Cruise Report
R/V Maurice Ewing
EW0207

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Astoria, Oregon – Newport, Oregon

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Scientific Objectives

The Juan de Fuca (JdF) Ridge has been intensively studied and monitored since the early 1980s resulting in detailed knowledge of its seafloor geology, tectonics, hydrothermal systems and recent volcanic history unmatched anywhere else along the global mid-ocean ridge system. The region has been the focus of several observatory efforts over the past decade and will be a site of increasing activity for both R2K studies and the developing NEPTUNE cabled observatory effort. The region is the site of the ODP FlankFlux program as well as ongoing CORK experiments targeted at understanding ridge flank hydrothermal circulation. Three separate volcanic eruptions have been detected since real-time acoustic monitoring of the JdeF Ridge became available in 1993; the June, 1993 CoAxial eruption, a February, 1996 eruption on the northern Gorda Ridge and a January, 1998 event at Axial Volcano and along its South Rift Zone.

Despite the extensive mapping, sampling and hydrothermal studies carried out along the JdF Ridge, and the evidence for ongoing volcanic activity, little has been known about the crustal structure of the JdF Ridge. Our experiment was motivated by both the need for an improved understanding of axial crustal structure at the JdF Ridge in order to relate this structure to the recent eruptive history of the ridge, and the unique opportunity in this area to investigate the alteration of young ocean crust caused by low-temperature ridge flank circulation and its relationship to environmental variables.

Our multichannel seismic (MCS) investigation of the intermediate-spreading JdF Ridge was designed to accomplish three primary goals:

- *Characterize axial structure along the Juan de Fuca including the location and dimensions of crustal magma bodies and relate these observations to the recent eruptive history of the ridge and morphologic indicators of magmatic state.*
- *Measure the variation in velocity and thickness of the shallowest crust (seismic layer 2A/2B at the axis of the intermediate spreading JdF Ridge*
- *Characterize the evolution of the upper crust (layer 2A/2B) as a function of sedimentation history, crustal age, and basement relief to provide new constraints on crustal alteration and ridge flank fluid circulation.*

1. Characterize axial structure along the Juan de Fuca Ridge.

The observation of symmetric pairs of "bow form" ridges on either side of the axis of the JdF Ridge has led to the development of models for crustal accretion at intermediate spreading ridges that involve volcanic-tectonic cycles. The fundamental assumption in these models is that spreading and crustal extension are relatively continuous on time scales of thousands of years while volcanic activity is episodic on these same time scales. During Stage 1 a constructional volcanic high develops in a period of high magmatic activity. In Stage 2, a down-dropped axial graben forms, splitting the ridge in half. The two halves of the split axial ridge are rafted away and preserved on the ridge flanks as the "bow-forms" first noted by *Kappel and Ryan* [1986]. Continued extension in Stage 3 can result in a fissure–dominated axial valley. In Stage 4, a new axial ridge begins to form and the cycle repeats. Based on morphology it appears that the major segments of the JdF are in different stages within this cycle with Endeavour Segment in Stage 2, Cleft Segment between Stage 3 and 4, while the Vance and Northern Symmetric Segments are in Stages 4 and 1, respectively. The goals of our ridge crest studies were to address the following questions.

• *Does the presence or absence of crustal magma bodies along the JdF Ridge support inferences based on axial morphology that these segments are in different stages of a volcanic/tectonic cycle? How do the depth and dimensions of magma bodies, where present, change along the ridge?*

• *Do mid-crustal magma bodies exist at Co-Axial segment and Axial Seamount or were the diking events on these segments in 1996 and 1998 fed by a deeper magma reservoir?*

• *Is the 'axial reflector' observed in the limited existing data a melt sill similar to that found on the EPR, or is it a hydrothermal cracking front and thus of a fundamentally different origin?*

• *How does crustal thickness compare within these segments of contrasting magmatic state?*

2. Characterize the structure of the shallowest crust (layer 2A) at the axis.

Seismic studies at the East Pacific Rise (EPR) document a 3-4 fold increase in the thickness of layer 2A from 150-200 m at the ridge axis to 400-600 m 1-3 km off-axis. The implication of this observation depends on the physical origin of this layer. Many investigators have argued that for young oceanic crust the base of layer 2A coincides with the extrusive/dike transition. If this lithologic interpretation is correct, images of this boundary can be used to draw inferences on accretionary processes in different tectonic settings. For example, the 3-4 fold increase in layer 2A thickness indicates a process of off-axis lava deposition resulting from overflow of lava outside of the axial trough and/or off-axis eruptions. The Kappel and Ryan (1986) model of magmatic –tectonic cycles for the JdF Ridge predicts that the extrusive layer (layer 2A) should be thicker beneath abyssal highs than the intervening valleys.

Alternatively, the layer 2A/2B transition may correspond with a porosity boundary within the extrusive section and the systematic thickening observed at the EPR could reflect downward migration of a cracking front as young crust evolves. Existing inversions of deep tow magnetic data along the JdF predict differences from segment to segment in the accumulation of the extrusive layer. Comparisons of layer 2A thickness derived from our studies with estimates of extrusive layer thickness from co-located magnetic studies would provide strong support for the lithologic interpretation of layer 2A. Our second objective was to determine the velocity and thickness of the upper crust to address the following questions:

• *Is there a characteristic pattern of off-axis thickening of seismic layer 2A at the intermediate spreading JdF Ridge similar to that observed at the fast spreading EPR?*

• *Is there a correspondence between seismic layer 2A thickness and predictions of extrusive layer thickness from magnetic inversions on the JdF Ridge?*

• *Does layer 2A thicken beneath abyssal highs corresponding to the split-volcanoes of the Kappel & Ryan model?*

<u>3. Characterize the evolution of the upper crust (layer 2A/2B) within 5 ma.</u>

The flanks of the JdF Ridge have been the site of numerous heat flow and hydrogeological studies and much of what we know about low-temperature hydrothermal circulation within oceanic lithosphere comes from studies in this region. Most recent work has concentrated within the FlankFlux corridor extending east from the Endeavour ridge. Along this corridor, oceanic crust becomes fully buried by sediment at ages of only 0.6 Ma. Heat flow and water chemistry data indicate that the buried to exposed basement transition corresponds with a transition from a hydrothermal regime within oceanic crust dominated by open exchange with the water column to a regime effectively closed to seawater exchange due to the sealing sedimentary blanket. Coincident with this transition, *Rohr* [1994] reports an abrupt increase in the seismic velocity of layer 2A.

The increase in layer 2A velocity is the primary known change in the seismic structure of oceanic crust with age and is commonly attributed to precipitation of low-temperature alteration minerals within the extrusive rocks during ridge flank hydrothermal circulation. Global compilations reveal that the change in layer 2A velocity typically occurs within 5 ma of crustal formation. This change occurs at even younger crustal ages at the Endeavour segment. The study of Rohr (1994) also reveals a direct relationship between layer 2A velocities and a change in the ridge flank hydrothermal regime, indicating that layer 2A velocities may provide a useful remote sensing tool for studies of ridge flank circulation.

The third main objective of our study was to study the influence of several of the primary environmental factors believed to influence ridge flank circulation and crustal alteration; crustal age, sedimentation history and local basement morphology. Our goal was to collect data within three spreading corridors crossing the JdF where differences in sediment cover and spreading history are observed in order to address the following questions:

• *Are there systematic changes in the age and rate at which layer 2A velocity increases as a function of sedimentation and spreading history?*

• *Does upper crustal velocity reach the same maximum level independent of local hydrothermal conditions or are there variations as a function of environmental parameters?*

• *How representative is crustal alteration measured along one transect to that observed in crust 5-10 km away? or in crust within an adjacent ridge segment?*

• *Is there evidence for variations in crustal velocity associated with basement topography?*

Tectonic Setting

The JdF Ridge is spreading at intermediate rates of 60 mm/yr and displays the wide range of axial morphologies typical of intermediate spreading centers. Our MCS program targeted three of the JdF Ridge segments; Endeavour, Axial and Cleft. All three of these segments have been the focus of observatory studies in the past decade. Endeavour is a rifted segment, which shoals in mid-section to a local high 18 km long within which the active vents of the Endeavour Observatory and R2K Endeavour ISS program are focussed. At the southern end of this segment, the ridge axis steps east 4.5 km at an overlapping offset with the Northern Symmetrical segment. Axial topography is subdued and the axial region is difficult to identify along the north end of this segment. A small overlapping offset at 46°38'N marks the southern end of Northern Symmetrical and the beginning of Coaxial, a broad (9 km) wide plateau characterized by hummocky volcanic terrain and elevated shoulders. The Axial segment is dominated by Axial Volcano, the most recent of the Cobb-Eickelberg seamount chain. Water depths shoal to less than 1500 m at the volcano summit where an elongate caldera, 7 km long by 3 km wide is found. Three meters of subsidence were observed within the caldera during the 1998 eruption at Axial, detected with instruments deployed as part of the NOAA Vents Observatory. Extending south of Axial, a wide (3.5 km) shallowly rifted valley defines the axial zone of the Vance segment. The Cleft segment is the southernmost segment of the JdF and is characterized by symmetrical ridge flank structure and a narrow linear depression (cleft) < 1 km wide, which marks the neovolcanic zone.

Survey Design

Our MCS experiment included three main elements:

1. detailed surveys of the ridge axis at Endeavour, Axial Volcano, and the Cleft segments (due to minimal equipment and weather delays, a detailed survey of the Vance segment was also carried out).
2. reconnaissance profiling along the length of the ridge axis from Endeavour to the Blanco transform including several cross-axis lines at the Coaxial, and Northern Symmetrical ridge segments.
3. flowline transects crossing the Endeavour, Northern Symmetrical and Cleft segments extending out to crust of 5 my age on each ridge flank.

Detailed surveys at Endeavour, Axial Seamount and Cleft-Vance were carried out to characterize magma bodies, the architecture of the upper crust (layer 2A) and Moho in these contrasting areas (Fig. 1). The Endeavour (Fig. 1a) and Cleft-Vance (Fig. 1f) surveys included 30-40 km-long ridge-perpendicular lines spaced 3-10 km apart as well as ridge-parallel lines at 0.25 and 0.5 Ma on both ridge flanks. Two of the 11 cross-axis lines within the Endeavour survey extended to 40 km on the east flank (~1.3 Ma) in order to further investigate the change in upper crustal velocity associated with crustal alteration reported by Rohr (1994). Isochron lines were placed along abyssal hills where possible to minimize side-swipe from shallow nearby topography. Six axis crossing lines were collected along Northern Symmetrical segment, three as part of the flank transect centered at ~46°50'N and three between 47°10-47°00'N near where the ridge axis becomes well-defined (Fig. 1c). The Coaxial – Axial survey included five axis crossing lines as well as axial lines along the overlapping northern limb of Axial and the Coaxial axis (Fig. 1e). The Coaxial line transected the 'Flow' and 'Source' sites of the 1993 eruption, as well as Helium Basin. The Axial survey included a grid of orthogonal tracks oriented parallel and perpendicular to the trend of the caldera. Four parallel and six perpendicular lines spaced ~2 km apart and 25-km long were shot. Three axis-perpendicular lines were run across the southern limb of Axial and the overlap region with the Vance segment. The Cleft-Vance survey included a total of 12 cross-axis lines at Cleft and 7 cross-axis lines within Vance (Fig. 1f). Isochron lines were collected only within Cleft. Two ridge axis lines were run within the wide valley floor of Vance spaced 2-3 km apart. Where possible throughout the survey, locations of the AMC reflection observed in the along-axis lines were used to position the axis crossings.

The crustal alteration study involved acquisition of data within three flow line corridors across Endeavour (Fig. 1b), Northern Symmetrical (Fig. 1d) and Cleft segments (Fig. 1g) and extending to crust 4-5 Ma in age. Coverage to 4-5 Ma was obtained in order to encompass the age range at which change in layer 2A velocity is observed in existing JdF data and in global compilations. Each transect was optimally located for differences in sedimentation history. Initial and return lines within flank corridors were collected to provide data suitable to study along-isochron variability in upper crustal structure.Ten-km-long isochron profiles were also shot within each corridor to provide data suitable for detailed velocity analysis using waveform inversion. The east flank Endeavour transect was located to cross the ODP holes of the FlankFlux corridor. The other transects were situated based on variations in sediment cover and to avoid seamounts.

Shipboard operations

MCS

For this experiment, MSC data were acquired using a 6-km-long, 480 channel Syntron digital streamer with a mix of 13 depth controlling and 11 compass-enhanced DigiCourse birds, plus GPS on the tail buoy to monitor both streamer depth and feathering. The 10-gun, 3005 cu. in. airgun array was used with shot-by-distance at a 37.5 m spacing. The 37.5 m spacing is equivalent to a 15 second shot interval for speed-over-the-ground-of 4.86 knots. Early in the survey, speeds were reduced to 4.7 knots in order to keep the guns floating at a nominal depth of 7.5 meters. The streamer was also floated at a depth of 7.5 meters until the weather deteriorated on JD203 when it was reset to 10 meters to improve towing stability for the remainder of the leg. The streamer and gun configurations are included in Table 3 and Figure 2. Ten-second data records were recorded to 3490e tape in SEGD format, using the Syntron Syntrak 480 seismic data acquisition system. A 2 msec sampling interval was used for the ridge flank lines and a 4 msec interval for the ridge axis work.

Concept System's SPECTRA was used to manage survey acquisition, and generate UKOAA navigation files. SPECTRA controls gun firing, survey line management and logs all streamer compass, depth, and tail buoy data as well as ship navigation. SPECTRA also provides QC monitors for communication with navigational inputs and Helmsman displays to monitor both actual and planned survey track, as well as streamer feathering. Airgun array performance is monitored by the Syntron GCS90 airgun controller software. Hydrosweep DS2 data were acquired throughout the cruise, operating in 120° beam survey mode. Underway gravity data were acquired with a Bell BGM-3 meter and magnetics data with a Geometrics 886 proton precession Magnetometer.

A summary of general survey operations follows:

The initial streamer deployment began after a transit of only 14 hours to our first waypoint. The total deployment time was 16 hours and involved replacing three active sections as well as the two front stretch sections and the repaired 300 m tow cable. Reballasting of the streamer was carried out during deployment, initially removing 2 lbs of lead weights from each section up to module 18, removing 4 lbs from each section for the remainder of the streamer. During this deployment, data transmission from the tail buoy became intermittent and then ceased completely.

After shooting our first two lines on JD191, we stopped firing due to problems with data transmission of gun firing times. The problem was eventually located with the circuit board for the port side guns. The guns were initially deployed with 7.5 m tow lines and consistently towed too shallow (3.8 to 6.8 m) at our initial survey speeds of 4.86 knots. After an additional 4 meters of tow line were added to each gun, gun depths remained somewhat shallow (6.5-7.5 m) and we reduced our target survey speed to 4.7 knots to reduce kiting.

While underway, streamer canisters failed on two separate occasions requiring recovery of part or all of the streamer. The first can failure occurred on JD194 when telemetry from section 16 failed as we were about to begin line 13. We recovered the streamer to the failed can and swapped it out. Since the 40 sections are numbered from the tail forward, we were at this point close enough that we recovered the rest of the streamer to fix the tail buoy. During reployment, an additional 2 lbs of lead weight were removed from the rear sections up to module 18 and birds 10 and 24 were swapped to improve the distribution of compass birds within the mid-section of the streamer. After the tailbuoy module was replaced, tailbuoy communication was excellent for the rest of the cruise. We typically would lose communication only during parts of the turns.

The second streamer canister failure occurred on JD199 and involved can 3, 450 m from the front of the streamer. This can was swapped out and we resumed shooting after a total delay of only 3.25 hours. The sonobuoy launcher was set up on JD200 during our ridge flank transect and a few sonobuoys were deployed during the remainder of the cruise in areas of flat topography.

We had radio contact with Bob Embley on the *R/V Thomas G Thompson* on JD204 as we reached Axial Volcano. They had been working in the area to deploy a moored buoy for realtime data transfer from bottom sensors at Axial. Our planned survey tracks for

Axial were later modified in order to keep a minimum distance of 1.5 km from the buoy (location 45°56.235 –130°00.633' – 820 m watch diameter).

We had a major failure of grampus early on JD208. Richard was unable to reboot as the root partition was corrupted. After numerous attempts to restore grampus, on JD212 Richard successfully rebooted off CD, was able to reformat the root partition and restore from backup. During this time, we were able to work around the grampus failure for our tape copying and stacking needs. Hence, the impact of the grampus failure was confined to the daily data reduction and our onboard processing. Once grampus was restored Richard was able to plow through the reduction backlog very quickly.

Overall, the Ewing data acquisition effort ran very smoothly throughout the cruise with total delays due to equipment problems of only 23.75 hours. We acquired a total of 27 days of MCS data. Track maps are shown in Figs. 1 and an inventory of all lines is included in Table 4.

Onboard processing

SIOSEIS was used onboard for copying all 3490e tapes to DLT and to generate near real-time brute stacks (Fig. 3a, 3f-h). Brute stacks were created using the ESP 5 crustal velocity model of Vera et al., (1990) hung from the seafloor and a band pass filter of 5-40 hz. Only the inner 3 km were stacked, with a mute tied to the seafloor designed to preserve some of the layer 2A event in the mid-offset traces. During the cruise Paul Henkart developed a dynamic mute parameter (dstretch), which allows trace muting based on a user-defined maximum % stretch of sample interval. Brute stacks were used to monitor the quality of system output and to guide survey strategy. The ability to view data in near real-time was crucial to the success of our program enabling survey changes to be made based on what had just been imaged.

During the cruise Paul Henkart wrote a new process for SIOSEIS (SEGDDIN) which reads the SEISNET format files, strips off the header and trailer that SEISNET adds to each trace, and writes to SEGY. He used his process to generate real-time stacks of the data**.** For future operations, DLT tape backups could be carried out using SIOSEIS to read the SEISNET files, with output to SEGY. Paul plans to implement output to SEGD on the upcoming Gulf of california cruise. Scripts for using SIOSEIS for brute stack and copying from SEISNET disk files are included in Appendix A and B. SIOSEIS was also used on board for processing select line segments of particular interest during the cruise (Fig. 3b-3e)

Spectra

Spectra was upgraded prior to the cruise in Astoria and was much more stable than expected based on pre-cruise reports. Spectra crashed and required rebooting only once early on in the cruise. Although waypoint entry was done by hand for most of the cruise, John Diebold discovered how to upload waypoints from a file, and this could be done routinely.

Sprint

Sprint was installed in Astoria and tested during the cruise by John Diebold. Sprint's purpose is to allow post-acquisition processing of Spectra's UKOOA output. Two UKOOA files are created in real time; P2/94 files with network information and raw observations, and P1/90 files, which contain source and receiver locations for every shot, and are used by processing software such as ProMax and Focus in lieu of geometry for CDP binning. Spectra revisits the P2/94 files, allows the observations to be filtered, smoothed and re-weighted if necessary, and creates new and improved P1/90 files for data processing. Nearly all of the Concept Systems engineer's time in Astoria was spent doing the installations, and only a few hours were left for a whirlwind Sprint training session, but during the cruise we learned enough to allow reprocessing of 80% of the shotpoint navigation. As the result of a leftover configuration, Spectra's realtime P1/90 files gave receiver locations for a 240 channel streamer. The Sprint output files are properly reconfigured for the actual 480 channels.

SEISNET

Seisnet was installed in Kodiak in June and was tested during our cruise. Seisnet is a hardware/software "splitter' package that captures each shot as it is acquired on the Syntron system and write a copy to the Seisnet PC. Each shot gather can be displayed on the Seisnet PC after it is written to 3490e, providing realtime QC of the acquired data. As Seisnet is currently configured, if shot files are not written to tape they are not written to the Seisnet PC.

Seisnet stores files in it's own format on the Seisnet PC. The Seisnet format encapsulates the SEGD General Header with it's own header, in PC byte order, and also adds a trailer to each SEGD trace. Files are transferred over the net to grampus via a cron job. By the end of the cruise, the file transfer to grampus involved removing the oldest files on Grampus as the new files are added. Files can be converted from Seisnet format to SEGD via Landmark software and to SEGY using the SIOSEIS SEGDDIN process. Promax users should be able to generate realtime stacks using the Landmark generated SEGD files although this was not tested. There may be a problem using more than 100 shots for entry into Promax, which would be a serious drawback, if this can not be overcome.

Seisnet is a very welcome addition to the QC and real-time capability of the Ewing acquisition system. It appears to be a robust system which provides the functionality we need. Thank you John! By the end of the cruise, thanks to Paul Henkart's new Sioseis process, we accessed the Seisnet files directly for our realtime brute stack. Producing a DLT copy of the SEGY/D files direct from the Seisnet files has yet to be tested.

Hydrosweep Bathymetry

Hydrosweep DS2 bathymetry were collected throughout the survey to position reflection lines and provide new bathymetric coverage during ridge flank transects (Fig. 4). The bathymetric compilation currently available for the JdF was derived from early generation Seabeam data navigated by Loran C and systematic positioning errors were present in the original data. The publicly available versions of these data on the RIDGE multibeam synthesis site do incorporate the corrected navigation but the GPS navigated bathymetry collected during our program may be useful for a future bathymetric compilation to replace the existing one currently used.

Hydrosweep bathymetry were ping edited onboard to eliminate the variety of artifacts found with the outer beams. In some areas, pronounced railroad tracks are found with the beams beyond the track looking acceptable. In other places there is an abrupt step in the outer beams and elsewhere, the beams curl-up or curl-down. We could not discern any systematic relationship between the nature of the artifact and for example, sea state or nature of the terrain. Although Hydrosweep DS is an improvement over the old Hydrosweep, it isn't up to the quality of a modern Simrad. During ping editing, the outer 7-9 beams on each side were flagged for removal (beams 1-6,9 and 131, 133-138). For our typical survey depths of 2200-3200 m useable data extends a maximum of 3-4 km to a side. Aside from the outer beams, the rest of the data needed little editing except for, on occasion, an entire beam would appear rotated from horizontal and would be edited. Processing included recalculating bathymetry values using a sound velocity profile derived from XBT's taken during the survey. A total of 3 XBT profiles were acquired. During the beginning of the cruise, a roll bias was apparent in the data acquired over the heavily sedimented ridge flank terrain, with the port side outer beams too shallow. A roll bias correction of –0.1 was calculated from repeat tracks on JD 196/197 covering the same seafloor in opposite directions. This roll bias correction was input directly to Hydrosweep on day 201 and was applied to all data files prior to this using *mbprocess*. Sonar amplitude data were gridded for each of the areas and sample plots are included in Fig. 5**.** From these data, volcanic flow fronts can be identified as well as some seafloor scarps and relative sediment cover. However, the backscatter appears very limited in dynamic range and these data do not appear very useful except for broadly delineating sedimented and unsedimented terrain (e.g. Fig. 5a and 5c).

Marine Mammal Procedures

The new marine mammals procedures require guns to be ramped down and back up in a defined sequence whenever shooting is stopped. With Spectra, if lines are shot by distance, each line must be defined, with lines ending at the beginning of each turn and shooting off. In order to avoid the gun ramp down/ramp up with each turn, we switched to gun firing via the internal trigger, rather than firing through Spectra at the end of each line. Lines can be shot on time continuously through turns without interruption. Although the bridge logged over 24 sightings, only 6 of these were close enough (within 2 km) to require interruption in operations. Table 2 provides a summary of all interruptions due to mammal sightings.

Preliminary Results

Endeavour

A bright magma lens event was imaged beneath the ridge axis in the vicinity of the Endeavour ISS vents (line 14, Fig. 3a). This event was discontinuous and varied in depth from 0.8 to 1.2 sec twtt. The AMC reflection was shallowest beneath the inflated central part of Endeavour with a weak event continuing and deepening to the south. The AMC event was difficult to identify in most axis crossing lines (mostly due to a too low stacking velocity during real-time stack) and was apparent only after correlation with the along-axis data. Layer 2A appeared to be thick, ~0.4-0.5 msec, considerably thicker than is observed on the EPR. From the limited data examined thus far, 2A does not appear to thicken off axis. Moho was imaged along both ridge flank lines at depths which varied from 2.0 to 2.2 seconds. It also varied considerably in character from a well-defined, continuous event to a faint and intermittent reflection. Unlike to the south, both ridge flanks were largely buried by sediment in this region and the northern end of the JdF has not been an effective barrier to the post-glacial turbidite sedimentation.

Northern Symmetrical Ridge

Along the axial line continuing south of Endeavour (line 24), we imaged a bright isolated AMC event at a depth of 1-1.1 sec beneath the Surveyor/Split seamount, a small seamount located at the north end of the Cobb propagator (Fig. 3b). South of this seamount, the ridge axis was difficult to define with little elevation of the axial region above surrounding ridge flank terrain until 47°20'N. As the axis shoaled, a weak, deep (1.3 sec) AMC event was detected, shoaling to 0.9 sec and brightening as we continued south (Fig. 3c and d). The AMC was present continuously for much of the remainder of this segment.

A large contrast in sediment cover was present about the Northern Symmetrical ridge with the west flank almost completely sediment free, and the east flank fully buried by only 25 km from the axis. Moho was present along most of the east flank transect whereas it was only occasionally present on the west flank, possibly reflecting the improved imaging conditions in sediment covered terrain. An unusually bright and impulsive Moho was present at approximately the same distance off-axis on both ridge flanks (Fig. 3e). This Moho event was located on the young crust side of a v-shaped bathymetric low associated with the propagating trace of the Cobb offset. This unusual Moho event appears to be associated with the initiation of crustal accretion at a new ridge segment.

Co-axial and Axial Segments

The Coaxial and Axial segments were surveyed over a 12 day period, with a lengthy excursion southward to the Vance/Cleft segments due to increased winds and sea-state. In total, some 20 MCS profiles were collected, including a dense survey over Axial seamount. Not to disappoint, magma bodies were imaged beneath both the Coaxial and Axial regions, although absent in regions where previous work suggested sub-surface melt accumulations; in contrast, large magma bodies (e.g., SE flank Axial) were also imaged in regions thought to be devoid of significant amounts of melt!

An AMC reflector was seen along extended parts of Coaxial, in particular a continuously "bright" event was observed in between the conjugate set of ridges along 46°25'N to 46°15'N. This region was the site of a recent extrusive event, although the source for this eruption was thought to lie to the south, around 46°09'N. Interestingly, the southern section of Coaxial appeared to be devoid of a melt-lens, at least in the real-time stacks. Further south, toward Helium basin, a small stranded melt lens was imaged, approximately 46°05'N. Due to server problems with *grampus*, we did not have time to do further velocity analysis and imaging of the Coaxial segment, so images of Layer 2A were not generated. Some Moho reflectors were present on cross-axis profiles, although not as spectacular as other segments along the Juan de Fuca Ridge.

MCS profiling across Axial seamount (Fig. 3f) revealed a very complex set of reflections, with significant depth (actually travel time) variations, so the true dimensions of the magma chamber will take some time to construct. What we do know to date is that the minimum depth, based in traveltime modeling of a supergather, is about 1400 m (or 0.6 s), with a depth (or traveltime) variation that might be twice that amount. Melt seems to underlie most of the cauldera, although depth variations are significant. Outside of the caldera region, most of the melt is observed extending outward, along the SE flank of Axial seamount. This body is seen to a distance of at least 12 km on the unmigrated sections, and appears to be quite extensive. No significant melt bodies were observed along either of the ridge-related rift zones. Reflections from the base of Layer 2A were not imaged in abundance across Axial, partially because the shallow depth, which is not conducive to imaging this wide-angle reflection, but also due to a more complex structure (seen on at least one supergather), which maybe less gradient-like, and more step-like in structure. Some pre-critical events were imaged in the shallow-most crust, near the SE vent field. Moho reflections were not seen beneath Axial, although they may be hidden in the seafloor multiple.

Cleft and Vance Segments

The Vance and Cleft segments were extensively surveyed in a series of along-isochron and cross-axis profiles. The along-isochron lines were shot first. The main events observed in the brute stacks of these lines served as a guide to choose the location of the cross-axis lines.

Vance

Two lines were shot along the axial trough of Vance. Line 38 runs along a neovolcanic ridge that extends along the northern half of Vance in the eastern side of the axial trough; while Line 42 and part of Line 39 run along a neovolcanic ridge that extends along the southern half of the segment in the western side of the axial trough. Layer 2A varies in thickness from ~0.5 s TWTT in the northern part of the segment to as little as 0.2 s near the center of the segment. The AMC is seen along most of the segment. In the southern and center sections of the segment the AMC is a bright and flat, at a depth of ~1.0-1.1 s TWTT bsf. Along the northern half of Vance the AMC is more discontinuous, and may be slightly deeper (1.2 s TWTT bsf).

Six lines were shot across the axis of Vance (Lines 67, 68, 69, 70, 71, and 84, from north to south), reaching ~17 km off-axis (~0.55 Myr-old crust). We see the AMC in all of these lines (except Lines 70 and 84), at depths of ~1.10-1.15 s TWTT bsf, consistent with the observations in the along-axis lines.

Only the southern part of Vance was surveyed by off-axis, along-isochron lines. Line 40 runs along the southern half of the segment ~7.5 km (~0.25 Myr) to the west of the axis. Line 41 runs along the southern third of the segment ~9 km (~0.3 Myr) to the east of the axis. Some weak Moho events were seen in these lines, at a depth of 2.2-2.3 s TWTT bsf. The cross-axis profiles 69, 70, 71, and 84 also show Moho events at both flanks of the ridge axis, at depths of 2.1-2.3 s bsf.

<u>Transition from Vance to Cleft</u>

Lines 72 and 85 crossed the small left-stepping discontinuity that separates the Vance and Cleft segments. In Line 72 we see a weak westward-dipping mid-crustal event that could be AMC, between lines 38 and 39. Line 86 catches the AMC of the Cleft magmatic system at the crossing with Line 38, at 1.0 s TWTT bsf. There is a second, westward-dipping AMC-like event that reaches 1.9 s TWTT bsf beneath Vance. This could be the southern limit of the Vance magmatic system. Most interestingly, there is clear Moho beneath the dipping AMC, at depths of 2.2-2.3 s TWTT bsf. This Moho event was crossed by Line 39, where it was clearly observed at the same depths.

<u>Cleft</u>

Line 38 was shot along the axis of the Cleft segment. Layer 2A is seen along most of the segment, with thicknesses of 0.2-0.3 s TWTT. We see AMC along the northern two thirds of the segment. The AMC is bright and flat along ~10 km-long sections, and more patchy and discontinuous in between, lying at depths of 0.90-0.95 s TWTT bsf. On Line 38 we stopped seeing the AMC along the southernmost Cleft segment (near the Cleft Observatory Site) but a later line (Line 80) displaced ~500 m to the west of Line 38 found more AMC evidence. The AMC lays at 0.9 s TWTT bsf, and it is observable up to near the southern end of the Cleft segment on Line 80 (Fig. 3g).

Eleven lines were shot across the axis of Cleft (Lines 73, 86, 74, 75, 87, 76, 77, 81, 78, 82, and 79, from north to south), reaching ~17 km off-axis (~0.55 Myr-old crust) (Lines 86 and 87 are two long flank transects up to 5 Myr-old crust.) We see the AMC in all of this lines (except Lines 76 and 79), at depths of ~0.90 s TWTT bsf, consistent with the observations in the along-axis line (e.g. Fig. 3h).

The flanks of Cleft were surveyed by four isochron lines located at 9 and 4.5 km to the west of the ridge axis (Lines 41 and 39, respectively), and 11 and 4 km to the east of the ridge axis (Lines 83 and 40, respectively). All lines show Moho events with depths ranging from 2.2 s up to 2.45 s TWTT bsf. Lines 39 and 40 show also a lower-crustal (?) event at a depth of ~1.9 s, with Moho beneath it. This event is also present in the cross-axis line 75, at 1.95 s TWTT bsf. All of the cross-axis lines show Moho events at the flanks of the ridge axis at depths of 2.1-2.3 s TWTT bsf.

Recommendations for future operations

Our cruise was a terrific success. We acquired beautiful data and lots of it. We achieved all of our science goals and more. The science support personnel were excellent and the data acquisition effort ran very smoothly and efficiently with a minimum of delays. The high quality of the support personnel is essential to the *Ewing* operation and it is remarkable this small group of people can keep this operation running so well.

Recommendations for improving operations follow:

Hardware

Heezen needs to be replaced. It is a machine with barely adequate capacity for tape copying which is the one function it is used for. At the beginning of the cruise we switched to grampus for this purpose because Heezen was too slow to keep up with new tapes every 20 minutes acquired for 2 msec data (grampus was 3 times faster). When grampus crashed we were able to hobble along with Heezen while collecting 4 msec data. For the current low price of computer hardware there is no need to operate such a low end machine. However, it is important that Heezen be replaced, not eliminated. As our experience with the grampus failure demonstrated, we need to acquire and maintain redundant capability on board.

A dedicated computer for processing including a terabyte RAID array is needed on board. Although Grampus is adequate for processing a select subset of the data collected, it does not have the CPU or disk required for systematic effort. With the manpower typically available for a cruise, considerable progress could be made onboard with post-processing if the hardware were available.

Both a color laser printer and a faster B/W Laserjet printer are needed. Graham suggests an HP DN4550, it's under 5 k and could be used as both a color and black and white printer.

Spectra/Sprint

The addition of Sprint software to produce post-processed UKOAA files will hopefully solve the problem of generating useable UKOAA files. However, at this point the Sprint package is only available for use onboard the Ewing. Post-processing is going to need to be incorporated into the tasks during a cruise. And it's not yet clear how this will be done, and who will do it. The system administrator already has a very full job onboard. A license for Sprint use at Lamont should be seriously considered. With a license at Lamont, the system administrators could potential process UKOAA files after a cruise while on shore.

We had some discussions with Richard about changing the Spectra set up to correct the streamer configuration from 240 to 480 channels. This turned out to be a complicated undertaking. Spectra operations do not seem to be well understood and the system administrators should still be sent for training (probably for the advanced course and including training for Sprint?).

Seisnet

Seisnet is a very welcome addition to the QC and real-time capability of the Ewing acquisition system. It appears to be a robust system which looks very promising for providing the functionality we need onboard to generate realtime brute stacks and tape copies. Exploiting Seisnet for these purposes should be incorporated as a standard part of the Ewing acquisition effort and part of the watch routine.

Bridge Navigation

The InStar navigation system used by the bridge is cumbersome, waypoints need to be entered by hand, and it is difficult for the mates to change the order of waypoints. The bridge needs an improved navigation package with easy upload of waypoint files and with electronic charts, which can be updated electronically. They need a system that can be integrated with Spectra. They also need their navigation system to be integrated with the helm and for the helm to be able to accept input from Spectra.

Personnel

The job of the Systems Administrator is very intensive and appears to be growing. The need to process UKOAA files with Sprint in order to generate useful files could add another job to the System Administrator's daily tasks. Two system administrators may need to be considered, especially for extensive MCS operations. For 3-D operations, it would probably be wise to hire a Concept Systems employee for that leg, along with the lease of Reflex, a flexible binning package that is a must for 3-D surveys.

Hydrosweep

The outer beams (outer 7 to 9 beams, both sides) display a variety of artifacts with no systematic relationship to seastate, nature of terrain imaged, etc. There are also beam pattern effects across the whole swath. When we compared the new Hydrosweep DS data with the old Seabeam Classic data which served as our basemap for the survey, both gridded at the same spacing, the Hydrosweep looked considerably nosier on <u>some</u> swaths. The modified Hydrosweep is an improvement but it is not yet a competitive system. Replacing Hydrosweep needs to be seriously considered in the upcoming Ewing refit.

The screen display for the backscatter data is very poor and the real-time bathymetry contour display is not very useful. The waterfall display is better and was useful for driving the ridge axis but only because we had good base maps to begin with.

If the Hydrosweep computer crashes, previous swaths are gone and the display renews with only the post-crash data. We need the ability to reload the previously acquired data for display purposes.

Main lab/Quality of life onboard

A larger map cubby would be very useful and should be included in any remodelling of the main lab.

More flat surfaces to lay out maps and section and work on them in lab is very much needed.

The new ergonomic chairs are great. The rest of the chairs in the lab should also be replaced.

Both scientists and crew would greatly appreciate a coke machine. …

Personnel

Science Party

Carbotte, Suzanne	Chief Scientist	Lamont-Doherty Earth Observatory
Detrick, Robert	Co-Chief Scientist	Woods Hole Oceanographic Institution
Kent, Graham	Co-Chief Scientist	Scripps Institution of Oceanography
Canales, Juan Pablo	Scientist, Co-PI	Woods Hole Oceanographic Institution
Cochran, Ian	Scientist	Lamont-Doherty Earth Observatory
Diebold, John	Scientist, Co-PI	Lamont-Doherty Earth Observatory
Dingler, Jeff	Scientist	Scripps Institution of Oceanography
Epstein, David	Scientist	Lamont-Doherty Earth Observatory
Harding Alistair	Scientist, Co-PI	Scripps Institution of Oceanography
Henkart, Paul	Scientist	Scripps Institution of Oceanography
Jacobs, Allison	Scientist	Scripps Institution of Oceanography
Nedimovic, Mladen	Scientist	Lamont-Doherty Earth Observatory
Van Arken, Emily	Scientist	Woods Hole Oceanographic Institution

Science Support

Admunsen, Leah	Air Gun Technician
Byrnes, John	Head Air Gun Technician
Koczynski, Ted	Electronics Technician
Oliver-Goodwin, Richard	Systems Administrator
Stennet, Joe	Science Officer
Walsh, Justin	Air Gun Technician

R/V Maurice Ewing Crew

Mark Landow	Master
Jay Thomas	Chief Mate
Scott McGeough	2nd Mate
Richard Thomas	3rd Mate
David Philbrick	Bosun
Jack Baird	A/B
Felepe Hontiveros	A/B
Scott Wilson	A/B
William Brannon	O/S
James Syferd	O/S
Albert Karlyn	Chief Engineer
Miguel Flores	First Engineer
Nicholas Neil	3rd Engineer
Thomas Hickey	3rd Engineer
Ian McRae	Oiler
Rodolfo Florendo	Oiler
Alfred Potts	Steward
John Smith	Cook
Frederick McNeal	Utility

Cruise Narrative

Monday July 8 (JD 189)

We left Astoria Oregon 10:00 local (17:00z) with calm seas, slightly overcast skies, wind 10-15 knots. The magnetometer was deployed and Hydrosweep was turned on early in our transit. Joe couldn't find any evidence for the Hydrosweep heading problem reported from the end of the previous leg. A fire drill and abandon ship drill were held at 15:30 local and we convened a science meeting at 1300 local. Initial ETA to streamer deployment was 0200 local, July 9 but with transit speeds of 11.5 knots this was revised by dinner time to 23:45 local.

We slowed to begin deploying streamer at 23:45l (06:45z, JD190) as estimated. Total transit time 13 hrs 45 min. Weather excellent.

Tuesday July 9 (JD190). Wind speed 10-15 knots, air temp 15°C.

Streamer deployment went smoothly and took a total of 16 hours. Two sections were swapped out during deployment as well as the two front stretch sections and the tow leader. Each section is 75 m long, digitizing and telemetry cans are every 150m. 24 birds were deployed in total at 150 m intervals for the front and end 1 km of section, and at 300 m intervals within the middle 4 km. Birds were programmed to fly at 7.5 m depth. Compasses are within every second bird in front and tail sections (bird numbers 2, 4, 6, 8, 12, 16, 18, 20, 22,23,24). During streamer deployment, data transmission from the tail buoy became intermittent after 11:56z, (3.6 km of streamer deployed) and eventually ceased completely.

Reballasting of the streamer was needed to accommodate the cooler NE Pacific conditions relative to the last cruise. At the tail end of the streamer, every 2 lbs weight out of 8 lbs on each section were removed. By mid-section, the streamer still appeared to be towing deep and for the rest of the deployment, 4 lbs were removed from every section (every other lead weight removed).

Shooting began at 17:34l (00:34z, JD191) 17.75 hrs after start of streamer deployment. Guns were ramped up in accordance with the marine mammals procedures beginning with 2 smallest outer guns. Paul Henkart set up a SIOSEIS tape copying and brute stack procedure.

Wednesday July 10 (JD 191). Winds 8-10 kts, air temperature 15°C, mixed sun and clouds.

We finished lines 1 and 2 and began line 3 when Joe reported that he needed to shut down firing in order to work on the gun synchronization. During acquisition thus far, we were not receiving the data packet of actual firing times for the individual guns. Joe eventually located the problem with the circuit board for the port side guns. Total delay was 7 hrs.

The gun display indicated guns were all towing much shallower than the target depth of 7.5 m, from 3.8 to 6.8 m. Guns had been deployed with 7.5 tow lines which, with the additional length associated with the tow chains and buoy float level, was expected to be adequate. To increase gun depths, the gunners began recovering guns one at a time and lengthening tow lines. After adjustment, the guns were now towing at depths of 6.8-7.5m with the exception of gun 7 which continued shallow. Transducers on guns 4, 9, and 14 were not working. Joe reported that it is difficult to keep the guns down at 7.5 m for speeds greater than 4.5 kts and we decided to use a target speed of 4.7 kts.

Richard reported some problems with the network connection to the Hydrosweep computer and was initially unable to copy HS data to Grampus.

Brute stacks of the first two lines reveal an intermittent Moho reflection at ~ 2 sec below seafloor. A potential 2A event is seen at ~0.4-0.5 sec within the basement lows. The sedimentary package is well imaged throughout the eastflank transect and shows bright long continuous reflections within the shallow part of the section.

Thursday July 11 (JD192)

Weather remains good. Seas calm, winds 10-15 knots, temp 14°-15°C, skies variable clouds and sun. We continue to sit beneath a large high pressure zone.

We are surveying at speeds of 4.7-4.8 knots on average so we are making up time relative to our predicted survey times. We crossed the ridge axis last night and saw a weak reflector beneath the axis that looks similar to the event imaged in Rohr's paper. It is a weak low frequency event and doesn't look like a compelling AMC. Other ridge crossings show no indication of an axial AMC event.

Teddy and Joe worked today to address the tail buoy problem. Teddy built a new GPS receive/transmission package to swap out with the one currently on the tail buoy. We discussed with the captain using the zodiac to do this, should the winds drop.

We had 1 minor gun ramp down period for porpoises.

Friday July 12, 2002 (JD193)

Winds 10-15 knots, temperatures 14-15°C. Depth for bird 17 was incorrectly programmed during streamer deployment and Joe reset it to 7.5 m. Magnetometer was behaving intermittently with periods of extremely noisy data. Joe and Teddy had the magnetometer brought in to examine it and found a faulty O ring. We continued on ridge axis crossing lines for the rest of the day. Inventory for day included lines 6 through 10. We had 2 minor gun ramp down periods for marine mammals, both for whale sightings.

Saturday July 13 (JD194)

Winds 20 knots. We had one marine mammal sighting and gun ramp down today. The final preplanned cross axis line (11) was shot and we began the axis parallel lines with line 12. Telemetry from streamer section 16 failed as we were about to begin line 13 and we needed to recover the streamer. Problem began at 14:14z. We brought the streamer in to section 16, changed out the digitizing canister and telemetry from the rest of the streamer was confirmed. We then recovered the rest of the streamer and replaced the tail buoy GPS unit. On redeployment we removed additional weights within the tail end of the streamer. We also moved one compass bird to even out the bird distribution along the streamer mid-section. Tail buoy transmissions were steady during entire streamer deployment.

Sunday July 14 (JD195)

Winds 20-28 knots. We finished deploying the streamer at 0200z, turned to head into the wind and returned to the start way point for Line 13. The guns were deployed while travelling into the wind. The total delay time was 13.5 hrs. As we were 6 hours ahead of schedule at the beginning of this delay, we were now 7 hours into our contingency time and we decided to modify tracks to eliminate planned lines 15 and 16. Transmission from the tail buoy was briefly lost during the turn onto line 13 but was recovered as we came out of the turn. We resumed shooting line 13 at 03:30z. Later in the day Joe did the first XBT of the cruise. The streamer was now reacting quite violently to turns – the head of streamer coming to the surface at the beginning of a turn and then diving down to 20 m, this wave then propagating through the streamer.

We began along-axis line 14 at 12:00z. The Hydrosweep beam profile display was the most useful bathymetry display for driving the axis and we needed to make only one course adjustment to stay roughly centered. In spite of how difficult it was to pick the axis from our maps away from the vent area, we were able to identify it with considerable confidence from the beam profiles.

On line 14, we finally imaged a convincing AMC event; a bright low frequency event at about 1.1-1.0 sec with an impressive diffraction tail right under where the vents are located. Another weaker event extends to the south and appears to overly the bright event where it begins. Looks like we may have imaged one (old depleted ?) lens and a new pulse of magma migrating up beneath it? Pablo located the bright AMC event on our bathymetry and we find that we did miss the brightest spots in our previous axial crossings. We decide to put in 3 new axial crossings on our way back after the ridge flank transect.

Monday July 15 (JD196)

We begin long flank transect, line 17 at 06:30z and continue until 1430z. A revised plan is made for the transect back through the axial region of Endeavour tomorrow, which includes 3 new cross-axis lines through the bright spots of the axial AMC reflection. These bright spots do not underlie the existing vents but are between them. Skies are overcast but seas are calm with winds at < 10 knots for much of the day. No marine mammal delays today.

Tuesday July 16, (JD197)

Continuing on the flank transect back to the ridge axis (line 18/20). Excellent Moho is observed for part of this transect at roughly the same location in both the east-to-west and west-to-east run. Tail buoy is continuing to function well. We have some issues regarding speed and agree again to 4.7 knots over the ground. We had slowed to 4.5 knots but will have trouble meeting our science objectives if we stick strictly to 4.5 knots. No marine mammal issues recently. Man overboard drill today. We finished the flank transect back to the ridge and begin the three short axial crossing lines (lines 21-23) located over the brightest magma lens events observed on line14.

Wednesday July 17, (JD198)

We finished the Endeavour survey early last night (05:11z) and began the transit south along the ridge toward Axial (line 24). We imaged a bright isolated magma lens event beneath the Surveyor seamount at the north end of the Cobb Propagator. The AMC reappears further south along the Northern Symmetrical segment, beginning at 47°21.73'N as a weak event which becomes quite strong when we reach the portion of Northern Symmetrical where the axis becomes well defined. It's surprising that an event is present here at all given how poorly defined the axis is. The axis is much more poorly defined and elevated than at Endeavour. One marine mammal incident during the day.

Thursday July 18, (JD199)

JD199 began with a short streamer party. A cable error (can 3) was observed at 03:39z, 450 m of the streamer were recovered, and a frayed tow leader was fixed. Shooting resumed at 06:55z. We continued our transit south along Northern Symmetrical and observed a magma lens event for much of the transect. We decided to move the location of one of the flank transects in order to obtain additional crossings of the ridge axis through the magma lens.

Friday July 19, (JD200)

We began the Northern Symmetrical east flank transect (line 31) at 23:30z (JD199) (end line 31 at 17;22z). The flank transect was recorded at 2 msec. We had two read errors in a row with the 3490 drives and a couple of missed shots. The problem cleared after we cleaned the drives. JohnD and Teddy set up the sonobuoy launcher and launched 3 sonobuoys during the line. Sediment cover is extensive on this line with full burial of the basement by 129° 02.295’W. A bright distinctive Moho event is observed in the same location on both east flank profiles.

Saturday July 20, (JD201)

4-6 foot seas, sunny skies, minor low pressure system sitting above us. We run lines 32/34 back to the ridge crest. A beautiful wide AMC reflection is observed on the ridge crossing. We continue onto the western ridge flank where we observe a bright Moho event at approximately the same distance off-axis as it was seen on the east flank. The Smith and Sandwell predicted bathymetry shows that a v-shaped low, which may be the propagating trace of the Cobb offset is located on the old crust side of the bright Moho event. Shingled Moho is observed in places.

Sunday July 21, (JD2002)

Winds 20-25 knots, Overcast and early fog. Air temps 14°C.

Continued on the Northern Symmetrical west flank transect line 34 until 10:30z. Very little sediment is found on this flank of the ridge and it appears that the ridge axis has served as a very effective barrier to the post-glacial terrigenous sedimentation . This was not true along the west flank Endeavour transect where there is a significant sediment cover. One sonobuoy was deployed during the west flank isochron line.

Monday July 22, (JD203)

We have our first spell of rough weather, winds gusting over 30 knots and 8-10 foot seas. Through much of the night we had problems keeping the steamer down at our target depth of 7.5 m and there were several incidents where portions of the streamer were riding on the surface. Joe reset the streamer depth to 10 m (16:44z) and the streamer eventually stabilized. We experienced one problem with the guns tangling in the streamer. Once we got on the southward heading line down the ridge crest (line 38), towing conditions improved. We reran the southern end of the Northern Symmetrical ridge crest line and picked up the AMC event again. We then headed south to CoAxial.

Tuesday July 23, (JD204)

Winds continuing 20-30 knots. Survey condition were adequate with following seas on our south heading course along the ridge. However, we were concerned about conditions should we begin working into/across the seas, and so we decided to continue the along-axis line down to the Cleft segment. Bob Embley called from the Thomas G Thompson (~0300 z). They had been working at Axial Volcano doing ROV work as well as deploying a buoy for bottom sensors, when they were shut down by the weather. They were about to head to Victoria in order to change personnel and back out to Explorer Ridge later in the week. Embley gave us their buoy location (45°56.235 –130 00.633 – 820 m watch diameter) which we will watch carefully when we work in Axial, particularly for streamer feathering. He also suggested that we run 2 axial lines on Vance segment, one along the neovolcanic ridge and a second within the low region of faulting to the west of this ridge. Along line 38, we imaged a weak AMC event along northern Co-Axial, a short event centered at 46°20', to the south of the Co-Axial flow site, and a brighter although very short event south of the Coaxial Source site. We then headed toward Axial, reaching the ridge axis just to the south of the caldera where we imaged a booming shallow reflection at 0.625 sec with a strong diffraction tail. Continuing south of Axial we saw two possible short events before reaching Vance. We discover that the UKOOA files are providing positions for only 240 channels. Turns out the number of channels was incorrectly set in Spectra when the streamer was configured. This will hopefully be fixable via Sprint. We had several gun tangling problems in the night/early morning.

Wednesday July 24, (JD205)

By the early morning, winds had died down to 15-20 knots, with 4-5 foot seas. Conditions continued to improve through the day. We continued on the N-S isochron lines of Cleft, and reassessed the survey plan for Axial given the location of the NOAA buoy. In order to accommodate possible streamer feathering we decided to keep our survey tracks a minimum of 1.5 km from the buoy (2x the watch diameter) which meant repositioning 2 lines.

Thursday July 25, (JD206)

Winds died down to 12-15 knots, with 2 foot seas. We finished the isochron line on 0.25 ma crust at Cleft and a second ridge axis line at Vance. Then we resumed our survey of Axial with a line along the axis and then several lines parallel to the elongated trend of Axial caldera. We had the NOAA buoy in sight on the first crossing of the Axial summit. Streamer feathering was minimal, at a few 100 m maximum during the day.

Friday July 26 (JD207)

Winds up 20-25 knots with the forecast for gusting up to 30 knots tomorrow. We continued with our crossings of Axial. Streamer was somewhat less stable than yesterday but conditions were still adequate. New time estimate for rest of Axial is 2 days 8 hours as of 6 PM Friday. When we passed the NOAA buoy it was located ~ 360 m from the anchor position, so very close to its full watch radius. On our crossings of Axial we continued to see isolated magma events with the main event underneath the caldera.

Saturday July 27 (JD208)

Grampus crashed at 5 am local. Richard discovered that the root partition was hosed and he was unable to reboot. Richard worked all day trying to restore Grampus with no success. Fortunately, our data acquisition efforts were minimally impacted. The weather remains good.

Sunday July 28 (JD209)

Winds 15 knots, seas 2-4 feet, conditions are very good. However, Grampus is still down. We are now doing our tape copying and stacking on Heezen and, as we are unable to use the Atlantek plotter, we have figured out how to plot stacks on the HP plotter through the Macintosh. So we have a work-around for our surveying operations. Now the impact of being without Grampus is only in processing and the daily data reduction. We continue our survey of Axial Volcano.

Monday July 29, (JD210)

One marine mammal sighting and gun ramp down period at 1805z. Guns are down for a total of 7 minutes. The ramp down occurs in the middle of a line 64, right as we were crossing the axis. The weather is good with winds less than 10 knots. Grampus continues down. Richard talks to Ethan at Lamont. We finish our survey of Axial today.

Tuesday July 30, (JD211)

Finally some sunshine. People are in great need of some diversion and it is nice to have going outside as an option. Grampus is only partially accessible. We spend the day on cross-axis lines of Vance (66-70).

Wednesday July 31 (JD212)

Richard successfully restored Grampus late last night by rebooting off the CD and then restoring off of backup copies. We continue with cross-axis lines of the Vance and Cleft, lines 71-74. We are back in business for processing and are all very grateful for Richard's hard work and persistence! Weather remains good .

Thursday August 1 (JD213)

Weather remains good. Richard moved over to Grampus the backlog of Spectra and Hydrosweep files accumulated while Grampus was down. We continue on cross-axis lines of the Cleft survey.

Friday August 2 (JD214)

Richard is caught up on the data reduction backlog from the Grampus failure. More cross-axis lines of Cleft (80-84).

Saturday August 3 (JD215)

We finish the cross-axis lines of the Cleft survey with a final two near the Cleft-Vance transition zone and then we begin the Cleft west flank transect (Line 86).

Sunday August 4 (JD216)

We finish Line 86 and begin the transect back to the ridge axis (87 and 89). Weather remains good and we plan our final ridge crossing.

Monday August 5 (JD217)

We continue on our flank transect crossing the ridge axis a final time, and began our final east flank transect.

Tuesday August 6 (JD218)

We ended the east flank transect at 02:45z and began hauling the gear. We finished our survey and accomplished all we had set out to do! Joe carried out a series of streamer noise tests and was ready to begin streamer recovery at 05:00z. During recovery we swapped out two sections, and had the tail buoy onboard by 11:00z. Then underway for Newport on a sparkling bright sunny day.