14:40 (Rejected)
EPR3D-1700P 16:22 – 19:27
EPR3D-1860R 21:10 - 00:06

•

On August **6th** acquisition is routine. Extended lines changes were made for gun maintenance. The recording system problems did not return.
The PIs gave a science presentation at 6:30 pm in the movie room.

On **August 6th** the following lines were acquired:
EPR3D-1692P 01:19 - 04:06
EPR3D-1852P 05:24 - 08:26
EPR3D-1684P 09:42 - 12:52
EPR3D-1700P 15:30 - 18:48
EPR3D-1676P 19:05 - 23:46

•

August **7th** was a routine day of acquisition. Continued progress through racetrack #2 at a good rate. Progress was considerably faster than through racetrack #1.

On **August 7th** the following lines were acquired:
EPR3D-1836P 00:50 - 03:31
EPR3D-1668P 04:46 - 08:06
EPR3D-1828P 09:24 - 11:55
EPR3D-1660P 13:12 - 16:36
EPR3D-1820P 17:51 - 20:37
EPR3D-1652P 22:00 - 01:17

•

August 8th was another day of routine acquisition on racetrack #2 with one line change extension for preventative maintenance of the gun array.

On **August 8th** the following lines were acquired:
EPR3D-1812P 02:35 - 05:41
EPR3D-1644P 06:59 - 09:53
EPR3D-1804P 11:52 - 15:38
EPR3D-1638P 16:52 – 19:51

•

Today August **9th** saw the completion of all primaries on racetrack#2 and the beginning of work on racetrack#3. Running the lines on this racetrack was more efficient, generating less need for infill. Extended line changes were used for planned preventative maintenance on the source arrays.

The workboat was launched with the intention of carrying out maintenance of positioning systems on tailbouys and streamer. However on reaching the location of the tailbuoy on streamer#1 the boat developed steering problems that appeared to be due to lack of fluid in the steering system and the boat returned to Langseth without accomplishing the intended maintenance.
Given the excellent operations on racetrack#2 a third racetrack was planned with the same configuration as racetrack#2, with minimum distance between lines making the acquisition most efficient.

On **August 9th** the following lines were acquired:
EPR3D-1796P 22:53 - 02:05
EPR3D-1700R 03:37 - 07:40 Small Reshoot
EPR3D-1468P 09:10 - 12:05
EPR3D-1628P 13:40 - 17:11
EPR3D-1788P 18:31 –21:13
•
Today August **10th** there were two significant events. The workboat was launched around 09:30 and successfully carried out repairs that were planned for the previous day. Tailbuoy lights where changed on streamers #3 and #4 and an antenna replaced on tailbuoy GPS #1. Acoustic Pod # 6 on streamer#4 was also replaced in this operation. The workboat personnel also carried out an inspection and recognized that the leader to Techno Float #4 had parted and would need to be taken into consideration when retrieving the streamer. The workboat then returned to Langseth at 1:15 pm local time. This workboat operation did not encounter any of the boat performance issues of the first attempt and the maintenance was carried out very smoothly.

The second significant event occurred during the afternoon when one of the cylinders of the ships main starboard engine failed to fire. The engine was shut down for maintenance and the gun strings were brought aboard in order to reduce drag and permit the Langseth to maintain around 3.5 knots on the port engine (note that both ship's engines are required running at around 90% to maintain the vessel at acquisition speed with all the towed equipment deployed). The maintenance was rapidly achieved but approximately half a line of acquisition was lost.

We also had to power down due to a whale sighting during the day.
On **August 10th** the following lines were acquired:
EPR3D-1620P 22:32 - 01:54
EPR3D-1788R 03:13 - 05:01
EPR3D-1788R 15:01 - 06:03 – Reshoot sp 1121 – 894
EPR3D-1612P 07:27 - 10:47
EPR3D-1460P 12:03 - 15:27

EPR3D-1604P 18:00 - 19:34
EPR3D-1452P 20:50 - 00:01

•

Acquisition during the day of August **11th** was relatively routine. No major failures or interruptions. Streamer positioning became somewhat compromised because of progressive loss of acoustic pods due to battery failure. Acoustics on tailbuoy's 2 & 3 stopped working this day. The units working as of this day are AA07, BA07, CA01, CA03, CA07, DA03, DA04, and DA07 (A = Streamer #1, B = Steamer #2, etc; Unit #1 at the head, unit # 7 on the tailbuoy).

Because of the ships engine issue of the previous day completion of racetrack#3 became impossible and the science party began to plan alternate lines that include more exploratory work south of the intended area of racetrack#3.

On **August 11th** the following lines were acquired:
EPR3D-1604R 01:15 - 02:33
EPR3D-1604R 02:33 - 04:15- Infill
EPR3D-1444P 05:32 - 08:40
EPR3D-1596P 10:27 - 13:58
EPR3D-1436P 15:11 - 18:06
EPR3D--1596I 19:24 - 22:26

•

This day August **12th** included the curtailing of acquisition due to sighting of a killer whale that caused sufficient interruption that Line EPR3D1588P had to be rejected. Increased winds and seas required a reduction in ship speed through the water to 4 knots. This day the acquisition continued to fill out racetrack #3.

On **August 12th** the following lines were acquired:
EPR3D-1428P 00:34 - 04:38
EPR3D-1588P 05:56 - 09:35
EPR3D-1420P 11:14 -15:22.
EPR3D-1588R 16:46 -18:18 Infill sp 895 - 1220
EPR3D-1588R 18:18 -19:48 Reshoot sp 1221 – 1365
EPR3D-1412P 02:11- 05:45 Single Source sp 1538 to 1237

•

August **13th** was a reasonable day of acquisition with three extended line changes for various reasons. Early in the day gun string #1 developed an air leak just before the start of line EPR3D1412P and that line was acquired with partial single and partial dual sources. On the following line change the last half of streamer #4 dove to ~35m likely due to lack of tension in the port turn and marine growth on the cable. Finally, the breaker that powers the UPS for streamers 1 & 2 tripped briefly causing recording interruptions.
This day, in addition to continuing racetrack #3 an extensions was made to the south to acquire two lines at around latitude 9° 36' intended to be at the southern end of the third order discontinuity at that location. These lines are also intended to check for the southern extent of an off axis feature that appears like an AMC event recognized on the

eastern side of the ridge. The feature is similar to one seen in the north but is not associated with a topographic ridge. This extension is made because it is not likely that the extent of the feature would be fully mapped by cross-axis lines in the 3D grid of racetrack#3.

On **August 13th** the following lines were acquired:
EPR3D-1268P 02:08 - 04:59
EPR3D-1476P 06:43 - 09:06
EPR3D-1276P 11:34 - 14:28
EPR3D-1404P 16:14 - 19:24
EPR3D-0972P 21:46 - 02:40

•

On August **14th** a long extension south was made with the dual purpose of making a repeat of Conrad line 31 from the 1985 survey that shows very good record quality, and to continue a line east into the region of an off axis mantle tomography anomaly defined by Toomey in an earlier study of the region. No major issues with acquisition occurred this day with the exception of an extension to one line to avoid shipping.

EPR3D-Transit #3 03:16 - 05:35
EPR3D-1396P 05:57 - 08:58
EPR3D-1580P 10:47 - 14:03
EPR3D-1388P 15:35 - 18:39
EPR3D-1596R 20:13 - 23:59 (Infill and re-shoot)

•

On this day August **15th** acquisition on the cruise was completed. Because of the inability to fully complete racetrack#3 and the recognition of an off-axis AMC-like body on the eastern side of the ridge in the central region of racetrack#3 a line, AXIS5, was run in N-S direction over the feature, beginning at the southern end of the northern racetrack#3 lines and heading south. Following this line the vessel turned east and north to shoot the last of the possible racetrack#3 southern group lines, then north into the area of racetracks 2/3 to compete re-shoots and infill before ending.

Acquisition ended at 01:56 on the 16th.

On **August 15th** the following lines were acquired:
EPR3D-1380P 00:58 - 04:15
EPR3D-1572P 05:42 - 07:34
EPR3D-AXIS5 5 07:40 - 09:18
EPR3D-1372P 12:37 -15:52
EPR3D-1788I 18:26 - 21:42
EPR3D-1380P 23:33 - 01:56

Equipment retrieval and transit to Manzanillo (August 16th-August 19th)
Guns and streamers were recovered on the 16th while making a pass over the Lamont seamounts to acquire multi-beam data in the area. There was very little damage to the

equipment although there was a significant amount of fishing gear on streamers #1 and #2. There was also a great deal of marine growth on all streamers, birds and acoustic pods and to the extent reasonable this was removed during retrieval operations.

The Lead-in #2 showed signed of electrolysis and a significant portion of the outer layer of armor was missing about 60 m up for the outer end termination (away from the vessel). This lead-in #2 needs to be re-terminated before re-use.

Retrieval operations were very efficient. Two streamers were brought in at the same time – first streamers #2 and #3 then after bring paravanes on board, streamers #1 and #4.

Retrieval proceeded as follows:
Guns retried 01:56 - 03:23
Tailbuoy #3 on board 11:00
Stbd Barovane on board 11:17
Tailbuoy #2 on board 11:25
Port Barovane on board 11:40
Tailbuoy #1 on board14:55
Tailbuoy #4 on board 16:11
Transiting back to Manzanillo 15:11

5. Survey operations and data quality

5.1 Acquisition parameters for MGL0812 are included in Table 5.1 and the summary tow configuration is included in Figure 5.1 below. Full details on the streamer and gun string tow configuration including all tow offsets are provided in the MGL0812 Job Report Book produced by the shipboard technical support staff. A 7.5 meter tow depth was used for both the guns and streamers during acquisition of the initial axial lines (AXIS1, AXIS2, AXIS3, AXIS2R1). Due to weather conditions at the beginning of racetrack 1 we decided to lower the steamer to 10 m to help alleviate persistent cable swell noise. We also increased recording time from 8 seconds for the axial lines to 10 seconds for the cross-axis lines.

Table 5.1 Summary Acquisition Parameters

Acquisition Parameters	
AcquisitionParameterID	MGL0812_ACQ01
Acquisition System Name	Syntron Syntrack 960
Seismic_Nav_System	C-Nav primary
Survey_datum	WGS84
Navigation Reference Point (NRP)	Fore/Aft+4.87 m, Stb/pt +8.055 m, vertical +14.5 m
NRP_to_Antennae	4.87 m
NRP to source	295 m
Antenna_to_Source	299.87 m
Source_to_Near_Channel	200 m
Number _of_channels_recorded	1872
Number _of_cables	4
Number_of_channels_each_cable	468
Channel_length	12.5 m
Cable_length	6000 m
Cable_spacing	150 m
Near_Channel_Number	468
Cable_depth	7.5 m (AXIS1, AXIS2, AXIS3, AXIS2R1), 10 m (rest)
Number_source_arrays	2 (each with two strings)
Alternate_Shooting	Yes
Source_array_separation	75 m nominal
Source_volume	3300 cu in
Source_pressure	2000 psi nominal
Source_make,model	Bolt
Source_number	20 (10 guns per string)
Source_depth	7.5 m
Shot_control	Distance
Shot_Interval	37.5 m
Sample_interval	2 ms
Record_length	8.190 s (4096 samples) (AXIS1, AXIS2, AXIS3, AXIS2R1), 10.240 sec (5120 samples) (rest)
Compass_birds	Yes
Tail_buoy_Positioning	Yes

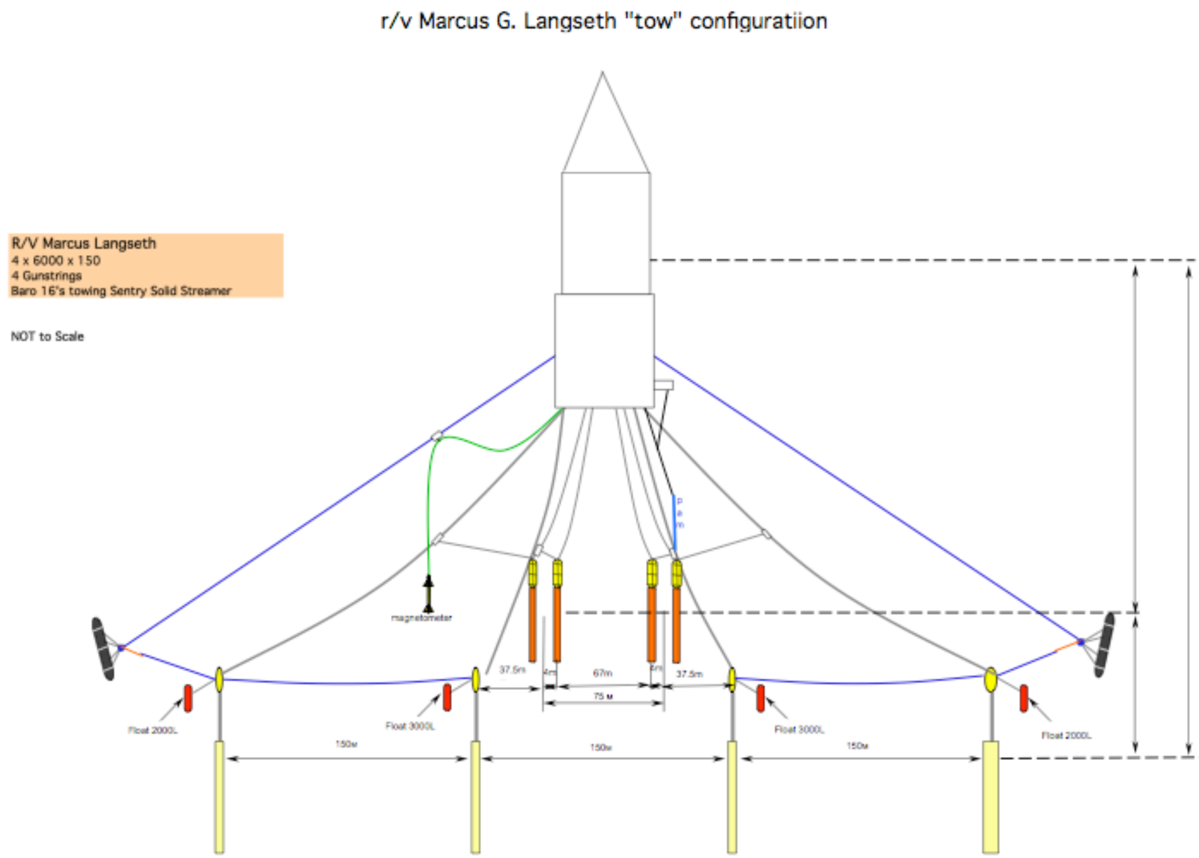

Figure 5.1 Schematic of gun string and streamer configuration for the survey.

5.2 Seismic Acquisition Watch Procedures.

During routine 3D seismic operations, the round-the-clock seismic watch included a team of up to 3 people assigned to the Seismic Acquisition watch and 2-3 for the Navigation watch. These watches were staffed by the shipboard science support staff with 2 technicians contracted from NCS SubSea and assistance from the visiting science party. The primary functions of the Acquisition Watch were to monitor the streamer displays, bird depths, streamer tension, and the gun monitors for timing errors and misfires. The acquisition watch also initiated data recording at the beginning of each line, and monitored data recording during acquisition. There are two gun displays, one which schematically depicts all 10 guns plus the spare for each of the 4 gun strings and indicates which guns fired during each shot. The second display monitors each shot showing the the pulse from each gun detected using the air pressure sensors in the solenoids and is used to visually detect and assess gun-timing errors or no fires. The DigiSHOT system detects and reports timing errors or misfires if a gun fires more than 1 ms from (before/after) the target interval. The Acquisition Watchstanders note all timing errors and misfires in the Observers Log (see shipboard technical logs). They assess whether any action is required with respect to the gun drop out specifications provided by the visiting science party (see Appendix 5.0) and notify the gunners as needed. If guns consistently misfire, they are turned off and the spare turned on following the science party specifications. Documentation of all gun misfires provided in the Observers Log will be essential for evaluation of the consistency of the seismic source during later data processing and will be particularly important for any AVO/AVA analysis and potential future 4D experiments.

The Navigation Watch was led by the NCS SubSea contractors and was responsible for maintaining the Navigation Log (see shipboard technical logs) and for providing instructions to the bridge on small course adjustments needed to maintain optimal positioning of each line with respect to bin coverage from the previous track. The Navigation Watch "drove" the ship using the Helmsman display, which shows the planned track and a real-time bin map for the current line derived from realtime positioning information obtained from the streamer acoustic array. The Navigation Watch was also responsible for monitoring the streamer displays to ensure proper streamer separation is maintained. This function was especially critical during turns when there is the greatest risk of streamers deviating from their optimal separation and crossing. Streamer tension must also be watched closely during turns to ensure it does not exceed acceptable levels.

In addition to leading the Navigation Watch, the NCS SubSea contractors also provided post-processing of the seismic navigation to generate processed U.K.O.O.A. P1/90 files as well as bin coverage maps to assess data fold as the survey progressed (see section 5.4). This navigation processing was carried out by Dave Martinson using Concept Systems Sprint software package and the binning using Reflex. A summary of the navigation processing is provided in the Job Book – Final Report. This navigation processing resulted in achieved positional accuracy of better than 3 m for receivers locations, better than 2 m for shot locations, and better than 1 m for the ship position.

5.3 **Streamer feathering assessment**

The deviation of the towed receiver cables from a simple line-astern configuration is known as "feathering". Feathering is generally caused by currents, and can have an impact on the homogeneous fold coverage across different offsets before infilling, particularly at far offsets. This impact can be more serious if currents change direction in the survey area, resulting in feathering variations both in amplitude and direction across contiguous sail lines.

Feathering of each cable was monitored in real time during our survey from Spectra, both graphically and numerically. This capability was particularly important during acquisition of infill lines so they could be navigated in real time to fill in the missing offsets according to the feathering of the moment.

Feathering also will be an important factor to consider before attempting any 2-D imaging or velocity modeling along individual profiles (e.g., traveltime tomography of the upper crust), which usually assume perfect alignment of sources and receivers. These analyses should be restricted, if possible, to lines with minimal feathering.

We assessed the extent of feathering throughout our survey as part of our navigation QC procedure. Each P190 navigation file was read in MATLAB and feathering was computed for each cable along the profile as the difference in angle between the best linear fit of the receiver positions at each shot and the general bearing of the line estimated from the shot positions. The average feathering of the 4 cables at each shot was saved in a disk file; this information was use to make a “feathering map” near the end of our survey (fig. 5.3.1). The feathering map provides a quick visual synthesis of the range and direction of feathering we have encountered along our survey. We encounter currents with both southward and northward component that resulted in average feathering of 0°±5° (fig. 5.3.2); southward feathering was slightly more prevalent than northward feathering. Currents seemed to change directions within a few hours, so lines adjacent to each other but shot a few hours apart could occasionally display feathering of opposite direction (fig. 5.3.1).

Figure 5.3.3 shows examples of one profile with no feathering and two profiles with the most extreme cases of northward and southward feathering we encountered.

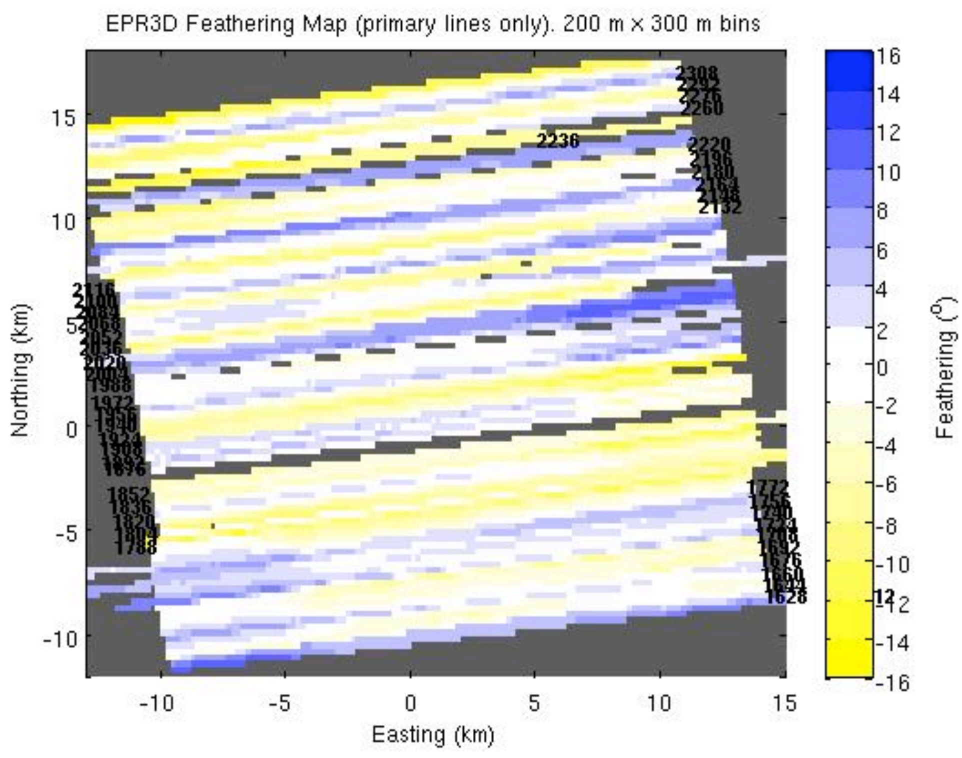

Figure 5.3.1. Feathering map of primary lines for the primary 3D box (racetracks 1 and 2). Feathering is measured as angle with respect to the bearing of the sail line, averaged for the 4 cables. Positive and negative values correspond to cables displaced to the north and south of the sail line, respectively. Every other sail line is labeled.

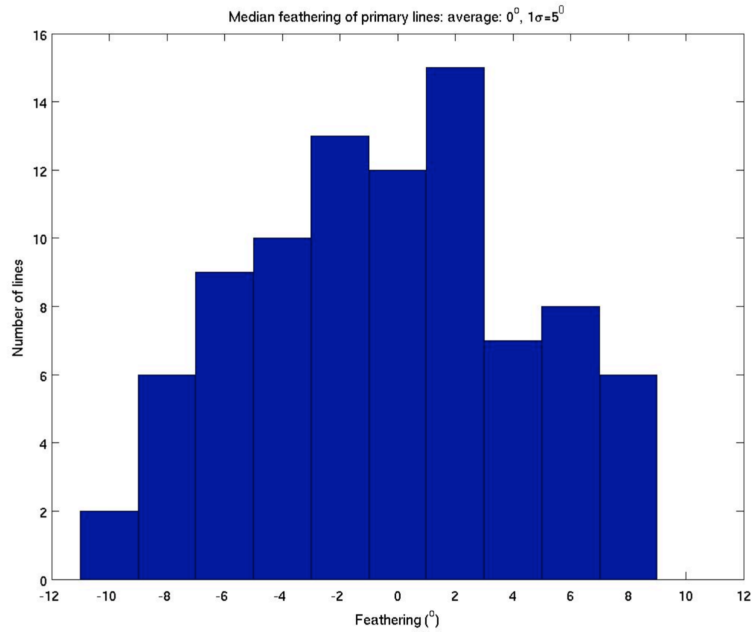

Figure 5.3.2. Histogram of median average feathering of primary lines for 3D box (racetracks 1 and 2). Average value is 0°, standard deviation is 5°.

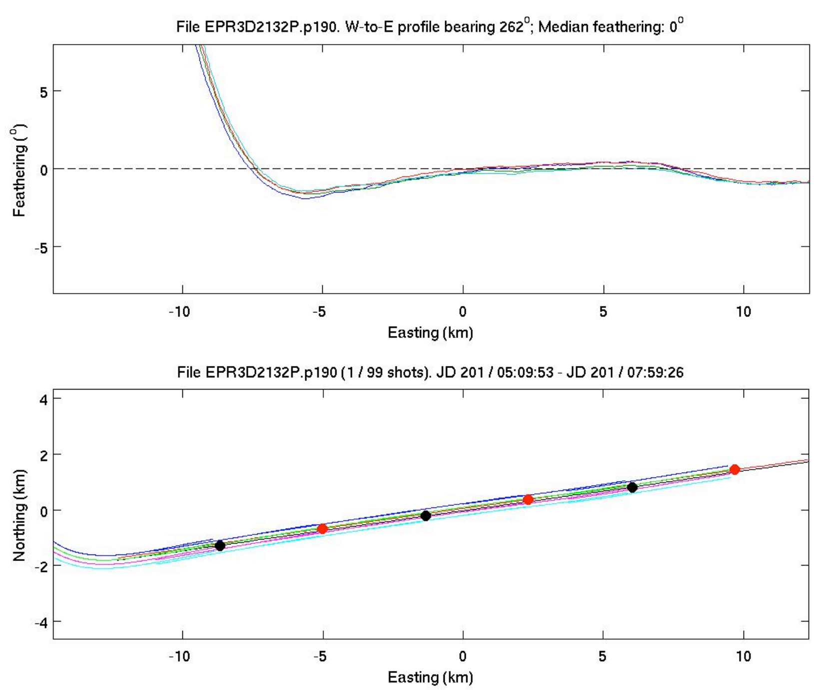

Figure 5.3.3. Feathering displays for (A) line EPR3D2132P, (B) EPR3D1996P, and (C) EPR3D2316P. Top panels show feathering as a function of X-distance along the line for each of the cables. Dashed line shows the median average feathering. Bottom panels show map display of shot lines (red and black for each of the alternating sources) with shot positions (1 out every 99 shots) shown as black and red circles. Receiver positions along the four cables are plotted for each of the shots shown.

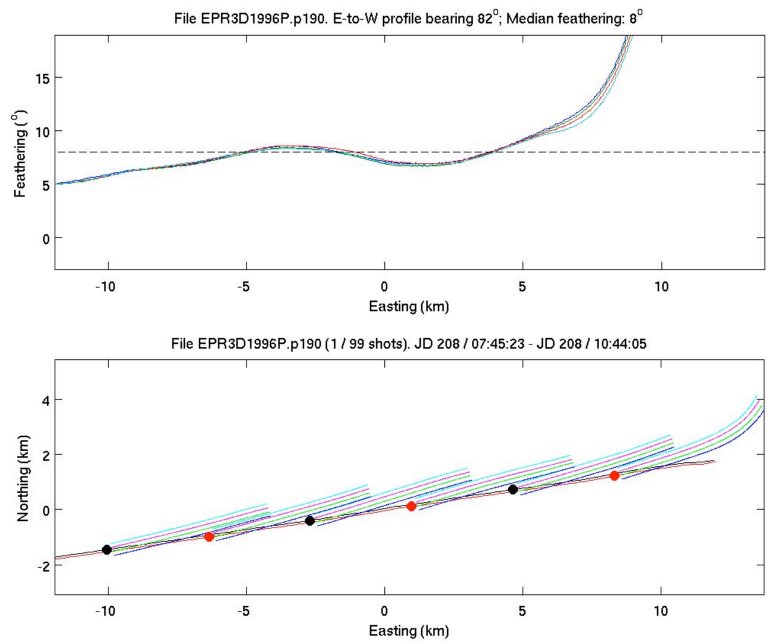

Figure 5.3.3. (B).

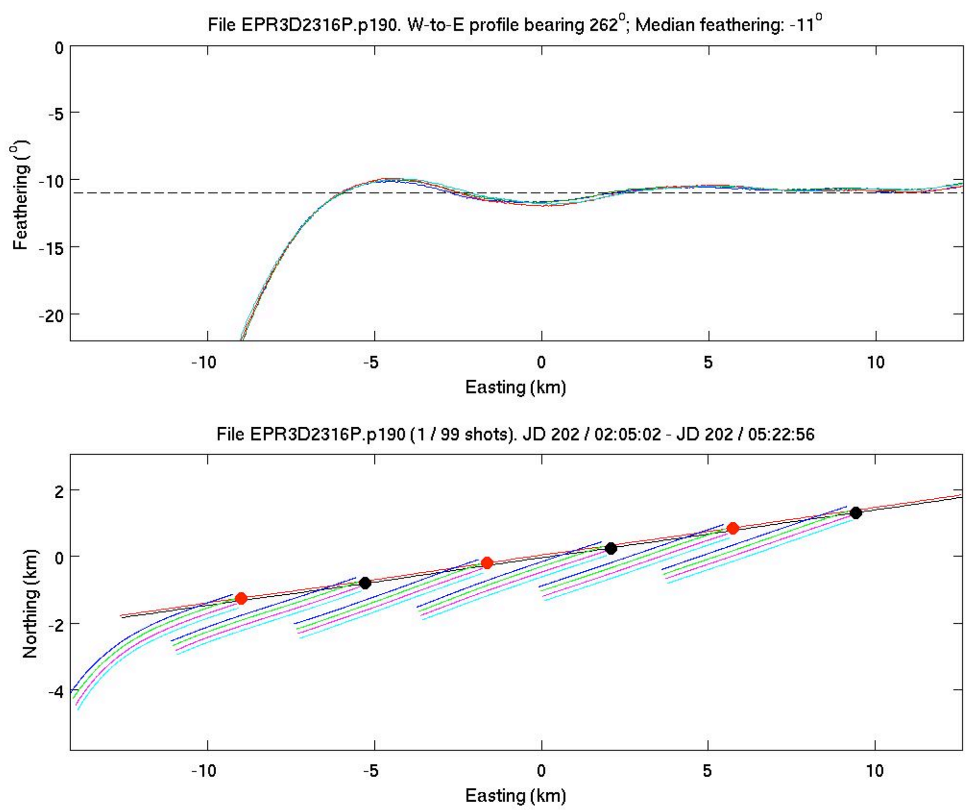

Figure 5.3.3. (C).

5.4 Bin infill

3D MCS surveys are designed so that the recorded data traces within the targeted area are evenly distributed in terms of bin fold and source-receiver offset. However, due to streamer feathering caused by ocean currents and surveying gaps caused by marine life, bad weather and technical shutdowns, all 3D MCS datasets are characterized by an uneven data trace distribution. Data infill, or bin infill, is therefore a critically important operation after the 3D racetrack is completed as it assures that the minimum seismic reflection imaging requirements are met with the collected data.

When the industry collects 3D MCS data, minimum seismic reflection imaging requirements are outlined in the contract and the data infill will continue until they are met. This is not the case in academia where a certain number of days are allocated for a particular cruise, and where the number of days for data infill has to be requested at the proposal writing stage. As it cannot be accurately predicted what type of an infill a 3D MCS dataset requires before it is collected, it is not possible to fully develop an infill plan for academic 3D MCS work before the survey track is completed. Moreover, the number of available infill days during a particular academic cruise may be smaller or greater than the allocated number of infill days because allocated contingency time for surveying gaps caused by marine life, bad weather, and technical shutdowns may be smaller or greater than needed. For these reasons, the data infill during academic 3D MCS cruises is a real time process ameliorated by pre-cruise planning.

<u>Infill strategy</u>
The planned bin fold for our survey is 40, where the bin size is 6.25 m x 37.5 m in cross-axis and along-axis direction respectively. Data traces in each bin are evenly spread over ~6 km of offset, at about every 150 m. The planned, or "ideal" data trace distribution is chosen to provide for high-quality imaging of all expected subsurface structures. As achieving this survey standard is usually not possible in the field, we developed a strategy that prioritizes infill work based on importance. The developed strategy is based on the following three main factors:
1. Minimum seismic reflection imaging requirements for targeted structures;
2. Available time;
3. Feasibility.

1. *Minimum seismic reflection imaging requirements for targeted structures.* This infill factor can to a large degree be planned before the survey takes place as the basic expected geometry of the targeted subsurface structures is often known. For our study area we define this factor for each imagable structure in terms of offset range as follows:

a) Seafloor; imagable at all offsets; offsets from 0 to 2 km most important. Seafloor in our study area is fairly smooth and gently dipping away from the axial high. Faulting sparse and fault throws are small.
b) Layer 2A; imagable at offsets from 1.5 to 3.0 km; most important offsets 1.5 to 2.5 km over the axial region and 2.0 to 3.0 km on the flanks.

c) Mid-crustal AMC and off-axis melt lenses; imagable at all offsets (except at offsets of 2 to 3 km if the polarity is reversing due to high melt content); offsets from 0 to 2 km, where the reflection is strong and its polarity is reversed relative to the seafloor, most important for imaging; all offsets important where physical property studies are planned.
d) Diffractions; imagable at all offsets; most important offsets from 0 to 2 km.
e) Moho; all offsets equally important; signal-to-noise ratio low so the wider offset range or fold the better; far offsets (2 to 6 km) critical for imaging Moho below melt lenses such as the mid-crustal AMC.
f) Sub mid-crustal-AMC melt lenses; Moho Transition Zone melt lenses imagable at all offsets (0-6 km); reflection amplitude decreases with increasing offset but near offsets (0 to 1 or 2 km depending on the width of the mid-crustal AMC) fall into a mid-crustal AMC shadow zone, so 1-2 to 6 km offsets are critical for imaging; imagable offset range for lower crustal melt lenses changes with their depth; probably from 1-2 to 4 km for those in the uppermost lower crust, and 1-2 to 5-6 km for those in the lowermost lower crust; all numbers assume undershooting the mid-crustal AMC.

Overall, offsets from 0 to 2-3 km are most important throughout the survey region for most of the targeted structures. Offsets from 2-3 to 6 km are important for select regions and structures, particularly for areas where melt bodies are imaged or expected. Minimum fold in terms of percentage hits for each targeted structure and specific offset range is shown in Table 5.4.1 below.

	Target structure		0-2 km bin	Min. % hit/fold	2-4 km bin	Min. % hit/fold	4-6 km bin	Min. % hit/fold
1	On-axis MCML		Key	85/11	Not-key	50/7	Not-key	50/7
2	Off-axis MCML		Key	85/11	Not-key	50/7	Not-key	50/7
3	MCML diffract.		Key	85/11	Not-key	50/7	Not-key	50/7
4	LCML	MCML present	Not-key	50/7	Key	80/10	Key	70/9
5	MTZML		Not-key	50/7	Key	80/10	Key	70/9
6	MOHO		Not-key	50/7	Key	80/10	Key	70/9
7	LCML	MCML not present	Key	85/11	Key	80/10	Not-key	50/7
8	MTZML		Key	85/11	Key	80/10	Useful	60/8
9	MOHO		Key	85/11	Key	80/10	Useful	60/8
10	Layer 2A		1.5-2 Key	60/8	2-3 Key	70/9	Not-key	50/7
11	Seafloor		Key	85/11	Not-key	50/7	Not-key	50/7

Summary							
1	MCML present or MTZML/LCML target (select areas)	Key	85/11	Key	85/11	Key	85/11
2	MCML not present and not select areas	Key	85/11	Not-key	60/8	Not-key	50/7

Table 5.4.1. Infill criteria based on targeted structures: MCML – Mid-crustal melt lens; LCML – Lower crustal melt lens; MTZML – Moho Transition Zone melt lens.

2. *Available time.* The project proposal was written with a single airgun array and streamer capabilities in mind, and the number of days allocated for contingency and infill were not applicable for the actual data collection as it was carried out using multiple airgun arrays and streamers.

3. *Feasibility.* Data infill is increasingly more challenging with increasing source-receiver range because of the feathering due to ocean currents, which is not fully predictable. Therefore, our primary objective was to infill offsets from 0-3 km along most of the collected racetracks, with the secondary objective to infill offsets from 3-6 km where particularly large gaps in data exist.

Infill execution

Ocean currents during the survey changed in strength and direction, and we measured feathering of up to about ±11°. However, much of the surveying was done with feathering of less than ±5°, similar to what was anticipated. This resulted in a midpoint and source-receiver distribution along the racetracks that is more uniform than for an average 3D survey, and there was little to moderate need for infill. Figures 5.4.1a through 5.4.5a show data CMP bin fold in terms of percentage relative to the planned fold for the full dataset, as well as for various offset ranges. Figures 5.4.6a through 5.4.10a show the same information but after flexible binning of 50% at the near offset and 150% at the far offset, with linear interpolation in between. Note how the density of data coverage is reduced with the increasing offset range due to feathering.

Altogether, 14 infill lines were shot to remove major gaps in data coverage. Considering that each line required 4 to 5 hours to complete, the infill took some three and a half days of available survey time. Due mostly to "turtle gaps" (shutdowns caused by proximity of turtles to the seismic sources) and air compressor problems, 10 lines had to be reshot. Reshooting took two+ days to complete. Figures 5.4.1b through 5.4.5b show data CMP bin fold in terms of percentage relative to the planned fold for the full dataset, as well as for various offset ranges, after the infill and reshooting. Figures 5.4.6b through 5.4.10b show the same information but after bin flex of 50% at the near offset and 150% at the far offset, with linear interpolation in between. The density of data coverage is significantly improved after infill and reshooting and allows in general for proper imaging of the targeted subsurface structures.

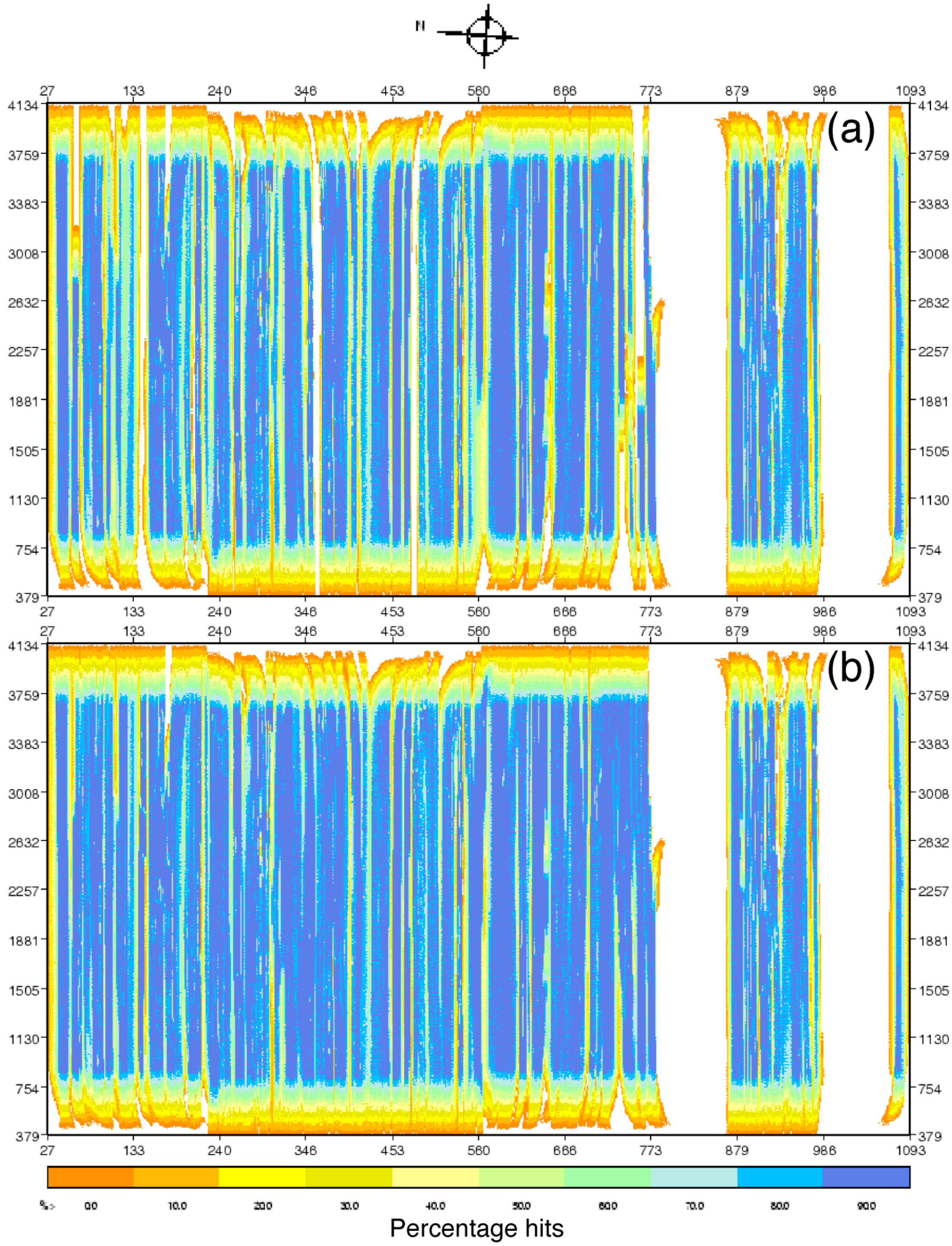

Figure 5.4.1. Bin fold as percentage of the nominal full fold before (a) and after (b) infill and reshoot. All source-receiver offsets, from 200 m to 6050 m are taken into account. Both axes indicate bin numbers. Bin size horizontally is 37.5 m and vertically 6.25 m. No bin flexing was applied.

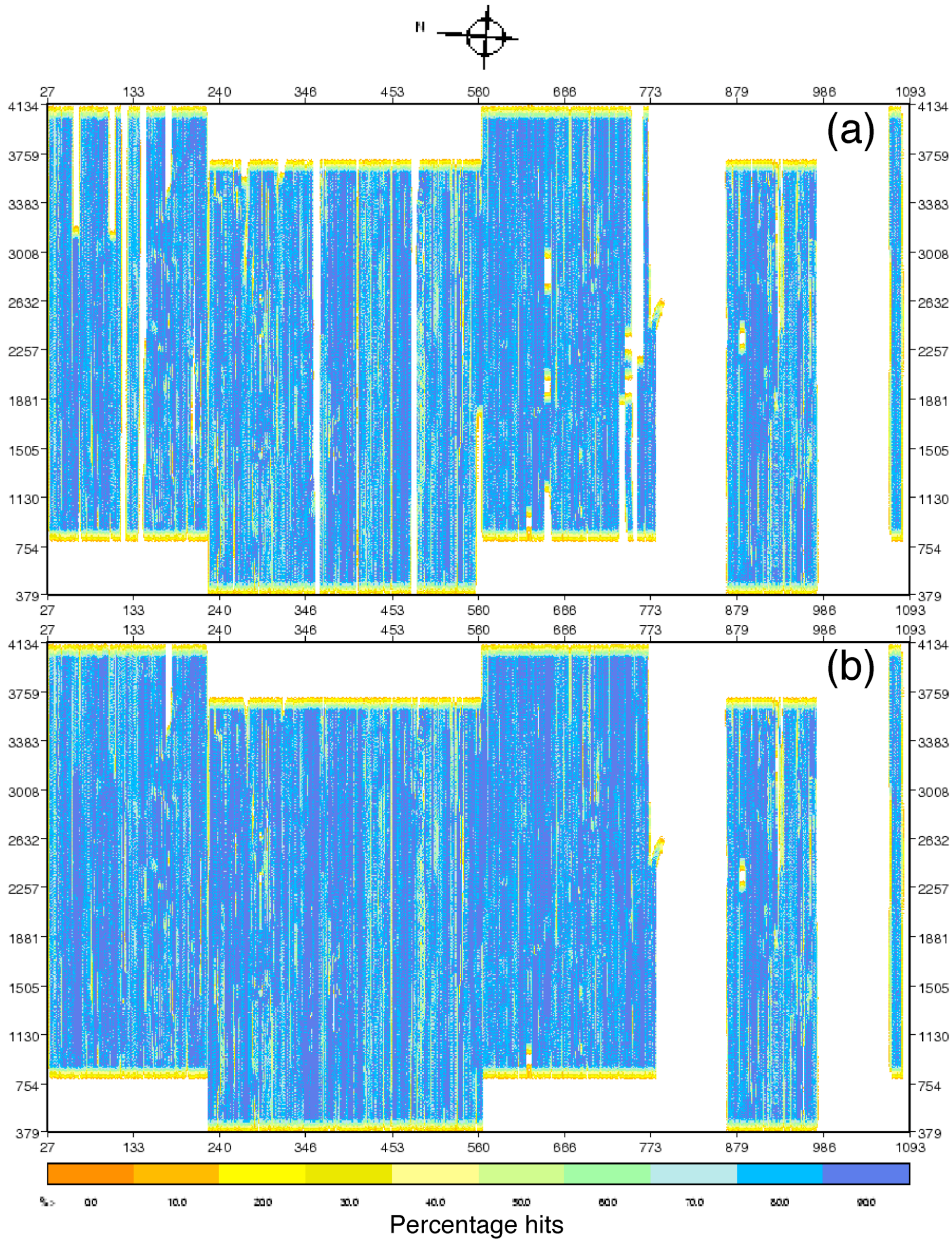

Figure 5.4.2. Bin fold as percentage of the nominal full fold before (a) and after (b) infill and reshoot. Source-receiver offsets from 200 m to 1662 m are taken into account. Both axes indicate bin numbers. Bin size horizontally is 37.5 m and vertically 6.25 m. No bin flexing was applied.

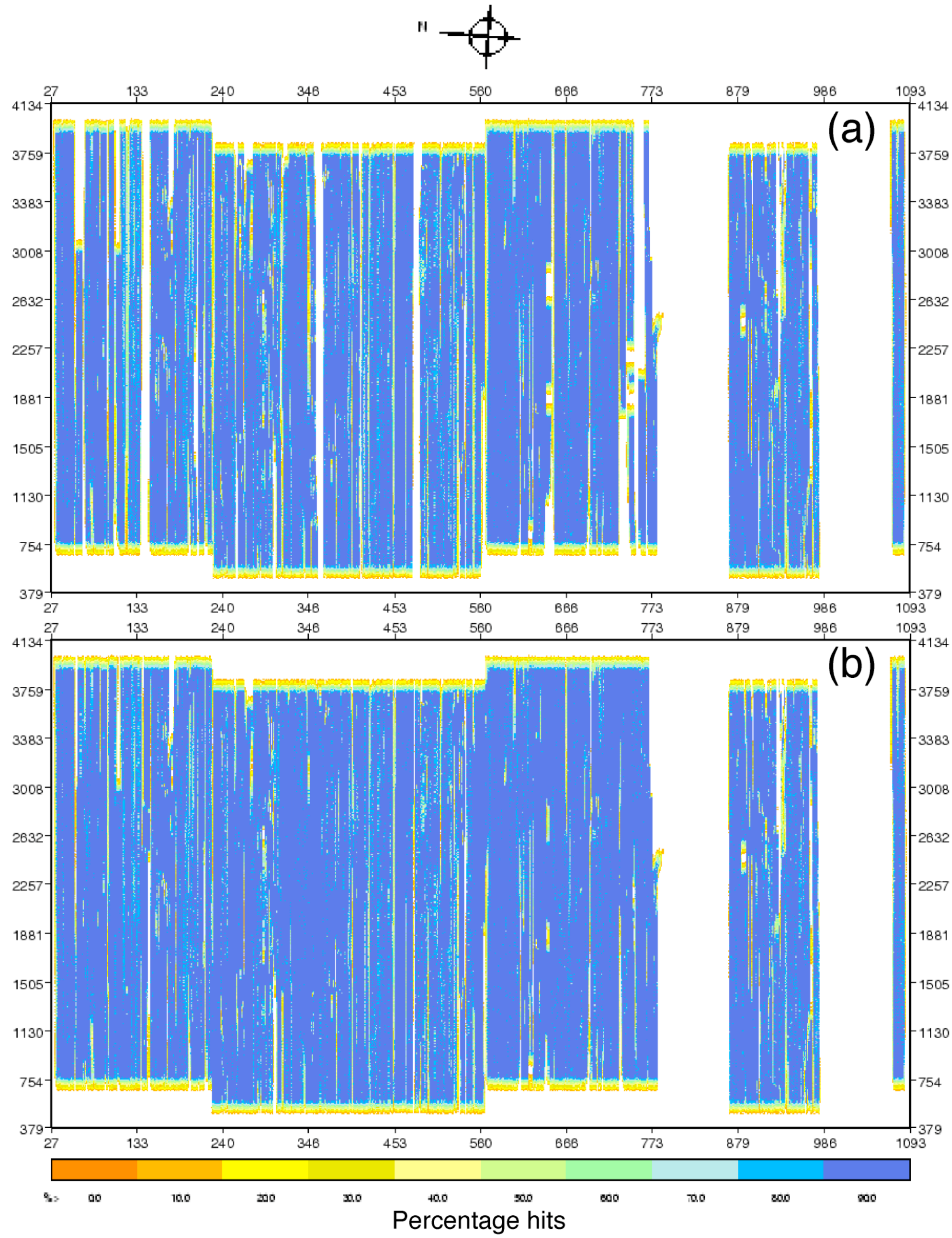

Figure 5.4.3. Bin fold as percentage of the nominal full fold before (a) and after (b) infill and reshoot. Source-receiver offsets from 1662 m to 3125 m are taken into account. Both axes indicate bin numbers. Bin size horizontally is 37.5 m and vertically 6.25 m. No bin flexing was applied.

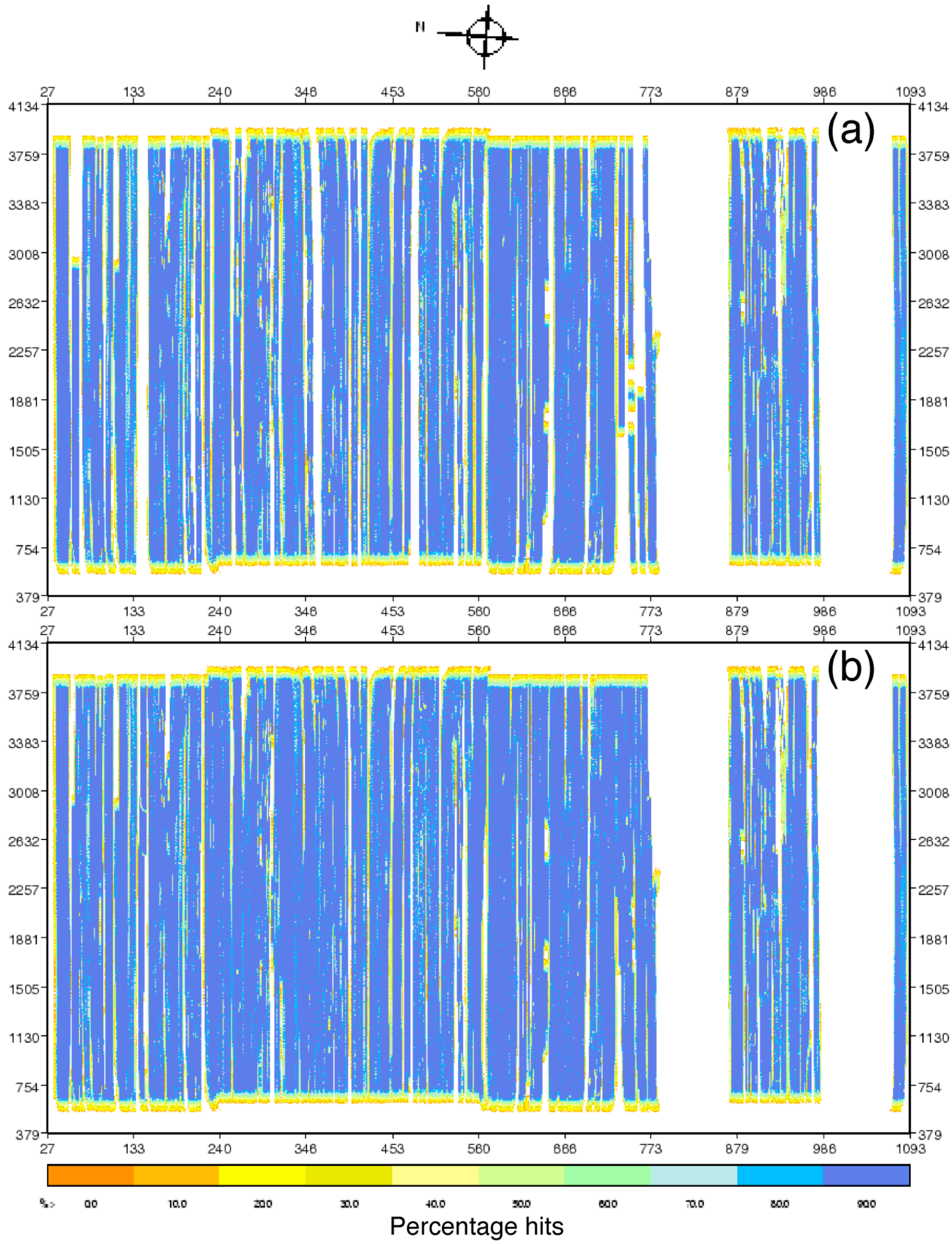

Figure 5.4.4. Bin fold as percentage of the nominal full fold before (a) and after (b) infill and reshoot. Source-receiver offsets from 3125 m to 4587 m are taken into account. Both axes indicate bin numbers. Bin size horizontally is 37.5 m and vertically 6.25 m. No bin flexing was applied.

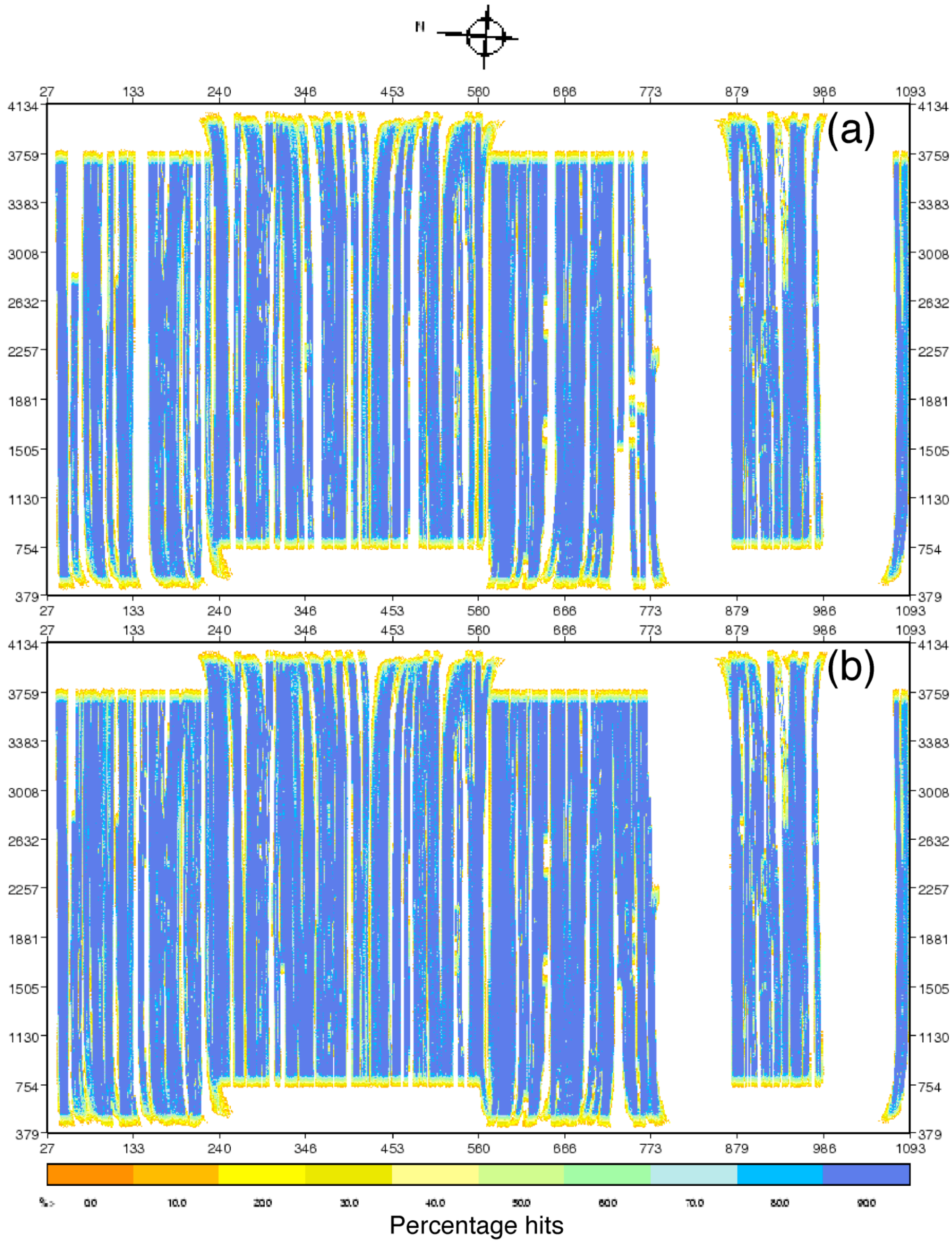

Figure 5.4.5. Bin fold as percentage of the nominal full fold before (a) and after (b) infill and reshoot. Source-receiver offsets from 4587 m to 6050 m are taken into account. Both axes indicate bin numbers. Bin size horizontally is 37.5 m and vertically 6.25 m. No bin flexing was applied.

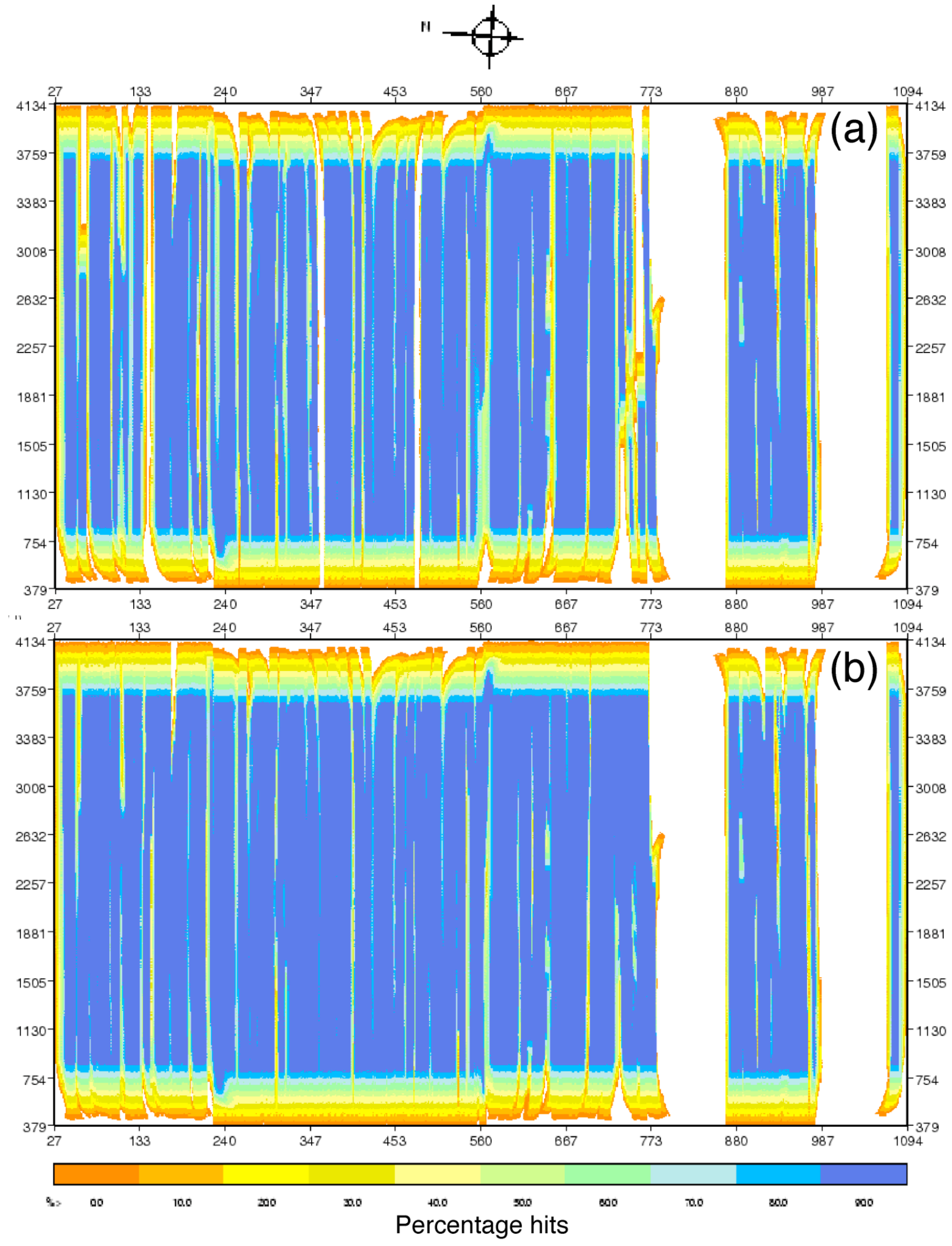

Figure 5.4.6. Bin fold as percentage of the nominal full fold before (a) and after (b) infill and reshoot. All source-receiver offsets, from 200 m to 6050 m are taken into account. Both axes indicate bin numbers. Bin size horizontally is 37.5 m and vertically 6.25 m. Bin flexing is 50% at near offsets and 150% at far offset with a linear taper in between.

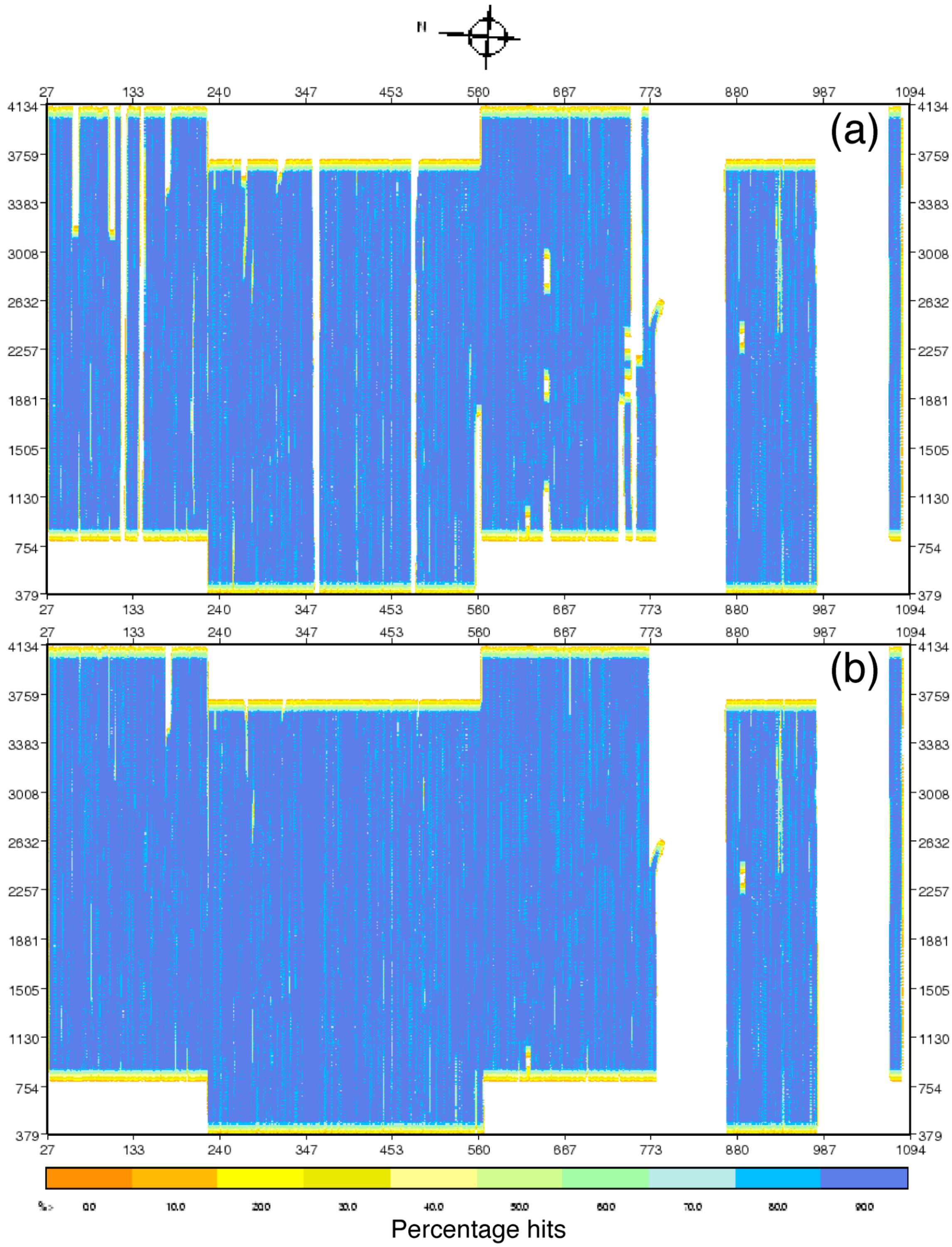

Figure 5.4.7. Bin fold as percentage of the nominal full fold before (a) and after (b) infill and reshoot. Source-receiver offsets from 200 m to 1662 m are taken into account. Both axes indicate bin numbers. Bin size horizontally is 37.5 m and vertically 6.25 m. Bin flexing is 50% at near offsets and 150% at far offset with a linear taper in between.

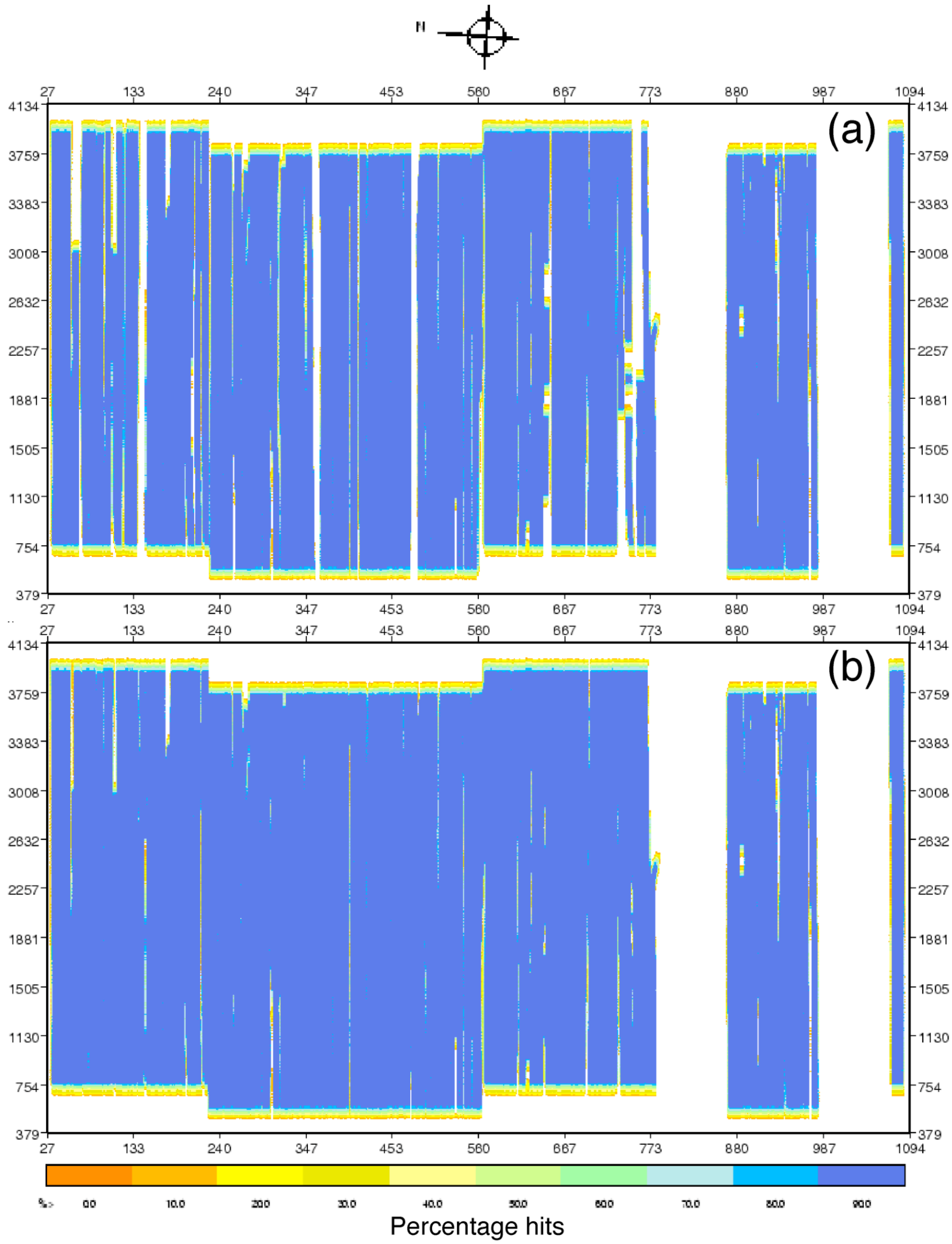

Figure 5.4.8. Bin fold as percentage of the nominal full fold before (a) and after (b) infill and reshoot. Source-receiver offsets from 1662 m to 3125 m are taken into account. Both axes indicate bin numbers. Bin size horizontally is 37.5 m and vertically 6.25 m. Bin flexing is 50% at near offsets and 150% at far offset with a linear taper in between.

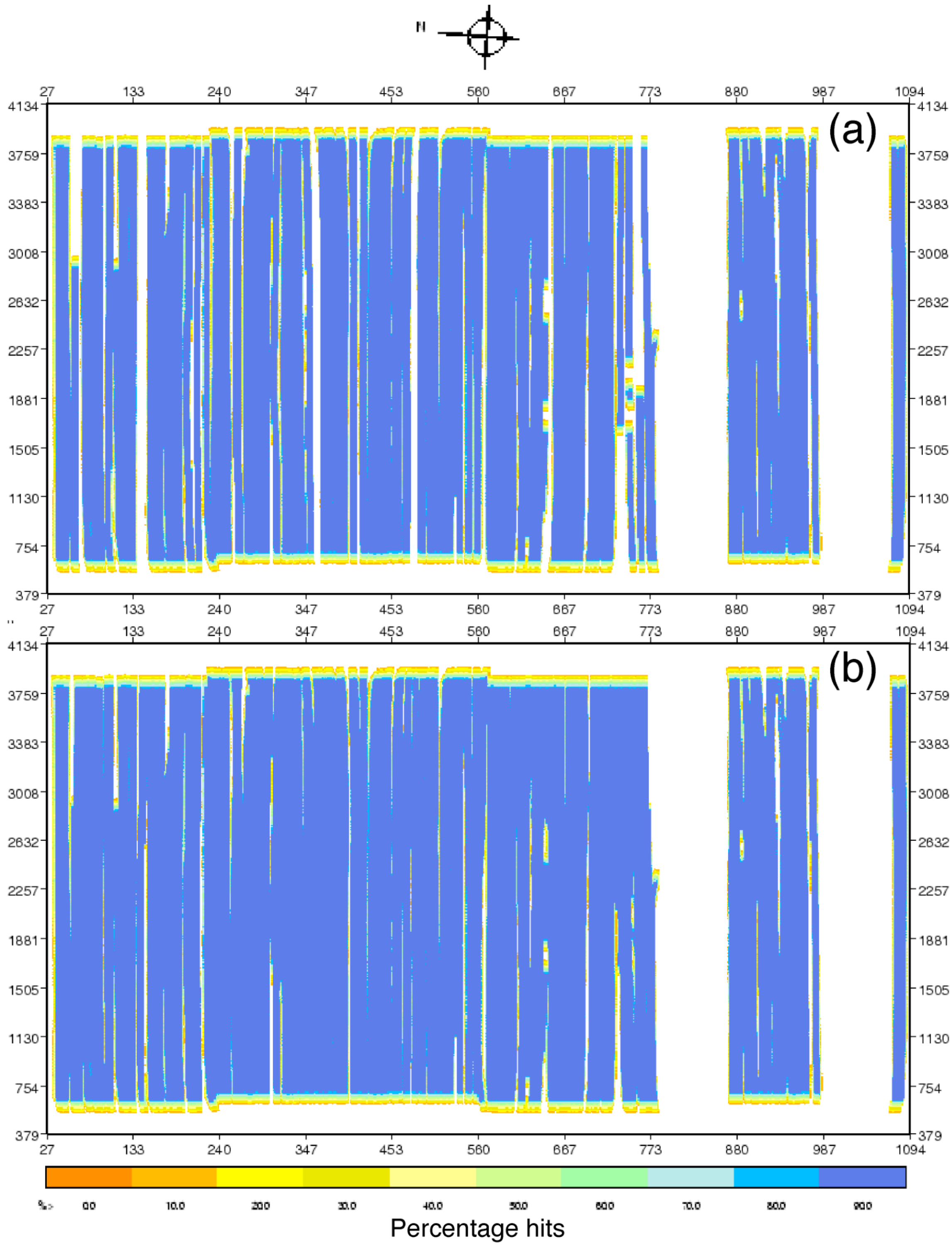

Figure 5.4.9. Bin fold as percentage of the nominal full fold before (a) and after (b) infill and reshoot. Source-receiver offsets from 3125 m to 4587 m are taken into account. Both axes indicate bin numbers. Bin size horizontally is 37.5 m and vertically 6.25 m. Bin flexing is 50% at near offsets and 150% at far offset with a linear taper in between.

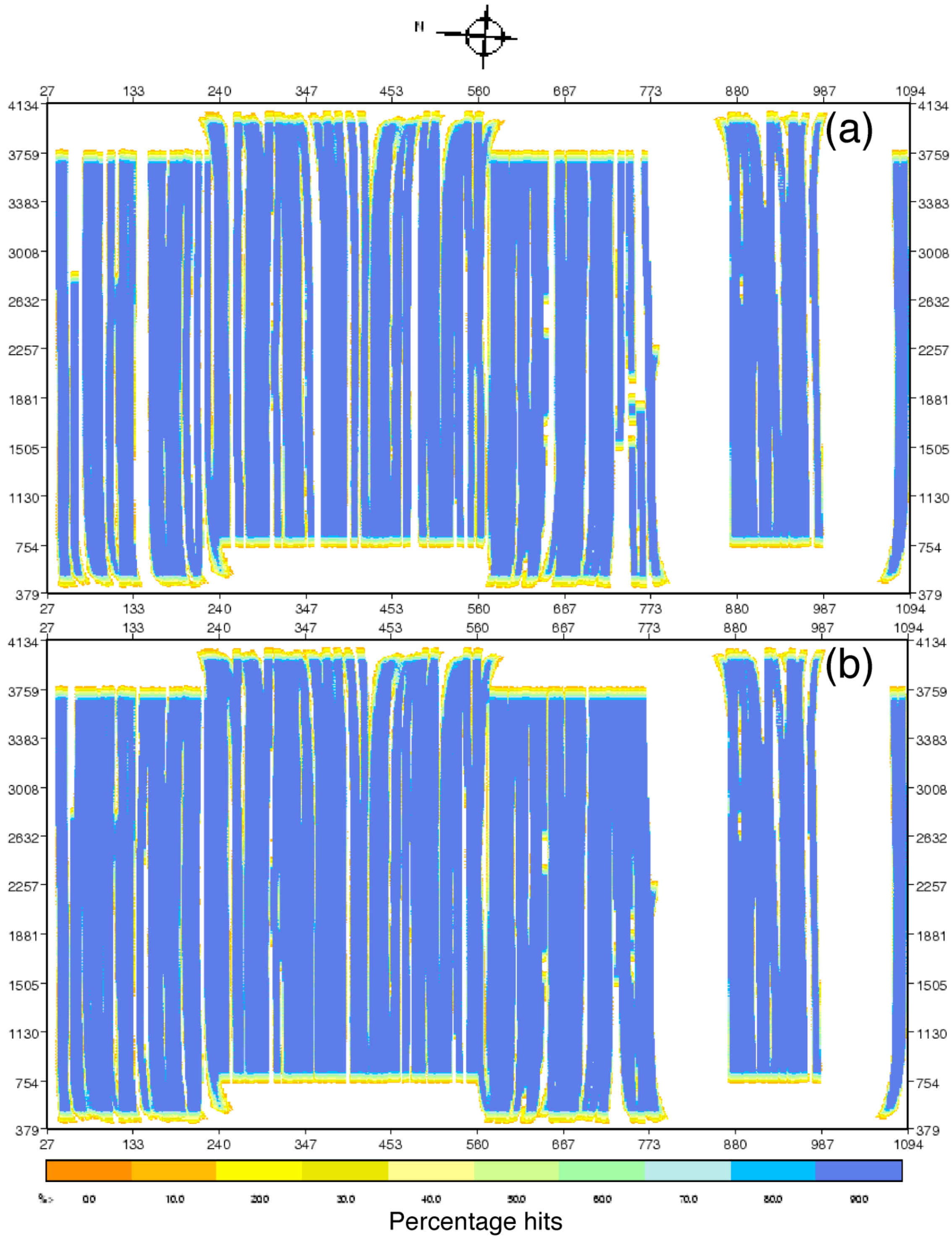

Figure 5.4.10. Bin fold as percentage of the nominal full fold before (a) and after (b) infill and reshoot. Source-receiver offsets from 4587 m to 6050 m are taken into account. Both axes indicate bin numbers. Bin size horizontally is 37.5 m and vertically 6.25 m. Bin flexing is 50% at near offsets and 150% at far offset with a linear taper in between.

5.5 Initial assessment of seismic data quality

Quality of the recorded data is generally very high. For most shots only several channels per streamer are noisy, of which a few appear to have a good enough signal to noise ratio to be used after noise removal, amplitude balancing and frequency conditioning. As a result, only about one percent of the data may have to be discarded.

Initial tests on whole shot gathers suggest that the frequency content of the data is better than expected, in line with what was predicted based on pre-cruise source modeling and, to the best to our knowledge, better than observed on any academic regional MCS dataset collected prior to the availability of the Langseth.

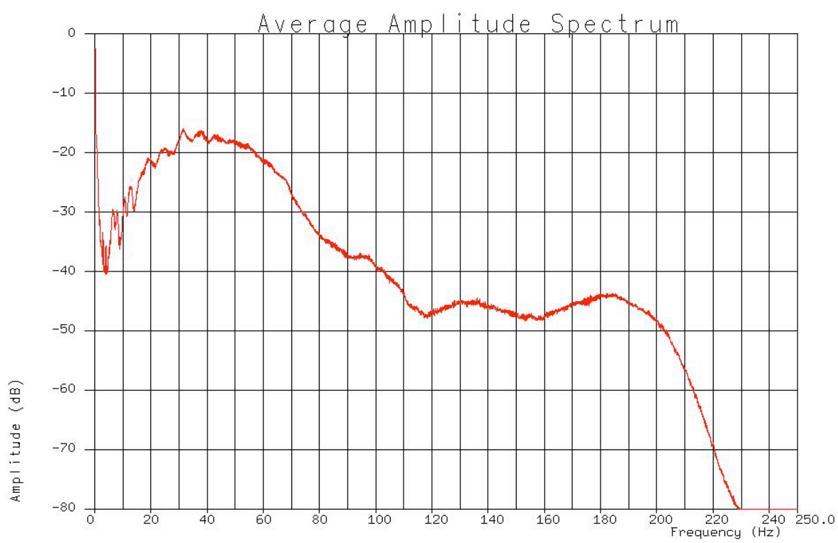

Figure 5.5.1. Frequency amplitude spectrum for shot 1300, line 1708P, streamer 2.

Amplitude spectrum for a typical shot gather (streamer two only) is shown in Figure 5.5.1. Strongest signal is found within the frequency range from about 5 to 80 Hz, but there also appears to be a significant amount of signal at frequencies from about 80 to just over 200 Hz. Note that the recording instrument filter is 2 Hz / 12 db (low pass) and 206 Hz / 276 db (high pass). Therefore, the rapid drop in amplitudes above 200 Hz is expected. Amplitudes should similarly diminish at frequencies below 2 Hz, but there they reach the largest observed values, particularly at the zero frequency. This low frequency noise, including the strong static shift on data traces, is easily recognized in the shot gathers (Figure 5.5.2).

The recording system and the streamers are digital, meaning that the signal is digitized at A/D converters located within the streamer every 300 m or so and then sent to the recording system to be stored. Despite the digital equipment, low frequency noise has somehow leaked into the data while transiting through the streamer. We eliminate other possibilities because the observed noise is stronger when the streamer tension is higher. Noisiest gathers are recorded after looping back onto the line, before the streamers come out of the turn. The strength of the low frequency noise also increased with time during the survey due to growth of barnacles and entanglement of fishing gear that increased the tow resistance. For this reason, we had to reduce ship speed through water during the second half, and particularly last third of the survey.

Examination of shot gathers and their frequency amplitude spectrums raises two additional questions regarding the data quality. First, it is unclear if the frequencies above ~80 Hz are reflection signal and are above the background noise level. In other words, will the high frequency data contribute constructively to the formed reflection images? Second, is it possible to remove the large amplitude low frequency noise without modifying the reflection signal or introducing unacceptable levels of filter noise?

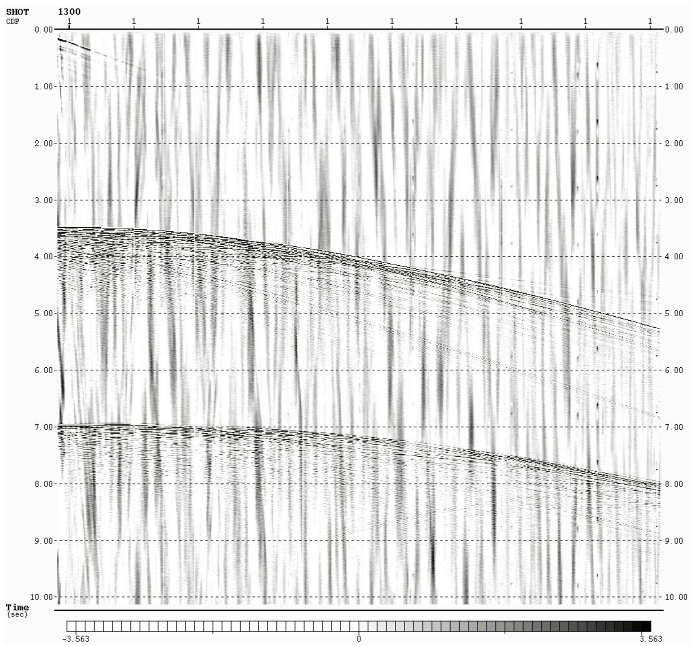

Figure 5.5.2. Shot 1300, line 1708P, streamer 2.

To answer these questions we first examine f-k spectrums of shot gathers (Figure 5.5.3). The wave numbers of the recorded signals show that the high frequency information is indeed reflection signal and not noise (wave numbers for the high frequency signal correspond to wave numbers for the low and mid frequency reflection signal), and that only a very small portion of the signal between 60 and 90 Hz is aliased. The shot gather f-k spectrums also show that the low frequency noise is equally distributed over all wave numbers and is therefore well separated from the reflection signal except near k=0.

Plots of shot gathers in t-x domain after filtering using limited, 20 Hz frequency windows (Figure 5.4.4) further indicate that the high frequency reflection signal is above the background noise level at all recorded frequencies (up to about 210 Hz) and can constructively be used during the imaging process. Resampling the data to 4 ms to reduce the data size and make processing faster is not an option.

We tested two 2D filters to remove the low frequency noise, an f-k and an f-x filter. The design of both filters is shown in f-k domain in figures 5.5.5 a and b, respectively. Comparison of the raw and filtered shot gather using the f-k filter is shown in Figure 5.5.6. Comparison of the raw and filtered shot gather using the f-x filter is shown in Figure 5.5.7. Both filters are successful at removing the targeted noise. However, more testing is needed before the final low frequency noise filter and its parameters are chosen.

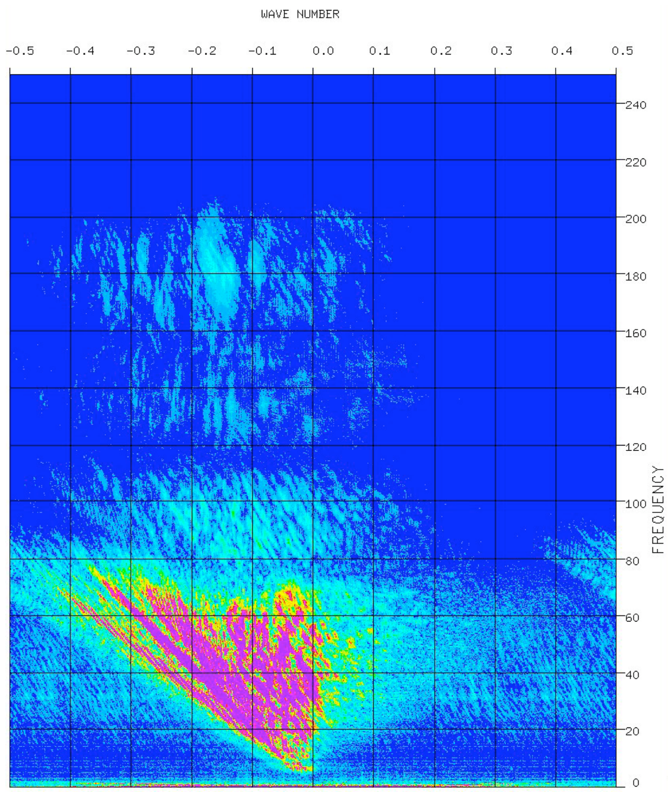

Figure 5.5.3. F-K spectrum; Shot 1300, line 1708P, streamer 2.

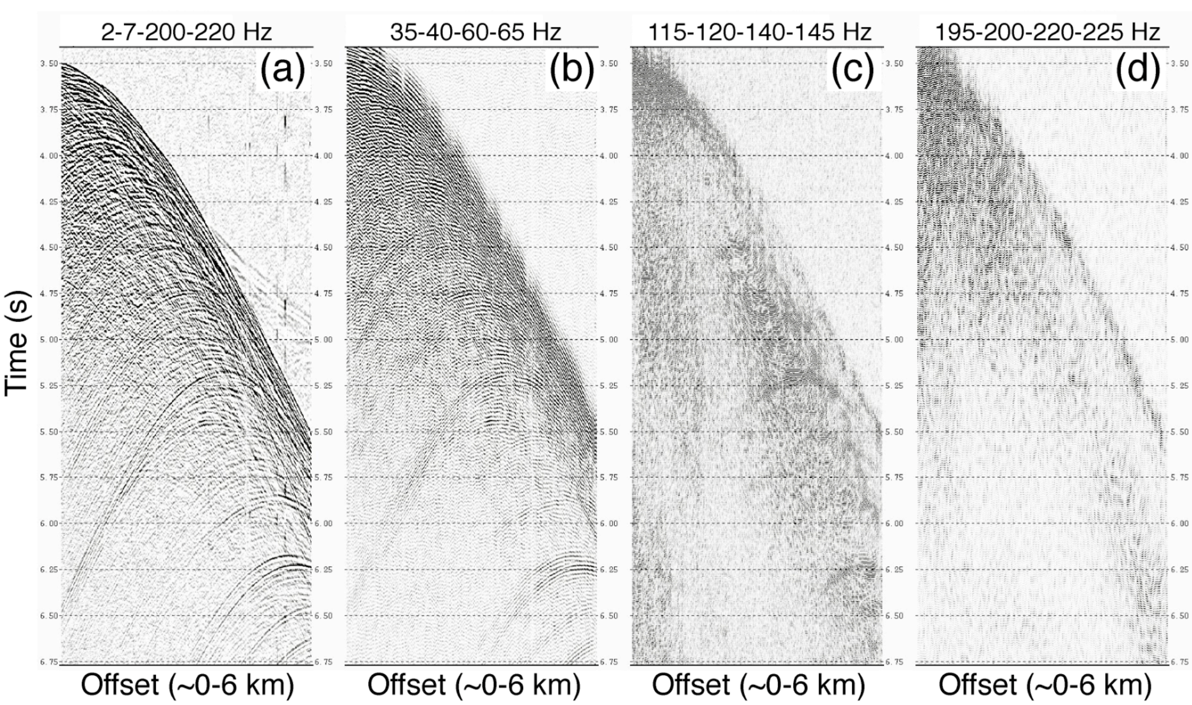

Figure 5.5.4. Test of signal frequency content in shot gather 1300 (line 17008P, streamer 2) using limited frequency range windows. Note that reflection and diffraction signal is present in at all frequency ranges up to just over 200 Hz.

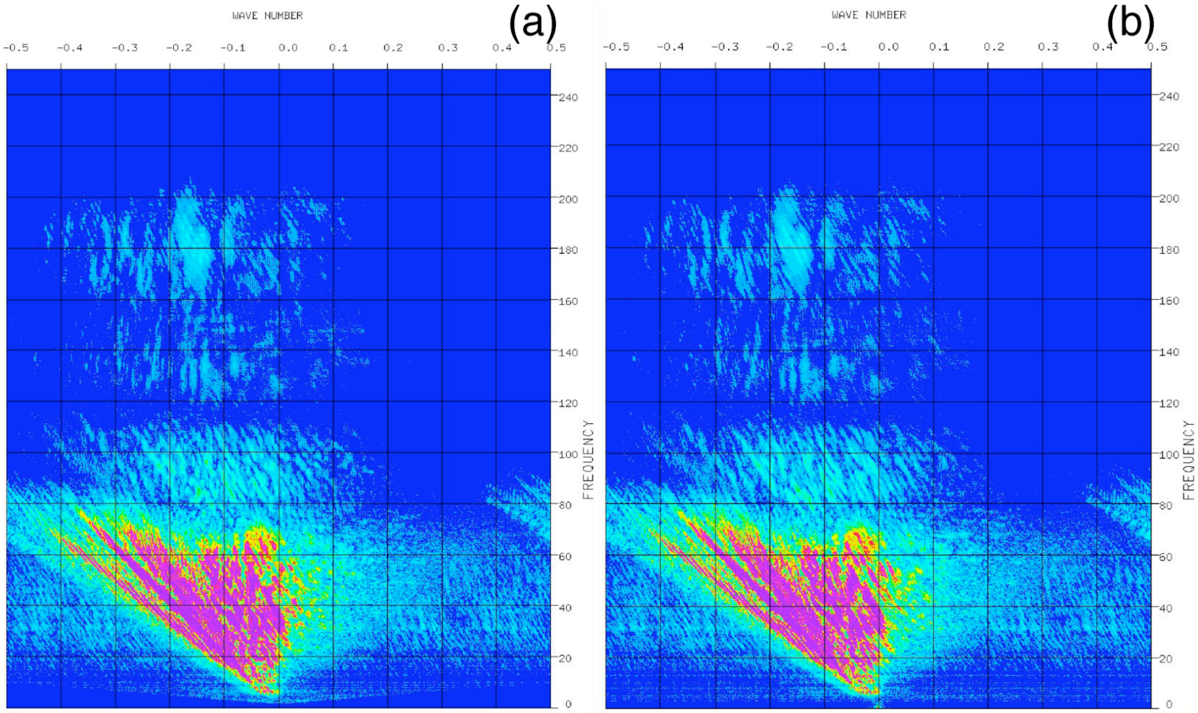

Figure 5.5.5. F-K spectrums of shot gather 1300 (line 17008P, streamer 2) after applying f-k (a) and f-x (b) filters. The upper points of the f-k filter are: -500 k/10 Hz; -20 k/2 Hz; 20 k/2 Hz; 500 k/10 Hz. Lower point have the same k but are all 0 Hz. F-X filter is applied in the range from 0-5 Hz.

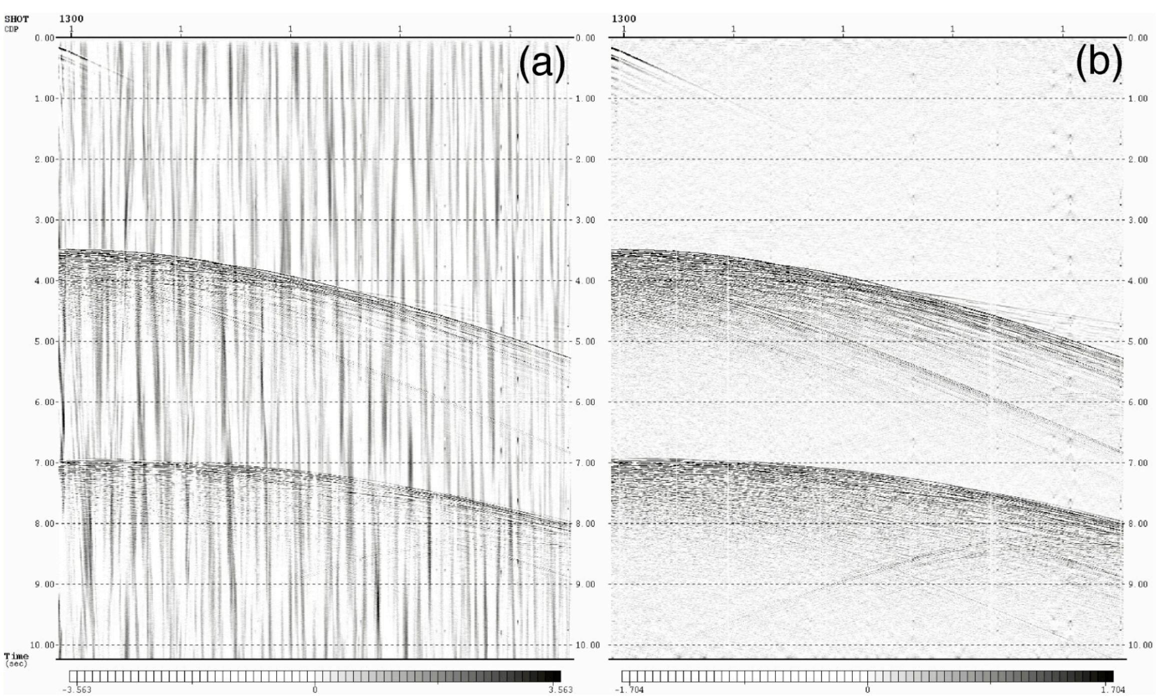

Figure 5.5.6. Shot gather 1300 (line 1708P, streamer 2) before (a) and after (b) applying the f-k filter. Much of the low frequency noise is gone after applying the filter.

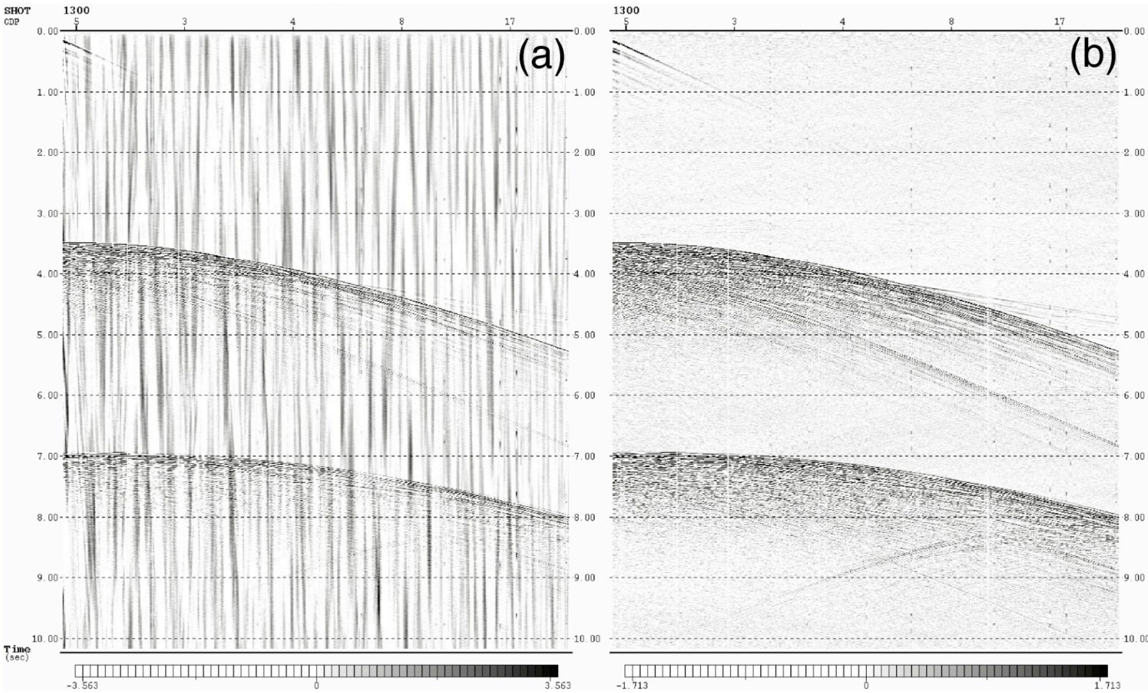

Figure 5.5.7. Shot gather 1300 (line 1708P, streamer 2) before (a) and after (b) applying the f-x filter. As in Figure 5.5.6, much of the low frequency noise is gone from the shot gather after applying the filter.

5.6 Multibeam Bathymetry Data.

The Langseth is equipped with a 1°x1° beam Simrad EM120 multibeam swath sonar**.** Nominal sonar frequency is 12 kHz with an angular coverage sector up to 150 degrees and 191 beams per ping. Achievable swath width is approximately six times the water depth. In our working water depths of 2500-3000 m, the system acquired a useable swath width of ~12-13 km.

During operations multibeam data were cleaned and ping edited on a daily basis. Minimal ping editing, confined to the outermost beams, were required during the first leg of the cruise prior to our July 10 return to Manzanillo. However, on our return to the study site during and immediately following tropical storm Elida, multibeam data were much noisier and considerable editing of spurious beams within the central part of the swath was needed. A few days (July 18 and 19) were extremely noisy and required very extensive editing.

Initial sound velocities used prior to leg 2 of the cruise were taken from Levitus at 11°N. A good XBT extending to ~1800 m was obtained on July 14 and used for the rest of cruise. XBTs were deployed fairly routinely during periods of gun maintenance but most did not reach depths beyond ~500 m. Approximately one in three launches achieved the desired 1800 m range. With the existing configuration for launching XBT's during 3D operations it is a challenge to get them far enough from the ship that they do not get entangled in the towed seismic gear. Figure 5.6.1 shows the sound velocity profile from July 14 used for multibeam data acquisition after this day.

Raw XBT's data provide measurements of sea water temperature as a function of depth. Salinity values obtained from the Thermosalinograph (TSG) are used to process the XBT data for sound velocity. The TSG was serviced in June 2008, but part way through the cruise (07/26) Anthony discovered that the wrong calibration for the system was being used- (old calibration from 2004). This was corrected and the TSG data were reprocessed.

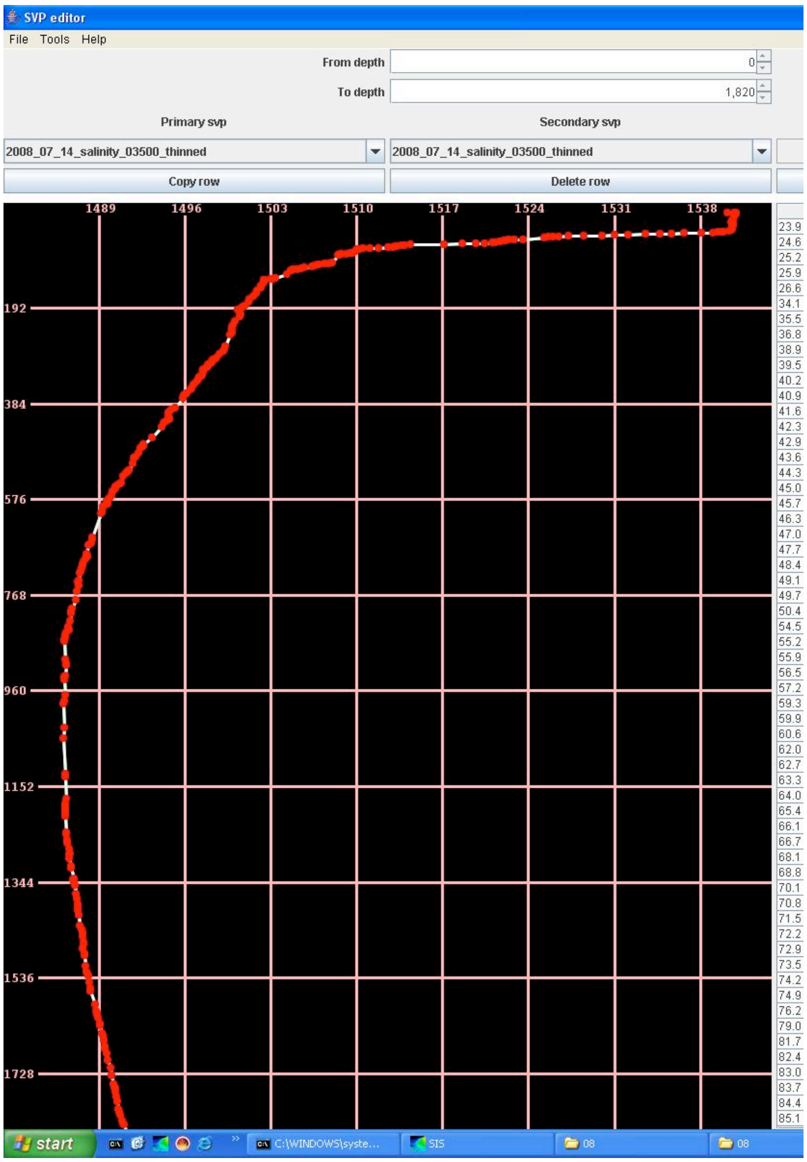

Figure 5.6.1 Sound velocity profile from July 14 used for multibeam data acquisition after this day.

Multibeam Data Quality

Once cleaned, data quality is excellent and far exceeds the quality of much of the existing swath bathymetry for the region. Prior to our survey the best quality bathymetry grid for the survey region was from Cochran (1999) and was limited to -104°09’-23’ and 9°32’-9°58’. In 2005 a 6 km wide EM300 swath was run along the ridge axis by Scott White et al. using the R/V Thompson. Figure 5.6.2 shows a comparison between the EM300 data (gridded at 30 m) for the bulls eye region with our bathymetry for the same region gridded at 50 m.

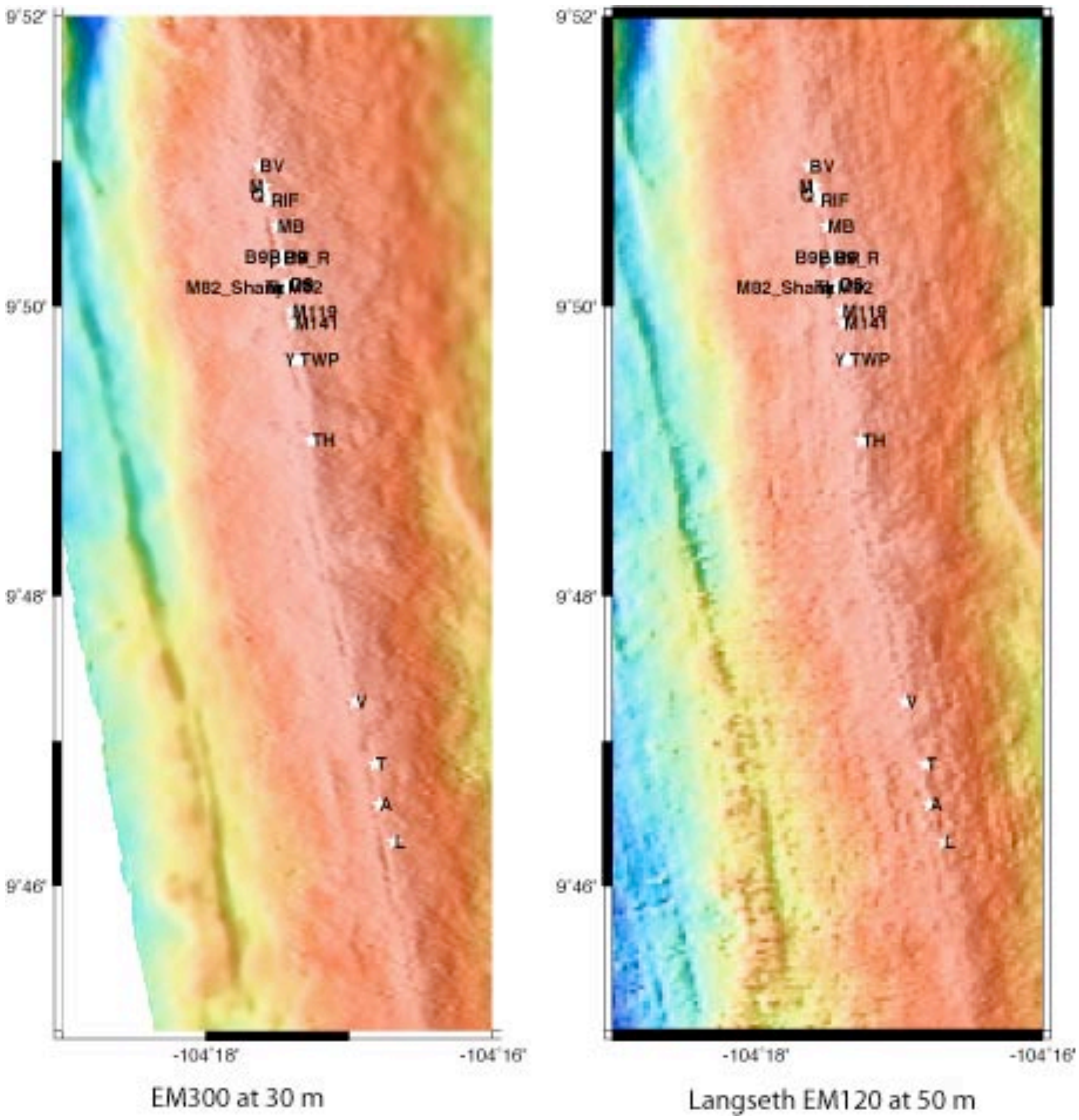

Figure 5.6.2. Comparison between the EM300 data (gridded at 30 m) for the bulls eye region with our bathymetry for the same region gridded at 50 m.

The EM120 data can be reliably gridded to 75 m based on the following approximation for the footprint of the sonar beam on the ocean floor:

If the EM120 data is collected in equidistant mode, approximate grid cell size is given by the equation beam=tan(total_angle/2)*depth/(#beams/2). If your total angle is 135 degrees and 191 beams are collected, the equation simplifies to beam=.0226*depth.

However, as indicated in Fig. 5.6.2, with the great data redundancy acquired during our cruise, the data may be usefully gridded to as fine as 50 m interval.

5.7 Other underway data

The gravimeter was operated throughout the cruise with gravity ties made in Manzanillo July 12 and then again at the end of the cruise on August 20. Gravity data were plotted on a daily basis and a few days were filtered, but no other data reduction has been applied (Eovtos correction, conversion to FAA).

The magnetometer was operated until August 1 (instrument failure) and produced good quality data during this time. The Knudson subbottom profiler was operated for most of the cruise although data quality is marginal and the system was turned off after we switched to using the hydrophone in the sonar pod for passive acoustic monitoring. The system was turned on again once we had the gear on board and were underway to Manzanillo.

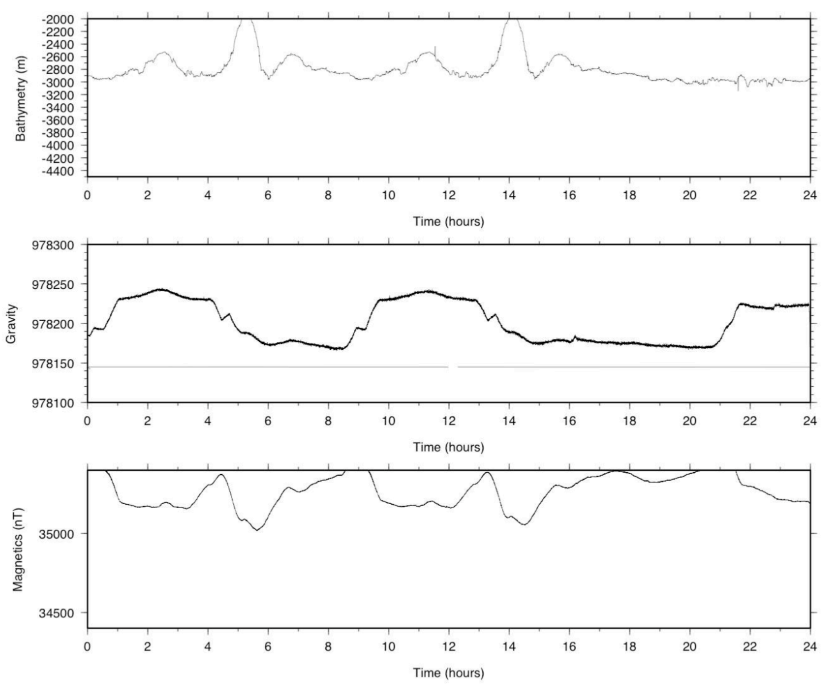

Figure 5.7.1 Plot of EM120 centerbeam depth (top), raw gravity counts (middle panel) and magnetometer data (bottom panel) for JD205.

6.0 Onboard processing of MCS data

6.1 Brute stacks.

Near-real time brute stacks were generated as data were acquired using SIOSEIS (brute468-EPR3D-newsioseis, see Appendix 6.1). The stacks were sent to the atlantek thermal plotter as they were acquired. Only 20 minutes of delay passed between the time of shooting and the time of plotting. This real-time procedure allowed us to assess quickly that data were being acquired and recorded to disk correctly, and provide a preliminary assessment of data quality. In addition, the brute stacks were used for preliminary interpretations that guided us throughout the survey and allowed us make changes to the initial plan as new geological features were recognized.

This processing was done in the computer "mcs" (as sioseis user); we run all scripts from directory ~sioseis/MGL0812/. SEG-D files written to seisnet were copied automatically to the nas server (/remote/nas/working/MGL0812/stack/). The perl script init.pl (see Appendix 6.2) was used to make a temporary list of the path to the latest shot file to be added to the stack. This script must be running before and during the sioseis stacking, so it was left running uninterrupted. The sioseis script brute468-EPR3D-newsioseis (Appendix 6.1) requires two input parameters: line name and direction of plotting (ltr or rtl, for left-to-right or right-to-left):

brute468-EPR3D-newsioseis EPR3D2316P ltr

and it consists of:

segddin: reads the front half of streamer #2 from the latest SEG-D file.
geom: definition of 2D geometry
wbt: adds water bottom time to headers based on EM120 center beam depth.
gather: sorts in CMP gathers.
nmo: applies NMO correction with a velocity model based on the ESP5 results of Vera et al. (1990). The model is automatically hung from the seafloor to account for variations in bathymetry.
mute: outer trace mute.
stack: stack of CMP gathers.
diskoa: save stack to disk file (e.g., /remote/nas/working/stack/SEGY/EPR3D2316P-stack.segy).
avenor: amplitude correction.
agc: AGC amplitude scaling.
filter: Band-pass filter.
plot: creates raster file for atlantek plotter.

At the same time as the stack was being created it was sent to the plotter with the command atlantek; e.g.:

atlantek /remote/nas/working/stack/SEGY/EPR3D2316P-stack.atlantek

6.2 Navigation QC

Processed P1/90 files contain information about source, receiver, tailbuoy positioning, and other navigational parameters, and they were provided to the scientific party by the shipboard technical staff in the standard U.K.O.O.A. format. These files will be input into the seismic processing software to create the 3D geometry. We performed a preliminary QC of the files by reading them into MATLAB to assess the feathering of the streamers, and plot the shooting lines and receiver positions. This allowed detection of occasional errors in the navigation processing, for example, as one streamer cross-cutting the other three, or one of the streamers showing abnormal positions for a large group of receivers.

The P1/90 files were also read with Focus and converted to Focus internal navigation format (so-called fmt files). The fmt files were inspected using the 3D Geometry utility of Focus. The main purpose of this step was to make sure that the P1/90 files were fully compatible with Focus. In some occasions, missing information in one or more of the shot headers in the P1/90 file can make Focus crash. These errors were tracked and reported to the navigation team, who would reprocess navigation information into a new P1/90 file. A more in-depth inspection of the navigation geometry with Focus was done later on during merging with the seismic data (see next section).

6.3. Conversion to Focus format and integration with navigation.

Onboard processing consisted on: (1) read SEG-D files into Focus database; (2) read P190 navigation files into Focus database; (3) merge data with navigation and output DSK files (Focus disk format) for onshore processing. Detailed instructions for the watchstanders about the steps to follow to perform these tasks are given in Appendix 6.3, and a checklist spreadsheet is given in Appendix 6.4.

A critical step was the proper reading of the SEG-D files with Focus. For this we used the module SEGD in two steps:

Read SEG-D step 1. The first pass of SEGD was done in WRITE mode, which scans a SEG-D shot file and writes out a file with the format of the SEG-D file. This is useful if all of the subsequent files to be read are expected to have the same format and acquisition parameters. We run Focus job epr3d_line1_read_segd_part1.dat once to extract the SEG-D format and save it to the file format_raw_epr3d. A copy of this raw format file extracted from the Focus database is given in Appendix 6.5. Figure 6.1 shows a screen capture of this Focus job and the parameters used.

(Note: This job runs without problem in computer mcs, which is a Sun workstation running Focus 5.4. However attempts to run it in a Linux desktop with Focus 5.3 were unsuccessful, as well as attempts done remotely at WHOI in a SGI Linux cluster also with Focus 5.3. At this stage it is unclear if the different behavior of the Focus job was due to the difference in platforms –SUN vs Linux- or the different Focus versions used. This problem will have to be solved onshore by contacting Paradigm technical support).

Read SEG-D step 2. The second pass of SEGD read a complete set of SEG-D shot files taking the raw format form the file created in the previous pass. We encountered problems reading shots number less than 1000 and larger than 1000 in the same job, so reading was split into two steps, one for shot numbers below 1000 and a second one for shot numbers above 1000. The Focus jobs are read_segd_file_part2_TAPE?????_shotsbelow1000.dat (Figure 6.2 and Appendix 6.6) and read_segd_file_part2_TAPE?????_shotsabove1000.dat (Appendix 6.7). The resulting 2 data files were later merged into a single one (see Appendix 6.3 for details about this).

The SEGD job defines the following headers, read from the SEG-D external header created by Spectra (see LangsethNavManual.pdf in Appendix 6.8 for details of the external header), that are used later on in the processing:

STATIME: This header contains a concatenation of the status of the line (run-in, main line, run-out, etc.) plus the shot time (hour, minute, second). The reason to read all this information together was to avoid having problems reading the headers when the time starts with a 0. Later on in the processing this header will be split into several ones.
YMD: This header contains a concatenation of the year, month, and day.
LINENUM: This header contains the line number. Only valid for profiles within the 3D box, and it does not differentiate between P (primary), R (reshoot), or I (infill) lines.
CBDEPTH: Integer part of the center beam depth.
SPLAT: Integer part of the shot point latitude.
SPLON: Integer part of the shot point longitude.
DECSEC: Decimal part of the seconds (shot time).
DECCBDEP: Decimal part of the center beam depth.
DECSPLAT: Decimal part of the shot point latitude.
DECSPLON: Integer part of the shot point longitude.
SHOT: Shot number.

Before the final merging with the navigation, some of the headers of the data were modified and new ones created. This was done with a Focus job named like: read_allshots_modifyheaders_epr1660p_new.dat (Appendix 6.9). Key modifications done with this job are:

HEADPUT: Defines header LINETYPE, which is assigned a value of: 1=P (primary), 2=R (reshoot), or 3=I (infill).
HEADDEL: Deletes the headers JULDAY and DAY (both have the same information) that were written by Spectra into the SEG-D internal trace headers. The reason to delete them is that Spectra did not account for the fact that 2008 was a leap year, so julian day output from Spectra is off by 1 day. This is a critical error that needs to be corrected because later on the seismic data and the navigation files are merged based on TIME (not SHOT or FFID #).
HDRMATH: New definition of headers MONTH, DAY, and JULDAY, extracted from header YMD read from the external SEG-D header.

HDRMATH: Defines STATUS, which contains the first number of the header STATIME and refers to the status of the line (run-in, main line, run-out, etc.). It also defines HR (hour), MN (minute), and SEC (second) from the information in header STATIME.

The P90 navigation files were read with Focus using the job navdisk_2036P.dat (Appendix 6.10). The navigation files in Focus (fmt) format were then inspected with the 3D GEOMETRY tool (Figure 6.3). Zooms into a few areas allowed confirmation that the dual source geometry was correct. The Single-Cable Display allows sequential display of each shot and receiver locations in a movie-like fashion. This was done for several sections of each profile to detect abnormal source or receiver geometry that were undetected in the preliminary QC with MATLAB.

Final merging of the seismic data and the fmt navigation files was done with Focus job merge_2036P.dat (Appendix 6.11), which outputs a .dsk file for each processed profile. These files can be read directly from Focus and contain all the header and geometry information for further processing. If for onshore processing it is decided to create a new geometry, the headers created by Focus module PROTAPE (see Appendix 6.11) need to be deleted first, and then the data and navigation merged. See Focus manuals for PROTAPE headers.

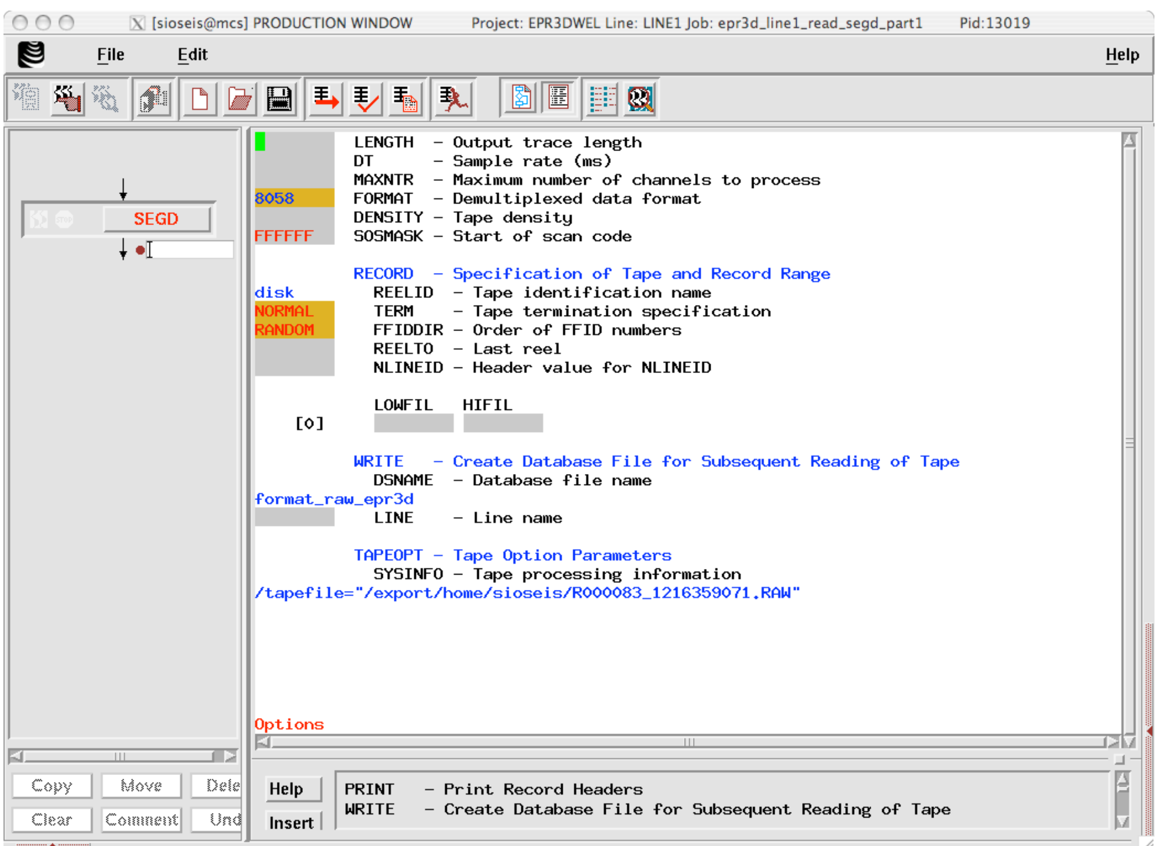

Figure 6.1. Screen shot of Focus job epr3d_line1_read_segd_part1.dat to read the SEG-D raw format (pass 1 of SEGD in WRITE mode). The raw SEG-D format is written to a Focus database file called format_raw_epr3d.

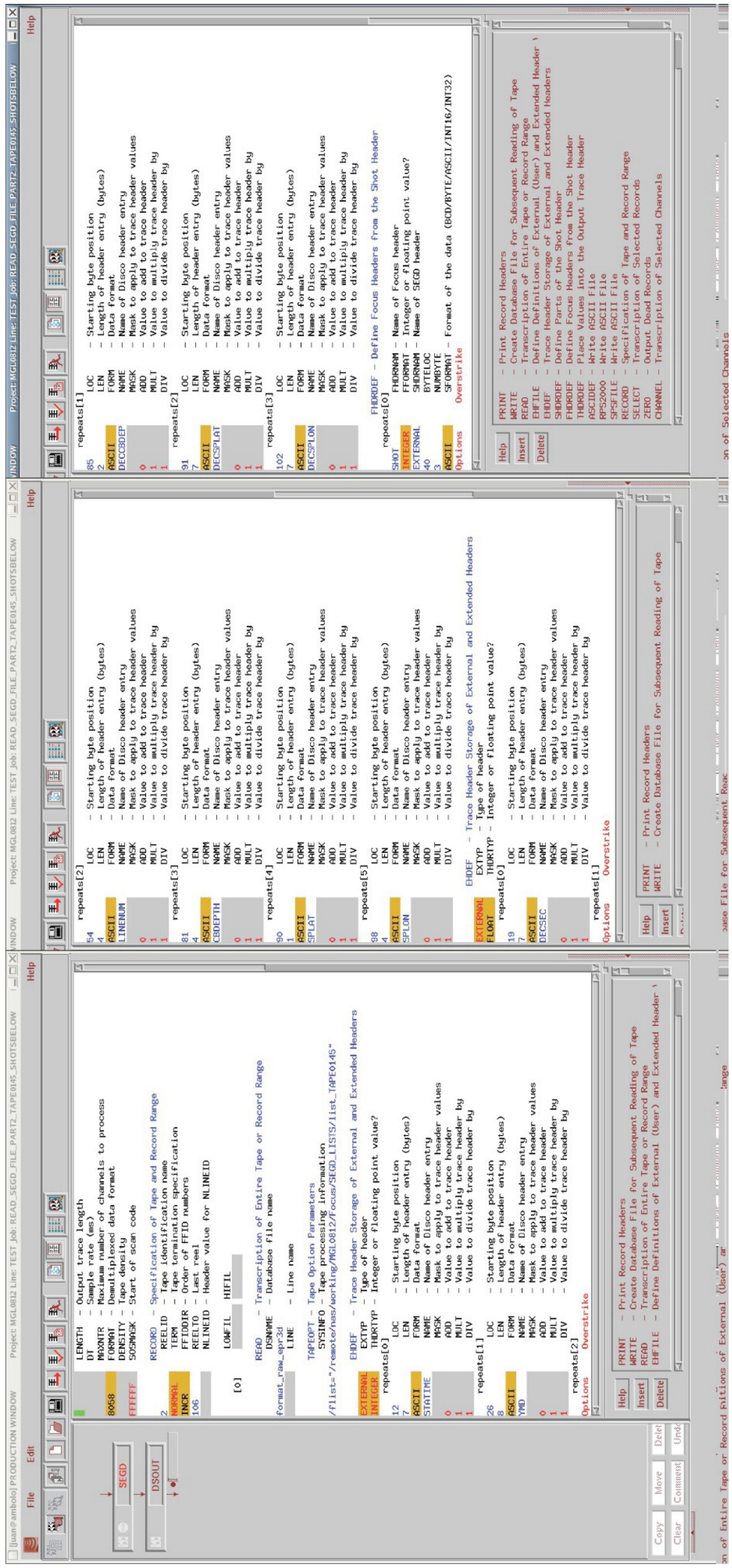

Figure 6.2. Screen shot of Focus job read_segd_part2.dat to read a set of SEG-D shot files.

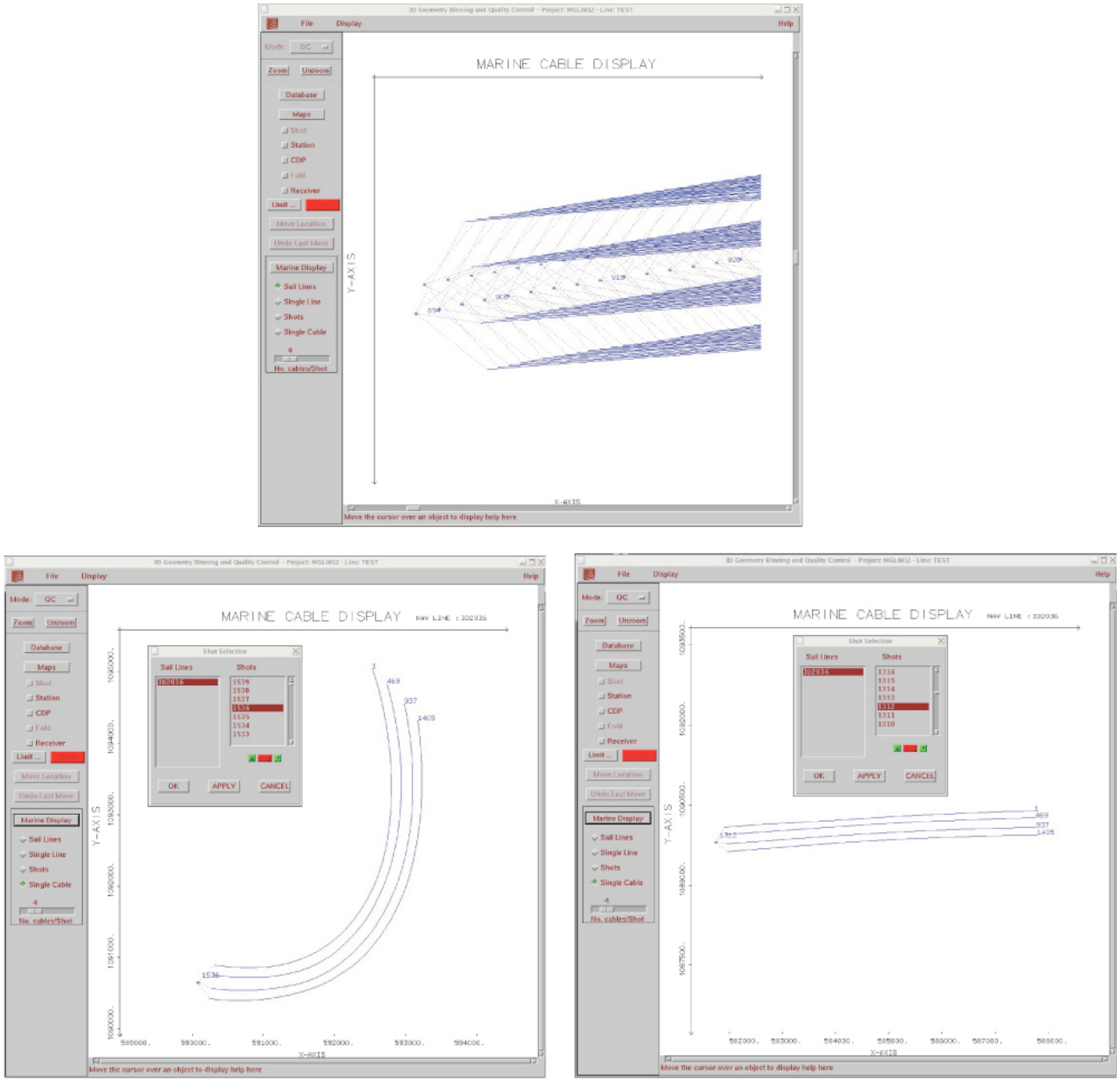

Figure 6.3. Screen shots of 3D GEOMETRY tool for QC of navigation files. Top shows a zoom in the first shots of the lines, and bottom panels show receiver locations for two shots.

7.0 Initial Results

The real time brute stacks generated onboard allowed a first pass assessment of our findings and reveal line-to-line variations in the AMC and Moho reflections as well as previously unrecognized intra-crustal events that appear to be off-axis magma lenses and that would likely have been disregarded as side-scatter events in single pass 2D lines. Persistent fine-scale variations in the axial magma lens event are evident including discontinuities at the small 4th order tectonic discontinuities of the axis defined by the surface morphology, with two distinct diffractive events detected at most discontinuities. 3D processing and migration of the data volume will be required to accurately image these fine-scale variations, but the implications are that discrete magma lenses underlie each of these volcanic segments. In some locations along the ridge, the apex of the AMC event has a complex form whereas in others it is simpler event possibly reflecting variations in the thickness of the melt sill. The magma lens also varies from symmetric under the axis to a strongly asymmetric event dipping primarily to the west. Beneath the primary area of the 1991 and 2005-06 eruptions, the magma lens reaches its shallowest point along the ridge axis, consistent with the earlier Conrad data set. The magma lens in this region also appears “dimmer” than the adjoining lenses to the north and south, possibly reflecting diminished melt content relative to the neighboring segments.

Bright intracrustal reflections, similar in character to the axial magma lens were imaged in several locations in our dataset including on the west flank of the ridge just south of the Lamont seamounts, and in two locations on the east flank of the ridge at the northern and southern parts of our survey. These events are associated with distinct hummocky volcanic texture and constructional relief on the seafloor and are likely off-axis magma lenses, although careful examination of the data for waveform polarity information will be needed to confirm this hypothesis. The northern event is accompanied by two other deeper AMC-like features, stepping up from near Moho through the mid-crust. These features were missed in previous studies of the area, and shallow mantle anomalies beneath these features are not obvious in the Undershoot tomography results. If they indeed represent off-axis melt sills, then one might expect hydrothermal activity and lavas of different age and chemical composition in the region, but we are aware of no surveys in the region to support that conjecture, almost all studies having concentrated on the axial region itself. A small isolated AMC-like event was also detected beneath the youngest of the Lamont seamounts. This is the first time a candidate magma lens has been detected beneath an off-axis seamount and if confirmed, indicates this seamount is currently active.

Layer 2A was not well imaged in the brute stacks as these stacks only include the inner 3 km of the streamer whereas the layer 2A event is a refracted arrival present in the farther offsets of the streamer. However, the 2A event can be detected discontinuously in our stacks, especially at local bathymetric lows (abyssal valleys), and the thickening of layer 2A away from the axis can be detected. Data processed onboard from our axial lines showed the 2A event at ~100 msec along the ridge axis.

Moho varies substantially in character and strength across the survey area and in some areas is quite asymmetric across the axis, notably stronger beneath one flank than the other. Processing of the 3D volume for Moho will target understanding the spatial distribution of these Moho variations and relationship to the surficial axial segmentation and subcrustal shallow mantle structure. Near the Lamont seamounts, Moho is well imaged on the east flank, but absent on the west flank. South of this region the sense of asymmetry reverses. In some locations Moho is a "bright" single continuous reflection event whereas in others it has a more complex form. We also see evidence for variations in the width of the region of low-velocities at the axis associated with the crustal magma zone; along some crossings Moho dips strongly at the ridge axis whereas at others the near-axis increase in Moho two-way travel time is more gradual. Regional variations in Moho depth from ~2 to 1.8 s are also apparent and these will be examined in the context of previous studies of crustal thickness in this region.

In some places, also identified were sub-Moho reflections coming up to 1-2 s after the Moho event and extending over large sections of the profiles. These events need to be confirmed through careful data analysis. Their origin is not known.

8. Summary recommendations

8.1 Personnel:

The science support team lead by Robert Steinhaus is outstanding. Their professionalism, skill and dedication pulled this cruise through a difficult start to a fine successful ending. The gun department led by Tom Spoto and Robbie Gunn is excellent. Anthony Johnson is crucial to many facets of the operations. With the core team now in place, the Langseth has the needed personnel for conducting seismic operations successfully. The issues now will be to train adequate staff to cover functions of the current team leaders for rotations. A top priority is to find a rotator for Anthony Johnson in handling shipboard systems administration and data streams.

It is important also to acknowledge that the ship's engine department put in massive effort to try to make repairs to the compressors at sea and the repairs made in port were not possible in an at sea situation.

The role of the visiting science party in assisting data acquisition operations is not yet well defined and this will likely continue to evolve over the coming year. During our cruise, the science party assisted the shipboard technical staff with streamer deployment and recovery and contributed to the routine watches. However, watch responsibilities were less than was standard for 2D operations on the Ewing, which from our experience is necessary due to the much greater complexity and associated risks of 3D operations. The Senior Science Officer in charge needs to have sufficient technical support staff under his/her authority to handle the multiple streamer deployment and recovery operations safely as well as enough trained technical support to ensure adequate continual monitoring of the seismic gear during data acquisition. With the amount of gear in the water and complexity of the towed arrangement, the risks of entanglement are high and associated costs due to entanglement or loss would be very large. We expect that during

2D operations, the visiting science party could play a larger role in routine watchstander functions but also with a higher level of shipboard seismic support staff supervision than was routine on the Ewing.

8.2 Living Conditions

Living spaces- As all are aware, the state rooms for the crew are extremely small and are marginally usable during their off time. There are too few public spaces for the crew to use as alternates to their rooms. The new TV room seating installed in San Diego is a significant improvement over what was previously in place. The library was made somewhat usable during the cruise, but desperately needs comfortable seating. There are few books and shelving needs to be installed. Both the TV room and library should be top priority for replacing the carpeting, which is dirty and unwelcoming.

A functioning satellite TV hook up for use while in port would be highly appreciated by the crew and should be a top priority for the maintenance period this coming fall. Portable lawn chairs for sitting on the top deck, with a designated storage place would be appreciated.

Additional workstations for the crew to use for email should be a top priority.

The ship's office appears under used. A functioning printer in the office would be useful.

The weekend telephone call system is a great idea and was very much appreciated by the crew and science staff. Any enhancement to that such as more hours or the possibility of calling some foreign countries would be appreciated.

Sunday BBQs should return.

8.3 Seismic Systems

Maintenance of the compressors is top priority given that we have only two on board and the demand is high during 3D operations. An adequate inventory of spares is essential. It would be very desirable for training of the engineer department personnel in compressor maintenance. It might be a good idea to have the two first assistant engineers go through training at Caterpillar. We understand that most seismic vessel carry personnel who are dedicated to compressor maintenance.

Streamer deployment: It is difficult to launch birds over the side on cables #2 and #3 and there is considerable potential for damaging the birds with the current configuration. This seems to be due to the low overhead on the streamer deck which could not be dealt with short of a major refit but some thinking needs to go into this issue.

Spare streamer sections are hard to reach and there is no good space to store bad sections. Again there may be little that can be done about this short of major restructuring of spaces.

8.4 Marine Mammal Observation requirements

During the cruise both the primary PAM and spare that had been obtained for the cruise failed. We were able to continue acoustic monitoring using a hydrophone available in the sonar pod. This proved adequate and on 3 occasions, marine mammals were detected through acoustic monitoring prior to visual identification. The current PAM needs to be towed from the stern along with the array of seismic gear and it is difficult to find a towing arrangement that does not pose considerable risk of entanglement with the other gear or risk of damage to the PAM itself. Towing options are particularly difficult for 2D operations. Robert suggests that hydrophones deployed using the through hull pinger holes could provide a much superior system for both the MMO and seismic operations. Transducers deployed through the pinger well could be readily worked on at sea, the MMO recording apparatus could reside in the wet lab rather than in its current location on deck where it is subject to damage, and the complications of finding a way to tow the PAM off the stern without getting tangled in the gun strings would be alleviated. This option should be pursued by OMO as the primary mode for passive acoustic monitoring.

A handbook covering actions to take under various circumstances of marine animal observation needs to be developed by the OMO to provide general guidance when new situations arise. Definition of the origin of various requirements should also be included. When turtles were observed on MGL0812, the ramp-up requirements were not clear from the existing specifications and the maximum ramp-up as defined for mammals was followed while we sought guidance regarding what was required. The marine animal mitigation requirements impact 3D operations heavily as any ramp down/ramp up period means the line will need to be re-shot. Since turtles were not included explicitly in our IHA and are not part of NMFS jurisdiction it was unclear what procedures should be followed for turtle observations and who was the authority defining the requirements.

8.5 IT systems

More readily accessible information needs to be provided to the visiting science party on the ship web site regarding the architecture of the computer systems on board, where data are located, how to get connected to the SAN, and where to locate working directories. Information on how to run the real-time brute stack using SIOSEIS should be well documented and readily available. Locations of all science software needs to be well documented. Right now the ship's web site contains many broken links and placeholders.

The visiting science party should be set up with a standard login on "compute" and "mcs" with paths set to science software, man paths etc. Logins should be established before the science party arrives. Ideally users should have one home directory and mcs and compute should be cross-mounted so that users can work between them.

OMO and the IT group should investigate obtaining a license for FOCUS that does not require access to the external internet. During periods when the internet was down, FOCUS would fail. Paradigm supplies at least temporary licenses that do not require connection to the internet and it may be possible to get such a license for the shipboard installation.

Matlab on the ship did not work properly.

Data QC and basic reduction for the underway data streams are in the process of being established and need to become a routine part of operations. At a minimum, daily QC of the underway data streams is needed to ensure that the systems are functioning as expected. Several data streams still need to be hooked up to the data monitors, e.g., the gravity and magnetics to the main lab navigation/data monitors.

Computer systems are not sufficiently robust, e.g., when the Sun machine "mcs" goes down, after reboot often the external disks would need to be manually remounted.

Options or upgrading internet access currently provided through to HiSeasNet should be investigated. Seismic industry colleagues suggest that we are paying too much for the poor bandwidth HiSeasNet provides compared with the services available to the offshore seismic industry.

8.6 Operations

Spares and requisition delays: requisition delays are crippling and have the high potential to jeopardize operations in that crucial spares in most departments are inadequate and in some cases non-existent.

Fuel monitoring: We lost two days of planned operations because of uncertainties in the levels of the fuel tanks due to inoperative sounding systems. This causes dual problems. The first is that the tanks cannot be fully filled due to concern that will overfill and cause spillage. This has the obvious effect of reducing the duration of the vessel. The second is that the length of the cruise becomes unknown. This needs quite high priority.

Chase boat: We experienced an incident with a fishing boat that crossed our stern through the towed gear and caused damage to the forward acoustic units on streamer 3. Approximately 18 hours were lost to replace these units as well as an additional bird that had failed earlier in the survey. On retrieval of the towed equipment at the end of the cruise there was considerable fishing gear including floats on the starboard streamers. A chase boat would have prevented this incident and would be highly advantageous as a routine part of operations. Such a vessel could have brought supplies on occasion and be used for the Medivac that we needed to lease a vessel to accomplish. A chase boat will be essential for any near shore work.

Medic on board: There are services that provide medics for offshore work. Given the potential for injury associated with seismic operations, this should be considered, especially for operations very far from shore. Obviously it could avoid the potential for a Medivac that might involve diverting the vessel with loss of operations.